Postglacial Human and Environmental Landscapes of Northeastern Alberta: An analysis of a late Holocene sediment record from Sharkbite Lake, Alberta

by

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Abstract

Sharkbite Lake lies in northeastern Alberta's lower Athabasca River Valley, within which lies the modern boundaries of the Mineable Oil Sands Region (MOSR). Much of the palaeoecological research to date has addressed the establishment of the Boreal Forest; however, the late Holocene palaeoenvironment in the Athabasca River valley has not been studied in detail. Sharkbite Lake's record fills this gap in knowledge, and aids in the understanding the archaeological history. Archaeological investigations since the 1970s have resulted in the discovery of thousands of sites relating to almost 10,000 years of human occupation in the lower Athabasca River Valley. Nonetheless, the archaeological record is usually limited to stone tools situated in poorly stratified sites, often lacking independent chronologic control. With this limited record, the analysis of supplementary records like lake sediment cores becomes valuable in framing past and future CRM work and the human history in the region. This project analyzed a sediment core from Sharkbite Lake with a basal date of 3,320 rcyBP—the only high-resolution palaeoenvironmental record covering this interval in the Athabasca River valley—to help reconstruct local scale environmental changes as they relate to First Nations ancestors living in the Boreal Forest. The resulting pollen, microcharcoal, and botanical analyses of Sharkbite Lake help demonstrate how the ecological history adds to the narrative of the archaeological record. To address this relationship, all radiocarbon dates from the area were assessed. Sharkbite Lake's palaeoenvironmental record was compared with five dated archaeological sites in order to demonstrate the environmental background within which First Nation communities in the region lived and interacted.

Preface

This thesis is original work by Christina Livia Poletto. No part of this thesis has been previously published.

Acknowledgements

I would like to acknowledge that my studies took place at the University of Alberta, located on Treaty 6 land, the traditional lands of the Papaschase and the homeland of the Métis nation. I would also like to recognize that my research is in Treaty 8 land, the ancestral and traditional lands of the Nīhithawīwin, Dene Sųłiné, Tsattine, and the Métis.

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Chapter 1 Introduction

Northeastern Alberta is within the Boreal Forest of Canada and has a longstanding human occupation. The history spans the interval from when the earliest First Nations groups inhabited the region, through the exploration age of trappers and cartographers, to the origins of the oil sands development. Throughout the millenia, humans navigated and used the landscape, forming relationships with the region, including landscape management practices and seasonal movements. As humans moved across the region, the palaeoenvironmental conditions would be changing drom the early Holocene until the late Holocene, developing into a modern Boreal Forest. Unfortunately, the archaeological record in the area is usually limited to stone tools in poorly stratified sites that provide no indication of this relationship. It is critical to supplement current archaeological findings using a variety of means to provide a more holistic picture of Alberta’s north. Palaeoenvironmental studies provide an opportunity for recreating the landscape’s history and the context from which to examine past interactions between inhabitants and the vegetation. Sharkbite Lake is a small lake located northeast of Fort Mackay in northeastern Alberta (Figure 1.1). A lacustrine sediment core retrieved in 2010 yielded a 3,320 rcyBP record that became the basis of late Holocene palaeoenvironmental investigations for this study.

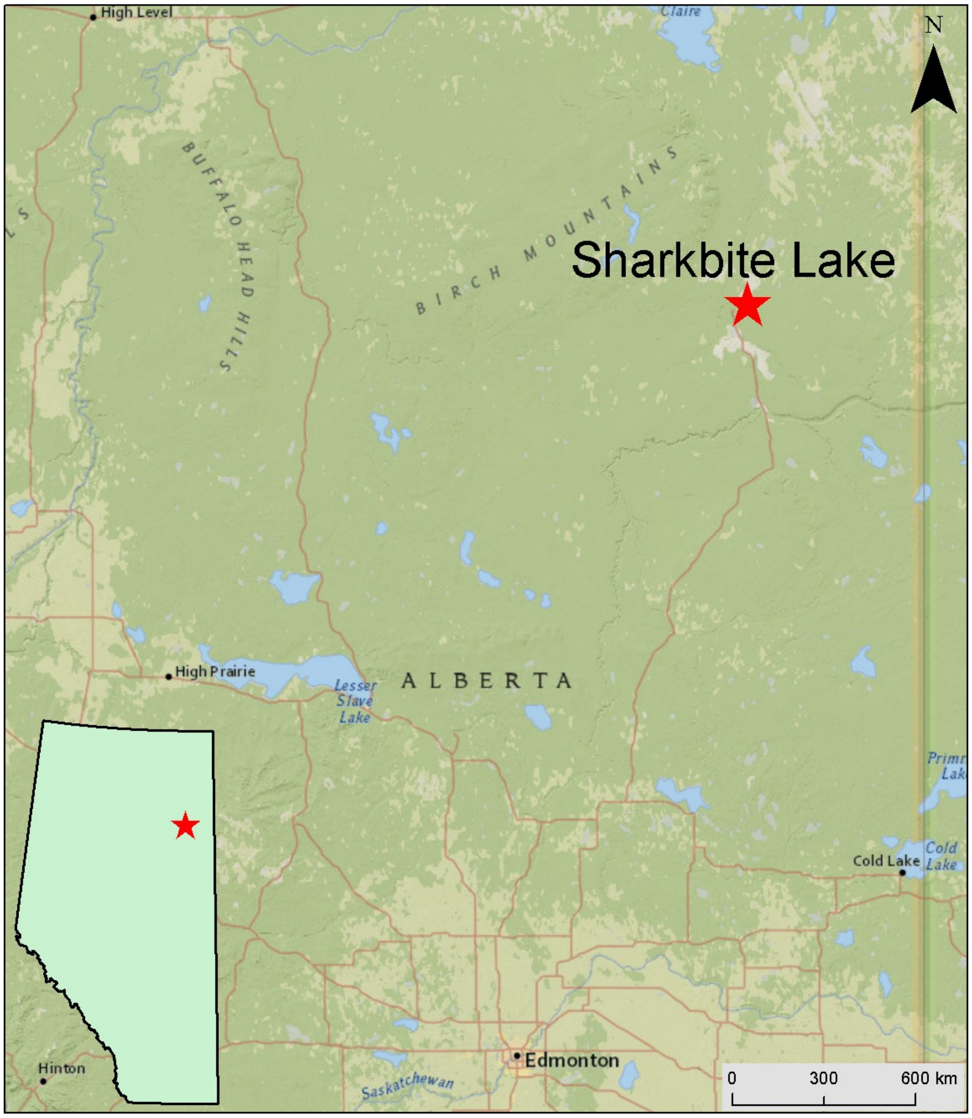

Figure 1.1 Location of Sharkbite Lake in Alberta

Bouchet-Bert (2002), Hutton et al. (1994), MacDonald et al. (1991), and Vance (1986) have conducted palaeoenvironmental studies in northern Alberta. Although these previous records span most or all of the Holocene (see Chapter 2), they are of comparatively low resolution. The sedimentation rate of the Sharkbite Lake core allowed for the analysis of an unusually detailed record of the late Holocene. This high-resolution record is the only late Holocene record in the lower Athabasca River Valley and complements the record from Kearl Lake that ends by 5,900 rcyBP (Bouchet-Bert 2002). Palaeoenvironmental reconstructions allow us to examine the fine-scale variability of the Boreal Forest, which is a product of terrain features, drainage channels, and fire ecology. Recognizing what vegetation changes First Nations ancestors may have encountered and the impacts vegetation had on animal populations, is integral to improving our understanding of Boreal Forest archaeology. While these human and landscape dynamics reach deeply into the region's prehistory, it is also true that the Boreal Forest environment—with changing fire regimes and habitat restoration projects—continues to challenge people living and working in the region today. This thesis aims to encourage archaeologists to use the environmental data as a tool in their interpretations (see Chapter 5). This work also emphasizes the importance of acquiring the best data possible when considering the constraints Boreal Forest conditions create for archaeological research.

Sharkbite Lake yields a late Holocene record for the lower Athabasca River Valley, and more broadly the northeastern Boreal Forest ecoregion in Alberta. These data provide insight into the nature of the established Boreal Forest, and the region's response to climatic or vegetational changes. This palaeoenvironmental record can be used with the archaeological record to better understand human-landscape dynamics through the past 3,000 years. This research was undertaken with the following research objectives:

1. To derive and document a late Holocene palaeoenvironmental record for the Lower Athabasca River Valley;
2. To provide background information to researchers and archaeologists to better inform site interpretations; and,
3. To demonstrate the benefits of palaeoenvironmental research in archaeological investigations in the Boreal Forest, especially in the light of the limited culture history chronology.

This thesis also sought to address the following research questions:

1. In the lower Athabasca River Valley, what role did the environment play in site selection and site patterning in the Late Prehistoric Period?
2. How did the late Holocene environment impact the occupations during the Late Prehistoric Period?
3. How can the significance of existing radiocarbon dates be evaluated in this region, and how can they be related to the Sharkbite palaeoenvironmental record?

1.2 Thesis Overview

Following this introduction, Chapter 2 presents the geologic and vegetational history for this region of the Boreal Forest. It provides a review of the previous research conducted in the area. Following a description of the current research of the northern outlet of Glacial Lake Agassiz outburst event, the chapter outlines the subsequent changes in the region's past environments. The chapter reviews 13 palaeoenvironmental studies to illustrate vegetation changes through the Holocene, starting around 12,000 rcyBP, until the establishment of the relatively modern Boreal Forest. This chapter also addresses arguably the most important ecological variable in the region: fire. Its impacts and the successional communities that follow are described. An important perspective adopted in this thesis is the recognition of anthropogenic modification of the landscape, specifically through the use of fire. Both natural and anthropogenic fires have shaped the Boreal Forest. Evaluations of change in the archaeological record need to take into account the critical role of fire in the Boreal Forest region. By reviewing the glacial and geological history of the region, we can better frame the vegetational changes that led to the environment we see today; and better frame the beginning of the archaeological record in the region.

Chapter 3 presents information on the palaeoenvironmental record from Sharkbite Lake. This chapter describes the Sharkbite Lake locality, methods used in the field and in the laboratory, and presents the results from all palaeoenvironmental analyses conducted. The analyses include pollen analysis, micro-charcoal analysis, loss-on-ignition (LOI), targeted macrofossil screening, and radiocarbon dating. Sharkbite Lake has one of the few records in the region from which multiple lines of evidence have been derived to reconstruct past environmental conditions. The combination of these various proxy records allows for more detailed interpretations of the vegetational changes during the late Holocene in the lower Athabasca River Valley.

Chapter 4 presents the archaeological history of the region from the early Holocene until to the Historic period. Specific attention is paid to the Late Prehistoric Period, because this is the interval that coincides with Sharkbite Lake's record. This chapter reviews some adaptive strategies employed in the Boreal Forest, including anthropogenic landscape management practices. The chapter concludes with a review of site density and distribution through the Holocene and presents specific interpretations for site selection and patterns in the late Holocene.

Chapter 5 is the synthesis of the palaeoenvironmental record and the archaeological record of the lower Athabasca River Valley and Mineable Oil Sands Region (MOSR). The chapter begins with an assessment of all radiocarbon dates in the area available as of June 2018. Each date is assessed based on four criteria and assigned a reliability score. Of these dated sites, five Late Prehistoric archaeological sites were chosen due to their closeness to Sharkbite Lake. Each site was discussed in relation to the vegetation history as interpreted from the Sharkbite Lake sediment core analyses. Chapter 6 concludes this thesis with an evaluation of the core and its value to archaeological and palaeoenvironmental studies, and recommendations for both areas of research.

Throughout this thesis, the history of both humans and the landscape is evaluated in combination to best answer these questions. By reviewing both these histories, relationships become evident and can be explored. These histories are related spatially and temporally. Throughout this thesis, various types of dates presented but the standard ones are as follows: (1) radiocarbon dates that are uncalibrated are noted as “rcyBP”, (2) calibrated dates are noted as “cal yrBP”, and (3) dates that reference the total time passed—or “years ago”—are noted as “ya”. Chapter 4 presents dates from Reeves et al. (2017) that are identified as ‘BP’ to represent “dates that are in the nature of *estimates* founded on some form of comparative analysis” (Ronaghan 2017a:10, emphasis mine).

All maps and figures are created by me (unless otherwise stated) and all geospatial and map data is referenced accordingly (either in text or in the “Geospatial Data Sources”).

Chapter 2 Literature Review

Sharkbite Lake lies within the Boreal Forest ecoregion of North America. The ecoregion extends from Newfoundland to Alaska and is dominated by coniferous trees comprised of spruce, pine, fir, and larch, as well as deciduous trees including aspen, birch, and alder, and peatlands. For over ten thousand years, First Nation communities called this place home. The homogeneity of the ecoregion, however, is often taken for granted, and leads to broad generalizations at the provincial and continental levels. However, on a finer scale, edaphic conditions, anthropogenic use of the landscape, and fire are all factors that create local heterogeneity in the ecoregion, resulting in a diverse patchwork of plant communities in which animals thrive in. This chapter reviews the geologic, glacial, vegetation, and fire history of the Boreal Forest region in Alberta. It considers how more quantitative methods, such as surficial geology and palaeoenvironmental research, and qualitative research, such as ethnographic studies aid in and contribute to understanding the human aspects of landscape use.

This chapter highlights how Sharkbite Lake's record fits into the geologic and vegetation history in the region. The palaeoenvironmental and geologic histories are necessary to understand the regional changes as a background for the investigation of the human occupation in the region and the palaeoenvironment derived from Sharkbite Lake's record. Research to date has addressed the establishment of the Boreal Forest and major trends in the region after deglaciation. However, the palaeoecological history during late Holocene in the Athabasca River Valley has not been intensively studied, nor has there been high resolution research conducted that spans the entire late Holocene interval. Sharkbite Lake's record has yielded valuable new data for the last 3,000 years of the region, complementing the early to mid-Holocene record from Kearl Lake (see Chapter 3).

The aim of this review is two-fold: 1) to synthesize information from previous studies in the region that sets the stage for my research on the late Holocene record from Sharkbite Lake, and 2) to highlight the importance of Sharkbite Lake's high-resolution record and its significance for human occupation in the region. In this chapter I review northeastern Alberta's glacial geology, beginning with the retreat of ice-sheets from northeastern Alberta; and focus on post-glacial events as related to vegetational models and processes. I discuss vegetational changes in the region during the Holocene, and reflect on the changes throughout the Boreal Forest in Alberta as interpreted through data obtained from lacustrine sediment records. This review also examines fire as a major factor in the Boreal Forest. I discuss the differences between natural fires and anthropogenic fires: both impacted vegetation but differ in their natural and planned outcomes and influences on plant communities.

2.1 Geologic and Glacial History

An important area of research revolves around the shaping of the region's surface because of the Laurentide Ice Sheet (LIS), focusing on the timing of the glacial retreat to the timing of the outburst flood from Glacial Lake Agassiz. An analysis of the research is relevant to this thesis because the glacial retreat is referenced in the timing of both vegetation re-establishment itself and the arrival of First Nations. The flood from Glacial Lake Agassiz is perhaps most relevant to both the human and natural history. This catastrophic event correlates with the formation of the Clearwater and Athabasca River valleys and created a topography that was colonized by plants, animals, and people. It also exposed the primary lithic material for the region: Beaver River Sandstone (see Chapter 5).

Northern Alberta was affected by the Laurentide Ice Sheet during the late Wisconsinan glaciation, which occurred toward the end of the Late Pleistocene until its deglaciation in the earliest part of the Holocene (Dyke 2004; Dyke and Prest 1987; Dyke et al. 2003; Marshall et al. 2002). A significant portion of the surrounding region was also beneath ice until around 11,000 rcyBP (Dyke 2004:391). The timing of such glacial events, which has been constrained using various methods, and their geographic extent are important for understanding the surficial shaping of the study area. The use of surficial geology techniques like landform mapping and mapping glacial sediments allows researchers to delineate and refine glacial boundaries. As an example, the presence and directionality of glacial fluting and hummocky topography have been assessed to yield information about the LIS's past flow and extent (Andriashek and Atkinson 2007; Atkinson et al. 2014; Dyke and Prest 1987; Fenton et al. 2013; Shaw et al. 2000; Woywitka et al. 2017). The use of LiDAR imagery has been a recent advance, resulting in the production of maps that have greatly refined interpretations of glacial landforms, and provided further insight into the complexities of glacial geomorphology (e.g., Atkinson et al. 2013; Margold et al. 2015; Utting et al. 2016).

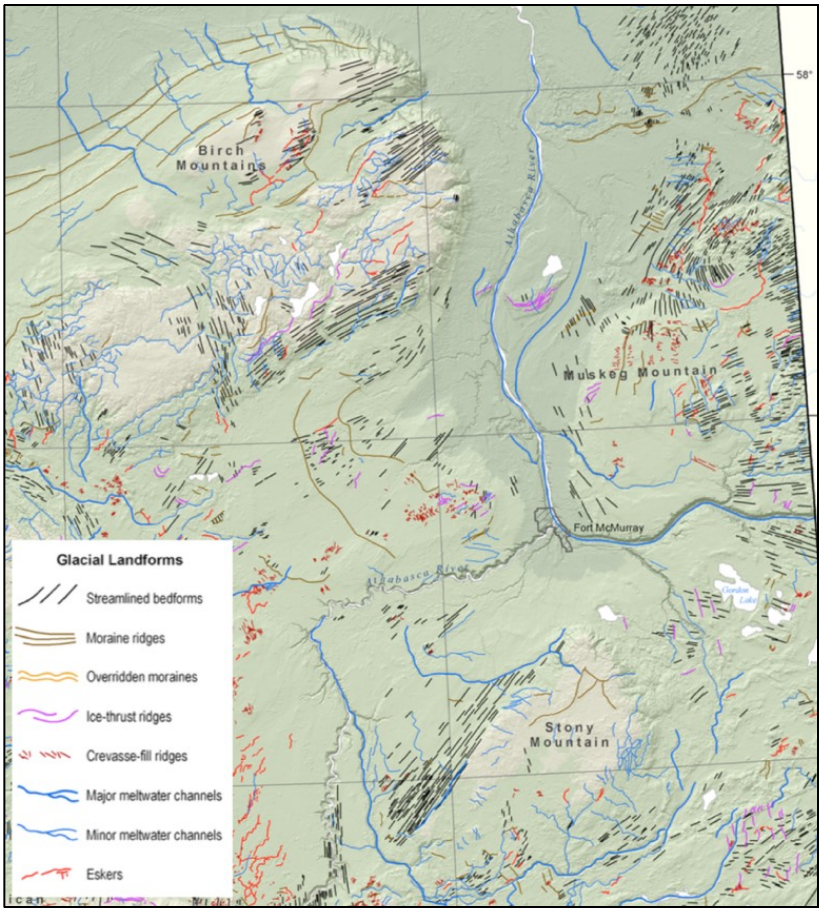

Figure 2.1 Examples of glacial landform mapping in northeastern Alberta. Adapted from Atkinson et al. (2014)

Ice from the LIS dominated northeastern Alberta's past landscape for thousands of years. Following the coalescence of the LIS from the east and the Cordilleran Ice Sheet from the west within the modern boundaries of Alberta around 17,500 rcyBP (Dyke et al. 2003), the ice began to retreat by 15,000 rcyBP (Dyke 2004; Dyke and Prest 1987; Fulton and Prest 1987), eventually exposing the northeastern corner of Alberta that was once overridden by the LIS. Studies of the deglacial history have focused on establishing chronologic control for the moraines that lie southwest to northeast in the Oil Sands Region (OSR) in orderto date the glacial retreat (e.g., Fisher et al. 2009). The parallel orientation of the moraines shows the retreat of the LIS from the southwest to the northeast. Earlier studies associated the Cree Lake moraine with the 10,000 rcyBP Laurentide ice retreat isoline (Dyke and Prest 1987), but new dates from OSR studies suggest a somewhat later deglacial chronology (around 9,700 rcyBP) (Fisher et al. 2009). More recent OSR studies by Fisher et al. (2009) constrained the Stoney Mountain Moraine and Don's Moraine at about 10,500 rcyBP, the Survive Moraine at around 9,900 rcyBP, and the emplacement of the Firebag Moraine at about 9700 rcyBP (Figure 2.2).

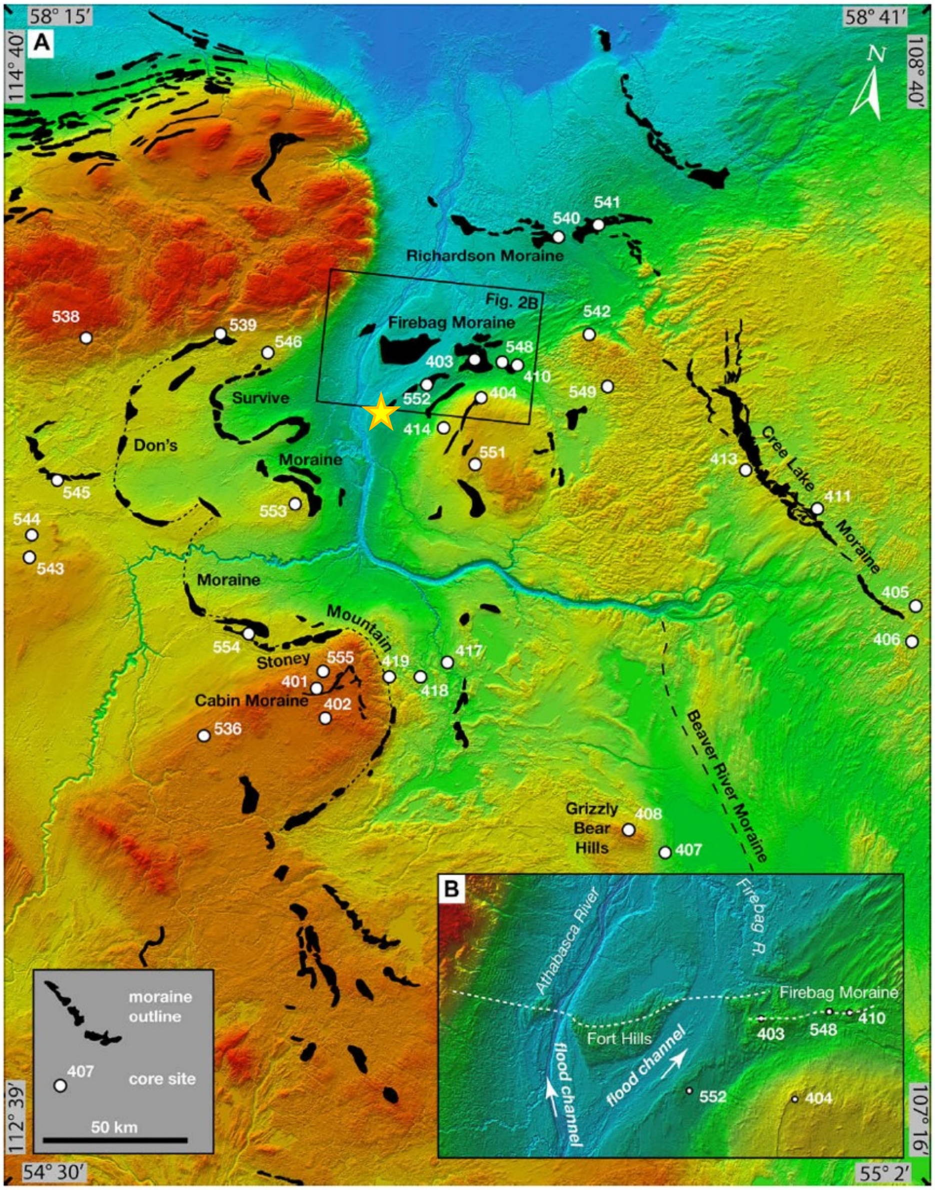

Figure 2.2 Locations of dated glacial moraines as used to interpret the glacial retreat and flood through the Clearwater River Valley (from Fisher et al. 2009). Sharkbite Lake is denoted by the yellow star. Kearl Lake is core site 552 on the map. Note lighter tones represent higher elevations.

The decanting of Glacial Lake Agassiz was one of the most dramatic and important geologic events in the region's late Quaternary history. Glacial Lake Agassiz was an extensive proglacial lake located along the southwest margins of the LIS. It formed as the icesheet retreated and melted. Through its 5000-year existence, Lake Agassiz's fluctuating water levels covered a total surface area of 1.5 million km^2 (Teller and Leverington 2004:729). As the ice retreated between 12,000 - 9,000 rcyBP, continued meltwater and non-glacial runoff increased the surface area of the lake. Glacial Lake Agassiz experienced several decanting events as ice retreated and opened successively lower drainage outlets. Isostatic rebound changed the elevation of potential outlets. Glacial Lake Agassiz drained through three routes at different times: through the St. Lawrence system, through the Mississippi system, and through the Clearwater-Athabasca-Mackenzie system (Dyke 2004; Fisher et al. 2009; Teller and Leverington 2004). An ice dam containing the lake was breached during the Emerson Phase, leading to a dramatic draining of the lake, dropping levels by 52 meters. This decanting episode has been studied in-depth by researchers for decades in order to understand which route the outflow took, whether there was a single decanting event through the northwestern outlet or two decanting events, and the subsequent effects on the landscape.

The first evidence for the timing of glacial Lake Agassiz drainage places an initial northwestern outburst event around 11,000 rcyBP and a second decanting sometime around 9,900 rcyBP. (Teller et al. 2005:1900). Further supporting the Clearwater-Athabasca drainage are claims by Murton et al. (2010), who use gravels and regional erosion surfaces along the Clearwater and Athabasca valleys to date an early drainage of glacial Lake Agassiz through this northwestern outlet, in addition to a more recent flood. Optically stimulated luminescence (OSL) dates of erosion surfaces near the Mackenzie delta indicate that the outlet would have been open around

13,000 kyr and represents the path for glacial Lake Agassiz's flood through the Mackenzie River (Murton et al. 2010:742). More recent research by Keigwin et al. (2018) in the Beaufort Sea also supports an early decanting episode through the Mackenzie River. Supporters of this early decating episode argue that this event likely triggered the Younger Dryas cold event (Keigwin et al. 2018; Murton et al. 2010; Teller et al. 2005).

The second school of thought places a single decanting episode through the Clearwater-Athabasca spillway much later, sometime between 9,800 – 9,600 rcyBP (Fisher and Lowell 2017:63). Fisher and Smith (1994, Smith 1994) used morphological and sedimentological evidence to demonstrate a northwestern outlet through the Clearwater-Athabasca rivers around 9,900 rcyBP. They determined that initial drainage occurred through the Mississippi River system and then through the St. Lawrence system, and then shifted into the Clearwater-Athabasca route around 9,900 rcyBP. This reconstruction is supported by Leydet et al. (2018), who argue that, based on ^{10}Be dates, the St. Lawrence drainage was open by 13,500 BP, acting as the eastern outlet for glacial Lake Agassiz and potentially triggering the Younger Dryas (Leydet et al. 2018:157-158). Further, they state that the Clearwater-Athabasca route would have been available during the middle of the Younger Dryas and would have extended the cold period by a few centuries (Leydet et al. 2018:158).

Further challenging the understanding of this event are recent OSL dates of sand hills and dune fields within Alberta in order to establish the date of the glacial retreat. Munyikwa et al. (2017:163) acquired a sample from the Fort McMurray Sand Hills and obtained an OSL date of 14.0 ± 1.0 ka that indicated the nearby area would have been ice-free by then, earlier than previously thought. They stated that sometime by 12.0 ka, the drainage through the Clearwater-

Athabasca route towards the Mackenzie would have been open in time for an early decanting episode.

Both arguments, however, hold that around 9,900 / 9,800 rcyBP (11,335 cal yr BP) there was a catastrophic drainage of Lake Agassiz through Lake McConnell towards the Arctic Ocean. Revised models demonstrate that this event could have occurred as early as 10,000 rcyBP (Teller et al. 2005; Murton et al. 2010; Froese et al. 2010 [as cited in Woywitka et al. 2016]). This decanting is thought to have lasted several years (Fisher and Smith 1994), discharging over 21,000 km^3 of water; then maintained a steady flow of water for several hundred years (Fisher and Lowell 2017). This catastrophic draining of glacial Lake Agassiz flowed through the Methye Portage area, draining through the Clearwater and Athabasca rivers valleys, carving out the Clearwater-Lower Athabasca Spillway with a steep-walled, straight-trending meltwater channel (Fisher et al. 2009; Fisher and Lowell 2017; Fisher and Smith 1994; Murton et al. 2010; Young 2018:52). These floodwaters flowed into Glacial Lake McConnell and followed the Mackenzie River drainage to the Arctic Ocean. With this discharge meeting the Arctic Ocean, the ocean would have risen the equivalent of six metres during maximum discharge (Fisher et al. 2002). As the fresh water mixed with ocean water, the process increased pack ice thickness in the Arctic (Fisher et al. 2002; Fisher et al. 2009).

However the decanting of the northwest arm of Glacial Lake Agassiz played out, the landscape in northeast Alberta was shaped by the LIS and massive flooding, leaving numerous surficial geologic markers across the region. The catastrophic flooding through the river valleys led to the formation of gravel bedforms (Woywitka et al. 2017). Many of these landforms within the Athabasca River valley tend to have two major orientations - northeast and northwest. Around the Muskeg-Firebag valley, landforms trend northeast and are found in a “higher-relief combined ridge-to-rhomboidal pattern” that indicates the floodwater outflow around the valley was much stronger (Woywitka et al. 2017:77). Loose sediment on the newly exposed landscape was reworked to form sand dunes as strong winds blew across drainage channels, deltaic areas, and lake basins following retreat of the LIS and flood waters (David 1981). Reworked glaciofluvial and glaciolacustrine sediments from these sand dunes offer insight into prevailing wind directions during the Late Pleistocene and early Holocene. Parabolic dunes extend from the northeastern part of the province and into northwestern Saskatchewan, and were created when katabatic winds blew in a southeastern-northwestern direction off the ice sheets (David 1981). These elongate dunes were probably active from 10,000 to 8,800 rcyBP (David 1981; Wolfe et al. 2004:326).

These dates are critical for framing the timing of the flood and the surficial changes on the landscape that have been the basis for the early culture history in the Boreal Forest (e.g. Saxberg and Reeves 2003; see Chapter 4). However, until dates for ice margins across the LIS are firmly established, an understanding of these flood events and the timing of routes of floodwaters is yet to be obtained. Regardless of the timing of the drainage, the changes to the Athabasca River Valley impacted the archaeological record because the exposed terraces and flood drainage scars would have influenced human occupation and site selection. Following the changes resulting from deglaciation, landscapes stabilized in the early Holocene, allowing plants and animals to return to the region. Sharkbite Lake lies within these reworked landforms, near ice margins and within the direct path of Lake Agassiz flood. These changes are crucial for our understanding of the relationships between the landscape and human inhabitants as the influences on humans are sustained long after the geologic events occurred.

2.2 Vegetational History

As the Laurentide Ice Sheet retreated northeastward from Alberta in the early Holocene, vegetation quickly occupied the newly exposed landscape. Plants such as grasses and forbs were first to inhabit this open landscape, which resembled a steppe-tundra ecosystem. Not long after, coniferous and broadleaf tree species found their way into the region. First, *Betula* sp. appeared in the pollen record, shortly followed by *Picea* sp. These plants, as well as *Pinus* sp. and *Alnus* sp., began to dominate the vegetation, eventually to become by the mid-Holocene the closed Boreal Forest we recognize today. By 5,000 rcyBP, peatland formation expansion accelerated continuing into the late Holocene until it extended to modern limits (Bouchet and Beaudoin 2017). The following section highlights the palaeoenvironmental studies that have been used to reconstruct the region's vegetational history. Table 2.1 presents all palaeoenvironmental studies that have been conducted in the boreal ecoregion of Alberta prior to this study, and highlights three major environmental transition intervals that are critical in the establishment of the regional vegetation. These environmental shifts are discussed as four areas in order to demonstrate the movement of species into the region (Figure 2.3). The areas are defined by the modern vegetation and environment, and the distinctions used are not reflective of characteristics throughout the Holocene. Area A comprises the southern limit of the Boreal Forest and of the discontinuous permafrost zone, Area B comprises the Birch Mountains uplands, Area C comprises the Athabasca lowlands and the Muskeg Mountains and Thickwood Hills; and Area D comprises the study's northern portion of the Boreal Forest, including the Caribou Mountains and the Slave River lowlands. For each environmental interval, the events are discussed in chronologic order to summarize the vegetational shifts.

Figure 2.3 Map of the northeastern Boreal Forest region and lakes discussed.

2.2.1 Remnants of Steppe-Tundra

Steppe-tundra is defined as open vegetation rich in grasses and forbs, associated with well-drained soils (Strong and Hills 2005; Vance 1986; Zazula et al. 2003, 2006). When identifying shifting vegetation communities, key taxa to look at are the non-arboreal pollen (NAP) types, which indicate the presence of open vegetation such as steppe-tundra and grasslands (Bouchet-Bert 2002; Bradley 2015). Within the pollen record, the degree to which these NAP taxa are present in relation to arboreal taxa helps to determine how open or closed a vegetation formation may have been. Pollen from Boreal Forest taxa like *Picea* (both *P. glauca* and *P. mariana*), and *Pinus* (*P. banksiana*), and to some degree *Betula* have been noted in the earliest parts of the record in many studies, although often in limited quantities. Their representation in the record indicates a shift from the tundra-like grasslands to an open spruce forest, which is followed by an addition of further deciduous elements (Bouchet-Bert 2002:23). Steppe-tundra vegetation appears in Alberta's Boreal Forest following the retreat of the LIS. However, its timing varies within the four areas.

In Area A, steppe-like vegetation is present as indicated by the pollen record by 12,000 rcyBP (Hutton et al. 1994). The Mariana Lake record shows high levels of *Artemisia* (>50%), Gramineae (>20%), and Cheno-Am pollen (Hutton et al. 1994). Low pollen accumulation rate and pre-Quaternary spores in the lake's record has been attributed to sparse vegetation cover, which is noted as a contributing factor to high sediment accumulation rates (Hutton et al. 1994:422). Early in Lofty Lake's record, *Populus* pollen appears, around 10,700 +/- 170 rcyBP (Lichti-Federovich 1970). Shortly after, *Betula* and *Picea* begin to appear in the records. Because it was probably free of ice earlier on due to its elevation, Area B's Eaglenest Lake shows that the pollen record from the early Holocene (~11,800 rcyBP) was dominated by NAP taxa such as sage (*Artemisia)*, grasses (Gramineae), sedges (Cyperaceae) and diverse herbs, not long after these taxa appear in Area A (Vance 1986; Hutton et al. 1994). Willow (*Salix*; 5-20%) and poplar (*Populus*; 5-21%) are arboreal (or shrub) taxa represented in the pollen record but are noted in low quantities (Vance 1986). Vance (1986) also concluded that the basal zone from the Eaglenest Lake core was indicative of dry, windy conditions preceding rapid warming after glacial retreat. To the north in Area D, steppe-tundra vegetation appears in the earliest part of the records. Given the direction of the LIS retreat, and the higher elevation of Wild Spear Lake, by 11,000 rcyBP (although it was likely earlier) the Caribou Mountains were dominated by herbs and shrubs, notably *Artemisia* sp*.,* Gramineae*,* Cyperaceae*, Salix* sp*.,* Compositae, and Cheno-Am (MacDonald 1987).

In Area C, in the lowlands to the east of Area B, by 10,250 rcyBP, at Kearl Lake, *Betula* pollen has a maximum value of 55%, which highlights the quick advance of this tree taxon following the glacial retreat (Bouchet-Bert 2002). At this time, *Artemisia* pollen is well-represented at 5%, while some Compositae and Cheno-Am pollen values reach 3-4%, highlighting that remnants of steppe-tundra are still present (Bouchet-Bert 2002). This record documents the transition from steppe-tundra to open woodlands, which occurs, chronologically, shortly after the areas to the south. Because there are some NAP taxa represented in the lower pollen zone, in addition to a sediment accumulation averaging 28 years per 1 cm, the basal pollen zone may reflect a rapid transition from NAP to arboreal vegetation (Bouchet-Bert 2002:38).

Steppe vegetation occurs in the region for only a short period. Once the landscape is open and primed, conifers such as spruce and pine, and arboreal birch are quick to migrate into the region.

2.2.2 Timing of spruce migration into northeastern Alberta

The initial advance of spruce in the region follows the retreat of the Laurentide ice. The colder and moister climate of the Younger Dryas interval would have encouraged the spread of spruce. Studies of white spruce spread have indicated that the strong adiabatic winds from the remnant Laurentide Ice Sheet may have promoted this rapid migration (McLeod and MacDonald 1997; Peters 2006; Ritchie and MacDonald 1986). Other studies farther south note of a slower migration from the southern refugia (0.38 km/^{14}C year rather than 2.0 km/^{14}C year) (Yansa 2006:278). An alternate explanation placed refuge populations of white spruce in Alaska and indicates that gene flow of non-Alaskan populations was important for the structuring of the white spruce migration, linking stands from Alaska to stands in the boreal via chloroplast DNA (Anderson et al. 2011). This genetic evidence contradicts the palaeoecological records that use the absence of white spruce pollen as an indicator of a migration to the north (Anderson et al. 2011; McLeod and Macdonald 1997; Yansa 2006). Towards the end of and following the Hypsithermal, spruce begins to become more abundant (Bouchet-Bert 2002; Schweger and Hickman 1989).

To the north, Area D, MacDonald (1987) notes the initial presence of *Picea* in Wild Spear Lake's pollen record around 10,000 rcyBP, but it does not dominate the pollen assemblage until 8,500 rcyBP. Before 8,500 rcyBP, the record had little representation for *Picea mariana* and *Picea glauca*; but following this time, both increase in abundance and replace NAPs, including *Artemisia* and Gramineae (MacDonald 1987:249). In the Birch Mountains, Area B, the advance of spruce can be seen as early as 11,000 rcyBP, when there is a distinct increase in *Picea* pollen percentages, as well as in *Betula* pollen in Eaglenest Lake's record (Vance 1986). *Picea* maintains its dominance in the record, likely due to the uplands altitude and climatic conditions.

The presence of *Sphagnum* throughout Eaglenest Lake's record and diatom records from Otasan Lake support the idea of cooler and moister temperatures until around 7,300 rcyBP (Vance 1986; Prather and Hickman 2000). Starting around 7,500 rcyBP, a *Pinus-Picea-Alnus* assemblage developed and was maintained for quite some time.

To the east of the Birch Mountains, in Area C, Kearl Lake records an early appearance of spruce by *ca.* 10,250 rcyBP. Spruce pollen's frequency decreases between 9,820 to 7,580 rcyBP, but higher frequencies are re-established by 7,580 to 5,900 rcyBP (Bouchet-Bert 2002). The most precise indicator of local spruce in the Kearl Lake record is the charred spruce needle that was used to obtain the 10,100 rcyBP date. Its presence in the record is indicative of spruce stands nearby and cannot be confused with pollen rain from a distance. Here, in the lowlands of the Athabasca River valley, the macrobotanical evidence shows that spruce arrived shortly after the glaciers retreated; and not long after steppe vegetation became present (Bouchet-Bert 2002). Beierle (1996:7-8, as cited in Bouchet-Bert 2002:55) notes an increase in charcoal counts at this time, and attributed this increase to the Younger Dryas and a decrease in dense spruce stands. However, Bouchet and Beaudoin (2017:100-101) suggest the increased charcoal count is attributable to more available fuel sources, and the decreased *Picea* values are attributed to the Hypsithermal interval.

To the south, within Area A, *Picea* appears early in the records, on average between 11,800 – 10,500 rcyBP. Hickman and Schweger (1996) noted *Picea* pollen in the earliest part of Moore Lake's record (11,830 rcyBP) but attribute this occurance to a reworking of modern sediments. Hutton et al. (1994) noted the initial presence of spruce during 10,500 rcyBP at Mariana Lake, with a *Picea glauca* forest replacing the previous steppe vegetation. By around 9,000-7,500 rcyBP, *Picea* counts decrease, though *Picea* influx values stayed consistent, leaving a degree of uncertainty associated with its relative abundance (Hutton et al. 1994:423). At around the same time, *Picea* dominates the pollen record in Lofty Lake—almost 50% of the record – and maintains this high level until *Betula* appears in the record (Lichti-Federovich 1970). This general trend (an early and often abundant presence of *Picea* sp. followed by a decline) is also seen by Lichti-Federovich (1972) in the Alpen Siding Lake record.

The timing of spruce arrival in the region is variable, which is perhaps attributable to how the vegetation responds to climatic changes. MacDonald's study (1984:164) of postglacial plant migration places the establishment of *Picea* in northeast Alberta by 8,700 yr BP, migrating northward from a southern refugium. However, Kearl Lake's record arguably yielded the best indicator of the early rise of spruce: a charred spruce needle that was radiocarbon dated to 10,100 ± 60 rcyBP (Beta-94234) (Bouchet-Bert 2002:38). Whereas pollen represents both regional and local vegetational signatures (Faegri and Iversen 1989; Pearsall 2002), macrobotanical evidence creates a firm association with the arrival of spruce early in the record. As was mentioned previously, the migration and timing of *Picea* is a topic of debate, however; Yansa's review of 26 radiocarbon dates indicate that the migration of spruce into the modern boreal ecoregion was much slower, not reaching southern Saskatchewan until 10,300 rcyBP (2006:267, 278). This dating is contradicted by the dated macrofossil from Kearl Lake, leading to the conclusion that *Picea* may have had small establishing communities within the lowlands (as evidenced by the needle's presence in the record), and large stands did not develop until a much later date.

Fluctuations in spruce's relative abundance have been attributed to effects from latitudinal and altitudinal differences, as well as climatic shifts like the Hypsithermal, the warming period around 9,000 to 6,000 rcyBP (Deevey and Flint 1957; Hutton et al. 1994; Schweger and Hickman 1989). It is evident, however, that shortly following the retreat of the glaciers and the establishment of steppe vegetation, spruce dominated much of the landscape in the central and northern areas of the region until the development of the modern Boreal Forest in the mid Holocene (see Chapter 2.2.4). Its presence early in the record highlights the diverse vegetation the region would have supported following the deglacial activity and vegetational shifts.

2.2.3 Establishment of Wetlands

One of the major characteristics of the Boreal Forest region is the presence of wetlands, specifically muskegs. Wetlands are defined as "land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation and various kinds of biological activity which are adapted to a wet environment" (Tarnocai 1980:11). Wetland classes include bog, fen, marsh, swamp, and shallow water; these are defined by the overall properties of the wetlands formation and the wetland environment which influence pH values (National Wetlands Working Group 1997:2). These classes are further categorized by forms and types (National Wetlands Working Group 1997:2), but only classes relevant to the discussion are defined.

A fen is a peatland in which the water table fluctuates and is influenced by groundwater and surface water movement. The peats are comprised of decomposed sedge and brown moss. Water-level fluctuation influences vegetation on and near the fens—for example, drier fens will include shrubs and trees on microtopographic features in the fen. Taxa that occur include *Sphagnum*, *Betula* spp., *Salix* spp., *Larix laricina*, and *Carex* and their distribution is based on water level and chemistry. Fens tend to have high pH levels (National Wetlands Working Group 1997:19). Bogs are defined by their accumulation of peat that is dominantly decomposed

Sphagnum and woody remains. Bogs are associated with low pH values and acidic conditions. The surface of a bog is level with the surrounding terrain or raised, is unaffected by groundwater and runoff water, and the primary water sources are snowmelt, precipitation, and fog. Vegetation in and on bogs is predominantly *Sphagnum* moss and can include trees or shrubs in drier or raised areas (National Wetlands Working Group 1997:19). Muskeg is most commonly associated with wetlands in the Boreal Forest region, and meets the criteria for a bog as defined above. However, it has come to refer to a specific type of organic terrain: "a living organic mat or mosses, sedges and/or grasses with or without tree and shrub growth. Underneath the surface there is a mixture of partially [or completely] decomposed…organic material, commonly known as 'peat'" (MacFarlane 1958:3). "Muskeg" is an Algonquian term that refers to a 'grassy bog'; and is associated with natural and undisturbed organic terrain that contains *Sphagnum* moss, sedges and open shrub and tree growth (Stanek 1997:46).

Peatland initiation varies in timing across the boreal ecoregion in Alberta. Because different conditions are the primary reason wetland development begins in different locales, no single temporal trend explains its development in the region. However, the one apparent trend that in the Boreal Forest ecoregion is that muskegs began to develop across the region after tree stands had been established. *Sphagnum*-dominated peatlands began forming near the central/southern forest limits near Mariana Lakes closed lake basin around 8,000 years ago, while the upper fens did not begin forming until 6,500 years ago (Nicholson and Vitt 1990:136). During the Hypsithermal, the temperatures in the summer began to rise and resulted in increased fire rates, which extended the grasslands into the southern forest limits (Schweger and Hickman 1989:1828; Lichti-Federovich 1970). At this time, lake levels also dropped, a development which could account for the lack of peatlands in the region (Nicholson and Vitt 1990:136;

Schweger and Hickman 1989:1830). To the east, the peatlands near Marguerite Lake developed around 3400 yr BP and were the result of paludification rather than lake filling, which was the dominant process for the region (Kubiw et al. 1989). Indirect evidence was found in the mineable oil sands; a set of elk antlers were retrieved during reclamation work by Suncor Energy near Mildred Lake. Radiocarbon dating revealed that the antlers were 5,500 years old. Owing to their stratigraphic position at the base of muskeg deposits within grey sands, they have been used to suggest that muskeg formation began around Mildred Lake at this time (Burns and Young 2017).

The review of basal peat deposits across western Canada shows that along the modern southern limits of peatlands, peatland initiation did not begin until the end of the middle Holocene/late Holocene (Halsey et al. 1998:322). The climatic variables attributed to development of peatlands is evident when considering initiation dates near the Athabasca lowlands (i.e., Mariana Lake) to southern boreal/parkland area (i.e., Lofty Lake) (Halsey et al. 1998:329-330). Halsey et al. (1998) indicate that while both areas began peatland development at different times, both the lowlands and southern area had a stable Boreal Forest signature by 4,000 rcyBP, and by 2,000 rcyBP, the southern limits of the Boreal Forest were established.

Recent work within the Athabasca lowlands has looked at the last thousand years of vegetation changes and climate change through five peatland cores from the Fort McMurray area (Magnan et al. 2018). Magnan and colleagues noted two major trends in the region: 1) during the Little Ice Age, there was permafrost aggradation and an increase in *Picea mariana* and shrubs in the Fort McMurray are;, and 2) *Sphagnum* sect. *Acutifolia* became established during the mid-20th century, indicative of warmer conditions (Magnan et al. 2018:239-240). The signature from these cores in the Athabasca River Valley is a more recent record of climatic conditions, but the regional response to change is valuable for understanding past peatlands dynamics in the region.

2.2.4 Late Holocene Boreal Forest Establishment

Tree taxa common to the modern Boreal Forest appear during the late Holocene and maintain their relative abundance in the region. This development occurs almost simultaneously with the establishment of the wetlands. Stands are characterized by aspen, jack pine, white spruce, balsam fir, and mixed woods on raised terrain features, while wetlands are treed with black spruce in this area. The broad-scale make-up of the Boreal Forest has been relatively stable for the past 5,000 years. However, factors like fire occurrence, terrain features, and edaphic conditions produce the patches of varying successional communities within the broad regional homogeneity frequently associated with the biome.

The earliest presence of a modern Boreal Forest can be seen in Area B. Early in the record, *Pinus* values increase to near modern levels by 7,500 rcyBP at Eaglenest Lake (Vance 1986). With this increase, we see modern vegetation communities establishing themselves and staying relatively stable throughout the late Holocene. Established forest in the area also causes an increase in nutrient supply within catchment areas for peatlands, allowing the peatlands to develop faster (Prather and Hickman 2000). In Area A, by 5,000 rcyBP, the peatland and *Pinus, Picea,* and *Betula* dominated landscape, showing little change to modern day (MacDonald 1987). *Picea* seems to be established later in the region, but one can expect that this late appearance is partially due to its northern latitude. Once the vegetation has established itself, the fire history and successional communities shift and begin to develop into the patterns recognized today. Fire cycles that have been recorded in the region average around 69 years in the latest Holocene, based on the cycle for *P. glauca* forests (Larsen and MacDonald 1998; MacDonald et al. 1991).

Throughout the southern limit of the Boreal Forest in Area D, there is more variability in plant community composition until the later part of the Holocene. This development is explicable when considering the dominance of deciduous stands in the Boreal Forest within the southern limits (Downing and Pettapiece 2006). The abundance of taxa such as aspen is hidden in the pollen records, overpowered by the overrepresentation of conifer pollen. Also, aspen reproduce via suckering. This feature leads to a disconnect between the pollen assemblages and inferred vegetation. Along the eastern border of the province, *Pinus* and *Picea* values reach modern values around 7,100 rcyBP, but the complementary boreal taxa like *Betula* and *Alnus* do not reach and maintain modern values until around 4,000 to 5,000 rcyBP (Hickman and Schweger 1996). This later date coincides with the establishment of the Boreal Forest throughout the rest of the area, with the presence of *Pinus* and *Picea* at modern values (30-40%), and *Betula* and *Alnus* also represented (Hutton et al. 1994; Lichti-Federovich 1970, 1972).

The arrival of trees like *Pinus banksiana, Alnus* sp., and *Betula papyrifera* has been studied extensively by MacDonald (1984; McLeod and MacDonald 1997), and their delayed arrival can be attributed to physical and edaphic factors. *Pinus banksiana* (jack pine) requires high light to grow, needs conditions to open its serotinous cones (i.e., forest fire), and has restrictive edaphic demands that led to the species being present only by 6,000 rcyBP. However, during the Hypsithermal, drier conditions led to an increase in fire frequency which aided jack pine’s rapid migration. Similarily, *Alnus* and *B. papyrifera* required specific edaphic conditions and due to low seed viability for *B. papyrifera*, they did not establish themselves until 7,800 and 8,000 rcyBP respectively (MacDonald 1984:171-2, 187, 190). Following this event, around 3,000 rcyBP Lofty Lake's record indicates a southward shift in the northern margin of the grasslands (Lichti-Federovich 1970). More recent studies attribute the grassland expansion and contraction to bison activity and fire, which are parallels that highlight the responsive nature of the ecoregion throughout most of the Holocene (Campbell et al. 1994). While a degree of stability was achieved, fire, fauna, and climatic changes led to variations in the boreal limits.

The only lake in Area C for which palaeoenvironmental data existed prior to this study is Kearl Lake, which does not have a record that extends into the late Holocene. The record ends around 5,900 rcyBP; however, it does show trends that indicate the forest in this area started to show some of the characteristic of the modern Boreal Forest (Bouchet-Bert 2002). Pollen indicates that the forest included *Alnus, Betula, Picea*, and *Pinus*, with some wetlands also established to the north of the Clearwater River. The climate at this time was inferred to be cool and wet, following the Hypsithermal (Bouchet Bert 2002:60-62). Otherwise, little is known about what occurred from a palaeoecological perspective in the late Holocene in the Athabasca lowlands, aside from regional signatures and records in the southern Boreal Forest area. This situation is what makes the analysis of Sharkbite Lake a valuable addition (this study, Chapter 3). Sharkbite Lake shows that by 3320 rcyBP, a modern Boreal Forest existed. Subsequent variation that occurred within the lowlands was limited to local episodes of edaphic changes and fire. The high degree of variability from Sharkbite Lake's record is due to the variation in the lake's catchment and pollen seasonality (see Chapter 3.3.1).

Lake	Remnants of Steppe	Timing of Spruce	Late Holocene / Modern Vegetation	Notes
1. Rainbow Lake A *Boreal Subarctic* (MacDonald et al. 1991; Larsen and MacDonald 1998)	n/a	n/a	Fire history; fire cycles, average of 69 years between fires, like the fire cycle for *P. glauca* forests.	Last 200 yrs, fire/charcoal history and the resulting vegetation changes.
2. Wild Spear Lake *Boreal Subarctic* (MacDonald 1987)	Zone 1 (>11,000 rcyBP) dominated by pollen from herbs and shrubs	Initial presence during Zone 2, and by 9,000-7,500 rcyBP. While *Picea* counts decreases, its influx stayed consistent	By 5,000 rcyBP, the peatland and *Pinus, Picea,* and *Betula* dominated landscape is established; and shows little change to modern day.	Early steppe vegetation. Later establishment of *Picea*
3. Eaglenest Lake *Upper Boreal Highlands* (Vance 1986)	Lake's basal zone (11,800-11,000 rcyBP) is dominated by NAP taxa	Initially notes around 11,000-7,500 rcyBP. Established around 7,500 rcy BP	Once *Pinus* values increased around 7,500 rcyBP, modern vegetation assemblages are achieved and little changes occur.	Highest elevation. Early steppe. Earliest spruce based on pollen
4. Otasan Lake *Upper Boreal Highlands* (Prather and Hickman 2000)	8,200 rcyBP, low diatom concentrations; high abundance of *Ellerbeckia arenaria* suggests turbid, shallow, nutrient-poor water; expected during the initial stages of a lake. High pH	Zone 2, ca. 7,300 rcyBP diatom numbers increase, increased nutrients in lake from higher runoff due to higher precipitation. Small drop in pH level.	Stabilized pH levels. As peatlands developed in the catchment area, and as nutrient supply included more runoff from established forests, the pH dropped (lowest at 5,000 rcyBP).	Although the Boreal Upland vegetation & climate patterns established by 7,200 rcyBP, there were still small changes in the climate to change the acidity of the lake.
5. Kearl Lake *Central Mixedwood* (Bouchet-Bert 2002)	*ca.* 10,250 to 9,820 rcyBP, dominated by *Betula* pollen; *Artemisia* pollen is well-represented, some Compositae and Cheno-Am	Early appearance of spruce *ca.* 10,250 to 9,820 rcyBP. Decreases, but re-established *ca.* 7,580 to 5,900 rcyBP.	*Record ends at 5,900 rcyBP*	Best chronologic constraints. Minimal NAP/steppe vegetation. Earliest evidence of spruce (macrobotanical)
6. Mariana Lake *Central Mixedwood* (Hutton et al. 1994)	ca. 12,000-10500 rcyBP contained high levels of *Artemisia* (>50%), *Gramineae* (>20%), and Cheno-Am.	Initial presence during Zone 2, and in Zone 3 (9,000-7,500 rcyBP) while Picea counts decreases but influx consistent	Modern vegetation composition. Concentrations of upland and peatland species hint at close to modern distribution.	Earliest note of steppe vegetation.
7. Christina Lake *Central Mixedwood* (Laird and Campbell 2000; Philibert et al. 2003)	n/a	n/a	n/a	No regional charcoal signatures found in the study; all appear to be local. Diatoms show no changes as a result for fire (2003)

8. Lofty Lake *Dry Mixedwood* (Lichti-Federovich 1970)	11,400 rcyBP, record dominated by *Populus*, and other steppe-like vegetation (*Salix, Shepherdia,* and *Artemisia*).	Around 9,800 rcyBP, *Picea* dominates the record, ~50%. Once *Betula* appears in the record, spruce sharply declines; returns to modern levels by 3,400 rcyBP.	By 3,400 rcyBP, *Picea, Pinus, Betula,* and *Alnus*	First reported occurrence of an early pollen assemblage dominated by *Populus.* Mazama Ash noted in the record (at 398 cm level)
9. Moore Lake *Central Mixedwood* (Hickman and Schweger 1996)	By 11,830 ± 330 rcyBP, the landscape is dominated by *Artemisia,* Cyperaceae, and Gramineae. *Salix* recorded in small quantities.	Picea and Pinus pollen appears 11,830 ± 330 rcyBP, likely due to reworking. Picea dominates the record between 11,300 – 9,900 yr BP.	By 6,200 rcyBP, *Pinus* and *Picea* represent modern values. Rise in *Alnus* equates to increase of moist peatlands in the region.	Vegetation development earlier than Mariana Lake. Palaeoclimatic record for Canada/Boreal Forest.
10. Alpen Siding Lake *Dry Mixedwood* (Lichti-Federovich 1972)	Around 10,700 ± 170 rcyBP, assemblage dominated by *Populus*, *Salix,* sedges, grasses and sagebrush (390 – 380 cm level)	*Picea* dominates shortly after (378 – 353 cm level); but *Populus*, *Salix,* sedges, grasses, and sagebrush still significant.	Upper units show *Picea, Pinus,* and *Betula* dominating the assemblage, and herbaceous species decreased.	Supports Lofty Lake record, supports early presence of *Populus* in southern boreal limits early in the record.
Peatland	**Early Holocene**	**Middle Holocene**	**Late Holocene**	**Notes**
11. Mariana Lake Peatland *Central Mixedwood* (Nicholson and Vitt 1990)	Peatland development was beginning with transitional poor fens, lakes, mineral soil outcrops, and floating mats around 7,000 rcyBP	Peatland development expanding, like early Holocene but shrub sedge ferns replacing some of the transitional fens by 5,000 rcyBP.	By 3,000 rcyBP, forested sphagnum fens well developed. Water track present and encompass around 60% of modern peatland extent.	Development of peatlands greatly influenced by local factors, but many of the peatlands in northern Alberta were fully developed after 5,000 rcyBP.
12. Marguerite Lake Peatland *Central Mixedwood* (Kubiw et al. 1989)	n/a	n/a	Peatland development begins around 3,400 rcyBP. Begins due to paludification. Increased wetness likely due to periods of increased humidity ~ 6,000 yr BP	

Table 2.1 Summary of the Holocene vegetation studies conducted in the study area. Locations are listed northernmost (top) to southernmost (bottom), with corresponding Boreal Forest subregions following the lake as context for modern vegetation (Downing and Pettapiece 2006).

2.2.5 Modern Vegetation

With close to modern values of pollen, palaeoenvironmental records throughout the region show that vegetation began to stabilize as early as 6,000 rcyBP. This modern boreal assemblage continues into the recent interval, leading to the establishment of the Boreal Forest Region and subregions as defined by the Natural Regions Committee (Downing and Pettapiece 2006). Currently, the area around Sharkbite Lake falls under the Central Mixedwood Natural Subregion, as defined by the Natural Regions Committee (Downing and Pettapiece 2006). Vegetation is characterized by aspen, white spruce, and mixed woods in the uplands, jack pine on well drained materials, and wetlands treed with black spruce in the central areas and plains.

Given that this subregion occupies 25% of Alberta, the distribution and variation of plant species are significantly determined by their geographic location and the geologic and geomorphological settings of the study area. For example, the southern and northern limits of the Boreal Forest can yield similar assemblages, but are varied due to different geomorphological settings on a broader scale. This feature is best demonstrated by the formation of subregions within the Boreal Forest ecoregion. The area around Sharkbite Lake was affected by the LIS retreat and the flood from Glacial Lake Agassiz, leading to a number of forest types as a result of topographic variability. On well-drained deposits, jack pine (*P. banksiana*) stands are often associated with understories of lichen, bearberry, and feathermosses. As the moisture levels increase in deposits, aspen (*P. tremuloides*) and white spruce (*P. glauca*) accompany *P. banksiana* with understories of rose (Rosaceae), green alder (*A. viridis*), bearberry (*Arctostaphylos uva-ursi*), and common Labrador tea (*Ledum groenlandicum*). In fens and along the margins of peatlands, increased moisture leads to black spruce stands that are associated with Labrador tea, sedges, willow (*Salix* spp.), and dwarf birch (*B. glandulosa*) (Downing and Pettapiece 2006:138).

2.2.6 Discussion

This assessment of the changing environmental conditions in the area (Table 2.1) demonstrates that the retreat of the LIS and early vegetation would have opened the area for First Nations ancestors. In parts of northeastern Alberta, around 11,000 rcyBP, a spruce-birch-herb dominated vegetation was in place, following the retreat of the ice. These plant communities were relatively open, with higher proportions of NAP, shrub and herb steppe-like vegetation, and some arboreal species represented. By 9,800 rcyBP, following the end of the Younger Dryas interval and because of a warmer and drier climate, spruce stands seem to have dwindled, leaving a more prominent role for deciduous trees. Pine trees appear in the area, and spruce, birch, and alder trees become more abundant by *ca.* 7,580 rcyBP. The scarcity of NAP and herbs may be indicative of a more closed forest. During this time as well, *Sphagnum* is prominent in the palaeoenvironmental record, suggesting intensive peatland formation during this period. At the southern end of the region, climatic changes around 8,500 rcyBP led to an increase in non-arboreal elements in the Lofty Lake record, indicating a northern advance of grassland margins. By the end of the middle Holocene, the vegetation composition of the region is like today's vegetation cover, indicating that the broad scale make-up of the Boreal Forest has been relatively stable for the past 5,000 years (Downing and Pettapiece 2006; Bouchet and Beaudoin 2017). Differences between the lakes can be attributed to latitudinal and altitudinal differences which influenced vegetation cover and forest composition. Without a synthesis of records from the study lakes within the broader Boreal Forest of northeastern Alberta, these variations of the region's development would be harder to distinguish, emphasizing the value of palaeoenvironmental studies.

2.3 Fire History in the Boreal Forest

Fire is a major, but common, natural disturbance in the Boreal Forest. The region's history is marked by annual cool and wet intervals followed by hot, dry, and fiery periods, all exemplifying the boreal dynamics (Pyne 2007:20–21). Fire frequently occurs throughout the region, and is an important factor for promoting patchiness and diversity in an area (Downing and Pettapiece 2006; Cumming 2001; de Groot et al. 2013; Pyne 2007). The patchiness of the Boreal Forest is caused by fires, and the regrowth that comes from these burning episodes creates a symbiotic relationship between successional communities and faunal communities (Pyne 2007). Ash and charcoal from fires enhances soil fertility and can often promote seedling growth of angiosperm trees within the succession after fire (Pluchon et al. 2014; Timoney et al. 1997). Due to the increased nutrients available after a fire, angiosperms are favoured and rapidly begin to re-establish. Some gymnosperms are not as sensitive to the soil nutrients and do not thrive as quickly or extensively immediately following a fire (Pluchon et al. 2014). Cumming (2001) shows that black spruce stands are the most susceptible to fire, followed by pine, white spruce, and finally deciduous stands. This cyclical burning of the landscape makes the region more habitable for both animals and people, both of which require successional communities (Pyne 2007).

Understanding the nature of fires—fuel preference, stages of succession, natural or anthropogenic fires, and impacts to plant and animal communities—allows archaeologists to use the charcoal record to assess the effects of fire. The fire, depending on its severity, would have had a tremendous effect on resources used by people inhabiting the region. In the context of wildfires, this research can lead to the reconstruction of fire histories and frequencies, and the implications of these natural events for past populations.

2.3.1 Impact of Natural and Anthropogenic Fires

Fire is critical for successional communities and plant variability in the Boreal Forest. The forest responds differently to anthropogenic and natural fires, and this feature is seen through patterns of regrowth and sustained plant communities noted following a burn. Modern fire ecologists understand the susceptibility of different stands to fire (Cumming 2001), but this information would have also been part of the traditional knowledge systems for Boreal Forest peoples. Understanding what would burn, when it would burn, and how vulnerable it was to fire all would have framed the way a controlled burn would be undertaken. The extent and severity of natural fires depends greatly on the available fuels, such as deadfall and fallen trees, and the forest composition, such as deciduous or coniferous trees and/or shrubs (Rowe and Scotter 1973; Cumming 2001; Fisher and Wilkinson 2005; Wein 1991).

Wildfires tend to occur during two periods: spring and summer. Fire season length is determined by spring and fall temperatures. Wildfires are often caused by lightning strikes (the source of 60% of ignitions and 80% of area burned); and can cause a dry, fuel-laden area to burn rapidly and over a great area (Pyne 2007:22). The forest composition and species burned during fires also return at different rates (Table 2.2). For natural fires, conifers are primary burners and crown fires occur in these stands. This kind of fire occurs less often in deciduous stands, and is less likely to result in large-scale stand replacement post-fire (Pyne 2007). Immediately following a fire, the opened canopy allows for lower shrubs and berries to receive sunlight and dominate the forest floor (Natural Resources Canada 2016). Conifers with serotinous cones, such as jack pine and lodgepole pine (*Pinus banksiana* and *P. contorta*), thrive following fires because the heat from the fire allows the seeds to be released from the cones and begin germinating. Taxa such as aspen (*Populus tremuloides*) and birch (*Betula*) are well adapted to forest fire conditions. With fire having exposed mineral soils and depositing charcoal, the resulting environment is productive and nutrient rich. Pioneer species are in optimal conditions to re-establish themselves via seeding and suckering (Cumming 2001; Downing and Pettapiece 2006; Natural Resources Canada 2016; Rowe and Scotter 1973). Other common plants in the Boreal Forest, such as black spruce (*Picea mariana*) and balsam fir (*Abies balsamea*), are not as well adapted to return following a fire. Black spruce has semi-serotinous cones, which is beneficial following a fire, but prefers shade and so grows slower than other pioneer species (Cronan and Jandt 2008; Cumming 2001; Kasischke et al. 2010). Balsam fir has no adaptations to fire, which means seeds must be brought into the area (via wind or animals) in order to re-establish in the area (Boucher and Grondin 2012; de Lafontaine and Payette 2012; Natural Resources Canada 2016). The ecological process that follows a fire changes the vegetational communities in the recently disturbed area, creating new habitats for animals (Fisher and Wilkinson 2005; Rowe and Scotter 1973).

Vegetation Type	**Fire Return Interval (years)**
grassland	1 – 5
aspen parkland	10 – 25
jack pine	50 – 100
white spruce	100 - 150
black spruce	100 - 200

Table 2.2 Fire Return Interval for different vegetation types (Wein 1991:45).

Lee (2002) outlines five successional stages following a fire in an aspen-white spruce forest. They include the Initiation Stage (0-10 years), Establishment Stage (10-25 years), Aggradation Stage (26-75 years), Mature Stage (76 – 125 years), and Old-Growth Stage (>125 years). In a similar fashion, Fisher and Wilkinson (2005) identified four stages. Their pattern follows that of Lee's (2002), with the Initiation Stage (0-10 years), Establishment Stage (11-25 years), and Aggradation Stage (26-75 years). Their successional stages varied because they identity Old Growth stage as 76-125+ years and omit a Mature stage (Fisher and Wilkinson 2005). As such, the vegetation composition and stages outlined by the researchers are similar, and can be discussed in association with one another.

The Initiation stage is characterized by low structure canopy, with aspens, early pioneering shrubs, and herbs re-establishing themselves while patches of live vegetation become established amongst the destroyed areas (Lee 2002:3-1). During the Initiation stage, there are few or no caribou, mustelids (weasel family), lagomorphs (hares and rabbits), and arboreal sciurids (squirrels), most likely due to lack of food (such as lichens) and shelter immediately after the disturbance (Fisher and Wilkinson 2005). Moose and other ungulates, ursids, and canids still use this area for foraging. Although shrubs are initially scarce for ungulates, the fire stimulates the return of deciduous species (Fisher and Wilkinson 2005; Hauge and Keith 1980; Penner et al. 1980; Rowe and Scotter 1973). Increased sunlight at the ground surface promotes rapid regeneration of vegetation like blueberries and bearberries, which attracts bears to the area (Penner et al. 1980).

The Establishment stage is characterized by stands that lack a proper canopy structure due to loss of leaves and branches. By this time post-disturbance, the initial communities of trees and shrubs have continued to grow and dominate the lower vegetation (Lee 2002:3-2). During this stage, arboreal sciurid and ungulate populations continue to increase (Fisher and Wilkinson 2005; Rowe and Scotter 1973). Mustelids appear but have poor-quality habitats (Fisher and

Wilkinson 2005; Gilbert 1979). **The Aggradation**, or seral, **stage** sees the canopy redeveloping and dominated by smaller trees. During this time, there is an emergence of white spruce, which breaks lower canopy levels (Lee 2002:3-2). This stage sees an increase in lichen and moss cover, which attracts ungulates like the woodland caribou (Fisher and Wilkinson 2005; Fuller and Keith 1980). As the understory begins to diminish, moose populations decrease in the area. There is still a low abundance of arboreal sciurids as well as mustelids, due to poor habitat (Fisher and Wilkinson 2005; Gilbert 1979; Green 1979).

During **the Mature/Old-growth stage**, less light reaches the forest floor because the canopies are well established. Stands achieve their peak size, and little growth is achieved after the mature stage (Lee 2002:3-2 – 3-3). Because of the relative stability in the canopy and gradual build-up of standing or downed woody material, rodents, mustelids, and arboreal sciurids have high species richness (Fisher and Wilkinson 2005; Green 1979; Rowe and Scotter 1973). Caribou thrive in this stage because lichen has returned; this cover is suitable forage for caribou because of their unique digestive capacities (Fisher and Wilkinson 2005; Fuller and Keith 1980). At this stage of vegetation diversity, the stands are well established, and the mosaic becomes relatively stable, completing the successional cycle.

Anthropogenic fires can initiate these successional stages in the Boreal Forest ecoregion but vary from natural fires in their seasonality, frequency, and extent. The seasonality of controlled burns is different from that of natural fires (Kimmerer and Lake 2001; Lewis 1977, 1982; Lewis and Ferguson 1988). For northern Alberta, early spring was the time that was preferred to burn (Lewis 1982). Soils were moist enough to limit the amount of available fuel, but the grass was dry enough to burn. This timing precedes the natural fire season, a factor which led to an extended growing season. This feature in turn attracted new game into the area. It was critical to ensure that burns would not rapidly engulf large areas, so great care and planning was taken before starting a burn.

Ethnographic accounts and oral traditions indicate that anthropogenic fires were much more frequent than natural fires and different schedules were employed from year to year depending on the goals of the fire. Annual fires would be conducted to increase game, a cycle of 3-5 years was employed to maintain berry patches, and spans of 10-12 years were used to maximize regeneration of aspen and willows around beaver ponds (Kimmerer and Lake 2001:39). Anthropogenic burns were modest in scale relative to natural fires, and maintained small successional patches. Larger scale burns were considered “maladaptive, disrupting the diverse mosaic, disrupting ecotones, and decreasing productivity and stability of the food supply” (Kimmerer and Lake 2001:39).

The locations targeted for controlled burns may not have been affected by natural fires. Riparian areas, for example, would probably not burn without human intervention; but were often targeted for controlled burns. The location of these fires is thought to be indicative of movement along a landscape, and sometimes followed elevational gradients to ensure species richness throughout the seasons (Kimmerer and Lake 2001:40). Targeted burns enhanced First Nation communities’ mobility and productivity of the area upon returning. Lewis (1977, 1982) documented more than 70 uses of fire, including tree felling, clearing travel corridors, fireproofing settlements, and hunting. Burning also was used to reduce pest populations, including rodents and biting insects in the summer months in northern Alberta (Lewis 1977, 1982). Indigenous people used fire to modify the environment for their survival. Most importantly, fires created a mosaic of habitats, the diversity of which promoted food security (Lewis 1982; Kimmerer and Lake 2001). In Alberta, the Boreal Forest's southern extent has been noted to be moving farther south into the areas previously dominated by grasslands. This transition is captured in palaeoecological and historical records for Alberta, by which Campbell et al. (1994) demonstrated that in addition to fire, bison activity helped maintain the grasslands. Fire suppression and the removal of bison from the region led to an expansion of *Populus* and a broadening Aspen Parkland. Lewis (1982) also noted this shifting of ecoregion boundaries, with narratives from elders that attributed the southern extension of the Boreal Forest to the cessation of traditional anthropogenic management practices that resulted in the formation and maintenance of grasslands and meadows.

2.3.2 Use of Pollen and Charcoal to Interpret Fire Histories

Monitoring and documenting modern fires over the last 100 years has provided valuable information about successional communities in the Boreal Forest. However, proxy records must be employed to assess prehistoric fire frequency, fire severity, and successional communities over longer time frames. Lacustrine sediments are suitable for assessing this prehistoric fire frequency because the waterlogged sediments create conditions that preserve both pollen and charcoal. Pollen is used to determine the regional stand composition before and after a fire, and charcoal can be used to infer fire frequency, severity, and the local or regional extent.

Pollen has become one of the most common proxies used for interpreting and detecting human activities in a landscape (Li et al. 2008). Markers of these human activities are a decline in certain pollen taxa, flourishing or pioneer plants, and rapid or abrupt shifts in pollen concentration and richness (Birks et al. 2016; Faegri and Iversen 1989; Havinga 1967; Li et al. 2008). As an example, the ratio of arboreal pollen to non-arboreal pollen grains (AP/NAP) has been interpreted as a potential indicator for precipitation change, community composition, and structure in forested environments (e.g., Li et al. 2010:255; Davis 1980). This ratio of AP/NAP taxa is commonly applied to naturally modified vegetation communities but can reflect anthropogenic modification of plant communities and structure in pollen records.

Taxa that indicate human activity are traditionally associated with agricultural practices, such as *Rumex*, Gramineae, *Chenopodium*, and *Ambrosia* which are common to disturbed areas and areas prepared for agricultural use (Swain 1978). Many plants from families like Gramineae, Cucurbitaceae, and Leguminosae require humans for their dispersal and distribution and demonstrate a link to landscape use and human activities (Li et al. 2008, 2010; Swain 1978). Palaeoenvironmental records are usually continuous (Faegri and Iversen 1989; Pearsall 2002) and so are valuable for contextualizing the often episodic archaeological record. These proxy records become valuable in areas like the Boreal Forest, where recovery of physical artifacts is limited due to acidic soil conditions. In lacustrine sediment, a visible charcoal band or a peak in micro-charcoal concentration signifies a fire event. The composition of a forest before a fire can be determined from the pollen record and can indicate if a forest was well established or if it had recently been subject to a fire. Following a fire event, pollen richness and the taxa present indicate the new species present in the recently burned area. The technique of interpreting pollen assemblages before and after a fire has been used in many studies (e.g., Asselin and Payette 2005; Cui et al. 2014; Iglesias et al. 2015; Laird and Campbell 2000; MacDonald et al. 1991; Power et al. 2008; Sugita et al. 1997; Tinner et al. 2006; Worona et al. 2010).

Pollen as an independent marker is not as effective at presenting regional and local vegetation and fire trends because some pollen grains are subject to long-distance transport. Perhaps the most direct way of constructing fire history is through charcoal. Charcoal within a sediment record yields essential clues for palaeoenvironmental reconstructions, as well as for its use as a dateable macrobotanical source (Bird 2013). The presence of charcoal in sediment cores can inform researchers of long-term trends of fire occurrence, as well as provide context for vegetational shifts following a fire (Iglesias et al. 2015; Tinner et al. 2006; Whitlock and Tinner 2010:55). The size of charcoal fragments can be used to determine the scale of burns, with larger pieces being indicative of more local scale burns near the sampling site (Asselin and Payette 2005). Identifying and dating these 'local scale episodes' in the context of an archaeological site and its surrounding landscape helps refine our understanding of the region.

Key factors to consider when understanding proxy records such as sediment cores are the temporal and spatial resolution that each record represents for an area. Accumulation rates, local environment, climatic changes, and variability in the record are factors that will determine the ability to infer human activity and local scale changes in these proxies (Pearsall 2002). If accumulation rates are low, and few macrobotanicals are present in the record, constraining environmental events and dating accuracy are limited. Large intervals between accumulation episodes present a low-resolution reconstruction of human activity in an area. Factors independent of lake processes, such as local environmental changes and dominant wind flow, are also important to consider in relation to preferentially targeting areas to survey and test. Different research designs allow researchers to understand what type of record was captured in the lake, and what information it yields for understanding human-landscape dynamics.

2.4 Summary and Conclusions

Palaeoenvironmental research to date has addressed issues such as when the Boreal Forest was established and major postglacial environmental trends in the region. However, the late Holocene in the Athabasca River Valley has not been studied, nor has there been high resolution research conducted that spans the entire late Holocene. Sharkbite Lake's record has valuable data to offer, and new information to present for the late Holocene (see Chapter 3). Dramatic changes occurred in the Boreal Forest region at the beginning of the Holocene, and these changes led to the transformation and shaping of a landscape. This landscape was scoured by glacial ice sheets, river valleys were formed by catastrophic floods, and the terrain was quickly re-occupied by plant communities. As the geologic history of the region is continually refined with new research, these early events are critical to our understanding of humans arrival and occupation of the region. For the landscape, once vegetation was established, the Boreal Forest did not become a static backdrop to human and animal activity. It was susceptible to human and natural fires. Fire is essential to the maintenance of the Boreal Forest. The region's vegetation and environmental history sets the stage for human occupations. For First Nations, the environment is an important tool that they use to influence hunting rounds and anthropogenic landscape management practices (see Chapter 5).

The last 3500 years of the region's palaeoenvironmental history is poorly understood, in part due to the lack of detailed records, but also due to few significant changes in the environment prompting new research. In looking at the Holocene records from across the region, these last millennia are found within as few as 50 cm of lacustrine sediments. Teasing apart valuable information is challenging. Records yield broad regional trends. Overall, we see an established Boreal Forest, unchanged and without major disruptions to vegetation. Although this view is in part true because the forest has maintained relative stability since approximately 5,000 rcyBP, the region is not without vegetation events. It has not remained unchanged. During these past 3500 years, these changes occur on a much smaller scale, and reflect local events that influenced vegetation diversity, faunal distribution, and human landscape use. Because these events represent a few years at most, without a high-resolution record these changes are hidden. Sharkbite Lake provides a unique perspective into the region, because it tracks the responses to climatic changes that informs our understanding of the late Holocene.

Chapter 3 Sharkbite Lake Core Introduction

3.1 Field Work

3.1.1 Site Context

Sharkbite Lake is a small lake located northeast of Fort Mackay in the Central Mixedwood section of the Boreal Forest (Downing and Pettapiece 2006), where slightly elevated terrain features are dominated by aspen, mixedwoods, and white spruce, with abundant black spruce around fens and bogs in wetland areas (Downing and Pettapiece 2006:136-137). Topographically, the region has a number of elevated landforms but local relief is low; only perhaps 5m to 10 m at most in the area around Sharkbite Lake. The lake is one of three lakes in a chain that drains to the Muskeg River. At an elevation of 282 masl, Sharkbite is a relatively small lake with an approximate surface area of 0.05 km², or 52745.58 m². From the northern tip to the southern edge it extends 455 m and is 120 m at its most narrow point east to west[1]. Sharkbite Lake is situated in the muskeg-dominated landscape south of the Muskeg River (Figure 3.1, Figure 3.2. Sharkbite Lake drains through an ephemeral stream into Keyhole Lake, and from here both Keyhole and the third unnamed lake drain into the Muskeg River (Figure 3.3). The lake is in the active mining area of the Muskeg River Mine that is jointly owned by Canadian Natural Resources Limited, Chevron, and Shell Canada. The mine has been in operation since 2003.

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[1] Area and dimension measurements derived from Google Maps and DaftLogic Google Maps Area Calculator (Dec. 2017)

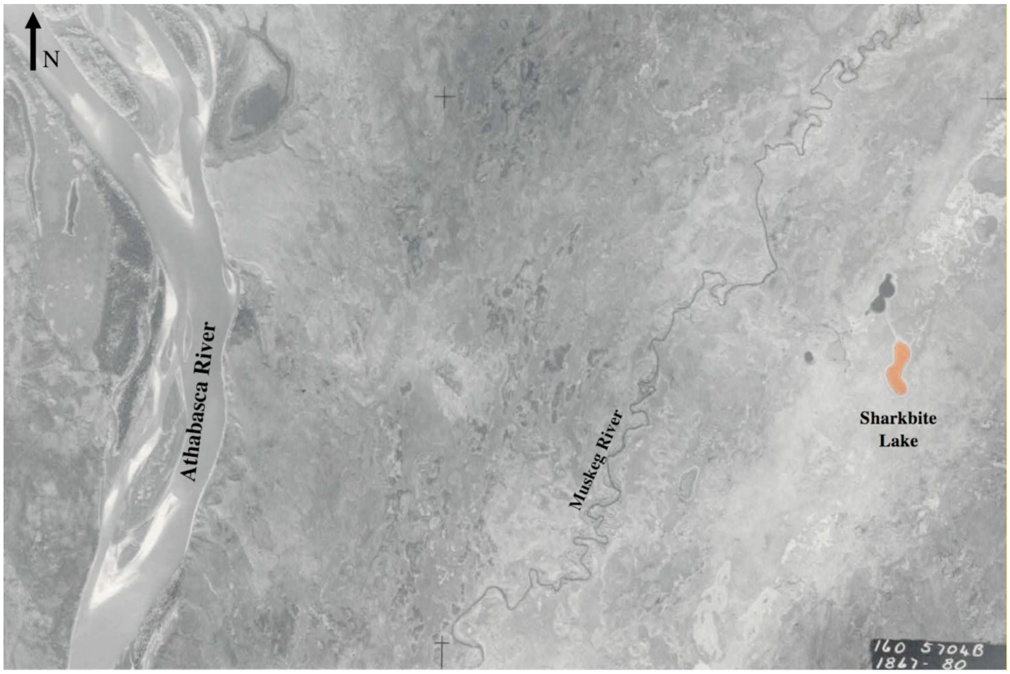

Figure 3. 1 Sharkbite Lake prior to major development. Source: Alberta. Department of Lands & Forests. 1867-5704B-80. Scale 1:40,000. Edmonton: 1950. Cropped by C. Poletto 12/2017

Figure 3. 2 Sharkbite Lake (Google Maps 2015) and development footprint of the Muskeg River Mine.

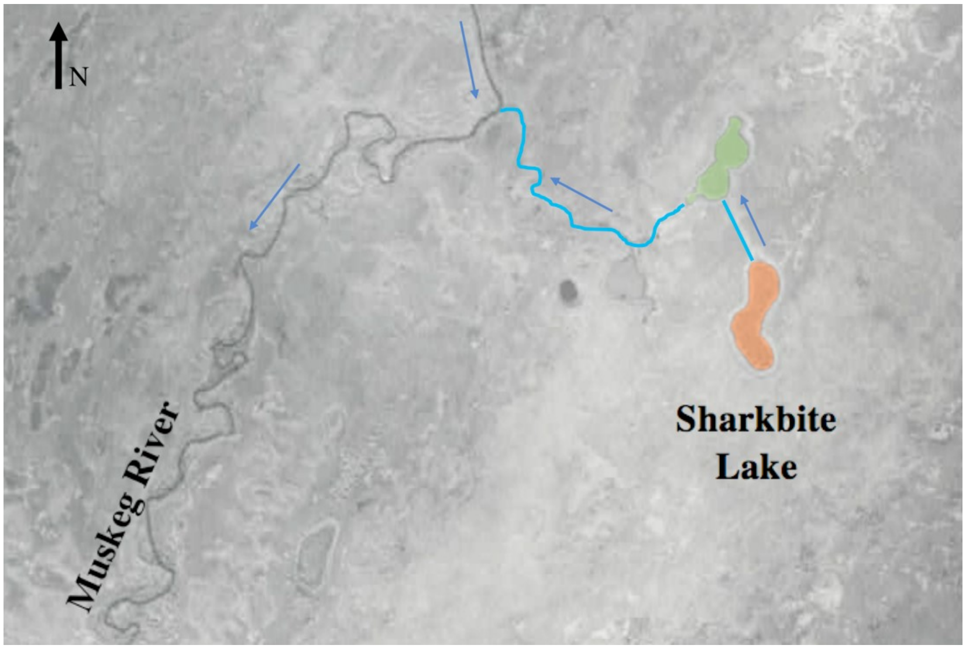

Figure 3. 3 Drainage to Muskeg River (in light blue), into Keyhole Lake (in green) from Sharkbite Lake. Blue arrows denote the flow pattern in the Muskeg River watershed. Source: Alberta. Department of Lands & Forests. 1867-5704B-80. Scale 1:40,000. Edmonton: 1950. Cropped by C. Poletto 12/2017

3.1.2 Coring Procedure

A 3.8 m length of core was obtained from Sharkbite Lake in February 2010 by Robin Woywitka[2], Alwynne Beaudoin[3], and Darryl Bereziuk[2]. Three coring locations were sampled in total, but the core analyzed for this study is from location ‘F1’, approximately 40-50 m in from the lake’s outlet. Here, the water depth was 16.35 m below the ice surface. The core was obtained using a Reasoner corer (Reasoner 1986, 1993). The drive bottomed out at 5.30 m below the sediment-water interface and was brought back to the surface for a recovery length of 4.87 m. The uppermost unconsolidated samples were drained as the core was initially intended for Early Holocene work. Once drained, the empty length of PVC pipe was sawn off and the sediment-

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[2] Government of Alberta, Alberta Culture and Tourism.

[3] Royal Alberta Museum

filled pipe was capped. The PVC pipe containing the core was then split into two segments (Referred to as Top Half (½) and Bottom Half (½)) for ease of transportation (Figure 3.4). The core was kept at below freezing temperatures overnight and transported back to Edmonton the following day. The core was brought to the Royal Alberta Museum (RAM, Glenora site) and was stored in a walk-in freezer set at -25ºC (-13˚F) until sampling began in October 2016.

3.2 Methodology

3.2.1 Splitting the core

The core's segments were split in several stages. First, the frozen core lengths were transported from the RAM to the University of Alberta Prep Lab, and the PVC tubing was split with a circular saw. Once split, the lengths were stabilized with thick plastic wrap, a large plastic tube casing, and multiple layers of duct tape. Each piece was relabelled as soon as any identifying numbers were removed.

The first section of core to be subsampled was the Bottom ½ of Sharkbite F1. In order to split the core, it was removed from the freezer for 13 hours to thaw at room temperature. Because it had not thawed completely, it was then stored in a fridge at 3ºC (16ºF) overnight. A jab saw and modified kitchen knife were used to split the core; a piece of plastic wrap was tucked in behind the knife as the core was split. Owing to the amount of time that the core had to be left out, the sediment had settled primarily in the bottom horizontal length of the core. As a result, all but the bottom 38 cm of the top horizontal length of core was vacant (referred to as the 'residual core'). The core was assessed for integrity: banding present in the core suggests that although the sediments had settled during thawing, there was minimal disturbance to the original depositional pattern. The residual core was transversely sectioned into 2 cm disks and stored in clean plastic bags for eventual wet sieving.

Even with minimal disturbance to the sediments with the previous method, the other pieces of the core were not split until access to a bandsaw was obtained. In mid-December 2016, the bandsaw was available for use and the top segments of the core were split. To transport this core, and to allow for a cleaner cut with the bandsaw, this section of core was further split into two pieces; Top ½ A (absolute top of core to new cut) and Top ½ B (new cut to previous field cut) (Figure 3.4). A jig was created to glide the core smoothly through the bandsaw, splitting from top to bottom to follow the original deposition flow.

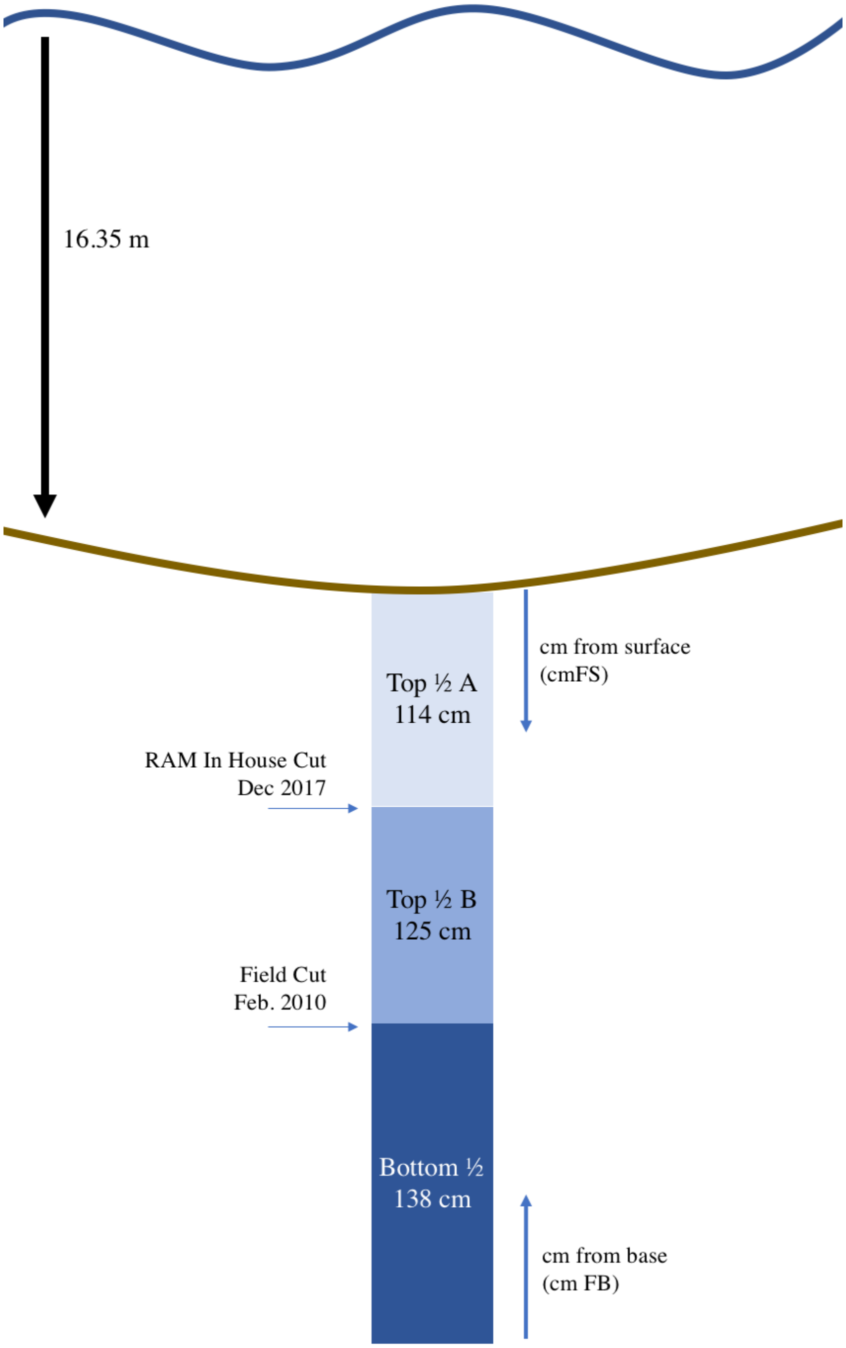

Figure 3.4 Visual representation of the core drive as recovered from the lake, reflecting how the PVC was subsequently split. This sketch is not to scale. (C. Poletto)

3.2.2 Core descriptions

Sharkbite Lake Core F1 has 13 visually discernible units (Table 3.1). The core has a strong smell of bitumen throughout and a thin film iridescence noticeable under light. In addition, many of the units near the base of the core drives are massive with limited banding. Upper sections of core contain dominantly molluscs and some macrobotanicals, the latter primarily aquatic plants. There were no macrobotanical mats or charcoal layers in the core, but rootlets and molluscs did appear periodically throughout. Depths of the core are referenced as cm from base (cmFB) or cm from surface (cmFS) (see Figure 3.4 for a visual representation of these measurements)

Most of the units in the core were massive, composed of either silt, sand, or clay in varying quantities. Only the Bottom ½ had strong to moderate effervescence, while the rest of the core reacted minimally to the diluted (10%) hydrochloric acid. The first laminations appear in Unit 2, where five large laminations alternate in colour. These laminations range in size from 1 cm to 2.5 cm. After 144 cmFB (Unit 7) laminations appear more frequently and are 0.25 to 0.75 mm in thickness. The final unit of the core, Unit 13, is comprised primarily of gyttja and, during the sampling stage, this unit lost a great deal of its volume as the water drained from the sediment.

Coning—resulting from percussion coring—appeared and shifted sediments substantially only in Unit 7. Minor coning can be noted throughout the core however the sediments have moved only a centimetre or two in most places, whereas in Unit 7 sediments shifted by approximately five centimetres. This shifting did not affect sampling, however, because the laminations were easily traced and samples were removed only from the central undisturbed sediments.

	Unit	Structure	Sediments/ Texture	Colour	Efferves-cence	Sampling Locations	Notes	Unit Start (dfb) / (dfs)	Unit End (dfb) / (dfs)
Bottom 1/2	1	Massive, no laminations or structural changes.	silty	10YR 2/1 Black	Moderate	16	No visible roots, possible macrobotanicals.	0 cm / 377 cm	64 cm / 313 cm
	2	Laminated units (5 bands).	silty - fine sand.	2.5Y 3/2 Very dark greyish brown	Strong	5	Laminations between 1 cm – 2.5 cm	64 cm / 313 cm	71.5 cm / 306.5 cm
	3	No visible structures, massive.	silty	10YR 2/1 Black	Moderate - Strong	5	1 modern intrusion on surface. No visible macros.	71.5 cm / 306.5 cm	94.5 cm / 283.5 cm
	4	No visible structures or macros, massive, one distinct band.	clayey-silt	2.5Y 3/2 Very dark greyish brown	Strong	1	No visible macros.	94.5 cm / 283.5 cm	95.75 cm / 282.75 cm
	5	No visible structures, massive.	silt	10YR 2/1 Black	Moderate	10	No visible macros.	95.75 cm / 282.75 cm	137.5 cm / 240.5 cm
Top 1/2 B	6	No visible structures, massive, no visible macros.	sandy - silt	2.5Y 3/2 Very dark greyish brown	Mild	3	No visible macros.	137.5 cm / 240.5 cm	144 cm / 233 cm
	7	Highly laminated.	clayey-silt	10YR 2/1 Black	Mild	10	2 molluscs. Coning between 173-185 cm. Coning = 7.5YR2.5/1 and 10YR 2/2.	144 cm / 233 cm	185 cm / 194 cm
	8	Tiny laminations, minimal coning, massive.	clayey-silt	10YR 2/1 Black	Very little - None	11	Band of white/blue material. Herbaceous material.	185 cm / 194 cm	230 cm / 143 cm
	9	Mainly massive, no visible structures.	silty-clay organic rich	10YR 2/1 Black	None	8	Organic rich. One shell found.	230 cm / 143 cm	262 cm / 115 cm
Top 1/2 A	10	Some faint laminations mottled in parts. Massive overall.	silty-clay	10YR 2/1 Black and 10YR 3/2 Very Dark Greyish Brown	None	7	Shell found.	262 cm / 115 cm	287 cm / 90 cm
	11	Very few laminations at beginning of unit. Minor mottling. Massive.	silty	10YR 2/1 Black and 10YR 2/2 Very Dark Brown	Very little	7	One frost crack.	287 cm / 90 cm	312 cm / 65 cm
	12	Massive, no visible structures.	silty with some sand	10YR 2/1 Black	Very little	3	One frost crack.	312 cm / 65 cm	325 cm / 52 cm
	13	Massive, loose organic rich sediment.	fine silt / gyttja	7.5YR 2.5/1 Black	Very little - None	12	Some clay clumps. Lost much of its water content. Two shells.	325 cm / 52 cm	374 cm / 4 cm

Table 3.1 Outline of all criteria and results from visual inspection of Sharkbite Core (Note: dfb means depth from base, dfs means depth from surface).

3.2.3 Sampling the core

Once the cores had thawed and the sediment was sufficiently soft, sampling began. Five cubic centimetre (cc) plastic syringes were modified with a Dremel tool and an exacto-blade to widen the nozzle. The interior lip was filed so that it would glide into the sediment more easily.

The entire core was sampled at 4 cm increments, starting at the base. Certain areas of interest deviated from this sampling pattern, such as the laminated segments of Sharkbite F1 Bottom ½ at 64 cm from base, because these were the only visible structures in the core. In addition, initial samples from Top ½ A and Top ½ B followed a slightly different procedure. Sets of samples were taken from 4 cm from the previous sample in the other core, and then at 4 cm from the base of the new core length in order to ensure the areas where the core was split were still properly represented (See Appendix A for all sample depths).

At each sampling interval, two sets of 2 cc were taken (parallel to each other); and were bagged as individual 1 cc bags (a total of 4 bags per interval). For samples at 12 cm from base (cmFB) and 14 cmFB, the presence of the core catcher resulted in the collection of 3 cc rather than 4 cc. Due to the organic-rich nature of the gyttja sediment, the top samples at 368 cmFB and 372 cmFB lost a significant amount of water during sampling, so only 2 cc was collected for these depths. One cc aliquots were collected at each interval for pollen processing, and 1 cc was collected for loss-on-ignition. The remaining 2 cc were collected and stored for any potential future analyses.

After each interval was sampled, small ethafoam plugs were placed in the cavity so sediments would not re-distribute and to maintain the integrity of the sample location. At the end of processing, the core was photographed again, wrapped with plastic, and stored in tight-fitting core bags to minimize the risk of freezer-burn. Only half of Top ½ A and Top ½ B was used for sampling. The other halves act as undisturbed, archival cores. These lengths are currently stored in the walk-in freezer at the Royal Alberta Museum (Glenora site).

3.2.4 Pollen Processing

As previously outlined, pollen samples were taken from the entire length of the core at 4 cm increments using plastic syringes and a metal spatula when required. In the laboratory, each pollen sample was prepared according to the following method, adapted from Faegri and Iversen (1989:72–82):

1. Each 1 cc plug was wet screened with distilled water to remove large organic materials and pebbles. Samples were transferred from a 50 mL beaker to a 25 mL plastic centrifuge tube.
2. Two *Lycopodium* tablets (batch #483216, a mean of 18,583 spores; batch #414831, mean of 12,100 spores; or batch #710961, mean of 13,911 spores) were added as the exotic spike.
3. Five millilitres of cold 10% hydrochloric (HCl) acid solution was added to the samples to remove calcium carbonates. Samples were rinsed twice if colloidal materials appeared after the first rinse, to a maximum of three rinses (then centrifuged, decanted, rinsed with distilled H_2O, and centrifuged and decanted again).
4. Five millilitres of sodium hydroxide (NaOH) were added to remove humic acids in the sample. The sample was processed with NaOH until the supernatant was a straw-like colour. No more than three rinses of NaOH occurred (the sample was then centrifuged, decanted, rinsed with distilled H_2O, and centrifuged and decanted again).
5. Five millilitres of hydrofluoric (HF) acid was added to cover sediment and the tube was placed in a boiling water bath for one hour (then centrifuged and decanted).
6. Five millilitres of 10% hydrochloric (HCl) acid was added to remove fluorosilicates (then centrifuged, decanted, rinsed with distilled H_2O, and centrifuged and decanted again).
7. Samples were washed with 5 mL of glacial acetic acid.

8. The samples were boiled for five minutes in a 15 millilitres acetolysis mixture (a 9:1 mixture ratio of acetic anhydride ($(CH_3CO)_2O$) to sulfuric acid (H_2SO_4) to remove cellulose) (then centrifuged and decanted).
9. The samples were neutralized with a rinse of 5 mL glacial acetic acid (then centrifuged and decanted).
10. The samples were rinsed with distilled water to further neutralize (then centrifuged and decanted).
11. Three drops of safranin stain were added to samples along with distilled water to stain pollen grains.
12. Samples were dehydrated with alcohol and tertiary-butyl alcohol (TBA) (centrifuging and decanting between each of these).

Samples were transferred to an Eppendorf vial, then silicone oil was added to cover stirred samples. Sample left uncovered for TBA to evaporate for 24 hr (longer if required). All pollen processing took place at the University of Alberta Department of Anthropology Biological and Chemical Lab under the supervision of Harvey Friebe. Great care was taken to ensure that there was no contamination between samples. An average of eight samples was processed at a time. Once the TBA evaporated, the pollen vials were labelled and stored in the Environmental Lab in the Department of Anthropology.

Not all the 98 samples were counted, but a broad analysis of the core (at an interval of 20 cm between samples) yielded a sufficient overview of pollen for the scope of this study. Certain depths of interest, such as the mineralogical inclusion at 140 cm from base and the laminations beginning at 64 cm from base, were analyzed at a finer resolution, and areas of interest based on LOI values or initial scan sample counts were counted. In total, 54 samples were analyzed for this study. Each slide was counted to a minimum of 500 grains, apart from 140 cm FB where only a count of 255 was achieved. Counts ranged from 255 to 1261, with an average of 685 grains. Each slide was analyzed at equal transects, using the Olympus BX53 Microscope at 40x magnification. Pollen sum is the total number of terrestrial tree, shrub, and herbaceous grains counted, and specific spores (such as *Lycopodium* sp., *Equisetum* sp., *Dryopteris* sp., and *Sphagnum* sp.). Identification was done using the pollen reference collection at the University of Alberta's Department of Anthropology Environmental Lab and the Pollen Identification Key by Habgood and Simons (1985) and Kapp *et al*. (2000). To ensure identification consistency, the first eight samples counted were recounted at the end.

For arboreal taxa, *Betula* was identified as either three-pored or four-pored, and the size of these grains was measured in samples at intervals of 20 cm. Although it can be challenging to distinguish *Betula* species, specifically identifying *B. glandulosa, B. papyrifera,* and *B. nana*, grain diameters are believed to be a distinguishing characteristic between arboreal (>20 microns) and shrub species (<20 microns) (MacDonald 1987; Vance 1986). Although Ives (1977) found that there is considerable overlap between arboreal and shrub species, the information yielded from this analysis can still be used to interpret some ecological variability. *Pinus* and *Picea* were not identified to species level, due to the tedious nature of the distinction (i.e., using discriminant function analysis (DFA) based on three measurements on the grains) (e.g., Brubaker et al. 1987; Hansen and Engstrom 1985; Lindbladh et al. 2002). Because the core is known to represent the late Holocene, it is quite likely that both *Picea mariana* (black spruce) and *Picea glauca* (white spruce) are represented in the assemblage but not in any significant variability. *Pinus* pollen grains are likely all the diploxylon pine *P. banksiana,* because *P. contorta* are uncommon to the region. Diploxylon pine pollen grains are distinguished by the absence of verrucae along the distal portion of corpus (Habgood and Simons 1985). Plant names largely follow Moss (1989).

However, some plant family names have changed, so the following equivalencies are used in the discussion of the core: Poaceae for Gramineae, and Asteraceae for Compositae.

3.2.5 Wet Sieving

Wet screening of material from the Residual Core and select depths of Top ½ A length occurred in 2 cm intervals. Samples were prepared using an adapted protocol from Beaudoin (2007) (for depths see Appendix B). These sections of core were targeted specifically to retrieve a sample for radiocarbon dating. Future research would benefit from an examination of the rest of the core's sediments, and for more potential radiocarbon samples. Each sample was weighed in its whirlpak bag and then added to a 120 mL specimen container. Water was added to the sample to help disaggregate any clay particles prior to screening.

Samples were sieved through 5 sieves of 1.00 mm, 500 µm, 250 µm, 150 µm, and 90 µm mesh size. Screens were thoroughly washed between samples to remove any materials caught in the mesh. Any material caught in the screens between 500 µm to 90 µm was left to dry and stored in scintillation vials. Materials found on the 1.00 mm mesh were sorted for identifiable macrobotanicals and invertebrates. All residues and macroremains were dried and stored in scintillation vials. To ensure there was a sample remaining for cryptotephra analysis, an additional 63 µm sieve and a catch bottom was used for Top ½ A. The samples were washed carefully through the 90 µm and 63 µm mesh using distilled water, and all residual sediment passing through the 63 µm mesh was retained for potential tephra analysis.

Once sorted, all macroremains were inspected under a dissecting microscope for identification. Molluscs were identified with the aid of Clarke (1981), and identification was confirmed with the Royal Alberta Museum's mollusc reference collection. Similarly, seeds and identifiable botanical elements were identified using Montgomery (1977), Martin and Barkley (1961), Harris and Harris (1984), and then verified with the Royal Alberta Museum's Quaternary Environments Seed Reference Collection. Entities were vialed based on type and depth, and all relevant information for the samples were included on the vial labels.

High numbers of macrofossils were not expected from the core. The core was taken from the deepest part of the core basin, where macrofossils rarely reach (Birks 2001:51-52). The littoral zones of small and shallow lakes location are considered the most suitable location for macrofossil studies (Birks 2001:51-52). However, Sharkbite Lake's modern extent and depth is small and shallow relative to some of the other lakes in the region and would likely capture some macrofossils within the deepest part of the basin (Figure 3.5).

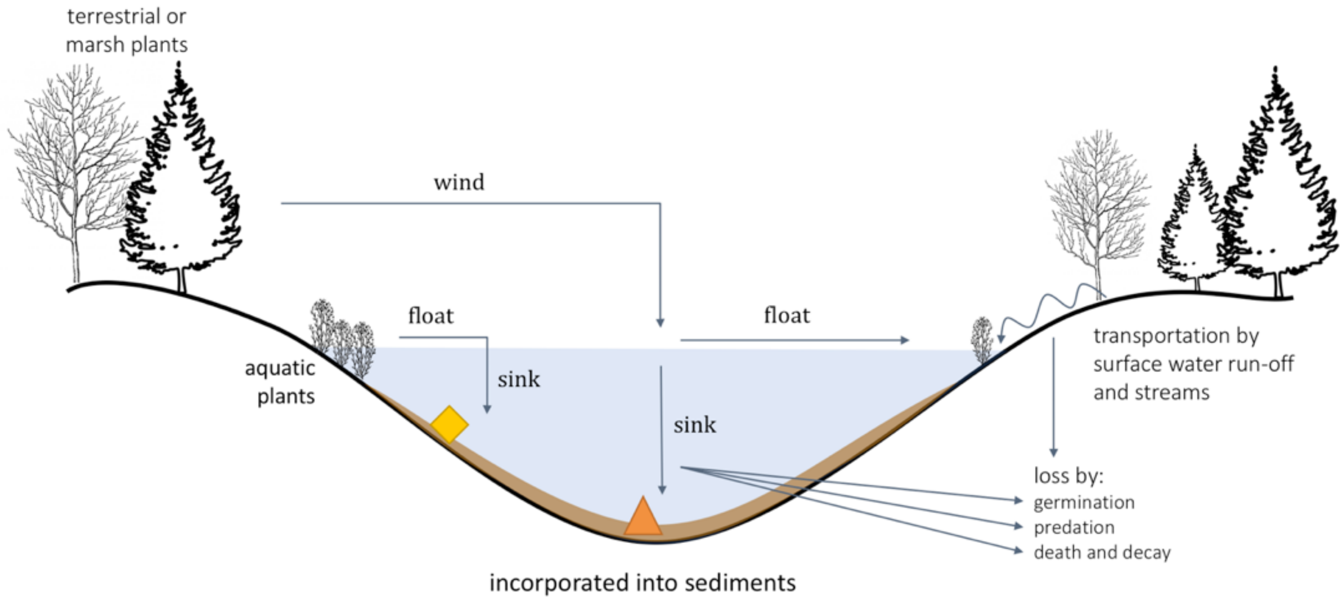

Figure 3.5 Taphonomic processes and processes of deposition in a temperate lake. The orange triangle is a representation of where Sharkbite Lake's core would have been taken in a lake such as this, whereas the yellow diamond shows the most suitable location for future macrofossil studies of the area. Adapted from Birks (2001:53).

3.2.6 Loss–on–Ignition

Loss-on-ignition (LOI) is a fast and effective process commonly used to estimate organic and carbonate content in sediments. Samples of sediment are heated to predetermined temperatures, and the recorded loss of weight after heating is used as a measure of organic and inorganic content (Boyle 2001). The temperatures indicated by Dean (1974:242) represent the temperatures by which organic material will be completely ignited (550˚C), and when CO_2 will change from calcium carbonate (850˚C). Critics (e.g., Boyle 2001) of the method highlight the sometimes-unstable nature of sediments. Sediments can in some cases present results that are not consistent with alternative methods for calculating the organic and carbonate content. However, studies have shown that LOI, when done using consistent and rigid procedures (Heiri *et al*. 2001; Beaudoin 2003), produces accurate measures and is a fast and effective process.

From each sample interval, 1 cc of sediment was left overnight in a Blue M Stabil-Therm Gravity oven at 105˚C for 24 hours to determine the dry weight (DW). Once the dry weight was recorded, the samples were then placed in a ThermoLyne 62700 muffle furnace at 550˚C for 4 hours to oxidize the organic material. Once complete, the weight of the sample was recorded. The LOI residue of samples processed only for organic content were transferred to Eppendorf vials for storage. Samples from every 20 cm of the core, and any additional depths of interest, were returned to the muffle furnace for 2 hours at 950˚C to oxidize carbonate material. Sample weights were recorded after the cycle and remaining materials were stored in Eppendorf vials.

The following equation was applied to determine the proportion of organic material in each sample:

$$LOI_{550} = ((DW_{105} - DW_{550})/DW_{105})*100$$

where LOI_{550} represents the percentage of loss on ignition at 550˚C, and DW_{105} is the dry weight pre-combustion and DW_{550} is the weight following the organic heating cycle (Heiri et al. 2001:102).

Similarly, the equation for carbonate content is:

$$LOI_{950} = ((DW_{550} - DW_{950})/DW_{105})*100$$

where LOI_{950} represents the percentage of loss on ignition at 950˚C, and DW_{550} is the dry weight following the organic cycle, DW_{950} is the weight following the carbonate cycle, and DW_{105} is the dry weight pre-combustion (Heiri et al. 2001:102). Variations in organic and carbonate content provide insight into lake productivity, clastic influx, organic content, and pH levels.

3.2.7 Chronologic Controls

3.2.7.1 Radiocarbon Dating

Two wood samples from Sharkbite Lake were submitted to UC Irvine Keck AMS Laboratory for radiocarbon dating. The first sample was a 9.2 mm twig from 0-2 cm FB (FIRCP-01) (Figure 3.6). This piece was visually inspected for any identifying features, and then prepared using a Soxhlet pre-treatment (see Young 2018:54 for methods). Soxhlet extraction sonicates samples in a 2:1 toluene/methanol solution to remove any of the bitumen or other solvents (Jull 2013; O'Keefe et al. 2009). This pre-treatment was followed by an Acid-Base-Acid (A-B-A) pre-treatment. The Soxhlet pre-treatment was necessary prior to radiocarbon analysis due to the bituminous nature of the sediment, as evident by the strong bituminous scent and thin iridescent film that is apparent on the core surface. Bitumen contains ancient carbon that would have made the dates appear anomalously old (Scott 2013; Jull 2013; Fuller et al. 2014). Sharkbite Lake is situated in the lower Mannville Group of the Lower Cretaceous bedrock. These McMurray Formation sandstones are rich in bitumen (Prior et al. 2013). Pretreatment of samples to remove bitumen is uncommon for studies within the Oil Sands region (e.g., Vance 1986; Joseph Young, personal communication, June 2018); however, the procedure should be applied more often, especially with materials in suspect sediments (e.g., Fisher et al. 2009). Once pre-treatment was complete, the sample was sent to the Keck AMS lab for radiocarbon analysis.

A second sample found in the middle of the Top ½ A of the core, at 234 cm FB, was a twig approximately 4 cm long (F1RCP-02) (Figure 3.6). The same Soxhlet and A-B-A pre-treatment was conducted, and the sample was sent to the UC Irvine Keck AMS lab.

Figure 3.6 Radiocarbon dated wood samples from Sharkbite Lake.

3.2.7.2 Sedimentation Rate

Determining the rate of sedimentation was crucial for contextualizing the pollen data obtained from the core. Sedimentation rate of the core was calculated manually (assuming constant deposition) and with age-depth models in OxCal (Bronk Ramsey 2009). The manual calculations were achieved by dividing the length of sediment between the dates by the amount of time represented. These calculations resulted in a deposition rate of one centimetre every seven rcyBP, or one centimetre every 8.5 cal yrBP.

To arrive at more precise dates for periods of interest and to take into account the greatest variability in the deposition rate and environments, a Poisson Sequence age-depth model was used (Bronk Ramsey 2008; Bronk Ramsey and Lee 2013). The Poisson model also assumes that events happen at certain rates, but are at random. This means that the model accounts for random depositional rates that are occurring at varied intervals and does not assume constant rates of deposition. As recommended by Bronk Ramsey and Lee (2013), the lack of *a priori* information meant that the variable k-parameters were to be used. The k-value chosen was ‘1’ (correlating to the depths being in cm), and the interpolation rate was ‘1’ as well. The k-value defines how tightly constrained the model is, so the higher the k-value, the more constrained the model. Additionally, if creating age-depth models with the intent of using the interpolated ages OxCal produces, the frequency of the produced dates (e.g., every cm, every 10 cm, every m) is also defined by the k-value and interpolation rate (Bronk Ramsey and Lee 2013; Lauren Davies, personal communication, 2016). Both models were run to determine the variability between them, and how OxCal would produce the extrapolated dates based on the defined parameters.

The first model was:

```
P_Sequence(“”,1)
```

wherein 1 represents the central estimate for the rigidity k (for deposits where depth is measured in cm). This model considered the fewest variables, and due to the limited number of dates available, offered little insight into natural fluctuations in the lake’s deposition.

The second model was as follows:

```
P_Sequence("variable",1,1,U(-2,2))
```

wherein 1 represents the central estimate for the rigidity k (for deposits where depth is measured in cm), 1 represents the interpolation rate per cm (1 output every 1 cm), and U(-2,2) is for the k-parameters—allowing it to vary by a factor of 100 in either direction (from 0.01 to 100) (Bronk Ramsey 2008; Bronk Ramsey and Lee 2013).

Due to the more rigid statistical nature, and greater consideration for variability, with the second model, the second P_Sequence equation was used. Of note is that the model is based on only two radiocarbon dates. Ideally, a third date from the centre of the core would yield a more successful depositional model. In the future, combining radiocarbon dates and tephras (if found to be present) would be the most successful in producing a model. This model provides us with a refined calculation of the deposition rates in Sharkbite Lake. This analysis gives the study a detailed outline of dates that are correlated to the high-fidelity record.

3.3 Results

3.3.1 Chronologic Controls

3.3.1.1 Radiocarbon Dates

The two wood samples sent for AMS radiocarbon dating frame the bottom and top of the complete core length. For F1RCP-01, the wood dates to 3,320 ± 15 rcyBP (conventional radiocarbon age; UCIAMS # 187142). The second wood sample, F1RCP-02, dates to 1,320 ± 20 rcyBP (conventional radiocarbon age; UCIAMS # 197746). Because both samples underwent Soxhlet pre-treatment and were not likely to have moved during thawing of the core because of their large size, the radiocarbon dates are regarded as valid. Given that there are two radiocarbon dates from the core, from both the base and near the top, we can derive an age-depth model for the core. This procedure is critical in contextualizing the palaeoenvironmental signatures throughout the record.

3.3.4.2 Sedimentation Rate

Sedimentation rate in the core was derived using the available radiocarbon ages. The manual sedimentation rates were calculated to be 7 years uncalibrated or 8.5 years calibrated years represented in one centimetre. Due to the core yielding only two radiocarbon dates, the depositional models created contain a wider range of variability with each calculated age. The models, however, allow us to link extrapolated dates to points of interest in the core.

Two variations of the P-sequence depositional model were run, primarily to determine if there was any variability between them. In the future, including a third date from the centre of the core and tephras would produce a more detailed model[4]. Recent research has recommended that reliable chronologies should be produced using Bayesian age-depth models with considerations for chronological ordering (which the P_Sequence in OxCal does) (Blaauw et al. 2018:60), but also recommends a minimum of two dates per millennium (Blaauw et al. 2018:58, 64). Sharkbite Lake does not have enough radiocarbon dates to produce a refined age-depth model; however, the record does meet the "skeleton chronology" outlined by Blaauw et al. (2018:64), supporting the validity of using the P_Sequence depositional model.

The first model, P_Sequence (1), factored in the least variability, resulting in smaller age ranges (Figure 3.7). This model, while valuable, does not present the most accurate variation that is expected in lacustrine sediments. The second model, P_Sequence ("variable",1,0.2,U(-2,2)), factored in the greatest degree of variability and yields the largest age ranges for modelled dates (Figure 3.8). When comparing the results of two models, the modelled dates vary in the range of one to ten years depending on the depth modelled. This difference is not substantial enough to invalidate the interpretations, despite the fact the model is based on only two radiocarbon dates. However, for this study, I use the second model's results when referencing dates for interpretations because it has less variability in derived confidence intervals. The resulting dates used are modelled radiocarbon age BP within the 1σ range, and are referenced in the pollen discussion.

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[4] Because no visible tephra layers were found in the core, and due to the bitumen, cryptotephra work was suspended on the core. Future analysis on the core would benefit from a new cryptotephra extraction technique for the core.

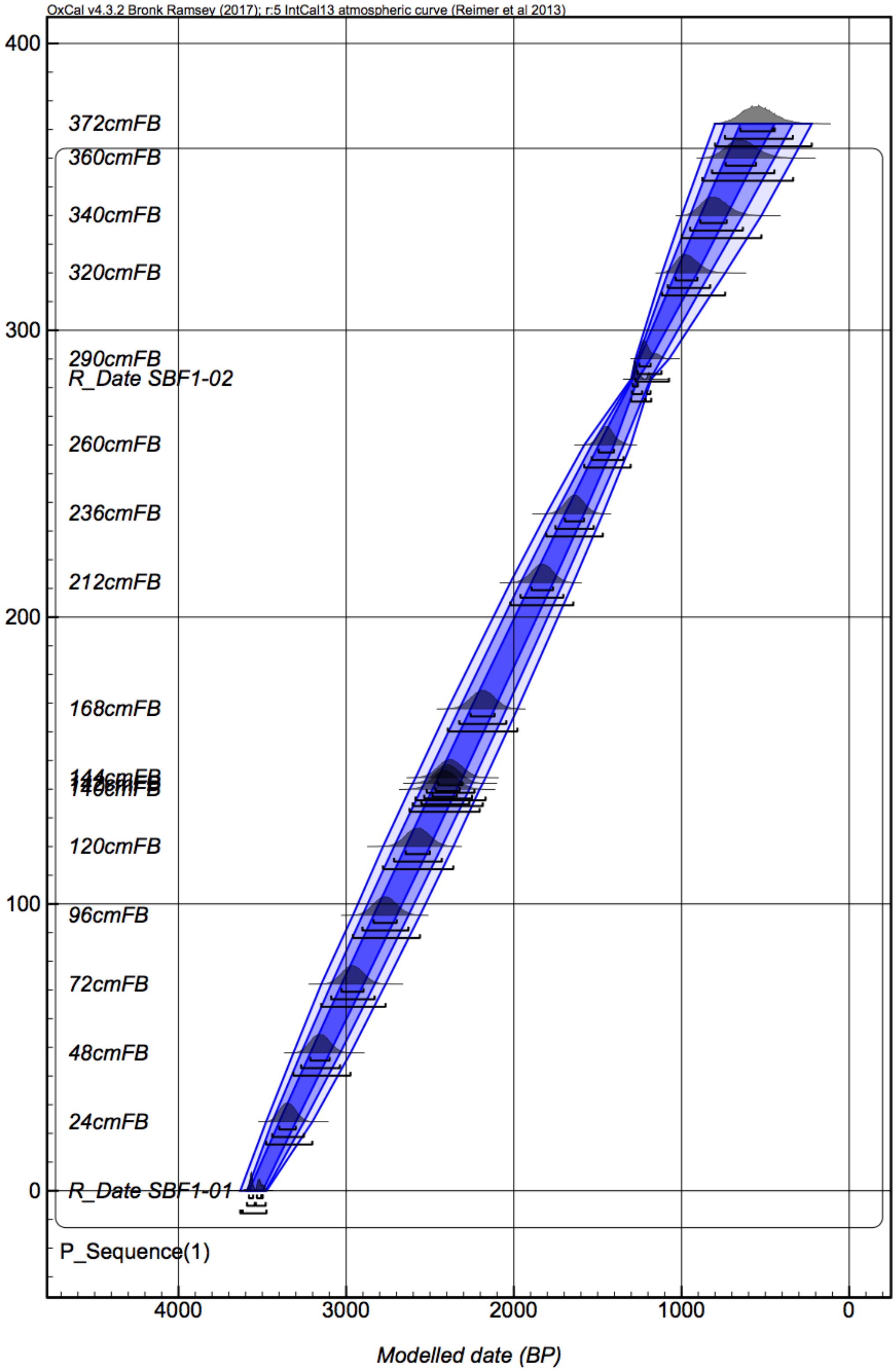

Figure.3.7 Age depth model using a P_Sequence (1) model on OxCal.

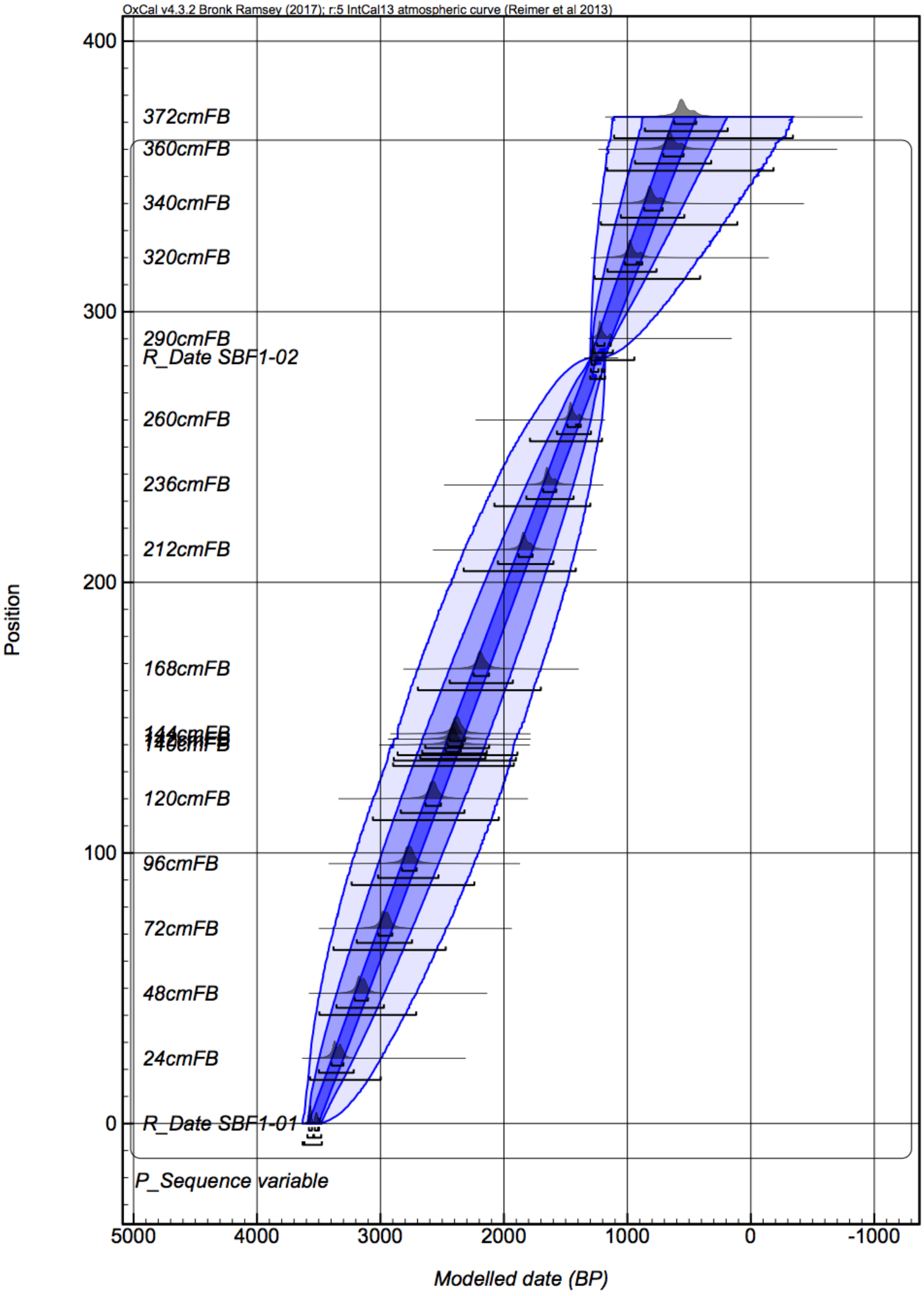

Figure 3.8 Age depth model using a P_Sequence ("variable" 1,0.2,U(-2,2)) model on OxCal. Dates referenced in the pollen discussion were derived from this model.

3.3.2 Pollen

Pollen throughout the core was representative of a modern Boreal Forest. *Picea* and *Pinus*, likely *P. glauca, P. mariana,* and *P. banksiana*, represent canopy tree species and are well represented in the pollen record (see 3.2.4 for the reason why the pollen was not identified to species). In small quantities, *Abies* sp. was found in the core. Balsam fir (*Abies balsamea*) is known to occupy modern banks along the Athabasca River (Bouchet and Beaudoin 2017:85). *Betula* sp. and *Alnus* sp. were common taxa found in the core, along with pollen of *Larix* and *Populus.* Birch and alder pollen probably represent *B. glandulosa* and *B. papyrifera,* and *A. viridis* (previously known as *A. crispa*) respectively. Shrubs, forest floor taxa, and upland herbs are found in varying proportions and are represented by pollen from *Salix,* Rosaceae*, Juniperus* sp., *Corylus, Myrica, Artemisia* type grains, Chenopodiaceae-*Amaranthus* grains, *Eleocharis (*likely either *E. palustris* or *E. acicularis)*, Poaceae sp., Liliaceae sp., *Shepherdia canadensis, Thalictrum venulosum*, Asteraceae sp. (high and low spine), and *Viola*. *Equisetum*, *Dryopteris*, *Typha*, *Nuphar*, and *Sphagnum* represent aquatic or wet site taxa, alongside local signatures of *Lycopodium*.

Interpretations of the postglacial history of the Boreal Forest from pollen in lacustrine records requires a critical review of the factors that can influence the preservation, deposition, and production of pollen. These factors include pollen activity and seasonality, the geomorphic activity of animals, and moisture levels of lacustrine sediments. Although some of these factors can vary between individual plants and communities and regional differences may occur (Calcote 1994), they maintain a pattern that allow us to recognize the trends.

Seasonality of pollination is based on time of reproduction for each taxon. Edmonds (1979:42–43) outlines three groups of seasonality: (1) at the beginning of the growing season, temperate forest trees and shrubs produce and emit pollen, (2) the annual and perennial herbaceous plant communities that pollinate during late summer / early fall, and (3) other herbaceous plants that emit pollen for several months. In addition to this seasonality, each taxon is subject to its own pollination cycle. For example, pine will begin to produce pollen seven years after seed germination and flower every year thereafter, whereas hardwoods do not flower in their first 45-50 years (Edmonds 1979:44). After pollination begins, a plant's internal cycle influences pollen yield. An example of this factor is *Betula* sp., whose pollen yield cycles through two-year intervals of high production and low production (Edmonds 1979:46).

During the onset of a taxon's pollination period, air temperature can affect the onset of flowering, which is associated with the accumulated annual heat sum (the sum of degree days above a minimum temperature threshold) (Edmonds 1979; Zasada et al. 1992:89). For example, *Populus* sp. and *Betula* sp. have lower heat sum thresholds and flower before conifers, and *P. tremuloides* has been observed flowering as early as February in interior Alaska (Zasada et al. 1992:89). This feature means pollen grains from these taxa are released and integrated into lacustrine records earlier than conifers. Abrupt changes in temperature such as frost can lead to the loss of flowers and a decrease in pollen output (Zasada et al. 1992). The amount of pollen dispersed can depend greatly on the physical location and relationship of an individual tree to the rest of the stand. Individuals that do not reach the upper canopy become suppressed and produce less pollen (Faegri and Iversen 1989:14). If forest cover were to disappear, following a crown fire for example, increased light would allow lower vegetation to flower and wind could disperse these pollen grains. When large quantities of pollen from anemophilous (wind-pollinated) plants is released, its deposition on the ground or in water is known as pollen rain (Faegri and Iversen

1989). Most of the major boreal forest tree taxa are anemophilous, while many forbs are entomophilous (insect-pollinated). This results in a pollen record that favours anemophilous taxa.

Once pollination begins, depositional environments and pollen preservation become a primary focus. The waterlogged lacustrine sediments allow for preservation of pollen grains, and the grains are less susceptible to mechanical degradation and impacts (Pearsall 2002; Havinga 1967). Pollen preservation is highly dependent on the amount of sporopollenin (a mechanically and chemically resistant biopolymer) in the pollen wall (Havinga 1967). Havinga (1967) conducted investigations on depositional environments (both in the field and in laboratory experiments), and demonstrated the effects that oxidation and microbial activity have on pollen preservation within different soil types. He concluded that both soil types and pollen characteristics influence pollen preservation. Pollen grains such as *Populus* have thin walls, and therefore less sporopollenin, a feature which leaves them more susceptible to corrosion and degradation. Recognizing the impacts these factors have on pollen records is critical to interpretations of past and future palynological studies.

Lake deposition and the integration of pollen into lacustrine records can be impacted by different variables and can affect interpretations. Geomorphic activities from animals are due primarily to the production and maintenance of beaver lodges and dams. Once completed, dams are maintained through spring and summer, and beavers both will preferentially choose building materials while also being opportunistic (using existing tree fall and rocks) (Butler 1995a:153). Once in place, the disruption to the flow of water can cause riparian habitats to expand. Elevated water tables and flooded soils are by-products of dams in an area, and can cause trees to die due to over-saturation and uprooting by winds (Butler 1995a). Effects on sediments and sedimentation occur throughout a dam's lifetime. During the dam's construction, sediment is redistributed through the lake (Butler 1995a). After they are established, dams and lodges continue to influence sedimentation rates. Some lakes are subject to an infilling of sediment due to slope changes at their mouths and reduced stream erosion. Sediments can include gravels, sands, and silts in addition to the accumulated organic debris (Butler 1995a). Other geomorphic activities caused by animals include mammalian burrowing. Although burrowing is less of a concern for effects to pollen deposition in a lake, there are by-products of these actions. Animals digging for food can disturb lake margins and cause materials to be redistributed or even become over-represented in the pollen and fossil botanical records (Butler 1995b). As an example, grizzly bears are known to dig for plant bulbs from April to November and tend to dig near riparian environments, leading to a disturbance in sediments and plant materials (Butler 1995b).

Understanding the conditions and factors that influence pollen preservation and pollen influx are important for interpreting pollen assemblage data. This requirement means that the high-resolution record from Sharkbite Lake warranted a critical assessment of the peaks with consideration for these factors.

Both pollen percentages and concentrations were modelled using Tilia (Grimm 1990) (Figure 3.9 and Figure 3.10). Modelled ages are included as calculated from the depositional model. Percentages are representative of a taxon's percent of the pollen sum, and does not take into consideration the exotic spike added to the sample. Concentrations were calculated in Tilia, using the standard equation:

$$\frac{\text{grains counted}}{\text{spike counted}} \times \frac{\text{spike added}}{\text{sample volume}}$$

wherein the exotic spike, amount of spike added, and sample volume are used in addition to pollen count sum to derive the number of grains per cm^3. Much of the variability that is seen in the Tilia graph is due to the high-resolution nature of the record. Many of the peaks are indicative of the year-to-year variability in pollen production for different taxa rather than large-scale changes in the pollen record. Secondary evidence supporting the peaks as resulting from variable pollen production in the local catchment rather than marked assemblage change is the consistent increase in pollen percent across multiple taxa, not just a single taxon. There are, however, some episodes where the changes in pollen percentage are more indicative of changes in the landscape around Sharkbite Lake. These phases are discussed from the base of the core, working upwards.

1. At 234 cmFS (140 cmFB), 2,410 rcyBP, there is a marked decrease in Pinaceae pollen grains, below a total count of 60 for the slide (Figure 3.10). This is contrasted, however, by a relatively high value of *Betula* (three and four pored), and only slightly below the average representation of *Alnus*, *Populus*, *Salix*, and *Larix*. This sharp decrease in Pinaceae grains (both *Pinus* and *Picea*) indicate a change to the canopy. Because approximately 40% of pollen deposited and recorded is derived from a regional signature (Calcote 1994; Chapter 3.2.4.1), this dip in values indicate an effect to the immediate canopy and, perhaps, the broader canopy to the south of the Muskeg River. The fact that pollen from pioneering taxa, including *Betula*, *Alnus*, *Populus*, and *Salix*, maintain average values noted in the core supports the assumption that this decline in pine represents a local forest fire episode. Given that this change occurs so quickly, and that shortly after (approximately 28 years) the canopy taxa appear to recover, this episode could be attributed to a forest fire. Secondary lines of evidence support this idea–LOI organic values at this time decrease from 55% to 9.4% (see Chapter 3.3.4) and a mineralogical inclusion manifests itself within these processed pollen samples. Also, charcoal peaks (both local and regional) correspond with this episode.

Based on all this evidence, I have interpreted this to represent a local fire, along the margins of Sharkbite Lake. Sometime between 2,410 and 2,377 rcyBP, a stand-clearing fire burned in the vicinity of the lake, destroying the canopy and burning down to the mineral soil. The exposed soils resulted in some eroding of the banks, redepositing the mineralogical soils and probably washing some charcoal into the lake's basin (e.g., Cwynar 1978:20). Fine-grained mineral material would quickly reach the deepest part of the lake basin, where it settled out of the water column, and charcoal would have been left around the margins of the lake. Material could have been derived from runoff from the nearby watersheds. However, its abundance leads to the conclusion that it is likely from the margins of the lake itself.

Detecting local fire episodes and interpreting their severity can be a challenge. Variation in the charcoal levels can be attributed to sedimentary processes and secondary sources, including bioturbation and remobilized charcoal (Iglesias et al. 2015:5). However, the pollen record further supports the notion of a local fire near Sharkbite Lake, with the presence of disturbance indicators, such as aspen, willow, and birch. These taxa are represented in abundance in the pollen assemblage compared to the other taxa, further supporting the evidence of an intense fire. Although this fire appears destructive, the fire-exposed mineral soils and open canopy allowed spruce to regenerate. The fire transformed dead organic matter that would have likely covered the forest's floor into nutrients for plants, and an open canopy allowed floor vegetation to develop, such as berries, shrubs, and the pioneering boreal species.

2. At around 174 cmFS (200 cmFB), 1,923 rcyBP, there is a peak in most pollen—this peak could be indicative of a more productive pollen rain during one or more year(s) that has been integrated into the sample. This peak also strongly correlates to a peak in *Typha* pollen. This could represent a more productive littoral zone around Sharkbite Lake (Figure 3.10). Changes to the littoral zone could represent either an expanding or shrinking lake area. Macrobotanical and LOI evidence at this time does not provide any indication either way. Macrobotanicals from this level were not part of the targeted samples, and LOI carbonate and organic values are within the average range of the core. If the littoral zone increased, this change would allow for more *Typha* to grow along the margins. If this change represented lake levels rising, it could be interpreted as an increased littoral zone along the margins of the lake. However, if the zone decreased with a lower lake level, the littoral zone would expand initially, and *Typha* would grow in these areas. There would temporarily be an increase in *Typha* before the zone would be overgrown by upland plants. As the peak is sustained over many years, the length of time implies that this change is more likely to have been the result of a decrease in lake levels, an abundance of *Typha*, followed by the littoral zone becoming dominated by upland plants. *Typha* is pollinated by wind and by insects. Wind-pollinated species present the unusual challenge of representing pollen from a more considerable distance, and often produce more pollen.

3. A peak of *Salix* occurs around 150 cmFS (224 cmFB), 1,727 rcyBP. Although this peak does correlate with higher levels of pollen through the assemblage, the peak deviates enough from the norm to warrant a closer look (Figure 3.9 and 3.10). One explanation is that this peak of *Salix*is a side-effect of snowmelt runoff. Sheltered from the sun under the forest canopy, pollen from spring flowering plants such as willow can land undisturbed onto snow banks, accumulating a higher level of pollen grains that are then deposited through the snowmelt runoff into the lake's basin. The second consideration for this peak is the shrubs' response to a ground fire, wherein the tree stands and canopies were minimally impacted. This situation could have led to a response in shrub species, quickly propagating to re-establish following the fire.

4. Between 46 cmFS and 86 cmFS (288 cmFB and 328 cmFB), 1,206 – 884 rcyBP, there is very little charcoal represented, and this low input continues for more than 300 years. This feature is interesting because all other periods of infrequent charcoal input are followed by episodes of frequent charcoal input. The pollen record does seem to decrease in abundance around 60 cmFS but returns to average pollen percentages by 50 cmFS (Figure 3.10). This change could be indicative of a smaller lake area, wherein less pollen and charcoal could be caught in the lake. When comparing this feature to the inferred Holocene central Boreal Forest moisture data, this period does correlate to a slight increase in precipitation. Trends also show that there is a marginal increase in temperature (Viau and Gajewski 2009b). Changes to moisture and climate can change lake levels greatly in the Boreal Forest (Campbell et al. 1994). Campbell et al. (1994:211) state that lake sensitivity appears to be binary, as a lake will be sensitive to climate and moisture changes. Boreal Forest lakes tend to be more sensitive than Parkland lakes due to high annual runoff, reaching >10 cm/yr, which exceeds the potential evapotranspiration (Campbell et al. 1994:210-211). As such, the decrease in charcoal representation could be attributed to changes in the lake levels that resulted from climatic changes. A second explanation can be found in the pollen record from this interval. Pollen over this period fluctuates between the core's average levels and peak values, but these changes do not correspond to the decreased charcoal levels. However, it is possible that the increased precipitation led to moister conditions that promoted vegetation growth, coupled with a decrease in fire frequency.

5. At 18 cmFS (356 cmFB), 659 rcyBP, the ratio of local pollen to *Lycopodium* spike grains is quite high, 597:509 respectively. A second slide was produced, and the spike to local ratio was counted to ensure it was not an overrepresentation of spike grains that had not been properly incorporated with the rest of the sample. The second slide yielded similar values, ruling out improper pollen or slide preparation. This change in pollen ratio could perhaps result from a sediment texture that was fine silt to gyttja and was poorly consolidated. The higher water and gyttja content at this level may have led to more weight-loss during the pollen processing stage. The second option could reflect decreased pollen productivity over the course of some years, which correlates to a decreased moisture level (Viau and Gajewski 2009b). This trend is not sustained for long. By 368 cmFB pollen ratios have returned to values similar to those in the rest of the core.

6. Micro-charcoal peaks are found throughout the core, although there were no macroscopic charcoal pieces or layers found in the core, possibly due to the chosen coring location. Because the core was retrieved from the centre of the lake, and at the deepest level, much of the larger charcoal pieces would have settled along the shallower margins of the lake (see more on the lake deposition processes in Chapter 3.2.5). Because each aliquot of sediment was screened before pollen processing, and due to acetolysis, there is a strong chance that much of the charcoal could have been lost at either of these stages. We are looking, therefore, at the charcoal that survived processing, and should recognize that this is not the complete, original record. However, because each sample was processed in the same fashion, I have made the assumption that the loss of some of the charcoal record is consistent throughout the core.

The micro-charcoal peaks (Figure 3.113.11) are of value in understanding, to some degree, the regional fire signature. The average time between microcharcoal peaks (cumulative charcoal value greater than 215) is 155 years. The shortest period between regional fire episodes is between 309 cmFS and 307 cmFS (65 cmFB and 67 cmFB), where only 14 years pass between the charcoal peaks. The longest time between fire episodes is the seeming apparent hiatus between 98 cmFS and 34 cmFS (276 cmFB and 340 cmFB), totalling 549 rcyBP (from 1323 rcyBP to 774 rcyBP). This pattern is contrasted to modern Boreal Forest fire frequency, in which spruce and pine-dominated stands tend to cycle through fire every 69 years (Larsen and MacDonald 1998). However, the core consistently yielded no less than a total of 255 microcharcoal pieces, indicating that microcharcoal was regularly deposited into the lake from regional and local fires. The consistent deposition of charcoal brought into the lake via the watershed or via wind dispersal reflects regional fire frequency. Although charcoal is produced in large quantities at irregular intervals, the different sizes of charcoal lead to its frequent deposition in lakes at various distances by wind or water.

As is evident from the micro-charcoal record from Sharkbite Lake, even regional fire episodes are challenging to interpret. The record from Sharkbite Lake could yield even more data when combined with other studies across the region in which the micro-charcoal and macro-charcoal data were compared. Sharkbite Lake's micro-charcoal record stands as an independent record for late Holocene forest fires, and one that is arguably a clearer picture of the broad local fire episodes than previous records due to its resolution. Aside from the records from Christina Lake and Rainbow Lake A (Laird and Campbell 2000; Larsen and MacDonald 1998; MacDonald et al. 1991), all other charcoal records demonstrate trends across the Holocene. While these Holocene records can be used to review fire frequency changes across the last 10,000 years, sampling locations in the core can represent upwards of a hundred years, obscuring trends.

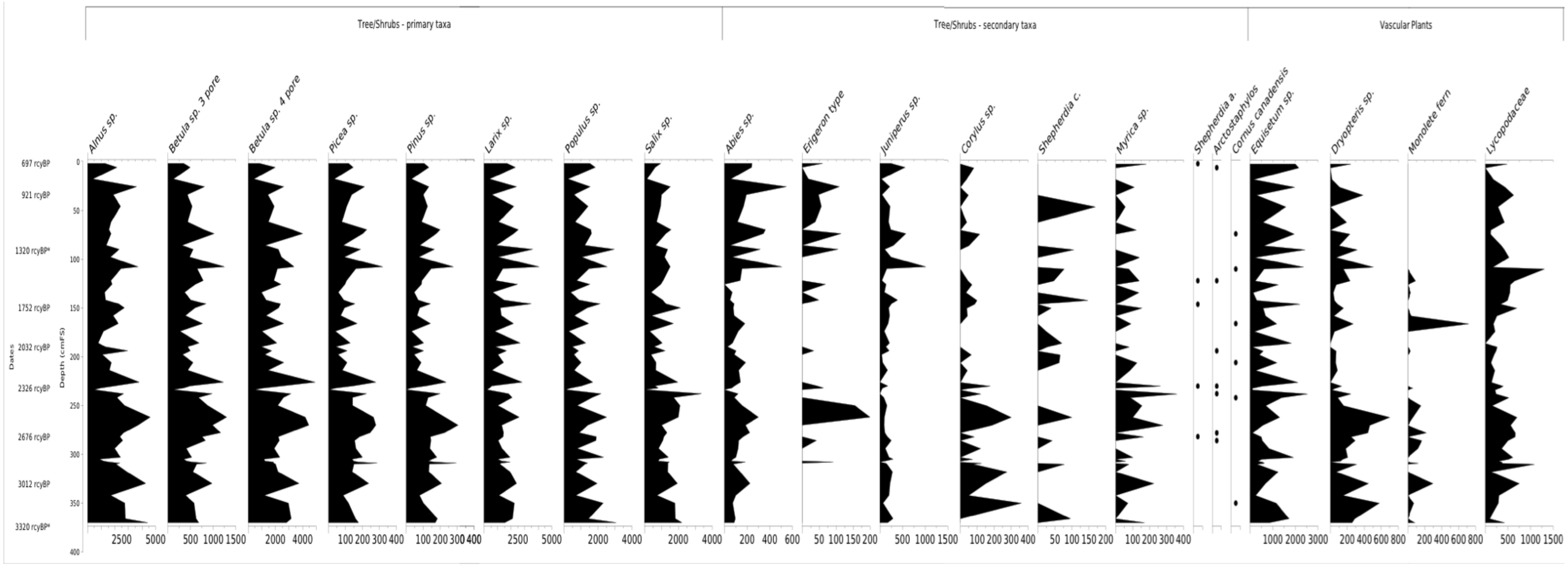

Figure 3.9 Tilia chart of pollen concentrations (Part A, continued on next page). Pollen with single occurrences were omitted from the graph but included in Appendix A

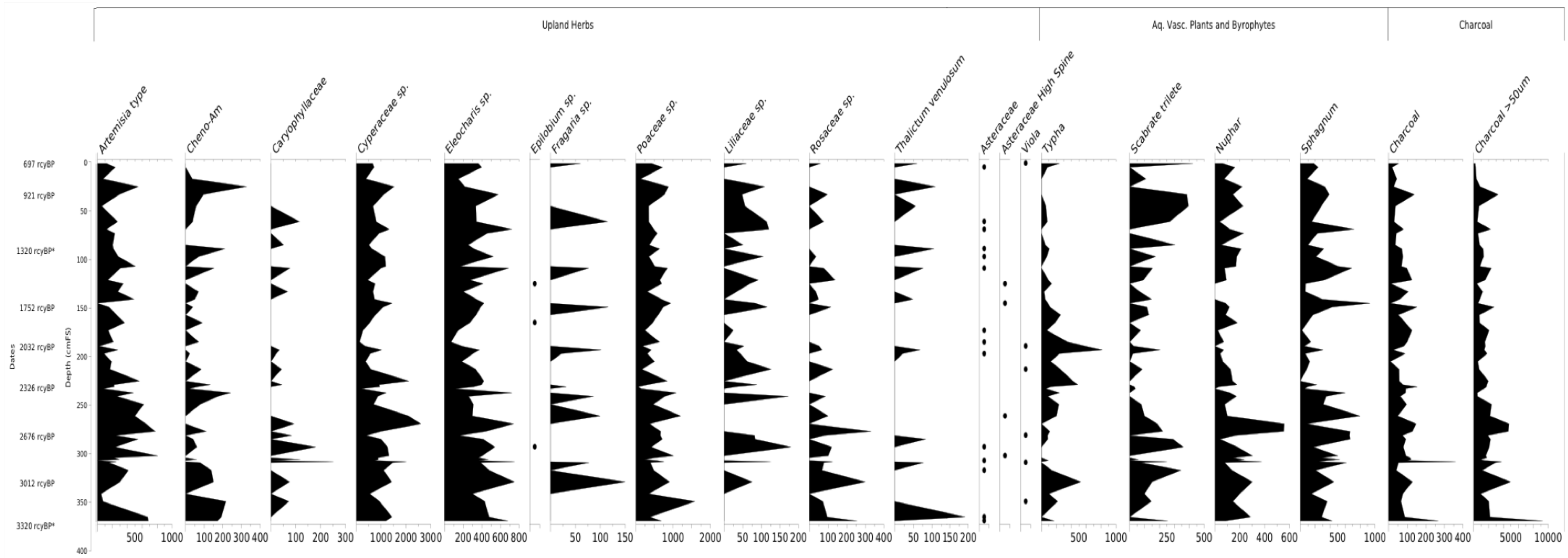

Figure 3.9 Tilia chart of pollen concentrations (Part B). Pollen with single occurrences were omitted from the graph but included in Appendix A

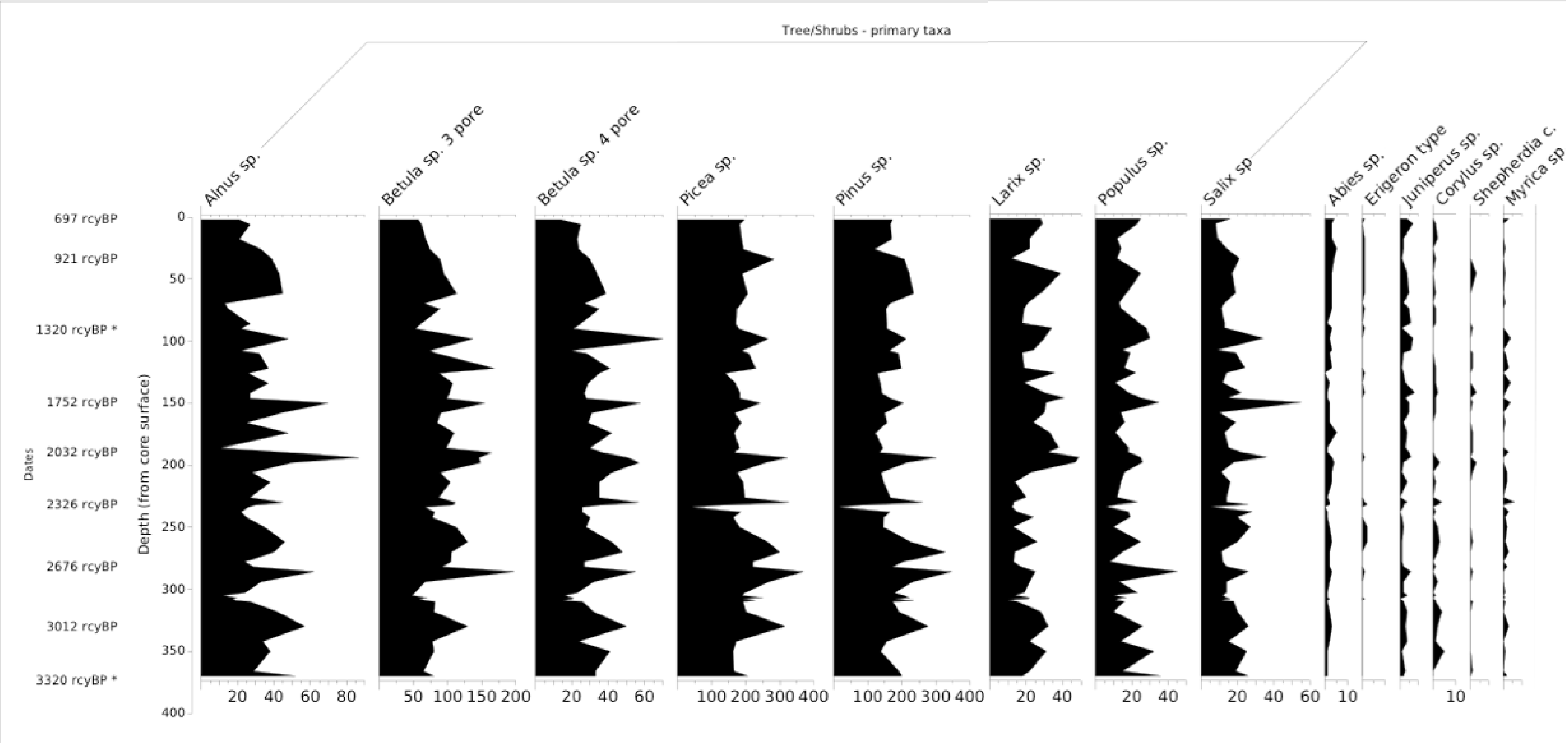

Figure 3.10 Tilia chart of pollen percentages (Part A continued on next page). Pollen with single occurrences were omitted from the graph but included in Appendix A

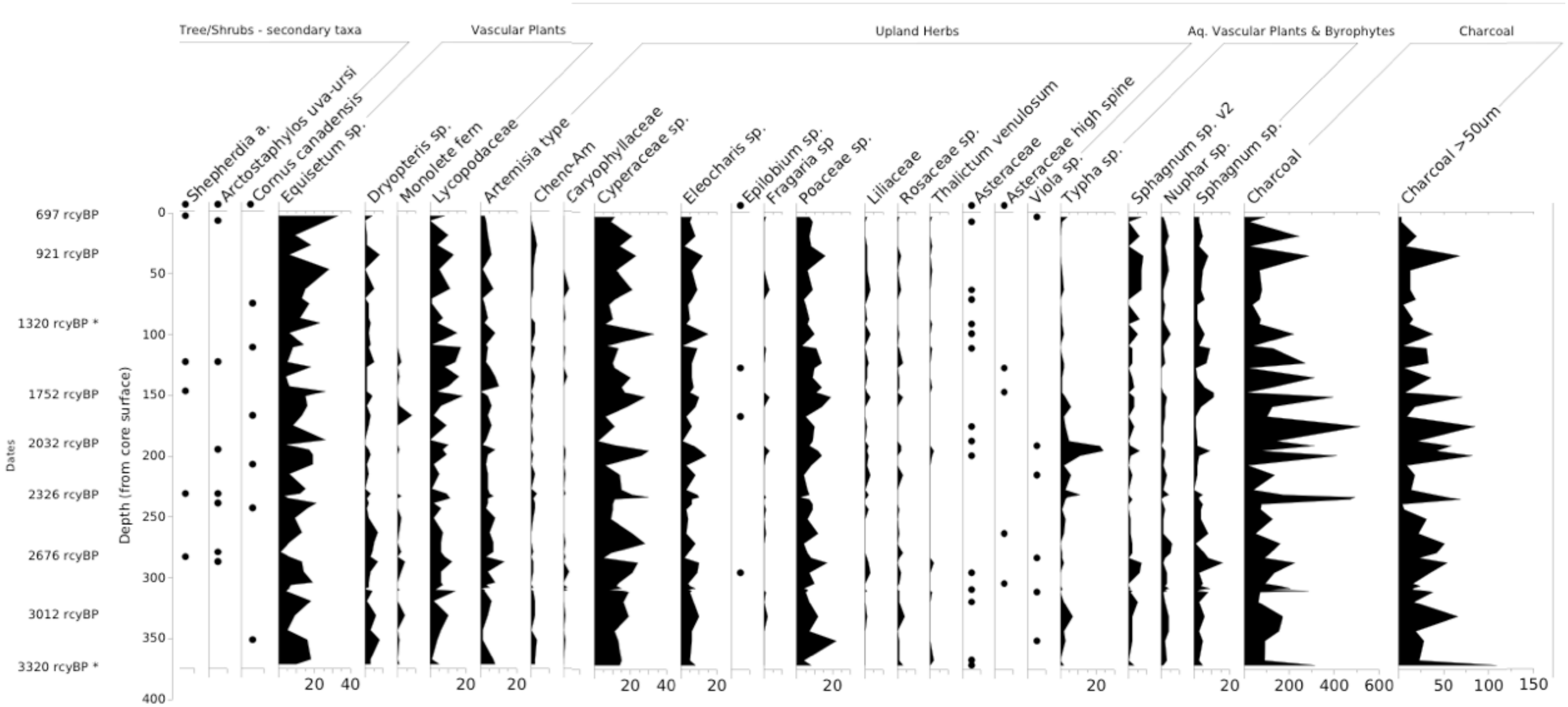

Figure 3.10 Tilia chart of pollen percentages (Part B). Pollen with single occurrences were omitted from the graph but included in Appendix A

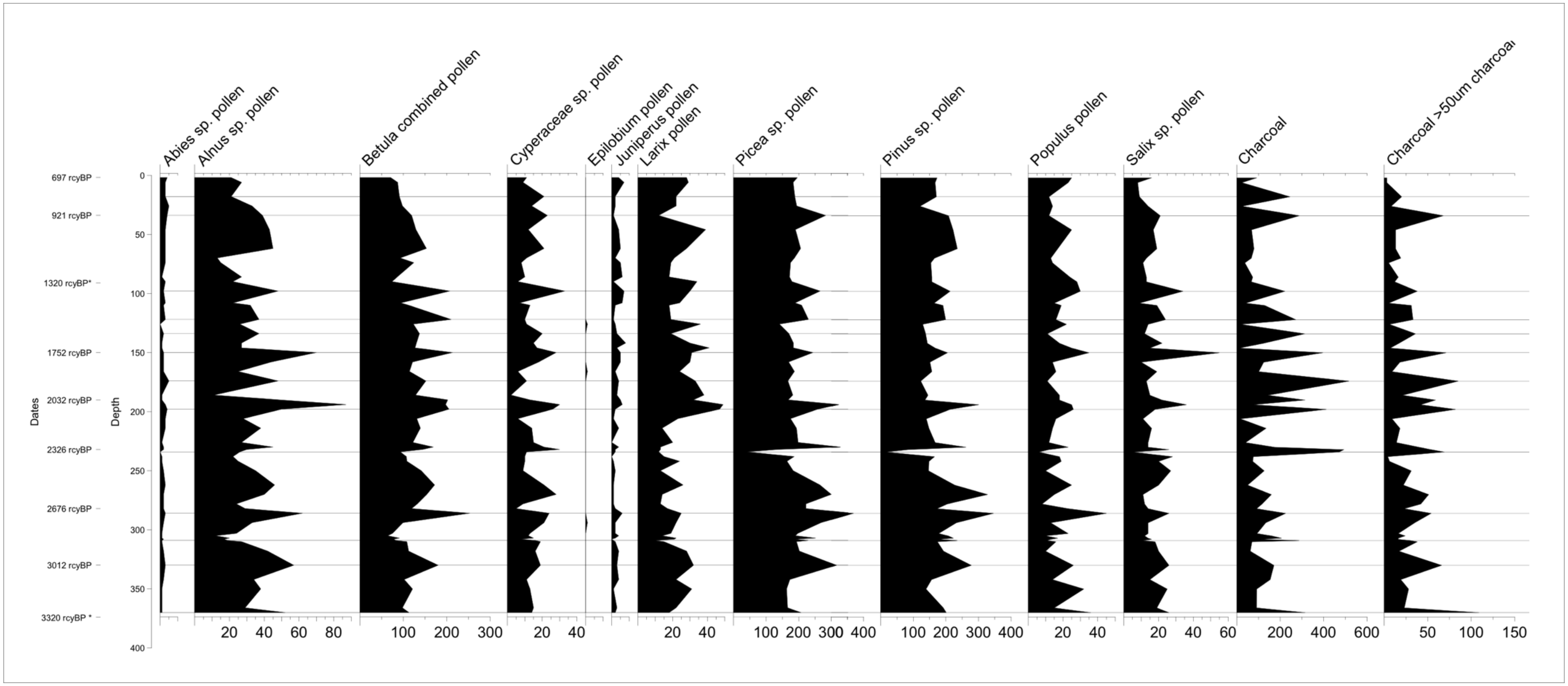

Figure 3.11 Tilia chart showing selected taxa and charcoal concentrations. Each line represents a charcoal peak of more than 200 charcoal pieces counted.

3.3.3 Wet Sieving and Macrofossils

Due to the nature of the core – having been collected from the centre of the lake basin rather than from the lake margin – it is normal to have few macrofossils appear in the wet screening. Samples from the bottom residual core and specific intervals of the Top ½ A core barrel yielded a total of 158 entities that were identified (total quantity of 337). Of these entities, 57 were mollusc shells, 43 were from aquatic plants, 48 were wood fragments, 29 were invertebrate fragments, 21 were seeds of identifiable botanical elements, and 120 were miscellaneous plant fragments (Figure 3.12 and 3.13). The absence of macrofossils from specific levels cannot be assumed to represent poor conditions; instead, given the size of the lake and the coring location, it is more likely to represent a portion of the macrofossil record that was not captured within the 3-inch core barrel, given that macrofossils are thinly dispersed near the centre of lakes.

Wetland and aquatic macrofossils found in the core indicate a productive habitat within Sharkbite Lake and along the lake's margins. When considering the location of the core, the presence of aquatic plants such as the gametophytes from bryophytes, it is likely that at these depths in the core, the gametophytes could represent a decrease in water levels. Changes in the water's depth would have shifted the littoral zone and allowed for more wetland and aquatic macrobotanicals to be captured toward the center of the lake. It is possible, however, that as with the other macrobotanical elements that are represented, these fragments floated along the surface of the lake only to be later deposited in the centre of the lake (refer to Figure 3.5).

Identifiable botanical elements included spruce and pine needles, Cyperaceae seeds, a *Nuphar lutea* seed, and a *Picea glauca* seed wing. There were also several insect (perhaps beetle) elements represented in the core including femora, wing cases, and other miscellaneous fragments. There were two grass node plates found in the core from the lower portion of the core. Both were in pristine condition but discoloured black, likely due to the bituminous sediments and because of degradation (Figure 3.12). Several different plant fragments were found; however, many were quite small and lacked discernible cellular structure to identify specimens accurately. Of note is that all macrofossils found in the core were in relatively good condition. It was evident that some of the samples absorbed the bitumen from the lake sediments because the specimens had a thin film iridescence and reflected a rainbow of colours when under the microscope.

The presence of identifiable botanical elements denote what vegetation might have been in the immediate area surrounding Sharkbite Lake. Remains of conifers, grasses, and aquatic plants support the pollen record and indicate that the littoral zone and margins of Sharkbite Lake yielded diverse vegetation. Invertebrate fragments are indicative of a local environment with a relatively complete ecosystem. Future research into the identification of taxa or species represented would provide more precise environmental indicators.

Many of the mollusc taxa (Figure 3.13), including *Gyraulus*, *Planorbella*, *Stagnicola*, and *Pisidium* occupy permanent waterbodies with a muddy substrate; and most all occur in association with vegetation. Two taxa worth noting are *Pisidium* c.f. *nitidium* and *Physa gyrina gyrina*. *Pisidium* c.f. *nitidium* (Figure 3.13, specimen k) is common to shallow waters, and its presence may indicate that water levels were lower around 1,200 rcyBP (Clark 1981:410). *Physa gyrina gyrina* (Figure 3.13, specimen o) when present and with no other mollusc taxa is indicative of organic pollution; however, in Sharkbite Lake's record it is found in association with other molluscs (Clark 1981:152).

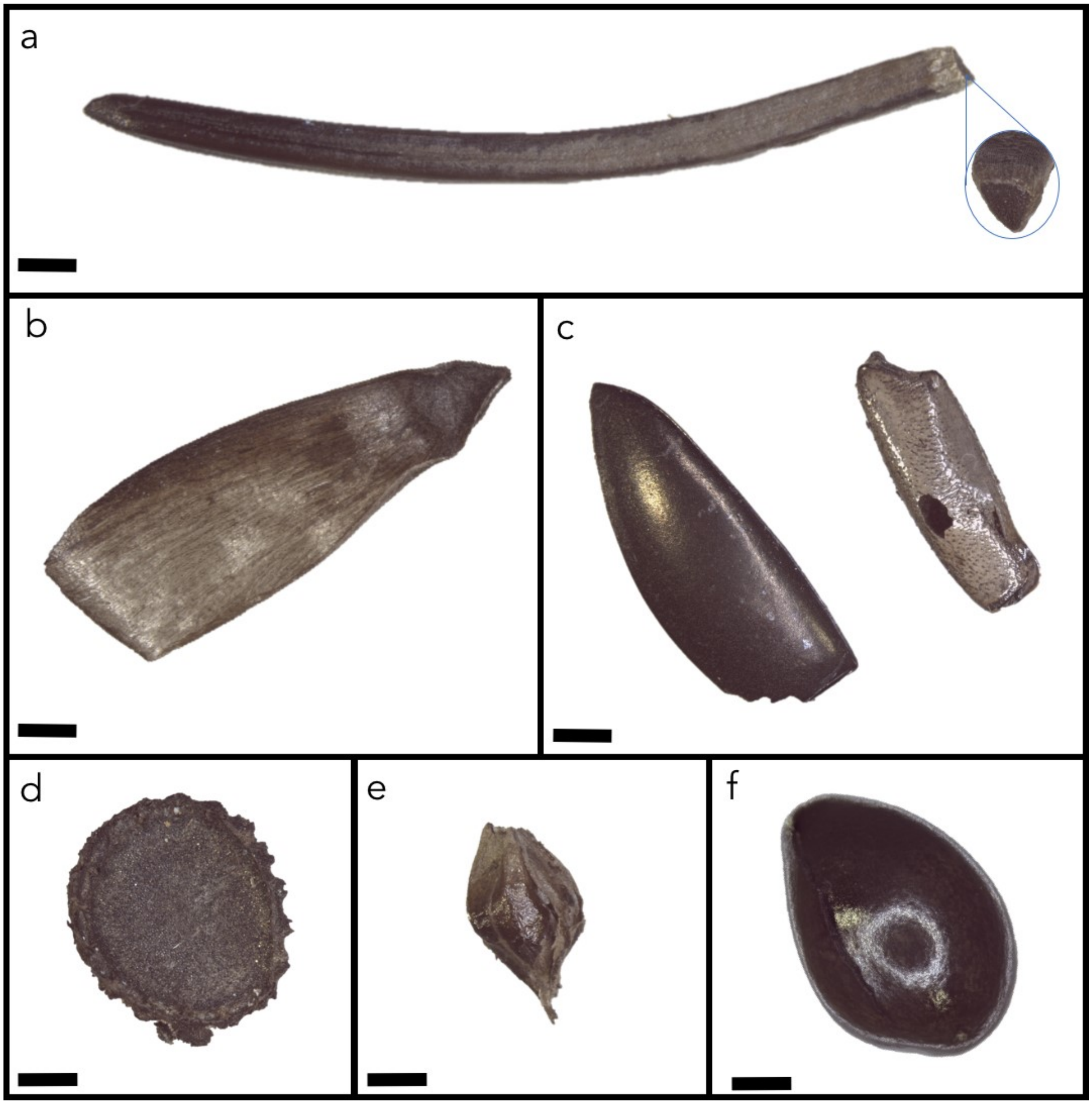

Figure 3.12 Examples of macrofossils found in Sharkbite Lake Core. (a) *Picea* sp. needle (enlarged cross-section not to scale), (b) *Picea* cf. *glauca* seed wing, (c) examples of insect fragments (L: wing case (?), R: femur), (d) grass node plate, (e) Cyperaceae seed, and (f) *Nuphar lutea* seed. Scale bar on each image denotes 1 mm unless otherwise noted.

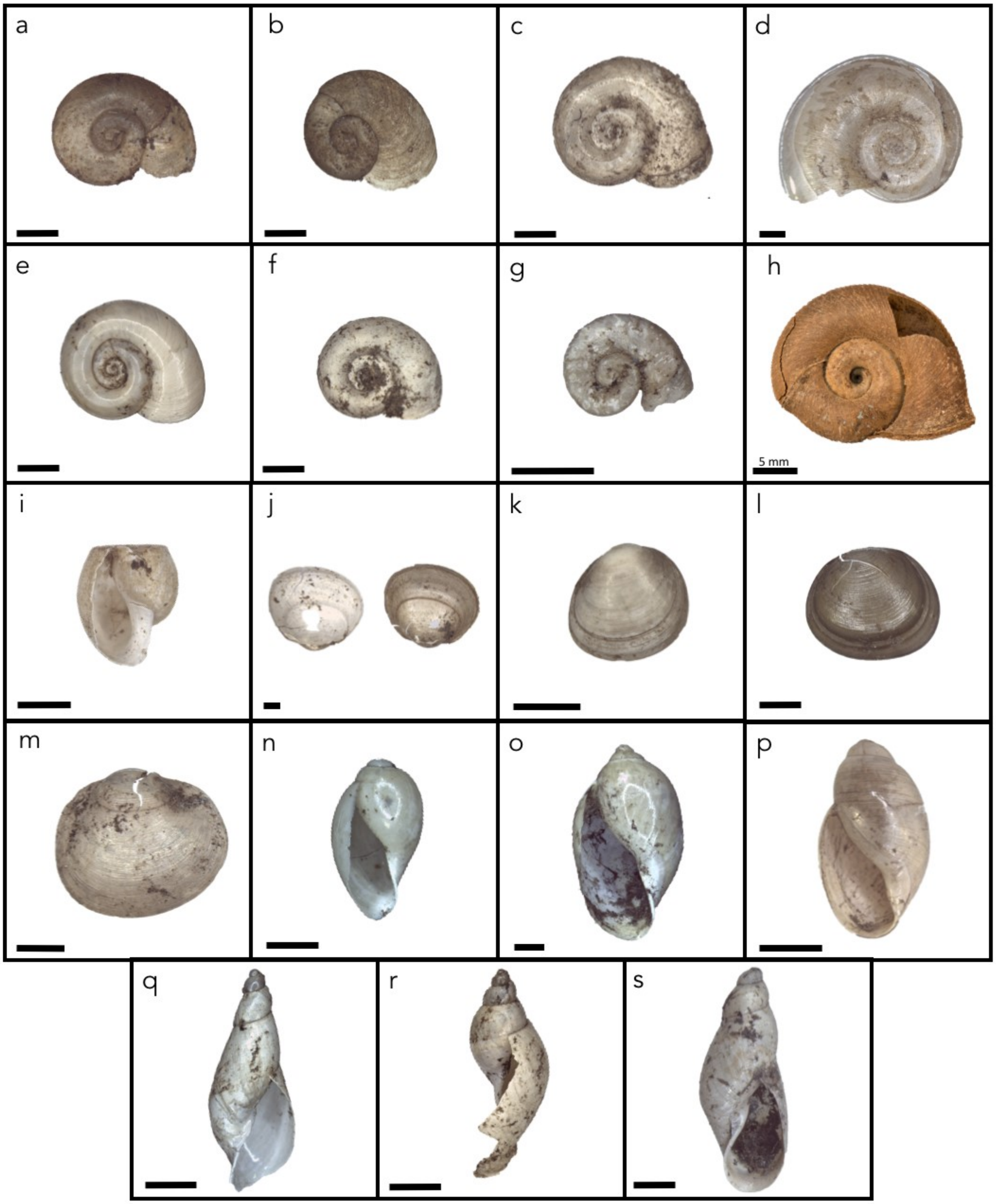

Figure 3.13 Molluscs from Sharkbite Lake Core. **(a)** *Promenetus exacuous*, **(b)** *Promenetus exacuous exacuous*, **(c)** *Gyraulus* cf. *deflectus*, **(d)** *Planorbella* cf. *subrenata*, **(e)** *Gyraulus circumstriatus*, **(f)** *Gyraulus parvus*, **(g)** *Gyraulus crista*, **(h)** *Planorbella subrenata*,**(i)** cf. *Helisoma trivolvis*, **(j)** *Sphaerium* sp., **(k)** *Pisidium* cf. *nitidium*, **(l)** *Pisidium* cf. (*Cyclocalyx*) *rotundaturm*, **(m)** *Pisidium* lilljeborjoi, **(n)** *Physa jennessi skinneri,* **(o)** *Physa gyrina gyrina*, **(p)** *Physa skinneri*, **(q)** *Stagnicola exilis*,**(r)** *Fossaria* cf. *modicella*, and **(s)** *Stagnicola elodes*. Scale bar on each image denotes 1 mm unless otherwise noted.

3.3.4 Loss–On–Ignition

Loss-on-ignition was conducted on all sampled intervals, and an additional stage of carbonate content analysis was conducted at specific intervals. Figure 3.14 shows the resulting organic and carbonate content of the core.

Carbonate content of Sharkbite Lake sediments was relatively consistent, with only one major change (discussed later in this section). Carbonate content rarely exceeded 20% DW, with the average being 7% DW. However, the organic content of the core fluctuated. Higher values have been associated with unstable lake catchment (see Prather and Hickman 2000:192). Organic content throughout the core averages approximately 43.8% DW. Organic content fluctuates at various intervals (e.g., between 24 cmFB to 36 cmFB; 180 cmFB to 196 cmFB). Although carbonate values less than 10% are not always reliable (e.g., Boyle 2001), Beaudoin (2003) has shown that LOI can still be a suitable method for determining carbonate content at low values.

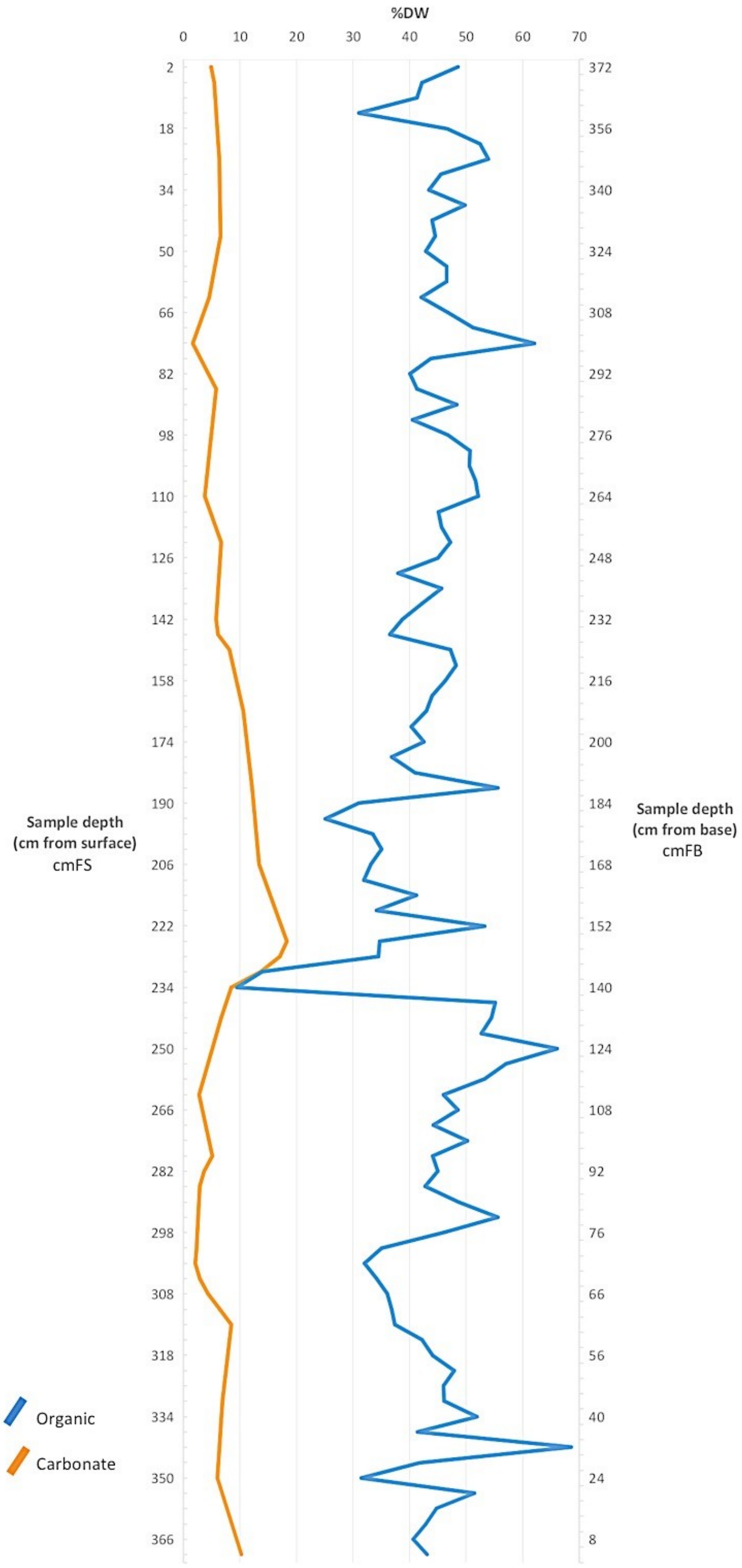

Figure 3.14 LOI for Sharkbite Lake

There are, however, depths that warrant more careful analysis. The low organic content of 9.45% at 234 cmFB corresponds with a slight increase in carbonate content. Once the organic levels begin to return to average amounts at 226 cmFS there is a rise in carbonate content as well, which shortly thereafter returns to values within the core's average carbonate content. It is also important to note that at this same interval, there is a mineralogical inclusion in the sediments. This inclusion appears as both a physical marker in the final processed pollen sample and in the slides produced from the corresponding sample. There was no change noted in the physical core itself, as this corresponded to the base of core Top ½ B. This change is associated with a dramatic decrease in Pinaceae pollen grains and is a result of what appears to be a forest fire adjacent to Sharkbite Lake. This is discussed further in the pollen results. Aside from this mineralogical inclusion that coincides with a marked decrease in organic content, all fluctuations in organic content are assumed to be due to lake level changes, or variability in lake productivity, or variability in sediment input to the lake.

The largely massive structure of the core was of little assistance in the interpretation of depositional and environmental conditions. However, the LOI results were valuable in aiding in the interpretations of climatic and lacustrine environmental changes that occurred over the last 3,300 years in this part of the Boreal Forest. Shifts in organic and carbonate values help to refine interpretations of pollen and microcharcoal records, providing supplementary information to help understand changes to the late Holocene history of the lower Athabasca River valley and within Sharkbite Lake's watershed.

3.4 Summary and Conclusions

Sharkbite Lake’s environmental record highlights the dynamics of the Boreal Forest region, specifically within the lower Athabasca River valley. A lake which was once situated in a muskeg-forest environment has since had the land around it transformed into a microcosm of industrial activity along the lake's margins. As the only high-fidelity record of the late Holocene in the region, in addition to the only late Holocene record for the lower Athabasca River valley, the core has enhanced our understanding of the fire and vegetation dynamics in the region. With this record, dated archaeological sites can be situated and contextualized within the landscape. The pollen record shows the responsiveness of the Boreal Forest, to variables such as edaphic conditions and fires, and highlights the sensitive nature of pollen records.

Beginning around 3,320 rcyBP, the lower Athabasca River Valley featured a modern Boreal Forest with modern composition, which has probably existed since the mid-Holocene (this study; Bouchet-Bert 2002). Many of the peaks in pollen percentages are due to the high-resolution of the core, because it captured seasonal variability and pollen production variations in detail (see Chapter 3.2.4.1). A careful review of the record uncovered periods of vegetation change, such as the local fire episode at 234 cmFS (2,410 rcyBP). Independent anomalous peaks in a single pollen taxon, such as *Salix* at 150 cmFS and the increase of *Typha* at 174 cmFS, reflect local episodes of change. *Pinus*, *Picea*, *Betula*, *Alnus*, *Larix*, *Populus*, and *Salix* are dominant taxa throughout the record; and combined with the herbs, shrubs, and aquatic plants show that the area around Sharkbite Lake would look similar to the modern vegetation around the lake: an established canopy comprising of typical boreal species with a lush, productive lake margin, and nearby muskeg.

Micro-charcoal from Sharkbite Lake yields a detailed record of fire history in the Boreal Forest, demonstrating the response of vegetation to fire in the region, and the critical role fires have in sustaining a productive Boreal Forest. On average, charcoal peaks occurred every 155 years, with the shortest interval between peaks at seven years and the longest at 549 years. Charcoal peaks strongly correlate to vegetation changes (such as the effects of a crown fire at 2,410 rcyBP), but also reflect vegetation trends (such as decreased charcoal from 1,206 – 884 rcyBP). Macrofossils and LOI values provide evidence to support and clarify variations in the palaeoenvironmental record. The macrofossil record in Sharkbite Lake as presented in this thesis is incomplete because only specific samples were processed; the data thus far shows a relatively complete ecosystem, because flora and fauna are represented and complement the pollen data.

The Sharkbite Lake records allow for interpretations of the local episodes that affected landscape conditions. This record becomes the background required to contextualize the Late Prehistoric archaeological record of the region, to be demonstrated in Chapter 5. Radiocarbon-dated archaeological sites from the Muskeg River watershed are correlated to the vegetation as reconstructed from Sharkbite Lake. Valuable to both the human and vegetation history of the Boreal Forest, Sharkbite Lake's record stands as one of the most complete late Holocene records in northeastern Alberta, and the only palaeoenvironmental record to date of the lower Athabasca River Valley spanning the last 3,000 years.

Chapter 4 Archaeological History of the Boreal Forest

The archaeological history of Alberta's Boreal Forest has challenged archaeologists since extensive excavations and surveying began in the 1960s. Dense overgrown stands, areas of muskeg, and accessibility are factors that hinder archaeologists from discovering sites. In addition to this problem, the acidic soils destroy much of the organic material in the record, making materials for radiocarbon dating rare (only 47 in the Mineable Oil Sands region [MOSR] [Woywitka 2016; this study], see Chapter 5.2 for an in-depth discussion). Slow sediment accumulation creates compressed stratigraphy at many sites, a situationwhich leads to uncertainty around artifact association and temporal occupation (single component versus multi-component) (Ives 1993:8; Reid 1988). To combat these challenges, Ives (1985) carefully provenienced artifacts and then used statistical analysis to understand site occupation patterns at Eaglenest Portage (HkPa-4) in the Birch Mountains. Rawluk (2017) continued this research with new excavations at HkPa-4. Using ArcGIS, he modelled artifact associations, inferred occupation layers, and identified features like a phantom hearth (Rawluk 2017). This procedure is similar to the 3D modelling used at the Ahai Mneh site in the parklands to successfully parse temporally related artifacts from a compressed stratigraphy and identify a Paleoindian component (Rawluk et al. 2011). However, industry deadlines make these forms of intensive analysis hard to accomplish within the scope of historical resource impact assessments (HRIAs) or mitigations. Archaeologists conducting regulatory work in this area are constrained by these limitations when reconstructing the region's prehistory.

Cultural chronologies for the region rely on lithic-dominated assemblages, looking to the fine distinctions in projectile point production and style, and the limited stratigraphy to establish cultural affiliation and complexes. The archaeological complexes rarely yield radiocarbon dates;

thus, their temporal extent is based on dates derived from the adjacent Northern Plains and Barrenlands traditions.

This chapter presents various types of dates. Radiocarbon dates that are uncalibrated are noted as rcyBP, and calibrated dates are noted as cal yrBP. Dates that reference the total time passed are marked with “ya” representing “years ago”. Dates from Reeves et al. (2017) are identified as ‘BP’, and represent “dates that are in the nature of *estimates* founded on some form of comparative analysis” (Ronaghan 2017a:10, emphasis mine). Figure 4.1 shows major geographic features and areas of interest in the Boreal Forest ecoregion across Alberta, Saskatchewan, British Columbia, and the Northwest Territories. Figure 4.2 illustrates major features within the study area and archaeological sites found within the map boundaries.

This chapter reviews technological influences on Boreal Forest archaeological assemblages through the Early and Middle Prehistoric Periods. This discussion highlights bordering cultural traditions and complexes, and the subsequent links between these traditions and the artifacts found within northeastern Alberta. The Late Prehistoric Period is described in greater detail and is the focus of the remainder of the thesis. Following this section and the description of the Protohistoric Period, I review Boreal Forest adaptations such as landscape management practices that were important to the success of First Nations ancestors. Although the archaeological record lacks a clearly defined cultural chronology, the number of sites in the region provides valuable insight into the past. Using density modelling, mobility extents, and site types, I discuss the strengths of the archaeological record, and indicators of landscape use in prehistory.

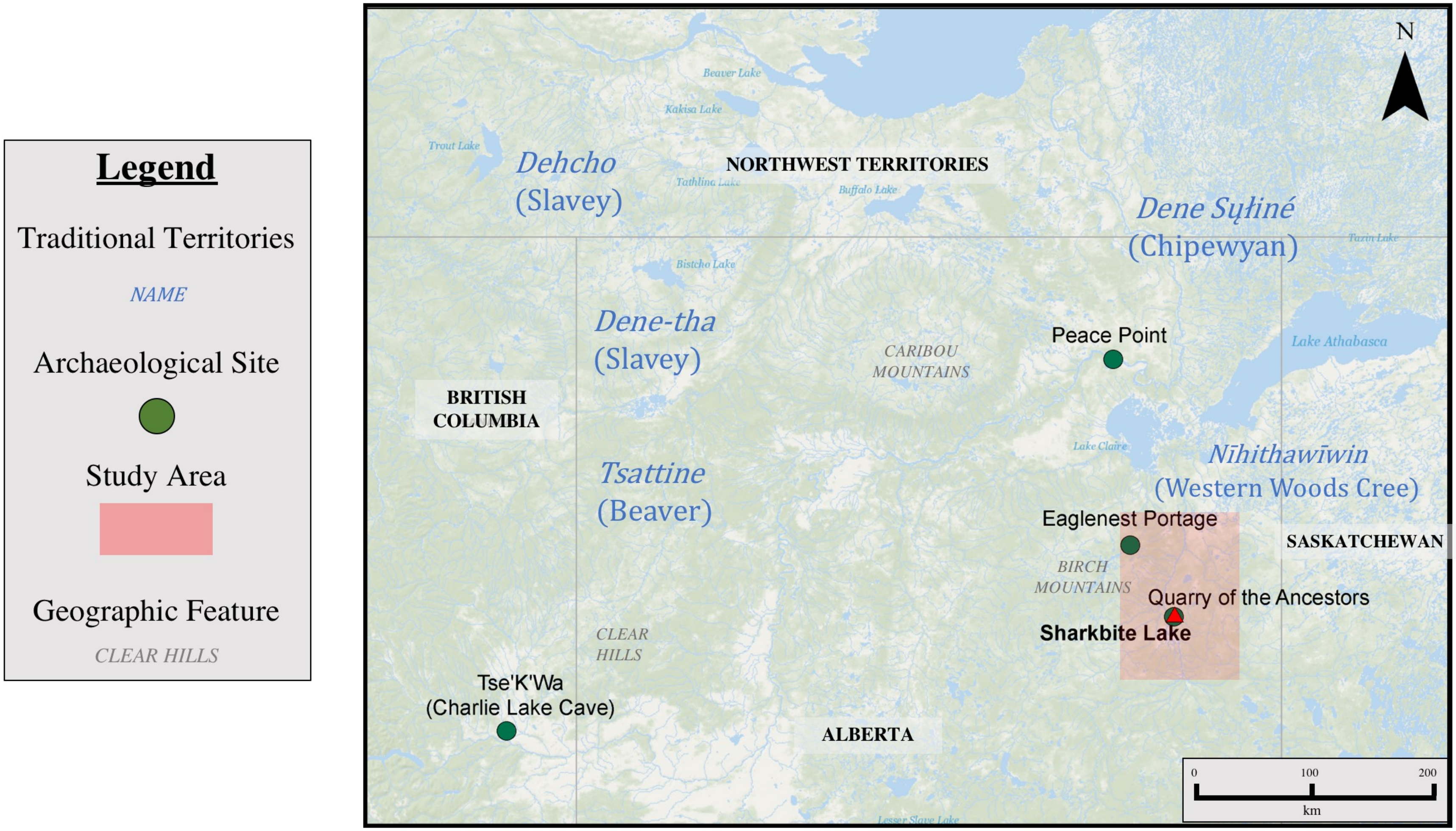

Figure 4.1 Map of the broad Boreal Forest ecoregion with key sites and features labelled.

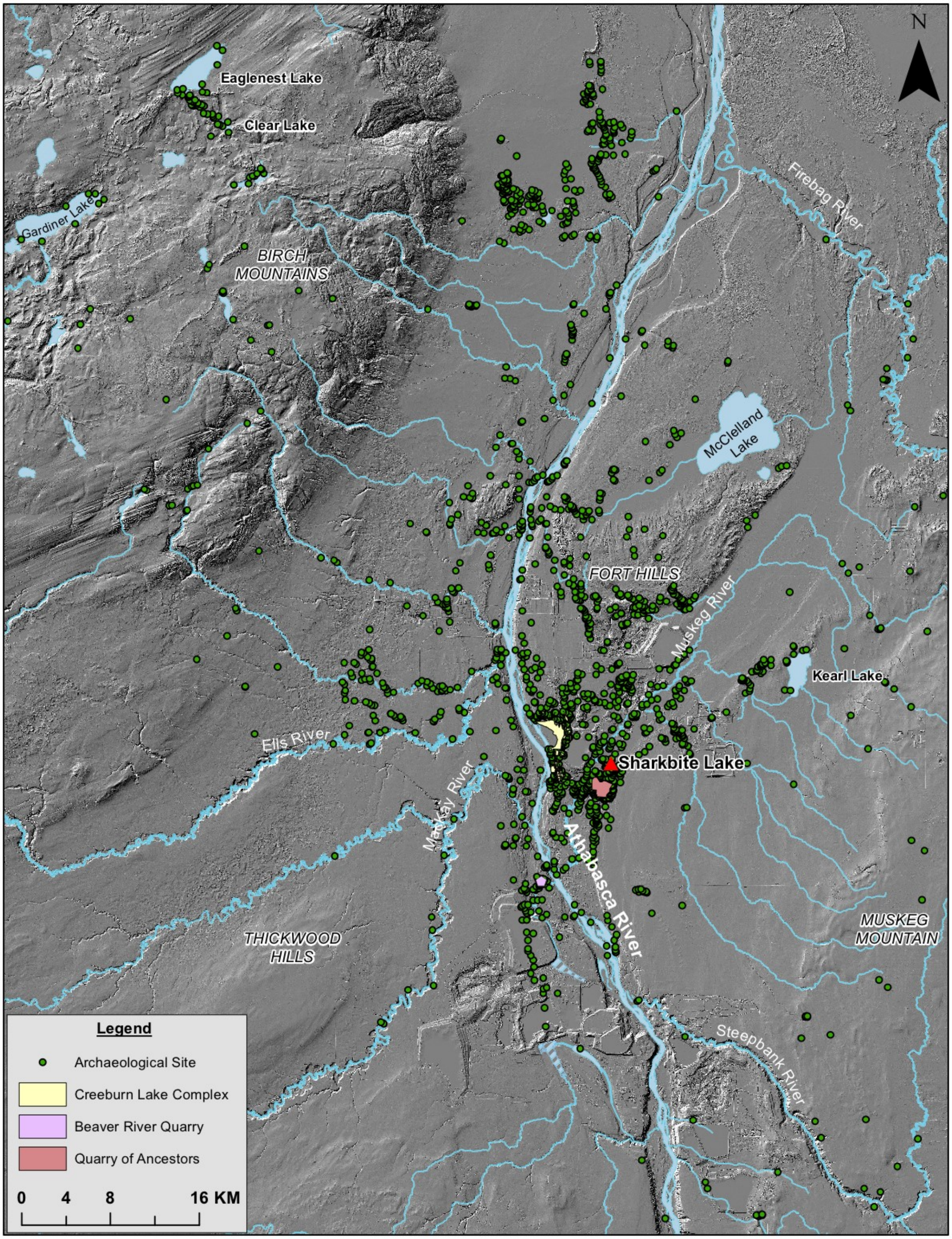

Figure 4.2 Map of the study area with key geographic features labelled

4.1 Culture History of Alberta’s Boreal Forest Region

The culture history of the Subarctic cultural region in the Boreal Forest began as early as 13,000 rcyBP when the Laurentide and Cordilleran Ice retreated and opened the Ice-Free Corridor (Potter 2017:540). Cultural traditions with Asiatic roots were brought to North America across Beringia as hunter-gatherers moved into this new landscape. Genetic evidence from Potter et al. (2018:2) demonstrated that ancestral Native Americans descended from a population from East Asia that yielded two splits. The first split formed an Ancient Beringian population, and a second formed subsequent northern and southern lineages (Achilli et al. 2018; Potter et al. 2018:2). This second population started as a single lineage that moved into North America from Asia and branched into two lineages sometime between 17,500 to 14,600 ya (Achilli et al. 2018). One branch was a northern indigenous lineage (haplogroup ANC-B) from which modern northern groups such as Athapaskans and Algonquians descended; the second southern lineage represents populations in the rest of the Americas (ANC-A) (Achilli 2018:965; Lindo et al. 2017; Rasmussen et al. 2014; Scheib et al. 2018:1026).

This history of cultural influences is a challenging one to interpret in the Boreal Forest because many of the archaeological sites that yield materials do not have associated radiocarbon dates, nor are sites well stratified. A few sites exist in the Boreal Forest that are well stratified with distinct occupational layers (Figure 4.1). In northeastern Alberta, Peace Point (IgPc-2) (Stevenson 1986) is the only site with deep intact stratigraphy. In the broader Boreal Forest region, the best dated and stratified site relating to Holocene history is Tse’K’Wa in British Columbia (Charlie Lake Cave [HbRf-39]) (Driver et al. 1996). Tse’K’Wa provides an example of technological and subsistence patterns through the entire prehistoric period, with more intensive occupations after 4,500 rcyBP. This extensive record provides an example of how hunter-gatherers would have utilized the landscape. The site's record also provides indicators of technological influences over time. Both Peace Point and Tse'K'Wa provide detailed records to illustrate examples of technology and resource use in the Boreal Forest.

Archaeologists rely heavily on interpretations of tool production and raw materials to infer human activity, mobility, and trade. Lithic assemblages in northeastern Alberta, specifically in the MOSR are predominantly made of Beaver River Sandstone (BRS). This raw material, originally called Beaver Creek Quartzite (Syncrude 1974), is an orthoquartzite from the lower member of the McMurray Formation (Fenton and Ives 1982:131-133; Ives and Fenton 1983:82, 85; Kristensen et al. 2016; Tsang 1998). Glacial processes and the catastrophic drainage of glacial Lake Agassiz exposed sources of BRS, and transported workable cobbles and pebbles to other areas within the region. The primary sources of this material are the Quarry of the Ancestors site complex and the Beaver River Quarry (HgOv-29). Materials derived from the Quarry of the Ancestors are microcrystalline and cryptocrystalline and are more desirable for flintknapping (De Paoli 2005:173; Martindale 2014:27; Saxberg and Robertson 2017). Although BRS from Beaver River Quarry is of poorer quality, Gryba (2017) and Fisher (2018) have demonstrated that the heat-treatment of the material improves its knapping characteristics, making it virtually indistinguishable from materials from Quarry of the Ancestors at the crystalline level. With heating, BRS that was previously coarse-grained becomes finer grained. The grain size of BRS is arguably the biggest factor for improving the workability of the sample (Fisher 2018). Aside from BRS, quartzites and pebble cherts are common in the region. High quality quartzites and cherts in glacial till have been found in the Birch Mountains and are the dominant toolstones found in the uplands (Martindale 2014:25; Ives 2017). Materials such as obsidian, basalt, Swan River Chert, and other exotic materials attest to a larger trade network of lithic materials. Conversely, the discovery of BRS artifacts as far south as Cold Lake and across northern Saskatchewan demonstrated that this was a two-way trade network (Martindale 2014).

One of the most significant challenges in understanding northeastern Alberta's culture history is that archaeologists use lithics to create cultural chronologies even though recovered artifacts rarely are associated with radiometric dates. To date, only one radiocarbon date has been obtained in association with a Beaver River Complex projectile point (Roskowski-Nuttall 2015:36-38). The radiocarbon date was recovered from a bone feature (possibly a hearth) at HhOu-113, where the projectile point was in association with these faunal fragments. The lack of chronologic controls makes interpretations challenging. New research (e.g., Woywitka 2018) aims to use OSL dating to obtain chronologic controls for the region. When combined with the archaeological record, this revised chronology will provide a more accurate representation of human history.

Reeves et al. (2017) presented a cultural chronology for the Lower Athabasca region based exclusively on lithic toolkits and projectile points, and extrapolated dates from neighbouring traditions and regions (Figure 4.3). This chronology is relevant for sites across northeastern Alberta because it can link similar artifacts across the region. However, the chronology must be used with great caution when applying it to site interpretations. The complexes defined in Figure 4.3 are consistently used in archaeological research in this area, and dominate CRM reports. The benefit of their use is the ease with which sites can be associated with one another across the region, based on recovered artifacts. However, until these complexes are verified with dates, the framework lacks temporal reliability.

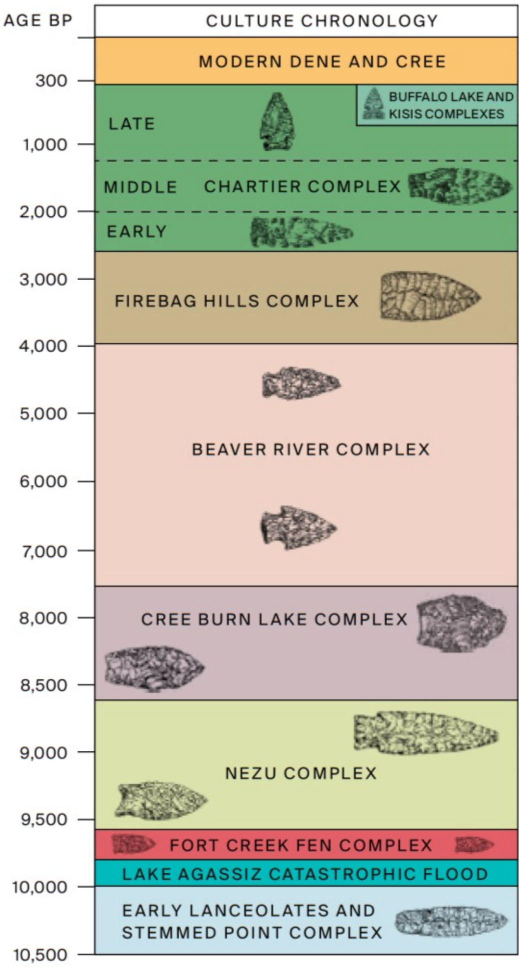

Figure 4.3 Proposed cultural chronology of the Lower Athabasca region (adapted from Reeves et al. 2017:164)

The discussion of the Boreal Forest’s culture history emphasizes the traditions influencing the prehistoric period. The culture history begins with the Early Prehistoric period, with influences from the Barrenlands tradition. It continues into the Middle Prehistoric, with influences from the Shield Archaic and Northern Plains. The culture history ends with the Late Prehistoric period, predominantly influenced by the Taltheilei tradition until contact with Europeans, which signals the beginning of the Protohistoric and Historic periods.

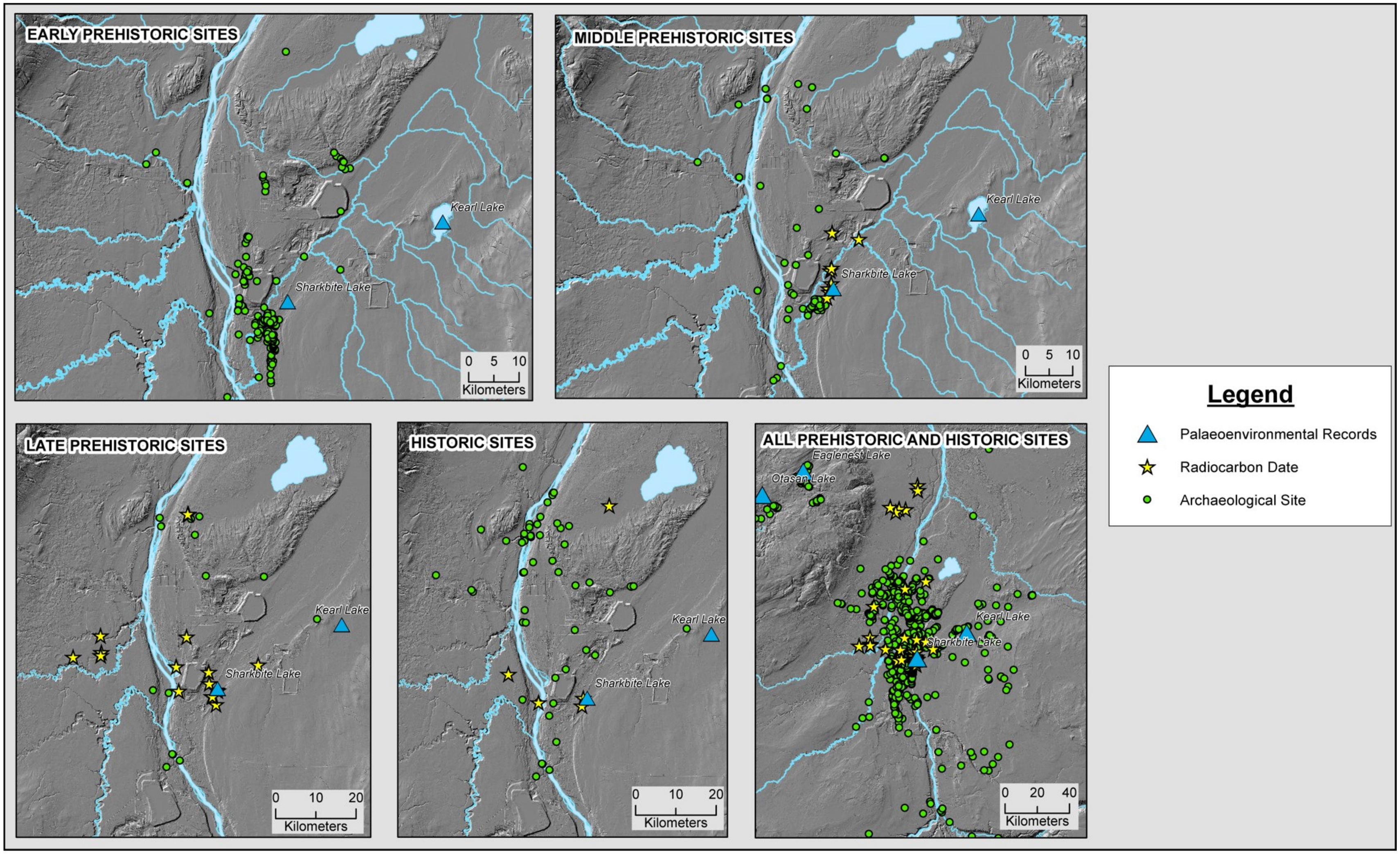

Figure 4.4 Map of archaeological sites from different time periods in the MOSR. Note the ‘All Prehistoric and Historic Sites’ map includes all undifferentiated prehistoric sites. These sites are often small scatters which cannot be associated with any specific prehistoric period. Note some hydrologic features are missing in the lower maps due to the change in scale.

4.1.1 The Early and Middle Prehistoric Periods

The Early Prehistoric period in the Boreal Forest spans an interval of climate and landscape changes that drove the transition from open forests to more closed forests. The changing landscape would have supported animal herds like caribou and bison, enticing people into the region. Reeves et al. (2017) stated that no fluted points were recovered from the MOSR; however, a point was found at HhOv-167 with two distinct basal thinning flakes that resembled late Paleoindian Crowfield points from Ontario (HhOv-167:716 [Ives et al. 2013:159]). The Duckett fluted point made from BRS found near Cold Lake also connects the MOSR to northeastern Alberta's earliest traditions (McCullough 1981; Gryba 2017). Several lanceolate and oblanceolate biface tools found in the Birch Mountains resemble Component 2 materials in Alaska's Dry Creek site that date to ~10,000 rcyBP (Ives 1993, 2017; Hoffecker et al.1996:347). These lithic tools demonstrate that early Paleoindian occupation began with the terminal portion of the fluted point era (Ives et al. 2013). Following this phase, the appearance of Agate Basin-like points is believed to have been associated with Northern Plano groups following bison into the grasslands that were expanding north, and perhaps following caribou into the Barrenlands due to the climatic shifts in the Hypsithermal (Gordon 1975:92, 1976:47, 1996:219; Martindale 2014:48; Potter 2017). Early prehistoric toolkits tend to frequently include *chi-thos* (also known as tabular bifaces, see Reilly 2015) and endscrapers. Points also exhibit characteristics of Hell Gap points from the Plains (Saxberg and Reeves 2003; Sims and Losey 1975). When mapped, sites clustered around the general area of Quarry of the Ancestors (Figure 4.4). Saxberg and Robertson (2017:386) have associated this concentration of sites with climatic conditions that "probably facilitated exposure of the BRS outcrops."

The Middle Prehistoric period is marked by the presence of side- and corner-notched dart points. The strongest influences on tool and point morphology appear to be those of the Northern Plains traditions. Martindale (2014:52) notes that this Northern Plains emphasis could be due to the fact that many archaeologists are trained and familiar with those materials. The Hypsithermal continued to impact the region as vegetation responded to warm and dry conditions, causing a shift in forest margins northward, drying lakes in the Parklands, and prompting the arrival of pine in the region (see Chapter 2.3; Lichti-Federovich 1970; Schweger and Hickman 1989). Projectile points found are reminiscent of contemporaneous northern Plains typologies like the Oxbow, McKean, and Pelican Lake complexes. They have been noted in assemblages in northeastern Alberta, such as Calling Lake (Gruhn 1981), Eaglenest Portage (Ives 1981, 1985), and the Beach Site (Pollock 1978a, b). Northern subarctic influences are seen in the notched bifaces; the notched, stemmed, and lanceolate projectile points, and the microblade cores and microblades. Sites are less concentrated around Quarry of the Ancestors, and more are in the north part of the study area (Figure 4.4).

Microblade technology is present in northeastern Alberta. Little Pond (HiOv-89) and Bezya (HhOv-73) are two of the best documented sites associated with microblade production in the northeastern Boreal Forest. Little Pond's assemblage represents the intermediate stage of lithic reduction and has several formal tools like scrapers and burins (Younie 2008; Younie et al. 2010:89). The Bezya site is believed to be a single occupation and contains evidence of the entire microblade reduction sequence, tool production, and maintenance (LeBlanc and Ives 1986:63). Tools at Bezya include microcores, core tablets, burins, and microblades (LeBlanc and Ives 1986). A radiocarbon date from Bezya determined that the occupation may represent 4870 to 3,973 cal yrBP; however, the date is not well constrained (see Chapter 5.2). Reeves et al. (2017)

most strongly associate the microblade tradition of the MOSR with the Pre-Dorset culture, an early Eastern Arctic variant of the Arctic Small Tool tradition (4,500 – 2,800 rcyBP). However, Younie et al. (2010) and Le Blanc and Ives (1986:81, 88-89) concluded that the best analogs for these assemblages came from Denali Complex assemblages in Alaska and the Yukon.

The Denali tradition falls under the Northwest Microblade Tradition (NWMt), due to similar production styles (Dixon 1999:175; Younie et al. 2010:73). Characteristic artifacts like the platform tablets and ridge flakes, along with wedge-shaped microcores from the Little Pond and Bezya assemblages, show a strong resemblance to NWMt/Denali complex tools, specifically the core-burins common at Little Pond (Younie et al. 2010:90). In addition, the complex at Little Pond is dominated by fine-grained materials like chert and silicified mudstone, with little BRS. Younie et al. (2010) see the lack of BRS and microcores and microblades styles like those of northwest traditions as evidence for a northern group's migration into the Boreal Forest. The Denali Complex in Alaska could date to as early as 10,600 to 5,000 rcyBP (Hoffecker et al. 1996). The NWMt has been identified in Alaska, Yukon, western Northwest Territories, and northern British Columbia and may date to 8,000 to 7,000 rcyBP (Clark 2001; MacNeish 1964:234, 252).

For the Early Prehistoric period, uncertainty surrounds the cultural sphere of influence. At best, what can be said without radiocarbon dates is that as early as the terminal fluted point tradition, humans inhabited the region. Lithics in the area also are similar to oblanceolates from Alaska. Given that both fluted points and oblanceolates are present, early records might represent populations from both a northern and southern origin.

Although ten dates are associated with the Middle Prehistoric period, only the projectile points have been used to anchor the cultural sequence. Neighbouring traditions from the Northern Archaic, Shield Archaic and northern Plains contain projectiles that vary between notched, stemmed, triangular, and lanceolate points. However, these broad styles found in the Boreal Forest could represent thousands of years.

4.1.2 The Late Prehistoric Period

The Late Prehistoric Period follows the Pre-Dorset Tradition and was at some point probably marked by the appearance of Athapaskan-speaking people. Gordon (1996:239, 2005:158) believes the Taltheilei tradition reflects ancestors of the Dene-speaking Athapaskans. Ives indicated that "no good antecedents for Taltheilei have come to light in recent years" but noted that Gordon's Late Taltheilei might "represent a new, Athapaskan presence" (1990:41). There is some evidence in the archaeological assemblages from northeastern Alberta that Late Taltheilei tradition material is present in the Late Prehistoric record approximately 1,200 ya (Ives 1993:17). Dene migration in the Subarctic may have followed eruptions within the Wrangell volcanic fields, specifically the Bona-Churchill massif. That volcanic field produced two eruptions, the first around 1,900 cal yrBP (Lerbekmo 2008) and the second around 1,110-1,117 cal yrBP (A.D. 846-848, Jensen et al. 2014). The second eruption, known as the White River East eruption (WRAe), was the larger of the two. It has been suggested by researchers that this eruption triggered the Dene expansion to the east and southeast (e.g., Ives 2003; Kristensen et al. 2018; Moodie et al. 1992).

The best-known example of a Late Prehistoric site in the Boreal Forest is the Peace Point Site (IgPc-2). This site is in Wood Buffalo National Park along the shores of the Peace River and was occupied as early as the late Middle Prehistoric period (Stevenson 1986). Peace Point is also well dated, with a total of eight radiocarbon dates (Stevenson 1986:45). The site has 18 distinct cultural layers interlain with fluvial deposits (flooding occurred approximately every 125 years). Occupations at the site began as early as 2,210 ± 115 rcyBP (S-2158) (Stevenson 1986:45) and continued into the 18th century, when the Tsattine (Beaver) and Nīhithawīwin reached a peace agreement at the site (Stevenson 1986). Lithic materials and tools found at Peace Point include a single side-notched point, microblade cores, scrapers, retouched and utilized flakes, burins, choppers, hammerstones, bifaces and unifaces, and other expedient tools. The side-notched projectile point, from level 13 (level dated to 1,040 ± 75 rcyBP [S-2157]) is technologically similar to Prairie side-notched projectile points (Stevenson 1986:45, 93). The consistent sedimentation rate and non-acidic soils preserved features like hearths, artifact distributions, and faunal remains. This situation is best demonstrated by the distinct arrangement of chert flakes in a Y-shaped pattern in level 1 (Stevenson 1986:50). This distribution resembles an activity area where an individual would have been kneeling while flintknapping. Other sites within northeastern Alberta that have radiocarbon dates or tools stylistically similar to those of the Late Prehistoric period include the Wentzel Lake site (IfPo-1), the Pelican Beach site (HkPa-14), and the Eaglenest Portage site (HkPa-4) (Ives 1985, 2003, 2017).

Projectile points that are characteristic of the Late Prehistoric period include dart and arrow points that stylistically resemble Plains technology, such as Prairie side-notched or Cayley series points (Ives 1985, 1993; Le Blanc 2005; Peck and Ives 2001; Reeves et al. 2017). Reeves et al. (2017) also associated bipolar split chert pebble technology, adze-like tools (bi-pointed or lanceolate shaped), and *chi-thos* with the period. Ceramics have been found in the latter part of the Late Prehistoric period in other parts of the Boreal Forest (e.g., Saskatchewan, Alberta/Saskatchewan border), but none have been found in the Lower Athabasca region to date. Ceramics have been identified in the Buffalo Lake Complex (Young 2006) and the Kisis Complex (Paquin 1995) in Saskatchewan, and in Alberta near Lac La Biche (Connor Learn 1986), but are interpreted as occupations distinct from the Taltheilei tradition.

The most probable reason for the increased number of late period dates would not be increased activity on the landscape but less time for soils to degrade datable materials. The Late Prehistoric period contains a total of 39 radiocarbon dates, accounting for approximately 80% of all dates found in the region. Even with the number of dates obtained, we must remember the challenges associated with the limited sedimentation rate. These dates correspond to an occupation surface; although without careful mapping and excavation, no definitive point typology connections can be made with radiometric dates. This issue is explored further in Chapter 5.1.

The Late Prehistoric period ends at the start of the fur trade in the region, after which these sites begin to have historical items such as fur trade goods and metals (Gordon 1996:239-240; Korejbo 2011:44; Meyer and Russell 2007; Reeves et al. 2017). At this time population sizes would have begun to experience a decrease as a result of the spread of smallpox brought by fur traders (Binnema 2006; Hodge 2012). The Taltheilei groups represent the end of the Precontact period, and the subsequent Athapaskan-speaking Dene are the first tradition during the Historic period (Gordon 1996:239-240). The transition to the Historic period is marked by the presence of Nīhithawīwin (Cree), Dene Sųłiné (Chipewyan), and Tsattine (Beaver) trading parties coming to the lower Athabasca for trade (Ives 2003, 2017).

4.1.3 The Protohistoric and Historic Periods

The Protohistoric and Historic periods are marked by the appearance of European trade items in archaeological assemblages. The local Taltheilei group of the Late Prehistoric period is thought to represent an Athapaskan group in the region, based on the known distribution of Dene people at the time of the fur trade (Ives 2003; Van Dyke and Reeves 1985). At the time of European contact, Dene Sųłiné occupied the far north and their subsistence patterns relied on the migrations of the barren-ground caribou. Prior to contact, Dene occupied much of the northern Boreal Forest ecoregion in Alberta and Saskatchewan, from the area north of the Seal River, Black Lake, and Athabasca Lake, to the Great Slave Lake in the west (Gillespie 1976, 1981; Smith 1976a, 1981b). The Nīhithawīwin occupied the southern Boreal Forest, focusing on moose, wood bison, and other animals for subsistence. Prior to contact, the Nīhithawīwin occupied the land south of the Dene Sųłiné domain, stretching to the Peace River delta in the west and terminating by the Beaver River and Saskatchewan River to the south (Meyer 1983:141; Meyer and Russell 2007:111-112).

Although the boundaries noted resembled the traditional area for groups’ seasonal rounds, it is possible that there was a geographic overlap between the Dene Sųłiné and the Nīhithawīwin. Dene Sųłiné groups would spend time in both the tundra/boreal transition landscape and the nearby Boreal Forest as was required by the migratory routes of barren-ground caribou (Gillespie 1976; Smith 1976a, b). The archaeological assemblages in the region support the idea of the temporal and geographical overlap between the Dene Sųłiné and the Nīhithawīwin, because the Athapaskan-speaking Dene are descendants of the Taltheilei and the Algonquian-speaking Cree descended from the Selkirk culture (Martindale 2014:56-58; Meyer and Russell 2007:315; Wright 1981:92).

The Nīhithawīwinmet with European fur traders before the traders encountered Dene groups. The connection between the Nīhithawīwinand Europeans has led to misconceptions about Nīhithawīwintraditional territory and range. Early accounts of the boreal inhabitants, such as the journals of Mackenzie (1971[1801]), led earlier researchers such as Jenness (1932) and Mandelbaum (1979) to argue that the Nīhithawīwinmoved into the region from the east with the Fur Trade. More recent research has suggested that the expansion of the Nīhithawīwin occurred before the European Fur Trade, and that the Nīhithawīwin and Dene Sųłiné had an overlap temporally and geographically before and during European contact (Gillespie 1976, 1981; Meyer 1983; Meyer and Russell 1987:10-12; 2007:112-114; Russell 1991; Smith 1976a, 1976b, 1981a, 1981b; 1987). As the Fur Trade progressed, Dene Sųłiné groups moved further into the Boreal Forest to the south, occupying the areas near the Slave River and Athabasca River valleys (Gillespie 1976, 1981; Smith 1981b).

Through the late 1700s and into the 1800s, the Northwest Company and the Hudson's Bay Company established trading posts in the traditional territories of the Nīhithawīwin and Dene Sųłiné, allowing for easier access and trading with Indigenous groups (Gillespie 1976, 1981; Smith 1976b, 1981a, 1981b). The Methy Portage has been an important travel route between the Mackenzie system and the Hudson Bay drainage, particularly during the Fur Trade. Connecting the Clearwater and Athabasca with the Churchill River, its headwaters served as a meeting location for Nīhithawīwin and Dene Sųłiné groups (Smith 1981a, 1981b). Following fur traders' movement into the region, missionaries arrived in the late 1800s and early 1900s (Smith 1976b:259).

4.2 Boreal Forest Adaptations

The tangible archaeological record of the Boreal Forest region yields artifacts that inform our understanding of technological changes. These changes provide archaeologists with some information on past lifeways but do not produce a complete picture of the nuanced relationships between groups living in the region and the landscape. The dominant factors that influenced human adaptations were: 1) mobility through elements like snow, muskeg, water bodies, 2) fluctuating food resources, and 3) a landscape that saw game dispersed across the region. These factors were linked and influenced each other.

Mobility across the landscape is an important element of a communities success in the Boreal Forest. In a study done by Winterhalder (1983:232-33):

> "[the] species used by the Cree are usually associated with five patch-types (aspen-birch forest, recent burn, aquatic vegetation, vegetation of lake margins, and aquatic areas) … [of which] the productive 10% is scattered in an irregular distribution of small patches surrounded by the larger areas of bog, muskeg, and water. This pattern makes mobility critical to the forager."

The use of snowshoes, and toboggans facilitated easy movement throughout the region during winter (e.g., Steegmann 1983). The network of rivers, lakes, and streams in the Boreal Forest allowed people to travel from one area to another with by canoerelative ease in summer.

First Nations ancestors dealt with fluctuating and unevenly distributed food resources by maintaining smaller co-residential group sizes. In parallel, Athapaskan and Algonquian communities also had low population densities. The average local group reported by ethnographers consisted of 25-30 people, with population densities as low as one person for every 100-400 km^2 (Ives and Sinopoli 1980; Ives 1990; Jarvenpa 2004; Turner 1979). Historic records affirm that bands in the Boreal Forest consisted of 10 to 14 individuals for the Nīhithawīwin and somewhere between 25 to 100 for Dene Sųłiné (although 50-60 was more common) (Ives 1990; Smith 1981a:259, 1981b:276). This, coupled with an extensive social network, allowed First Nations to maintain territorial population levels while responding to fluctuating game populations. Smaller groups required less food. Larger regional gatherings of people required the resources from large hunts or major fish spawns. During specific times in the year, local bands would congregate and form seasonal regional bands that consisted of anywhere from 200 to 400 people (Athabasca Chipewyan First Nation 2003:34; Ives 1993:24; Smith 1976b:14-16, 1981a).

For the Nīhithawīwin, regional bands would gather during fall along lakeshores and plan for the winter. This initial meeting would be spent hunting, fishing, and preparing for the winter. During the winter the regional band would divide into respective local camping groups to reach their wintering areas, trapping and hunting caribou, moose, and fur-bearing animals during that season (Smith 1981a:259-260). This was different from the patterns of the Dene Sųłiné whose seasonal cycle, distribution, and social organization was based on barren-ground caribou herds (Smith 1981b:272-273). Regional bands would form for the spring and fall caribou migrations, and groups would engage in large hunts at main treeline crossings. Summers would be spent as local camping groups (and sometimes regional bands) along lakes, reflecting the congregation patterns of the caribou. This pattern extended into the winters, when small local bands would move into the forest to the south, following the caribou (Athabasca Chipewyan First Nation 2003:34; Smith 1981b:274-275).

Theoretical frameworks like optimal foraging theory (Winterhalder 1983) and Binford's (1980) approach to hunter-gatherer settlement systems reinforce the importance that seasonal rounds had for the economic success of a group. Hunting and foraging strategies where smaller parties would leave the "residential base" to the "location" (Binford 1980:9) to procure resources would have been frequently employed in the Boreal Forest, because food resources were widespread across the region. This foraging strategy, where "…[f]oragers move consumers to goods with frequent residential moves" allowed First Nations ancestors in the Boreal Forest to access numerous essential resources (Binford 1980:15). Diet breadth, patch selectivity, and forager movement among patches are behaviours that Winterhalder (1981:68) identified as responses to foraging stresses and ecological variables.

Ultimately, however, economic strategies among Subarctic peoples were the consequence of socially structured principles of group formation that influenced the relationship between smaller co-residential groups and larger regional groups (Ives 1990:314-315; 1998). Where exogamous marriage practices prevailed, these principles allowed the creation of geographically expansive kin networks. Such strategies may very well lie behind the distribution of BRS. The material is found in exposures along the Athabasca River Valley, at Quarry of the Ancestors, and at the Beaver River Quarry. However, as artifacts, the material is also found as far as the Birch Mountains to the west (Ives 1985), and to the northwest in the Caribou Mountains (Fenton and Ives 1990). BRS artifacts have been found as far south as the Duckett Site (Gryba 1988 [as cited in Gryba 2017]) near Cold Lake and in the Barrhead District (Fenton and Ives 1990), supporting the wide movement of people and the economy of First Nation Ancestors.

To the northwest of the MOSR, sites in the Birch Mountains are linked with BRS and the broader mobility networks of the Boreal Forest. Excavated in the 1970s - 1980s (Ives 1985), and re-assessed in 2016 (Rawluk 2017), the Eaglenest Portage site (HkPa-4) is a large unstratified site at an elevation of approximately 715 masl along the confluence of the Eaglenest Lake and Clear Lake drainages in the Birch Mountains. Probably inhabited by the Tsattine (Beaver First Nations) in later prehistory, the site location would be consistent with a resource emphasis on spring fish spawns (northern pike, walleye, and sucker) followed by a shift to ungulates such as moose, bison, and elk (Ives 1985:37, 106; 2017:307). Eaglenest Portage appears to have been occupied for the last ten thousand years, with earlier oblanceolate bifaces, to late smaller side- and corner-notched late Prehistoric points and Historic artifacts like rifle shells, seed beads, and evidence of two cabins (Ives 1985:37-38; 1993:9, 15; 2017:295,305). BRS found at Eaglenest Portage can be linked to sources in the lower Athabasca like Quarry of the Ancestors (Ives 2017; Kristensen et al. 2016). This toolstone was probably moved through the seasonal rounds by smaller local groups and through exchange in the larger regional gatherings mentioned above. While spring and summer would be the most likely times that the Quarry would have been accessed, there is a strong possibility that some exposures would have been accessible year-round (Ives 1985:30).

For Athapaskan-speaking groups, their landscape relationship manifests itself in the language used to define and describe areas. Humans and the environment are rarely seen as mutually exclusive and instead as inclusive of each other. A deep knowledge of the animals and plants is vital for Athapaskan peoples because they constitute significant features of the environments or habitats (Johnson 2008; Nelson 1983; Parlee et al. 2012). As hunting communities, the Dene are attentive to the habits and ecological requirements of animals and of the locations and habitats of plants which they harvest or use (Johnson 2008). Johnson (2008) notes that terms used have an explicit spatial relationship, in which the speaker is situated in the landscape rather than separate from it. “Plants…mediate our encounter with landscapes: we walk in the forest, among the trees, through the brush, and on the grass” (Johnson 2013:85). Many of the keywords to describe environments and landscapes are descriptive of being *in* a landscape rather than as a passive observer (Johnson 2008). It is important to recognize that the landscape is something beyond the physical surroundings which provide people with resources, it is imbued with meaning and deep connections. Landscape studies include “examining [the] evidence for human recognition, use, and modification of a particular position, locality, or area over the full span of its existence” (Ashmore 2002:1178). Archaeologically we rarely find physical evidence of this connection with the landscape, but oral traditions provide some insight into this relationship. This thesis looks at one relationship in the region—anthropogenic landscape management practices and how First Nations actively shaped and changed their landscape, most notably with their use of fire.

4.2.1 Anthropogenic Landscape Management Practices

> *“...Fire, properly used, has a multiplicative effect. It propagates. It compounds and magnifies the effects of other processes with which it is associated. It can create, but even more powerfully, it can sustain. Intelligent beings armed with fire can apply it at critical times for maximum spread and effect.”*
>
> (Pyne 1991:505)

Anthropogenic landscape management practices have been discussed in some studies of northern Alberta (e.g., Lewis 1982; Lewis and Ferguson 1988; McCormack 2010, 2017), but few in the region explore its potential relevance to communities’ success in the region. In anthropological literature, Steward (1955:5) viewed cultural environmental studies as part of cultural ecology and believed that humans adapted to environments but did not influence them. Steward (1955:21) stated that “culture is modified in a particular environment,” and these changes to culture represent the conceived deterministic fashion of the environment. While the environment is a critical actor in cultural changes, it is not the determining factor. The environment is the backdrop upon which cultural adaptations evolve.

The work of Stewart (1963, 2002), Day (1953), and eventually Lewis (1977, 1982) migrated to the forefront of anthropological discussion; these researchers recognized that Indigenous communities were recognized as active in shaping their landscape. Anderson (2002:61) correctly notes that the dynamics of controlled burns were much more refined and references occasions when burning was not encouraged. An example of this from the Boreal Forest would be ensuring that specific berry patches were left untouched. "Saskatoon berries…did not respond to frequent burning […but burning] was good for strawberries…and raspberries…" (Lewis 1982:41). The most appropriate perception of fire was that if it *could* be used, it *may* have been used if all conditions were met.

As active actors in the landscape, "… [First Nations'] selective employment of fire for Boreal Forest adaptations indicated an understanding of both general principles and the local specific environmental relationships that are the subject of modern fire ecology" (Lewis 1982:17). Fire is critical to the mosaic landscape of the Boreal Forest region of Alberta, and actively affects populations in the area. In prehistoric times, the role of fire would have been facilitated in a more controlled manner through human landscape management practices. Ethnographic studies of the Dene-tha (Slavey) in northwestern Alberta demonstrated the tradition of controlled burning through narratives of the elders in the communities (Lewis and Ferguson 1988). This burning would have increased the diversity of certain plant communities in an area, an effect which would have had a positive impact on human communities and resource procurement in the north.

Fire was used by First Nations in northern Alberta to modify the landscape by creating fire yards and corridors and maintaining trail systems (Lewis and Ferguson 1988; McCormack 2017) (see Chapter 2.3 and 5.1). These events facilitated the movement of people and encouraged processes of ecological succession that could encourage animals to revisit areas (Lewis 1982; Lewis and Ferguson 1988).

4.3 Late Prehistoric Archaeological Research

Although there are profound challenges to framing a culture history for this region, the archaeological record of the region can be effectively contextualized when viewed from a landscape-use perspective. There are over 1,000 sites recordedwithin the Athabasca lowlands, one of the densest concentrations of archaeological sites in all of Alberta. Only 47 sites are dated and few of these are multi-component; the hundreds of other sites can provide meaningful glimpses into mobility and toolstone use in the region. To best assess the strengths of the archaeological record, the following topics are discussed in this section: site distribution, landscape mobility, and site types and functions.

4.3.1 Site Distribution

In the archaeological investigations of the 1970s and earlier 1980s, sites throughout the MOSR, the broader Athabasca lowlands, and the Birch Mountains were typically discovered on elevated landforms with well-drained soils and a waterbody (a river, stream, or lake) nearby. Other settings were regarded as having low potential for the presence of archaeological sites. This discovery pattern was particularly true of earlier regulatory studies (CRM) in the region. Subsequent research and regulatory work revealed that archaeological sites did occur in considerable densities at locations previously regarded as having low archaeological potential (Ives 1982; Ronaghan 2017b; Woywitka 2018).

Here I undertake a review of the regional site distribution intended to refine our understanding of site patterning and as a prelude to exploring the relationship between particular sites and Sharkbite Lake's palaeoenvironmental record. Site distribution patterns in the region were first analyzed by looking at all sites because this approach produced more readily identifiable trends. An analysis reviewing all sites prevents inconsistencies in trend identification based on unsubstantiated temporal associations. Using ArcMap, site locations were plotted and then analyzed according to the density surface. Kernel Density analysis was used to model site density as it "calculates a magnitude-per-unit area from point […] features using a kernel function to fit a smoothly tapered surface to each point" (ArcGIS Pro, 2018). Sites were imported as point features, meaning the central geographic coordinates defined the site and site boundaries were not considered for the analysis.

The distribution of these sites shows a concentration near modern Fort Mackay (Figure 4.5), with many sites near the Athabasca River and the Quarry of the Ancestors. Some of this high density can be attributed to archaeological biases. Intensive development within the MOSR has triggered more impact assessment and mitigation studies and therefore more sites have been discovered in the area. The same forces that exposed the mineable oil sands also exposed parts of the Fort McMurray Formation containing the BRS unit. Although some of the density bias may arise from regulatory work triggered by industrial activity, the concentration of sites also reflects the accessibility of BRS and its significant value as a prehistoric technological resource.

Portions of the region that are currently dominated by muskeg and fens would have been more accessible in earlier prehistory because peatland development appears to have expanded in the late Holocene (Chapter 2.2.3). It is probable that more of the landscape would have been available during the Early and Middle Prehistoric periods. Woywitka (2018:46-47) obtained basal beat radiocarbon ages from the MOSR with dates ranging from 10,480 to 10,252 cal yrBP to 2,309 to 2,142 cal yrBP. What is of particular interest, however, is the basal age of a wetland in Quarry of the Ancestors that dates to 907 to 740 cal yrBP (UCIAMS# 122307, Woywitka 2018:47). This date comes from branch fragment and is associated with nearby flakes that sit "above the base of the organic silts from tests near the edge of the wetland [indicating] human occupation at sometime after this date at Quarry of the Ancestors" (Woywitka 2018:47). Woywitka (2018:103) has demonstrated that young peatland initiations would impacted BRS exposures at Quarry of the Ancestors and may have buried sites and archaeological materials. A date from a buried landform nearby Ronaghan's ridge reflects 932 to 798 cal yrBP range, indicates that further north younger peatlands were developing. The record from Sharkbite Lake shows a shift in vegetation composition around this time: a decrease in charcoal that is sustained through the rest of the pollen record; a peak of *Eleocharus* sp.; and relatively stable and abundant levels of *Sphagnum*. All these factors support that conditions were favorable in the area to young peatland shifts. If this late peatland initiation was occurring across the landscape, even more recent prehistoric occupations may be recovered from wetland environments, with the added benefit of the preservation and collection of organic artifacts in these water-logged conditions. This means that many earlier sites may have been obscured by peatland expansion and may not be detected with traditional testing methods. Assessments of lower potential areas have resulted in the discovery of some sites, changing site distribution patterns slightly; however, sites may still be hidden due to the extensive peatlands in the area. Current reconstructions of landscape use and the distributions of archaeological sites need to consider this trend and recognize that the absence of a site in an area may not relate to limited or no use but may mean that these areas need to be further investigated with non-traditional methods. This consideration becomes especially critical at the regulatory stage when project footprints are used to determine an area's archaeological value and whether assessments are required.

Ethnographic accounts indicate that First Nations groups living in the area followed seasonal rounds, tracking seasonal movements of animals and responding to vegetational changes (such as those created by fires). It is likely that similar practices occurred in prehistory (e.g., Athabasca Chipewyan First Nation 2003; Smith 1976b, 1981a, 1981b). Quarry of the Ancestors is situated near Sharkbite Lake, and the high concentration of sites there illustrated in Figure 4.5 demonstrates that this part of the lowlands was frequented as a critical area for First Nations ancestors. High-quality lithic materials drew groups in, but the mosaic of elevated terrain features, muskeg, and water bodies created a hospitable environment within which Precontact populations could circulate to hunt, fish and camp.

In addition to the dense concentration of sites around the Quarry of the Ancestors, there are two concentrations along the west side of the Athabasca River. One lies almost directly north of the main cluster, and one west of the quarry (Figure. 4.5). These clusters were noted in research done by Fisher (2017) when he looked at BRS assemblage composition across the lower Athabasca River Valley. Both clusters, which Fisher (2017:31) call the "Northwest Cluster" and "West Cluster" respectively, represent sites with high and low percentages of BRS yield. These BRS frequencies may reflect movement in the region, with sites resulting from groups both entering and exiting the Birch Mountains (where non-BRS materials are common), and travelling toward BRS sources in the lowlands (Fisher 2017; Ives 2017).

It is known, based on historical and ethnographic work, that traditional wintering grounds of Dene and Nīhithawīwin populations were commonly in the treed areas and near water sources (Smith 1981a, 1981b), and it is plausible that this pattern existed in prehistory. The only research to focus specifically on site distribution was done by Ives (1982). A survey of the Alsands lease was conducted following the clearing of vegetation and draining of the muskeg. This operation provided optimal conditions to survey the shallow deposits with minimal excavation. This survey data was used in conjunction with the site information from earlier studies to demonstrate that site density in this previously "low potential" area actually averaged 10-15 sites per square kilometre, with the potential to reach 30 sites per square kilometre (Ives 1982:104, 108). Sites were situated on slightly raised terrain features. In several instances, microtopography suggested that wind direction was considered because strong westerly winds would have affected the winter camps (Ives 1982:101,104). This survey, as well as shovel testing methods focussing on elevated terrain features (Ronaghan 2017b:489), led to the discovery that areas that may have been deemed low potential could contain sites that were obscured by modern vegetation. Simply targeting "high-potential" areas had led to a self-fulfilling prophecy in which "low potential" areas were avoided, and sites went undiscovered. Subsequent regulatory and research work revealed the tremendous density of sites now known for the region (Figure 4.5). More recently, Woywitka (2018) has shown how approaches based on the region's unique geomorphology can further refine site detection strategies for a variety of settings, including those once regarded as having low potential. This is especially true for sites in areas where factors such as aeolian deposition and peatland development may bury occupations more deeply than testing can reach.

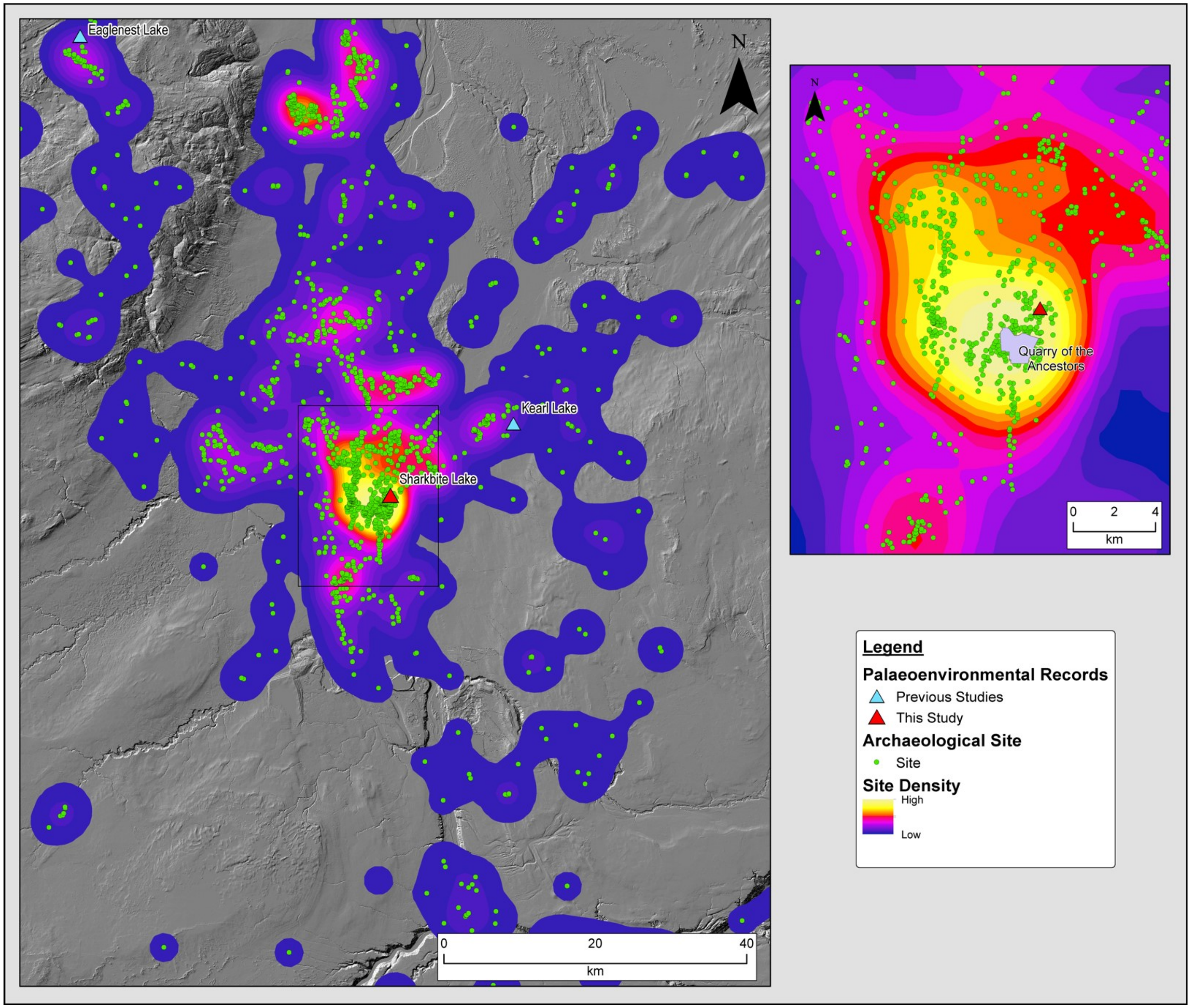

Figure 4.5 Site density modelled by number of sites within the study area. All prehistoric site locations were used in this analysis.

4.3.2 Landscape Mobility

In a study done by Rogers (1972, as analyzed by Kelly [1983]), the Mistassini Cree were shown to be highly mobile, frequently moving across the landscape. Historically, the groups diet was comprised of products from 50% hunting, 20% gathering, and 30% fishing (Kelly 1983:282). This pattern of activities might also be characteristic of the Boreal Forest of Alberta (Smith 1971; Gillespie 1971). Globally, leaving a residential location to accomplish a single task is rare, but was necessary for groups living in the Boreal Forest (e.g., Binford 1979; Ives 1993; Kelly 1983). Large game animals in the region are highly dispersed, and there is a low species diversity in the Boreal Forest on a global scale (Kelly 1983:288). Logistical mobility represents the movement of individuals or small groups from a residential site to another location to procure resources. For the Cree, these logistical moves historically averaged 8–32 km/trip, and could be single day excursions or multi-day trips (up to 20 days) (Kelly 1983:298-299).

The artifact concentrations at Beaver River Quarry and Quarry of the Ancestors indicate that they were primary locations for the recovery of BRS. Like the nearby Cree Burn Lake site complex, they were in ideal locations for residential camps for both local and regional groups. Figure 4.6 illustrates projected mobility using the two quarries as “anchoring” sites. The blue represents a 15-km radius from the quarries, and the green buffer denotes a 30-km radius. Both reflect the underlying assumption that all areas of the landscape are equally traversable and do not consider elements like travel corridors or preferred routeways. This radius was also chosen based on previous studies (see Fisher 2017; Ives 1993). Kelly states that “…extensive logistical mobility becomes viable only when large faunal resources are to be acquired and becomes more important with an increased need to depend on such resources and a decreased capacity to store resources…” (1983:298).

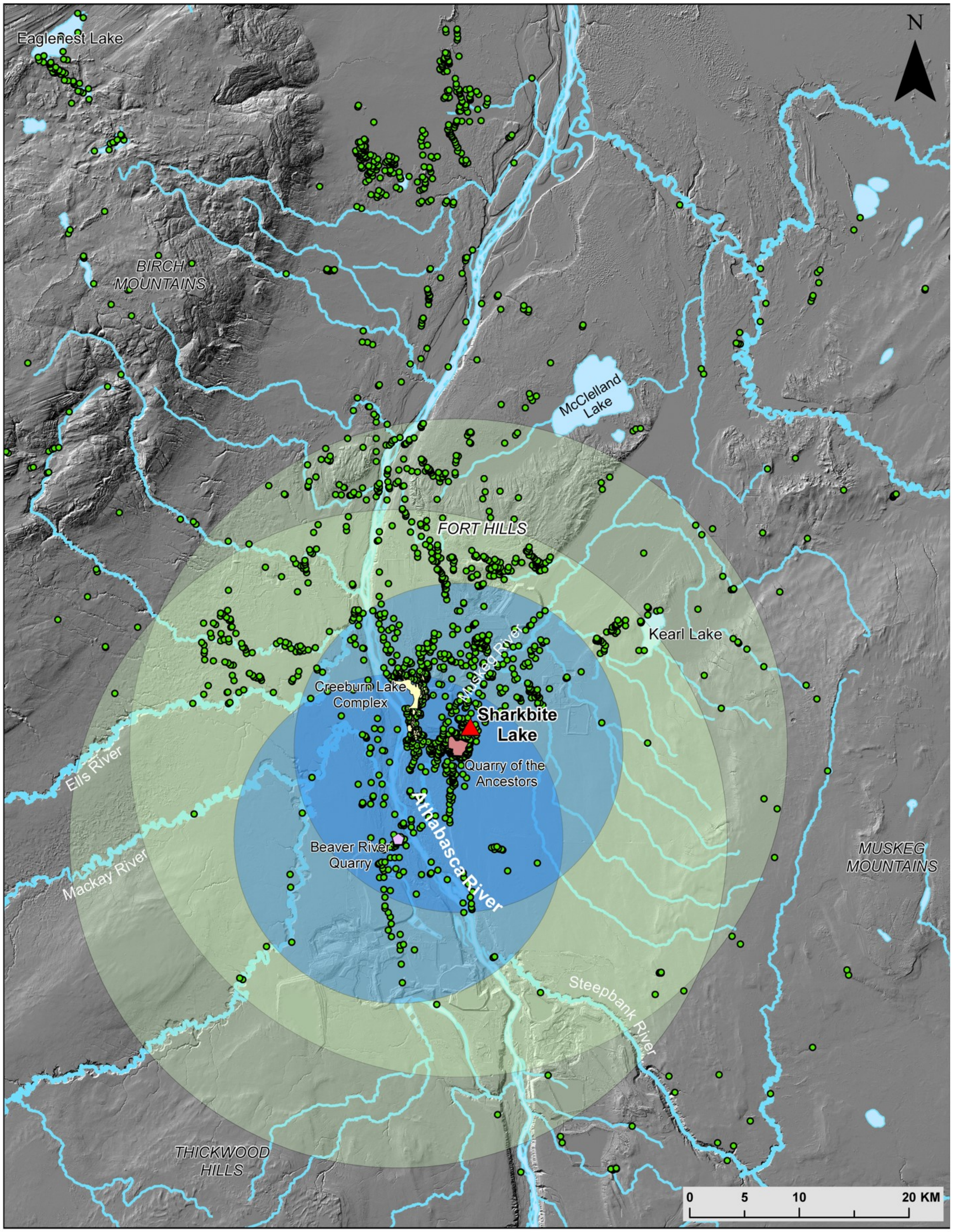

Figure 4.6 Projected mobility extents in the study area. Using both Quarry of the Ancestors and Beaver River Quarry, a 15 km (blue extent) and 30 km (green extent) buffer was created using each BRS source as the locus.

A new assessment of the drop-off zone for BRS distribution was done by Fisher (2017), and included newly discovered sites (since the 1990s) which showed the 30 km fall off zone again. There are some sites, like HiOw-37, that fall within both 30-km mobility extents but are dominated by non-BRS materials. In the case of HiOw-37, the site is near the edge of the 30-km radius for a region in which we could expect local hunter-gatherer groups to cross when shifting residential locations, either to depart from the Birch Mountains or to head southeastward to the BRS localities. Fisher (2017) noted these trends as well and believed that these sites represented a departure from the Birch Mountains into the lowlands, at which time a group’s tool kit would largely be composed of raw materials other than BRS.

The addition of the 15-km radius was included because this distance represents a full day’s travel but with a return to an original campsite such as Beaver River Quarry, Quarry of the Ancestors, or Cree Burn Lake. Given the dependence on highly dispersed food resources, small parties would have left the central campsite to return after hunting. Since Cree logistical moves ranged 8-32 km/trip, this 15-km radius accounts for single day excursions that did not require breaking down camp (Kelly 1983:298-299). Examples of such excursions could include parties departing a central campsite to one of the nearby BRS sources to obtain more raw material, to acquire birch bark or spruce root for fabrication of perishable artifacts, or to return the proceeds of a kill to the encampment.

There also appears to be a linear trend in the sites closer towards the Birch Mountains. The movement into or out from these uplands is reflected in sites locations. Sites trend along the primary waterways, which have both been shown to be feasible entry points to this part of the region geospatially (e.g., Fisher 2017) and traditionally important travel routes (e.g., McCormack 2017; Oetelaar and Meyer 2006:360-361).

Some areas of the distribution map are not truly devoid of archaeological sites. Rather, some places have not been examined yet simply as a consequence of where industrial development has been planned. Accumulated survey results for the entire study area show that archaeological sites occur widely across the region. Secondary concentrations of sites can be found around the Fort Hills and farther to the northwest, on the east side of the Athabasca River. As the Sharkbite Lake and Kearl Lake records make evident, the lower Athabasca River Valley would have been rich in both riparian and forested habitats with animal resources and plant communities important in First Nations lifeways (Bouchet-Bert 2002; this study). Sharkbite Lake lies near the centre of this sphere of movement. Its palaeoenvironmental record provides details on the conditions that foraging populations would have encountered over the last 3,300 years (see Chapter 5).

4.3.3 Late Holocene Site Types

The identification of site types and functions is important to archaeologists working within the Boreal Forest region. When assemblages are limited in the types of materials recovered and confined to shallow deposits, information like site function allows us to understand patterns of past human occupation. For this section, I have used the site types as identified by researchers in the private sector (CRM), regulators, and academics. These site types include artifact scatters (>10 or <10), workshops, dwellings, and caches. I reviewed sites classified as Late Prehistoric based on available radiocarbon dates or cultural affiliations through projectile point characteristics, as well as additional information provided by the Archaeological Survey of Alberta. I then compared this data-set to the frequency of different site types across prehistory.

Figure 4.7 demonstrates the varying site types with radiocarbon-dated assemblages. Sites fall into two major categories, campsites and workshops. Some sites are defined exclusively as campsites, while some are termed both a campsite and a workshop. Although this selection comes down to a preference by the reporting archaeologist, it probably does reflect some defining characteristics of sites in the Boreal Forest. Campsites in the region sometimes yield faunal remains, and on occasion contain hearths. In lieu of these materials at sites, campsites are often distinguished by the types of lithic materials present and the distribution of materials across a landform. Short term campsites for small local groups would have been established and broken down within a few days or just a few weeks, whereas long-term campsites, including those for regional gatherings, may have been occupied for several weeks (see Chapter 4.2). Archaeologically, it is difficult to determine how long a campsite has been occupied without faunal material or other organic evidence. Inferences can be made based on the lithic activities occurring at a site. Short-term campsites would not have as many distinct activities with dense accumulation of artifacts, but instead may have lithics reflective of tool maintenance.

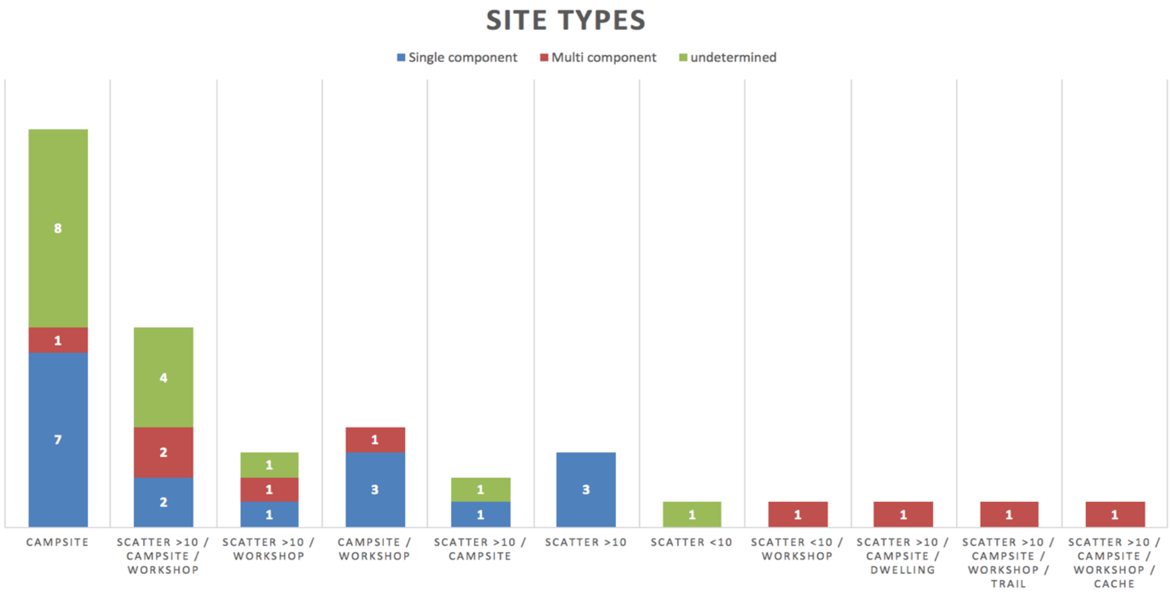

Figure 4.7 Radiocarbon dated site types – Late Prehistoric only

The clear majority of the Late Prehistoric sites in the region are single component or lack the stratigraphic context to discern components. Only eight sites are classified as multi-component, and some of these are due to the Historic component noted in the assemblages. While most multi-component sites contained just two identifiable components, HhOv-506 contains four. Four of the eight multi-component sites are within the HhOv Borden Block, perhaps because radiocarbon dates have more often been obtained from this specific Borden Block. The somewhat higher number of dates may indicate that the parent geologic material or soils in the area degrade organic material more slowly, but the presence of the Quarry of the Ancestors and the Cree Burn Lake site complex may also be factors influencing the decision to try to obtain radiocarbon dates. For the larger population of sites, 36% have an undetermined number of components, potentially owing to compressed stratigraphy and the few opportunities regulatory work has afforded to record detailed three-point proveniences. Distinctions between campsites and workshops are made within the site listings, but these definitions are fluid and could represent both types of occupation. Workshop style activities would have been common at campsites, but many of the associated artifacts would have been lost due to soil conditions. Kill sites are frequently found in the parklands and in southern Alberta. However, the accelerated degradation of faunal materials and the smaller kills in the Boreal Forest obscure this kind of from the record. This problem is in addition to the fact that large mammals are widely dispersed across the landscape and a kill site would represent at most a few animals. Instead, it is likely that several of the small scatters and areas of lithic resharpening represent kill sites.

When looking at all site types for all time periods (Table 4.1), similar trends exist to those noted in the Late Prehistoric sites. Overwhelmingly, we do see that most of the sites represented are reflective of a fine-grained record (scatters and isolated finds). These sites defined as scatters or isolated finds may represent human mobility in the region (see further remarks in Section 5.1). Campsites and workshops are the most frequently found sites, second to scatters. The inclusion of Historic sites is reflected in the structures, settlement, and trading post site types. This table allows researchers to understand some of the trends in site types for northeastern Alberta. However, categories like scatter inhibit detailed research into site function in prehistory. Nonetheless, the wide variety of sites and the volume of sites reflected in the table speaks to First Nations ancestors success in the region for over the past 10,000 years.

Site Type	Number of Sites
Scatter	**897**
scatter	43
scatter (artifact)	5
scatter (lithic)	15
scatter <10	494
scatter >10	342
Isolated Find	**433**
isolated find	433
Campsite	**346**
campsite	274
campsite, workshop	85
scatter <10, campsite, dwelling, trail	1
scatter <10, workshop	1
scatter >10, campsite, dwelling	1
Workshop	**316**
workshop	308
campsite, workshop	6
workshop, quarry	1
Dwelling	**6**
dwelling	5
historic feature, dwelling	1
Workshop / Quarry	**4**
scatter >10, workshop, other	2
workshop, quarry	2
Trail	**4**
trail	4
Structure	**4**
structure	4
Campsite / Other	**3**
campsite, trading post	1
campsite, workshop, dwelling	1
scatter >10, campsite, settlement	1
Trading post	**3**
trading post	3
Quarry	**3**
quarry	1
quarry (pipestone (limestone), palaeontological, dwelling, scatter <10	1
scatter >10, quarry	1
Hunting Stand/Lookout/Killsite	**2**
lookout	1
scatter <10, hunting stand/lookout	1
Settlement	**2**
scatter >10, settlement	1
settlement	1
Other	**2**
isolated find, trail, midden	1
rock art	1
Grand Total	**2026**

Table 4.1 All Site Types from the study area (not including industrial or contemporary sites).

4.4 Summary

In northeastern Alberta, the cultural history of the region relies on comparisons with cultural traditions from neighbouring regions: the Arctic to the north, the Northern Plains to the south, and the central and eastern Subarctic to the east. The work of consulting archaeologists, academics, and government researchers has provided a tentative framework for the cultural chronology in the region; but refining this framework will require the discovery of more multi-component sites and obtaining associated radiocarbon dates. For the time being, the Late Prehistoric period in northeastern Alberta has the best radiocarbon data for a time range that parallels much of the Sharkbite Lake record. In the next chapter, I will integrate archaeological and palaeoenvironmental information for this time range in an effort to see First Nation ancestors not as passive actors on ancient landscapes, but as active agents responding to boreal forest ecological dynamics in this region.

Chapter 5 Synthesis

"Every landscape reflects the history and culture of the people who inhabit it. The worldview of a society is often written more truthfully on the land than in its documents."

(Kimmerer and Lake 2001:36)

This chapter presents examples that synthesize palaeoenvironmental data with archaeological data in meaningful ways to better inform site interpretations. In archaeological research, palaeoecological data is often used to present broad generalizations of the landscape but is less frequently used to understand human history. One of the first researchers to focus on palaeoenvironmental data from the lower Athabasca River valley in relation to human movement and lifeways in Alberta's northeastern Boreal Forest was Bouchet-Bert (2002). Bouchet-Bert (2002) reconstructed early Holocene environments and used his interpretations of the landscape to test models for the peopling of the Boreal Forest. It was one of the first in-depth studies to challenge single migration theories and apply multiple lines of evidence to reach a more holistic interpretation of human history in the Boreal Forest. Traditionally, Boreal Forest vegetation is seen by researchers as a passive and static element of the landscape and is taken for granted in understanding the region. However, information obtained from pollen reconstructions provides a background against which archaeological sites can be better contextualized. The palaeoenvironmental work done by Bouchet-Bert (2002) is frequently cited in archaeological research, along with the work from Eaglenest Lake (Vance 1986) and Mariana Lake (Hutton et al. 1994). However, Kearl Lake's pollen record ends by 5,900 rcyBP, and the late Holocene records in Eaglenest Lake and Mariana Lake lack detailed resolution. Sharkbite Lake's record of the late Holocene palaeoenvironment illuminates a dynamic landscape and becomes highly applicable to Late Prehistoric archaeological work in the area.

The questions I explore are: how did the landscape and the area's ecology influence and affect Late Prehistoric hunter-gatherer populations, if at all; and was there anything of note occurring archaeologically at the time? To address these questions, this chapter presents the palaeoenvironmental record from Sharkbite Lake in conjunction with dated Late Prehistoric archaeological sites. Sharkbite Lake lies within an area containing numerous archaeological sites, waterways, raw material sources, and habitation zones for game animals. This lake occurs within an important locality in the region that would have been travelled by First Nations ancestors. To discuss the vegetation and dated archaeological sites in the MOSR, I undertook a thorough review of all related late Holocene radiocarbon dates. This assessment aimed to rank the reliability of the dates and to assess the impacts of the depositional environments at each site on its associated date or dates.

Archaeological records can either be fine- or coarse-grained. Binford (1980:17) defines fine-grained records as those with sites where "an assemblage accumulated over a short period of time," such as a single lithic re-sharpening episode. Coarse-grained records are "the accumulated product of events spanning [an extended period of time such as] an entire year," such as a campsite (Binford 1980:17). In the lower Athabasca River Valley, much of the archaeological record has only a handful of sites with stratigraphic and chronologic controls, due to poor soil conditions. Thousands of years of occupation may be compressed into only a few centimetres of sediment, resulting in a coarse-grained record. Places like the Quarry of the Ancestors have better defined stratigraphic profiles, but even here the majority of the exposed stratigraphy is comprised of flood deposits from the late Pleistocene / early Holocene deanting episode. However, the regional record also contains many small sites, strengthening the fine-grained record. Through time, as more radiometric dates are associated with these fine and coarse-grained records, the regions's history may be refined. Palaeoenvironmental records from localities like Sharkbite Lake can supplement the information from lithic assemblages, allowing for more holistic interpretations of human occupation.

5.1 Applications of Palaeoenvironmental Records and the Synthesis of Prehistoric Data in the Boreal Forest

Perhaps most relevant to this analysis is the mosaic nature of the Boreal Forest and the effect local vegetation would have had on food resources, specifically animals, in the region. By looking at the palaeoenvironmental record, we can start to piece together in greater detail the characteristics of the Boreal Forest. Specifically, we can see how the patterning of vegetation change could attract plant and animal species into or out of an area. The more recent relationships between First Nations ancestors, the landscape, and animals are recorded in ethnographic literature and demonstrate their importance to the success of hunter-gatherer groups in the Boreal Forest (e.g., Lewis 1977, 1982; Lewis and Ferguson 1988; McCormack 2017; Smith 1976; Winterhalder 1983). It is also probable that hunter-gatherers' knowledge of pioneering plant species post-fire, and the impacts this event would have had on food resources (both faunal and floral), were a part of the toolkit they used to forage efficiently and to move throughout the region.

For this discussion, I used modern and ethnographic accounts to understand the human-landscape dynamic through a research method called "ethnographic analogy" (White 1976). Ethnographic analogy is divided into two main approaches: the "direct historical approach" and the "general comparative analogy" (Peterson 1971:240). The direct historical approach in ethnographic analogy assumes that there is cultural and temporal continuity between modern and past groups; however, it does not account for temporal or spatial change or cultural differences

(Gould 1977; Peterson 1971). The general comparative analogy is used when there is no cultural continuity and the intended research studies broad models of behaviour from similar areas that may be distant from the current research region (Gould 1977). Both strategies are applied in this study. Ethnographic analogy needs to be used with caution. For instance, this method uses more recent cultural studies to interpret prehistoric human behaviour which may differ from modern behaviours (e.g., Peregrine 1996; Wobst 1978). Although ethnographic analogy has its weaknesses, it is informative, much like oral traditions, which can demonstrate elaborate movements and relationships between groups and the landscape. It provides richly-detailed information on some human behavioural traits and subsistence patterns that can be applied to the Boreal Forest's limited archaeological record. I argue that the inclusion of ethnographic analogy and ethnographic data is important, given the distribution of thinly-stratified sites in the region. This approach is especially valid when considering that temporary camps established during travel may have left no trace in the archaeological record, as discussed in the next section.

5.1.1 Human mobility and successful foraging strategies in Boreal Forest environments

Sharkbite Lake lies near the centre of human movement in the MOSR. The nearby lithic resources, waterways for boat travel, and raised terrain features with a mosaic of vegetation would have attracted First Nations ancestors to this area. Fire arguably plays the largest role in shaping the Boreal Forest. In combination with edaphic conditions and varying terrain features, the successive communities that follow a fire create a mosaic landscape critical to the adaptations of plants, animals, and humans in the Boreal Forest. Once these patches, or 'islands' of vegetation diversity are established, they are used by humans moving through the landscape.

The relationship between vegetation and First Nations groups on the landscape is important for understanding human occupation in the region. Numerous adaptations and economic strategies ensured the success of these groups in a region typified by widely dispersed and fluctuating food sources, as evidenced by the long occupation in the region (see Chapter 4.2). These resource dynamics are part of the social and economic sphere for hunter-gatherers in the Boreal Forest.

Ethnographic evidence indicates that fire was used to create and maintain elements like trails to aid in hunting and movement in the region (Lewis and Ferguson 1988; McCormack 2017). The creation of meadows and trail systems using fire allowed for relatively easy travel and enabled specific plant communities to grow in an area. Although we cannot see archaeological evidence of this practice, it is likely that anthropogenic landscape modification played a large role in shaping the region. This modificationhas been identified in other parts of North America. In the Yukon, for example, Schweger et al. (2011) believed that the presence of humans was a major trigger for increased fire activity and for the consequent abundance of pine in northern Canada in the late Pleistocene/early Holocene. It is possible that anthropogenic landscape management practices were employed in the past and were critical to human success in the region.

Sharkbite Lake's record yields information about the fire history and ecological conditions experienced by prehistoric First Nations ancestors during the late Holocene. Although anthropogenic fires cannot be distinguished in Sharkbite Lake's record, the charcoal record indicates that on average, every 155 years there was a major fire episode close to Sharkbite Lake. More recent fire studies in the region indicate that some areas are prone to burn every 10 years (Figure 5.1; Canadian Forest Services 2019). This fire activity can be considered a conservative estimate of recent fire frequency, given the modern fire prevention campaigns and anthropogenic fires that are not noted on the map. Many areas of the landscape would have been more accessible following a burn, and the new vegetation growth would have been beneficial in some specific ways to the First Nations inhabitants of the Boreal Forest. Using eight decades of data, Figure 5.1 illustrates how fires would affect the region on a decadal scale, promoting new vegetation growth and causing shifts in the faunal communities in the region. It is important to note that fire records, such as these map data, were initially recorded in the early 1900s, coinciding with the start of total fire suppression policies in Canada (Murphy 1985). These regulations had a great impact on traditional lifeways (see Ferguson 1979:85-86). With the fire suppression policies leading to the build-up of deadfall, fires from the last century may have been more intense and burned greater areas than would have been the case in prehistory. Nonetheless, the ethnographic evidence would suggest that Boreal Forest fires would have impacted movement through the region and decision making around seasonal movements. Following fires, moose and hare would have been attracted to the area, and as the forest re-established itself, animals like lynx would have arrived to hunt the hare (see Chapter 2.3).

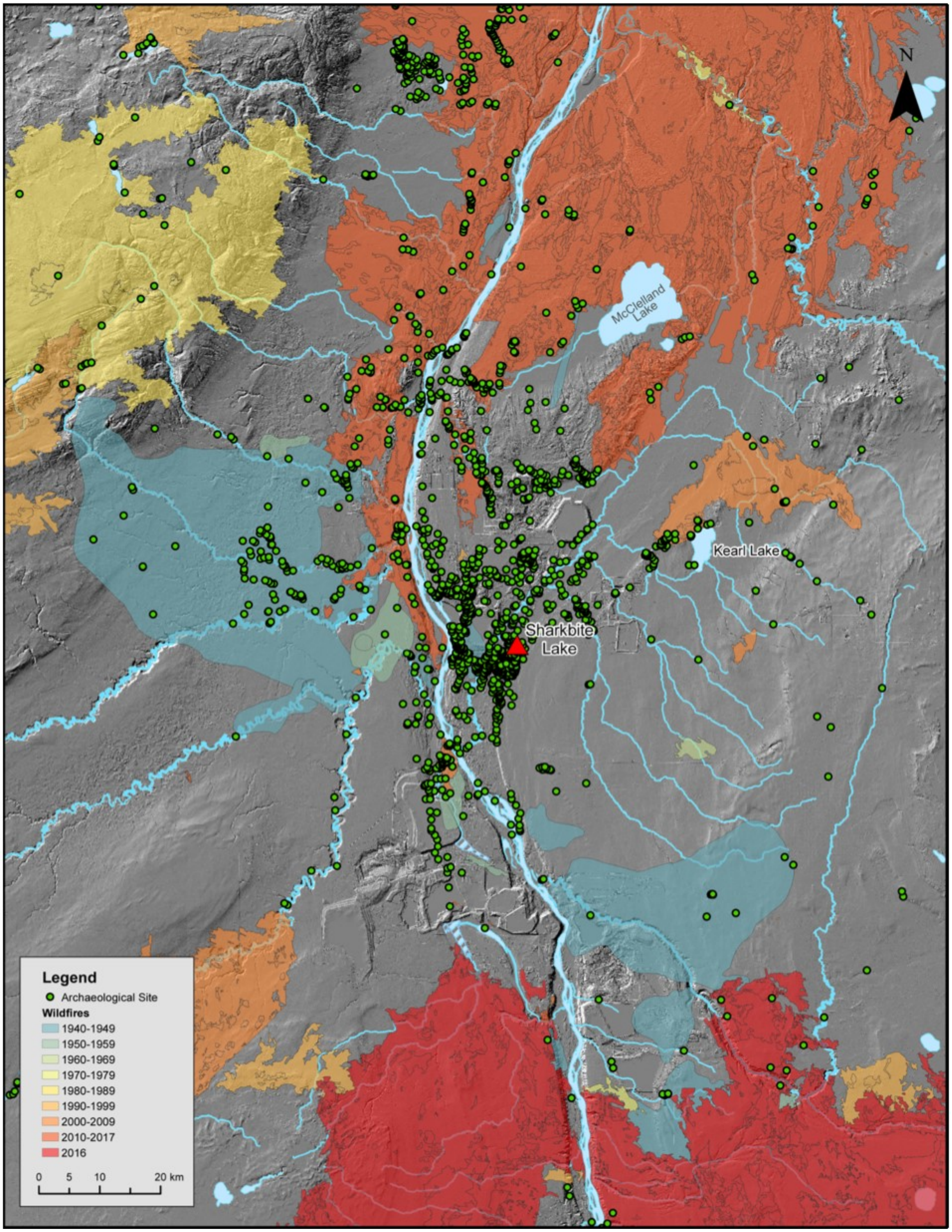

Figure 5.1 Wildfire extents by decades. Note the 2016 Fort McMurray fire is identified as its own feature due to its size and impact on developed areas. Fire data from Canadian Forest Services 2019.

The resulting patchy network of vegetational variation arising from anthropogenic and natural fires would have aided in buffering food resource stress and fluctuations for human groups moving throughout the landscape. This movement was an important part of an interstitial foraging pattern, and small hunting parties would travel through intervening muskeg to these 'islands' of ecological diversity (Binford 1980; Winterhalder 1983). The record from Sharkbite Lake reinforces that micro-variations are a defining feature of the Boreal Forest. For example, the Sharkbite Lake pollen record at 2020 rcyBP (see Section 5.3.3) indicates that the local vegetation did not match regional reconstructions. The current status of local settings would be the driving force behind mobility strategies.

Moose distribution records from 2018 show how dispersed moose are across the landscape (Government of Alberta 2018). Aerial surveys along the eastern edge of the Athabasca River—which extended to the Saskatchewan border, the Clearwater River, and to the shoreline of Lake Athabasca—calculated an estimated 2,307 moose across a survey area of 4,532 km. This survey results in a density of 0.12 moose/km^2 across the entire area. Looking at the southern section of the study area, south of 57˚50” 0’, where the natural subregion changes from boreal Athabasca plains to boreal central mixed-wood, the estimated population density is 0.15 moose/km^2. Although it is probable that recent industrial activity has forced some moose populations out of their historic habitats, a study from 1978 revealed similar trends prior to much of the intensive Oil Sands development (Hauge and Keith 1980). With an average encounter rate of 0.07 moose/km^2 in the southern section in 2018 (Government of Alberta 2018), humans clearly require a high degree of mobility to successfully access this dispersed food resource. Although this is just a single example of the limited density of faunal resources in the region, it emphasizes the necessity of movement in the area.

Following a successful hunt, small local groups or bands would have had to decide whether it was more practical to move the kill to a campsite or to move the group to the kill location and establish a new campsite. This lifestyle required movement across the landscape, and is represented by the small sites and scatters noted across the region. Although large, organized campsites with defined production zones are more telling of a range of behaviours and social patterns, it is the small sites, scatters, and isolated finds that demonstrate this extensive mobility network.

Temporary campsites produced few artifacts, and single-use hearths may not have stained soils or left an impression. These small sites comprised of lithic scatters are important markers of this extensive movement in the region (e.g., Ives 1982:35-36, 1993:8; Smith 1981:276). Many of the smaller sites in the region yield less information for archaeological research about lithic production through prehistory. This situation means these small, temporary occupations are sometimes disregarded because they do not yield detailed information for understanding prehistoric cultural complexes; yet they are important because of how they demonstrate a high degree of mobility.

Mapping archaeological sites based on artifact sample size allows for a visualization of mobility in the region. In Figure 5.2, I used the site types outlined on the CRM site forms to divide artifact scatters greater than 10 and less than 10. However, the distinction of less than or greater than ten artifacts has some interpretive limitations because sites with different functions may be grouped. For example, a site with 60 artifacts may represent a temporary workshop, or a campsite, or perhaps a full occupational surface. Also, the numbers of artifacts recovered are directly influenced by the testing intensity employed during site discovery. However, interpreted with caution, this data set is a useful tool in evaluating the degree of Precontact human mobility throughout the region.

From this map, the combination of the fine and coarse-grained record described by Binford (1980:17-18) is evident in the MOSR. The map shows no clear patterning in the distribution of coarse- and fine-grained sites. There are areas that represent an aggregation of both types (such as near the centre of the mat by Sharkbite Lake and Quarry of the Ancestors). There does appear to be a few more fine-grained sites to the north and northwest of the map if we look at the area identified as the West cluster in Chapter 4.3. Into the Birch Mountains, along the boundaries visible in the map extent there are also exclusively fine-grained (or sites with less than 10 artifacts) plotted. There are a few coarse-grained sites in the vicinity, but the fine-grained sites tend to be more frequent in this area. This concentration could be due to movements in and out of the Birch Mountains. Overall, the raw count demonstrates that there are marginally more coarse-grained sites than fine-grained sites, indicating that the entire area was well used. It is likely that there are more fine-grained records that have yet to be discovered because they lie in areas not often surveyed (see Chapter 4.3.1), and new analysis in the future will reveal more telling patterns of mobility and land use.

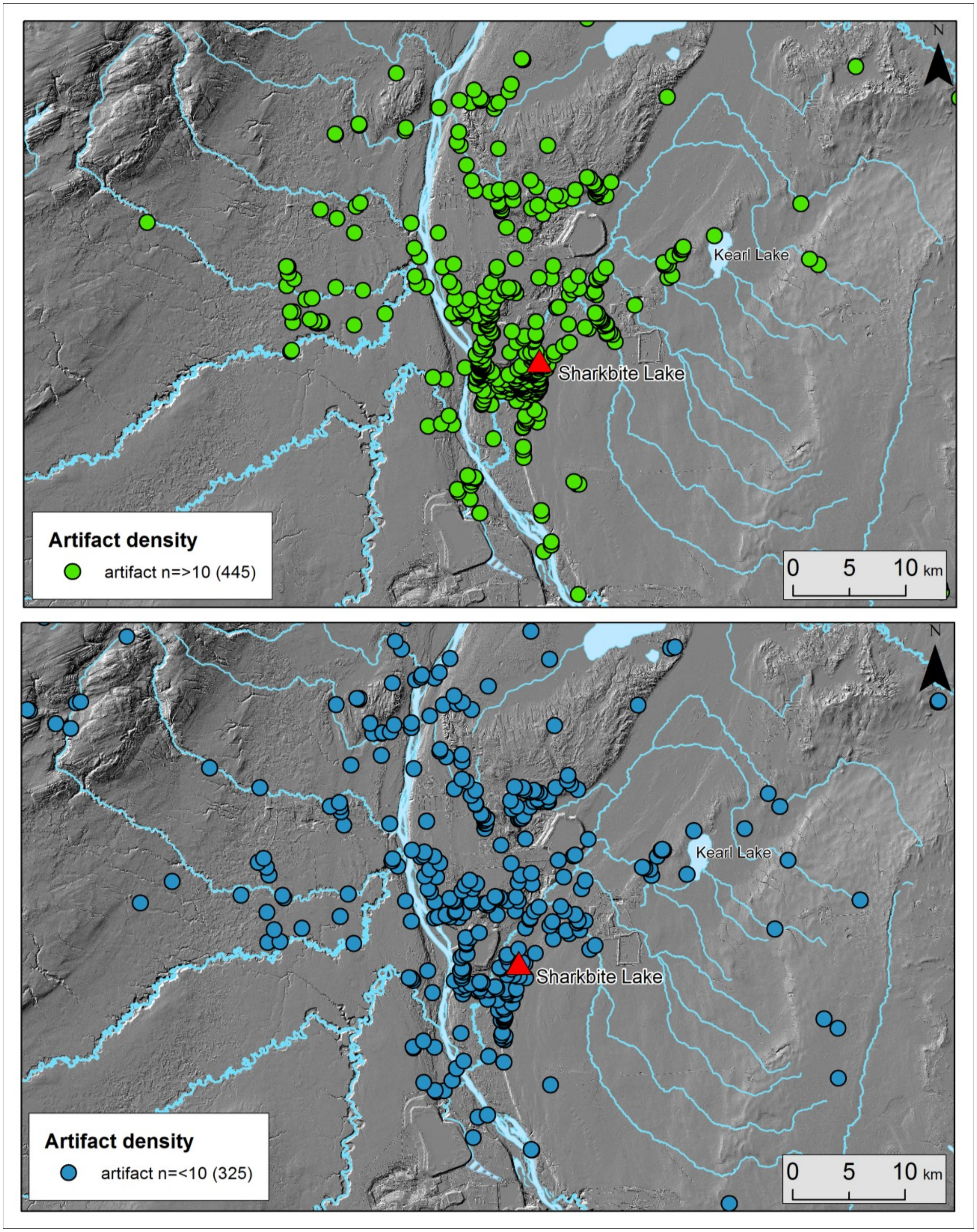

Figure 5.2 Site distribution based on artifact density. Top map represents sites with greater than 10 artifacts recovered, lower map is sites with less than 10 artifacts. Number in parentheses represents the number of sites with this distinction in the map extent.

5.2 Radiocarbon Dates

Our understanding of the Boreal Forest's prehistory and how First Nations would have utilized the landscape is constrained by the artifacts found at archaeological sites. Reconstructions of human behaviour are limited to ethnographic accounts, and cultural chronologies are presently based solely on lithic artifacts. However, some organic materials have survived and have been radiocarbon dated. Much of the material recovered for radiocarbon dating has consisted of faunal elements such as calcined bone, although some dates have come from unmodified bone. Some dates are based on charcoal, and a few dates are from soil organics. Pollock (1978b) obtained the first dates from northeastern Alberta in 1976 during his work in the Clearwater River area.

Beaudoin (1987a) recommended standards for collecting and submitting samples for radiocarbon dating. Beaudoin (1987a:188-190) outlines in detail many points that are still relevant today, including the stratigraphic context of samples and contamination issues. Conventional radiocarbon dating at that time required a large amount of material, approximately 200 g for bone in most labs (Beaudoin 1987a:194). In contrast, AMS dating requires much smaller samples to yield a date. For example, the A. E Lalonde AMS Laboratory in Ottawa can accept bone samples as small as 300 mg (preferred minimum two grams) for radiocarbon dating (St-Jean and Crann 2014). This development is important because samples from earlier excavations that were too small to date then with conventional radiocarbon dating can now be dated with AMS.

For this section I reviewed 47 radiocarbon dates (Figure 5.3), and assessed their context and reliability. Although I acknowledge the challenges that archaeologists face, such as lack of available dating material and client deadlines, new and improved dating methods can be applied.

These result in better-constrained dates and should be the required standard in the region. By mitigating the number of errors that could be encountered early in the dating process, each radiocarbon date becomes more reliable for its use in the Boreal Forest record.

5.2.1 Methods

Woywitka (2016) reviewed the calcined bone radiocarbon dates from the Boreal Forest, and this analysis expands on his study. Although Woywitka (2016) addressed only calcined bone dates, I reviewed all materials dated in the study area (Table 5.2). As part of the review, I documented all information available in field reports for sample collection and stratigraphic context and used much of these data to evaluate the date. I evaluated the radiocarbon dates according to the following criteria: (a) the stratigraphic context; (b) the distribution of the material collected (i.e., confined to one unit, across multiple units, in discrete areas, or in bulk assemblage), (c) how much material was submitted, and (d) radiocarbon date standard deviations (Table 5.1). These criteria were chosen for their relevance to radiocarbon dating procedure (primarily criteria (c) and (d) above), the date's ability to provide context for a site (criteria (a), (b), and to some degree (d)), as well as the confidence in the date (all criteria). Once the criteria were established, each date was assigned a reliability score (for a breakdown of values see Appendix D). For samples that lacked data, such as the weight or amount of material submitted or stratigraphic contexts, I assigned standard and modified scores. Modified scores were calculated as the percentage of available points. For example, if only three categories were met, the score was calculated as a score out of 15. The year that the radiocarbon date was submitted/obtained was taken into consideration, and ad hoc adjustments were made accordingly (noted with two asterisks (**) on the score and criteria). All sample association information was derived from the final reports submitted to the Archaeological Survey of Alberta. Any radiocarbon dates that have information related to each assessment category but were not discussed in the final permit report are not reflected in the review of the dates. I did not review any catalogue sheets (unless included in the submitted report) because the time required for that activity was beyond the scope of this research. All dates were calibrated using OxCal v4.3 software (Bronk Ramsey 2009, 2019) and the IntCal13 radiocarbon age calibration curve (Reimer et al. 2013).

	VALUE				
Assessment Category	1	2	3	4	5
A) What was the stratigraphic context?	Not reported.	Out of context/mixed.	Approximate depths (i.e., shovel test).	Screened material (i.e., specific quadrant).	Three-point provenience or equivalent (i.e., GPS point).
B) What was the distribution of the material collected?	Not reported.	From across multiple blocks/levels.	From one block / level.	From a single unit / level.	Discrete location, no disturbance, known association.
C) How much material was submitted?	> 100g or not reported.	<100g, >50g.	<50g, >25g.	<25g, >10g.	<10g, >0g or single element.
D) Radiocarbon date ranges.	High range (>120).	Moderate range (>100, <120).	Low range (>50, <100).	Adequate range (>20, <50).	Well constrained range (>0, <20).

Table 5.1 Radiocarbon Date Assessment Categories

Site Info		Date Info					Assessment Category				Score	
Borden No.	**Permit No.**	**One Sigma Calibrated Age Range (cal yr BP)**	**Conventional Radiocarbon Age (rcyrBP)**	**$^{13}C/^{12}C$ (o/oo)**	**Lab Number**	**Material**	**A**	**B**	**C**	**D**	**Score**	**%**
HhOu-113	12-234	8160 to 7962	7220±40	-23.1	Beta-333309	Calcined bone	4	4	1	4	13	65
HhOv-528	12-085	7156 to 6803	6090±40	-23.1	Beta - 340828	Calcined bone	5	5	5	4	19	95
HhOv-508	11-070	6541 to 6319	5660±40	-24.8	Beta-298152	Calcined bone	3	1*	5	4	13	65
HhOv-520	11-167	6180 to 5928	5260±40	-24.4	Beta - 312098	Calcined bone	1*	1*	1*	4	7	35
HhOv-256	06-376	5589 to 5327	4750±40	-25.5	Beta - 239181	Charcoal	4	4	1*	4	13	65
HhOv-156	11-167	4524 to 4415	3990±30	-23.7	Beta - 312092	Calcined bone	4	4	1*	4	13	65
HhOv-73	83-053	4870 to 3973	3990±170	Not reported	Beta - 7839	Charcoal	2	2	1*	3**	8	40
HhOv-384	07-280	3207 to 2960	2930±40	-21.7	Beta-248249	Calcined Bone	3	3	4	4	14	70
HhOv-506	11-070	3076 to 2880	2870±30	-24.4	Beta - 298151	Calcined Bone	4	5	5	4	18	90
HhOv-384	10-093	2945 to 2765	2750±40	-24.2	Beta-248280	Calcined Bone	4	4	5	4	17	85
HhOv-350	10-093	2738 to 2380	2490±40	-24.4	Not Reported	Calcined Bone	4	3	2	4	13	65
HhOv-350	10-093	2702 to 2353	2430±40	-24.1	Not Reported	Calcined Bone	4	3	1*	4	12	60
HhOw-45	08-208	2460 to 2163	2320±40	-23.3	Beta-255737	Calcined Bone	4	4	4	4	16	80

Site Info		Date Info					Assessment Category				Score	
Borden No.	Permit No.	One Sigma Calibrated Age Range (cal yr BP)	Conventional Radiocarbon Age (rcyrBP)	$^{13}C/^{12}C$ (o/oo)	Lab Number	Material	A	B	C	D	Score	%
HiOv-46	08-163	2352 to 2155	2270±40	-23.1	Beta-258073	Calcined Bone	2	2	2	4	10	50
HhOx-18	08-166	2150 to 1946	2080±40	-22.4	Beta - 255742	Calcined Bone	2	2	2	4	10	50
HhOv-87	09-168	2109 to 1883	2020±40	-25.8	Beta - 277702	Calcined Bone	4	5	5	4	18	90
HkOv-100	12-157	2034 to 1880	2000±30	-25.6	Beta-337912	Calcined Bone	3	3	5	4	15	75
HhOw-46	08-208	2037 to 1826	1980±40	-25	Beta-255739	Calcined Bone	3	4	3	4	14	70
HhOv-387	07-280	1944 to 1734	1910±40	-22.2	Beta-248281	Calcined Bone	4	4	4	4	16	80
HhOv-351	10-148	1929 to 1741	1910±30	-25.5	Beta-295837	Calcined Bone	4	3	5	4	16	80
HhOv-387	10-093	1876 to 1634	1840±40	-26.1	Beta-248281	Calcined Bone	4	4	2	4	14	70
HeOn-1	76-040	1881 to 1410	1735±105	Not reported	S-1275	Unknown	4	4	1*	3**	12	60
HiOv-70	08-163	1710 to 1540	1710±40	-23	Beta-258075	Calcined Bone	4	4	4	4	16	80
HhOw-20	07-393	1698 to 1420	1670±40	-23	Beta-244942	Calcined Bone	2	1	4	4	11	55
HhOu-70	07-219	1690 to 1415	1650±40	-15.6	Beta-248279	Calcined Bone	4	4	3	4	15	75
HhOv-184	99-073	1718 to 1354	1640±80	Not reported	Beta-141288	Charcoal	4	4	1*	3	12	60

Site Info		Date Info					Assessment Category				Score	
Borden No.	**Permit No.**	**One Sigma Calibrated Age Range (cal yr BP)**	**Conventional Radiocarbon Age (rcyrBP)**	**$^{13}C/^{12}C$ (o/oo)**	**Lab Number**	**Material**	**A**	**B**	**C**	**D**	**Score**	**%**
HjOv-63	15-087	1295 to 1181	1310±30	-23.5	Beta - 424812	Burned bone carbonate	3	4	5	4	16	80
HiOw-37	03-269	1303 to 1150	1300±40	-27.5	Beta-188773	Charcoal	5	5	1*	4	15	75
HhOv-524	12-085	1282 to 1086	1260±30	-22.1	Beta-340829	Bone collagen	4	4	2	4	14	70
HhOv-16	88-032	1290 to 1007	1240±60	Not reported	TO-1439	Soil organics	3	2	5	4**	13	65
HkOv-92	12-157	1064 to 937	1100±30	-20.9	Beta-337911	Calcined Bone	3	2	5	4	14	70
HhOv-528	12-085	1056 to 932	1080±30	-26.2	Beta - 340826	Calcined Bone	4	4	3	4	15	75
HhOv-528	12-085	1056 to 932	1080±30	-26.2	Beta - 340827	Calcined Bone	4	4	5	4	17	85
HhOv-528	12-085	1055 to 929	1070±30	-25.9	Beta - 340825	Calcined Bone	4	4	3	4	15	75
HjOv-64	15-087	1049 to 834	1030±30	-23.9	Beta - 424815	Burned bone carbonate	3	4	5	4	16	80
HhOv-449	06-376	688 to 556	680±40	-26.7	Beta-229415	Charcoal	4	4	1*	4	13	65
HjOv-55	15-087	655 to 546	610±30	-26.9	Beta - 424807	Burned bone carbonate	3	4	5	4	16	80
HhOv-528	12-085	646 to 528	570±30	-24.6	Beta-340830	Charcoal / Soil sample	4	3	5	4	16	80
HcOn-3	76-040	731 to 319	570±115	Not reported	NMS-1274	Bone/Calcined	3	2	1*	3**	9	45

Site Info		Date Info					Assessment Category				Score	
Borden No.	**Permit No.**	**One Sigma Calibrated Age Range (cal yr BP)**	**Conventional Radiocarbon Age (rcyrBP)**	**$^{13}C/^{12}C$ (o/oo)**	**Lab Number**	**Material**	**A**	**B**	**C**	**D**	**Score**	**%**
HhOv-506	11-070	639 to 517	550±30	-20.4	Beta-312096	Bone collagen	3	3	5	5	16	80
HhOv-245	06-376	631 to 495	500±40	-24	Beta-229413	Calcined Bone	4	4	4	4	16	80
HiOu-8	08-163	281 to 6	130±40	-25.6	Beta-258074	Calcined Bone	1*	1*	4	4	10	50
HhOv-506	11-070	276 to 9	130±30	-24.2	Beta - 298151	Bone	3	3	5	4	15	75
HhOw-55	08-166	271 to 11	100±40	-21.9	Beta - 255740	Burned Bone Organics	2	2	1*	4	9	45
HhOv-506	11-070	266 to 22	90±30	-21.2	Beta-312093	Bone	3	3	4	5	15	75
HhOv-506	11-070	260 to 26	70±30	-20.9	Beta-312097	Bone	3	3	5	5	16	80
HkOv-101	13-157	260 to 26	70±30	-23.4	Beta-337913	Bone Carbonate	3	4	5	4	16	80

Table 5.2 Radiocarbon dates with assigned assessment scores, from oldest to youngest. Note the score percentage is the unmodified score. For modified scores, descriptions of the sample's context, and report citations, refer to Appendix E. Any assessment category

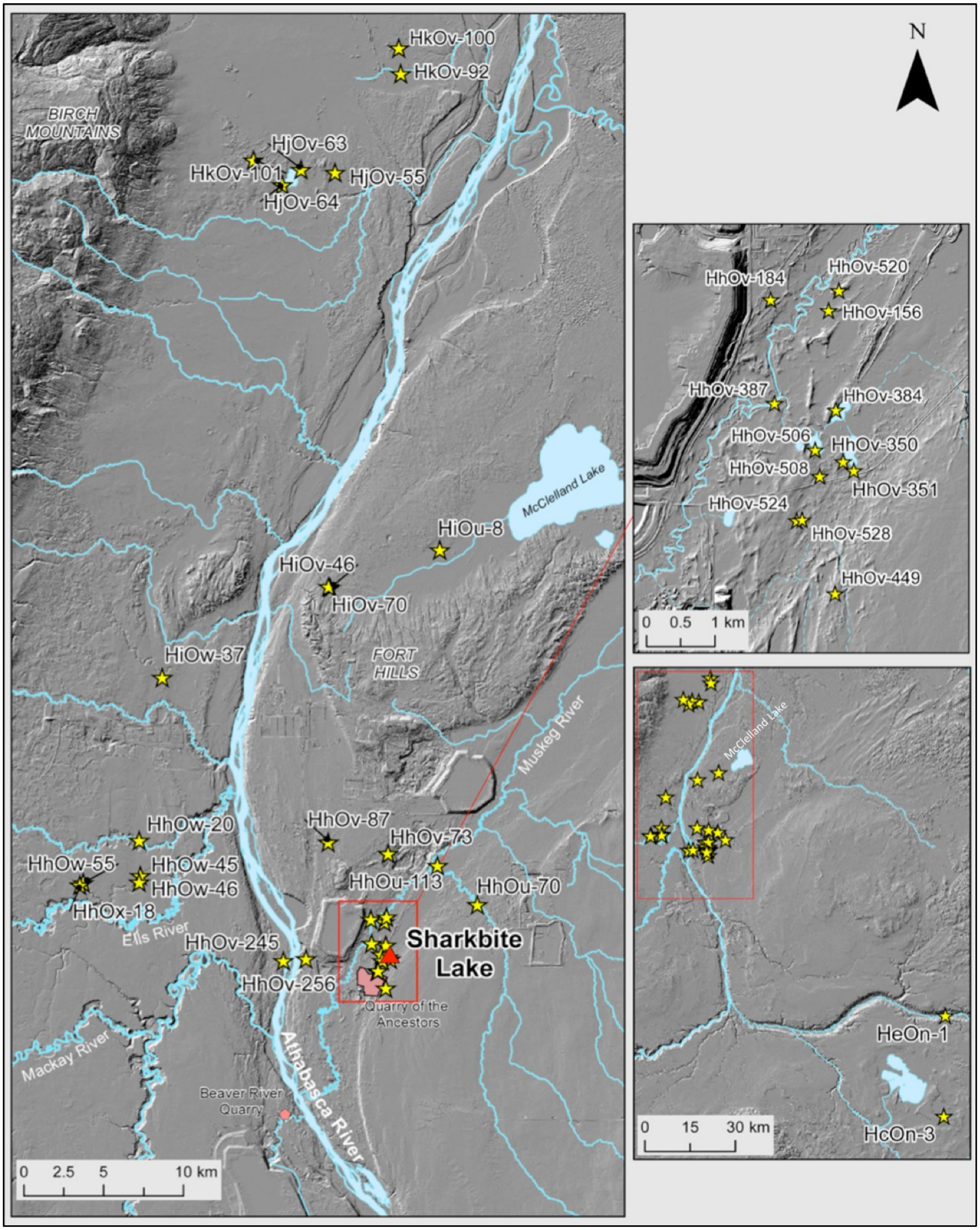

Figure 5.3 All radiocarbon dated sites in the lower Athabasca River Valley assessed in the radiocarbon evaluation.

5.2.2 Results of Existing Samples Radiocarbon-dating Analysis

The analysis of 47 radiocarbon-dated samples showed that less than half of the reports included detailed descriptions of the material collected. Some descriptions simply indicated that a ‘conglomerate (or composite) sample’ was submitted and radiocarbon tested. Composite samples, especially ones that are taken from across an excavation block, risk returning inaccurate dates because the materials could represent different occupation episodes. When materials of different ages are pretreated and processed together, there is a strong likelihood the radiocarbon date would be erroneous (Scott 2013). Because many of the radiocarbon dates from the region lack reliable associations and stratigraphic context, there is a great deal of uncertainty about what the radiocarbon date actually reflects. When mixed assemblages or bulk dates are submitted for radiocarbon dating, it is difficult to understand what material is being ‘dated’ and what the date represents (e.g., Beaudoin 1987a). For example, if materials came from an arbitrary level 2 (5-10 cmBS) across an excavation block of seven square metres, the mixed assemblage could represent multiple occupations because we know many sites have compressed stratigraphy. The radiocarbon date from this block would consequently misrepresent the true situation. To reiterate the recommendations of Beaudoin (1987a) and Woywitka (2016:6), “reports should include detailed descriptions and mapping of the horizontal and vertical distribution of the samples collected, and provide a clear representation of the depositional context through sediment description, photographs, and profile drawings.”

Potential Contamination

Potential sources of contamination must be considered in samples from the region. The most common sources of contamination include those which make dates appear younger, for instance, root and rootlets in the sample, and “young carbon” leaching into materials like shell and bone.

Sources of contamination which make dates appear older include detrital carbonate within a sample, “old carbon” derived from lake waters, and contaminants like bitumen (Beaudoin 1987a:189-190; Scott 2013; Jull 2013; see Section 3.2.7 for more on bitumen). Many of these contaminants can be mitigated with careful sample preparation and proper pretreatment, ensuring accurate dates are recorded (Brock et al. 2017). For charcoal dates, care must be taken to ensure the sample itself is truly charcoal, that it does not incorporate bituminous materials, and that it does not involve charcoal from natural fires unrelated to a cultural occupation.

Preservation and types of materials

The preservation of material is a perennial discussion in archaeological literature. Through continued excavations, patterns have emerged that could allow us to understand why organic material may not be preserved. Calcined bones dominate faunal assemblages because bio-apatite in faunal remains recrystallizes at temperatures above 600°C, allowing for better preservation (Lanting et al. 2011:250; Woywitka 2016:2). Although this feature helps preserve samples, this high temperature degrades the protein fraction needed for radiocarbon dating (Bowman 1990:29). The preserved fragments indicate that most of the dates are from the late Holocene, specifically the last 3,000 radiocarbon years. The most likely reason for this observation is that the fragments have been in acidic soils for less time and therefore are better preserved (Woywitka 2016:6). Given the amount of degradation that is noted on faunal materials dated pre-3,000 rcy BP, the soil composition greatly impacts organic elements and would strongly affect older materials (Woywitka 2016). The $\delta^{13}C$ values are within the ranges for terrestrial mammals except for a sample from HhOu-70 (Beta-248279 [Roskowski et al. 2008]). This sample’s $\delta^{13}C$ value of -15.6 could represent a bird. Because there are no known C4 plants in the boreal forest at this time, a higher $\delta^{13}C$ value could be due to marine sources like fish. However, because there are no nearby marine sources that would contribute to apex predators in the region, this sample could represent a migratory bird which had access to a wider dietary breadth (Boecklen et al. 2011; Post 2002).

Aside from calcined bones, charcoal and soil samples have been submitted for radiocarbon dating. These materials are less reliable than faunal elements in the archaeological record. Soil organic matter can easily be redistributed, and the large amount of material that was once required to obtain a date, prior to the availability of AMS dating, could yield erroneous dates representing thousands of years. Charcoal samples present a different challenge. Given that fires frequently burn across the Boreal Forest, we cannot be certain that a charcoal sample is necessarily associated with human occupation or from features such as hearths. Even where a hearth has been confidently identified, dates from it need to be evaluated carefully because they represent the age of the material that was burned, not the age of the hearth and burning episode itself (Beaudoin 1987a:189). Isolated charcoal samples should not be used if any alternative material is available because they could represent a naturally burned surface and not a period of human occupation. However, relative ages can be obtained when correlated to these fire episodes. Hearths are found in the study area. However, they sometimes lack the discernable features characteristic of hearths, such as soil staining and texture changes.

Date Reliability Results

Only five of the 47 dates scored 81 or higher, indicating that few reports included the required data for understanding the date's association with other artifacts recovered based on the assessment table (Table 5.1). The histogram showing radiocarbon date scores illustrates that many of the dates fall within a 74-87% range (Figure 5.4). Most reports had limited detail about what sample material was submitted, and how much was submitted, but the lack of detail on stratigraphy or location presents challenges for future researchers. In some cases, radiocarbon dates may suggest an age that varies from the cultural chronology presented by Reeves et al. (2017) (e.g., Turney 2014). This case merits additional investigation to see if the material dated was clearly associated with the specific lithics identified in the cultural chronology. The association of a date with other artifacts may not become clear until after excavation, when artifacts and their proveniences have been thoroughly analyzed. These problems highlight the importance of careful sample selection to ensure that a date's association cannot be questioned later. Some archaeologists still feel that projectile points are the best form of chronologic control, even when they acknowledge the challenges of using them as diagnostic temporal markers. However, local radiocarbon dates that have a secure connection to cultural components may be used to calibrate the chronology proposed by Reeves et al. (2017).

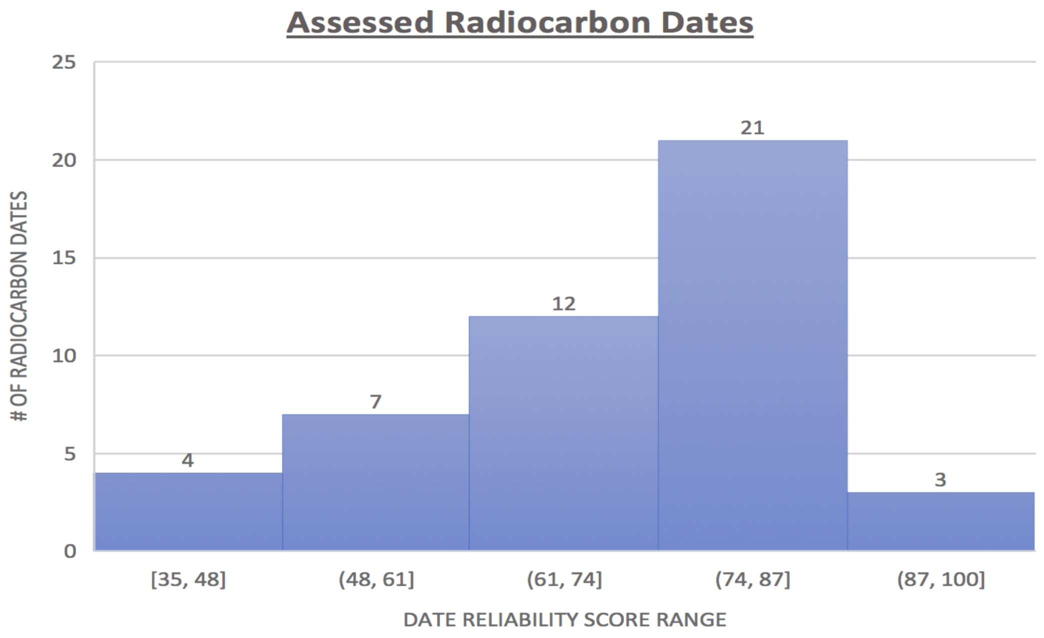

Figure 5.4 All radiocarbon dates from the area plotted as a histogram based on date reliability score.

Spatial Distribution of Samples

Of note is the distribution of radiocarbon-dated materials. Figure 5.5 shows the location of the dates in question and indicates that 16 come from the broad Quarry of the Ancestors area. In addition to this group, two clusters of dates are noted on the west side of the Athabasca River. Coincidentally, these clusters appear to match the clusters associated with BRS distribution and site density (see Chapter 4.3).

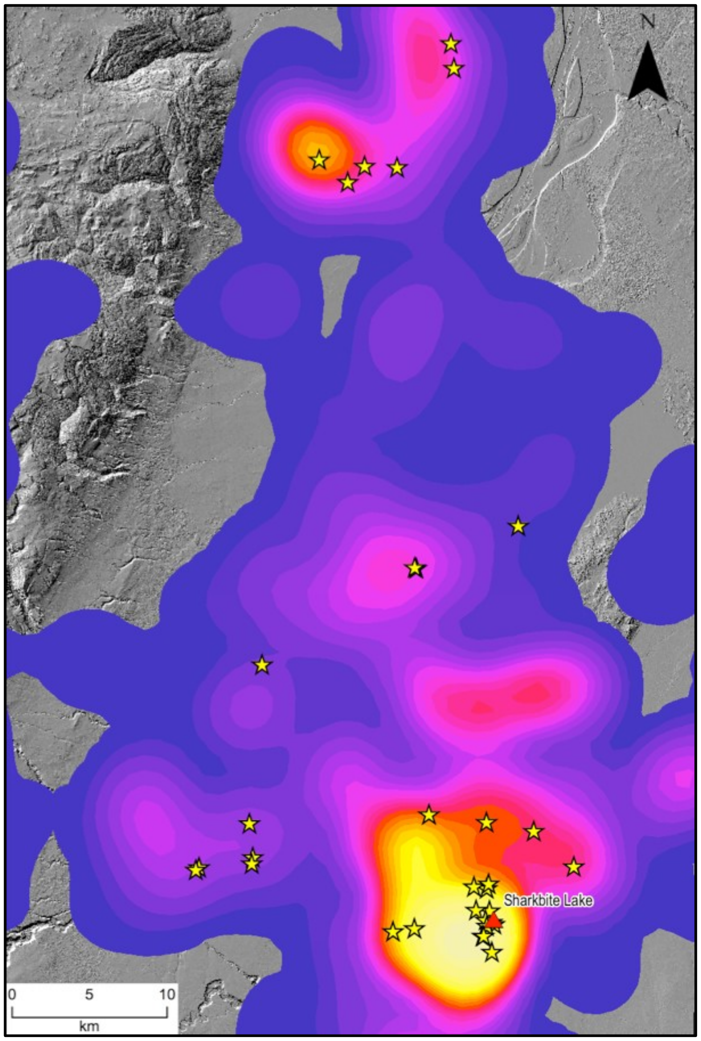

Figure 5.5 Radiocarbon dates (stars) superimposed on archaeological site density.

On the west side of the Athabasca River, in the lowlands adjacent to the Birch Mountains, it appears that some soils may be more conducive to preservation of organic material. At sites like HjOv-63, many of the faunal elements were only minimally heat-modified, some not at all, and both are well preserved (Foster 2016:133). Foster (2016:133-34) hypothesized that this could be due to local conditions, such as lower acidity or anaerobic environments in soils due to periodic flooding. Similar soil conditions could exist for the cluster north-west of Beaver River Quarry and Sharkbite Lake. Future research exploring the parent geologic materials and soil acidity levels in different parts of the region may help to explain differential preservation.

Summary

This review of radiocarbon dates is important not only for our understanding of the region, but for guiding future CRM work and reporting. Many reports did not outline the context or stratigraphic context of the materials used for radiocarbon dating. The addition of a paragraph outlining the date, location within the excavation, all stratigraphic context, and the amount of material submitted (weight and/or quantity) would be advisable.

Following the review of radiocarbon dates, five sites were chosen for analysis alongside Sharkbite Lake's record. These sites (in chronologic order) are: HhOv-506, HhOv-384, HhOv-87, HhOv-351, and HhOv-528. These sites lie close to Sharkbite Lake and would have experienced local vegetational changes at different times. It was preferred that target sites had a minimum unmodified radiocarbon score of 80; however, in some instances this ideal was not possible. Other sites that did not meet the minimum score (such as HhOv-384 or HhOv-87) were still included because of their relevance to the overall analysis, or their temporal association.

5.3 Reviewed Archaeological Sites

The synthesis of archaeological material with palaeoenvironmental records aims to show the value in using both lines of evidence when interpreting site function and human mobility in prehistory. This section presents summaries of five radiocarbon dated sites with late Holocene occupations, ranging from 2870 rcyBP to 1080 rcyBP. These are examples of the type of work that can be undertaken in future archaeological projects in the Boreal Forest. Each description is followed by an analysis of the palaeoenvironmental record at the time, and its implications for human activity. Each date reflects a single instance in time, whether or not the sample is natural or cultural in origin, and, in sites with coarse-grained records, we need to be aware that the actual time range of human occupation may be much greater than the single date reveals. The environmental reconstructions cannot be extended to explain all artifacts or patterns noted at a site.

Just as modern vegetation is used in site descriptions, palaeoenvironmental reconstructions are valuable in understanding the vegetation dynamics in the region. Using this analytical approach, I show how a high-resolution record like that from Sharkbite Lake can contribute to our understanding of the archaeological record. The local ecology around Sharkbite Lake would have affected access to the Quarry of the Ancestors and BRS, which would have influenced the seasonal rounds of communities. On a broader scale, the pollen signals could indicate a shifting climate, such as changes in moisture and precipitation, as this shift applies to the lower Athabasca River Valley. Some sites are farther from Sharkbite Lake than others. These distant sites can still be referred to Sharkbite Lake's record because they provide details of relative moisture levels, climate conditions, and regional vegetation. Regional climate trends discussed with the record from Sharkbite Lake come from the work done by Viau and Gajewski (2009a) and values are drawn from the tabulated data set (Viau and Gajewski 2009b).

The sites investigated represent the coarse-grained record of the Boreal Forest. Unfortunately, there are few fine-grained sites with radiometric dates to discuss in relation to the palaeoenvironmental record. Around Sharkbite Lake, both fine and coarse-grained records occur in high concentrations (Figure 5.2), implying that the area was significant in prehistory. The small sites indicate both logistical and small residential camp forms of mobility. Such sites may have been frequently used throughout the Holocene. While any form of temporal control is lacking, these sites display the larger network of mobility in the area. In the following section, I discuss the coarse-grained archaeological record. The radiocarbon dates discussed are associated with the palaeoenvironmental record, providing more information about these intervals in history. Although a coarse-grained record makes it more difficult to tease apart occupations, these dates provides a glimpse into palaeoenvironmental conditions that would have been critical to the mobility and economic success of First Nations ancestors in the region.

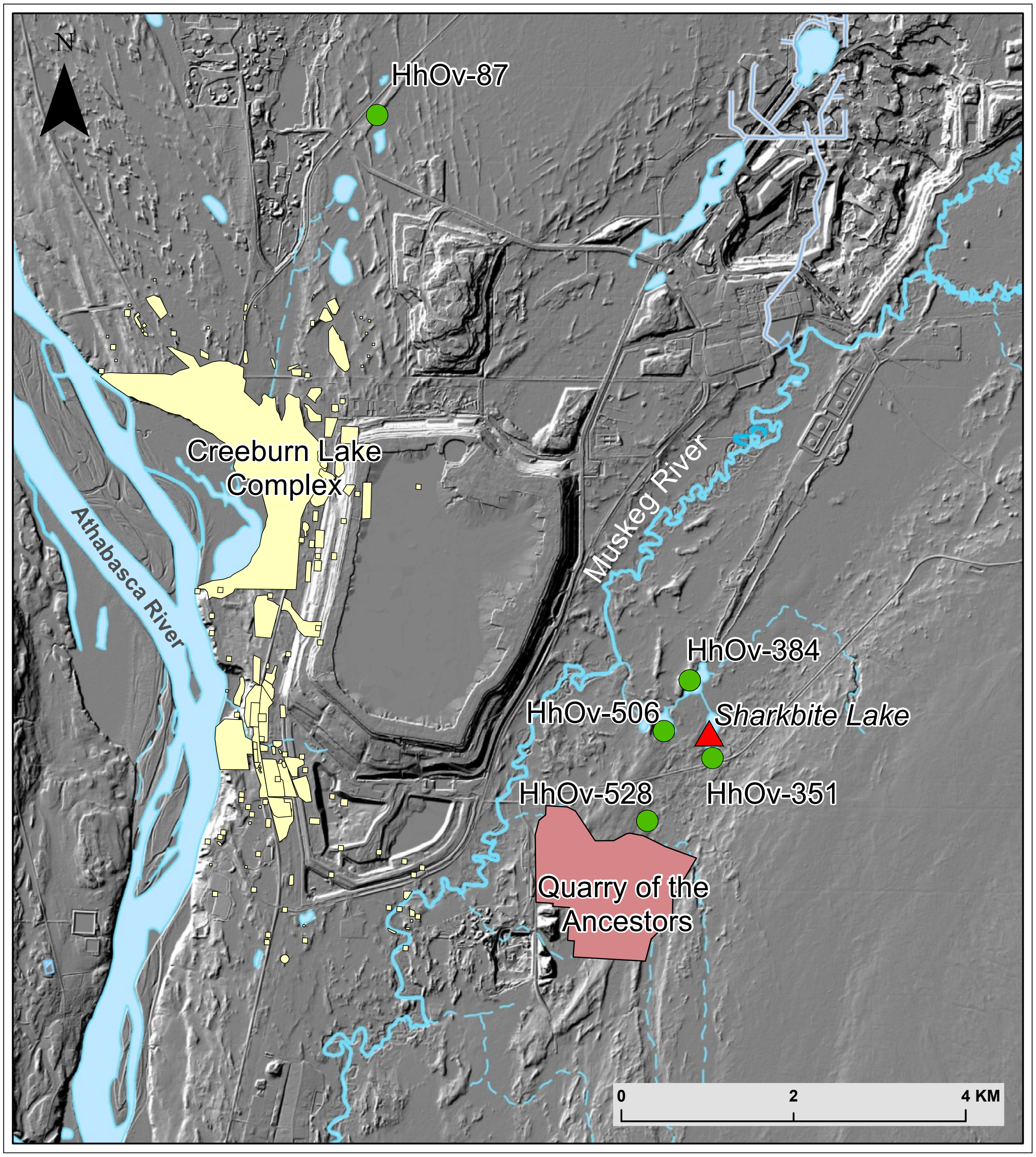

Figure 5.6 Map showing discussed archaeological sites. Note the areas associated with the Creeburn Lake complex, shown in yellow, are non-contiguous.

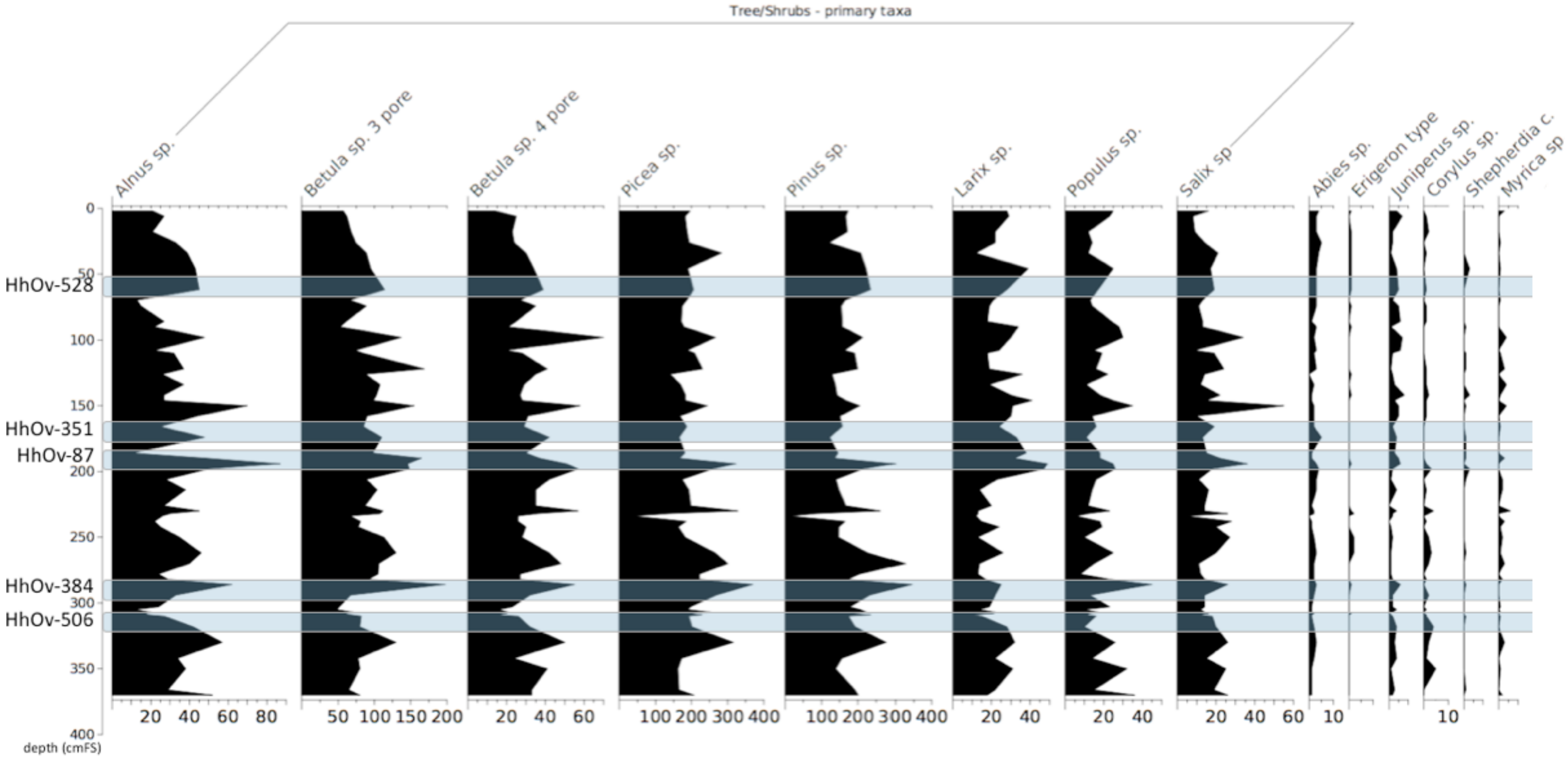

Figure 5.7 Sharkbite Lake pollen diagram with specific site intervals highlighted (Part A, continued on next page).

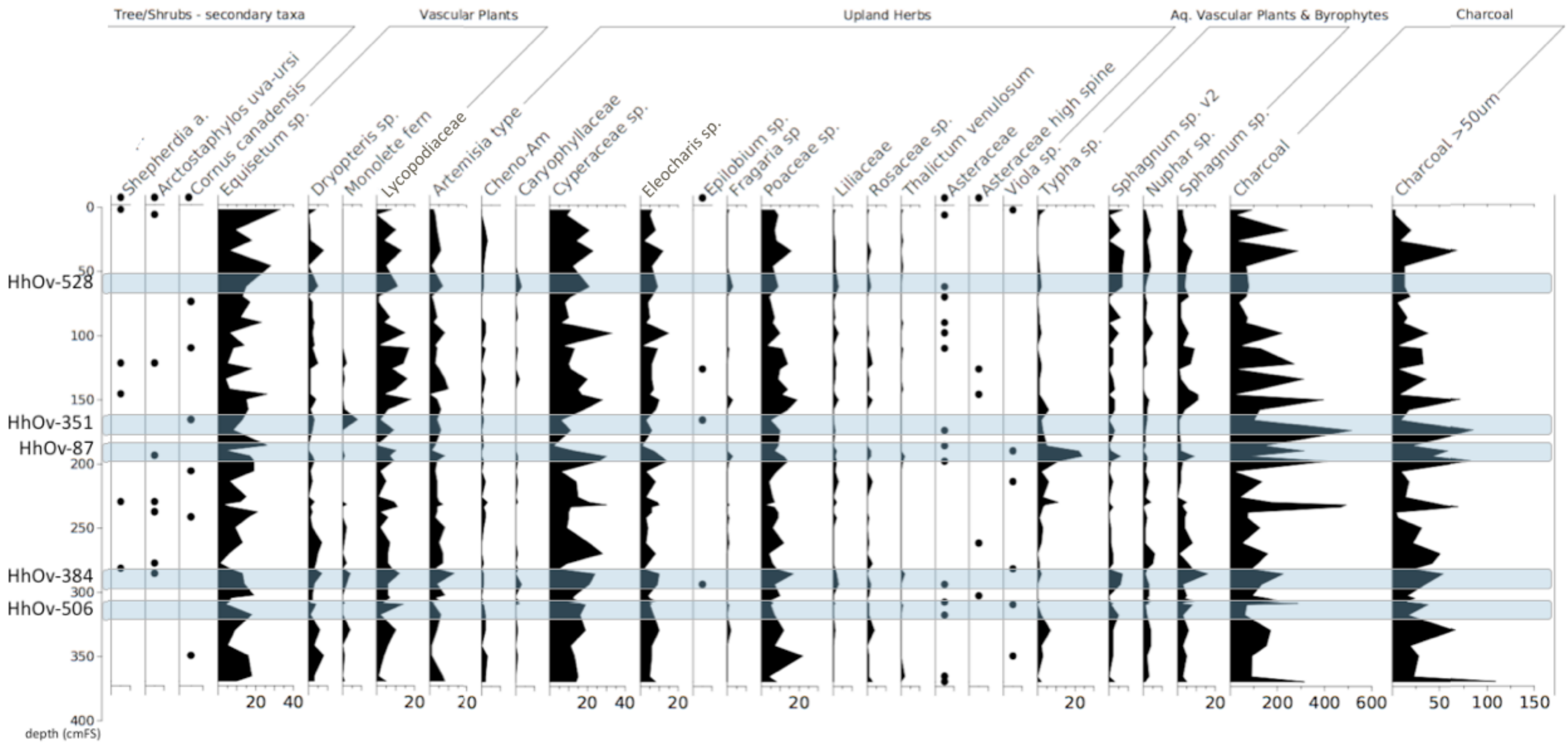

Figure 5.7 Sharkbite Lake pollen diagram with specific site intervals highlighted (Part B)

5.3.1 HhOv-506

Description:
HhOv-506 is a campsite and workshop located on glacial outwash deposits to the east of the Athabasca River. Contemporary vegetation on the landform includes an aspen forest with rose, alder, blueberry, cranberry, and *Sphagnum* moss understory. The site, first recorded under Permit 10-244, is near the Muskeg River and a pothole lake that is fed by an underground stream. A large shovel testing program resulted in 227 probes, of which 35 shovel tests were positive, and yielded 1,117 lithics and 251 faunal fragments (Roskowski-Nuttall and Netzel 2015:75). Given the high concentration of artifacts found during the shovel testing, Stage I and Stage II mitigation resulted in 231 m^2 of excavation. Between the 10-244 and 11-070 permits, 55,741 artifacts were recovered, including seven endscrapers, 86 biface and biface fragments, one uniface, 20 retouched and patterned retouch flakes, 461 core and core fragments, 48,671 pieces of debitage, 336 FBR pieces, five historic artifacts, and 6,086 faunal fragments. The lithic assemblage material types included BRS, northern quartzite, coarse-grained quartzite, chert and pebble chert, massive quartz, and salt-and-pepper quartzite (Roskowski-Nuttall and Netzel 2015:86). The number of artifacts present, and their diversity, indicate that this site was used as a campsite and manufacturing area. Of note are the five historic artifacts. These historic artifacts, including a harness snap hook and strap and a rifle casing, demonstrate that this site locationwas desirable and was used frequently from prehistoric to historic times.

Block E yielded a small number of lithic artifacts (n=69) relative to the faunal remains present there (n=429) (Roskowski-Nuttall and Netzel 2015:149). A bone feature in Block E was accompanied by a change in soil compactness around the feature. Of the 429 faunal remains found, most were identifiable only as medium or large mammals. However, there is evidence of at least one beaver in the assemblage. The bone concentration is seen in the SW quad of Unit 693N 796E, and into the SE quad of 693N 795E. A 4.3 g sample of medium/large bones from the bone feature in Block E was submitted and yielded an AMS radiocarbon date of 2,870 ± 30, or 3,076 to 2,880 cal yrBP (Beta-298151) (Roskowski-Nuttall and Netzel 2015:153).

The only formal tools found in Block E were two scrapers and a single core. Interestingly, the lithic materials from Block E were dominated by quartzites, with more than half the assemblage being salt-and-pepper quartzite, and only two pieces of BRS. Given the site's proximity to the Quarry of the Ancestors, the low BRS yield is surprising. Roskowski-Nuttall and Netzel (2015:154) suggest that "this assemblage may represent precontact inhabitants travelling through the area on their way to the [quarry]…or by people who were unaware of the source…located 1 km…south of the site".

Palaeoenvironmental Context:

Sharkbite Lake's pollen record around 3,000 cal yrBP indicates that a mixed-forest with the typical boreal understory would have been present, including *Pinus, Picea, Betula, Salix, Alnus,* and Rosaceae among several other taxa (Figure 5.7). The averages for the tree and shrub species all appear slightly below core average, a distribution which could represent less productive pollen intervals. *Typha*, *Equisetum* and Cyperaceae values, however, are above core average. The increased Cyperaceae and *Equisetum* counts could indicate that there were more moist conditions around the Sharkbite Lake area that would promote the growth of these sedges and horsetails. This is supported by a regional increased annual precipitation anomaly that began in 2,800 cal yrBP (up 36 mm from 1 mm in 2,900 cal yrBP)(Viau and Gajewski 2009b). This moister vegetation comes after a charcoal peak, which was probably a regional fire signature because fire-susceptible taxa in proximity to Sharkbite were not affected by the peak. The landscape would have supported several animal species including moose, bison, fur-bearing animals, birds, and fish.

Possible Implications for Human Occupation:
The moister conditions could indicate that wetlands may have expanded, an effect which would have made foot travel more challenging in the summers. Conversely, increased moisture could allow creeks and streams to be accessible for watercraft for longer intervals. Water travel would also be restricted to the timing of break-up and freeze-up of waterways, which is influenced by temperature and not wetland extents. Some forms of travel would have been challenging if wetland areas increased, but most of the lithic material assemblage at HhOv-506 indicated that local resources were used. Block E, however, had little BRS in its assemblage, which, as mentioned, led Roskowski-Nuttall and Netzel (2015:154) to believe the occupation could represent inhabitants travelling through the area heading to the quarry, or a group unaware of the nearby Quarry of the Ancestors. If this occupation does represent a group unfamiliar with the area and raw material sources, increased wetland coverage may have made navigating this area more challenging.

5.3.2 HhOv-384

Description:
HhOv-384 is a campsite and workshop located in the Sharkbite Lake area. It was first identified under Permit 04-249 as a lithic scatter. The site is located on a ridge that overlooks an unnamed lake to the east (Bryant et al. 2011). Soils are predominantly sandy, with both Ah and Ae horizons identified in the excavation block profiles. Under the 04-249 permit, a total of 47 shovel tests led to the recommendation of 40 m^2 for Stage 1 mitigation, which was conducted under Permit 07-280 (Woywitka and Younie 2008). The artifact yield following Stage 1 mitigation was

sufficient to lead to 116 m^2 of Stage 2 mitigation work. Stage 2 mitigation opened six excavation blocks and 27 shovel tests. One of the excavation blocks, Block A, yielded the second largest assemblage at the site. Block A contained evidence of core reduction, tool manufacture (including mid to late-stage biface production and blade/microblade production), and food and hide processing areas. In Block A, most of the assemblage (92%) was recovered in levels 2 and 3. Block A and nearby Block B were the most active areas in HhOv-384, representing places of tool production and food and hide processing. Other blocks, like Block C, produced blades and microblades and could represent food butchering rather than processing. The three projectile points found were identified as an Agate Basin, a Scottsbluff, and a Late Beaver River Complex (Bryant et al. 2011:304). Although the Agate Basin and Scottsbluff date to the Early Prehistoric period, the Late Beaver River Complex (as defined by Reeves et al. 2017) overlaps with the radiocarbon dates from the site.

Block A’s Unit 397N 695E yielded a faunal sample that was submitted for radiocarbon dating from Level 1, SE quad. A sample of 11 calcined fragments weighing 4.2 g was submitted and yielded a radiocarbon date of 2,750 ± 40 (Beta – 248280) (Bryant et al. 2011:287). This sample was recovered immediately west of the sample dated under the 07-280 permit, but is only slightly younger (2,930 ± 40 rcyBP [Beta – 248249]) (Bryant et al. 2011:287; Woywitka and Younie 2008:38-39). These calibrated dates are 2,875 to 2,785 cal yrBP and 3,156 to 3,005 cal yrBP respectively, and were modelled by Woywitka (2016:5, Figure 4). Because the plotted dates do not completely overlap, there is the possibility that each date represents a distinct occupation rather than a continuous occupation. As is evident from the lithic assemblage, HhOv-384 was probably revisited throughout the Precontact period, from as early as the Early Prehistoric period based on the Agate Basin point.

Palaeoenvironmental Context:
The pollen record from Sharkbite Lake around 2,700 cal yrBP indicates that the surrounding vegetation is representative of a modern Boreal Forest, with Cyperaceae and *Larix* peaks and a decrease in *Artemisia*-type pollen grains (Figure 5.7). The peaks during this time appear to be a response to seasonal variability, because other taxa and climate models do not provide an explanation for these peaks. An increased regional annual precipitation anomaly began in 2,800 cal yrBP and was sustained until 2,100 cal yrBP (Viau and Gajewski 2009b). Low charcoal levels could be correlated to the increased moisture levels, inhibiting fires. Increased precipitation levels may have led to the rising of water tables throughout the region and may have caused wetlands to expand. The precipitation anomaly comes after a period of low moisture, and this increase (from 1 mm to 36 mm [Viau and Gajewski 2009b]) would have impacted water networks (such as perennial streams). However, Sharkbite Lake's record shows no indication of higher water levels.

Possible Implications for Human Occupation:
Changes to water table levels and water networks may have presented a challenge during summer travel for hunter-gatherers in the region. In addition to this problem, a decrease in fire frequency could have led to greater areas of old growth forest and increased fuel build up. Lewis (1977:71, 1982:36) indicated that the over-abundance of deadfall and tight quarters of old growth might have been frequently managed by First Nation Ancestorss. During this time, controlled burns along banks to clear access to waterways, or the creation of meadows to promote new growth and new habitats would have assisted with food procurement. "By maintaining a mosaic pattern in the Boreal Forest, fires assist in the maintenance of diverse wildlife populations" (Rowe and Scotter 1973:458). The increased moisture in the area may also have benefitted different animal communities. The wetter conditions causing an increase in wetlands may have

attracted medium-sized mammals like beavers and muskrats into an area. Other animals such as caribou may have flourished: decreased fire activity would have favoured lichen communities in old growth forests.

Of note in the archaeological record between the dated occupations of HhOv-506 and HhOv-384 is the presence of ASTt or pre-Dorset technology in northeastern Alberta. MacKay and Andrews (2016) summarize the work of researchers like Gordon (1996) that suggests the period of warming associated with the Shield Archaic ended approximately 3,500 ya, and was followed by a cooler climate that triggered a southward shift in treelines (Moser and Macdonald 1990). As a result of the cooler climates and unpredictability in Arctic sea ice conditions, it is believed that Pre-Dorset populations entered the Barrengrounds and the interior to find more stable resources (MacKay and Andrews 2016; McGhee 1996). From approximately 3,500 to 2,700 ya, ASTt peoples could have engaged in Barrenground caribou “herd following”, making their way into the northern forests of Alberta and Saskatchewan on a seasonal basis (MacKay and Andrews 2016:571). These cooler and moister conditions, along with limited fire activity, would plausibly promote old growth forests, which are known to be attractive winter habitat for caribou. Palaeoenvironmental evidence from Sharkbite Lake at 3,000 cal yrBP and 2,700 cal yrBP (as described in 5.3.1 and 5.3.2) shows an increase in moisture as well, indicating that local conditions would support the over-wintering caribou. Archaeologically, the presence of a “distinctive banded cream-and-white chert [that is] described by Gordon (1996) as a diagnostic Pre-Dorset tool stone type” (Reeves et al. 2017:200), and tools like symmetrical and asymmetrical end blades along with lanceolate points seem to link the ASTt to northeastern Alberta (Ives 2017:300-301). With the treeline shifted farther south and the possibility that local conditions in the lower Athabasca River Valley were suitable for overwintering caribou, it is plausible to believe that changing climatic conditions were among the factors that led Pre-Dorset populations to arrive in northeastern Alberta (Ives 2017:301; Reeves et al. 2017:199).

5.3.3 HhOv-87

Description:
During the Alsands Project, HhOv -87, known as Ronaghan's Ridge, was originally recorded under his 80-091 permit as part of five lithic scatters. A site revisit in 1996 (Permit 98-036) of the scatters combined all five into the single site designation of HhOv-87. The site is located on a 1.2 km linear landform south of the Fort Hills that extends northeast/southwest. Vegetation on the ridge is dominated by open aspen woodland, with some white spruce and understories of *Sphagnum* mosses, blueberry, cranberry, and kinnikinnick (bearberry), while the surrounding area is muskeg (Roskowski and Netzel 2011a:33). Excavations in 2009 yielded a total of 98,432 artifacts, which included 91,171 lithic and 7,261 faunal remains. There were 415 tools recovered, but the lithic assemblage was predominantly debitage. Raw materials included BRS, quartzite, chert, siltstone, cryptocrystalline silicate, granite, and chalcedony (Roskowski and Netzel 2011a:43). Most of the artifacts (just under 50%) were found in Level 2 (Roskowski and Netzel 2011a:112). The site was an extensive campsite and lithic workshop and featured numerous activity areas. The nearby site HhOv-200 is considered a hide processing area. When analyzed together these two sites suggest the area was a campsite, even though it yields no evidence of a hearth as required by the Royal Alberta Museum site definitions (Roskowski and Netzel 2011a:167-68).

Locus 15, or Activity Area A of HhOv-87, is the southern activity area. Based on materials recovered, such as calcined bone and northern quartzite artifacts, this area possibly reflects food-processing activities. Tools included three biface fragments, a single retouched flake, and four utilized flakes (Roskowski and Netzel 2011a:120). All but 33 artifacts were uncovered between Levels 1 and 2, although more were found in Level 1. Calcined bone was recovered from an oval concentration that was surrounded by quartzite artifacts. There was evidence of a red-orange stain below the faunal remains, but no ash was associated with the soils. Charcoal was present, but because its abundance was similar to other units at the site, the authors attributed it to forest fires (Roskowski and Netzel 2011a:123). A bulk bone sample from Locus 15 from the oval concentration of calcined bones was submitted for AMS radiocarbon dating. The sample produced a date of 2,020 ± 40 radiocarbon years (Beta 277702), placing the occupation in the Late Prehistoric Period (Roskowski and Netzel 2011a:126). The date represents a calibrated age range of 2,041 to 1,927 cal yrBP.

Microdebitage recovered from Activity Area A indicated that tool maintenance occurred in the area alongside food processing. The presence of medium to large flake fragments could be indicative of early-stage tool reduction, but these were likely used as expedient tools (Roskowski and Netzel 2011a:127). BRS at the site was probably collected from a nearby source because artifacts exhibit water-worn nodules and cortex. This feature, in addition to the varying quality and presence of polychaete worm tube fossils, indicate the BRS was local and not from the Quarry of the Ancestors (Roskowski and Netzel 2011a:169).

Palaeoenvironmental Context:

The pollen record from Sharkbite Lake indicates that there was an increase of *Salix* recorded around 2,000 cal yrBP, an increase which is most likely attributed to seasonal variation (see Chapter 3.3.2) (Figure 5.7). Taxa like *Alnus* and *Larix* have slightly elevated levels and *Corylus* is present. *Larix* is a tolerant species, surviving in moist soils and as a pioneer species following a fire. Increased charcoal from fire occurrence in Sharkbite Lake's record around this time could be a reason for this increase in *Larix* pollen. In the pollen record, this occupation coincides with the end of an *Equisetum* peak and peak of Cyperaceae before their values decrease to below core average levels. Regional climate models (Viau and Gajewski 2009b) indicate that following the period of increased moisture, conditions began to dry by 2,000 cal yrBP, and markedly decreased by 1,900 cal yrBP (annual precipitation anomaly value: -11.1431 mm). However, this drier period contradicts the peak of *Typha* recorded in the core, indicating that the broad regional trends do not always correlate with local changes in an area. A similar type of discrepancy is also found in the peat cores within the Athabasca lowlands, where the vegetation remains relatively stable during climatic changes noted in regional proxy records (see Magnan et al. 2018:239). Based on the record from Sharkbite Lake, this late prehistoric occupation layer dated at 2,000 cal yrBP follows a local fire by approximately 100 years. By this time, vegetation would have been completely re-established, and be considered an old-growth forest. The years leading up to the old-growth forest would have seen the forest regenerate from shrub and deciduous-rich areas to conifer-dominated forests.

Possible Implications for Human Occupation:

Given the role that fire has in creating and maintaining the mosaic pattern in the Boreal Forest (e.g., Lewis 1977; Rowe and Scotter 1973), the more active fire years during this interval may have affected faunal communities' movement in the region, in turn influencing hunter-gatherers' movements. Although species like caribou are less attracted to freshly-cleared areas, bear, moose, and other ungulates were probably abundant and took advantage of the understories and berries that flourished below the open canopy during the years following the fire. Following the fire, the burned area would have regenerated and succession proceeded through different plant communities, a development which would in turn draw animals into the area (Davidson-Hunt et al. 2012). The presence of *Corylus* (hazel/hazelnuts) is noteworthy because it is rarely recorded in Sharkbite Lake's pollen record. It is commonly found on well-drained uplands, associated with understories of *Vaccinium oxycoccos* (low-bush cranberry) and *Shepherdia* sp. (buffaloberry. In British Columbia, hazelnuts were an important Indigenous food, and hazel was a technological and medicinal resource (Armstrong et al. 2018). In Alberta, ethnobotanical work shows that hazel was used as a food source by the Wabasca/Desmarais Cree, and has been cited for its medicinal value to the Algonquian and Cree (Siegfried 1994:100; Leighton 1985; Black 1980 [as cited in Siegfried 1994:333]). Leighton (1985:86) also notes that the Chippewa (Ojibwa) used *Corylus* as a building material. The presence of *Corylus* does not indicate that it was available as an abundant food source. Shay (1980:256) shows that if half of a ground cover's area is *C. cornuta*, only 20% of the plants will produce nuts.

5.3.4 HhOv-351

Description:

HhOv-351 is a core reduction workshop and campsite located on the southern end of Sharkbite Lake. The site was identified in survey under permit 2004-249 by surface exposures along a vehicle trail. It is situated in a mixed forest with blueberries, cranberries, wild rose, and other edible plants. The dominant activity at the site appears to have been lithic reduction, specifically the production of bifaces, which are an efficient way to transport raw materials. There is evidence of tool production and use alongside campsite activities. Artifact distributions indicate that there were several activity areas represented, but it is unknown if they represented multiple occupations. BRS at the site is mostly low-quality but is consistent with nearby sites even though the Quarry of the Ancestors is nearby. Roskowski and Netzel (2011b:58) speculate that the underrepresentation of high-quality BRS could reflect the fact that the Quarry may have been covered by well-established muskeg. Stage 2 mitigation yielded a total of 23,404 lithic artifacts and 34 pieces of calcined bone. From all archaeological assessments, 52,388 artifacts were found. Faunal elements were found in Block A/B and across several units. Only 34 pieces of faunal material were recovered, and none were identified to taxon. This entire sample was submitted for radiocarbon dating (weight=4.2 g) (Roskowski and Netzel 2011b:51). The researchers believed that all 34 faunal fragments probably reflected one animal based on the limited number of pieces recovered and their similar degree of calcination. They argued that if multiple animals were represented there would be greater variation in the fragments' attributes and a greater concentration of bone (Roskowski and Netzel 2011b:51). The sample yielded an AMS date of 1,910 ± 30 radiocarbon years (1,883 to 1,824 cal yrBP) (Beta 295837) (Roskowski and Netzel 2011b:51-53).

Palaeoenvironmental Context:

Overall, Sharkbite Lake's record indicates a modern Boreal Forest composition at this time (approximately 1,880 cal yrBP) (Figure 5.7). The diverse food resources (both animal and plant) and raw materials within the immediate vicinity of Sharkbite Lake made it an ideal campsite location. Roskowski and Netzel (2011b) believed that the Quarry of the Ancestors would have been covered by muskeg and BRS would have been procured from an exposure at a nearby creek. Wetland taxa like *Sphagnum* and *Equisetum* are at core average, a distribution which does not demonstrate a significant change in wetland extents in the immediate area surrounding Sharkbite Lake that would have affected access to the Quarry of the Ancestors. However, this time frame does precede an *Equisetum* peak, which could support the idea of increased moisture. *Myrica* sp. is noted in the record, but then disappears for about 200 years. Because *Myrica* sp. is a shrub that grows in moist bogs and swamps, its presence could also support the idea of an increase in moisture levels during this interval (Moss 1989:215). Regionally, moisture levels begin to increase (Viau and Gajewski 2009b), and the moister conditions and pollen record could support the idea that the Quarry of the Ancestors would have been partially covered by muskeg. Beginning around 2,100 cal yrBP, there was a distinct *Typha* peak that continues until this interval. The end of the *Typha* peak may indicate that the littoral zone of Sharkbite Lake shifted, either increasing or decreasing. Given the location of HhOv-351 in relation to Sharkbite Lake's modern shoreline, it seems plausible that the shorelines could have fluctuated without a major disturbance to the elevated landforms.

Possible Implications for Human Occupation:

Typha, commonly known as cattail, is an important food plant noted in ethnobotanical records (Leighton 1986:62; Siegfried 1995:313, 328). It is also noted for its medicinal use by the Wabasca/Desmarais Cree and is used by other boreal groups as construction material, diaper material, and toy material (Leighton 1985:87). *Myrica*, which also inhabits the edges of wet areas, has been documented as an ingredient that the Nīhithawīwin (Wood Cree) in Saskatchewan use for fishing lures (Leighton 1985:46). Both taxa would be valuable to local and non-local groups accessing the area and were accessible even with a change in lake size. Both were indicators of moisture changes, and any subsequent increase or decrease in lake size may have presented a challenge to First Nations ancestors, given the slight elevation of many landforms in the area. If the changes to the water table affected the local environment, the Quarry of the Ancestors would have been partially inaccessible to First Nations ancestors. This hypothesis outlined by Roskowski and Netzel (2001b:58) is supported by the record at Sharkbite Lake. Although access may have been minimally altered, the fact that the site was dominated by low quality BRS indicates either that groups could not easily access the better quality raw material, or that a group unfamiliar with the quarry's location was occupying the site at the time.

5.3.5 HhOv-528

Description:
HhOv-528 is a campsite and workshop located southeast of the Muskeg River. The site boasts a deep, intact stratigraphy that is unique for the area (Turney 2014:404). The site contains "bituminous cross-bedded lenses inclined to the west… [which were] …encountered in all of the profiles at a depth of approximately 45 cm below surface." This feature is important to take into consideration if an occupation yielded dates from samples in contact with these lenses because of the possibility of dead carbon contamination of radiocarbon samples (Turney 2014:404). Although the presence of bituminous material was noted, no precautions, such as Soxhlet extraction, were taken to remove potential contamination in any radiocarbon samples according to the report (see Turney 2014).

BRS is the dominant lithic material at the site, which is unsurprising, considering that it borders the Quarry of the Ancestors. Other lithic materials include various quartzites, chert, granite, siltstones/silicified siltstone, massive quartz, and sandstone. Northern quartzite, salt-and-pepper quartzite, and Swan River Chert are also present at the site (Turney 2014:411). Interestingly, in the BRS assemblage, tools account for 0.3-1.3% of the assemblage but in the non-BRS assemblage, tools account for 14.3 to 28.2% (Turney 2014:411).

In total, 476 m^2 was excavated during Stage I and II mitigation. Excavations yielded a total of 630,188 artifacts. The assemblage includes 5,842 tools, 3,854 core/core fragments, 421 wedges, 234 retouch flakes, 203 manufacturing rejects, 194 biface preform fragments, 174 wedge fragments, 138 utilized flakes, 131 tested cobbles, 101 biface fragments, 84 scrapers, 66 microblades, 59 biface preforms, 42 anvils, 38 projectile points, 31 bifaces, 27 hammerstones, 12 gravers, eight spokeshaves, five blades, four unifaces, three bifacially retouched stone tools, two unifacially retouched stone tools, two manuports, a single projectile point preform and one uniface fragment (Turney 2014:227). A total of 104 faunal fragments were recovered. Block K had seven calcined bone clusters, between levels 1 and 2 (Turney 2014:363). From this block, three faunal and one charcoal sample were submitted for AMS dating. A fifth radiocarbon date came from Block P (see Table 5.1 for all dates).

At the site, four broad activity areas were identified. The NW activity area was a core reduction area, the NE activity area was a more general campsite/workshop area, the Centre activity area was another general campsite/workshop area, and the SW activity area was considered to have been an area for organic material processing and some limited campsite/workshop activity (Turney 2014:365-368). Because all artifacts are found within one or two of the excavation levels, Turney (2014:369) determined that this distribution represents a deflation surface with multiple occupations compressed into shallow stratigraphy. This was supported by optical profiling performed by Western Heritage. Three probable deflation surfaces were noted (Gilliland 2010 as cited in Turney 2014:405), of which the upper surface “matches excavation levels with the highest frequency of recovered artifacts…” (Turney 2014:405). Turney (2014:414) states that the site was most intensively used during the Middle Prehistoric period by Shield Archaic / Beaver River Complex people. It was used to a lesser degree in the Late Prehistoric, as evidenced by the higher volume of recovered materials in level 2, the non-local lithic materials, and pitted anvils.

This site yielded five radiocarbon dates, three of which represented a similar time frame. This number is unusual in the Boreal Forest, where sites rarely yield even a single radiocarbon date. The samples referenced in this analysis are three faunal sample from two units in Block K. The first from Unit 454N 184E, SW quad, level 2 was a subsample of three fragments weighing 0.7 g which yielded an AMS date of 1,080 ± 30 radiocarbon years, or 1,056 to 932 cal yrBP (Beta – 340826) (Turney 2014:364). From the same unit, a sample from level 1 comprising of 69 calcined bone fragments weighing 29 g yielded a date of 1,080 ± 30 radiocarbon years, or 1,056 to 932 cal yrBP (Beta – 30827). The third sample of 38 calcined bone fragments (weighing 24.3 g) came from the NE of Unit 453N 184E and yielded a date of 1,070 ± 30 radiocarbon years, or 1,055 to 929 cal yrBP (Beta-340825). HhOv-528 is the best dated site in the region, with indications that there were three major dated occupations: the first around 7,000 cal yrBP, the second at 1,000 cal yrBP, and the third around 500 cal yrBP (Woywitka 2016:5, Figure 4). Remarkably, two separate samples from the site yielded the same dates, and the same delta values, which could indicate that the same animal or samples from a single event were being dated. The third date is 10 years younger and plots closely to the previous dates mentioned. This could mean that there was a rather large hunting episode that was returned to camp, or the continued returning to this site.

Palaeoenvironmental Context:

Five dates exist for HhOv-528, but the palaeoenvironmental context discussed will reflect conditions around the three dates that cluster around 1,050-1,000 cal yrBP. They are from one of the productive excavation blocks at HhOv-528, Block K. Sharkbite Lake's record at this time highlights the diverse vegetation in the area (Figure 5.7). Understory taxa like *Fragaria*, Liliaceae, Rosaceae, *Artemisia*, and Asteraceae are all present. There is also an increase in

Dryopteris and Lycopodiaceae, which would be indicative of conditions with more moisture. Cyperaceae percentages are higher than average, indicating that the extent of wetlands located along the margins of Sharkbite Lake may have increased. Viau and Gajewski (2009b) modelled an increase in regional precipitation (precipitation anomaly change from -1 mm to 12 mm). These indicators of slight moisture increase coincide with the decreased charcoal abundance that was noted since approximately 1,300 cal yrBP. However, because taxa like *Fragaria*, Liliaceae, Asteraceae, and *Artemisia* require well-drained and sandy soils, there was potentially minimal change to the water table levels. There is also an increase in Poaceae (grass) values in the pollen record at this time, potentially indicating more open areas in the area adjacent to Sharkbite Lake.

Following this climatic interval, there is a major charcoal peak. This peak is one of the strongest in the core and could demonstrate that the previous period of decreased charcoal activity and increased precipitation led to deadfall build-up and the formation of old growth forests. This deadfall build-up may in turn have led to a substantial burn, which would have been recorded in the charcoal peak. As moisture levels decreased moving into 1,000 cal yrBP, summer temperatures also increased (Viau and Gajewski 2009b). Both deadfall and old-growth forests are extremely susceptible to fire, and these factors would have made the area potentially more flammable.

Possible Implications for Human Occupation:

Although the faunal remains found at the site cannot be identified to species, there is a strong possibility that they could represent bison or other large ungulates based on the environment at the time. Species like bison and other grazers would have been attracted to grasses as a food source, which would, in turn, allow First Nations ancestors to access bison for food and materials. Of note is the diversity that continued to be maintained in the region during decreased fire activity. Numerous animal and plant taxa would be represented and are not diminished by old-growth forests. This situation seems to hold for the area around Sharkbite Lake; however, periods in which old-growth forests dominate tend to stress resources, since old-growth forests are not rich in food resources (e.g., Davidson-Hunt et al. 2012). Because food sources were widely dispersed across the landscape, newly burned areas would become areas for species such as moose and hare.

The lithic raw material composition at HhOv-528 appears to indicate a group arriving from elsewhere, rather than a group from the mobility zones around the BRS quarries (see Chapter 4.3). This low representation of BRS could indicate that a group arriving from elsewhere would be replenishing their toolkits with BRS. It is possible that a group arriving into the Quarry of the Ancestors area around this time was familiar with other toolstone sources in the area. The group would have supplemented their toolkits with these non-BRS materials, and that their "toolstone reserve/stockpile had not been fully depleted" (Turney 2014:425), due to the presence of both non-BRS tools and debitage. This could explain why BRS tools account for 0.3-1.3% of the assemblage while non-BRS tools account for 14.3 to 28.2% (Turney 2014:411). It is possible that this period of intense old-growth caused groups to move around more in orderto access areas of new growth, eventually leading them to the area around Sharkbite Lake, where they would benefit from a number of food sources and the nearby Quarry of the Ancestors for knapping material.

5.4 Conclusions

Throughout the last 3,000 years covered by this analysis, there were no major environmental shifts in the study area. Instead, there were smaller, more common and frequent changes in variables like edaphic conditions and fire frequency that triggered small-scale ecological processes. These changes in seasonal climates and landscapes were precisely the types of conditions that First Nations ancestors would have adapted to throughout the millennia. The palaeoenvironmental record from Sharkbite Lake gives archaeologists a record of the late Holocene that can be applied to site interpretations. Archaeologists can develop more holistic site interpretations farther into the past and across the region by using Sharkbite Lake's record along with the records from Kearl Lake and Eaglenest Lake. In the future, as we obtain more radiocarbon dates from the region, we can begin to model the patterning and distribution of sites at different times in the Holocene in order to interpret the effects local ecology has had on site selection.

A critical examination of radiocarbon dates has helped to assess their reliability for indexing archaeological contexts. Although the culture history of the region often refers to neighbouring traditions for dates, this approach is less than desirable. Those inferred dates may not necessarily accurately reflect the period in which these technologies actually appeared in the lower Athabasca River Valley. Through the years, better laboratory protocols and procedures will continue to allow for smaller, more discrete samples to be successfully submitted for radiocarbon dating. Vegetation data are useful for developing insights into the economies and lifeways in the region. Indeed, the survival and movement of First Nations ancestors are so strongly tied to the land around them that a researcher's awareness of these past landscapes is critical. Sharkbite Lake's high-resolution palaeoenvironmental record allows us to look at the late Holocene with a view to more accurately contextualizing occupations with the surrounding vegetation. As demonstrated above, there are instances in which the vegetation record provides new information to better inform interpretations of site activity.

Chapter 6 Conclusions

Sharkbite Lake's sediment core offers a record of late Holocene environmental conditions during the last 3,000 years. This record provides much needed information about late Holocene palaeoenvironments in the lower Athabasca River valley and landscape context for archaeological research in the area. Here I review the research objectives introduced at the beginning of the thesis, and assess the results arising from the study.

(1) To derive and document a late Holocene palaeoenvironmental record for the lower Athabasca River valley.

Sharkbite Lake's record spans most of the late Holocene and yielded evidence of local and regional trends. It is the only late Holocene pollen record in the lower Athabasca River valley and is one of few studies in northeastern Alberta to incorporate different lines of evidence to reconstruct the environment—including pollen, charcoal, LOI, and macrofossil records. The addition of Sharkbite Lake's record to Kearl Lake's record creates a palaeoenvironmental history that spans most (but not all; see Chapter 2) of the Holocene in the lower Athabasca River valley. These palaeoenvironmental conditions present us with glimpses into past landscapes that would have provided opportunites and challenges for First Nation Ancestors living in the area.

(2) To provide background information to researchers and archaeologists to better inform site interpretations.

The high-resolution nature of Sharkbite Lake's core allows researchers to refer to it as a record of the local environment for both archaeological and environmental research. Sharkbite Lake provides much needed context for Late Prehistoric sites in the area, specifically those near important toolstone sources loci like Quarry of the Ancestors (see Chapter 4.3). Sharkbite Lake also provides a similar resolution record to those from lakes such as Wild Spear Lake and

Christina Lake, allowing for comparisons between these different parts of northeastern Alberta. In addition to this advantage, the palaeoenvironmental record from Sharkbite Lake can be applied to interpretations of the archaeological record.

(3) To demonstrate the benefits of palaeoenvironmental research in archaeological investigations in the Boreal Forest, especially in the light of the limited culture history chronology.

Pollen records from across the region emphasize the patchy network of environmental conditions that were the largest factor for human success in northeastern Alberta. Chapter 5 integrates the palaeoenvironmental record with available dates from the archaeological record. Five sites were presented along with interpretations of landscape use and local environments. I was able to connect the time frames for specific archaeological site activities with local conditions as revealed in the palaeoenvironmental record. In addition to this analysis, another human narrative evolved from the discussion when I looked at the potential environmental implications for human occupation, one that is often neglected in the archaeological research due to lithic-dominated artifact assemblages. Some assumptions based on archaeological evidence alone were supported by the palaeoenvironmental record, and some new connections between the two were made. As an example, Roskowski and Netzel (2011b) believed that the poorer quality BRS recovered at HhOv-351 is due to limited access to Quarry of the Ancestors because of muskeg cover at the time. The record at Sharkbite Lake does not support a significant change in wetland extents in the immediate area, demonstrating that access may not have been a factor in material quality. This synthesis demonstrated the benefit of incorporating vegetation information in late Holocene site interpretations and discussions.

The research questions this thesis aimed to address were met with success, but the lack of data in some areas prompted new questions and avenues of research. Much of what can be done on the basis of new information from Sharkbite Lake's palaeoenvironmental record concerns connecting Late Prehistoric occupations to specific time frames reflected in the lake core. Chapter 5 demonstrates what can be done and provides a template for connecting the palaeoenvironmental record to the available archaeological record. Although few connections could be made due to the limited archaeological dating, this template has implications for current and future archaeological work.

(1) In the lower Athabasca River valley, what role did the environment play in site selection and site patterning in the Late Prehistoric Period?

There were not enough Late Prehistoric sites to note trends associated with site selection and occupation. Although some sites can be defined as Late Prehistoric, the number of secure associations to this period is few, and any trends that may be interpreted for site occupation are unsubstantiated by firm evidence. However, the environmental conditions and variation noted during this interval would have impacted the movement of people and animals through the region. Fire and edaphic conditions had the most significant impact on mobility in the region, and would subsequently influence site selection choices and options.

Sharkbite Lake's record highlights that **local change** may differ from larger regional trends (e.g., moisture levels over the years) that are derived from broad-scale integrative analyses. Regional trends are not always supported in the local pollen record. Although regional trends tell of broader climatic variables that may have impacted local vegetation (Viau and Gajewski 2009b), this local record now provides a more detailed representation of vegetation for a specific locality.

The sensitive and variable nature of the Athabasca lowlands is noted in Sharkbite Lake and peatland cores from the surrounding area (Magnan et al. 2018).

Mobility through the region is the consequence of a muskeg-dominated landscape that had widely dispersed food and raw material sources. This movement along terrain features scattered through the region had a significant role in site selection and movement for resource procurement. The patterns of interstitial foraging and logistical mobility (Winterhalder 1980; Ives 1982, 1993) reflected the fact that groups foraged widely for materials. Groups moved along these raised landforms and used waterways that provided ecological productivity for animals and humans.

Studies like those of Fisher (2017) and Martindale (2014) have depicted BRS mobility as a proxy for human movement in both the MOSR and broader northeastern Alberta and northwestern Saskatchewan Boreal Forest region. Building from their work, my research plotted different site types (scatter > or < 10) (see Chapter 5.1.1) to provide a visual representation of what sort of movement might have been exhibited in the region. BRS was abundant and frequently left in the fine-grained archaeological record which attests to the movement around the region and in the vicinity of Sharkbite Lake. Mapping coarse-grained records in the region hints at underlying structure of landscape use that would be further revealed by additional geospatial analysis. Future geospatial analysis that incorporates variable such as elevation, vegetation (as inferred from palaeoenvironmental records), and eventually radiometric dates for sites, can help tease apart landscape use during prehistory.

(2) How did the late Holocene environment impact the occupations during the Late Prehistoric Period?

Although Sharkbite Lake's core provided a detailed record of vegetational change, there were no significant environmental changes noted. However, Sharkbite Lake's record does document the successional changes that are within the normal scope for Boreal Forest plant communities. We do see several episodes of ecological variability that are local in scale. Within the lower Athabasca River Valley, changes like wetland expansion may have affected access to Quarry of the Ancestors and raw materials (see 5.3.4). One of the major triggers for variability is fire. The relationship of natural fires and its impact on humans is evident; but it is the anthropogenic use of fire, and its ability to restore, revitalize, and renew parts of the landscape that is important. The region's fire history encompasses wildfires and, very likely, anthropogenic fires. Ethnographically, we know that First Nations use of fire for landscape management was purposeful and undertaken with a deep understanding of the vegetation and fire's mechanisms. Sharkbite Lake's record provides evidence of late Holocene fires and some information on the frequency at which fires would burn in the region. The fire episode at 2,410 rcyBP offers an example of how fire changed the landscape, and how plant communities returned after a stand-clearing fire (see Chapter 3).

Although no direct cause and effect links could be made between archaeological sites and environmental shifts, the five sites analyzed benefitted from the additional information on environmental conditions and vegetation obtained from Sharkbite Lake's record. As more sites are discovered, and as more research correlates radiometric dates with occupational surfaces and artifacts, this research question can be explored in greater detail. The more dates available to be added to the radiocarbon table (Chapter 5), the more connections that can be made. Researchers have suggested that the Arctic Small Tool tradition arrived into northeastern Alberta as a response to climate trends, with ASTt groups moving away from the coast and into the Barrengrounds. As these climatic trends resulted in the treeline moving further south, migrating caribou may have penetrated more deeply into the boreal forest of northeastern Alberta when seeking winter shelter and lichen food sources, bringing ASTt groups following the herds with them (see MacKay and Andrews 2016). Sharkbite Lake's record provides evidence of a shift to more old growth forest in its immediate vicinity in the 3,000 to 2,700 cal yrBP time range that is consistent with this line of thought. Further investigations into the presence of distinctive ASTt material in northeastern Alberta and the palaeoenvironmental factors that might have contributed to this fascinating interlude are certainly merited. Additional avenues of research such as these should be revisited once more data becomes available, and as more palaeoenvironmental records are analyzed.

(3) How can the significance of existing radiocarbon dates be evaluated in this region and how can they be related to the Sharkbite palaeoenvironmental record?

This question continues the research that Woywitka conducted in 2016, when he began assessing the archaeological radiocarbon record in the MOSR. Through the review of the submitted reports, it was evident that consistent reporting within the archaeological community when it comes to the dated record is lacking. The provenience of the artifacts needs to be carefully assessed and reported in orderto ensure that there are valid reasons for associating a radiocarbon date with a particular feature or artifact assemblage. More consistent piece-plotting of artifacts would allow archaeologists to have greater confidence in evaluating spatial relationships among artifact distributions, features, and radiometric sample locations when there are all too frequent challenges like condensed stratigraphy. This provenience information should be presented in a way that other researchers can easily reconstruct and interpret. I agree with Woywitka's (2016) call upon archaeologists to consistently delineate where the submitted sample material is coming from when sending material for dating.

Given that no radiocarbon dates were used to anchor the sequence that Reeves et al. (2017) proposed for the culture history, any date with a score above 80 can be considered valuable in the creation of a well-dated sequence. Although it is likely that there will be a bias towards Late Prehistoric sites due to preservation issues, other radiometric dating options should be incorporated in future research. The use of various radiometric dating methods would prove valuable and help strengthen a cultural sequence in the region (e.g., applying OSL dating [Woywitka 2018] along with radiocarbon dating).

Applications:

The value of Sharkbite Lake's core lies in its addition to the lower Athabasca's late Holocene palaeoenvironmental record, and its applicability to the archaeological history of the Boreal Forest. Cultural Resource Management practitioners often find themselves caught between heritage preservation objectives and strict industrial timelines. In this process, the archaeological investigations are subject to and limited by the scheduling challenges and preservation. This factor, in addition to the lithic-dominated assemblages, leads to an overall lack of site interpretations. The insights provided by my research, specifically of the prehistoric landscape and interpretations of human-environmental relationships, will help further analyses done during archaeological investigations in the area. This work will also help to incorporate research approaches from earth sciences that are not always components of the investigations of Alberta's human heritage.

The record from Sharkbite Lake has implications for current research. Many modern climate scientists are continuing to delve deeper into palaeoenvironmental records to better model future climate trends. Research continues to explore how palaeoenvironmental and sometimes archaeological records can contribute to our understanding of climate change and impacts (e.g., Roddick 2018). For example, this is seen in the work done by climate scientists understanding the recent large-scale and devastating fires in northern Alberta. Fires are prevalent in Alberta's north, and their impacts can be felt on not only the environment but on human communities. Wildfires have been at the centre of attention lately, given that the summer of 2016 saw widespread fires that severely impacted communities like Fort McMurray in northern Alberta. Most concerning is that fires have been promoted and exacerbated due to human interference, such as fire suppression strategies causing an abnormal build-up of fuel. As we enter an era of increasing climate change, historical and heritage-based knowledge becomes important in understanding what baseline boreal forest conditions were like, and how forest fires today could increase in scale and intensity with increasingly severe effects on modern-day populations (see Alberta Agriculture and Forestry 2017; Flannigan and Wotton 2017; Kochtubajda et al. 2017; Lagerquist et al. 2017; Schoennagel et al. 2017).

Finally, there is the option to use the late Holocene record as part of the guidance for reclamation work in northeastern Alberta. Land reclamation practices operate under the "Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region," which were first released in 1998. The guidelines were created as a "living" document to be updated as new data improved reclamation practices (Alberta Environment 2010:iv). In the MOSR, the reclamation methods used depend on the end land-use. There are four end land-uses: commercial forest, wildlife habitat, traditional land use (TLU), and recreation (Alberta Environment 2010:17-18). While from a reclamation perspective, dividing wildlife habitat and TLU may have its purposes, anthropologically these have historically been essentially the same. The lands which humans inhabited and hunted were no different from those occupied by faunal communities.

Reclamation for wildlife habitat intends to portray the ideas surrounding the symbiotic relationship between plant and animals, in which specific plants will encourage animals and vice versa (Alberta Environment 2010). Emphasis is placed on key animal species in the Boreal Forest such as moose, caribou, beaver, muskrat, snowshoe hare, lynx, and various bird communities. In 2006, traditional environmental knowledge (TEK) was gathered, but there is no indication whether this information was incorporated into reclamation guidelines (Alberta Environment 2010:103). For TLU, there is a consideration for land-uses such as trapping, hunting, fishing, plant harvesting, and trail access. TLU in the context of remediation is referred to as “a collection of land-based activities that involve the simultaneous proximal use of multiple resources which help sustain the economic, cultural, and spiritual foundation of Aboriginal life” (Alberta Environment 2010:182).

The wildlife and plant communities promoted during the reclamation stage are to resemble a pre-disturbance landscape (Alberta Environment 2010:102). The term “pre-disturbance landscape” appears to refer to how the landscape looked prior to EuroCanadian disturbances such as forestry and industrial activity. It does not consider what the prehistoric baseline represents, and the possibility that First Nations ancestors may have engaged in anthropogenic management practices and the informed use of fire. Nor does it take into consideration the decades of fire suppression through the region when addressing forest maintenance. Stockdale et al. (2018) have examined the relationship between landscape restoration and wildfire intensity in Alberta’s

Rocky Mountains. Their work showed that restoring forest areas to a pre-European landscape "resulted in dramatically lower mean probability… [of high-intensity fires] …and a smaller reduction in the mean fire size" (Stockdale et al. 2018:15). This same principle and style of research may be applied to the Boreal Forest and should be considered during reclamation work. Records like Sharkbite Lake become valuable baselines that can be used as targets for restoration, and in determining pre-disturbance (or pre-European incursion) landscapes. The incorporation of palaeoenvironmental records like that from Sharkbite Lake can assist in reclamation strategies to optimize faunal and plant population returns, and for enabling subsequent TLU.

Future Directions and Concluding Remarks:

Sharkbite Lake's pollen record has provided some critical information that was missing from lower Athabasca River valley. The more detailed understanding of environmental trends can be incorporated into archaeological site interpretations as secondary lines of evidence for the region's prehistory and history. In archaeological research, changes to the landscape would have influenced archaeological site location, specifically during major environmental shifts. Currently, because only 47 radiocarbon dates exist for nearly 2,000 recorded sites, there are too few mapped site locations from which to infer meaningful patterns for different time periods and environmental conditions. When comparing the number of radiocarbon dates from the HO Borden block in 1986 and 2018, we see that the number of dates relative to the number of sites has not grown much (Table 6.1). Although over 1,500 sites have been discovered in 32 years, this activity has resulted in only a 1.55% increase in radiocarbon date recovery. Although the recovery of datable material has increased due to the increase in sites, the number of dates has not grown substantially relative to the number of sites. Preliminary work done in this thesis touches on some of the reasons why dates may be more concentrated in one area rather than another. In the future, mapping site locations alongside environmental trends would be a valuable area of research. In a similar avenue of research, mapping of archaeological sites relative to soil acidity conditions and parent geologic materials could prove useful in determining where organic materials would best preserve.

Year	**Number of sites**	**Number of dated sites**	**Number of dates**	**% of sites dated**
1986	352	3	3	0.85
2018	1938	32	47	1.96

Table 6.1 Number of sites and radiocarbon dates in the HO Borden block in 1986 and 2018. 1986 data from Beaudoin (1987b:213); 2018 data from this study via Archaeological Survey of Alberta.

A call to action in this thesis echoes the sentiments of Beaudoin (1987a) and Woywitka (2016). New protocols for radiocarbon-dated materials need to be established and incorporated into site reports. New radiometric dating procedures such as OSL can and should be integrated into archaeological methodologies in order to better inform the culture history of the region (see Woywitka 2018). In addition to this methodological advance, sampling for AMS radiocarbon dates needs to be conducted with greater care. Composite samples from across multiple units should be avoided, even if an author feels that the materials represent a single episode. Careful consideration should be given to distribution, association, and type of material when collecting samples. With the various materials that can be submitted for radiocarbon dating—such as wood, bone, and charcoal—it is important to also determine a sample's degree of preservation, and to mitigate any potential contamination. Should the datable materials come from a feature and be distinctly associated with nearby artifacts, then a composite sample could be used *if required*. However, faunal samples of 200 mg with adequate protein fraction can yield radiocarbon dates, eliminating the need for composite samples in most cases. Although there are few dates for the region and dates greatly inform our understanding of a site, there needs to be careful thought and planning for sample selections.

Permit reports need to consistently and accurately describe the stratigraphic and spatial associations of the materials in the excavation and GIS techniques should be applied to distinguish artifact distributions. This technique perhaps is the most critical part moving forward in archaeological research for the region. My review of the dates indicated that dates from reports too frequently failed to describe in detail the provenience of the dated materials, or to take into account constraints over the degree to which we can be certain the sample and its age truly relate to surrounding features or artifact distributions, especially in thinly stratified sites. Without careful consideration for the sample's association, any acquired radiocarbon date may not accurately reflect an occupation interval at a site. This possibility makes it challenging for future archaeologists to understand what the date represents in relation to all other artifacts.

The palaeoenvironmental record from Sharkbite Lake filled a gap in the Boreal Forest literature by providing a detailed late Holocene record. Although it completes a gap, there is still much that can be analyzed within the Sharkbite record, including sedimentary pigments, more pollen sampling, and tephra analysis. My aim is to remind archaeologists of the value of palaeoenvironmental records, in order to provide a more local representation of the area during the late Holocene. The secondary emphasis of this project synthesized archaeological research in the area and illustrated that we *can* begin to achieve more penetrating research into past human behavioural patterns. My thesis highlights the cross-disciplinary applicability of palaeoenvironmental research and how different perspectives can lend to our understanding of the region's history.

The relationships among environment, animals, and First Nations are parts of the Boreal Forest’s postglacial history. First Nations peoples would have been mindful of the changes resulting from fires. Knowledge of pioneering species after fires, subsequent successional communities, and the impacts these would have had on food and other resources (both faunal and floral) were a part of the toolkit First Nations used, allowing them to make this region their home. This environmental history informs our understanding of the dynamics of the region, for both humans and vegetation. So, what may seem like an unsuspecting aliquot of sediment and hundreds of thousands of pollen grains and spores, can in reality, yield a rich history linked to the landscape and past human occupations.

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Geospatial Data Sources

**Spatial Data references listed as required, unless stated in figure caption.*

National Geographic BaseMap from ArcGIS BaseMaps. Sources: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Used in Figure 1.1.

World Topographic BaseMap from ArcGIS BaseMaps. Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, OpenStreetMap contributors, and the GIS User Community.

Used in Figure 2.3.

World Ocean BaseMap from ArcGIS BaseMaps. Sources: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors.

Used in Figure 4.1.

LiDAR from Archaeological Society of Alberta; obtained personally from the Archaeological Survey of Alberta

Used in Figure 4.2, Figure 4.4, Figure 4.5, Figure 4.6, Figure 5.1, Figure 5.2, Figure 5.3, Figure 5.5, and Figure 5.6.

Archaeological Site Data from Archaeological Society of Alberta; obtained personally from the Archaeological Survey of Alberta

Used in Figure 4.2, Figure 4.4, Figure 4.5, Figure 4.6, Figure 5.1, Figure 5.2, Figure 5.3, Figure 5.5, and Figure 5.6.

Base Features Hydrography; obtained from ArcGIS online. Copyright Government of Alberta (https://open.alberta.ca/licence) Map service by Brandon.mol@edmonton.ca (pub. 18/12/2017)

Used in Figure 4.2, Figure 4.4, Figure 4.5, Figure 4.6, Figure 5.1, Figure 5.2, Figure 5.3, and Figure 5.6.

Fire Data; from Canadian Forest Services (http://cwfis.cfs.nrcan.gc.ca/datamart/datarequest/nfdbpoly)

Used in Figure 5.1.

Appendix A – Pollen, Spore, and Microcharcoal Counts

Radiocarbon years BP (rcyBP)		697	725	809	865	921	1005	1117	1173	1201	1285	1313	1388	1458	1472	1556	1584	1640	1696	1724	1752	1808	1864	1920	2004	2032	2060	2088	2144	2200
cmFB		372	368	356	348	340	328	312	304	300	288	284	276	266	264	252	248	240	232	228	224	216	208	200	188	184	180	176	168	160
cmFS		2	6	18	26	34	46	62	70	74	86	90	98	108	110	122	126	134	142	146	150	158	166	174	186	190	194	198	206	214
Name	Group																													
Picea sp.	TRSH	196	183	188	194	283	190	206	187	175	172	179	266	189	209	230	141	170	184	184	244	169	187	167	182	168	323	258	175	193
Pinus sp.	TRSH	173	167	171	121	208	222	235	165	154	157	157	213	164	191	199	129	138	143	167	205	151	157	123	145	136	301	213	140	148
Betula sp. 3 pore	TRSH	57	62	68	74	89	95	114	66	89	61	53	137	74	84	169	88	108	103	99	155	90	85	110	98	165	146	148	89	104
Betula sp. 4 pore	TRSH	14	25	23	24	30	34	39	27	35	25	21	70	20	28	41	35	29	27	28	58	31	29	42	30	37	51	57	42	35
Alnus sp.	TRSH	21	27	21	33	39	43	45	13	15	27	22	48	22	32	37	26	37	27	27	70	44	25	48	11	49	87	50	28	38
Larix sp.	TRSH	28	29	22	22	12	39	28	21	19	18	34	30	24	18	19	36	19	30	41	31	30	24	33	38	32	49	47	23	14
Populus sp.	TRSH	25	23	12	14	12	25	17	13	14	24	28	30	15	19	16	22	11	18	25	35	14	16	11	18	18	25	26	16	14
Salix sp.	TRSH	16	8	9	14	21	17	19	13	11	13	13	34	9	19	24	14	12	22	15	55	10	19	13	15	22	36	18	11	16
Cyperaceae sp.	UPHE	11	9	21	14	23	12	21	11	8	10	6	33	7	13	10	11	20	15	17	28	18	6	11	2	13	30	26	6	14
Equisetum sp.	VACR	33	27	9	18	6	28	15	13	17	12	23	6	14	8	5	18	4	6	26	15	16	13	8	26	4	17	19	19	6
Gramineae sp.	UPHE	7	9	7	8	16	6	9	4	5	7	6	10	3	11	14	10	9	14	11	19	14	5	10	9	7	12	14	8	4
Lycopodaceae	VACR	8	0	10	4	13	5	11	1	1	7	4	15	1	17	14	8	16	10	4	18	6	2	9	0	10	7	9	2	5
Eleocharis sp.	UPHE	6	5	8	2	12	6	9	6	4	5	3	15	1	9	6	6	6	7	5	10	8	3	6	1	7	11	14	3	8
Sphagnum sp.	AQBR	3	3	5	3	8	5	4	6	2	2	3	6	3	9	7	1	2	6	11	11	4	1	1	2	2	9	3	2	2
Artemisia type	UPHE	2	3	4	5	6	1	7	1	2	4	2	8	3	4	3	5	8	10	0	4	6	4	6	3	1	8	4	3	4
Juniperus sp.	TRSH	4	7	2	2	1	4	5	2	5	6	1	7	6	2	1	2	3	8	3	5	5	2	4	3	5	6	2	1	4
Typha sp.	AQVP	4	1	0	0	0	1	2	0	0	1	1	2	0	0	2	2	1	1	1	3	6	2	3	5	22	24	11	2	6
Dryopteris sp.	VACR	4	0	1	1	8	0	5	0	2	2	3	2	3	2	5	1	1	1	1	4	1	3	2	0	0	2	3	1	2
Abies sp.	TRSH	4	3	3	5	4	3	3	3	3	1	3	2	3	2	3	0	2	1	1	2	2	2	5	1	1	3	4	3	3
Scabrate trilete	AQBR	7	0	6	0	8	7	7	0	0	6	0	5	0	2	2	0	2	3	0	3	3	0	3	0	1	6	1	0	2
Nuphar sp.	AQVP	1	2	4	2	3	4	1	1	2	1	2	5	1	1	2	0	0	0	1	3	2	2	1	1	0	2	2	1	3
Stephanoporate	UNKN	1	0	6	0	2	0	3	0	0	0	0	0	0	0	2	0	0	2	0	1	1	0	0	0	0	1	2	0	1
Myrica sp.	TRSH	3	0	0	1	0	1	0	1	0	0	0	4	0	1	3	0	4	1	0	4	0	1	0	0	3	0	0	2	2
Corylus sp.	TRSH	0	1	2	0	1	0	1	0	1	1	0	0	0	0	1	1	1	2	1	1	1	0	0	0	0	1	3	0	1
ChenoAm	UPHE	0	0	2	3	2	1	1	0	0	0	2	2	0	2	0	0	2	1	0	1	0	1	0	1	0	0	1	0	2
Liliaceae	UPHE	1	0	0	1	1	1	3	1	0	1	0	3	0	0	2	1	1	0	1	3	0	0	1	0	2	1	2	1	3
Rosaceae	UPHE	1	0	0	0	2	0	2	0	0	0	0	1	0	1	3	0	1	1	0	3	0	0	0	0	2	2	0	0	3
Monolete fern	VACR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	1	8	0	0	0	1	0	0	0
Caryophyllaceae	UPHE	0	0	0	0	0	0	3	0	0	1	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	1	1	0	1
Shepherdia canadensis	TRSH	0	0	0	0	0	3	0	0	0	0	1	0	0	1	1	0	0	3	0	1	0	0	1	1	1	0	3	1	0
Erigeron type	TRSH	1	0	1	1	1	1	1	0	1	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0
Compositae	UPHE	0	2	0	0	0	0	1	1	0	0	1	2	0	1	0	0	0	0	0	0	0	0	1	2	0	0	1	0	0
Fragaria sp.	UPHE	1	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	3	1	0	0
Thalictum venulosum	UPHE	1	0	0	1	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2	1	0	0
Potamogeton sp.	AQVP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	1	0	0	0	0	1	0	0	0
Arctostaphylos sp.	TRSH	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Tsuga sp.	TRSH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
indeterminate	UNDIF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Viola sp.	UPHE	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1
Cornus canadensis	TRSH	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0

Radiocarbon years BP (rcyBP)		697	725	809	865	921	1005	1117	1173	1201	1285	1313	1388	1458	1472	1556	1584	1640	1696	1724	1752	1808	1864	1920	2004	2032	2060	2088	2144	2200
cmFB		372	368	356	348	340	328	312	304	300	288	284	276	266	264	252	248	240	232	228	224	216	208	200	188	184	180	176	168	160
cmFS		2	6	18	26	34	46	62	70	74	86	90	98	108	110	122	126	134	142	146	150	158	166	174	186	190	194	198	206	214
Name	Group																													
Geranium sp.	UPHE	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shepherdia argentea	TRSH	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
High Spine	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Rumex sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Castilleja sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epilobium sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Cardamine sp.	UPHE	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. Disporum	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sanicula sp.	UPHE	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urtica sp.	TRSH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Impatiens	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lilium sp.	UPHE	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mentha sp.	UPHE	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes sp.	TRSH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spharganium sp.	AQVP	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triglochin sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Lycopodium Spike	CONC	100	76	509	85	193	165	243	77	81	183	88	266	55	121	151	101	205	142	82	180	142	67	249	86	229	178	279	97	144
Charcoal <50um	MACR	92	24	245	25	288	68	79	67	37	73	67	221	41	128	272	20	313	124	13	396	124	101	516	143	314	78	412	17	135
Charcoal >50um	MACR	3	3	20	8	68	13	13	19	5	16	12	38	5	31	33	6	36	17	7	71	18	9	85	21	59	42	82	9	18
Other Mites	INVT	4	3	0	1	4	3	2	0	2	3	1	20	1	2	3	1	0	1	0	3	0	1	0	0	1	1	2	3	1
Spike suspension	CONC	12100	12100	18583	18583	18583	18583	18583	18583	18583	18583	18583	18583	18583	18583	13911	13911	13911	13911	13911	13911	12100	12100	12100	12100	12100	12100	12100	12100	12100
Spike tablets	CONC	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sample quanity	CONC	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc
SUM(TRSH)	None	543	536	522	505	701	677	713	511	523	505	513	841	526	607	747	495	534	570	592	866	547	549	557	543	637	1030	829	532	572
SUM(UPHE)	None	32	28	42	34	62	30	59	25	20	28	26	75	14	45	38	35	49	49	35	74	47	20	35	18	34	70	65	21	40
SUM(VACR)	None	45	27	20	23	27	33	31	14	20	21	30	23	18	27	26	27	22	17	31	37	24	26	19	26	14	27	31	22	13
SUM(UNDIF)	None	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
SUM(AQVP)	None	5	3	4	2	3	5	3	1	2	2	3	7	1	2	4	4	1	1	2	7	9	4	4	6	22	27	13	3	9
SUM(AQBR)	None	10	3	11	3	16	12	11	6	2	8	3	11	3	11	9	1	4	9	11	14	7	1	4	2	3	15	4	2	4
SUM(MACR)	None	95	27	265	33	356	81	92	86	42	89	79	259	46	159	305	26	349	141	20	467	142	110	601	164	373	120	494	26	153

Radiocarbon years BP (rcyBP)		2284	2312	2326	2340	2368	2396	2452	2536	2592	2648	2676	2704	2760	2823	2837	2851	2858	2865	2872	2928	3012	3096	3152	3264	3292
cmFB		148	144	142	140	136	132	124	112	104	96	92	88	80	71	69	67	66	65	64	56	44	32	24	8	4
cmFS		226	230	232	234	238	242	250	262	270	278	282	286	294	303	305	307	308	309	310	318	330	342	350	366	370
Name	Group																									
Picea sp.	TRSH	198	328	136	41	186	164	183	265	300	222	222	369	268	197	190	252	190	229	193	202	316	173	163	166	207
Pinus sp.	TRSH	167	262	85	15	165	148	147	227	328	204	173	346	232	178	207	223	178	235	174	193	278	156	139	192	201
Betula sp. 3 pore	TRSH	87	112	108	67	81	78	113	130	106	105	92	198	67	52	48	70	58	68	82	80	130	78	80	65	80
Betula sp. 4 pore	TRSH	35	57	36	26	26	30	28	42	48	27	27	55	32	23	16	21	20	15	26	32	50	24	41	33	33
Alnus sp.	TRSH	27	45	30	26	22	25	35	46	40	24	29	62	33	24	12	20	17	19	27	42	57	34	38	29	52
Larix sp.	TRSH	20	13	13	12	15	24	13	26	14	13	17	25	22	19	14	22	21	10	15	28	32	22	31	22	18
Populus sp.	TRSH	12	23	12	6	18	19	10	25	15	8	23	45	13	23	10	17	13	11	16	10	26	14	32	15	36
Salix sp.	TRSH	14	14	26	5	28	20	27	20	11	12	14	26	14	14	12	14	16	11	18	20	26	15	25	19	26
Cyperaceae sp.	UPHE	15	21	30	11	10	10	9	21	28	9	5	24	21	13	12	15	8	16	19	16	19	11	13	15	14
Equisetum sp.	VACR	15	12	3	6	21	16	9	13	6	1	6	13	14	19	7	6	6	5	4	18	9	5	16	18	10
Gramineae sp.	UPHE	6	7	2	7	9	9	6	12	4	6	8	17	7	10	7	4	6	6	5	7	12	7	22	4	8
Lycopodiaceae	VACR	1	9	10	11	2	6	2	7	6	6	8	12	6	6	7	5	4	3	14	2	10	6	4	1	5
Eleocharis sp.	UPHE	3	9	10	6	6	3	4	3	8	4	2	10	9	4	5	8	4	6	5	7	10	6	6	5	8
Sphagnum sp.	AQBR	0	5	3	3	5	4	4	8	1	6	8	16	3	5	4	9	4	2	8	3	6	3	5	3	5
Artemisia type	UPHE	4	5	7	4	4	3	8	5	7	7	3	13	4	8	3	5	0	2	2	6	4	1	1	7	8
Juniperus sp.	TRSH	0	4	2	2	0	1	2	1	1	1	2	6	2	2	4	2	0	1	2	4	3	4	1	3	2
Typha sp.	AQVP	3	11	4	3	2	1	3	2	0	1	1	2	0	0	0	1	1	0	0	2	7	2	3	0	2
Dryopteris sp.	VACR	0	3	2	1	2	1	2	7	5	4	3	7	3	2	2	2	0	1	4	1	6	3	8	3	3
Abies sp.	TRSH	1	2	2	0	1	1	2	3	2	2	2	3	2	1	1	1	2	1	1	2	3	2	1	1	1
Scabrate trilete	AQBR	0	0	1	2	0	0	1	1	2	2	0	7	6	0	0	1	0	2	1	5	2	2	2	0	3
Nuphar sp.	AQVP	1	4	1	0	1	2	1	1	6	5	2	1	3	3	2	4	2	3	1	2	4	4	2	3	1
Stephanoporate	UNKN	0	1	5	6	0	1	4	0	2	3	1	0	2	1	1	3	1	4	1	3	3	0	0	2	1
Myrica sp.	TRSH	0	6	0	0	3	1	2	1	3	0	2	0	0	1	0	1	0	0	1	0	3	0	1	0	2
Corylus sp.	TRSH	0	4	2	0	1	0	2	3	2	0	1	0	2	0	1	0	0	1	1	4	2	1	5	0	0
ChenoAm	UPHE	0	3	2	1	2	2	1	0	0	1	0	1	1	0	0	1	0	0	1	2	2	0	3	2	2
Liliaceae	UPHE	0	2	1	0	0	2	0	0	0	0	1	2	3	0	0	0	0	1	0	0	1	0	0	0	0
Rosaceae	UPHE	0	0	0	0	0	1	0	1	0	3	1	0	2	1	0	0	0	1	1	1	4	0	1	1	3
Monolete fern	VACR	0	0	2	0	0	0	2		0	2	0	4	2	0	0	0	0	1	0	0	4	0	1	0	1
Caryophyllaceae	UPHE	0	1	0	0	0	0	0	0	1	0	1	0	3	0	0	2	0	2	0	0	1	0	1	0	0
Shepherdia canadensis	TRSH	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0
Erigeron type	TRSH	0	1	2	0	0	0	2	2	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Compositae	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	1	0	0		1	1
Fragaria sp.	UPHE	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0
Thalictum venulosum	UPHE	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	2	0
Potamogeton sp.	AQVP	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	1	0	0	0	2
Arctostaphylos sp.	TRSH	0	2	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0		0	0
Tsuga sp.	TRSH	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0	0	0	2	0
indeterminate	UNDIF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	3
Viola sp.	UPHE	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0
Cornus canadensis	TRSH	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Radiocarbon years BP (rcyBP)		2284	2312	2326	2340	2368	2396	2452	2536	2592	2648	2676	2704	2760	2823	2837	2851	2858	2865	2872	2928	3012	3096	3152	3264	3292
	cmFB	148	144	142	140	136	132	124	112	104	96	92	88	80	71	69	67	66	65	64	56	44	32	24	8	4
	cmFS	226	230	232	234	238	242	250	262	270	278	282	286	294	303	305	307	308	309	310	318	330	342	350	366	370
Name	Group																									
Geranium sp.	UPHE	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shepherdia argentea	TRSH	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
High Spine	UPHE	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Rumex sp.	UPHE	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Castilleja sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Epilobium sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cardamine sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. Disporum	UPHE	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Polygonum sp.	UPHE	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sanicula sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urtica sp.	TRSH	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Impatiens	UPHE	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lilium sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mentha sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ribes sp.	TRSH	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spharganium sp.	AQVP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triglochin sp.	UPHE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium Spike	CONC	43	137	192	305	77	70	78	93	100	84	113	145	101	92	127	158	101	74	120	88	124	121	84	97	71
Charcoal <50um	MACR	41	174	493	471	76	73	126	50	159	116	91	225	133	93	159	206	110	287	70	62	171	154	92	91	315
Charcoal >50um	MACR	14	40	54	69	4	6	31	22	51	42	23	54	35	16	24	16	16	30	38	17	66	19	28	23	109
Other Mites	INVT	5	6	3	0	0	2	5	7	5	7	10	8	4	5	6	5	3	10	15	4	10	1	2	5	8
Spike suspension	CONC	12100	12100	12100	12100	18583	12100	12100	18583	18583	18583	18583	12100	12100	18583	18583	18583	18583	18583	18583	12100	18583	12100	12100	18583	12100
Spike tablets	CONC	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sample quanity	CONC	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc	1cc
SUM(TRSH)	None	561	874	454	200	548	512	567	792	870	620	606	1138	688	534	516	643	516	601	558	617	926	523	558	548	658
SUM(UPHE)	None	29	48	53	29	32	31	28	44	50	30	23	70	53	37	27	35	19	34	36	41	56	25	48	37	45
SUM(VACR)	None	16	24	17	18	25	23	15	27	17	13	17	36	25	27	16	13	10	10	22	21	29	14	29	22	19
SUM(UNDIF)	None	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	3
SUM(AQVP)	None	4	15	5	3	3	3	4	3	6	6	5	5	3	3	2	5	3	3	1	4	12	6	5	3	5
SUM(AQBR)	None	0	5	4	5	5	4	5	9	3	8	8	23	9	5	4	10	4	4	9	8	8	5	7	3	8
SUM(MACR)	None	55	214	547	540	80	79	157	72	210	158	114	279	168	109	183	222	126	317	108	79	237	173	120	114	424

UNCALIBRATED (rcyBP)	Depth from surface (cmFS)	Sample Depth from base (cmFB)	Date processed	Processed By	Lyco Batch Tab	Lyco mean (for 1 tab)	HCl reaction	Slide Counted?	Count
697	2	372	Sep 15/17	CPoletto	414831	12100 ± 1892	+	Feb 5/18	739
725	6	368	Sep 15/17	CPoletto	414831	12100 ± 1892	+	Jan 26/18	615
	10	364	Sep 15/17	CPoletto	414831	12100 ± 1892	+		
	14	360	Sept 13/17	CPoletto	483216	18583 ± 1708	+		
809	18	356	Sept 13/17	CPoletto	483216	18583 ± 1708	+/++	Feb 25/18	649
	22	352	Sept 13/17	CPoletto	483216	18583 ± 1708	-/+		
865	26	348	Sept 13/17	CPoletto	483216	18583 ± 1708	+	Jan 31/18	573
	30	344	Sept 13/17	CPoletto	483216	18583 ± 1708	+/++		
921	34	340	Sept 13/17	CPoletto	483216	18583 ± 1708	++	Mar 5/18	1034
	38	336	Sept 13/17	CPoletto	483216	18583 ± 1708	+		
	42	332	Sept 13/17	CPoletto	483216	18583 ± 1708	+		
1005	46	328	Sept 12/17	CPoletto	483216	18583 ± 1708	++	Jan 31/18	694
	50	324	Sept 12/17	CPoletto	483216	18583 ± 1708	++		
	54	320	Sept 12/17	CPoletto	483216	18583 ± 1708	+		
	58	316	Sept 12/17	CPoletto	483216	18583 ± 1708	+		
1117	62	312	Sept 12/17	CPoletto	483216	18583 ± 1708	+++	Feb 24/18	627
	66	308	Sept 12/17	CPoletto	483216	18583 ± 1708	+++		
1173	70	304	Apr 24/17	CPoletto	483216	18583 ± 1708	+	Feb 1/18	657
1201	74	300	Sept 12/17	CPoletto	483216	18583 ± 1708	++	Jan 25/18	553
	78	296	Sept 12/17	CPoletto	483216	18583 ± 1708	-/+		
	82	292	Sept 11/17	CPoletto	483216	18583 ± 1708	+/++		
1285	86	288	Sept 11/17	CPoletto	483216	18583 ± 1708	+/++	Feb 12/18	709
1313	90	284	Sept 11/17	CPoletto	483216	18583 ± 1708	+	Jan 29/18	566
	94	280	Sept 11/17	CPoletto	483216	18583 ± 1708	+		
1388	98	276	Sept 11/17	CPoletto	483216	18583 ± 1708	+	Mar 3/18	607
	102	272	Sept 11/17	CPoletto	483216	18583 ± 1708	+		
	106	268	Sept 11/17	CPoletto	483216	18583 ± 1708	+		
1458	108	266	Apr 24/17	CPoletto	483216	18583 ± 1708	+	Jan 24/18	780
1472	110	264	Sept 11/17	CPoletto	483216	18583 ± 1708	+	Mar 7/18	1272
	114	260	Oct 17/17	CPoletto	710961	13911 ± 306	+		
	118	256	Oct 17/17	CPoletto	710961	13911 ± 306	+		
1556	122	252	Oct 17/17	CPoletto	710961	13911 ± 306	+	Mar 10/18	660
1584	126	248	Oct 17/17	CPoletto	710961	13911 ± 306	+	Jan 29/18	680
	130	244	Oct 17/17	CPoletto	710961	13911 ± 306	+		
1640	134	240	Oct 17/17	CPoletto	710961	13911 ± 306	+	Mar 2/18	948
	138	236	Oct 17/17	CPoletto	710961	13911 ± 306	+		
1696	142	232	Oct 17/17	CPoletto	710961	13911 ± 306	+	Mar 8/18	875
1724	146	228	Oct 17/17	CPoletto	710961	13911 ± 306	+	Jan 27/18	623
1752	150	224	Oct 17/17	CPoletto	710961	13911 ± 306	+	Mar 10/18	574
	154	220	Sept 22/17	CPoletto	414831	12100 ± 1892	+		
1808	158	216	Sept 22/17	CPoletto	414831	12100 ± 1892	+	Feb 21/18	613
	162	212	Sept 22/17	CPoletto	414831	12100 ± 1892	+		
1864	166	208	Sept 22/17	CPoletto	414831	12100 ± 1892	+	Jan 23/18	261
	170	204	Sept 22/17	CPoletto	414831	12100 ± 1892	+		
1920	174	200	Sept 22/17	CPoletto	414831	12100 ± 1892	-/+	Feb 25/18	538
	178	196	Sept 22/17	CPoletto	414831	12100 ± 1892	+		
	182	192	Sept 22/17	CPoletto	483216	18583 ± 1708	+		
2004	186	188	Sept 21/17	CPoletto	414831	12100 ± 1892	+	Jan 26/18	967
2032	190	184	Sept 21/17	CPoletto	414831	12100 ± 1892	+	Mar 5/18	610
2060	194	180	Sept 21/17	CPoletto	414831	12100 ± 1892	+	Feb 14/18	639

UNCALIBRATED (rcyBP)	Depth from surface (cmFS)	Sample Depth from base (cmFB)	Date processed	Processed By	Lyco Batch Tab	Lyco mean (for 1 tab)	HCl reaction	Slide Counted?	Count
2088	198	176	Sept 21/17	CPoletto	414831	12100 ± 1892	+	Feb 22/18	580
	202	172	Sept 21/17	CPoletto	414831	12100 ± 1892	+		
2144	206	168	Sept 21/17	CPoletto	414831	12100 ± 1892	++	Jan 30/18	944
	210	164	Sept 21/17	CPoletto	414831	12100 ± 1892	++		
2200	214	160	Sept 21/17	CPoletto	414831	12100 ± 1892	+	Mar 3/18	1171
	218	156	Sept 20/17	CPoletto	414831	12100 ± 1892	+		
	222	152	Sept 20/17	CPoletto	414831	12100 ± 1892	+		
2284	226	148	Sept 20/17	CPoletto	414831	12100 ± 1892	++	Jan 22/18	710
2312	230	144	Sept 20/17	CPoletto	414831	12100 ± 1892	+	Feb 27/18	595
2326	232	142	Sept 20/17	CPoletto	414831	12100 ± 1892	+++	Feb 27/18	619
2340	234	140	Sept 20/17	CPoletto	414831	12100 ± 1892	++	Feb 26/18	600
2368	238	136	Feb 7/17	CPoletto	483216	18583 ± 1708	+	Jan 18/18	635
2396	242	132	Sept 20/17	CPoletto	414831	12100 ± 1892	+	Mar 24/18	999
	246	128	Mar 31/17	CPoletto	483216	18583 ± 1708	+		
2452	250	124	Sept 20/17	CPoletto	414831	12100 ± 1892	+	Mar 4/18	671
	254	120	Mar 23/17	CPoletto	483216	18583 ± 1708	+		
	258	116	Sep 19/17	CPoletto	414831	12100 ± 1892	+/++		
2536	262	112	Jan 17/17	CPoletto	483216	18583 ± 1708	++	Mar 23/18	648
	266	108	Sep 19/17	CPoletto	414831	12100 ± 1892	++		
2592	270	104	Feb 7/17	CPoletto	483216	18583 ± 1708	+	Feb 28/18	610
	274	100	Sep 19/17	CPoletto	414831	12100 ± 1892	+		
2648	278	96	Apr 19/17	CPoletto	483216	18583 ± 1708	++	Mar 7/18	562
2676	282	92	Jan 17/17	CPoletto	483216	18583 ± 1708	++	Mar 21/18	826
2704	286	88	Sep 19/17	CPoletto	414831	12100 ± 1892	++	Mar 12/18	692
	290	84	Mar 23/17	CPoletto	483216	18583 ± 1708	+		
2760	294	80	Sep 19/17	CPoletto	414831	12100 ± 1892	+	Feb 22/18	562
	298	76	Apr 19/17	CPoletto	483216	18583 ± 1708	+		
2823	303	71	Feb 7/17	CPoletto	483216	18583 ± 1708	++	Mar 22/18	957
2837	305	69	Mar 23/17	CPoletto	483216	18583 ± 1708	++	Feb 28/18	575
2851	307	67	Mar 31/17	CPoletto	483216	18583 ± 1708	+	Mar 2/18	564
2858	308	66	Apr 24/17	CPoletto	483216	18583 ± 1708	+	Feb 6/18	567
2865	309	65	Apr 19/17	CPoletto	483216	18583 ± 1708	++	Mar 1/18	557
2872	310	64	Jan 17/17	CPoletto	483216	18583 ± 1708	+	Mar 20/18	820
	314	60	Apr 19/17	CPoletto	483216	18583 ± 1708	+		
2928	318	56	Sep 19/17	CPoletto	414831	12100 ± 1892	+	Feb 8/18	757
	322	52	Apr 24/17	CPoletto	483216	18583 ± 1708	+		
	326	48	Sep 19/17	CPoletto	414831	12100 ± 1892	++		
3012	330	44	Feb 7/17	CPoletto	483216	18583 ± 1708	+	Mar 19/18	811
	334	40	Sep 19/17	CPoletto	414831	12100 ± 1892	+		
	338	36	Mar 31/17	CPoletto	483216	18583 ± 1708	++		
3096	342	32	Sep 15/17	CPoletto	414831	12100 ± 1892	+	Feb 9/18	567
	346	28	Mar 23/17	CPoletto	483216	18583 ± 1708	+		
3152	350	24	Sep 15/17	CPoletto	414831	12100 ± 1892	+	Mar 22/18	605
	354	20	Mar 31/17	CPoletto	483216	18583 ± 1708	+		
	358	16	Sep 15/17	CPoletto	414831	12100 ± 1892	++		
	362	12	Sep 15/17	CPoletto	414831	12100 ± 1892	+		
3264	366	8	Jan 17/17	CPoletto	483216	18583 ± 1708	+	Feb 6/18	597
3292	370	4	Sep 15/17	CPoletto	414831	12100 ± 1892	+	Dec 5/18	636

Appendix B – Macrofossil Raw Data

Orig. Samp #	Full sample #	Entity #	Depth (cmFB)	Specimen Nature	Specimen	Quantity	Notes
F1RCP - 01	0001	0001	0-2	Macrofossil	Invertebrate fragment	1	
F1RCP - 04	0002	0001	6-8	Macrobotanical	plant fragments	1	
F1RCP - 07	0003	0003	12-14	Macrobotanical	gametophyte from byrophyte	1	
F1RCP - 08	0004	0001	14-16	Gastropod	mollousc fragments	7	
F1RCP - 08	0004	0002	14-16	Macrobotanical	Pinus sp. needle	1	accidentally broke in 2 pieces
F1RCP - 08	0004	0003	14-16	Gastropod	Gyraulus parvus	1	
F1RCP - 08	0004	0004	14-16	Macrobotanical	plant fragments	2	
F1RCP - 08	0004	0005	14-16	Pelecypoda	cf. Pisidium nitidum	2	
F1RCP - 08	0004	0006	14-16	Macrobotanical	gametophyte from byrophyte	13	
F1RCP - 09	0005	0001	16-18	Gastropod	mollousc fragments	4	
F1RCP - 09	0005	0002	16-18	Gastropod	Physa sp.	1	
F1RCP - 09	0005	0003	16-18	Gastropod	Physa cf. jennessi skinneri	1	
F1RCP - 10	0006	0001	18-20	Macrobotanical	Picea sp. needle	1	middle shaft
F1RCP - 10	0006	0002	18-20	Macrobotanical	leaf fragments	3	
F1RCP - 11	0007	0001	20-22	Gastropod	mollousc fragments	3	
F1RCP - 11	0007	0002	20-22	Gastropod	Fossaria cf. modicella	1	
F1RCP - 11	0007	0003	20-22	Gastropod	Physa sp.	1	Juvenile - broked
F1RCP - 11	0007	0004	20-22	Gastropod	Gyraulus circumstriatus	1	possible juvenile
F1RCP - 11	0007	0005	20-22	Macrobotanical	Grass node	1	
F1RCP - 11	0007	0006	20-22	Macrobotanical	plant fragments	2	
F1RCP - 11	0007	0007	20-22	Macrobotanical	gametophyte from byrophyte	6	
F1RCP - 12	0008	0001	22-24	Gastropod	mollousc fragments	3	
F1RCP - 12	0008	0002	22-24	Macrobotanical	Pinaceae wing	1	
F1RCP - 12	0008	0003	22-24	Gastropod	Promenetus exacuous exacuous	1	
F1RCP - 12	0008	0004	22-24	Gastropod	Gyraulus circumstriatus	1	
F1RCP - 12	0008	0005	22-24	Gastropod	Gyraulus crista	1	
F1RCP - 12	0008	0006	22-24	Macrobotanical	Cyperaceae seed	1	
F1RCP - 12	0008	0007	22-24	Macrobotanical	seed case fragment	1	
F1RCP - 12	0008	0008	22-24	Macrobotanical	wood fragments	5	
F1RCP - 12	0008	0009	22-24	Macrobotanical	plant fragments	5	
F1RCP - 12	0008	0010	22-24	Macrobotanical	gametophyte from byrophyte	5	
F1RCP - 13	0009	0001	24-26	Gastropod	mollousc fragments	3	
F1RCP - 15	0010	0001	28-30	Gastropod	Gyraulus circumstriatus	1	
F1RCP - 15	0010	0002	28-30	Gastropod	Physa jennessi skinneri	1	
F1RCP - 16	0011	0001	30-32	Gastropod	Promenetus exacuous exacuous	1	
F1RCP - 16	0011	0002	30-32	Macrofossil	insect fragment	11	
F1RCP - 19	0012	0001	38-40	Gastropod	Planorbella cf. subrenata	1	
F1RCP - 19	0012	0002	38-40	Macrobotanical	plant fragments	1	
F1RCP - 19	0012	0003	38-40	Macrobotanical	Picea sp. needle	1	
F1RCP - 20	0013	0001	40-42	Gastropod	Gyraulus cf. deflectus	1	
F1RCP - 20	0013	0002	40-42	Macrobotanical	carbonized twig	1	
F1RCP - 20	0013	0003	40-42	Gastropod	Gyraulus crista	1	
F1RCP - 20	0013	0004	40-42	Macrobotanical	Picea sp. needle	1	
F1RCP - 20	0013	0005	40-42	Gastropod	mollousc fragments	1	
F1RCP - 20	0013	0006	40-42	Gastropod	Gyraulus parvus	1	
F1RCP - 22	0014	0001	42-44	Macrobotanical	bark from twig	1	
F1RCP - 24	0015	0001	46-48	Gastropod	Valvata tricarinata	1	juvenile - broken
F1RCP - 24	0015	0002	46-48	Macrobotanical	twig fragment	1	
F1RCP - 24	0015	0003	46-48	Gastropod	Gyraulus parvus	1	
F1RCP - 25	0016	0001	48-50	Gastropod	Gyraulus cf parvus	1	
F1RCP - 26	0017	0001	50-52	Gastropod	Promenetus exacuous	1	
F1RCP - 26	0017	0002	50-52	Macrofossil	invertebrate fragment	2	strange pattern on one entity
F1RCP - 26	0017	0003	50-52	Gastropod	Promenetus exacuous	1	
F1RCP - 27	0018	0001	52-54	Gastropod	mollousc fragments	1	
F1RCP - 27	0018	0002	52-54	Macrofossil	insect fragment	1	
F1RCP - 28	0019	0001	264-266	Gastropod	Physa gyrina gyrina	1	
F1RCP - 28	0019	0002	264-266	Macrobotanical	twig fragments	2	
F1RCP - 28	0019	0003	264-266	Gastropod	Gyraulus cf parvus	1	
F1RCP - 28	0019	0004	264-266	Macrofossil	invertebrate fragment	1	
F1RCP - 29	0020	0001	266-268	Gastropod	mollousc fragments	2	
F1RCP - 29	0020	0002	266-268	Gastropod	Gyraulus parvus	1	
F1RCP - 29	0020	0003	266-268	Gastropod	cf. Physa sp.	1	

Orig. Samp #	Full sample #	Entity #	Depth (cmFB)	Specimen Nature	Specimen	Quantity	Notes
F1RCP - 29	0020	0004	266-268	Macrofossil	invertebrate fragment	2	femur?
F1RCP - 30	0021	0001	268-270	Gastropod	Gyraulus parvus	1	
F1RCP - 31	0022	0001	270-272	Macrobotanical	gametophyte from byrophyte	1	
F1RCP - 31	0022	0002	270-272	Macrobotanical	bark fragment	2	
F1RCP - 31	0022	0003	270-272	Macrobotanical	twig fragments	2	
F1RCP - 31	0022	0004	270-272	Macrobotanical	plant fragments	5	
F1RCP - 32	0023	0001	272-274	Macrobotanical	plant fragments	3	
F1RCP - 32	0023	0002	272-274	Macrobotanical	plant fragments - grass?	1	
F1RCP - 32	0023	0003	272-274	Macrobotanical	twig fragment	1	
F1RCP - 33	0024	0001	274-276	Macrobotanical	plant fragments	2	
F1RCP - 33	0024	0002	274-276	Gastropod	mollousc fragments	1	
F1RCP - 33	0024	0003	274-276	Macrofossil	invertebrate fragment	1	
F1RCP - 34	0025	0001	276-278	Gastropod	mollousc fragments	9	
F1RCP - 34	0025	0002	276-278	Gastropod	Gyraulus parvus	1	
F1RCP - 34	0025	0003	276-278	Gastropod	Gyraulus parvus	1	
F1RCP - 34	0025	0004	276-278	Gastropod	Physa cf. jennessi skinneri	1	slightly inflated body whorl
F1RCP - 34	0025	0005	276-278	Macrofossil	Invertebrate fragment	1	
F1RCP - 35	0026	0001	278-280	Macrobotanical	gametophyte from byrophyte	2	
F1RCP - 35	0026	0002	278-280	Macrobotanical	twig fragments	3	
F1RCP - 35	0026	0003	278-280	Macrobotanical	charcoal fragments	2	
F1RCP - 35	0026	0004	278-280	Macrobotanical	wood fragments	2	
F1RCP - 35	0026	0005	278-280	Macrobotanical	plant fragments	2	
F1RCP - 35	0026	0006	278-280	Macrofossil	invertebrate fragment	3	tentative for one
F1RCP - 35	0026	0007	278-280	Macrobotanical	Pinus sp. needle	2	
F1RCP - 37	0027	0001	282-284	Macrobotanical	wood fragments	1	
F1RCP - 37	0027	0002	282-284	Macrobotanical	gametophyte from byrophyte	2	
F1RCP - 37	0027	0003	282-284	Macrobotanical	plant fragments	2	
F1RCP - 41	0028	0001	290-292	Gastropod	Gyraulus parvus	1	
F1RCP - 41	0028	0002	290-292	Pelecypoda	bivalve fragment	1	
F1RCP - 41	0028	0003	290-292	Macrobotanical	Picea sp. needle	1	
F1RCP - 41	0028	0004	290-292	Macrobotanical	rootlet fragments	4	
F1RCP - 41	0028	0005	290-292	Macrobotanical	Pinus sp. needle	1	
F1RCP - 41	0028	0006	290-292	Macrobotanical	charcoal fragment	1	
F1RCP - 41	0028	0007	290-292	Macrobotanical	twig fragment	1	
F1RCP - 41	0028	0008	290-292	Macrofossil	insect fragment	1	
F1RCP - 45	0029	0001	298-300	Macrofossil	invertebrate fragment	1	
F1RCP - 45	0029	0002	298-300	Gastropod	Stagnicola elodes	1	
F1RCP - 45	0029	0003	298-300	Macrobotanical	twig fragment	1	
F1RCP - 45	0029	0004	298-300	Macrobotanical	rootlets	1	
F1RCP - 45	0029	0005	298-300	Gastropod	mollousc fragments	2	
F1RCP - 45	0029	0006	298-300	Macrobotanical	twig fragments	10	
F1RCP - 45	0029	0007	298-300	Pelecypoda	Pisidium cf. nitidium	1	
F1RCP - 45	0029	0008	298-300	Macrobotanical	bark from twig	1	
F1RCP - 45	0029	0009	298-300	Macrobotanical	plant fragments	12	
F1RCP - 45	0029	0010	298-300	Macrobotanical	wood fragments	1	
F1RCP - 49	0030	0001	308-310	Gastropod	Promenetus exacuous exacuous	1	
F1RCP - 50	0031	0001	310-312	Macrobotanical	plant fragments	4	
F1RCP - 50	0031	0002	310-312	Macrobotanical	Picea sp. needle	1	
F1RCP - 50	0031	0003	310-312	Macrobotanical	plant fragments - leaf blade?	1	
F1RCP - 50	0031	0004	310-312	Macrobotanical	plant fragments	5	
F1RCP - 50	0031	0005	310-312	Macrobotanical	Juncus sp. seed	1	
F1RCP - 51	0032	0001	312-314	Macrobotanical	plant/leaf fragments	5	
F1RCP - 51	0032	0002	312-314	Macrobotanical	wood fragments	12	
F1RCP - 51	0032	0003	312-314	Macrobotanical	gametophyte from byrophyte	1	
F1RCP - 51	0032	0004	312-314	Macrobotanical	plant fragments	3	
F1RCP - 51	0032	0005	312-314	Macrobotanical	rootlet fragments	12	
F1RCP - 52	0033	0001	314-316	Macrobotanical	Gametophyte from byrophyte	2	
F1RCP - 52	0033	0002	314-316	Pelecypoda	Pisidium sp.	2	
F1RCP - 52	0033	0003	314-316	Macrobotanical	rootlets	5	
F1RCP - 52	0033	0004	314-316	Gastropod	mollousc fragments	1	likely conical shell
F1RCP - 55	0034	0001	320-322	Gastropod	Stagnicola cf. elodes	1	apeture broken
F1RCP - 57	0035	0001	324-326	Gastropod	mollousc fragments	3	

Orig. Samp #	Full sample #	Entity #	Depth (cmFB)	Specimen Nature	Specimen	Quantity	Notes
F1RCP - 57	0035	0002	324-326	Gastropod	Promenetus exacuous exacuous	1	peeling
F1RCP - 57	0035	0003	324-326	Macrofossil	grass blades		
F1RCP - 58	0036	0001	326-328	Macrobotanical	Picea sp. needle	1	
F1RCP - 58	0036	0002	326-328	Macrobotanical	gametophyte from byrophyte	5	
F1RCP - 58	0036	0003	326-328	Macrobotanical	plant fragments	6	
F1RCP - 60	0037	0001	330-332	Macrobotanical	wood / bark fragments	3	
F1RCP - 63	0038	0001	336-338	Macrobotanical	plant fragments	8	
F1RCP - 68	0039	0001	346-348	Macrobotanical	rootlets	2	
F1RCP - 68	0039	0002	346-348	Pelecypoda	Pisidium cf. (Cyclocalyx) rotundaturm	1	
F1RCP - 68	0039	0003	346-348	Macrofossil	insect femus	1	
F1RCP - 68	0039	0004	346-348	Pelecypoda	Pisidium sp.	1	
F1RCP - 68	0039	0005	346-348	Macrobotanical	grass blade	1	
F1RCP - 68	0039	0006	346-348	Gastropod	Gyraulus parvus	3	
F1RCP - 68	0039	0007	346-348	Macrobotanical	plant fragments	6	
F1RCP - 71	0040	0001	352-354	Gastropod	mollousc fragments	5	
F1RCP - 71	0040	0002	352-354	Macrobotanical	gametophyte from byrophyte	1	
F1RCP - 71	0040	0003	352-354	Gastropod	Physa gyrina gyrina	1	
F1RCP - 71	0040	0004	352-354	Gastropod	Helisoma cf. (Piersoma) trivolvis subrenatum	2	broken
F1RCP - 71	0040	0005	352-354	Gastropod	Gyraulus cf. parvus	2	
F1RCP - 71	0040	0006	352-354	Pelecypoda	Sphaerium sp.	1	
F1RCP - 71	0040	0007	352-354	Gastropod	Promenetus exacuous exacuous	1	
F1RCP - 71	0040	0008	352-354	Gastropod	Promenetus cf. umbilicatellus	1	
F1RCP - 71	0040	0009	352-354	Gastropod	incomplete Planorbaceae	1	
F1RCP - 71	0040	0010	352-354	Macrofossil	invertebrate fragment	4	
F1RCP - 71	0040	0011	352-354	Macrobotanical	plant fragments	3	
F1RCP - 71	0040	0012	352-354	Macrobotanical	grass blades	2	
F1RCP - 71	0040	0013	352-354	Macrobotanical	bark fragment	1	
F1RCP - 75	0041	0001	360-362	Gastropod	Planorbella cf. subrenata	1	apeture and portion of body whorl missing
F1RCP - 75	0041	0002	360-362	Gastropod	Gyraulus parvus	4	
F1RCP - 75	0041	0003	360-362	Gastropod	Valvata tricarinata	1	
F1RCP - 75	0041	0004	360-362	Gastropod	Physa skinneri	1	
F1RCP - 75	0041	0005	360-362	Gastropod	mollousc fragments	13	
F1RCP - 75	0041	0006	360-362	Macrobotanical	plant fragments	3	
F1RCP - 75	0041	0007	360-362	Macrobotanical	seed case fragments	2	
F1RCP - 75	0041	0008	360-362	Macrobotanical	gametophyte from byrophyte	2	
F1RCP - 75	0041	0009	360-362	Macrobotanical	Helisoma sp.	5	broken.
F1RCP - 80	0042	0001	370-372	Macrobotanical	twig fragment	1	
F1RCP - 80	0042	0002	370-372	Macrobotanical	plant fragments	3	
F1RCP - 80	0042	0003	370-372	Pelecypoda	mollousc fragments	1	bivalve fragment
F1RCP - 80	0042	0004	370-372	Macrobotanical	charcoal fragment	1	
F1RCP - 80	0042	0005	370-372	Macrobotanical	plant fragments	3	
F1RCP - 80	0042	0006	370-372	Macrobotanical	gametophyte from byrophyte	1	
F1RCP - 356	0043	0001	356	Gastropod	Planorbella cf. subrenata	1	small fragment missing from whorl
F1RCP - 357	0044	0001	357	Macrobotanical	Nuphar cf. lutea seed	1	
F1RCP - F1-A	0045	0001	237	Gastropod	mollousc fragments	1	
F1RCP - F1-A	0045	0002	237	Gastropod	Stagnicola elodes	1	
F1RCP - F1-B	0046	0001	177	Pelecypoda	Sphaerium sp.	2	single specimen
F1RCP - F1-C	0047	0001	181	Gastropod	mollousc fragments		
F1RCP - F1-D	0048	0001	276	Gastropod	Stagnicola exilis	1	
F1RCP - F1-E	0049	0001	327	Gastropod	Stagnicola elodes	1	broken
F1RCP - F1-F	0050	0001	386	Gastropod	Stagnicola exilis	1	
F1RCP - F1-G	0051	0001	364	Gastropod	mollousc fragments	3	
F1RCP - F1-H	0052	0001	82	Pelecypoda	Pisidium lilljeborjoi	1	
SBF1-2	0053	0001	283	Macrobotanical	wood fragments	2	Orig. Sample # different because of submission for C14
F1RCP-364	0054	0001	364	Gastropod	Physa gyrina gyrina	1	

Appendix C – Loss-On-Ignition Raw Data

Date	Crucible #	Crucible weight (g)	Sample Added (cmFB)	Sample amount	Wet weight (g)	Sample weight (g)	Dry temp and time	Dry weight (with cruicible) (g)	Dry weight (no cruicible) (g)	LOI Organic Dry temp and time	LOI - O Dry weight (g)	Dry weight (no cruicible) (g)	LOI 550 (Organic) %DW	LOI Carbonate Dry temp and time	LOI - C Dry weight (g)	Dry weight (no cruicible) (g)	LOI 950 (Carbonate) %DW	Comments
Oct 17-19/17	6	3.9637	372	1cc	4.8289	0.8652	24h at 105C	4.0494	0.0857	4hr at 550	4.0078	0.0441	48.541424	2hr at 950	4.0036	0.0399	4.9008168	
Oct 17-19/17	5	4.1555	368	1cc	4.971	0.8155	24h at 105C	4.3534	0.1979	4hr at 550	4.2699	0.1144	42.193027	2hr at 950	4.2591	0.1036	5.4573017	
Oct 2&3/17	30	4.0839	364	1cc	5.1922	1.1083	24h at 105C	4.314	0.2301	4hr at 550	4.219	0.1351	41.286397					
Oct 2&3/17	28	4.5435	360	1cc	6.037	1.4935	24h at 105C	5.129	0.5855	4hr at 550	4.9471	0.4036	31.067464					
Oct 2&3/17	23	3.8752	356	1cc	4.8842	1.0090	24h at 105C	4.0628	0.1876	4hr at 550	3.9751	0.0999	46.748401					
Oct 2&3/17	22	3.8997	352	1cc	4.6169	0.7172	24h at 105C	3.9939	0.0942	4hr at 550	3.9444	0.0447	52.547771					
Oct 17-19/17	4	4.1198	348	1cc	4.8918	0.7720	24h at 105C	4.1947	0.0749	4hr at 550	4.1543	0.0345	53.938585	2hr at 950	4.1495	0.0297	6.4085447	
Oct 2&3/17	21	4.1673	344	1cc	4.9489	0.7816	24h at 105C	4.2996	0.1323	4hr at 550	4.2393	0.072	45.578231					
Oct 2&3/17	20	3.9613	340	1cc	5.9326	1.9713	24h at 105C	4.3895	0.4282	4hr at 550	4.2033	0.242	43.484353					
Oct 2&3/17	19	5.0691	336	1cc	5.7402	0.6711	24h at 105C	5.1456	0.0765	4hr at 550	5.1075	0.0384	49.803922					Sample spilled a bit when transferring into vial after LOI analysis
Oct 2&3/17	15	5.2267	332	1cc	6.4335	1.2068	24h at 105C	5.4485	0.2218	4hr at 550	5.3509	0.1242	44.003607					
Oct 17-19/17	3	4.173	328	1cc	5.657	1.4840	24h at 105C	4.4412	0.2682	4hr at 550	4.3216	0.1486	44.593587	2hr at 950	4.3038	0.1308	6.6368382	
Oct 2&3/17	14	4.1359	324	1cc	4.9783	0.8424	24h at 105C	4.2136	0.0777	4hr at 550	4.1803	0.0444	42.857143					
Oct 2&3/17	12	4.2063	320	1cc	4.9294	0.7231	24h at 105C	4.2987	0.0924	4hr at 550	4.2557	0.0494	46.536797					
Oct 2&3/17	11	3.9091	316	1cc	4.3766	0.4675	24h at 105C	3.9814	0.0723	4hr at 550	3.9477	0.0386	46.611342					
Oct 17-19/17	2	5.3245	312	1cc	5.9376	0.6131	24h at 105C	5.4239	0.0994	4hr at 550	5.382	0.0575	42.152918	2hr at 950	5.3775	0.053	4.527163	
Oct 2&3/17	10	3.6796	308	1cc	4.7498	1.0702	24h at 105C	3.8713	0.1917	4hr at 550	3.7815	0.1019	46.844027					
Oct 2&3/17	9	4.9104	304	1cc	6.2369	1.3265	24h at 105C	5.0758	0.1654	4hr at 550	4.991	0.0806	51.269649					
Oct 2&3/17	8	4.3781	300	1cc	6.1184	1.7403	24h at 105C	4.5031	0.1250	4hr at 550	4.4255	0.0474	62.08	2hr at 950				
Oct 17-19/17	11	3.9091	300	1cc			24h at 105C	4.5031	0.5940	4hr at 550	3.9547	0.0451		2hr at 950	3.9445	0.0354	1.6329966	dry weight - 3.9547. Sample tipped over and lost some material. tried to collect as much as possible
Oct 2&3/17	7	5.0016	296	1cc	5.8359	0.8343	24h at 105C	5.1339	0.1323	4hr at 550	5.0759	0.0743	43.839758					
Oct 2&3/17	6	3.9637	292	1cc	4.7472	0.7835	24h at 105C	4.0514	0.0877	4hr at 550	4.0162	0.0525	40.13683					
Oct 17-19/17	I	4.2548	288	1cc	5.2483	0.9935	24h at 105C	4.373	0.1182	4hr at 550	4.3241	0.0693	41.370558	2hr at 950	4.3173	0.0625	5.7529611	
Oct 2&3/17	5	4.1555	284	1cc	5.1093	0.9538	24h at 105C	4.2356	0.0801	4hr at 550	4.1969	0.0414	48.314607					
Oct 2&3/17	4	4.1197	280	1cc	5.1418	1.0221	24h at 105C	4.2717	0.1520	4hr at 550	4.2101	0.0904	40.526316					
Oct 2&3/17	3	4.1733	276	1cc	5.2134	1.0401	24h at 105C	4.2965	0.1232	4hr at 550	4.2389	0.0656	46.753247					
Oct 2&3/17	2	5.3248	272	1cc	6.3393	1.0145	24h at 105C	5.4845	0.1597	4hr at 550	5.4035	0.0787	50.7201					
Sept 28&29/17	I	4.255	268	1cc	5.1597	0.9047	24h at 105C	4.3974	0.1424	4hr at 550	4.3253	0.0703	50.632022					
Sept 28&29/17	E	4.9074	266	1cc	5.8884	0.9810	24h at 105C	5.0361	0.1287	4hr at 550	4.9696	0.0622	51.670552					
Oct 17-19/17	E	4.9074	264	1cc	5.7789	0.8715	24h at 105C	5.0451	0.1377	4hr at 550	4.9733	0.0659	52.142338	2hr at 950	4.968	0.0606	3.848947	
Sept 28&29/17	D	4.5278	260	1cc	5.7869	1.2591	24h at 105C	4.7235	0.1957	4hr at 550	4.6352	0.1074	45.120082					
Sept 28&29/17	40	4.9241	256	1cc	5.9818	1.0577	24h at 105C	5.0931	0.1690	4hr at 550	5.0159	0.0918	45.680473					
Oct 17-19/17	D	4.5276	252	1cc	5.5954	1.0678	24h at 105C	4.7241	0.1965	4hr at 550	4.6312	0.1036	47.277354	2hr at 950	4.6181	0.0905	6.6666667	
Sept 28&29/17	39	5.2916	248	1cc	6.4757	1.1841	24h at 105C	5.4558	0.1642	4hr at 550	5.3818	0.0902	45.066991					
Sept 28&29/17	38	4.1152	244	1cc	5.1241	1.0089	24h at 105C	4.3143	0.1991	4hr at 550	4.2386	0.1234	38.021095					
Sept 28&29/17	37	5.2793	240	1cc	6.6633	1.3840	24h at 105C	5.5305	0.2512	4hr at 550	5.4157	0.1364	45.700637					
Sept 28&29/17	36	4.1296	236	1cc	5.4652	1.3356	24h at 105C	4.3955	0.2659	4hr at 550	4.2831	0.1535	42.271531					
Oct 17-19/17	40	4.9241	232	1cc	5.9205	0.9964	24h at 105C	5.1258	0.2017	4hr at 550	5.0476	0.1235	38.770451	2hr at 950	5.0358	0.1117	5.8502727	
Oct 17-19/17	39	5.2914	228	1cc	6.8281	1.5367	24h at 105C	5.4829	0.1915	4hr at 550	5.4129	0.1215	36.553525	2hr at 950	5.4011	0.1097	6.1618799	bright pink/red colour. photos taken
Oct 17-19/17	38	4.1151	224	1cc	5.5261	1.4110	24h at 105C	4.3451	0.2300	4hr at 550	4.2364	0.1213	47.26087	2hr at 950	4.2177	0.1026	8.1304348	
Sept 28&29/17	35	4.1719	220	1cc	5.1537	0.9818	24h at 105C	4.3617	0.1898	4hr at 550	4.2701	0.0982	48.261328					
Sept 28&29/17	33	4.168	216	1cc	5.6134	1.4454	24h at 105C	4.4195	0.2515	4hr at 550	4.3028	0.1348	46.40159					
Sept 28&29/17	32	4.0179	212	1cc	5.1811	1.1632	24h at 105C	4.2164	0.1985	4hr at 550	4.129	0.1111	44.030227					
Oct 17-19/17	37	5.2794	208	1cc	6.6084	1.3290	24h at 105C	5.4944	0.2150	4hr at 550	5.4019	0.1225	43.023256	2hr at 950	5.3792	0.0998	10.55814	
Sept 28&29/17	30	4.0841	204	1cc	5.2410	1.1569	24h at 105C	4.2954	0.2113	4hr at 550	4.2103	0.1262	40.274491					
Sept 28&29/17	28	4.5435	200	1cc	5.3993	0.8558	24h at 105C	4.7608	0.2173	4hr at 550	4.6683	0.1248	42.567879					
Sept 28&29/17	23	3.8751	196	1cc	5.6846	1.8095	24h at 105C	4.1573	0.2822	4hr at 550	4.0534	0.1783	36.81786					
Sept 28&29/17	22	3.8998	192	1cc	5.2948	1.3950	24h at 105C	4.1760	0.2762	4hr at 550	4.0629	0.1631	40.948588					
Oct 17-19/17	36	4.1298	188	1cc	4.9339	0.8041	24h at 105C	4.2361	0.1063	4hr at 550	4.177	0.0472	55.597366	2hr at 950	4.164	0.0342	12.229539	
Sept 28&29/17	21	4.1675	184	1cc	5.1608	0.9933	24h at 105C	4.3752	0.2077	4hr at 550	4.3108	0.1433	31.006259					
Sept 28&29/17	20	3.9616	180	1cc	5.0754	1.1138	24h at 105C	4.2097	0.2481	4hr at 550	4.1474	0.1858	25.110842					
Sept 28&29/17	19	5.0692	176	1cc	6.4421	1.3729	24h at 105C	5.3461	0.2769	4hr at 550	5.2533	0.1841	33.513904					

Date	Crucible #	Crucible weight (g)	Sample Added (cmFB)	Sample amount	Wet weight (g)	Sample weight (g)	Dry temp and time	Dry weight (with cruicible) (g)	Dry weight (no cruicible) (g)	LOI Organic Dry temp and time	LOI - O Dry weight (g)	Dry weight (no cruicible) (g)	LOI 550 (Organic) %DW	LOI Carbonate Dry temp and time	LOI - C Dry weight (g)	Dry weight (no cruicible) (g)	LOI 950 (Carbonate) %DW	Comments
ept 28&29/17	15	5.227	172	1cc	6.1639	0.9369	24h at 105C	5.4061	0.1791	4hr at 550	5.3433	0.1163	35.06421					
Oct 17-19/17	35	4.1713	168	1cc	5.3015	1.1302	24h at 105C	4.3823	0.2110	4hr at 550	4.3122	0.1409	33.222749	2hr at 950	4.284	0.1127	13.364929	
ept 28&29/17	14	4.1363	164	1cc	5.2482	1.1119	24h at 105C	4.3707	0.2344	4hr at 550	4.2958	0.1595	31.953925					
ept 28&29/17	12	4.2063	160	1cc	5.3961	1.1898	24h at 105C	4.4498	0.2435	4hr at 550	4.3495	0.1432	41.190965					
ept 28&29/17	11	3.9092	156	1cc	5.0932	1.1840	24h at 105C	4.1473	0.2381	4hr at 550	4.0659	0.1567	34.187316					
ept 28&29/17	10	3.6886	152	1cc	5.1215	1.4329	24h at 105C	3.9471	0.2585	4hr at 550	3.8093	0.1207	53.307544					
Oct 17-19/17	33	4.1681	148	1cc	5.3508	1.1827	24h at 105C	4.4081	0.2400	4hr at 550	4.3248	0.1567	34.708333	2hr at 950	4.2808	0.1127	18.333333	
ept 28&29/17	9	4.9104	144	1cc	5.9842	1.0738	24h at 105C	5.1228	0.2124	4hr at 550	5.0494	0.139	34.557439	2hr at 950				
Oct 17-19/17	9	4.9103	144	1cc			24h at 105C	5.1228	0.2125	4hr at 550	5.0471	0.1368		2hr at 950	5.0109	0.1006	17.035294	
ept 28&29/17	8	4.3788	142	1cc	5.9188	1.5400	24h at 105C	4.9969	0.6181	4hr at 550	4.9109	0.5321	13.913606	2hr at 950				tipped over, about .02g lost but then collected/recovered
Oct 17-19/17	8	4.3782	142	1cc			24h at 105C	4.9969	0.6187	4hr at 550	4.9	0.5218		2hr at 950	4.8151	0.4369	13.722321	tipped over, about .02g lost but then collected/recovered
ept 28&29/17	7	5.0014	140	1cc	6.3074	1.3060	24h at 105C	5.4489	0.4475	4hr at 550	5.4066	0.4052	9.452514	2hr at 950				look under microscope
Oct 17-19/17	7	5.0016	140	1cc			24h at 105C	5.4489	0.4473	4hr at 550	5.3987	0.3971		2hr at 950	5.3608	0.3592	8.4730606	look under microscope
ept 28&29/17	6	3.9735	136	1cc	5.2422	1.2687	24h at 105C	4.1587	0.1852	4hr at 550	4.0565	0.083	55.183585					
Oct 17-19/17	32	4.0182	132	1cc	5.525	1.5068	24h at 105C	4.2484	0.2302	4hr at 550	4.1229	0.1047	54.517811	2hr at 950	4.1074	0.0892	6.7332754	
ept 28&29/17	5	4.1563	128	1cc	5.4804	1.3241	24h at 105C	4.3754	0.2191	4hr at 550	4.2599	0.1036	52.715655					
ept 28&29/17	4	4.1233	124	1cc	5.2091	1.0858	24h at 105C	4.2676	0.1443	4hr at 550	4.1721	0.0488	66.181566					
ept 28&29/17	3	4.1738	120	1cc	5.4286	1.2548	24h at 105C	4.3573	0.1835	4hr at 550	4.2525	0.0787	57.111717					
ept 28&29/17	2	5.3248	116	1cc	6.7449	1.4201	24h at 105C	5.5777	0.2529	4hr at 550	5.443	0.1182	53.262159					
ept 25&26/17	39	5.2914	112	1cc	6.5807	1.2893	24h at 105C	5.5541	0.2627	4hr at 550	5.4331	0.1417	46.060145	2hr at 950	5.4258	0.1344	2.7788352	
ept 25&26/17	I	4.2548	108	1cc	5.4440	1.1892	24h at 105C	4.4854	0.2306	4hr at 550	4.3734	0.1186	48.568951					
ept 25&26/17	E	4.9076	104	1cc	5.8188	0.9112	24h at 105C	5.0598	0.1522	4hr at 550	4.9924	0.0848	44.283837					
ept 25&26/17	D	4.5276	100	1cc	5.6338	1.1062	24h at 105C	4.7212	0.1936	4hr at 550	4.6239	0.0963	50.258264					
ept 25&26/17	40	4.924	96	1cc	6.1779	1.2539	24h at 105C	5.1728	0.2488	4hr at 550	5.063	0.139	44.131833	2hr at 950	5.0503	0.1263	5.1045016	
ept 25&26/17	38	4.1153	92	1cc	5.2565	1.1412	24h at 105C	4.3843	0.2690	4hr at 550	4.2631	0.1478	45.055762	2hr at 950	4.2532	0.1379	3.6802974	
ept 25&26/17	37	5.2794	88	1cc	6.5281	1.2487	24h at 105C	5.5588	0.2794	4hr at 550	5.4393	0.1599	42.770222	2hr at 950	5.4311	0.1517	2.9348604	
ept 25&26/17	36	4.1301	84	1cc	5.5433	1.4132	24h at 105C	4.4247	0.2946	4hr at 550	4.2813	0.1512	48.676171					
ept 25&26/17	35	4.1718	80	1cc	5.4713	1.2995	24h at 105C	4.3846	0.2128	4hr at 550	4.2661	0.0943	55.68609					
ept 25&26/17	33	4.1683	76	1cc	4.9272	0.7589	24h at 105C	4.2743	0.1060	4hr at 550	4.2254	0.0571	46.132075					
ept 25&26/17	32	4.018	71	1cc	5.3257	1.3077	24h at 105C	4.3805	0.3625	4hr at 550	4.2534	0.2354	35.062069	2hr at 950	4.245	0.227	2.3172414	
ept 25&26/17	30	4.084	69	1cc	5.5274	1.4434	24h at 105C	4.5898	0.5058	4hr at 550	4.4275	0.3435	32.087782	2hr at 950	4.4166	0.3326	2.155002	deep purple colour
ept 25&26/17	28	4.5434	67	1cc	5.7033	1.1599	24h at 105C	4.8499	0.3065	4hr at 550	4.7452	0.2018	34.159869	2hr at 950	4.7364	0.193	2.8711256	
ept 25&26/17	23	3.875	66	1cc	5.0917	1.2167	24h at 105C	4.1588	0.2838	4hr at 550	4.0565	0.1815	36.046512	2hr at 950	4.044	0.169	4.4045102	white material?
ept 25&26/17	22	3.8995	65	1cc	4.9095	1.0100	24h at 105C	4.1296	0.2301	4hr at 550	4.0449	0.1454	36.810083	2hr at 950	4.03	0.1305	6.4754455	
ept 25&26/17	21	4.1672	64	1cc	5.3278	1.1606	24h at 105C	4.3936	0.2264	4hr at 550	4.3088	0.1416	37.45583	2hr at 950	4.2896	0.1224	8.4805654	
ept 25&26/17	20	4.2463	60	1cc	5.3528	1.1065	24h at 105C	4.4679	0.2216	4hr at 550	4.3744	0.1281	42.193141					
ept 25&26/17	19	5.0691	56	1cc	6.1888	1.1197	24h at 105C	5.2826	0.2135	4hr at 550	5.1885	0.1194	44.074941					
ept 25&26/17	15	5.2265	52	1cc	6.6273	1.4008	24h at 105C	5.4908	0.2643	4hr at 550	5.3642	0.1377	47.900114					
ept 25&26/17	14	4.1357	48	1cc	4.9277	0.7920	24h at 105C	4.3036	0.1679	4hr at 550	4.2264	0.0907	45.97975					
ept 25&26/17	12	4.2064	44	1cc	5.1346	0.9282	24h at 105C	4.4164	0.2100	4hr at 550	4.3195	0.1131	46.142857	2hr at 950	4.305	0.0986	6.9047619	
ept 25&26/17	11	3.909	40	1cc	4.7965	0.8875	24h at 105C	4.0829	0.1739	4hr at 550	3.9926	0.0836	51.926394					
ept 25&26/17	10	3.6794	36	1cc	4.8208	1.1414	24h at 105C	3.9286	0.2492	4hr at 550	3.8252	0.1458	41.492777					
ept 25&26/17	9	5.001	32	1cc	5.9788	0.9778	24h at 105C	5.1698	0.1688	4hr at 550	5.0541	0.0531	68.542654					
ept 25&26/17	8	4.3778	28	1cc	5.8868	1.5090	24h at 105C	4.7210	0.3432	4hr at 550	4.5775	0.1997	41.812354					
ept 25&26/17	7	4.9099	24	1cc	6.1371	1.2272	24h at 105C	5.2536	0.3437	4hr at 550	5.1453	0.2354	31.510038	2hr at 950	5.1244	0.2145	6.0808845	
ept 25&26/17	6	3.9632	20	1cc	5.1185	1.1553	24h at 105C	4.1691	0.2059	4hr at 550	4.063	0.0998	51.529869					
ept 25&26/17	5	4.1556	16	1cc	5.2639	1.1083	24h at 105C	4.4329	0.2773	4hr at 550	4.3087	0.1531	44.789037					
ept 25&26/17	4	4.1195	12	1cc	5.5788	1.4593	24h at 105C	4.4174	0.2979	4hr at 550	4.2896	0.1701	42.900302					
ept 25&26/17	3	4.1731	8	1cc	5.6081	1.4350	24h at 105C	4.4822	0.3091	4hr at 550	4.3564	0.1833	40.698803					
ept 25&26/17	2	5.3243	4	1cc	6.4627	1.1384	24h at 105C	5.5456	0.2213	4hr at 550	5.4503	0.126	43.063714	2hr at 950	5.4276	0.1033	10.257569	

Scale Used	FisherScientific accuSeries accu-124
Drying Oven	Blue M Stabil-Therm Gravity Oven
LOI oven	ThermoLyne 62700 Furnace

Appendix D – Radiocarbon Lab Results

University of California Irvine Keck Radiocarbon Lab Results

Note: Soxhlet pre-treatment occurred at the University of Alberta by the Earth and Atmospheric Sciences Department. Blanks / standards were processed with each batch and underwent Soxhlet pre-treatment as well and are listed in italics below the dated sample from the radiocarbon batch.

UCIAMS #	Sample Name	$d^{13}C$ (‰)	±	fraction Modern	±	$D^{14}C$ (‰)	±	^{14}C age (BP)	±
187142	**FIRCP-001**			**0.6613**	**0.0010**	**-338.7**	**1.0**	**3320**	**15**
187143	*FIRI-F-Sox. (standard)*			*0.5686*	*0.0010*	*-431.4*	*1.0*	*4535*	*15*
187144	*AVR07-PAL-37-Sox. (standard)*			*0.0023*	*0.0001*	*-997.7*	*0.1*	*48900*	*210*
197746	**SBF1-2**			**0.8486**	**0.0017**	**-151.4**	**1.7**	**1320**	**20**
197737	*AVR-07-PAL-37 SX (standard)*			*0.0030*	*0.0001*	*-997.0*	*0.1*	*46580*	*220*
197748	*FIRI-F SX (standard)*			*0.5681*	*0.0012*	*-431.9*	*1.2*	*4545*	*20*

Radiocarbon concentrations are given as fractions of the Modern standard, $D^{14}C$, and conventional radiocarbon age, following the conventions of Stuiver and Polach (Radiocarbon, n. 19, p.355, 1977).

Sample preparation backgrounds have been subtracted, based on measurements of ^{14}C-free wood (organics) and bone (collagen).

All results have been corrected for isotopic fractionation according to the conventions of Stuiver and Polach (1977), with $\delta^{13}C$ values measured on prepared graphite using the AMS spectrometer. These can differ from $\delta^{13}C$ of the original material, and are not shown

Appendix E – Radiocarbon Date Additional Information

Site Info		Date Info						Criteria				Score		
Borden No.	**Permit No.**	**One Sigma Calibrated Age Range (cal yr BP)**	**Conventional Radiocarbon Age (rcyr BP)**	**13C/12C (o/oo)**	**Lab Number**	**Material**	**Context**	**1**	**2**	**3**	**4**	**Score**	**Percent (unmod)**	**pg#**
HhOu-113	ASA 12-234	8160 to 7962	7220±40	-23.1	Beta-333309	bone	Found in association with Early Beaver River Complex point. Sample from bone feature, Block A. Mostly in Unit 98N 199E, but also extended into Unit 98N 198E, and 98N 200E. No ash or staining but the surrounding BRS was blackened and britte (p. 36). feature extended 100cm N-S and 150cm E-W, depth of 10-20cmBS. total # found =51. Composite sample. Associated with BRC point	4	4	1	4	13	65	38
HhOv-528	ASA 12-085	7156 to 6803	6090±40	-23.1	Beta - 340828	bone	single sample; 505N, 152E SW Quad, Lvl 2. 3g Block P	5	5	5	4	19	95	399
HhOv-508	ASA 11-070	6541 to 6319	5660±40	-24.8	Beta- 298152	bone carbonate	4.2g calcined bone sample from ST3. HhOv-508:239-267	3	1*	5	4	13	65	217
HhOv-520	ASA 11-167	6180 to 5928	5260±40	-24.4	Beta - 312098	Unknown	single unit bone feature. total of 54 faunal fragments were recovered, primarily between 5-25 cmBS and believed by the authors to be a single occupation	1*	1*	1*	4	7	35	41, 44
HhOv-256	ASA 06-376	5589 to 5327	4750±40	-25.5	Beta - 239181	charred material	charcoal from hearth feature observed in unit 96N/100E	4	4	1*	4	13	65	245
HhOv-156	ASA 11-167	4524 to 4415	3990±30	-23.7	Beta - 312092	Bone	bone feature identified in ST2, Locus 2.	4	4	1*	4	13	65	30
HhOv-73	ASA 83-053	4870 to 3973	3990±170	not reported	Beta-7839	Charcoal	3 units across the NW corner of the microblade trench	2	2	1*	3	8	40	32
HhOv-384	ASA 07-280	3207 to 2960	2930±40	-21.7	Beta-248249	Calcined Bone	bulk bone (unknown weight, less than 18g) from area A Unit 397N 696E. All unident. faunal fragments. Lots of root disturbance noted in the block. Majority of artifacts retrieved from 10 - 30 cmBS). Authors state the bones occurred in a spatially resrticed area therefore are likely to represent a single deposition episode. Pg. 39 implies all calcined bone recovered in unit 397N 696E was submitted.	3	3	4	4	14	70	38-39
HhOv-506	ASA 11-070	3076 to 2880	2870±30	-24.4	Beta - 298151	Calcined Bone	4.3g of medium/large bones from Bone Feature in Block E	4	5	5	4	18	90	153
HhOv-384	ASA 10-093	2945 to 2765	2750±40	-24.2	Beta-248280	Calcined Bone	397N 695E. Level 1, SE Quad (n=11). 4.2g. Recovered immediately west of the 07-280 faunal sample location - Woywitka et al 2008	4	4	5	4	17	85	287; 306-7
HhOv-350	ASA 10-093	2738 to 2380	2490±40	-24.4	Not Reported	Calcined Bone	Block A1 93N 130E, NE Quad Level 1 and 2. N=18. Reported on the site form but not in the report. Beta Report in site report. No 13C/12C or lab reported	4	3	2	4	13	65	pdf page 874
HhOv-350	ASA 10-093	2702 to 2353	2430±40	-24.1	Not Reported	Calcined Bone	Bock B 111N 150E. NE Quad, level 1 and 2. N=17. Reported on the site form but not in the report. Beta Report in site report	4	3	1*	4	12	60	pdf page 874
HhOw-45	ASA 08-208	2460 to 2163	2320±40	-23.3	Beta-255737	Calcined Bone	Block A, recovered from calcined bone. Total # of 44 fragments of calcined mammal bones. South-central part of Block A (Unit 2200N 746E, 2201N 745E, 2201N 746E) depth of 0 to 20cm below surficial organic matt deposits	4	4	4	4	16	80	138
HiOv-46	ASA 08-163	2352 to 2155	2270±40	-23.1	Beta-258073	Calcined Bone	Two fragments, recovered from two different units. One was from the southwestern corner of the block and the western edge (SE Quad of 614N 153E, one from SW Quad of 615N 153E respectively).	2	2	2	4	10	50	106-107
HhOx-18	ASA 08-166	2150 to 1946	2080±40	-22.4	Beta - 255742	Calcined Bone	0-10cmFS. Block A, HhOx 18:123-460 were submitted for C14 dating. Densest concentration of bone was in the NW quad of 406N205E; but the bone recovered was co-mingled with artifacts and there was bioturbation present	2	2	2	4	10	50	226
HhOv-87	ASA 09-168	2109 to 1883	2020±40	-25.8	Beta 277702	Calcined Bone	bulk bone feature from locus 15. points from site include 2 Nezu style, 1 BRC, 1 Late Taltheilei. 4.8g sample	4	5	5	4	18	90	126

Site Info		Date Info						Criteria				Score		
Borden No.	Permit No.	One Sigma Calibrated Age Range (cal yr BP)	Conventional Radiocarbon Age (rcyr BP)	13C/12C (o/oo)	Lab Number	Material	Context	1	2	3	4	Score	Percent (unmod)	pg#
HkOv-100	ASA 12-157	2034 to 1880	2000±30	-25.6	Beta-337912	Calcined Bone	Four shaft fragments and 29 undif. scrap (weight = 4.1g) were submitted from a single shovel test	3*	3*	5	4	9	75	235
HhOw-46	ASA 08-208	2037 to 1826	1980±40	-25	Beta-255739	Calcined Bone	Block A, 38 fragments of calcined small mammal bone. South part (505N 910E, 504N 909E, 504N 910E, 504N 910E). Three fragments were IDable to element (rib, vertebra, and femur). collected from 0 to 10cm below surficial organic mat deposits	3	4	3	4	14	70	164
HhOv-387	ASA 07-280	1944 to 1734	1910±40	-22.2	Beta-248281	Calcined Bone	Block E1, 275N 936E level 1, NW Quad. n=91, w=20.1g bone fragments. Block E collectively contained 130 faunal frags, E1=108 pieces E2- 22 pieces. 108 in E1 came from the single quadrant of the highest lithic artifact density.	4	4	4	4	16	80	143
HhOv-351	ASA 10-148	1929 to 1741	1910±30	-25.5	Beta-295837	Calcined Bone	bulk bone (4.1g) from excavation block, not discrete but recovered from the densest concentration of faunal remains. All fragments calcined to similar degree leading the permit holder to beleive they represent a single event	4	3	5	4	16	80	51
HhOv-387	ASA 10-093	1876 to 1634	1840±40	-26.1	Beta-248281	Calcined Bone	Block E1, 275N 935E level 2 (10-20cm from surface). n=70 bone fragments.	4	4	2	4	14	70	370
HeOn-1	ASA 76-040	1881 to 1410	1735±105	not reported	S-1275	Unknown	Sample B, 24cm BS. found in Feature One - Hearth. Bulk sample	4	3	1	3	11	55	44
HiOv-70	ASA 08-163	1710 to 1540	1710±40	-23	Beta-258075	Calcined Bone	Most of the faunal remains came from the centre of Block B. Associated with a fire broken rock feature located in unit 301N 852E. weighed at least 10g, and from a single quadrant	4	4	4	4	16	80	169
HhOw-20	ASA 07-393	1698 to 1420	1670±40	-23	Beta-244942	Calcined Bone	Block A; Units 191N/97E and 192N/97E. Calcined bone fragments (unknown quantity, likely min. 10g due to report methods)	2	1	4	4	11	55	41
HhOu-70	ASA 07-219	1690 to 1415	1650±40	-15.6	Beta-248279	Calcined Bone	33.3g, single quad Block A, unit 100N/198E. Collection of calcined, comminuted bone and FBR led authors to believe . 13C value, more like marine? (could be bird, could be other)	4	4	3	4	15	75	78-80
HhOv-184	ASA 99-073	1718 to 1354	1640±80	not reported	Beta-141288	Charcoal	believed to be from a forest fire. From a layer of charcoal, at the bottom of the artifact bearing layer, taken from unit 5N 0E. was in association with the occupation.	4	4	1*	3	12	60	215
HjOv-63	ASA 15-087	1295 to 1181	1310±30	-23.5	Beta-424812	Burnt bone carbonate	ST24. HjOv-63:274-289. w=4.1g/ HIGH FAUNAL YIELD AT THIS SITE	3	4	5	4	16	80	133
HiOw-37	ASA 03-269	1303 to 1150	1300±40	-27.5	Beta-188773	charcoal	hearth, unit 48N 99E. discovered at 25cmBS, terminates at 42cmBS	5	5	1*	4	15	75	113
HhOv-524	ASA 12-085	1282 to 1086	1260±30	-22.1	Beta-340829	Bone collagen	Single sample; 75.4g. 223N 125 E, SWquad level 3 Block A	4	4	2	4	14	70	168
HhOv-16	ASA 88-032	1290 to 1007	1240±60	not reported	TO-1439	Soil organics	301N/299E. 20-25cmBS. Weight=3.2g.	2	2	5	4	13	65	56
HkOv-92	ASA 12-157	1064 to 937	1100±30	-20.9	Beta-337911	Calcined Bone	46 unidentifable scrap frags (3.8g) from shovel test 4	3	2	5	4	14	70	226
HhOv-528	ASA 12-085	1056 to 932	1080±30	-26.2	Beta - 340826	Calcined Bone	n=69, 29g. SE of unit 454N 184E, L1. Block K	4	4	3	4	15	75	364
HhOv-528	ASA 12-085	1056 to 932	1080±30	-26.2	Beta - 340827	Calcined Bone	n=3, 0.7g. SW of unit 454N 184E, L2. Block K	4	4	5	4	17	85	364
HhOv-528	ASA 12-085	1055 to 929	1070±30	-25.9	Beta - 340825	Calcined Bone	n=38, 24.3g. NE of unit 453N 184E, L1. Block K.	4	4	3	4	15	75	364
HjOv-64	ASA 15-087	1049 to 834	1030±30	-23.9	Beta-424815	Cremated bone carbonate	ST17. (HjOv-64:208-220). Undif. small mammal scrap w=3.8g	3	4	5	4	16	80	148
HhOv-449	ASA 06-376	688 to 556	680±40	-26.7	Beta-229415	Charcoal	Natural charcoal sample. Chosen as it represents a buried soil layer that directly overlays the lithic material	4	4	1*	4	13	65	366
HjOv-55	ASA 15-087	655 to 546	610±30	-26.9	Beta-424807	Burnt bone carbonate	Shovel test 7 (HjOv-55:26-69). w=4g	3	4	5	4	16	80	70

Site Info		Date Info						Criteria				Score		
Borden No.	Permit No.	One Sigma Calibrated Age Range (cal yr BP)	Conventional Radiocarbon Age (rcyr BP)	13C/12C (o/oo)	Lab Number	Material	Context	1	2	3	4	Score	Percent (unmod)	pg#
HhOv-528	ASA 12-085	646 to 528	570±30	-24.6	Beta-340830	Charcoal/Soil sample	0.9g, SW of unit 454N 184E, L2. Block K.	4	3	5	4	16	80	364
HcOn-3	ASA 76-040	731 to 319	570±115	not reported	NMS-1274	Bone/Calcined	61 pieces of unidentifies calcined and carbonized bone frags proccessed. Potetially all from single bone concentration in single unit.	3*	2*	1*	3	9	45	80
HhOv-506	ASA 11-070	639 to 517	550±30	-20.4	Beta-312096	Bone collagen	portion of caribou metapodial, single bone (partially fused, and evidence of butchering on the bone), Block F	3	3	5	5	16	80	162
HhOv-245	ASA 06-376	631 to 495	500±40	-24	Beta-229413	Calcined Bone	All faunal recoved from unit 101N/101E was sent for analysis (n=37, 11.4g)	4	4	4	4	16	80	190
HiOu-8	ASA 08-163	281 to 6	130±40	-25.6	Beta-258074	Calcined Bone	at least 10g of calcined bone	1*	1*	4	4	10	50	46
HhOv-506	ASA 11-070	276 to 9	130±30	-24.2	Beta - 298151	Bone	3.5g of small mammal bone (likely beaver); Block B. central concentration believed to be a hearth. identifiable fragments. sample is from ST7	3	3	5	4	15	75	112
HhOw-55	ASA 08-166	271 to 11	100±40	-21.9	Beta - 255740	Burned Bone Organics	Sample of faunal remains from Block B and C. Subsample taken from a total of 114 faunal remains (of which almost 50% was identified to a taxon). No other context	2	2	1*	4	9	45	82
HhOv-506	ASA 11-070	266 to 22	90±30	-21.2	Beta-312093	Bone	large ungulate (likely moose) single bone from the excavation block; 19.4g, Block B	3	3	4	5	15	75	112
HhOv-506	ASA 11-070	260 to 26	70±30	-20.9	Beta-312097	Bone	portion of moose tibia, Block I. Date is young (70+/-30) and therefore greater risk re: calibration?	3	3	5	5	16	80	196
HkOv-101	ASA 12-157	260 to 26	70±30	-23.4	Beta-337913	bone carbonate	ST1. 22 uniden. long bone and scrap fragments sumbitted (w= 4.2g)	3	4	5	4	16	80	238

Note: an (*) denotes data that was not presented in the report (e.g., value = 1*) or data that was inferred from a reports methods (e.g., value = 3*)