THE ICE-FREE CORRIDOR: BIOGEOGRAPHICAL HIGHWAY OR ENVIRONMENTAL CUL-DE-SAC

by

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ABSTRACT

As a theoretical concept, the ice-free corridor has given researchers a recognizable route for the Late Wisconsinan human colonization of the Americas. This dissertation re-examines that potential role by critically assessing plant and animal remains radiocarbon dated to between 9000 B.P. and 20000 B.P. To meet its theorized role as a north-to-south Late Wisconsinan human migration route the corridor must fulfill two criteria: 1. that eastern Beringia could have supported human populations before Clovis appeared (≈11500 B.P.) south of the ice sheets, and 2. that evidence from the corridor area shows that it was a biogeographic corridor capable of supporting human life.

To fulfill these criteria 600 published radiocarbon dates were assessed for their reliability. This original number was reduced to 293 radiocarbon dates. The remaining dates were divided into four temporal periods and plotted spatially. Environmental inferences were determined from these distributions.

The results support the first criterion: eastern Beringia could support human populations before Clovis. However, the results did not support the second criterion, and there is no evidence that a biogeographic corridor existed prior to 11500 BP. It was concluded that the ice-free corridor could not have been used as a north-to-south human migration route during the Late Wisconsinan. Therefore, other alternatives must now be considered to account for the arrival of Paleoindian cultures in southern North America.

Keywords

Ice-free corridor, Palaeoindian - origin, radiocarbon dating, biogeographical corridor, migration - human.

DEDICATION

To my family and friends who supported

me throughout the long trek.

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CHAPTER 1

INTRODUCTION

The objective of my dissertation is to assess the evidence for a late Pleistocene ice-free corridor that could have provided a migration route for ancestors of the first Palaeoindian cultures south of the Late Wisconsinan ice sheets. This involves evaluating the chronological and environmental information from archaeological, geological and palynological sites along the entire length of the proposed corridor. Specifically, radiocarbon dates on organic material would indicate when plants and animals were first present in various sections of the corridor. Presumably humans could not have existed for even short periods within the corridor without the presence of plants and animals. Thus, it is crucial that radiocarbon dates from within the corridor be critically evaluated for their validity to date such a presence accurately. Criteria outlined by Nelson (1998), as discussed in detail in Chapter 4, will be used in this evaluation. Radiocarbon dates that are validated will then be divided into four periods and discussed. This method may produce results that differ from other environmental reconstructions of this period.

Study Area and Temporal Limits

The ice-free corridor was defined as an unglaciated (Johnson 1933:22) area located east of the Rocky Mountains during the last glacial maximum. It existed between the continental Laurentide Glacier (moving generally west) and the Cordilleran and Mountain glaciers (moving east out of the mountains, Figure 1). Fladmark (1983:28) notes that ". . . the ultimate "corridor" was probably a complex region whose

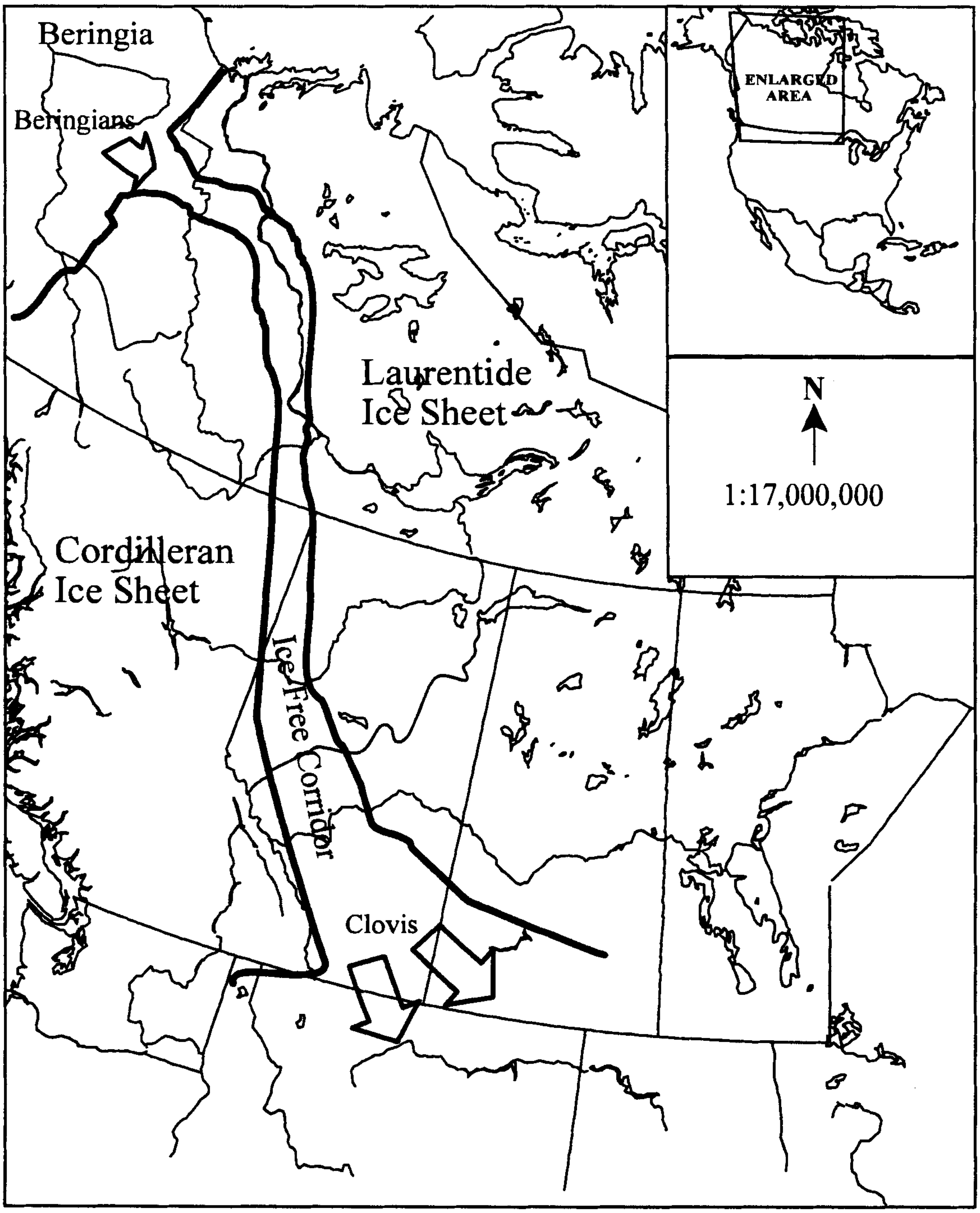


Figure 1. Traditional view of the ice-free corridor (after West 1996, Haynes 1971).

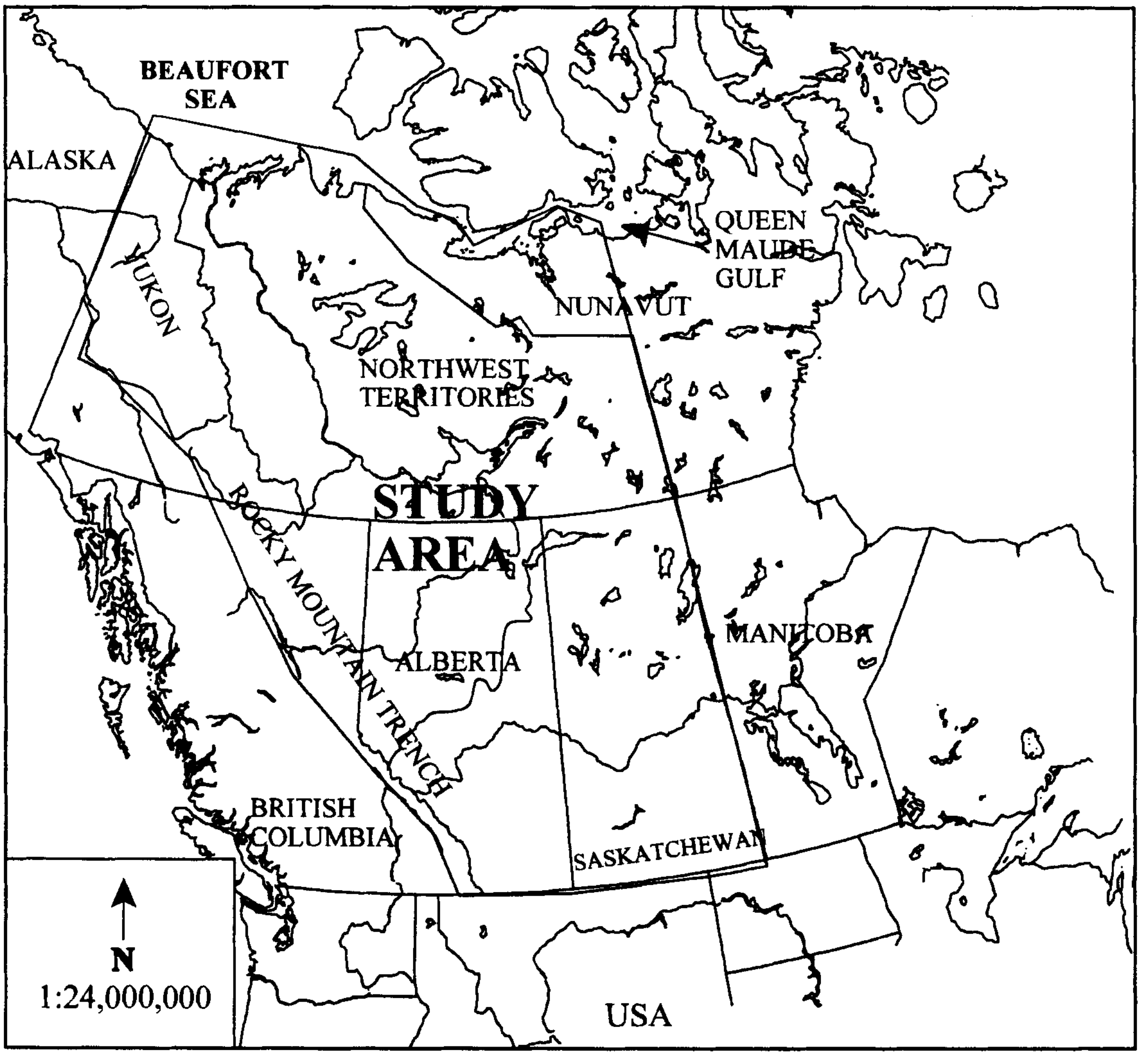


Figure 2. Limits of study area

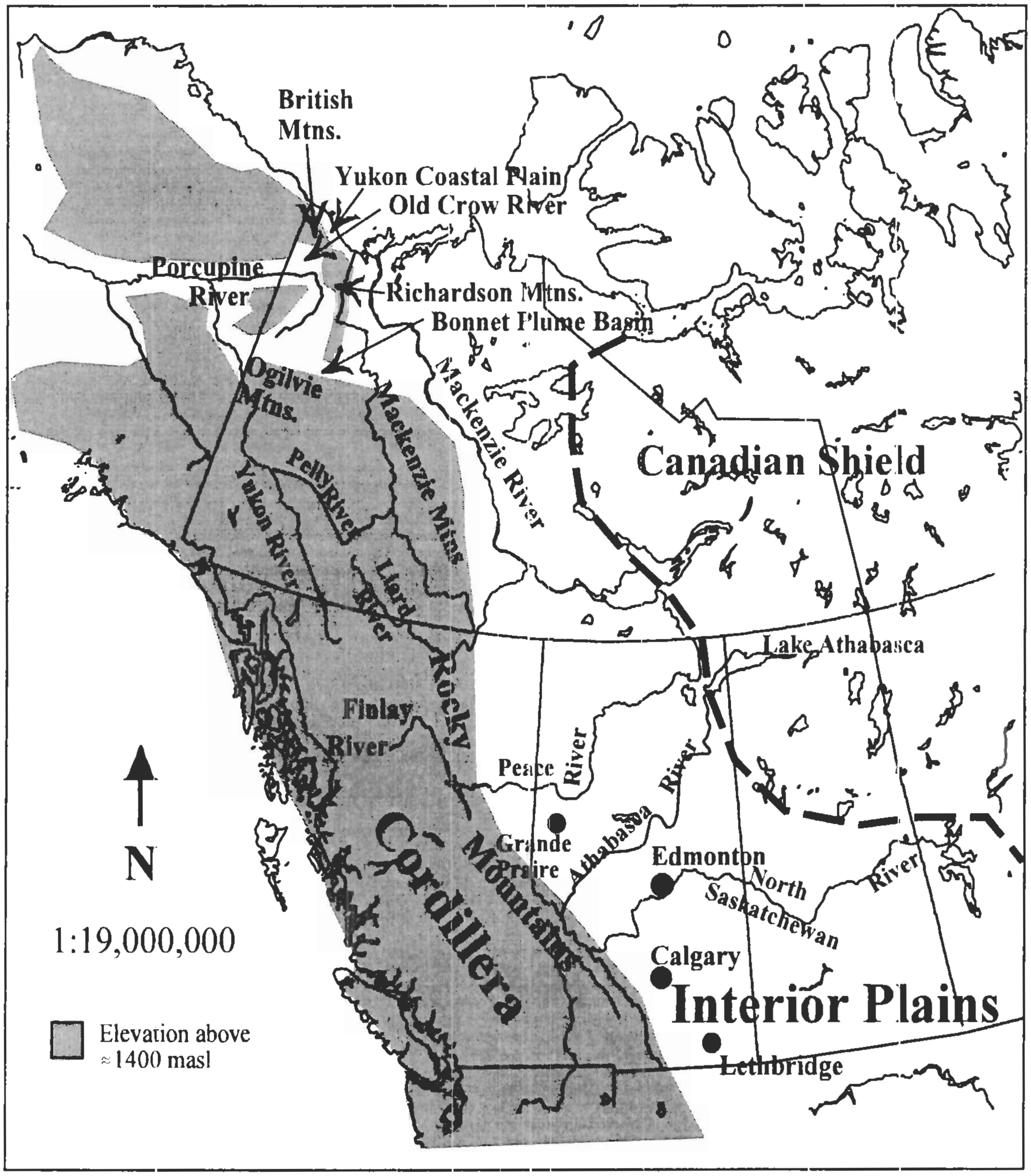


Figure 3. Geographical features in the study area (physiographic boundaries follow those defined by Driver 1998a).

exact limits and characteristics varied with time-transgressive and possibly diachronous eastern and western ice margins." To encompass such a dynamic phenomenon the following geographical limits have been set (Figure 2) (Figure 3 identifies important landmarks mentioned throughout the following text). The northern end of the study area includes eastern Beringia (in present day Yukon) that would have been the source area for groups migrating south through the corridor. If no viable biotic environment was present in this area it is unlikely the corridor was used by early Palaeoindians even if it physically existed. Ritchie (1980:15-16) used similar broad limits, including eastern Beringia, in discussing the palaeoecology of the corridor. This part of the Yukon remained unglaciated during the Late Wisconsinan (Clague 1989:40; Schweger 1989:492-493).

The western limit of the study area is defined mainly by the eastern side of the Rocky Mountain Trench lying west of the crest of the Rocky Mountains. Using this geographical feature encompasses all possible definitions of the western limits of the corridor, which is poorly defined by mountain ranges and their Late Wisconsinan glacier systems (Fladmark1983:28). This limit allows for easy determination of whether a potential site is within or outside the study area.

The Rocky Mountain Trench stretches north from the Canada/United States border to the the British Columbia/Yukon border. In the Yukon the western limit of the study area follows the Liard, Frances, Pelly and Yukon river valleys to the Alaska/Yukon border. It then extends along the Alaska/Yukon border to the Beaufort Sea. The study area's eastern boundary follows the Saskatchewan/Manitoba border extending north to the shores of Queen Maude Gulf. Saskatchewan is included because southern portions of the province may have been ice-free while northern parts were still ice covered. The northern limit is the Arctic coastline of Canada. The Canada/United States border at the 49th parallel approximates the southernmost continental and Cordilleran glacial limits, and provides a convenient and recognizable southern boundary for this study.

For several reasons, the temporal limits of this research are set between 9000 radiocarbon years Before Present (B.P.) and 20000 radiocarbon years B.P. The height of the last glaciation (for the central continental area) is usually given as 18000 B.P. and its end as 10000 B.P. (Fulton 1989:1,3; Prest 1984:26-28; Rutter 1980:1-2; Dyke and Prest 1987:240; Burns 1996:107; Catto and Mandryk 1990:80-82). A two thousand year margin is provided for the older limit because of evidence that the glacial maximum was not synchronous along the entire length of the corridor (Bobrowsky and Rutter 1992:35; Prest 1984:27-28). The younger limit also allows for asynchronous environmental conditions along the length of the corridor at the end of the Late Wisconsinan.

Conditions Supporting the Ice-Free Corridor as an Early Human Migration Route

Two conditions must be fulfilled to support the hypothesis that the ice-free corridor could have served as a human migration route during the Late Wisconsinan. First, assuming a post-20000 B.P. human migration, the unglaciated area of eastern Beringia must have acted as a source for any human populations using the corridor as a migration route. Therefore, evidence must exist that this area could have supported a human population before Clovis (≈11500 B.P. to 10900 B.P.).

Second, the corridor must have been a biogeographic corridor during this time. A biogeographical corridor is defined as an area of continuous habitat that due to its similar environmental conditions allows movement of plants and animals over wide areas or between regions (MacDonald and McLeod 1996:87). The presence of radiocarbon dated organic remains of plants and animals would indicate that a biogeographical corridor existed. West (1996:556) argued that the corridor needed to be completely vegetated along its entire route to allow for even a quick southern dash or trek by human populations in eastern Beringia. Thus, evidence of colonization by plants and animals along the corridor's entire route before 12000 B.P. must be present to demonstrate its potential utility by pre-Clovis peoples.

Assessing these conditions will involve reviewing the temporal and areal distributions of dated organic site locations and reconstruction of the environment during four periods: 1. glacial maximum, 20000 to 17001 B.P., 2. early deglaciation, 17000 to 14001 B.P., 3. late deglaciation, 14000 to 11001 B.P. and 4. early post-glacial, 11000 to 9000 B.P.

The approach of this dissertation, with its emphasis on establishing whether a biogeographical corridor existed and not just a physical corridor, may produce an environmental interpretation that is significantly different from other approaches. In this approach the dating of various geological features (e.g., end moraines), although not irrelevant is simply not emphasized. Thus, there will be no attempt to establish or present ice frontal positions. This research concentrates on using radiocarbon dates from organic material as both a dating source and as evidence that the environment could support life in the corridor. Only then will additional associative data (e.g, palynological cores or stratigraphy) be used to further interpret or enhance the environmental interpretation.

Dissertation Organization

Chapter 2 provides background on the corridor and includes brief reviews of the concept's development, the present state of knowledge on when the corridor was open, the history of environmental reconstruction and finally how the concept of the ice-free corridor relates to present theories on the first peopling of the Western Hemisphere. Chapter 3 discusses how radiocarbon dates were used in previous studies of the corridor. Chapter 4 presents the method used to assess the radiocarbon dates in this study. Chapter 5 applies the method to a database of 600 radiocarbon dates, and Chapter 6 examines the temporal and environmental implications of the radiocarbon dates that remain after the critical evaluation. Chapter 7 concludes the dissertation by relating the results from Chapter 5 and the implications of Chapter 6 to the research question posited at the beginning of this chapter.

CHAPTER 2

THE ICE-FREE CORRIDOR CONCEPT AND ARCHAEOLOGY

This chapter summarizes the history of the ice-free corridor concept, and examines its relationship to archaeology and hypotheses on the peopling of the Western Hemisphere. It will briefly discuss the introduction of the concept to archaeology, and its subsequent development, attempts at reconstructing the corridor's environment, and current knowledge of the ice-free corridor. Finally, it will compare the implications of this concept for two competing models of human population: the Clovis-first and pre-Clovis models.

In the following section the Late Wisconsinan refers to the final glacial stage of the Pleistocene. The Early Wisconsinan was a glacial period that lasted from approximately 115000 to 64000 B.P. and was characterized by large continental glaciers. The Mid-Wisconsinan was an interstadial that lasted from 64000 to 23000 B.P. when environmental conditions and temperatures were similar to the present. The Late Wisconsinan dates from 23000 to 10000 B.P. and was characterized by large continental glaciers. The term Last Glacial Maximum refers to the period of greatest glacial ice extent during the Late Wisconsinan and is roughly dated to 18000 B.P. Finally, the Younger-Dryas was an episode of climatic cooling between 11000 and 10000 B.P. in which temperatures returned to glacial maximum values and glacial margins briefly expanded. The effect of this climatic reversal appears to have been most profound around the circum-North Atlantic (Vincent 1989:103, Table 2.1; Heine 1998:1139).

The Ice-Free Corridor Concept

Johnson (1933:22,34) first connected the corridor to an archaeological problem by proposing that it could explain the reports of Folsom artifacts in association with extinct fauna (thought in the 1930s to date to between 15000 - 12000 years ago). Thus, from the outset the corridor was, as West (1996:554) states, a "theoretical construct", rather than being based on archaeological field evidence. Between the mid 1930s and the advent and refinement of radiocarbon dating after 1949, the glacial maximum for the Late Wisconsinan was thought to have occurred about 25000 years ago (Antevs 1935:304,306) with the corridor occurring between 20000 and 15000 years ago (Antevs 1935:302,306,307). The presence of Folsom and Clovis artifacts on the Plains and in the American Southwest made geochronological sense at the time (Antevs 1935:306), since these areas lay well to the south of the proposed corridor. Further supporting the corridor's use was evidence that purported Pleistocene age artifacts were found in association with pluvial or wet period deposits (Antevs 1935:304; Antevs 1937:126,128,131), which were believed to have been laid down after deglaciation had begun (Antevs 1934:308-309). Finally, geological evidence, in the form of glacial deposits and striations, suggested that Cordilleran and Laurentide glaciers were relatively contemporaneous during the early Late Wisconsinan (25000 year ago) north of 55° latitude (Antevs 1934:305,307; Antevs 1935:305-306) and closed the corridor along the Mackenzie River during this time. Only after the corridor opened (between 15000 and 20000 years ago) could people have migrated south. Thus, the 15000 to 12000 year old age estimate of Folsom and Clovis made sense geologically.

Radiocarbon dating revised these interpretations. It showed that early Palaeoindian sites (including Folsom and Clovis) and the Late Wisconsinan glaciation were more recent than Johnson and Antevs had assumed. Mandryk (1992:30) notes that this led archaeologists to abandon or at least ignore the corridor concept and shifted the archaeological focus to conditions in Beringia. Mandryk (1992:31) further contends that continued lack of evidence for any northeast Asian precursors to Clovis or Folsom led archaeologists to conclude that fluted points were a New World development. According to Mandryk (1992:31-32), this, combined with an unwillingness to accept a possible Mid-Wisconsinan human entry into the Americas, led archaeologists to redefine Johnson's deglaciation corridor as a glacial maximum corridor, which accounted for the migration of people south of the ice sheets before the onset of deglaciation.

Mandryk (1992:38) claims that the main focus of post-1960s corridor research was on the existence, or timing of an unglaciated corridor. Correspondingly, less debate and research on its specific environment was conducted, despite growing evidence that at least part of the corridor was closed during the Late Wisconsinan (Rutter 1980:7). Taking an almost conspiratorial stance, Mandryk (1992:38) suggests that the ice-free corridor was something one believed in despite facts. Both Reeves (1973:4) and Stalker (1977:2614; 1980:11) noted that the evidence for or against the existence of the corridor (or more properly stated, the position of the maximum extent of Laurentide ice) was essentially a dating problem. Stalker states that:

> ...the outer limit of the Classical Wisconsin Laurentide glacier in that region [southern and central Alberta] remains uncertain. There are several causes for this, but a major one is a deficiency of material suitable for radiocarbon dating, which has largely

> thwarted the establishment of radiometric ages for materials within and beyond the prospective margins (1977:2614).

Thus it appears accepting the ice-free corridor did not involve ignoring the facts but was instead one side of a scholarly debate on dating ice-front positions.

Prest (1984:22-36; Map) mapped the Late Wisconsinan glacial complex across North America. To deal with the controversy of conflicting data and interpretation of ice-front locations and times he mapped both maximum and minimum limits. In most areas he favoured the minimum limits and noted that, although he presented the maximum limits as part of the Late Wisconsinan glacial complex, he felt that they most likely represent Early Wisconsinan glacial limits (Prest 1984:27). Thus, he favoured an ice-free corridor over much of its proposed route (only the area in northwestern Alberta and northeastern British Columbia show closure). In the south, the Cordilleran Ice Sheet (defined as series of intermontane, mountain and valley glaciers) was interpreted as having less extensive ice coverage along its eastern edge. This, combined with southern Alberta data of less extensive Late Wisconsinan Laurentide tills, suggested to him a wider corridor extending as far north as 55° latitude (Prest 1984:26,28).

Between the Peace River valley of northern British Columbia and the Liard River of the southern Yukon the data suggested that the Cordilleran and Laurentide glaciers were in contact in some locales. In other areas, the data suggested that the two glacial systems may have been 'choreographed' so that as one retreated the other advanced to take its place. The geological data also suggested that during times of retreat the corridor between the two glacial systems held glacial lakes of various sizes (Prest 1984:28).

In the far north, Prest favoured the minimum glacial limits, which provided a corridor down the eastern side of the Mackenzie Mountains into northern British Columbia. He preferred the minimum limits because the maximum limits were represented by Arctic Ocean shoreline deposits (presently submerged at a depth of 45 m) developed on a Laurentide till. These deposits are coarser than modern shoreline analogues found along the Mackenzie Delta and Tukotyaktuk Peninsula. He inferred that for these coarser deposits to have developed, the Laurentide till must have been laid down during the Early Wisconsinan and then modified during the less extensive Late Wisconsinan glaciation (Prest 1984:28; Map).

Proponents of a glacial maximum corridor noted that the distribution of fresh hummocky moraine and other landscape features suggested that the Late Wisconsinan ice front limit was represented by the Lethbridge Moraine and its extension north to Edmonton (Rutter 1980:2; Stalker 1980:11-13; 1977:2616-2619; Reeves 1973:2-13). Areas to the west of this moraine suggested more eroded, and thus, older landscapes, indicating they had not been overridden during the Late Wisconsinan advance. This was in contrast to evidence for the coalescence or closure of the corridor area (e.g., the presence of drumlins, striations, etc.) south of the Athabasca River (Reeves 1973:10), a single till sheet at the same elevation in the Peace River area of northeastern British Columbia (Rutter 1980:5), and Laurentide tills in the Mackenzie Mountains in the Northwest Territories (Rutter 1980:4-5; Reeves 1973:11,13).

Until the time of the maximum westward extent of the Laurentide ice was determined the conditions within any possible corridor were purely speculative, at least in terms of its relationship to the peopling of the Americas.

Open or Closed: Current Understanding

Recent geological research provides evidence that west-central Alberta was blocked by coalesced glaciers during the Last Glacial Maximum. Young et al. (1994) studied five gravel pits in the Edmonton area (Figure 2) that reveal subtill valley fill deposits. They lacked Canadian Shield igneous and metamorphic clasts, which indicates that no Laurentide glaciation had reached this area prior to the Last Glacial Maximum. This is further supported by ^{14}C dates from floral and faunal fossils from various levels within those subtill facies. In contrast, the overlying till and glaciofluvial deposit had abundant Shield clasts (about 50%) (Young et al. 1994:684-685).

Young et al. (1994:685-686; 1999:1578-1579) conclude that the Late Wisconsinan Laurentide ice sheet originated at lower elevations north to northeast of Edmonton, and then passed through Edmonton to reach areas to the south and west. Due to this uphill movement the Laurentide ice sheets had a low angle surface profile and thus could have advanced roughly simultaneously over large areas of equal elevation. They suggest that the Laurentide ice would have advanced up to about 1400 m asl (≈4500 ft. asl) and may have stretched from west of Grand Prairie in the northwest, to west of Lethbridge in the southwest (Young et al. 1994:683, inset map Figure 1).

Levson and Rutter (1996:33-51) also summarize evidence of coalesced glaciers west and southwest of Edmonton between the Athabasca and North Saskatchewan rivers. Lithologic, stratigraphic and morphologic evidence indicate that combined valley and Cordilleran glaciers flowing east were deflected southeasterly. Since the natural flow is to the northeast, downhill, only the advancing Laurentide ice sheet could have provided the diversion necessary to deflect those east flowing glaciers (Levson and Rutter 1996:44-46, 48).

Lithologic evidence includes metamorphic and quartzitic erratics (the former of the Athabasca Erratics Train and the latter of the Foothhill Erratics Train) that originated in the Rocky Mountains to the west. Both were distributed southeasterly along the mountain front rather then easterly along the Athabasca Valley, which indicates that Laurentide ice had diverted them. The Cordilleran tills associated with these erratics also suggest that their originating glaciers were confined to high elevations by the Laurentide ice (Levson and Rutter 1996:45).

Those erratics designated the Foothills Erratics Train by Stalker (1956), consist of quartzite and pebbly quartzite boulders deposited in a 580 km long line from roughly the Athabasca River south to the international border (Stalker 1956:5; Jackson 1993:64). They originated from the headwaters of the Athabasca River in the lower Cambrian quartzite beds (Jackson 1993:71). Their north-to-south linear distribution east of the Rocky Mountains suggested that the deflected glacier that carried them was restricted on the west side by the elevations of the foothills. The eastern limits of the train approximates the line of merger between the glaciers and the ice sheet to the east. Their vertical distribution would approximate the highest elevation of the Laurentide glacier (Stalker 1956:16-17; Jackson 1993:71). Stratigraphically, both the Athabasca and Laurentide derived tills show a grading in composition, with no apparent disconformity separating the two tills, or evidence of one overlying the other (Levson and Rutter 1996:45). This stratigraphic relationship also supports coalescence of the two glaciers. Stalker (1956:17) determined the age of the Foothills Erratic Train to be Late Wisconsinan for several reasons: their present rapid rate of disintegration, their fresh appearance, and the large size of many erratics (any subsequent glaciation would have broken them into smaller rounder pieces). More recently, Jackson et al. (1997:195-198) have directly dated these erratics to the Late Wisconsinan by using chlorine dating (for description of ^{36}Cl dating see Zreda and Phillips 1994; Jackson et al. 1997 and Jackson et al. 1999).

Geomorphological evidence for coalescence took the form of an areal pattern of flutes and drumlins initially oriented parallel to glacial flow out of the major river valleys, such as Athabasca and North Saskatchewan. Once east of the foothills this flow showed evidence of a gradual diversion to the southeast, again suggesting a blockage (by the Laurentide ice sheets) to the east (Levson and Rutter 1996:45).

Levson and Rutter's (see Figure 9, 1996:42) line of contact between the east flowing Cordilleran glacier and the west flowing Laurentide glacier correlates to where Athabasca Valley till gave way to pure Laurentide till. This is roughly equivalent with Young et al's. (1994:685) assertion that the Laurentide ice sheets advanced up-slope to approximately 1400 m asl and to the eastern edge of the Foothills Erratic Train. Levson and Rutter (1996:49) conclude: "that the 'ice-free' corridor in west central Alberta was not ice free throughout the Late Wisconsinan period and palaeoenvironmental models incompatible with ice occlusion may have to be re-evaluated."

In southwestern Alberta (west and south of Lethbridge), recent research has shown that Laurentide and montane glaciers also coalesced during the Late Wisconsinan. Evidence indicates that combined mountain valley glaciers twice advanced at least 100 km east of the foothills, probably coalescing each time with the continental glacier. Even during retreat the presence of cross-bedded sands, or massive laminated silts, suggests lacustrine or outwash sediments between the glacier fronts (Holme et al. 2000:212-215). The lack of evidence of weathering or soil development in any section investigated led Holme et al. (2000:216) to further conclude that glacial sedimentation did not halt for any significant period of time, and that all sediments date to the same glaciation. Little et al. (2001:47-51), investigating the rise in elevation to the west of the continental ice sheet limits (as indicated by the presence of shield erratics),

conclude that ice flow convergence between the continental ice sheet and montane valley glaciers, along with topographic obstructions, accounted for more than 75% of the observed elevations. Regional tectonic uplift and glacio-isostatic uplift accounted for the remaining 25%. Again, Jackson et al. (1999:1353-1354), using ^{36}Cl dating on shield clast erratics associated with tills deposited by the continental glacier, found that all date to the Late Wisconsinan time period.

At the northern end of the ice-free corridor, the Late Wisconsinan Laurentide ice was stopped at the Richardson Mountains, but filled much of the eastern Yukon Coastal Plain (Hughes et al. 1981:330). Just to the south, in the Mackenzie Mountains, two Late Wisconsinan Laurentide ice advances and one Cordilleran advance have been recorded. The first Laurentide advance occurred about 30000 BP. This reached an elevation of between 1100-1400 m a.s.l. (Szeicz and MacDonald 2001:248; Szeicz et al. 1995:353). An ice-free area existed between these elevations and the higher ranges with the Cordilleran ice to the west. As the Laurentide ice retreated the Cordilleran ice advanced, reaching its maximum limits between 30000 BP and 23000 BP. Finally, as the Cordilleran ice retreated, a second less extensive Laurentide advance occurred sometime after 22000 BP (Szeicz and MacDonald. 2001:249; Duk-Rodkin et al. 1996:894). It now appears that some montane valley glaciers did coalesce with the retreating Laurentide ice during both Laurentide advances (Vincent 1989:131; Duk-Rodkin et al. 1996:891). Therefore, a continuous ice-free area did not exist along the ranges and foothills of the Mackenzie Mountains at all times during the Late Wisconsinan. The Bonnet Plume area lying between the Richardson Mountains to the north and the Mackenzie Mountains to the southeast, was glaciated sometime after 36900 BP with the ice in retreat by 16000 B.P. (Hughes et al. 1981:359). This area could have been a key portal to the northern end of the ice-free corridor, since it is physiographically less rugged than the mountains to the north (Richardson) and south (Mackenzie) and also provided access to the northern plains along the eastern slopes of the Mackenzie Mountains.

It is important to emphasize that geological evidence of coalescence (at any point along the corridor) neither proves nor disproves the corridor's existence during this time, or its potential use as a human migration route, unless that coalescence can be dated.

A History of Environment Reconstruction

Mandryk notes that the post 1960s period also saw "...a new interdisciplinary interest in environmental considerations, an increase in understanding the complexity of relationships between glaciation, climate, vegetation and humans..."(Mandryk 1992:48). There was also an increase in the amount of research conducted. This is reflected, in a general sense, by the number of radiocarbon dates published from the 1960s to the 1990s. Figure 4 illustrates this by showing the distribution of 575 published radiocarbon dates over this 40 year time span. It shows a steady increase in radiocarbon dates from the 1960s to the 1980s followed by a slight decline in the 1990s. This section summarizes the history of environmental reconstructions within the corridor from the 1960s to present. I review only those articles that attempted to reconstruct the environment of the

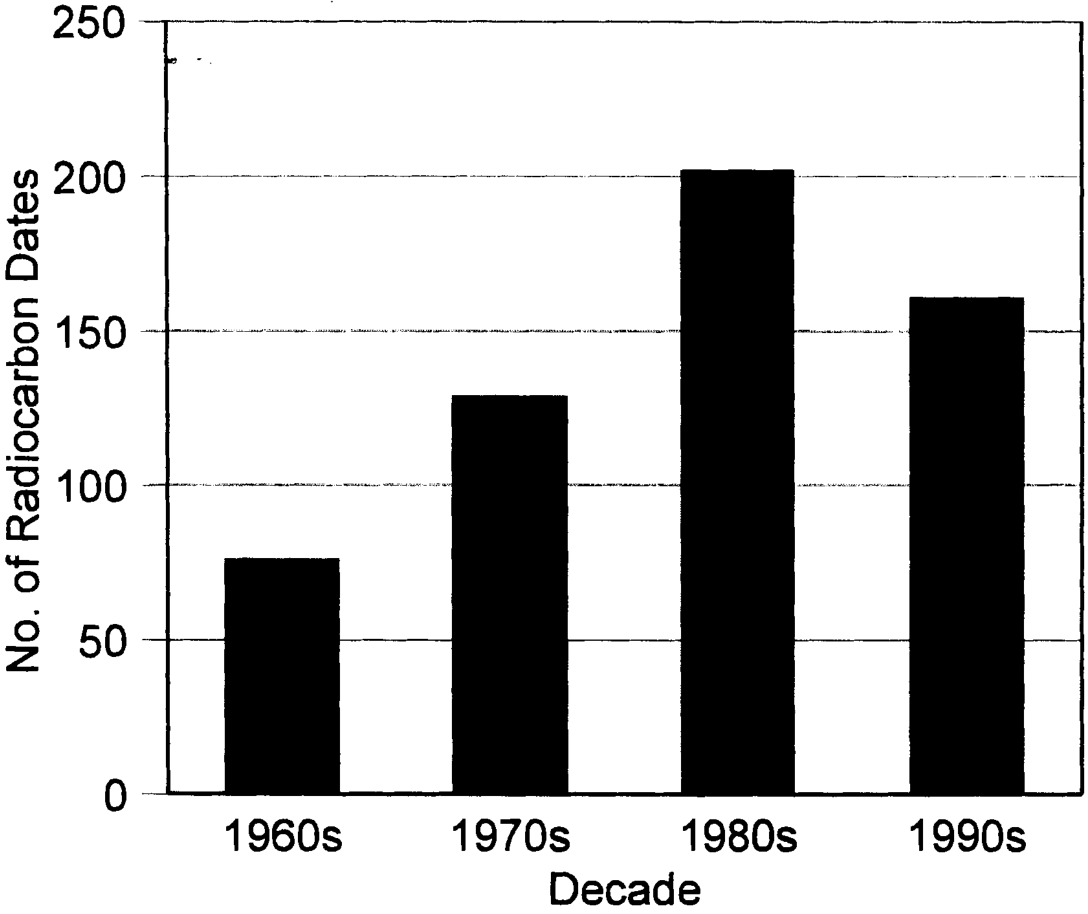


Figure 4. Published Radiocarbon Dates between 20000 and 9000 B.P. by Decade

corridor and do not review the data from individual archaeological, geological or palynological locales.

The Speculative Period

During the 1960s and 1970s knowledge of environmental conditions within the Late Wisconsinan corridor were largely speculative since little field data was available for that period. This is evident by the often brief statements made by researchers concerning conditions in the ice-free corridor

For instance, Haynes (1971:8-9) used one paragraph to summarize conditions. He noted that the chronology of glaciation was still not well understood, and that "ice-free" did not imply the corridor was immediately useable by humans. Noting that stratigraphic sections (although he quoted no sources) within the corridor indicated that the last glacial till was successively overlain with lake and then bog sediments, Haynes inferred that a corridor containing "...proglacial lakes and muskeg would be difficult to travel until after drainages became integrated" (Haynes 1971:9).

Reeves (1973:1-16) was equally uncertain on conditions within the corridor. After reviewing the evidence he concluded, in one sentence, that the corridor was open throughout the late Quaternary, but that whether or not conditions within the corridor could support "...viable biotic populations during the glacial maxima [was] another matter entirely" (Reeves 1973:13).

Bryan (1969:340-341), interpreted the geological evidence as suggesting that the southern portion of the corridor was closed during the Late Wisconsinan, and that periglacial conditions to the north were likely intolerable for humans. His interpretation of the evidence then available suggested that glacial ice and proglacial lakes covered much of present day Alberta and Saskatchewan during the Mid-Wisconsinan and that paleontological evidence of antelope, bison, mammoth and camel in the area probably dated to the Early Wisconsinan (Byran 1969:340-343).

Bryson et al. (1969:1-14) offered a more elaborate speculation on conditions, probably because their focus was on the continental glaciation in general and not just the area of the ice-free corridor. Using an existing series of radiocarbon dates to create isochrone maps of the entire Laurentide ice sheet and its disintegration (see Chapter 3), they interpreted the climatic implications of the deglaciation sequence (Bryson et al. 1969:5-6). Their maps revealed that the ice-free corridor opened sometime after 11000 B.P., but no later then 8500 B.P. They assumed that if the Arctic air mass was similar to its present structure then an opened corridor would have experienced a continuous flow of cold Arctic air. This could have lowered temperatures by as much as 20°C in southern Alberta and the northern plains, and may have made the winters severe enough to cause the extinction of many Late Pleistocene fauna species (Bryson et al. 1969:5-6).

By the end of the 1970s, Fladmark (1979:56) noted that questions of when, where, for how long, and if coalescence had occurred still remained unanswered. He also pointed out that reconstructing the climate of any corridor was difficult due to the lack of palynological data and analogous situations. His approach was to compare conditions within the corridor with those known to exist (based on the evidence then available) in Beringia (Fladmark 1979:56). He concluded that while Beringia consisted of well drained grassland, the glacial ice along the edges of any potential ice-free corridor would have blocked and reversed normal drainage patterns. The Laurentide ice in particular would have obstructed drainage and provided a constant source of large volumes of meltwater causing a continuously shifting and changing series of glacial lakes during either its advance or retreat. He likened condition in any corridor during deglaciation to a canal (Fladmark 1979:56).

Fladmark also suggested that chinook winds (which can ameliorate the present winter temperatures in portions of the corridor area) were probably reduced during glacial times because of changes in atmospheric circulation. Furthermore, he suggested that the corridor may have acted as an atmospheric low (a cold trap) much like river valleys in the region today. This would have trapped cold air coming off the surrounding glaciers and would have exacerbated already severe conditions caused by the proximity of glaciers (Fladmark 1979:56).

Fladmark doubts such conditions would have been encouraging for human occupation. In addition, the ever changing pro-glacial lakes and drainages would have created an unstable and unproductive biological landscape. Even the lakes and river systems would have been initially devoid of life (e.g., fish) that might have sustained migrating human populations. Compared to the productive grasslands of Beringia conditions within any corridor would have been extremely poor (Fladmark 1979:57).

The speculative nature of such environmental reconstructions for the corridor was constant throughout this period because direct data on the environment were largely non-existent. However, instead of preventing discussion on the corridor's environment, this lack of data encouraged researchers to apply other proxy data to the problem. The use of atmospheric circulation models and modern cold weather analogues, along with geological stratigraphy, allowed researchers to construct hypothetical conditions that could be later compared to field data. The proxy data meant that environmental reconstructions focused on climatic or weather conditions within the corridor and not on possible floral or faunal populations.

The Data Accumulation Period

By the early 1980s, the previous decade of geological and palynological field research began to have an effect on environmental reconstruction of the corridor. The accumulating data from this research allowed a more direct reconstruction of floral and faunal communities than the previous proxy data on potential weather or climatic conditions within the corridor.

Ritchie (1980:15-28) summarized the knowledge of these conditions within the corridor for the Mid and Late Wisconsinan using biostratigraphic data with an emphasis on palynology. He did not relate this to the question of human use of the corridor as a migration route. The data on the Mid-Wisconsinan indicated that Laurentide ice had retreated from an earlier advance and was situated near the eastern shore of Hudson Bay. Conditions within the corridor, based on the pollen and fossil record, appeared to be similar to those existing today (Ritchie 1980:22-23).

Ritchie (1980:23) divided the corridor into southern and northern segments for the Late Wisconsinan, with the area between Great Bear Lake and Great Slave Lake as the boundary (a precise boundary is not stated). He claims that the oldest sediments in the south were 13000 years old. Unfortunately, he does not explain how this date was determined. None of the southern pollen diagrams he refers to in his illustration have radiocarbon dates that old (Ritchie 1980:23-24, Figure 4). Those same pollen diagrams suggest that after deglaciation began the landscape was forested first by poplar and then by spruce but lacked pine, birch and alder. By 10500 B.P. the forest was replaced by grasslands. This conversion proceeded from south to north and took several thousand years to complete (Ritchie 1980:23).

In the northern segment, palynology indicated that Beringia was basically treeless and consisted of grass, sedges, sage or willow during the glaciation. This was slowly replaced from west to east with a plant community dominated by birch. It began in eastern Alaska between 13000 and 14000 B.P. and reached the lower Mackenzie by 12000 B.P. Finally, Ritchie notes that spruce showed evidence of migrating from the southern segment of the corridor between 12000 and 10000 B.P. and reached the lower Mackenzie River by 9500 B.P. (Ritchie 1980:24-25).

Fladmark (1983:13-41) summarized available data on environmental conditions of the Late Pleistocene (Mid and Late Wisconsinan) for North America and how it may have affected human settlement of the continent. For the corridor area, he divided the Late Pleistocene into four periods: Mid-Wisconsinan, 60000 B.P. to 25000 B.P.; Late Wisconsinan Advance, 25000 B.P. to 18000 B.P., Late Wisconsinan Climax, 18000 B.P. to 15000 B.P. and Late Wisconsinan Early Recessional 15000 B.P. to 11000 B.P.

As ice began to advance, Fladmark noted that any hypothetical human populations that might have migrated into central Canada could have been forced back into Beringia, if the advancing Laurentide glacier and associated environmental deterioration was rapid. If the advance was slower, then the glacier might have displaced populations in all directions. Which scenario was correct was difficult to determine, since the number and type of effects on the landscape and climate caused by the advancing glacier were immense (Fladmark 1983:19).

In Beringia, the advancing Laurentide glacier caused ponding in interior Yukon and probably severely altered the local environment and its productivity for plants and animals. Fladmark remarked, that during the glacial maximum the vegetation of Beringia had often been characterized as a 'steppe-tundra' or as 'Arctic-steppe' with no modern analogue. Archaeologists tended to favour the latter interpretation since it was interpreted as an environment that encouraged the spread of big-game hunting. Fladmark pointed out that palynological research available at that time suggested a polar desert actually may have been present. He suggested that the problem was in trying to impose a single environment and vegetational community on such a large geographic area. In all probability there was an increasing trend towards a more harsh continental climate from west to east across Beringia as the oceanic affects diminished (Fladmark 1983:20,22).

Fladmark (1983:20) observed that east of the mountain front the geological evidence suggested the ice attained its furthest westward advance first in the north and then progressively later in the south. He noted that advancing glaciers (both from east and west) were the ultimate restriction to habitability of the landscape, but that other environmental changes occurred ahead of the ice. At some point normal drainage patterns into Hudson Bay would have been blocked or diverted causing substantial ponding to develop quickly over wide areas. The location of outlets and extent of such pro-glacial lakes would have been constantly changing as the ice advanced. Eventually these ponded areas would themselves be overridden by the advancing glacier. He commented that biotic communities, including any possible human inhabitants, would have been increasingly stressed as the climate became cooler and more variable. The early advance of ice in the north may have acted as a wedge that split the biotic community. It would have forced some plants and animals to retreat northwest back to Beringia and others to the southwest. Life along the ice front may have been characterized by the development of permafrost, tundra and a sharp drop in temperature as one approached the glacial face. Conditions immediately adjacent to the glacier were raw and unpredictable with an unstable terrain that would not have encouraged the growth of productive biota (Fladmark 1983:20-21).

Fladmark noted that, with the data present at the time and with no modern analogues, it was difficult to reconstruct environmental conditions within any ice-free corridor. His reconstruction assumed that a narrow strip of land (as narrow as two kilometres) existed and paralleled the Rocky Mountain foothills Such a narrow strip would have been unstable in a geomorphic sense and would have funneled cold katabatic winds off the glaciers causing severe temperatures. Any lakes or pondages within the corridor would probably have been sterile, with unstable shorelines. He suggested that conditions would have been more severe than the proposed Arctic-steppe in Beringia. If the corridor could support any plant life that could sustain large mammals it may have been located on south facing slopes and uplands. Fladmark finished his reconstruction by noting that if humans did exist in the corridor at this time then they must have had a specialized technology and strong motivation to be able to survive in such a desolate landscape (Fladmark 1983:28-32).

Fladmark suggested that during the early recessional period the data indicated that the corridor widened significantly after 14000 B.P. Although this would have eventually improved conditions for biotic communities within the corridor, initially large volumes of meltwater would have ponded along the glacier fronts. During early deglaciation these lakes were probably unproductive due to cold water temperatures, erratic water levels, sediment input, and a lack of connections to productive aquatic systems from which plants and animals could migrate. Later as temperatures continued to rise, the freshly deglaciated landscape would have been rapidly recolonized by plants, animals and possibly humans. Early biotic communities appeared to be dominated by a herbaceous tundra plant community that was later replaced by a spruce dominated forest (Fladmark 1983:37).

Publication of mainly palynological and geological field research conducted prior to the 1980s, provided those researchers doing environmental reconstruction with more direct evidence of the changing conditions throughout the Late Wisconsinan in the corridor. This allowed them to construct more detailed descriptions of possible biotic communities in various segments of the corridor. Researchers no longer needed to rely solely on broad stroke proxy information, such as atmospheric circulation models, to determine climatic conditions. The data being published, and the increasing use of radiocarbon dates, meant that researchers could infer changing climatic conditions from the changing biotic communities revealed by palynological and geological research.

The Debate Period

Considering the similarity between Ritchie's and Fladmark's description of conditions within the corridor during the Data Period, one would expect that continuing research throughout the 1980s would have led to greater agreement on conditions during the Late Wisconsinan. In fact the opposite was the case. This was because the accumulation of increasing amounts of data from palynology, geology, archaeology, and related disciplines, allowed researchers to construct data sets for smaller areas of the corridor area or concentrate on specific subsets of data. This period is named for the debates over the nature of conditions within the corridor that the accumulation of data now inspired.

The evidence for this broadening of research perspectives on the corridor is illustrated by the fact that in 1996 the journal *Quaternary International* devoted an entire issue to the ice-free corridor (Mandryk and Rutter 1996). It reviewed evidence from palynology, biogeography, glacial geology, palaeogeography, vertebrate paleontology and archaeology. Those submissions that interpret the corridor's environment are discussed below.

MacDonald and McLeod (1996:87-95) used palynological data from 17 lake cores to show that the ice-free corridor could have acted as a biogeographic corridor at both the beginning and end of the last glaciation. Their article, however, only considered the glacial termination period and assumed that similar conditions existed at the beginning of the last glaciation. Although they did not list any radiocarbon dates, they noted that their periods were based on chronologies and dates published by the original authors (MacDonald and MacLeod 1996:87-88).

Although deglaciation within the corridor began as early as 14000 B.P., significant amounts of organic sedimentation appears to have begun only after 12000 B.P. MacDonald and MacLeod (1996:89) designated the period between 12000 B.P. and 10000 B.P. as the Open Corridor phase. In Beringia the pollen record during this time showed a landscape dominated by grass, sage, sedge, willow and herbs. Birch showed an increasing presence through time, and poplar was present after 11000 B.P. In the middle section of the corridor, between 69° and 55°, the environment was dominated by sage, grass, sedge, goosefoot, thistle and plantain. Trees present included willow, birch (more common in the north) and varying amounts of poplar. This was interpreted as a landscape of herbs and shrubs (MacDonald and McLeod 1996:89-90). In the south, on the western plains, the palynological record begins at 10400 B.P. and indicates a plant community dominated by sage, grass, sedge, goosefoot, thistle, willow and birch. In addition, there were low amounts of pine, spruce and poplar. This assemblage, like those further north, reflected an open (non-forested) vegetation (MacDonald and McLeod 1996:90).

Noting that pollen records from the corridor do not reflect modern tundra pollen assemblages, MacDonald and McLeod (1996:91) suggested that temperatures within the corridor at this time were warmer in the summer than at present. Several lines of evidence point to this conclusion. First, the presence of poplar and cattail pollen in lake deposits north of their present ranges suggested warmer temperatures. Second, the abundance of thistle and goosefoot suggested warmer and possibly more arid conditions. Third, the presence of spruce at high elevations while absent at lower elevations was consistent with dry conditions (MacDonald and McLeod 1996:91).

Their interpretation is that, as the glaciers melted, a biogeographical corridor appeared vegetated by herbs, grasses and shrubs (MacDonald and McLeod 1996:91-93) . After 10000 B.P. that vegetation corridor was quickly replaced by a more modern looking forest. Evidence for this sudden change was found in the rapid increase in spruce pollen in lake cores. This appeared to have occurred in two phases: first, a northward expansion of spruce from the plains and mountains in the south, and second, an increase in spruce density to the point where a closed forest was present. The latter phase effectively closed the biogeographical corridor to grazing animals adapted to the earlier open tundra like vegetation.

Similarly, Wilson (1996:97-105) also examined conditions within the proposed corridor from a biogeographical perspective. He, however, concentrated mainly on paleontological evidence in the form of dated bison remains, stating that "...the timing of the ecological opening of the corridor is to establish a chronology for the arrival of immigrant vertebrates through direct radiocarbon dating..." (Wilson 1996:98). Key to his interpretation was a taxonomic classification of northern and southern Late Wisconsinan bison. Bison probably entered North America about 200,000 years ago and by the Late Wisconsinan two subspecies had evolved: a northern *Bison bison occidentalis*, and a southern *Bison bison antiquus*. The characteristics that distinguished these two forms were overall size (the southern variety was larger) and horn core morphology. In the southern variety, horn cores were downswept and laterally directed from the cranium, while the northern form had horn cores that were backswept and rose above the plane of the frontal bones (Wilson 1996:96-97).

Wilson also noted that the presence of bison and other megafauna throughout Alberta, as well as pollen evidence, indicated that a mammoth steppe landscape existed within the corridor prior to 10000 B.P. The duration of those conditions varied to some degree between locales. Some areas experienced a brief open poplar woodland phase (Wilson 1996:101) before the transition to boreal forest. At the same time, bison remains, classified as *B. b. antiquus*, found as far north as the Peace River area and dating to between 11000 B.P. and 9750 B.P., indicated that steppe conditions were present (Wilson 1996:101).

Wilson suggested that the southern form of bison, along with other megafauna, moved as far north as the Peace River along the mammoth steppe landscape of the corridor. This was evident by the measurements on fossil bison crania that were similar to other *B. b. antiquus* skulls from the United States. In the Peace River area they met the northern bison subspecies and other fauna moving south along the same landscape. The northern form swamped the southern form producing the modern bison species. As MacDonald and McLeod noted above, after 10000 B.P. the open landscape began to disappear with the development of the modern boreal forest (Wilson 1996:102-103).

Burns (1996:107-112) also used radiocarbon dated paleontological specimens to assess the environment within the corridor. He took a broader approach than Wilson and looked at whole assemblages of faunal remains from the Middle Wisconsinan through to the Late Wisconsinan. Based on a list of 33 radiocarbon dates from Alberta spanning the Middle and Late Wisconsinan, he noted a lack of radiocarbon dates between 21000 and 11600 years ago (Burns 1996:110). He interpreted this as evidence that an ice-free corridor, which could have been used as a migration route during the last glacial maximum, did not exist at that time

Prior to 21000 year ago the paleontological assemblages suggested that most of Alberta was covered with a vegetation similar to mammoth steppe, dominated by grasses and herbs. This was evident from the composition of these faunal assemblages because they contained faunal elements from both northern and southern species. Such a faunal composition has no modern analogue, thus the landscape must have had a unique composition of plants. During the Late Wisconsinan deglaciation this steppe environment was re-established on the cold dry landscape of Alberta. Burns (1996:110) assumed that, because such communities thrived in cool, dry conditions of Beringia, they would quickly have become established and thrive in the analogous conditions of recently deglaciated areas of Alberta. This allowed large herbivores to quickly, within several hundred years, re-populate the landscape after deglaciation. In order to explain the earliest bone dates in the Edmonton area at only 11600 B.P. he suggested that deglaciation occurred well after the 14000 B.P. that had been advocated by Dyke and Prest (1987:245). He contended that this return to mammoth steppe conditions did not last long because by 11000 B.P. closed forest conditions were beginning to develop in the south (Burns 1996:110).

Mandryk's (1990, 1992, 1996; Catto and Mandryk 1990) aim in her dissertation (1992:1), was to determine if the corridor's environment allowed groups of hunter-gatherer societies to be reproductively viable. She concentrated on establishing the paleoecology of south central Alberta, by using palynology. Then, by analysing the relationships between the physical environment and social and biological factors, she tested the region's viability as a human environment (Mandryk 1992:1). Finally, she examined the implications of her regional study for the entire corridor and its potential role in the peopling of the New World.

Mandryk (1992:242-324), divided her regional analysis into qualitative and quantitative approaches. The former involved reviewing and comparing cold/dry environments (including primary productivity, primary biomass, animal species density and diversity) and hunter/gatherer adaptations to them from around the world. The latter involved integrating her palynological results from south central Alberta with her conclusion from the qualitative approach.

From the qualitative approach, Mandryk (1992:262-270) concluded that a cold/dry marginal environment was most likely present within the ice-free corridor. A minimum human population of 175 individuals spread over a maximum area of 2500 km^2 could have been economically and socially viable under such conditions (Mandryk 1992:282-283,316). In her quantitative approach, Mandryk (1992:305) used 3000 calories/day as the minimum required for humans within the corridor in a cold/dry environment. She then calculated when south central Alberta's primary productivity, biomass and faunal populations could have maintained a population of 175 individuals, spread over 2500 km^2, with this daily caloric intake (Mandryk 1992 305-324). She concluded that this could not have occurred prior to 12000 B.P. (Mandryk 1992:315,323). By implication she concluded that humans could not have used the ice-free corridor between 18000 B.P. and 12000 B.P. (Mandryk 1992:327).

Mandryk's interpretation of the timing of deglaciation was vital to her palaeoenvironmental reconstruction and was based on ^{14}C dates obtained from lake cores from west-central Alberta. Mandryk (1990:70-71; 1992:181-185; 1996:80-82) interpreted the process of deglaciation as having begun immediately after the glacial maximum at roughly 18000 B.P. Although she provided little physical evidence to support this claim, she did present a plausible alternative interpretation of maps showing successive ice front positions (e.g., Prest 1984; Christiansen 1979;923-931; Schreiner 1983:84-93). Mandryk (1992:190) interpreted those positions not as evidence of active ice fronts, but of stagnant down wasting ice. As this stagnant ice slowly melted, englacial debris accumulated supraglacially on the remaining dead ice allowing vegetation to grow. As a modern Holocene analogue, Mandryk (1992:193-197) used ice cored terrain and glacial karst topographies from the Martin River Glacier and the Klutan Glacier in the Yukon to interpret deglaciation within the corridor. Additionally, she observed the modern occurrence of thermokarst topographies and the formation of depressions from melting ground surfaces in areas of permafrost (Mandryk 1992:196). The occurrence of thermokarst topographies in areas of modern human habitation with ground ice (e.g., Siberia), which she equated to that covered by buried glacial ice, indicated to her that humans could have lived on such landscapes (Mandryk 1992:197).

Radiocarbon dates from cores in Mitchell Lake and Nordegg Pond in west-central Alberta supported her interpretation (see Table 1 for Mandryk's dates). Mandryk (1992:90) rejected the dates from a third core from Strubel Lake as being too old because they dated bulk inorganic clay lake-sediments that contained less than 2% organic carbon. The other dates were deemed acceptable, supporting her contention of an ice cored terrain and a short lived glacial maximum in west-central Alberta (Mandryk 1992:79, 190-191).

West (1996:537-539) synthesized the various research approaches and data sets to support the corridor as a migration route for populations from northeast Asia. He saw a continuity between Upper Palaeolithic artifact assemblages from Europe and Siberia with what he termed "Early American Beringia" in Beringia proper, and the later Paleoindian Clovis culture of the American plains (West 1996:553-554). West envisioned that near the end of the Pleistocene, populations in eastern Beringia (present day Yukon) found themselves in a cul-de-sac with rapidly deteriorating environmental conditions that affected their primary food source, the mammoth fauna. This fauna West (1996:543, 545) defined as a "...large, diverse, ungulate fauna..." that included mammoth, bison, horse, woolly rhinoceros, yak, muskox, saiga antelope and cave lion (although all species were not necessarily present at any one locale). This mammoth fauna relied on a mosaic vegetation he termed a tundra-steppe pattern dominated by sage to provide it with sufficient fodder (West 1996:545). A warming trend at the end of the Pleistocene caused a reduction in this vegetation pattern and resulted in a population crash for the mammoth fauna. Faced with famine, human populations present in the cul-de-sac were forced to follow whatever game was available through the ice-free corridor (West 1996:555-556), some 1600 km or more, to its southern terminus. This was seen by West as a determined trek (taking less then a few years) and not simply a population spread. This rapid, determined migration, according to West (1996:556), explained the lack of intervening sites along the corridor and the sudden appearance of Clovis on the Great Plains.

If the corridor was used for this determined trek, then it must have been completely vegetated (a biogeographical corridor) to support those traversing it (West 1996:555-556). Although he provided no detailed description, conditions within the corridor presumably supported the tundra-steppe that the mammoth fauna, and ultimately their human pursuers, needed to survive. In contrast, the rapid and determined nature of this migration suggested that West's vision of the corridor was not a desirable place to inhabit for either humans or animals. Otherwise, humans would have lingered and the intervening sites would be present.

During this Debate Period, accumulating data from the corridor area allowed researchers to use multiple approaches to investigate its environmental conditions. The quantity of radiocarbon dated material meant that researchers could now present conclusions backed up with a large and coherent data set. The result has been an array of sometimes overlapping, divergent and at times conflicting opinions. The ensuing debate however, must be considered healthy for our understanding of the ice-free corridor and its possible role as a Late Wisconsinan human migration route. My research adds to this diverse group of interpretations by emphasizing only reliably dated organic remains as a primary source for environmental reconstruction.

Since the 1960s, the trend in reconstructing the environment of any potential corridor has gone from almost pure speculation, based on very little evidence, to being based on a large accumulation of sometimes conflicting data. Although the quantity and types of environmental data have increased, our understanding of environmental conditions within the corridor has not necessarily become clearer. In particular, there is increasing evidence that conditions during the last glaciation created biotic landscapes with no modern analogues, and researchers have had to speculate on their nature. This has resulted in a variety of different terms used to identify and describe this biotic landscape: West (1996:545) termed it a "tundra-steppe" consisting of a mosaic vegetation, Wilson (1996:102) and Burns (1996:110) both used "mammoth steppe" to describe a grassland like environment, Fladmark (1983:29) a "high arctic tundra", and Ritchie (1980:25) suggested that it was like modern tundras found on coarse upland soils. The following section will discuss these mosaic vegetation interpretations.

Steppe or Tundra

None of the environmental interpretations mentioned above were considered unique to the corridor itself but were seen as an extension of conditions common throughout the Late Wisconsinan in northern latitudes. This section will not determine which interpretation is correct, since the debate continues, but discuss whether any of these environmental interpretations could have provided the necessary biogeographical corridor between Beringia and unglaciated areas south of the ice sheets.

The mammoth steppe was proposed to account for the recovery of mammoth fauna remains in the paleontological record over wide areas of the Northern Hemisphere dating to the Last Glacial Maximum (Guthrie 1982:308). Due to the ubiquity of woolly mammoth on this landscape, Guthrie (1982:308) felt that the term mammoth steppe more accurately identified the character and nature of the conditions and vegetation.

Guthrie (1982:308; 2001:350-351, Figure 8) envisions the mammoth steppe as stretching from western Europe across Asia to Beringia and down the ice-free corridor. Although it had many local variants, generally speaking the mammoth steppe consisted of low herbaceous plants, dominated by grasses, sedges, forbs and sages (Guthrie 1982:315; 1989:266-267; 2001:353). These plants, and the animals that fed on them, suggested an arid environment with incomplete ground cover and a firm substratum with permafrost far from the surface during summer.

To account for this unique set of environmental conditions, Guthrie (2001:557-559) proposes that the driving force was an increase in clear skies caused by moisture blocking features of mountain ranges, frozen oceans and glaciers. These conditions created a vast region of arid grassland like vegetation. The clearer skies and incomplete ground cover dried out the substratum and kept permafrost far from the surface during the summer, which allowed what little moisture that did fall to either quickly evaporate or run off. The increased sunshine would have been translated into higher plant growth productivity because of a higher turnover in nutrients and carbon in the upper soil layers. This in turn supported the megafauna (Guthrie 2001:554-559;568-569). In winter the clearer skies and decreased snow cover would have increased the heat loss. Guthrie (2001:558-559) believes this explains the proxy evidence of increased permafrost depth, ice-wedge development and sea ice expansion during the last glacial period.

Palynologists have been the primary opponents to the mammoth steppe interpretations. Their data (which includes plant macro-fossils and insect remains) from western Alaska and the Yukon suggested that a dry mosaic tundra was present between 20000 B.P. and 14000 B.P., with eastern Beringia being dryer than western (Anderson and Brubaker 1994:84, Figure 10). There also was debate on whether the wetter western tundra could support herds of megafauna (Colinvaux 1986:9; Anderson and Brubaker 1994:84). Some researchers described the western tundra as a birch-grass tundra (Elias et al.1996:62-63) while others described it as a moist herb tundra, with willow as the dominant shrub species (Anderson and Brubaker 1994:81-82,84). Evidence for the birch-grass tundra came from locales now underwater in the Bering and Chukchi Seas, while evidence for a herb-willow tundra came from areas farther east and inland (Elias et al. 1996:61; Anderson and Brubaker 1994:72, Figure 1). In dry eastern Beringia, sparse herbaceous tundra was present on the uplands, with sedge-grass meadow occupying the lowlands (Cwynar and Ritchie 1980:1377; Anderson and Brubaker 1994:84). It would not be unreasonable to speculate that from west to east the tundra graded from moister to drier environments. Altitude also affected vegetation patterns, with the mountains of western Alaska having a dry sparse tundra similar to eastern Beringia while lower altitudes had the moister tundra (Anderson and Brubaker 1994:84). Colinvaux likens the low altitude glacial tundras to modern mesic tundras of Arctic Alaska and the higher dryer tundras to a polar desert (Colinvaux and West 1984:11, Colinvaux 1996:23).

Palynologists have largely dismissed the relevance of faunal remains for establishing environmental conditions during the last glaciation. By implication, the conditions proposed for the mammoth steppe are considered unlikely. Such bones are considered to represent isolated individuals or populations that wandered or were forced into the marginal environments (Colinvaux and West 1984:10-11; Colinvaux 1996:23).

After 14000 B.P. conditions across Beringia generally became wetter and warmer, with vegetation shifting to a birch-grass tundra (Anderson and Brubaker 1994:82,84-85; Elias et al. 1996:62) This process began in the west and gradually moved east, although conditions still remained drier in the east until after 12000 B.P. Between 14000 B.P. and 12000 B.P. it appears that the earlier dry herb tundra of the east was able to expand into areas that previously had been too harsh (Anderson and Brubaker 1994:84). After 11000 B.P. poplar became common in the birch-shrub-tundra that now dominated from western Alaska to the Yukon. This lasted until about 9000 B.P. when spruce became abundant and a more modern looking vegetation regime appeared (Anderson and Brubaker 1994:84-85). The Younger-Dryas does not appear to have had a significant affect in Beringia.

Of the environmental reconstructions discussed above, the full glacial dry herb tundra, if present within any corridor, would not have been productive enough to provide a biogeographical corridor for megafauna or human populations. However, either the mammoth steppe (as defined by Guthrie) or the late glacial shrub tundra (occurring after 14000 B.P.) could have provided the appropriate conditions. Thus, if the ice-free corridor was used as a migration route then the following research should reveal if either of these types of conditions were present at the appropriate time.

The Ice-Free Corridor Concept and the Clovis-First vs. Pre-Clovis Debate

The basis of the Clovis-first model is that no definite antecedent archaeological culture is present in the archaeological record south of the glacial ice in the Americas. Thus, Clovis must represent the immediate descendants of the first human migrants through the ice-free corridor.

The pre-Clovis model advocates an earlier Pleistocene human occupation of the Americas that may or may not have involved the ice-free corridor (Whitley and Dorn 1993:627-628). This earlier population either developed into Clovis or was supplanted by Clovis immigrants arriving via the corridor. Numerous sites have been used as evidence for the pre-Clovis model and have subsequently been discredited (e.g., Taber Child Site in southern Alberta and Calico Hills in southern California). Newly discovered sites, however, are continually being put forward as examples of this pre-Clovis culture. According to West (1996:540), the common problem with all purported pre-Clovis sites is a pronounced lack of similarity among them. For West (1996:540), this heterogeneity defies what archaeologists have learned about cultural evolution, and challenges the definition of cultural patterning used in archaeology and anthropology (Winick 1977:405; Bray and Trump 1975:68). The fact that widely spaced Clovis sites do show similarities supports the notion that cultural patterning does exist in the archaeological record and supporters of the pre-Clovis model must explain why pre-Clovis sites do not show such patterning. A critical review of several of these sites and how the corridor concept relates to them will help illustrate the differences between these two models.

Although not exhaustive, the sites discussed provide examples of the complexity of the issues that surround purported pre-Clovis sites. Some have been debated for over 20 years (Meadowcroft and Monte Verde) while others have only recently been reported in the literature (Cactus Hill). They all illustrate that dating and association of possible cultural remains with datable material or geological stratigraphic units has generally been the Achilles heel of most alleged pre-Clovis sites. It is because of these problems that research in this thesis has emphasized using reliably dated organic samples to reconstruct the biogeographical nature of the ice-free corridor and its potential use by Clovis ancestors or predecessors.

In North America, five sites will be examined as examples of possible pre-Clovis occupation. Three are located within the study area in Alberta. These are the Varsity Estates, Silver Springs, and Grimshaw sites that have been interpreted as evidence of pre-Late Wisconsinan (Palaeo-American) human occupations. The other two sites, Meadowcroft Rockshelter and Cactus Hill, are in eastern United States.

The Alberta sites were discovered and reported by Jiri Chlachula (Chlachula 1996:285-313; Chlachula and Leslie 1998:871-884; Chlachula and LeBlanc 1996:61-74). Chlachula interpreted these sites as evidence of Mid-Wisconsinan Palaeolithic occupations based on his identification of presumed pebble and chopper tools reminiscent of Eurasian Pleistocene assemblages (Chlachula 1996:301; Chlachula and Leslie 1998:876). In many ways this revives Bryan's (1969:339-365) earlier hypothesis of a Mid-Wisconsinan migration for humans into the Western Hemisphere and , in particular, his contention that such 'early sites' may be represented by non-diagnostic cobble assemblages (Byran 1969:344).

At the Grimshaw site the purported Palaeolithic stone tools were incorporated into Late Wisconsinan till. The source of these artifacts was the surface of pre-glacial gravels underlying the till (Chlachula and Leslie 1998:873, 883). Similarly, the Silver Springs site was interpreted as consisting of Palaeolithic stone artifacts redeposited in a geological context by advancing Late Wisconsinan glaciers (Chlachula 1996:297). The third site, Varsity Estates, consisted of a lower assemblage of redeposited flaked artifacts entrained in glacial till and a largely *in situ* upper assemblage lying on the surface of a till covered by glacial lake sediments (Chlachula 1996:298).

In critiquing the artifacts from these sites Driver (2001a:871-874; 2001b:127-131) focuses on the method and logic used in identifying the purported artifacts as products of human manufacture. Chlachula (1996:301; Chlachula and Leslie 1998:876) used the following criteria:

1. Regularity of flaking
2. Recurrent and technologically coherent patterns of stone modification
3. Standardized size range of the resulting forms
4. Presence of a set of associated attributes diagnostic for stone tool production which are not found in clastic rock assemblages of identical lithologies from glacial and fluvial settings in Alberta despite similarity of depositional environments.

In addition to these formally stated criteria, two other informal criteria also were used. The first, involved 15 years of experience by Chlachula in identifying such artifacts (Chlachula 1996:301; Chlachula and Leslie 1998:876) and a survey of experts (Chlachula and LeBlanc 1996:72). The second, was a stated similarity to Holocene age cobble artifacts found throughout Alberta (Chlachula 1996:302-303; Chlachula and Leslie 1998:876). This was formalized in a comparison of the Silver Springs and Varsity Estates assemblage with the cobble tools from the Holocene age Slump Site (GiQu-3) on the shore of Lesser Slave Lake (Chlachula and LeBlanc 1996:61-74).

Driver (2001a:872; 2001b:129) concedes that the formal criteria listed above do occur on artifacts but that Chlachula and his colleagues failed to show that such criteria cannot also occur naturally. Citing examples from around the world, Driver (2001a:872-873; 2001b:127-128) shows that the debate over differentiating artifacts from naturally broken rocks has had a long history in archaeology and that studies suggest that the criteria noted above are not exclusive to artifacts. Driver (2001a:872) notes that the only evidence that such criteria were not produced naturally was from Chlachula's doctoral dissertation (Chlachula 1994). In order to accept the disputed objects Driver (2001a:872) suggests using a control sample of broken cobbles from an analogous geological context (a till laid down by continental glacier, that formed prior to early humans entering North Americas). Such a sample would guarantee that Chlachula was comparing naturally fractured cobbles with his purported stone tools.

Driver (2001a:872; 2001b:128-129) also is critical of the method of comparing selected broken cobbles from these different contexts, suggesting that bias was inherent in the selection process. He argues that control specimens and supposed artifacts should be considered as part of a total assemblage, or an appropriate sampling strategy employed for selecting those objects to be compared. At Grimshaw no attempt was made to compare entire assemblages of either natural or fractured cobbles. In the comparison of the Slump Site artifacts with the Silver Springs and Varsity Estates Sites, Driver (2001b:128) notes that the artifacts were selected because they looked similar. Instead the comparison should have been on a random sample or an entire assemblage, which in this case included artifacts made on cryptocrystalline material. Driver (2001b:129) suggests that it is possible that the original inhabitants of the Slump Site had transported naturally flaked cobbles to the site but had not modified them further. Any bias in the selection of which cobbles to compare might include these naturally flaked cobbles that would look similar to cobbles from Silver Springs and Varsity Estates.

Driver (2001a:872; 2001b:128-129) rejects both of the informal criteria. In critiquing Chlachula's use of "expert opinions" Driver notes two problems 1. a controlled test was not conducted showing that those individuals could consistently distinguish between rocks fractured by nature or humans (Driver 2001a:872), and 2. the "survey of opinions" did not include a valid survey of opinions from randomly selected experts (Driver 2001b:129). Based on these methodological problems, Driver (2001a:273; 2001b:129-130) concluded that Chlachula and his colleagues have insufficient evidence to identify these broken cobbles as artifacts, and the conclusion that humans occupied Alberta prior to the last glaciation is unsubstantiated

Chlachula and Leslie (2001:878) reject all of Driver's arguments. They dismiss Driver's reference to studies from around the world that caution against accepting broken cobbles from geological context, as irrelevant because they were not from glacial deposits (Chlachula and Leslie 2001:875-876). They cite instead several studies where they claim that identified artifacts are from contexts similar to Grimshaw, Silver Spring and Varsity Estates. They however, either fail to realize or simply reject the basic theme from Driver's example that broken rocks resembling artifacts can occur in a variety of geological deposits, and that a rigorous method must be used to distinguish between them.

Chlachula and his colleagues also object to Driver's critique of researchers' experience, arguing that this would suggest most Palaeolithic evidence from around the world is based on consensus and not objective criteria (Chlachula and Leslie 2001:875). Yet, they use consensus to support their claim by noting that "...fifty experienced archaeologists... had no problems accepting them as artifacts" (Chlachula and Leslie 2001:876; also see Chlachula and LeBlanc 1996:72). They also appear to misinterpret Driver's discussion of sampling and control specimens to mean that only statistics can differentiate between artifacts and naturally fractured cobbles and reiterate that researcher experience is vital to such separations (Chlachula and LeBlanc 1996:876). In fact, Driver was emphasizing that because studies from other geological contexts can produce naturally broken rocks resembling artifacts, it is necessary that a rigorous method be employed before accepting any disputed cobbles as artifacts.

Young et al. (1998:449-453) critique the geological interpretation presented by Chlachula (1996) for the Silver Spring and Varsity Estates sites. They dispute his reconstruction of the timing of the Bow Valley and Laurentide glacial advances by pointing out that the dates used for Chlachula's reconstruction are either tentative or assumed. In comparison they note radiocarbon dates from both north and south of the Bow valley that indicate coalescence between Laurentide and Cordilleran glaciers. They also note that geomorphological features to the west of the Bow Valley indicate that there was Late Wisconsinan coalescence between these ice-sheets (Young et al. 1998:449).

Chlachula is dismissive of this critique. First, he states that it is unimportant if the Bow Valley Ice advance took place after 23000 B.P. because there still would have been time for humans to occupy the area. The geomorphological features to the west of the sites are not directly dated to the Late Wisconsinan and so could be from an earlier glaciation, although he fails to explain how they survived the Bow Valley Ice advance (Chlachula 1998:456). He suggests that only the piedmont glacier emerging from the Athabasca Valley coalesced with the Laurentide glacier. Here the former deposited its load of glacial erratics (see above) on the latter which subsequently carried and deposited them as the Foothills Erratics Train. Thus, there is no need for coalescence all along the foothills (Chlachula 1998:457). He fails to explain what would have continued to deflect the Laurentide glacier to the southeast along the foothills, when its natural flow was towards the southwest. Finally, Chalachula (1998:457) asserts that the artifacts (if one accepts them as such) are themselves geological proof that coalescence did not occur in the Bow Valley during the Late Wisconsinan. This circular argument leads us back to Driver's demand that the objects be verified as artifacts (humanly manufactured) by unbiased means.

Excavations at the Meadowcroft Rockshelter in Pennsylvania began in 1973. Although the archaeological nature of the more recent (<12000 B.P.) deposits are not in dispute, an earlier suite of 13 radiocarbon dates (Adovasio et al. 1998:329) are controversial. Two separate issues are involved. First, is the extension of the Palaeoindian time period by between 500 to 3000 radiocarbon years to cover the Miller complex assemblage identified by Adovasio. This complex includes an unfluted lanceolate "Miller point", prismatic blades and polyhedral cores that Adovasio interprets as similar to material from Siberia of comparable age (Adovasio et al. 1998:320-323). Second, is the recovery of purported basketry/bark and prismatic flakes from deposits dated to about 19500 B.P. (Adovasio et al. 1978:156). This would push the Miller complex back to before the last glacial maximum.

Controversy has revolved around possible sources of contamination of the samples radiocarbon dated from the lower layers and the environmental implications of the floral and faunal remains recovered. As early as 1978, Adovasio and his associates (Adovasio et al. 1978:153-157; Adovasio et al. 1998: 331) attempted to rule out possible sources of contamination by particulates (small coal fragments) and, more recently, by solubles (Adovasio et al. 1998:332-333). Particulate contamination now appears to be a non-issue, leaving soluble contamination as the possible source (Adovasio et al. 1998:331-333). The exact nature and mechanism for contamination involve debates over groundwater percolation and Pleistocene water table levels. In his summary of the debate, Adovasio refused to date a walnut shell found at the same level as the bark basket, as requested by Haynes (an ardent critic of Meadowcroft's early dates), because he felt it would not end the controversy (Adovasio et al. 1998:335).

Adovasio et al. (1998) appear to be frustrated by the "could have been or might have been" scenarios constantly proposed for their early dates. They state that since 1978 they have attempted to satisfy their critic's concerns over these early dates, which they feel they have accomplished. This only resulted in having new dating standards imposed on them (Adovasio 1998:335). The debate appears to be at a stalemate, with various researchers either accepting or rejecting the early dates and the associated archaeological record.

The second controversial aspect of Meadowcroft involves the floral and faunal remains. Debate centres on the fact that the 218 bones (11 identifiable) and 11.9 grams of plant remains from the earliest levels suggest an environment not much different from that of today, which is at odds with regional palaeoenvironmental reconstruction during the Late Wisconsinan (Adovasio et al 1998:325). Specifically, there appears to be no Pleistocene-Holocene boundary in the record at Meadowcroft and that has prompted some to suggest that the entire sedimentary record of the rockshelter may be Holocene in age. Evidence for the Holocene nature of these early deposits comes from Davis (1983:166-183) who notes that oak and hickory (two species recovered by Adovasio) do not show a sharp increase of pollen or macrofossils in deposits until after 12500 B.P. and 10000 B.P. respectively in the area of Meadowcroft (Davis 1983:173-175). Adovasio and his colleagues counter by saying there is no evidence of wide spread boundary markers in closed archaeological or paleontological sites anywhere in North America (Adovasio et al 1998:331). Driver (1988: 1551-1552; 1996:25-26) however, would argue that Charlie Lake Cave provides such an example. Adovasio et al. (1998:327) also stress that the ice front had retreated about 150 km to the north during the earlier occupations and this could account for the more temperate faunal or floral assemblage. Finally, using a uniformitarian argument, Adovasio et al. note that the present area around Meadowcroft tends to have a more "southerly temperate regime" (more frost free days than surrounding areas) (Adovasio et al. 1998:328) and this may have been true in the past. Davis' evidence certainly does not conclusively disprove Adovasio's and his colleagues' contention that Meadowcroft is located in a unique climatic regime, but something other than a simple uniformitarian argument must be presented to explain the discrepancy with other environmental data.

Another potential pre-Clovis site is Cactus Hill, located south of Richmond, Virginia. Excavations conducted since 1993 have recovered quartzite blades, blade cores and a thin trianguloid to lanceolate biface below a well defined and dated Clovis (10920±240 B.P., BETA 81589), or fluted point level (Hall 1996:9; Beardsley 1998:34). This is strikingly similar to Adovasio's Miller complex from Meadowcroft and may be the first evidence of a pre-Clovis cultural pattern that West (1996:540; see above) notes is missing from pre-Clovis sites.

Dating of the suspected pre-Clovis level in the Cactus Hill excavation was done on white pine (no longer in area) charcoal that appeared to be from the same silt band, now designated a hearth, that was capped by the Clovis layer (Hall 1996:9-10). This charcoal produced a date of 15070±70 B.P. (BETA 81590). Additional evidence of the separation of the pre-Clovis from Clovis layer comes from the artifacts. Pre-Clovis artifacts are all made of a local fine grained quartzite compared to the chert that was the preferred, but not exclusive raw material in the fluted point layer (Hall 1996:10).

Problems with the site include the sandy soil (the site is located on an old sand dune that had been used as a sand mine) (Hall 1996:9), which may allow vertical movement of artifacts and the formation of deflation lag aggregate artifact assemblages. Although three excavated units produced clear stratigraphic evidence of separate Pre-Clovis and Clovis layers, a fourth unit produced a mixed assemblage. A recent pedological study of the site's soil revealed four buried horizons dating back to 19500 B.P. That horizon designated Soil II contains the Clovis artifacts near its surface and the Pre-Clovis artifacts near its base (ranging from 7 to 20 cm below Clovis). A radiocarbon date from below the Pre-Clovis artifacts indicates an occupation after 16900 B.P. The presence of lamellae in this soil horizon suggests a lack of pedoturbation and bioturbation during soil formation and that the Pre-Clovis cultural horizon is a separate occupation from the Clovis (Wagner and McAvoy 2004:316-320). Wagner and McAvoy (2004:314) do concede to the mixing of the cultural layers in some areas but note that profiles showing clear separation of cultural layers are equally as common as those showing mixing. They also are convinced that the lower Pre-Clovis artifacts were buried by aeolian sand deposition, but they do not rule out the burial of these artifacts by deflation or bioturbation (Wagner and McAvoy 2004:313-314). The study by Wagner and MacAvoy

(2004) has dealt with the mixing and separation issue of Clovis and Pre-Clovis cultural layers at this site to the point where evidence for the separation appears quite compelling. The timing of this earlier occupation at 5000 year B.P. before Clovis, however, is still in doubt and needs to be further clarified with additional radiocarbon dates in good association with cultural material.

At Pedra Pintada, in eastern Brazil, Roosevelt et al. (1996) claim to have evidence of generalized Palaeoindian foragers that were contemporaneous with North American Clovis big-game hunters. If these Amazonian Palaeoindians were contemporaneous with Clovis, then the latter could not be ancestral; and there must have a been a Pre-Clovis culture. Roosevelt et al. (1996:376-377) identify four Palaeoindian periods based on stratigraphy and changes in lithic raw material usage. Using multiple radiocarbon dates from each stratum she defined these periods as: Initial Period 11200 to 10500 B.P., Early Period 10500 to 10200 B.P., Middle Period 10200 to 10100 B.P. and the Late Period 10100 to 9800 B.P.

There is an inherent problem in categorizing all North and South American early cultural adaptions as either "big-game hunters" or "generalized foragers" since it suggests that modern humans are incapable of quickly adapting to a different economic strategy when conditions require it. The published criticisms of Roosevelt's findings have focussed on the radiocarbon dates defining these four periods. Haynes (1997:1948), Reanier (1997:1948-1949) and Barse (1997:1949-1950) have all stressed the internal inconsistences with the radiocarbon dates for each period, especially the Initial Period.

Roosevelt et al. (1997:1950-1952) counter by noting that if Clovis dates were subjected to the same rigorous criteria as Haynes, Reanier and Barse used on the Pedra Pintada radiocarbon dates, then most of them also would be excluded (although they provide no examples).

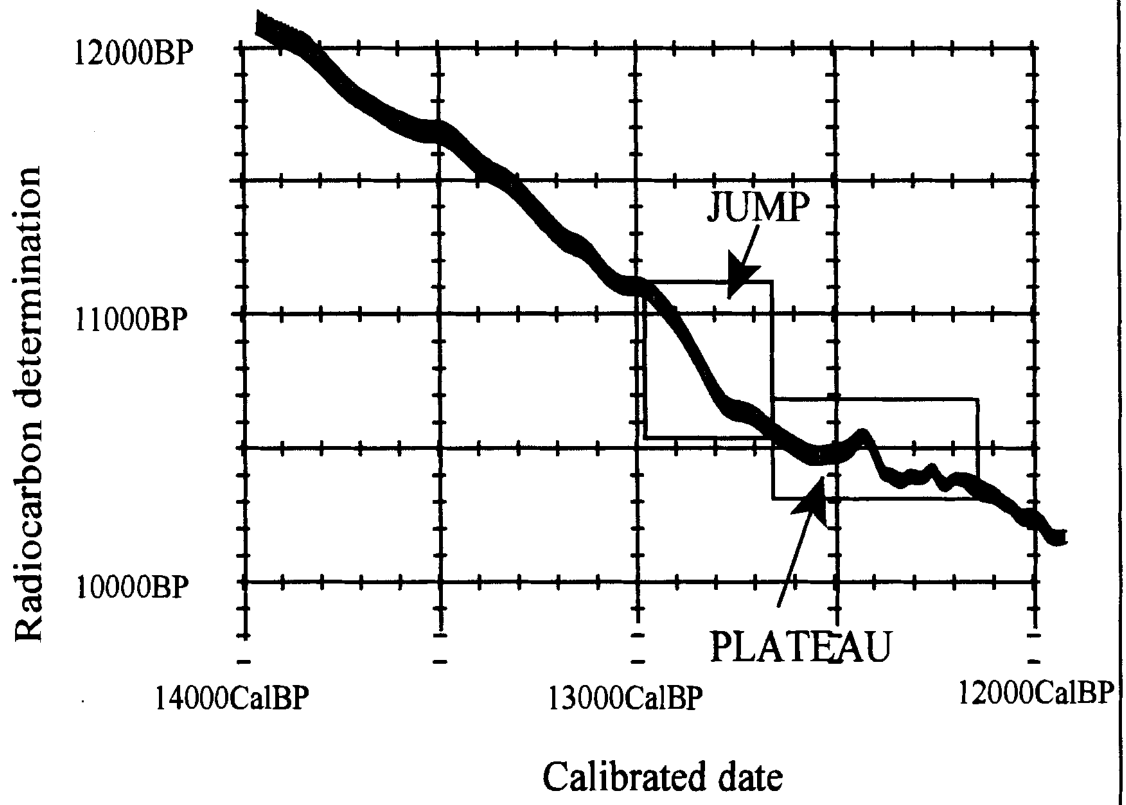
The final and most southerly pre-Clovis site is Monte Verde in Chile. Excavations started there in 1977 and ended in 1985, producing a diverse assemblage including wood, stone, fibre and bone in a buried stratified context. The site was located on the sandy banks of Chinchihuapi Creek, and appeared to have been occupied for about a year before abandonment. Soon after abandonment water and peat covered it preserving, the organic remains (Meltzer 1997:754). Radiocarbon dates from the MV-II level (the early occupation level) range from 13565 B.P. to 11790 B.P. (Dillehay and Pino 1997:44), with an average of 12500 B.P. (Adovasio and Pedler 1997:576;578; Meltzer 1997:754; Taylor et al. 1999:455). The youngest date (11790±200 B.P., TX-5376) has an error margin that overlaps with the oldest Clovis date of 11590±90 B.P. (AA-5274) (Taylor et al. 1996b:517). The authenticity of the majority of the artifacts and their stratigraphic context has been publicly acknowledged by some in the archaeological community (Meltzer et al. 1997:659-663; Gibbons 1997:1256). Not all, however, are convinced of the cultural origin of all of the artifacts or their stratigraphic provenience (see Fiedel 1999) and skeptics continue to search for evidence of contamination in the radiocarbon dates (Taylor et al. 1999).

Full acceptance of Monte Verde by its most ardent critics will probably have to await the discovery of a second site of similar age, with similar artifacts, as discussed by West (1996:540). With a mean age of 12500 B.P., approximately 1000 years B.P. older than the oldest Clovis site (although their ranges do overlap), Monte Verde currently provides the best evidence of pre-Clovis occupation. Its age and distance from Beringia also suggest, to some, a much earlier initial entry to the Americas (Meltzer et al 1997:662).

In order for any of these potential pre-Clovis sites to be as old as their proponents claim, (assuming their ancestors came from eastern Siberia) the ice-free corridor would need to be either: 1. a glacial maximum event (not likely considering the current state of knowledge as discussed above), 2. to have become open soon after the Last Glacial Maximum and to have become a biogeographical corridor almost immediately, or, 3. used by pre-Clovis ancestors before the Last Glacial Maximum. Determining which scenario or scenarios is correct requires knowing when the corridor existed. Thus, the corridor's timing is as relevant to the pre-Clovis model as it is to the Clovis-first model.

Clovis, Environment and Calibration

Fiedel (1999, 2004) has correctly noted, there is about a 2000 year difference between radiocarbon years and calibrated (calendrical years) for the age of the Clovis and Folsom age sites. Figure 5 displays the calibration curve for the period between 10000 B.P. and 12000 B.P., based on the most recent calibration data (Reimer et al 2004) as produced by OxCal3 calibration programme (Bronk 1995; 2001). Thus, the earliest Clovis site dates to about 13500 cal B.P.



Atmospheric data from Reimer et al (2004);OxCal v3.10 Bronk Ramsey (2005); cub r:5 sd:12 prob usp[chron]

Figure 5. Calibration curve, 10000 B.P. to 12000 B.P.

Relating ice core, uranium-thorium dates and radiocarbon dates, Fiedel (1999:100, 103,106) to a cold/wet period of the Intra-Allerød Cold Period at about 11500 B.P. (13500 cal B.P.). After a short (100-200 radiocarbon year) warm period, Clovis end about 10900 B.P, (12850 cal B.P.) at least in Western North America, being replaced with Folsom. There seems to have been about a 100 radiocarbon year overlap between these two cultures (see Taylor et al. 1996). This was also the start of the Younger-Dryas cold period and is represented on the calibration curve (Figure 5) by a steepening, 'a jump', of the curve that lasted till about 10600 B.P. (12600 cal B.P.) when the curve flattens out into a plateau. This plateau lasts till about 10150 B.P. and apparently heralded the end of the Younger-Dryas period and return to warmer temperatures. Folsom points are replaced in the archaeological record by non-fluted points, such as Agate Basin, starting in about 10200 B.P. (12200 cal B.P.).

Summary

This chapter has reviewed the concept of the ice-free corridor, its history of development, attempts to reconstruct its environment, recent research concerning its definition and how the concept relates to two competing models of the peopling of the Western Hemisphere. A review of the Clovis and pre-Clovis model has shown that the concept of the ice-free corridor is equally important to both.

Chapter 3

Radiocarbon Dating and Research on the Ice-Free Corridor

Radiocarbon dating has been the primary radiometric dating technique available to those researching the ice-free corridor. As Figure 4 indicates, radiocarbon dating has been important to researchers working on Late Wisconsinan timing issues in the corridor (the number of new published radiocarbon dates from the study area has remained above 100 per decade since the 1970s). Initially, radiocarbon dates were published in reports of individual research projects or in radiocarbon laboratory date lists (such as those published in the journal *Radiocarbon*) and these are still common and important sources of new dates. This chapter will explore how researchers have used the accumulation of radiocarbon dates in the presentation of their research and how this has affected the perception of the corridor.

Compilation Lists

These studies consist of lists of previously published radiocarbon dates and occur in two formats. These are a long list form (Fulton 1971; Wilmeth 1978; Clague 1980; Jackson and Pawson 1984; Brumley and Rushworth 1983:142-160; Beaudoin 1986:188-213; 1991:239-254; Bobrowsky and Rutter 1992:5-50; McNeely and Clague 1996; Morlan 2001) and a short list form (Christiansen 1979:913-938; Matthews 1980; Liverman et al.1989:266-274; Vreeken 1989:551-560; Beaudoin and King 1990:129-144; Klassen 1993:1-19; Lemmen et al. 1994:805-828; Young et al. 1994:683-686; Burns 1996:107-112; Catto et al. 1996:21-32; Wilson 1996:97-105). The former involve more than 100 radiocarbon dates and are separate publications, except for Bobrowsky and Rutter (1992). The short list format are mostly published in journals and have less then 100 dates.

Several of the long compilation lists are discussed only briefly here. Wilmeth (1978) published radiocarbon dates from archaeological sites from across Canada , but none of these dates fell within the temporal limits of this research. Similarly, Morlan (2001) is a world wide web database of radiocarbon dates from across Canada with no restriction on the type or age of radiocarbon date included. Many of the radiocarbon dates listed in other sources are also listed in this database. Brumley and Rushworth (1983:141-160) and Beaudoin (1991:239-254;1986:188-213) list dates produced from archaeological sites in Alberta over several years but provide no critique and little discussion.

The primary purpose of these compilations was to gather all the available dates into common format and place with little emphasis on interpretation. Often these lists focus on the dates from one specific discipline, such as archaeology (Wilmeth 1978, Brumley and Rushworth 1983; Beaudoin 1986; 1991), with very little overlap with other disciplines. The geological examples of these types of lists are discussed in detail since they provided most of the dates used in this study. Fulton (1971:1) appears to have simply collected all the geological radiocarbon dates available for southern British Columbia and fitted them into three pre-defined geological-climatic periods: Olympia Interglaciation (Mid-Wisconsinan), Fraser Glaciation (Late Wisconsinan) and Postglacial (Holocene). No apparent attempt is made to judge or assess the accuracy of the dates.

The only comment Fulton (1971:1) makes about the radiocarbon dates is that they are all based on the half-life of 5568±30 years.

Clague (1980) updates and expands on Fulton's earlier study by increasing the study area to include all of British Columbia. The increase in number of dates over the previous decade also allows Clague to further subdivide the data. Thus, in addition to Fulton's four divisions Clague adds tables on postglacial sea level changes, volcanic flows and tephras, postglacial climates and "miscellaneous" dates. This last table is an important difference between Clague's and Fulton's studies (Clague 1980:1) because, although not mentioned in Fulton's earlier report, he did preselect dates based on their perceived geological significance. What Fulton considers as insignificant (or significant) can be deduced from Clague's miscellaneous dates. Clague (1980:1) divided them into those relating to floodplain and deltaic development, eolian activity, landslides, microfossil zonation in lakes and bogs, prehistoric animal habitation, radiocarbon calibration and unclassified (including contaminated) samples.

Although Clague has a broader definition of what are relevant geological radiocarbon dates he is still not all inclusive. For example, only those radiocarbon dates from coastal archaeological sites that provide information on past sea levels are included, all other archaeological dates are not (Clague 1980:1). In addition to listing the radiocarbon dates Clague (1981), in a separate publication, provides a summary and discussion of these tables and figures (see Synthesis Studies below).

Jackson and Pawson (1984) did a similar compilation for Alberta radiocarbon dates. Like Fulton they only select radiocarbon dates that are significant to the regional geochronology (i.e., glaciation). Thus, dates on localized events such as landslides were not included. They admit that regional significance can be a subjective term and temper this by selecting only those radiocarbon dates that could be confidently placed in a proper stratigraphic context, based on published information. Finally, they note that they did not exclude dates based on their quality (likelihood of contamination or conflicts with surrounding dates).

The resulting series of 12 tables and maps reflect the similar categories previously used by both Fulton (1971) and Clague (1980). They emphasize the stratigraphic context of the sample dated (e.g., supratill dates) but with no interpretation, explanation or summary (Jackson and Pawson 1984:3-4). Presumably this is the task of individual researchers concerned with specific questions on Alberta geochronology. Thus these long compilations basically provide a common database (with some restriction on the content) to which other researchers can refer with specific geochronologic questions.

Short compilations, as the name suggests, list fewer radiocarbon dates. Unlike the long compilations that were concerned with tabulating broad geochronological trends, they focus on specific research questions, study areas and periods. These factors, plus the medium of publication (research journals), in part explainh the smaller lists, but preselection of dates is also a factor. Often the tables are titled or described as listing 'relevant' (e.g., Lemmen et al. 1994:814) or 'significant' (e.g., Christiansen 1978:920) radiocarbon dates pertinent to the study. Obviously, the listing of dates not germane to the focus of the research would be absurd, but such terminology suggests that other dates that may have indicated alternative or contradictory evidence could have been purposefully ignored. None of the short compilations provide an explanation of why the particular dates published are deemed significant. In some publications dates are limited to those from one or two specific sample types (Liverman et al.1988:267; Burns 1996:108; Wilson 1996:101) but in others many different sample types are listed (Christensen 1978:920; Lemmen et al. 1994:814-817). There is no apparent trend within these studies towards decreasing or increasing the heterogeneity of the samples included or of shorter to longer lists.

One element that both types of compilations share, especially if viewed as a whole, is a role as a database that other researchers could access. All provide reference to the original research publication source (if one exists) of the date and some list previously unpublished or obscurely published dates, such as conference abstracts (e.g., Livermore 1988:267). As a result, these compilations were a vital source to the present research in this fashion and their importance is hereby acknowledged.

Synthesis Studies

In contrast to compilation lists, synthesis studies emphasize summary and interpretation (Bryan 1969:339-365; Reeves 1973:1-16; Mathews 1978; Rutter 1980:1-7; Ritchie 1980:15-28; Clague 1981; Morlan and Cinq-Mars 1982:353-381; Fladmark 1983:13-41; Prest 1984:22-36; Rutter 1984:49-56; Dyke and Prest 1987:237-263; Catto and Mandryk

1990:80-85; Bobrowsky and Rutter 1992:5-50; MacDonald and McLeod 1996:87-95; Dyke et al. 2002:9-31). These studies attempt to digest the data from regional and locality specific studies to describe geological and environmental events affecting broad areas of the ice-free corridor. Some of these were partially discussed in detail in Chapter 2 (e.g., Fladmark 1983:13-41).

In such studies radiocarbon dates are either individually embedded in the text, usually accompanied by a laboratory number or reference, or summarized as a date range for a particular region. Both usages can occur in the same study. In both instances the dates are used to provide evidence for the author's interpretation of the timing of the event under discussion. When individual dates are listed there are often, but not always, multiple dates noted, which provide additional support for the author's interpretation. There is no discussion why the dates listed should be considered more reliable than others, and the sample material is not always mentioned.

When generalized radiocarbon dates are used they take the form of either a date range or a summary date for events. Rutter (1980:2, 5) provides examples of both usages when he notes "...At Medicine Hat, east of the Lethbridge moraine, ^{14}C dates varying in age from 24,000 to 38,000 years B.P. have been observed from material underlying two tills..." and farther north he states that "...One problem with dating this event [the Laurentide Glacial advance in the Richardson and Mackenzie mountains] that has not been resolved is the occurrence of wood dated at about 37,000 years B.P. found below Laurentide till...". In cases like this reference to specific studies (containing the radiocarbon dates) are not always mentioned, making it difficult to determine which studies and which dates were used to define the date range.

Although all of these studies are accompanied by maps, two are unique (Prest 1984:22-36; Dyke and Prest 1987:237-263) in that the text is secondary to the associated maps. These two studies summarize the glacial maximum and deglaciation of the Laurentide and Cordilleran glaciers during the Late Wisconsinan and early Holocene for the continent. As with the other syntheses studies, there is no discussion of why certain dates were chosen over others and this is compounded by the fact that both emphasize date ranges over the listing of specific dates. This hampers any assessment of whether the dates chosen reliably represent the timing of the glacial limits and deglaciation rates depicted on these maps.

Assessment Methods

The assessment of radiocarbon dates is not unique to research on the ice-free corridor and many approaches have been proposed for other areas and periods (Smith 1964:32-37; Säve-Söderbergh and Olsson 1970:34-55; Waterbolk 1971:15-33; 1983:57-70; Schiffer 1986:13-30; Hassan and Robinson 1987:119-135; Williams 1989:510-521; Spriggs 1989:587-613; Blakeslee 1994:203-210; 1997:303-326; O'Connell and Allen 1998:132-146). Despite this varied areal and temporal character, these other approaches can be grouped into categories based on their primary methodological focus. Those are selection of implied method, sample material, refinement of the archaeological or geological context of the sample material, calibration, and definition of a radiocarbon date. In some cases several of these approaches are linked together in a series of assessment steps (e.g., Williams 1989). This section reviews previous methods of assessing radiocarbon dates with a particular focus on the ice-free corridor.

Radiocarbon Assessments on Selected Materials

Some researchers have attempted to avoid methodological problems of conflicting radiocarbon dates by undertaking regional studies using dates from only certain kinds of material (Clayton and Moran 1982:55-82; Jackson 1983:vii-xiv; Jackson and Duk-Rodkin 1996:215-277). The rationale of such approaches is that problems in archaeological or geological chronologies are caused by the use of sample materials that provide erroneous dates, and the solution is to eliminate those dates and to use dates only from acceptable sample materials. For example, Clayton and Moran (1982:58-59) only used fossil wood dates with good stratigraphic association and considered free of contamination, and Jackson and Duk-Rodkin (1996:217) would only accept dates on wood and bone. All such studies identify and, to some degree, explain why certain materials should not be used for radiocarbon dates but do not discuss why other materials are acceptable and provide reliable dates. An underlying and seldom stated assumption of this approach is that radiocarbon dates from the same material are somehow inherently more similar and thus will provide a more consistent or accurate chronology.

Looking at Clayton and Moran (1982:58) as an example, they propose a new glacial retreat chronology for the midcontinental region of North America using only radiocarbon dates conducted on wood from glacial till (not a flow till). Their focus is on reconstruction of ice limits in Montana, North and South Dakota, Nebraska, Minnesota, Iowa and Wisconsin, which are outside the study area described above. They did, however, include dates from Alberta, Saskatchewan, Manitoba and Ontario so their method has relevance to the present research.

Before accepting a radiocarbon date they consider the stratigraphic reliability of the sample and the possibility of contamination. In regarding the former, they are concerned about accurately determining the stratigraphic position of the sample and its environment of deposition (till or flow till). They emphasize that problems with stratigraphic significance are the basis for differences in published chronologies of the glacial retreat (Clayton and Moran 1982:55,58). Similarly, they note that even with firm stratigraphic information, chronologies from different researchers for the same geological event can have discrepancies of several thousand years. These contradictions, they suggest, originate from contamination of the samples. Although they do not explain why, they state that wood dates are the least likely to be contaminated and would provide a consistent set of dates (Clayton and Moran 1982:58-59).

Their assessment saw the maximum Laurentide ice-sheet at the glacial maximum covering most of southern Alberta and Saskatchewan by 20000 BP (Clayton and Moran 1982:62:64). Deglaciation began in this area by 14000 BP, but even as late as 11700 BP large portions were still covered by the Laurentide ice sheet (Clayton and Moran 1982:70-73). This would suggest that the southern portion of the ice-free corridor was ice-free sometime after 14000 BP.

In commenting on Clayton and Moran's approach, Jackson (1983:vii-xiv) took issue with their method arguing that each date should be evaluated separately on its own merits, and that the wholesale rejection of non-wood dates is unreasonable (Jackson 1983:viii). He rejects Clayton and Moran's assertion that old carbon contaminated organic detritus, peat and lake mud samples. Jackson also correctly notes that they had not discussed bone dates and why they should be ignored (Jackson 1983:viii; Clayton and Moran 1982:59). As proof of the inherent bias in their method, Jackson produces two tables of radiocarbon dates from the foothills and interior plains of Alberta. They list radiocarbon dates from a variety of materials that he claims show internal consistencies with each other and known dated tephras (Jackson 1983:viii-xi). Jackson concludes that Clayton and Moran's use of only wood radiocarbon dates biased their chronology by eliminating any dates that would have disagreed with their reconstruction, which Jackson termed " . . . overly simple and incorrect ..." (Jackson 1983:xiii).

As another example, Jackson and Duk-Rodkin (1996:215-227) synthesize the Quaternary geology, paleoecology and geochronology of the ice-free corridor. They initially divide their study area into two sections: the area between 49° and 60° and the area north of 60°. In discussing the area south of 60° they first note that radiocarbon dates from earlier research, that suggested continuous ice-free conditions since the Mid-Wisconsinan, were probably contaminated by dead carbon. This dead carbon was from local coal, shales or carbonate rocks. They conclude that the only reliable dates from the western interior plains and foothills of Alberta are on wood and bone (Jackson and Duk-Rodkin 1996:217). There is no restriction on sample material for the area north of 60°, nor is there any explanation as to why this area would produce better results (Jackson and Duk-Rodkin 1996:221-223).

From this geochronological assessment they came to three conclusions. First, the Cordilleran ice sheet did not form until about 20000 B.P. Second, the northern ice-free corridor was buried under the Laurentide glacier from 30000 to 13000 B.P. (although later they say 11000 BP). Third, the coalescence between the Laurentide and Rocky Mountain glaciers lasted less then 6000 years (Jackson and Duk-Rodkin 1996:223).

The first problem with this approach is the underlying assumption that dates from a particular material will be more consistent (this is particularly relevant to Clayton and Moran's study). Researchers who advocate such an approach fail to understand: 1. the definition of a radiocarbon date, and 2. the radiocarbon event of the sample material being dated.

Stuiver and Polach (1977:355-363) state the definition of a radiocarbon date as::

1. the use of the 5568 year half life,
2. the assumption of constancy of ^{14}C atmospheric level during the past,
3. the direct or indirect use (as a standard) of the United States National Bureau of Standards (NBS) oxalic acid normalized to $\delta^{13}C = -19$ ‰ with respect to the PeeDee Belemnite (PDB) international standard,
4. isotope fractionation normalization of all sample activities to the base $\delta^{13}C = -25$ ‰ (PDB),
5. the year 1950 is automatically the base year, with ages given in years B.P. (Before Present).

Regardless of the sample material or measurement technique (conventional or accelerator mass spectrometry) all radiocarbon laboratories use this definition to calculate a radiocarbon date (Bowman 1990:31; Aitken 1990:93-95). Once the sample has been processed the radiocarbon date is obtained by taking the resulting count and applying the above definition. Thus, there is no basis for assuming dates from the same material will provide a more consistent or reliable chronology than dates on different materials. What is important is determining whether the material dated provides a reliable date of when the sample was last in equilibrium with the atmospheric carbon reservoir.

The radiocarbon event for organic matter occurs when it ceases interacting, or is no longer in equilibrium, with the atmospheric carbon reservoir (Aitken 1990:58; Nelson 1998:4). Thus, Clayton and Moran's method ignores the fact that only the outer rings of a living tree are in equilibrium. Once each yearly ring becomes a part of the tree's heartwood it begins losing ^{14}C. This is the source of the old wood problem (see Schiffer 1986:13-30), although this may not be as much of a concern for geologists as it is for archaeologists. Since researchers who use the approach fail to understand the radiocarbon event they also neglect or are unconcerned with its association to the geological or archaeological event under study.

Jackson and Duk-Rodkin provide an example of how this method can also suffer from inconsistency, which is not uncommon (see Williams 1989). Despite their claim of only using bone or wood dates from the area south of 60° latitude, the accompanying table of radiocarbon dates lists dates from other materials from this area. These other materials include peat, shell, gyttja and organic lake sediments, known to be problematical for dating, and plant material, tusk collagen, seeds and fecal pellets that may provide reliable dates (Jackson and Duk-Rodkin 1996:218-219). No explanation is given as to why these other materials are included or whether they are as acceptable as wood and bone dates. They also fail to explain why the area north of 60° latitude would produce reliable dates on sample material other then bone or wood; this despite the fact that the plains and mountains consist of similar bedrock materials as the southern area (Vincent 1989:101; Szeicz et al. 1995:353). This inconsistency makes it difficult to know what results are being conveyed by the table and text and whether the associations between the radiocarbon dates and the geological features are sound. It leaves the impression that not enough dates were present on the stated acceptable material to fully support their interpretation so additional supportive dates from these other materials were included.

Context Methods

Another method that researchers have used to assess radiocarbon dates emphasizes the context or provenance of the sample material. These researchers wish to ensure that the dated sample is closely associated in time with the geological or archaeological event under study. From the study area, only Bryson et al. (1969:1-14) explicitly use this approach in their construction of an isochrone map for deglaciation during the Late Wisconsinan. Other researchers (Prest 1984:23-36; Dyke and Prest 1987:237-263) may have used a similar approach, but did not explicitly discuss their methods (see above). In such assessments, researchers construct hierarchical lists of criteria for judging the appropriateness of dated samples. Once the dates have been assessed other criteria are applied to further judge their suitability.

Bryson et al. (1969:1-14) used 289 radiocarbon dates from areas covered by the last Laurentide ice sheet to construct radiocarbon dated isochrones of ice retreat at 1000 or 500 year intervals. This is interpreted as evidence of the rate of deglaciation. They first categorized the dates into six groupings based on their geological provenance:

> 1. Advance, such as organic materials buried in till,
> 2. Nearby ice front, such as organic materials in outwash,
> 3. Minimal ages for deglaciation, such as basal marl or bog material over till,
> 4. Minimal ages for drainage of *small* [emphasis in the original] ice-dammed lakes,
> 5. Dates on shell at, or near, the marine limit, if the writers stated that this represented the time of deglaciation,
> 6. Extrapolated dates for the marine limit when dates below the marine limit were given *and* [emphasis in the original] the height of the marine limit and regional rate of uplift were available.
>
> (Bryson et al 1969:2-3)

They considered three sources of errors while constructing the isochrones: the precision and accuracy of the radiocarbon dates, the scales of their maps (compilation map 1:8.87 million and published 1:26.6 million) and the 1000 or 500 year isochrone interval. They divide the precision and accuracy issue into three parts. First, they assume no bias toward the plus or minus side of the quoted date, which meant that 8500±200 BP (to use their example) represents 8500 radiocarbon years ago on their map. They felt this is a reasonable assumption considering the scale of their final map (Bryson et al. 1969:3). Second, radiocarbon dates older than 13000 B.P. use a plus or minus of two standard deviations. They felt that sometimes this might create a deviation greater that the 1000 year isochrone. This is dismissed as a possibility because surrounding dates would provide checks on such dates. Third, they note that radiocarbon years are not calender years, but they provide no discussion as to how or if this affected their mapping (Bryson et al. 1969:3)

There is no discussion of the error caused by the mapping scale but they emphasize that once the selected dates are plotted the isochrones are drawn without regard to field evidence. This meant that they did not try to fit isochrones onto known geological features such as moraines. There are two exceptions: isochrones are kept on the upstream side of dates from outwash provenance and minimal dates are kept outside the next older time interval. They accept as accurate those dates that the original researcher had suggested most likely represented initial deglaciation. In addition to this they rely on neighbouring dates to provide a check on any one date in determining deglaciation. Since no attempt is made at this point to interpret ice-front positions from the data the authors consider this procedure as providing an objective reconstruction of deglaciation (Byrson et al 1969:3).

The isochrone interval error involves the fact that small re-advances or stillstands of less then 500 years will not be identified by their map. Bryson et al. (1969:3) even note that their method would not identify such short term events unless the data interval is denser and the dating technique is refined.

Although the isochrones drawn through Alberta and along the Mackenzie River valley are generalized due to a lack of dates, they still conclude that a north-south passage would have been blocked by ice (about 3000 m thick) as late as 11000 B.P. They likewise conclude the corridor did not appear until sometime between 9000 and 8500 B.P. (Bryson et al. 1969:4-5).

Bryson et al's method shows some improvement over sample material methods in that it acknowledges the importance of the provenance of the sample and by understanding the event dated by the sample. The latter is evident from their acknowledgment that their isochrones could be interpreted as when "...organic materials migrated into the region abandoned by the ice..." (Bryson et al. 1969:4) even if they feel this point is unimportant to their reconstruction. Despite this, the relationship between the event dated by the sample and its association with the sample provenance and with the event under study (timing of deglaciation) is not fully explained by the researchers. For instance, any organic material is given an 'Advance' rating if it is found in till. No explanation is provided as to why being found in till would increase the likelihood that the material dated would provide a reliable age for till deposition. For example, organic material may have been growing in the area prior to being overridden by Late Wisconsinan glaciers and remained within the glacier until deglaciation when it was deposited in the till. A radiocarbon date on such material would give the till an erroneously old age.

Calibration of Radiocarbon Dates

A third method of reviewing radiocarbon dates from within the corridor has been for the purposes of calibration. The rational behind this approach is that calibration will provide a chronology that will allow easy comparison to chronologies from other areas or constructed using other dating techniques. In particular there is a concern for accurately identifying climatic or geomorphic events that allow for the comparison to climate changes from different regions. Wilson (1983:280-319) provides an example by comparing dates of climatic change from the Calgary area and correlating them to climatic events in surrounding regions since the Late Wisconsinan. Campbell and Campbell (1997:37-44) also use calibration to investigate the relationship between post-glacial geomorphic events and insolation (amount of sunshine) seasonality.

In his dissertation, Wilson (1983:280-282) looks at the geology and archaeology of the Bow River Valley at Calgary, Alberta in the southern portion of the ice-free corridor. His method is described in a single paragraph, table and figure in his dissertation (Wilson 1983: 280,Table XIII, Figure 73). He states that all radiocarbon dates within the text of the dissertation are not calibrated but that calendrical corrections are provided in the accompanying table. He uses an early calibration table by Damon et al. (1974) entitled *Dendrochonologic Calibration of the Radiocarbon Time Scale* for his calendrical corrections. Wilson's table lists 11 radiocarbon dates by site name and notes that they have been corrected for $\delta^{13}C$ and that a half life of 5570 was used for the calculation of each date. In the next column in the table the date is listed "minus 1950"to give an AD/BC age. Then the date corrected by calibration is listed and the final column provides the geological context for each. The figure (Wilson 1983: Figure 73, 282) lists each date chronologically with its site name, the date with 1σ and 2σ ranges in the form of a graph, the material dated and the geological or archaeological significance.

Of the 11 dates included all but one are accepted. The only rejected date is 4000±130 BP (RL-1058) on tusk. No explanation is given for rejecting this date (Wilson 1983:280-282). Presumably because Wilson rejected the implication that mammoths or mastodons (or any other elephant species) were present in the area at this time. His only comment on the accepted dates is that with the exception of the rejected date they fall into the ". . .expected sequence. . ." (Wilson 1983:280).

Wilson concludes from the alluvial deposition sequence in the Calgary area that the Holocene could be divided into three broad climatic periods: Anathermal (pre-12000 B.P. to 8300 B.P.), Hypsithermal (8300 B.P. to 5000 B.P.) and Neo-Glacial (5000 B.P. to present). Although these periods roughly paralleled climatic and geomorphological events seen across North America, their timing was unique to the Calgary area and more closely related to environmental effects occurring on a regional scale (Wilson 1983:283-320).

Campbell and Campbell (1997:37-44) provide a more recent example of this type of analysis. They examined 97 dates (including radiocarbon, thermoluminesence, tree ring dates and historic observation involving recent landslides) from the northern plains of Alberta and Saskatchewan. The majority (the exact number is not stated) are radiocarbon dates. Their approach is to calibrate the radiocarbon dates using Stuiver and Reimer (1993; program CALIB Rev 3.0.3), then plot the dates in calender years with post-glacial geomorphic events. They define "post-glacial" as occurring after the last glacial maximum (Campbell and Campbell 1997:37-40). They decided that calibration was necessary in order to:

> 1. determine true rates of occurrence of events,
> 2. compare radiocarbon dates with dates obtained from other dating techniques such as TL [thermoluminesence], OSL [optical spin luminescence], and dendrochronology,
> 3. establish meaningful regional chronologies
> 4. relate dated events to possible causal processes including insolation variations produced by variations in the Earth's orbital elements.
>
> (Campbell and Campbell 1997:37)

They provide no discussion of how they selected their dates, but they do note that those radiocarbon dates that are not corrected for $\delta^{13}C$ are labeled with different shading after calibrating. To calibrate the dates they used the probability method and their calibrated geomorphology chronology only displayed dates with "... 100 % probability at 1σ analytic uncertainty ... "(Campbell and Campbell 1997:40). No discussion on the other dating methods or of the sources of historic observations is provided .

Their method results in the identification of four geomorphologic periods following the last glacial maximum. They associate those with known insolation variations at 50° latitude (variability in the amount of sunlight reaching the earth). In the first period erosion and deposition by glacial and subglacial meltwater occurred before 20000 calibrated years BP and did not lag significantly behind the insolation seasonality minimum (the difference between winter and summer insolation) as suggested by the uncalibrated dates. Period 2 lasted from 20000 calibrated years BP to 12000 calibrated years BP and was characterized by water erosion during deglaciation. Insolation values had not reached maximum seasonality. The calibrated dates suggest that there was no lag between glacial maximum and the beginning of deglaciation. The third period, from

12000 to 10000 calibrated years BP, was characterized by landscape stability, maximum seasonality insolation and was the most arid period. The final period, from 10000 calibrated radiocarbon years BP to the present, was associated with decreasing insolation and landscape instability (Campbell and Campbell 1997:41-42).

Campbell and Campbell (1997:42) state that their method of calibrating dates shows: 1. a closer association between changing insolation and geomorphic events, 2. a need to re-examine the scale and rates of post-glacial geomorphic process and, 3. atmospheric circulation model simulations based on uncalibrated radiocarbon dates need to be reassessed. For the ice-free corridor, their conclusions suggest that the southern corridor began forming immediately after the glacial maximum, but that the most stable period for use of the corridor as a migration route would have occurred after 12000 B.P.

Assessment methods using radiocarbon calibrations are problematic, not because of calibration (for a history of the development of radiocarbon calibration see Aitkens 1990:99-101; Bowman 1990:43-46; Taylor et al. 1996a:655-659), but because users do not fully comprehend what calibration involves. The purpose of calibration ". . . is to convert ^{14}C time - which is expressed in terms of a *conventional radiocarbon age* [emphasis in the original] (Stuiver and Polach 1977) - to *calibrated time* [emphasis in the original] . . . and express the resultant transformation in a manner which accurately reflects the overall precision of the time span expression" (Taylor et al. 1996a:656). The four reasons for calibrating radiocarbon dates are: 1. to compare them with dates obtained by other dating methods, 2. to correctly determine the speed of cultural versus environmental change through time, because there are periods when a small difference in radiocarbon years equals a large change in calender dates and vice versa (Aitkens 1990:92-93; Taylor et al. 1996:663-665), 3. to critically evaluate the amount of age difference or contemporaneity in comparisons of ^{14}C dates, and 4. when ^{14}C inferences are compared with historical events based on historical calendric systems (Taylor 1996::664-665). The study by Campbell and Campbell (1996) obviously falls under the first and fourth reasons and Wilson's (1982) use of calibration fulfills both the first and second reasons.

In calibrating radiocarbon dates not corrected for $\delta^{13}C$, Campbell and Campbell did not fulfill the requirement of using conventional radiocarbon dates. Their use of these uncorrected dates is surprising considering their concern that such uncorrected radiocarbon dates "... hinder accurate sequencing of dated events ... " (Campbell and Campbell 1996:37). Furthermore, Stuiver and Polach (1977:358) explain how to use estimated values for various sample materials to make this correction.

When these estimated values are used, they are added in quadrature (if A±a is the date and B±b is the estimated value then the corrected date and error are found by $(A^2+B^2)^{1/2} \pm (a^2+b^2)^{1/2}$). Depending on the sample material dated, the change to the uncorrected radiocarbon date may be significant. The error term will certainly increase and that combined with the error associated with the calibration curve will result in wider date range then the uncorrected date provides. How this would affect their conclusions is hard to determine since Campbell and Campbell do not provide a list of dates, but it could make the boundaries between their four periods and their association with insolation values less distinct. Nevertheless, questions remain, why did they not correct these dates? Why did they include these dates if they felt such dates were problematic? Finally, if uncorrected dates were acceptable in their study then is their initial premise that they hinder accurate sequencing and comparisons invalid?

Wilson's use of calibration is also problematic. In his table of radiocarbon dates (Wilson 1983:281; Table XIII) he lists calibrated dates as single dates, not as ranges. In addition, the table lists calibrated dates from samples with conventional dates from 11300 to 6580 B.P. but the calibration table cited only provides calibration data up to 6523 B.P. No explanation is provided to document how these calibrated dates are obtained (Wilson 1983:280-282). In his table, the dates older then 6523 B.P. are bracketed, possibly suggesting that these are estimates or extrapolations from data provided by Damon et al. (1974:350-366), however this is not explicitly stated.

The dates in this study are not calibrated because the current research focuses only on radiocarbon dates and does not compare them with dates obtained from other techniques. It is not concerned with the actual speed of environmental change between 20000 B.P. and 9000 B.P., only whether the corridor could have provided a route for early Palaeoindian populations to migrate from Beringia to south of the continental ice sheets. Thus, the radiocarbon timescale is adequate for the purposes of this study. Finally, this dissertation is not interested in the contemporaneity of radiocarbon dates.

Conclusions

From the above review it is evident that all of the techniques commonly used to list, present or assess radiocarbon dates from the corridor area, are problematic. The long compilation list format focuses only on dates from particular disciplines (archaeology or geology) while the short list format suggested preselection (without explanation) of radiocarbon dates that would support the conclusions presented. The synthesis studies provide excellent summaries of existing data and interpretations, but fail to adequately explain why certain groupings of radiocarbon dates were considered more reliable then others. The calibration examples indicate that, although researchers understand the importance of calibration to their questions, they did not fully comprehended the technique. Finally, all attempts at assessing radiocarbon dates from the corridor show a lack of understanding of what a radiocarbon date is and how it would relate to the geological or archaeological research. It seems that a more formalized method is needed. It should be independent of specific research goals yet still define how the radiocarbon date relates to the research question. Such a method is discussed in the next chapter.

CHAPTER 4

METHOD

The following procedure will be used to evaluate the chronological information from radiocarbon dates that underlies our present understanding of the ice-free corridor:

1. A collection will be made of all published ^{14}C dates falling between 20000 and 9000 B.P. that have been taken on samples from archaeological, palynological and geological sites within the study area.
2. Each radiocarbon date will be evaluated following a method proposed by Nelson (1998). Those found to be unreliable will be removed from the analysis.
3. Environmental information from those sites with reliable dates will be used to determine if the corridor existed and what environmental conditions were present during the four time periods defined in Chapter 1

Assessing Radiocarbon Dates in the Corridor

Many methods of assessing radiocarbon dates have been proposed (Smith 1964; Säve-Soderbergh and Olsson 1970; Waterbolk 1971; 1983; Schiffer 1986, Hassan and Robinson 1987; Williams 1989; Spriggs 1989; Blakeslee 1994; 1997; O'Connell and Allen 1998) and the method used in this research (Nelson 1998) should be seen as a product or compilation of these previous attempts. Nelson is an acknowledged expert in radiocarbon dating, having pioneered the accelerator mass spectrometry (AMS) technique (Nelson et al. 1977:507-508). Nelson's method allows researchers to decide whether a radiocarbon date is useful to a specific problem under consideration. It requires answers to five questions connecting research goals, ^{14}C dating technique, and the material dated. Each is discussed in detail below, in relation to the research question addressed in this dissertation:

1. What is the research event of interest?

The research event is the earliest time after the last glacial maximum when the study area could have provided northern human populations with a migration route to the south.

2. Can the radiocarbon method provide the age information required?

This question is extremely important as, "...there is no sense in applying a tool to a task for which it is unsuited" (Nelson 1998:5). The answer to this question is "yes". A more detailed explanation requires answering two additional queries.

i How does the nature of the ^{14}C time scale and its correlation to the calendrical time scale affect the interpretation?

ii Does ^{14}C dating provide adequate accuracy and precision?

The period under study (20000 - 9000 B.P.) is well within the range of the dating method. Measurement accuracy for this period is typically ± 50 - 200 ^{14}C years and will be divided into 3000 or 2000 year segments for which the calibration curve connecting the radiocarbon and calendrical time scale is well understood (Bard et al. 1993:191-200; Stuiver and Reimer 1993:215-230, Kitagawa and van der Plicht 1998:1187-1189, Bard et al. 1996:241-244, Bard et al. 1990:405-410). Even though the calibration of radiocarbon dates may not be part of a research plan, it is important to know the nature of the curve for the period under study. If one's research goal involves determining a cultural or environmental change during a segment of the curve that is flat (a plateau) than radiocarbon dating may not be the best method for detecting the time of such a change.

3. What radiocarbon events are being dated by the sample materials?

The radiocarbon event is the time at which the sample material was isolated from active interchange of carbon with the atmospheric reservoir. This is the 'event' dated. As a consequence, reliable radiocarbon dates are difficult to obtain from sample materials that were not in equilibrium with this reservoir. Terrestrial plants and animals were in equilibrium with the atmospheric reservoir, so their remains generally provide reliable dates. Freshwater and marine plants and animals are more problematic.

Of particular concern is the 'hard water effect' in areas with dissolved carbonates in the groundwater (see Taylor 1987:48-49; 52; and Bowman 1990:36). Much of the bedrock in the study area consists of limestone formations (Clague 1989:17-96; Vincent 1989:100-137; Klassen 1989:138-174). MacDonald et al. (1987:837-840; 1991:1150-1155) have shown that aquatic shells, plants and organic lake sediments produce unreliable dates from within the study area because they incorporate carbon from ancient limestone formations. Even land snail shells may be affected by the limestone bedrock yielding ages up to 3000 years too old (Goodfriend and Stipp 1983:575-577; Goodfriend and Hood 1983:810-830; and Goodfriend 1987:159-167).

Samples from marine environments (e.g., shells, marine mammal or fish bones, or plants) may be affected by the 'marine reservoir effect'. In this circumstance it may be possible to provide corrections (for a description see Olson 1986: 292-293; Taylor 1987:64; Bowman 1990:24-25). As will be seen below, many samples from along the northern edge of the study are marine shells. For descriptions of the problems and solutions for dating other sample materials see Olson (1986:281-294), Taylor (1987:47-64), Aitken (1990: 86-89), Bowman (1990:27-30) and Nelson (1998:5-6).

4. How is the radiocarbon event (Question 3) associated with the research event (Question 1)?

Question 4 requires that the association between each radiocarbon event and the research event be evaluated. In this study, each radiocarbon sample can provide direct information on the corridor's environment during the Late Wisconsinan. Dated plant or animal samples indicate periods when environmental conditions would have supported those plants or animals in a particular region. The radiocarbon and research events are thus directly linked, except in situations where organic materials may have been transported long distances shortly after death.

5. Does the material, for which the radiocarbon event has been identified, meet the requirements for a "conventional radiocarbon age"?

As defined by Stuiver and Polach (1977:355-357), these requirements include:

1. the use of the 5568 year half life,
2. the assumption of constancy of ^{14}C atmospheric level during the past,
3. the direct or indirect use (as a standard) of the United States National Bureau of Standards (NBS) oxalic acid normalized to $\delta^{13}C = -19$ ‰ with respect to the PeeDee Belemnite (PDB) international standard,
4. isotope fractionation normalization of all sample activities to the base $\delta^{13}C = -25$ ‰ (PDB),
5. the year 1950 is automatically the base year, with ages given in years B.P. (Before Present).

Dates that fail to meet any of these requirements, or for which the magnitude of potential problems cannot be adequately evaluated, will be eliminated from further consideration.

In addition to these five requirements Stuiver and Polach (1977:362) also note reporting and rounding off conventions for the date and its error.

Before my final acceptance of a date, the original researcher's evaluation was considered. In some instances, the date had been rejected originally for laboratory reasons (e.g., counter malfunction), while others involved mis-labelling of field samples (e.g., reversed stratigraphy). In still other instances, there seems to be no reason for rejection other than it did not fit expectations. All samples were individually reviewed.

Summary

This method of assessing radiocarbon dates is a systematic and objective procedure for judging the reliability of published ^{14}C dates. This will provide a reliable chronology for the study area's environmental history and its relationship to the early human occupation of the Americas.

CHAPTER 5

RADIOCARBON DATE ASSESSMENT RESULTS

A total of 600 dates were obtained from the published literature. They represent 358 separate locations distinguished by different latitude and longitude, referred to here as sites (Figure 6). Due to the close proximity of many sites and the fact that some sites yielded multiple radiocarbon dates, individual site designations or radiocarbon dates were not included on Figure 6.

Question 3 and Question 4 Results

Questions 3 and 4 can be discussed at the same time since identifying the sample material, radiocarbon event and research event are closely linked. Of the 600 dates in this study 289 could be clearly identified as meeting this requirement. For 285 dates, this requirement was not met, as described for each in Appendix A. The remaining 26 are complicated and need explicit discussion as offered below. Figure 7 identifies the location of these 26 dates. Even so, some dates still remained provisional for the reasons noted below. The effect of these dates on the final interpretation will be discussed separately.

Complicated Date List

Coal Mine Lake 10300±60 BP (GSC-3729): This sample of willow and birch wood was recovered from a pocket of wood-bearing peat in a 1 m thick pebbly silt bed overlying ice slump sediments and underlying 1.5 m of reworked till and 0.5 m of silt. This deposit

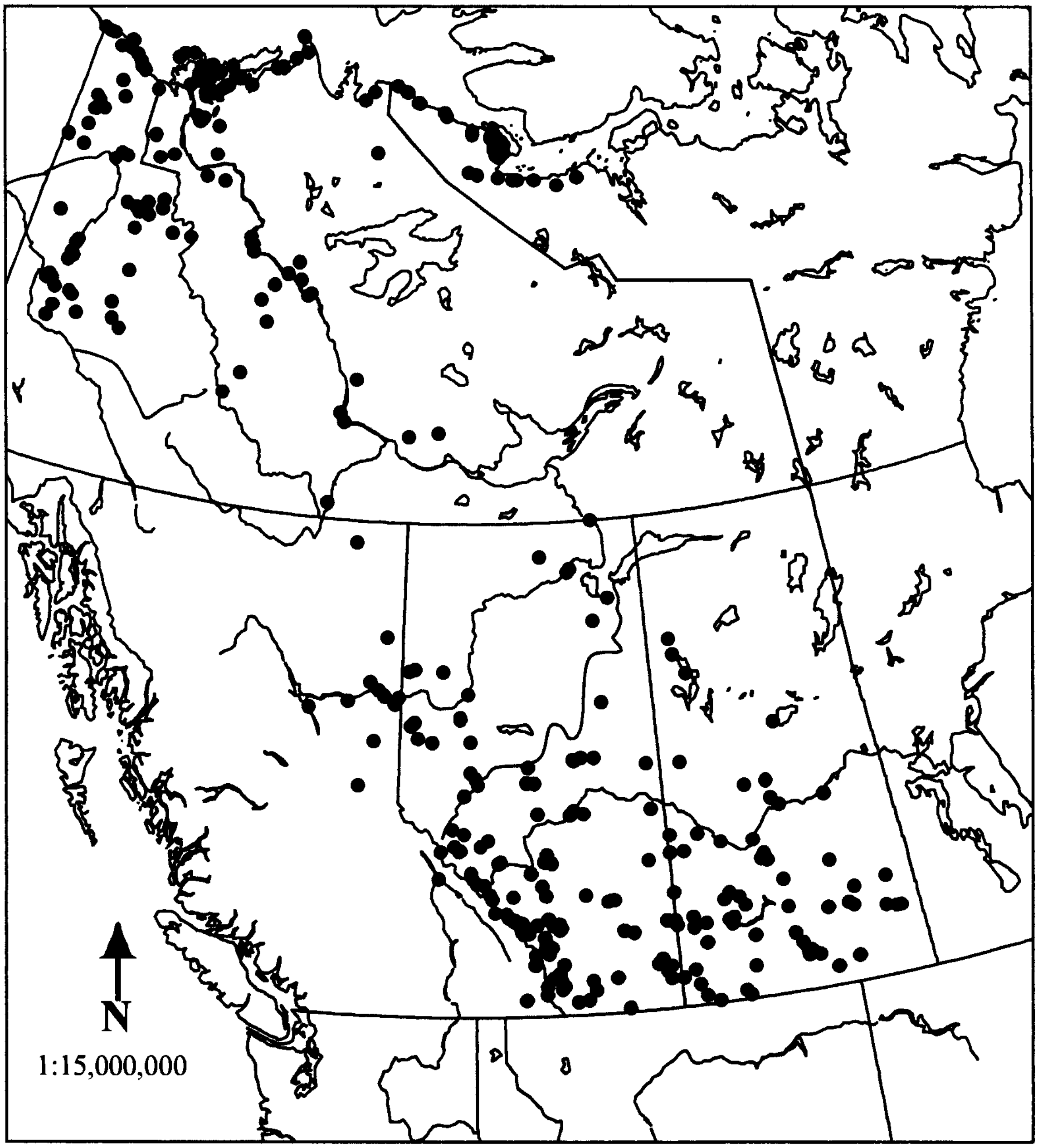


Figure 6. Distribution of sites producing radiocarbon dates between 20000 and 9000 BP.

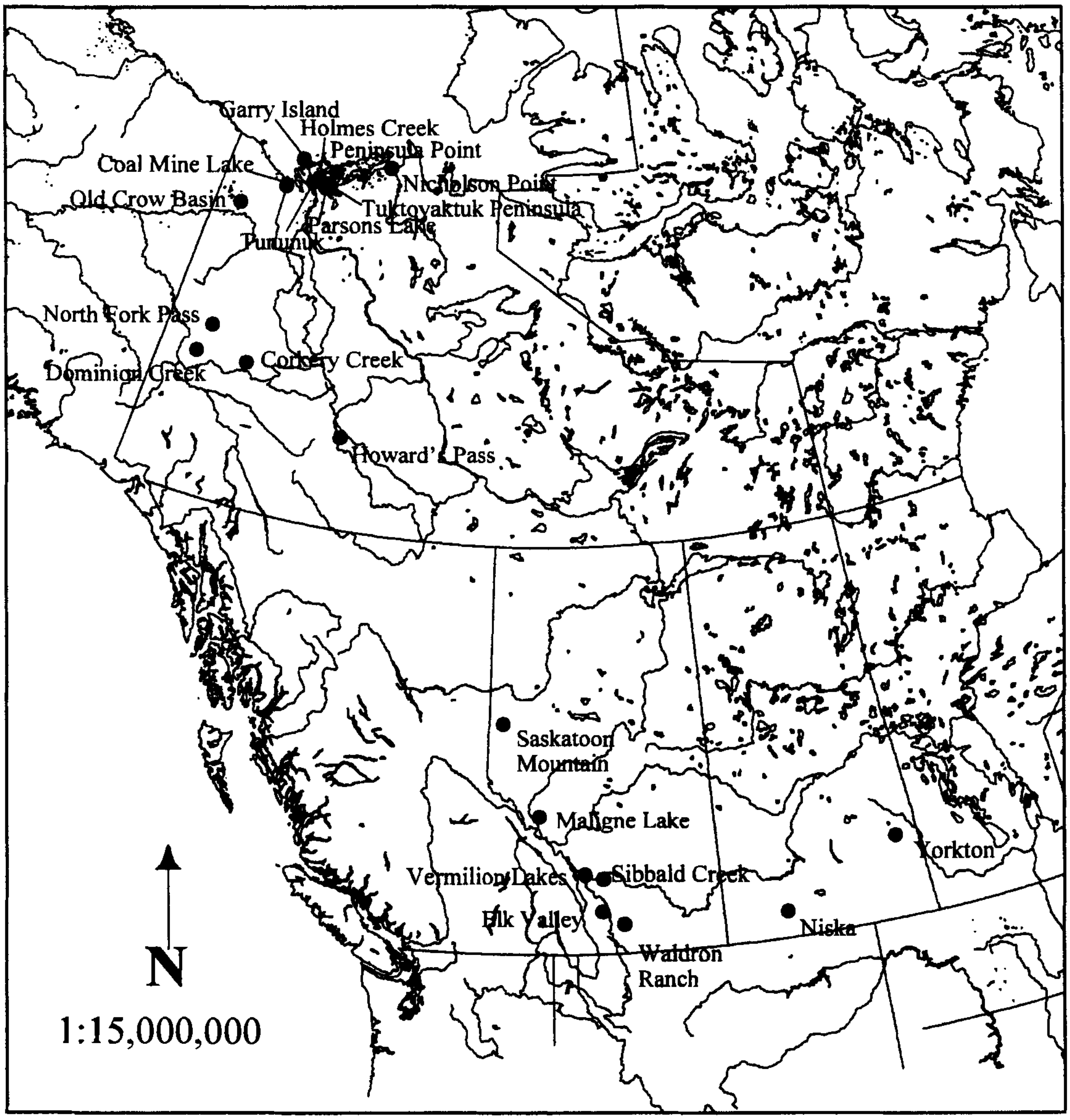


Figure 7. Location of 26 complicated dates.

was on a slope at the head of an ice slump. Although the separate species of wood could represent different radiocarbon events, the geological context of the samples indicates that they were buried at the same time by slumping ground ice and were probably growing at the same time (McNeely and Jorgensen 1992:61). This date is accepted.

Corkery Creek 9000±45 BP (GSC-4020): This sample consisted of moss, sedge and culms (joined stem fragments, probably from grasses). The sample was taken from the deepest part of a core (between 485 cm and 495 cm) in a perennially frozen bog. The author's description indicates that the sample components were taken from throughout that 10 cm section of core. Since there could have been a considerable time between growth of the different plant species, the radiocarbon event is poorly defined. Also, the moss species are not identified and their recovery at this depth in the bog suggests an aquatic variety that is affected by the hard water (McNeely and McCuaig 1991:85). This date is rejected.

Dominion Creek 12220±90 BP (GSC-2641): This sample was from a ground squirrel nest. It consisted of seeds, plant stems and faeces (Blake 1984:16). The relatively short life span of this animal (its remains were found in the nest) suggest that the radiocarbon event of each of the components of this sample span at most several years. The date is accepted.

Elk Valley 11940±80 BP (GSC-2142) and 12220±110 BP (GSC-2275): This sample (both dates were conducted on the same sample) consisted of wood and organic matter (identified as strongly decomposed coniferous woody tissue) from a silt cutbank along the Elk River. The organic horizon from which the sample was recovered was 1 cm thick and consisted of burnt and decomposing wood, organic matter and pollen. The horizon is believed to be the remnant of a forest fire swept into and buried in backwater deposits as the river channel migrated westwards across the alluvial plain of the river valley. The thinness of the horizon suggested it was a single forest fire event that was quickly deposited and buried. The 300 year B.P. difference between the two dates could be caused by old wood being incorporated into GSC-2275 (Harrison 1976:169-170; Lowdon and Blake 1976:9). From the sample description, no single radiocarbon event can be defined, however, the recovery context of the sample suggested they were temporally close. These dates remain provisionally accepted. If they are similar in age to other acceptable dates in the region of recovery then they can be viewed as providing additional support for the acceptable dates. If however, they provide the only evidence for vegetation in the region then they should be rejected.

Garry Island 9750±100 BP (GSC-575): This sample consisted of iron stained twigs and wood fragments found at the base of a gravel unit that overlay a marl and silt unit identified as lake deposits. The description of the sample material indicates that the radiocarbon events are not clearly defined (the wood fragments may contain old wood) (Lowdon et al. 1971:305). This date is provisionally accepted with the same conditions noted above.

Howard's Pass 9610±50 BP (GSC-3532): This sample consists of peat from between 100 and 110 cm in a blanket bog immediately above bedrock (Blake 1983:23). A blanket bog is defined as "A bog consisting of extensive peat deposits that occur more or less uniformly over gently sloping hills and valleys. The peat thickness is usually <2 m." (Agriculture and Agri-Food Canada 2003). This indicates that the plants making up the peat were not aquatic. The description of the sample suggested that it consisted of peat from the whole 10 cm. This represents a radiocarbon event stretching over many years. For example, if the bog began forming at about 10000 B.P. and its maximum depth was 110 cm, then deposition was approximately 0.1 mm per year. The 10 cm covered by the sample represents about 1000 years of bog growth and the date represents some average of the plants making up the peat. This broad time range must be borne in mind when assessing the date's validity. It remains provisional with the same conditions noted above.

Holmes Creek 9540±150 BP (GSC-1495): The sample consisted of peat containing mostly sedge fragments from the southeast bank of the East Channel of the Mackenzie River. It was recovered from near the base of 0.8 m of gravel containing peaty layers that overlies >1 m of oxidized gravel. Above these gravel and peat layers are 8 m of peat (Lowdon and Blake 1978:12). The context of the sample suggests that the peat did not develop in a lake or pond environment. Although many separate radiocarbon events may be present in the sample they were probably closely related in time during the formation of the peaty layer before being buried by gravel deposition. This sample is provisionally accepted because of the likely non-aquatic nature of the peat and the likelihood that the sedges were growing at about the same time.

Maligne Lake 10850±300 BP (BGS-627) and 13500±400 BP (BGS-629): Both of these samples consisted of twigs and needles from different depths in two palynological cores. Their presence at certain depths in the core suggest these radiocarbon events for each sample were closely spaced in time. Unfortunately, the samples were too small for pretreatment and upon examination were discovered to be contaminated with carbonates that explained the reversed dated stratigraphy (youngest date at the lower depth) in the core (Kearny 1981:185-186). These dates are rejected.

Nicholson Point 9020±80 BP (GSC-4362): This sample of birch wood and moss was recovered from an exposure of organic silt along the Arctic coast at 10 m above sea level. The description suggests that the wood and moss were recovered as a single sample, and that the moss was not related to the organic material in the silt (McNeely and McCuaig 1991:97). Although the wood and moss represent separate radiocarbon events they were probably closely related temporally, even if the moss grew after the death of the tree. This sample is accepted.

Niska Site 10880±70 BP (TO-956) 8475±650 BP (S-2510): The former sample consisted of charcoal fragments collected from around a cultural feature identified as a hearth on an archaeological site (Meyer and Liboiron 1990:300). The context of this sample suggested that multiple radiocarbon events were present in the charcoal fragments and that the old wood may have contributed to the date. The latter sample has been identified as charcoal (Meyer and Liboirion 1990:299) or as a paleosol (buried soil horizon) from a cultural layer (Morlan 2001). In either case the potential for multiple radiocarbon events is great. These dates are rejected.

North Fork Pass 11250±80 BP (GSC-470): This sample of willow twigs and organic silt was bored from a depth of 4.8 m in a peat hummock. The stratigraphy indicates that 1.8 m of fibrous peat overlay >3.0 m of silty sand, grit and pebbles that included sparse organic material (Lowdon and Blake 1968:231). The willow twigs could represent several different radiocarbon events that were closely spaced in time, and thus could be acceptable, but the organic silt could consist of many different radiocarbon events or could be composed partly of aquatic plants and so may have been affected by hard water. The date is rejected.

Old Crow Basin, Section REM-78-3 10400±90 (GSC-2773): This sample consisted of woody fragments recovered from a peat deposit. The deposit is 3.35 m below the surface and is draped into an ice-wedge pseudomorph that intrudes into glacial meltwater clays (Blake 1984:20). The woody fragments may represent different radiocarbon events. This date is rejected.

Parsons Lake 11380±140 BP (GSC-1160): This sample of twigs and peat was recovered from the base of a 5.5 m exposure of peat and lacustrine sediments. The researchers interpret it as dating the deposition of sediments in a thermokarst basin (Lowdon and

Blake 1973:32). With no description of the plant material in the peat it is possible that the aquatic varieties were present that could have been affected by hard water. This date is provisionally accepted.

Peninsula Point 12770±130 BP (GSC-1214): This sample of peat was recovered from the base of a mud flow colluvium that overlay sand. The mud flow is covered by lacustrine deposits and the sample is interpreted as dating the melting of the permafrost prior to the mud flow and lake deposits (Lowdon et al. 1971:306). Based on the description of the sample context, the plants making up the peat were probably terrestrial so the date is provisionally accepted.

Saskatoon Mountain 9400±370 (AECV-1474C) and 9360±60 (UCR-3275): The two samples consisted of charcoal and a combined sample of raspberry (11) and rose (12) seeds respectively, recovered from a hearth on this archaeological site (Beaudoin et al. 1996:117-118). The raspberry and rose seeds were probably growing and picked in the same year. The charcoal has an identical age. Both dates are accepted.

Sibbald Creek 9570±320 BP (GX-8808): This sample consisted of charcoal collected from fine screening of soil from between 35 cm and 40 cm in a stratigraphic column (Gryba 1983:122; Beaudoin 1987:209). This sample potentially contains many different radiocarbon events. The date is rejected.

Tuktoyaktuk Peninsula 9560±80 BP (GSC-1169): The twigs and peat of this sample were recovered from an exposure of a 313 m thick clayey colluvium mud flow. The date was interpreted as relating to the melting of permafrost and deposition of the mud flow (Lowdon and Blake 1973:33). The twigs and peat represent multiple radiocarbon events that would appear to be closely spaced in time. The peat appears not to be in an aquatic species so hard water is not an issue. The date is accepted.

Tununuk 10970±120 BP (GSC-1286): The peat sample was recovered from the base of a 3 m peat and sand sequence overlying >3 m of gravel in a road-cut exposure. The submitter interprets the date as indicating the beginning of thermokarst activity and peat accumulation at the site (Lowdon and Blake 1973 :31). The context suggests that the moss that formed the peat was not aquatic so the date is accepted.

Vermilion Lakes 9880±140 BP (AECV-121C), 10010±180 BP (RIDDL-82): Both samples were charred wood from Locality B, component 4, of this archaeological site. The occupation covered about 10 m^2 around a probable hearth feature (Fedje 1986:36-38; Fedje et al. 1995:87-94). The samples were part of a scatter of charred wood, bone and cultural remains around the hearth on the surface of this component, described as a weak regosol capped by aeolian sandy silt (Fedje 1986:38; Fedje et al. 1995:87,89). It is uncertain from this description whether each sample represented several pieces or a single piece of charred wood. Normally, such uncertainty would lead to rejection of these dates, but a third accepted date on bone collagen (9840±200 BP, RIDDL-77) from the same stratigraphic context indicates that the charred wood accurately dates this component. These dates are accepted.

Waldron Ranch 9560±90 BP (GSC-141): This sample consisted of small pieces of charcoal recovered from silty clay alluvium between 0.60 m to 3.65 m below surface (Dyck and Fyles 1964:170). This sample represents multiple radiocarbon events over a considerable time range. This date is rejected.

Yorkton 10300±80 BP (GSC-1356): This sample consisted of wood and organic detritus recovered between 6.97 and 7.0 m of a borehole in meltwater channel fill. Glacial till was encountered at a depth of 9.8 m (Lowdon and Blake 1976:9). The context of the sample, in channel deposits, would appear to rule out aquatic plants and hard water as a potential problem. Without knowing the nature or origin of the organic detritus, there are potentially many radiocarbon events represented in this sample. The date is therefore rejected.

This leaves 306 accepted dates and 293 rejected. (Appendix A lists these rejected dates and reasons for their rejection). The remaining 306 radiocarbon dates come from 195 separate locations, a reduction of about 36 % from the initial number of locations. Figure 8 shows the remaining site distribution after Question 3 and Question 4.

Compared to Figure 6 all regions of the study area are affected by the elimination of sites. The reduction is most noticeable from the Liard River in the north to the North Saskatchewan River in the south. This is because fewer of the sites in this area produced multiple radiocarbon dates so the elimination of any one site has a greater impact on the distribution. Figure 9 identifies the remaining provisional dates.

Question 5 Results

Of the 306 dates 293 were accepted and 13 rejected. Figure 10 displays the locations of the 293 accepted dates (including provisional dates) from 191 site locations. Many of the rejected dates had been rejected by the original researcher for various reasons. There were three variations from the calculation or reporting of a conventional radiocarbon date, as noted by Stuiver and Polach (1977:355-363), that could be corrected. First, the error term was sometimes reported at 2 standard deviations instead of 1 standard deviation. This is easily corrected by halving the published value. Second, the rounding off procedure for both the date and error did not follow the stipulated convention. This correction added or subtracted 50 years to either the date or error. Third, the date was not corrected for fractionation by some laboratories. Fortunately, if the sample material is adequately identified this correction can be applied from a known average age correction. The age corrections used in this study are those found in Stuiver and Polach (1977:358). The changes to dates ranged from an increase in age of 200 years to a decrease in age of 60 years, while the error changed by at most 90 years. Table 1 lists the final set of 293 conventional radiocarbon dates remaining for further analysis by province/territory and Appendix A lists the dates rejected. In all tables common names, if they exist, are used to identify the sample material dated, otherwise the Latin name is used. Table 1 lists the dates by latitude (west to east) and by longitude (north to south) for each province or territory.

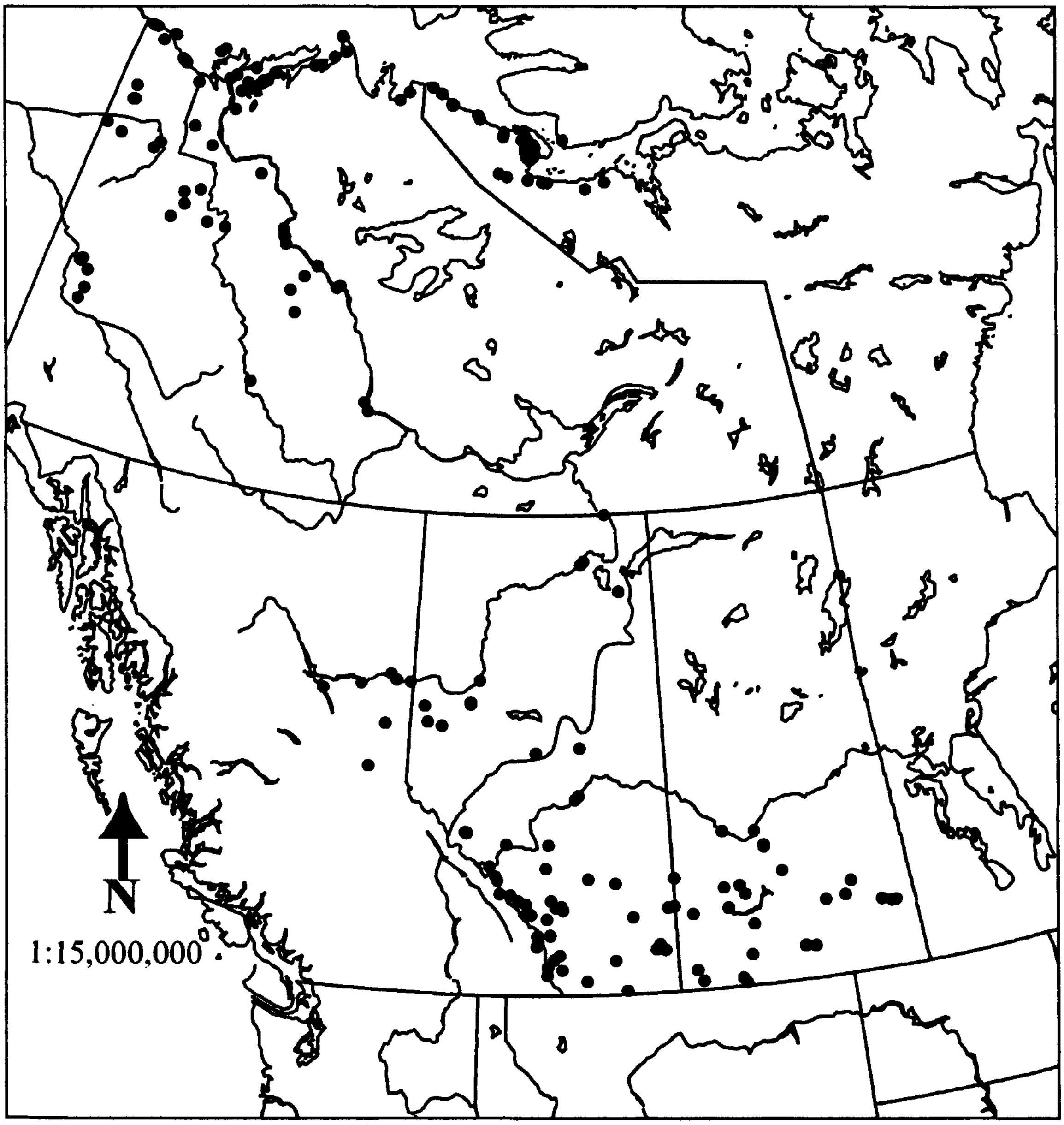


Figure 8. Sites remaining after Question 3 and Question 4 (including remaining provisional dates).

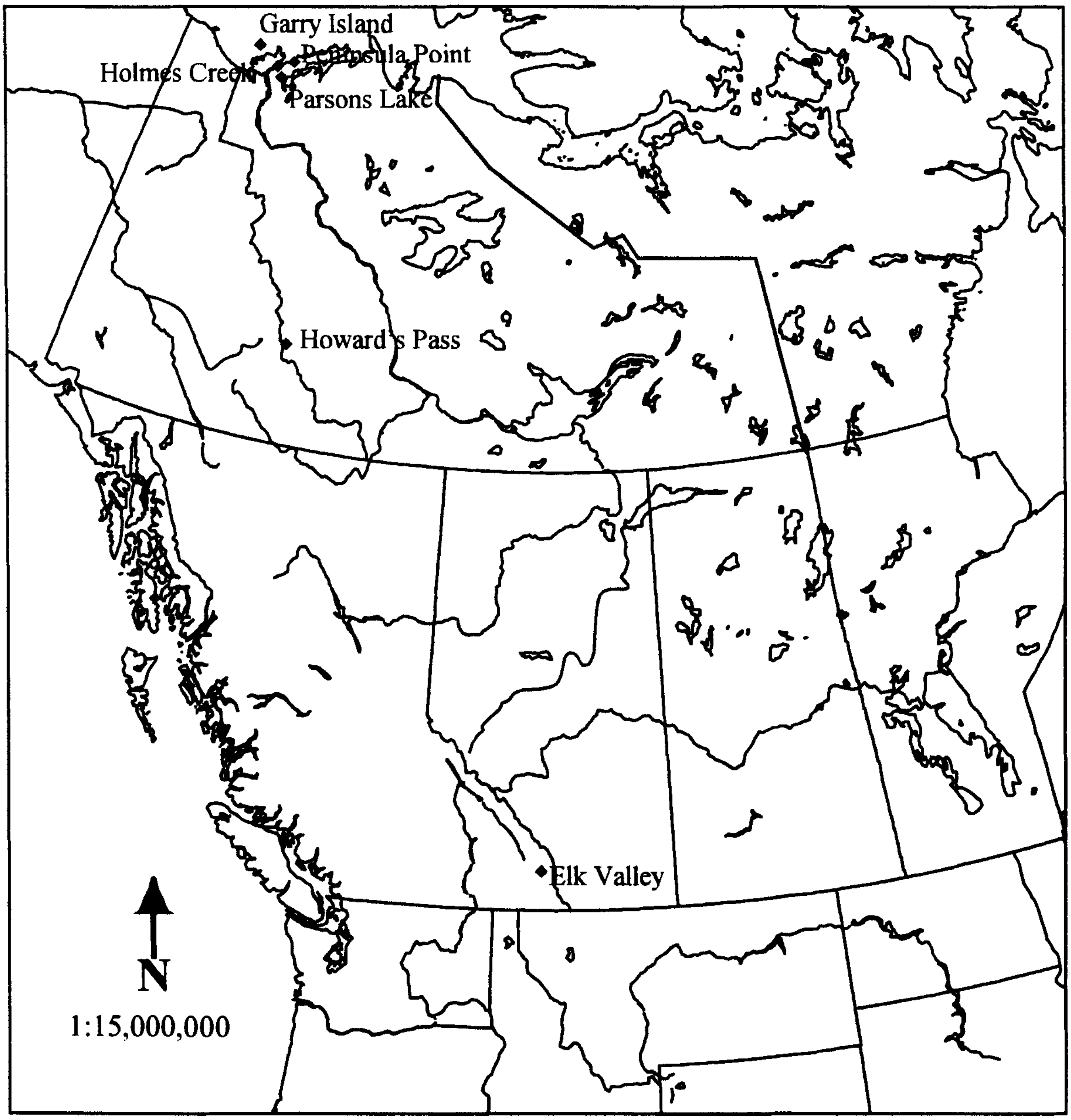


Figure 9. Location of remaining provisional dates.

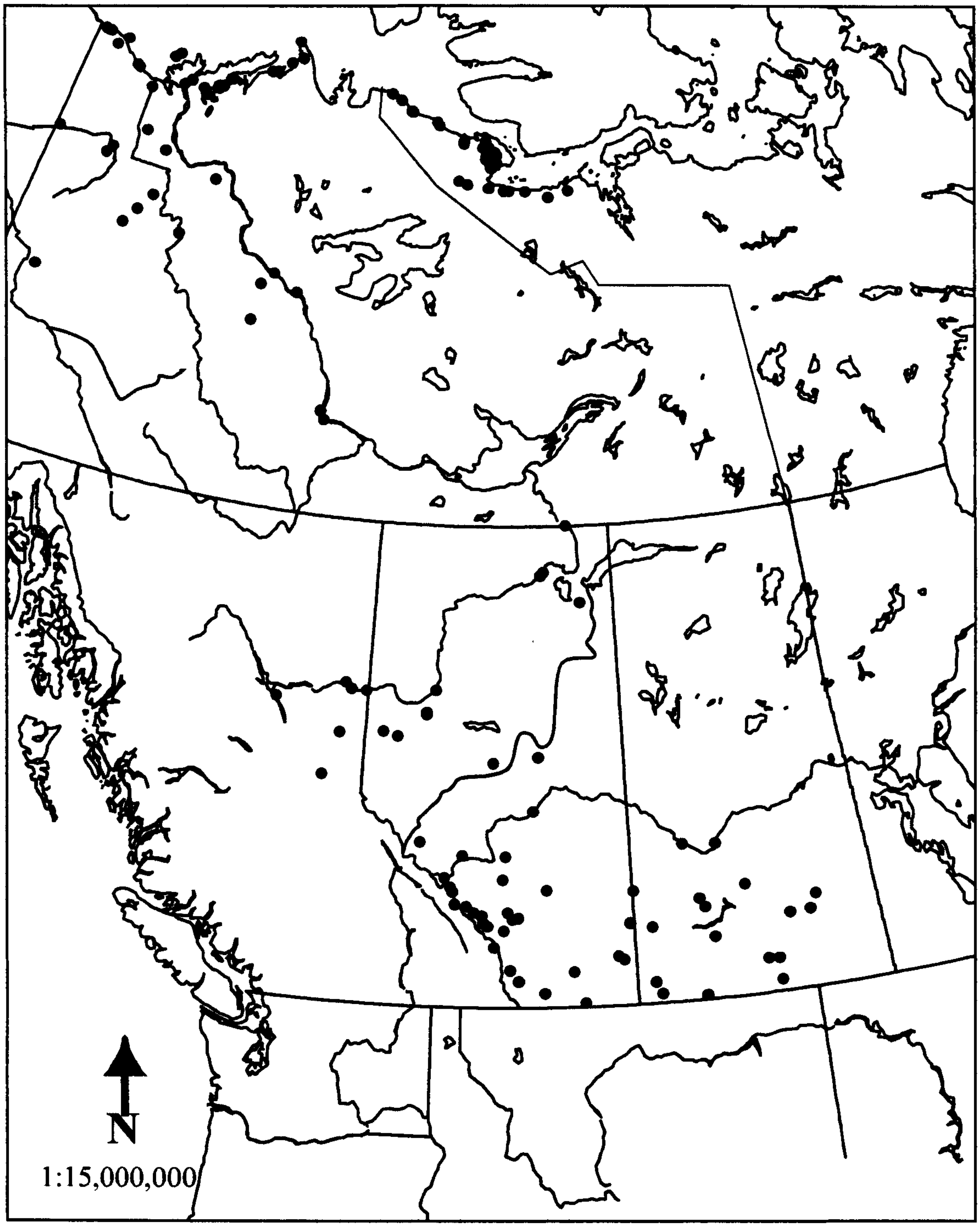


Figure 10. Sites remaining after Question 5

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Yukon Territory						
Backhouse River	69.36	-140.36	10920±80	GSC-1853	wood, birch	Lowdon and Blake 1976
Komakuk Beach	69.35.30	-140.22	10220±60	GSC-1838	wood, willow	
Komakuk	69.35.30	-140.14	10580±190	TO-651	fecal pellets, mammal	McNeely and Jorgensen 1992
			9900±100	GSC-4342	wood, willow	
Pauline Cove, Herschel Island	69.34	-138.58	9580±110	GSC-1483	peat, sedge	Lowdon and Blake 1976
Herschel Island	69.34	-138.54	16200±150	RIDDL-765	collagen, horse	Morlan 2001
			13300±60	Beta-71232	collagen, muskox	
			16700±200	RIDDL-766	collagen, horse	Harington 1989
Engigstciak, NiVk-1	69.21	-139.32	9870±180	RIDDL-319	collagen, bison	Cinq-Mars et al. 1991
			9870±180	RIDDL-362	collagen, bison	
			9770±180	RIDDL-281	collagen, bison	
King Point	69.05	-137.55	11270±110	GSC-3982	peat, taxon unidentified	Blake 1987
Sabine Point	69.04	-137.48	8980±45	GSC-3914	wood, willow	
Sabine Point east	69.02	-137.38	9960±90	GSC-2022	wood, poplar	Lowdon and Blake 1976
Old Crow River, CRH-87	68.09	-139.58	13420±390	CRNL-1218	collagen, mammoth	Morlan 1980
Old Crow River, Determination II	67.51.00	-139.46.10	14410±110	GSC-730-2	wood, taxon unidentified	Blake 1988
Old Crow, MkVl-12	67.50	-139.51	12360±180	I-7764	collagen, bison horn core	Morlan 1980
			12740±280	QU-782	collagen, bison	
			11530±200	QU-780	collagen, bison	
Old Crow, MkVl-9	67.20	-139.46	12540±220	I-3574	collagen, bison	
			12300±750	QU-783	collagen, bison	
			11990±90	I-7765	collagen, bison	

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Bluefish Cave 1, MgVo-1	67.08	-140.47	13580±80	CAMS-23473	collagen, sheep	Morlan 2001
			13940±160	RIDDL-559	collagen, mammoth	
			12210±210	RIDDL-277	collagen, caribou	
			12830±60	CAMS-23468	collagen, caribou	
			11570±60	CAMS-23472	collagen, moose	
			12850±250	CRNL-1220	collagen, mammoth	
			12900±50	GSC-2881	collagen, horse	Cinq-Mars 1979.
			17440±220	RIDDL-278	collagen, horse	Burke and Cinq-Mars 1996
Bluefish Cave 2, MgVo-2	67.08	-140.47	17880±330	CRNL-1221	collagen, mammoth	Morlan 2001
			15540±70	GSC-3053	collagen, mammoth	McNeely 1989
			19640±170	RIDDL-330	collagen, mammoth	Morlan 2001
			10230±140	RIDDL-561	collagen, bison	
Bluefish Cave 3, MgVo-3	67.08	-140.47	19000±1500	TO-1266	collagen, cougar	
			12370±440	CRNL-1236	collagen, horse	
			13390±180	RIDDL-279	collagen, saiga horn core	Harington and Cinq-Mars 1995
			10820±60	CAMS-23467	collagen, wapti	Morlan 2001
			14370±130	RIDDL-557	collagen, muskox	
			13350±100	Beta-129151	collagen, owl	
Whitefish Lake	67.08	-137.25	9550±110	GSC-1829	wood, willow	Lowdon et al. 1977
Upper Porcupine River	66.57	-137.42	13520±170	GSC-2553	wood, willow	Lowdon and Blake 1980
			9210±80	GSC-2461	wood, spruce	
Upper Porcupine River	66.57	-137.42	15920±110	GSC-2431	wood, taxon unidentified	Lowdon and Blake 1980

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Caribou River	66.22	-134.20	9800±90	GSC-3573	wood, willow	McNeely 1989
	66.13	-135.11	12370±110	GSC-3691	peat, taxon unidentified	McNeely and McCuaig, 1991
Peel River	65.57	-134.59	10620±110	GSC-2393	wood, taxon unidentified	Lowdon and Blake 1979
Snake River	65.41	-133.26.30	11720±90	GSC-2693	wood, willow	Blake 1984
			11820±100	GSC-2745	wood, willow	Morlan 2001
Hungry Creek, Bonnet Plume	65.34.30	-135.30.30	8950±110	GSC-2341	peat, taxon unidentified	Hughes et al.1981; McNeely 1989
Hunker Creek	64.01	-139.06	9540±100	GSC-73	wood, taxon unidentified	Dyck and Fyles 1963
	63.57	-139.13	11350±110	Beta-27512	collagen, caribou	Morlan 2001; Harington 1980
Dominion Creek	63.48	-138.41	15240±130	Beta-81133	collagen, badger	Morlan 2001
			14950±260	I-3659	collagen, horse species	Blake 1984
			12220±90	GSC-2641	seeds, plant stems and feces	
Gold Run Creek, KkVh-VP	63.24	-138.29	18030±120	Beta-70099	collagen, mammoth	Morlan 2001
Scroggie Creek	63.08.00	-138.37.30	16200±70	GSC-1893	collagen, mammoth tusk	Blake 1988
Howard's Pass	62.28	-129.12	9610±50	GSC-3532	peat, taxon unidentified	Blake 1983
Northwest Territories/Nunavat						
Baillie Island	70.37	-128.10	9600±110	GSC-2030	wood, willow	Lowdon and Blake 1978
	70.35	-128.06	14920±160	Beta-25119/ETH-3898	collagen, saiga	Harington and Cinq-Mars 1995
ObRw-1, Qugyuk	70.15	-127.43	9560±60	Beta-79861	collagen, bison	Morlan 2001
Cape Monte Casino	70.05	-128.24	9020±80	GSC-1989	wood, poplar	Lowdon and Blake 1978
Nicholson Point	69.50	-129.10	9020±80	GSC-4362	wood, birch moss, taxon unidentified	McNeely and McCuaig 1991
Liverpool Bay	69.48	-129.32	9150±120	GSC-1327	peat, *Ditrichum flexicaule*	Lowdon and Blake 1973
Keats Point	69.46	-121.40	10850±110	AECV-644Cc	marine shell, *Hiatella arctica*	McNeely and Jorgensen 1992
Clinton Point	69.38	-121.03	10350±100	AECV-642Cc	marine shell, *H. arctica*	

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Clinton Point	69.38	-121.03	10420±100	AECV-645Cc	marine shell, taxon unidentified	McNeely and Jorgensen 1992
Pelly Island	69.37.30	-135.30.30	9180±60	GSC-2197	wood, willow	Lowdon and Blake 1979
Pearce Point	69.35	-123.08	11800±110	AECV-643Cc	marine shells, *H. arctica*	McNeely and Jorgensen 1992
Garry Island	69.31	-135.47	11720±250	S-277	wood, taxon unidentified	McCallum and Wittenberg 1968
			11320±200	S-278	wood, taxon unidentified	
			9520±150	S-276	wood, taxon unidentified	
	69.30.05	-135.47.25	9750±100	GSC-575	iron stained twigs and wood fragments, taxon unidentified	Lowdon et al. 1971
Eskimo Lakes Postglacial	69.25	-131.58.30	9200±80	GSC-2023	wood, willow	Blake 1987
	69.25	-131.53	10320±90	GSC-1936	wood, taxon unidentified	
Buchanan River	69.24.39	-120.17.21	9810±60	GSC-4347	marine shells, *H. arctica*	McNeely and McCuaig 1991
Peninsula Point	69.24.30	-133.09	12770±130	GSC-1214	peat, taxon unidentified	Lowdon et al. 1971
Eskimo Lakes Outwash	69.24.30	-131.59.30	13200±100	GSC-1995	plant material, grass	Blake 1987
Buchanan River	69.24.30	-120.18.45	10700±50	GSC-4318	marine shells, *H. arctica*	McNeely and McCuaig 1991
Tinney Point	69.24	-120.20	10010±70	AECV-462Cc	marine shell, *H. arctica*	McNeely and Jorgensen 1992
	69.24	-120.16	10630±90	AECV-444Cc	marine shell, taxon unidentified	
Buchanan River	69.23.18	-120.13.29	10600±60	GSC-4339	marine shells, *H. arctica*	McNeely and McCuaig 1991
Darnley Bay	69.22	-123.40	11280±100	TO-217	marine shells	Vincent 1989
Eskimo Lakes Postglacial	69.13	-132.18	9150±160	GSC-1653	wood, willow twig	Blake 1987
Clifton Point	69.11.32	-118.38.49	10700±50	GSC-4390	marine shells, *H. arctica*	McNeely and McCuaig 1991
			10400±50	GSC-4424	marine shells, *H. arctica*	
			10310±50	GSC-4402	marine shells, *H. arctica*	
			8890±60	GSC-4425	marine shells, *Clinocardium cilatum*	

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Holmes Creek	69.08	-134.18	9540±150	GSC-1495	peat, mainly sedge	Lowdon and Blake 1978
Clifton Point	69.07.31	-118.30.55	9310±280	AECV-712Cc	marine shell, *H. arctica* and *Macoma balthica*	McNeely and Jorgensen 1992
Eskimo Lakes Postglacial	69.07.30	-132.32.30	10720±130	GSC-1710	wood, willow twigs with bark	Blake 1987
Clifton Point	69.07	-118.31	9610±160	AECV-473Cc	marine shell, *H. arctica*	McNeely and Jorgensen 1992
Eskimo Lakes Outwash	69.04	-132.43	12900±80	GSC-1784-2	plant material, grass	Blake 1987
Tuktoyaktuk Peninisula	69.03	-133.27	9560±80	GSC-1169	wood, willow twigs peat, taxon unidentified	Lowdon and Blake 1973; Ritchie and Hare 1971
Tununuk	69.00	-134.40	10970±120	GSC-1286	peat, taxon unidentified	Lowdon and Blake 1973
Zed Lake series	68.57.30	-133.13.30	9640±180	GSC-1469-3	wood, willow	Lowdon and Blake 1976
Parsons Lake	68.56	-133.38	11380±140	GSC-1160	wood, twigs and peat, taxon unidentified	Lowdon and Blake 1973
Stapylton Bay	68.48.15	-115.39.12	10100±45	GSC-4926	marine shells, *H. arctica*	McNeely and Jorgensen 1992
Harding River, Dolphin and Union Strait	68.47	-116.56	10540±280	I(GSC)-25	marine shell, pelecypod	Walton et al. 1961
Dolphin and Union Strait	68.44	-116.56.17	10430±280	AECV-713Cc	marine shell, *Mya truncata* and *H. arctica*	McNeely and Jorgensen 1992
	68.44	-116.56	10050±140	AECV-474Cc	marine shell, *Macoma* sp.	
Coal Mine Lake	68.42.24	-136.29.00	10300±60	GSC-3729	wood, willow and birch	
Stapylton Bay	68.39.31	-115.26.46	9690±80	GSC-4849	marine shells, *H. arctica*	
	68.39.21	-115.46.40	9850±40	GSC-4917	marine shells, *H. arctica*	
Kugaryuak River, Coronation Gulf	68.39	-113.19	9110±190	I(GSC)-16	marine shell, pelecypod	Walton et al. 1961
Coppermine	68.32.32	-115.05.40	9620±45	GSC-4749	marine shells, *H. arctica*	McNeely and Jorgensen 1992
Bernard Harbour	68.30.33	-115.10.53	9610±40	GSC-4846	marine shells, *H. arctica*	

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Bernard Harbour	68.29.12	-114.59.32	9530±40	GSC-4847	marine shells, *H. arctica*	McNeely and Jorgensen 1992
Coppermine	68.27.58	-115.34.34	9920±50	GSC-4727	marine shells, *H. arctica*	
	68.27.33	-115.05.54	9540±40	GSC-4696	marine shells, *H. arctica*	
Bernard Harbour	68.27.26	-115.21.23	9700±40	GSC-4848	marine shells, *H. arctica*	
Basil Bay	68.24.42	-115.15.52	9480±60	GSC-4930	marine shells, taxon unidentified	
Coppermine	68.22.41	-115.35.17	10700±50	GSC-4916	marine shells, taxon unidentified	
Twin Lakes	68.22	-133.44.30	11470±120	GSC-1514	peat, brown moss	Lowdon and Blake 1973
Coppermine	68.19.03	-115.22.28	9190±80	GSC-4709	marine shells, taxon unidentified	McNeely and Jorgensen 1992
Basil Bay	68.18.29	-114.59.49	9130±90	GSC-4845	marine shells, taxon unidentified	
Klengenberg Bay	68.14.42	-115.20.06	9520±40	GSC-4915	marine shells, *H. arctica*	
Coppermine	68.14.17	-115.28.59	11170±80	TO-1231	marine shell, *Portlandia arctica*	
	68.11.32	-115.18.47	9640±90	GSC-4747	marine shells, *H. arctica* and *Mya arenaria*	
Richardson River	67.52	-117.10	10300±120	GSC-3663	marine shells, *Macoma calcarea*	Blake 1983
Cox Lake, southwest	67.48	-116.40	9430±60	GSC-3941	marine shell, *M. truncata*	Blake 1987
Coppermine Area	67.48	-116.40	9810±100	AECV-403Cc	marine shell, *M. truncata* and H. arctica	McNeely and Jorgensen 1992
Coppermine River Valley	67.43.48	-115.25.34	9820±45	GSC-3327	marine shells, *M. calcarea*	Blake 1983
Rat River	67.43.30	-135.50.30	9990±110	GSC-147	wood, taxon unidentified	Dyck and Fyles 1964
Coronation Gulf	67.40.30	-114.16.30	9090±100	AECV-404Cc	marine shell, *H. arctica* and *M. truncata*	McNeely and Jorgensen 1992

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Coronation Gulf	67.40	-114.33	9560±130	AECV-472Cc	marine shell, *M. truncata*	McNeely and Jorgensen 1992
South Coronation Gulf Coast	67.38.37	-110.51.50	9620±70	GSC-3584	marine shells, *H. arctica*	Blake 1983
Tree River, Coronation Gulf	67.30.15	-112.02	10230±230	I(GSC)-17	marine shells, taxon unidentified	Walton et al. 1961
West of Frog Creek	67.25	-134.28	9490±90	GSC-1814	wood, poplar	Lowdon and Blake 1979
Grandview Hills	67.06	-131.13	9580±90	GSC-2298	wood, poplar	
Mountain River	65.58	-129.11	11440±90	TO-1191	wood, taxon unidentified	Smith 1992; Lemmen et al. 1994
	65.50	-129.05	11140±160	I-3913	wood, taxon unidentified	
			11530±170	I-3734	wood, taxon unidentified	MacKay and Mathews 1973; Lemmen et al. 1994
Sans Sault Rapids	65.49	-129.00	11220±130	GSC-1573	wood, willow	Lowdon and Blake 1979; MacKay and Mathews 1973
Many Beaver Lake	65.42	-132.24	8930±100	GSC-1865	wood, willow	McNeely 1989
Mountain River	65.39	-128.53	11760±90	TO-1190	wood, taxon unidentified	Smith 1994; Smith 1992; Lemmen et al. 1994
Norman Wells	65.18	-126.52	9340±90	GSC-2206	wood, birch and willow twigs	Lowdon and Blake 1979
Bell's Lake	65.01	-127.29	10230±150	TO-2375	wood, taxon unidentified	Szeicz et al.1995
Great Bear River	64.56.30	-125.29.45	10620±130	GSC-2328	wood, taxon unidentified	Lowdon and Blake 1979; Savigny 1989
Little Bear River	64.53	-125.40	11550±180	I-15,020	wood, taxon unidentified	Smith 1994, Lemmen et al. 1994
Andy Lake	64.39	-128.05	12060±80	TO-2295	wood, taxon unidentified	Szeicz et al.1995
Keele Lake	64.10	-127.37	9560±70	TO-3989	wood, taxon unidentified	
Root River	62.22	-123.25	10290±180	AECV-917C	wood, taxon unidentified	Smith 1992; Smith 1994; Lemmen et al. 1994

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Fort Simpson	62.11	-123.12	9110±240	AECV-916C	wood, taxon unidentified	Smith 1994
Fort Smith	60.01	-111.53	9830±360	S-1507	wood, taxon unidentified	Rutherford et al. 1984
British Columbia						
Charlie Lake Cave	56.17	-120.56	10290±100	CAMS-2137	collagen, raven	Driver et al. 1996; Fladmark et al. 1988; Fladmark 1996
			10500±80	CAMS-2129	collagen, Artiodactyl	
			10560±80	CAMS-2134	collagen, bison	
			10380±160	SFU-378	collagen, bison	
			10100±210	RIDDL-392	collagen, squirrel	
			9760±160	SFU-355	collagen, bison	Driver et al. 1996; Fladmark et al. 1988; Fladmark 1996
			10450±150	SFU-300	collagen, bison	
			10770±120	SFU-454	collagen, bison	
			9670±150	CAMS-2136	collagen, bison	Driver et al. 1996
			9490±140	CAMS-2318	collagen, raven	
Fort St. John	56.10	-120.44	13970±170	TO-2742	wood, taxon unidentified	Catto et al.1996
Ostero Gravel Pit	56.08.30	-120.40.30	10240±160	AECV-1206C	collagen, bison	Lowdon and Blake 1979
Clayhurst Gravel Pit	56.07.40	-120.05.00	10580±210	CAMS-398	collagen, bison	Apland and Harington 1994
			10230±140	AECV-1558C	collagen, bison	
			10750±180	RIDDL-220	collagen, bison	
			10600±160	AA-1219	collagen, bison	
			10340±150	CAMS-150	collagen, bison	
Finlay-Parsnip Access	55.48.00	-123.38.30	9280±100	GSC-1497	horn core, Bighorn sheep	Lowdon and Blake 1979; Rutter et al. 1972
Tumbler Ridge	55.08	-121.00	10380±100	BETA-44201	collagen, bison	Woolf 1993
Summit Creek	54.08.30	-121.31.30	10020±80	GSC-2964	wood, poplar	Lowdon and Blake 1980

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Lake O'Hara			10100±200	RIDDL-433	wood, conifer needles	Reasoner and Hickman 1989
Opabin Lake	51.21	-116.20	10060±160	RIDDL-511	wood, conifer needles	
Elk Valley, Weary Bog	50.23	-114.56	10130±290	GX-5598	wood, taxon not identifed	Ferguson and Osborn 1981; Clague 1982; Ferguson and Osborn 1982
Elk Valley	50.09.30	-114.57.20	11940±80	GSC-2142	wood, conifer	Harrison 1976; Lowdon and Blake 1976
			12220±110	GSC-2275	wood, conifer	
Alberta						
Peace Delta	58.57	-112.55	9830±80	WAT-2662	wood, taxon unidentified	Smith 1994
	58.53	-113.02	9850±80	WAT-2661	wood, taxon unidentified	
Athabasca Delta	58.15	-111.25	9910±45	GSC-4302	wood, taxon unidentified	Smith 1994; Rhine and Smith 1988
			9710±70	AECV-1183C	wood, taxon unidentified	Smith 1994
Peace River	56.13.40	-117.18.10	9880±70	GSC-2865	collagen, bison.	Lowdon and Blake 1979
Watino	55.43	-117.37.30	10200±50	GSC-2895	collagen, bison	Lowdon and Blake 1979
			10200±50	GSC-2902	collagen, bison	
Wakaluk Quarry	55.40.	-117.37.30	9160±310	S-2614	collagen, wapiti antler	Burns 1986
Boone Lake	55.35	-119.26	11700±260	SFU-223	wood, poplar	White and Mathewes 1986
Saskatoon Mountain, GhQt-4	55.13.50	-119.18.30	9400±370	AECV-1474C	charcoal, taxon unidentified	Beaudoin et al. 1996
Saskatoon Mountain, GhQt-4	55.13.50	-119.18.30	9360±60	UCR-3275, CAMS 12365	seeds, raspberry and wild rose	Beaudoin et al. 1996
Wood Bog, GgQq-7	55.09	-118.43	9730±110	AECV-1620C	wood, poplar	Beaudoin et al. 1996; Beaudoin pers com. email 2000
Athabasca River	54.43	-113.17	10200±160	GSC-1205	collagen, bison	Lowdon and Blake 1979
Freeman River	54.35	-115.00	10920±110	GSC-859	wood, taxon unidentified	Lowdon et al. 1971

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Clover Bar Sand and Gravel Ltd.	53.35.50	-113.21.30	11620±170	AECV-1203C	bone, bison	Burns and Young 1994
North Saskatchewan River	53.30	-113.30	11430±420	S-2385	bone, taxon unidentified	Rains and Welch 1988
			10820±470	S-1923	bone, taxon unidentified	
Whitemud Creek, Edmonton	53.30	-113.30	8300±1100	S-1798	collagen, bison	
Muskiki Lake peatland	52.50	-116.51	9000±230	AECV-103C	peat	Kubiw et al. 1989
Lorraine Lake	52.45	-117.40	9180±320	AECV-591C	plant remains, charred, taxon unidentified	Beaudoin 1991
Nordegg Pond	52.29	-116.06	8930±150	Beta-252261/ETH-3740	wood, spruce	Mandryk 1992
Rocky Mountain House	52.28.16	-114.32.00	9750±140	I-5677	collagen, bison	Harris and Boydell 1972; Jackson and Pawson 1984
North Saskatchewan Crossing	51.58	-116.43	9350±110	GSC-332	charcoal, taxon unidentified	Dyck et al. 1966
James River, EkPp-VP	51.56.02	-114.38.30	10320±330	GX-2918D	collagen, mammoth	Burns 1996; Morlan 2001
EkPu-8, James Pass Meadow Complex	51.45	-116.30	10140±80	TO-3000	collagen, taxon unidentified	Ronaghan 1993
			9750±80	TO-2999	collagen, bison	
Three Hills	51.41.30	-113.04.30	9720±150	GSC-1894	collagen, bison	Lowdon and Blake 1979; Shackleton and Hills 1977

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Three Hills, Milan Site	51.41.30	-113.04.30	9750±160	I-8579	collagen, bison	Lowdon and Blake 1979; Shackleton and Hills 1977
Crowfoot Lake	51.39.08	-116.25.40	9060±370	CAMS-3064	wood, fir needle	Reasoner et al. 1994; Leonard and Reasoner 1999
			10020±70	CAMS-3063	wood, pine needle	
			10070±420	CAMS-3177	seed, sedge	
			11330±220	CAMS-3065	wood, willow twig	
			9470±70	CAMS-6843	wood, pine needle	
Copper Lake	51.18.35	-115.55.20	10490±160	RIDDL-664	wood, taxon no identified	White and Osborn 1992
			9650±150	RIDDL-88	wood, spruce needle	
Clarke Gravel Pit, Cochrane	51.10.40	-114.27.30	11180±90	GSC-989	collagen, bison	Lowdon and Bake 1970; Churcher 1968; Stalker 1968
			11450±100	GSC-613	collagen, bison	Lowdon et al. 1967, Churcher 1968; Stalker 1968
Griffen Gravel Pit, Cochrane	51.10.40	-114.27.10	10840±90	GSC-612	bone, bison	Lowden et al. 1967; Churcher 1968
Vermilion Lakes	51.10.36	-115.38.40	11000±1600	RIDDL-217	charcoal, taxon unidentified	Fedje 1986; Fedje et al.1995
			10090±130	AECV-124C	collagen, bison	
			9570±150	RIDDL-75	wood, taxon unidentified	
			10180±130	RIDDL-73	charcoal, taxon unidentified	
			10040±200	RIDDL-71	collagen, bison	
			9700±130	RIDDL-83	collagen, bison	
			10040±160	RIDDL-72	collagen, bison	
			10060±220	RIDDL-84	collagen, bison	
			10660±650	RIDDL-216	wood, taxon unidentified	
			9880±140	AECV-121C	charcoal, taxon unidentified	
			10010±180	RIDDL-82	charcoal, taxon unidentified	

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Vermilion Lakes	51.10.36	-115.38.40	10100±210	RIDDL-81	charcoal, taxon unidentified	Fedje 1986; Fedje et al.1995
			9840±200	RIDDL-77	collagen, bison	
			10270±100	RIDDL-79	charcoal, taxon unidentified	
			10570±150	RIDDL-85	seed, taxon unidentified	
			9870±230	RIDDL-317	collagen, bison	
			10310±190	RIDDL-528	seed, taxon unidentified	
			10780±180	RIDDL-215	wood, taxon unidentified	
			10390±140	RIDDL-70	collagen, bison	
			10210±130	RIDDL-282	wood, taxon unidentified	
			10310±230	RIDDL-318	collagen, bison	
			9840±60	GSC-3804	charcoal, from flowering plant	McNeely and McCuaig 1991
Second Lake Site	51.10.36	-115.38.40	9470±460	S-2759	charcoal, taxon unidentified	Fedje 1986
Johnson Lake	51.06	-115.22	9440±230	TO-5186	wood, taxon unidentified	Beirerle and Smith 1998
Aquitaine Pit	51.02.55	-114.04.25	10200±140	GSC-3065	collagen, bison	Blake 1986
EgPn-480, Stonepine	51.01.21	-114.17.20	9540±70	Beta-127235	collagen, bison	Tom Head Pers com, 1999, Bison Historical Services.
Empress, CPR Pit	50.57.50	-110.00.50	14200±560	GSC-1199	collagen, mammoth	Lowdon. and Blake 1975
Gallelli Gravel Pit	50.57.45	-114.01.00	11380±290	RL-757	collagen, bison	Wilson and Churcher 1978, Jackson and Pawson 1984
Bindloss Gravel Pit	50.57	-110.08	10930±100	TO-8514	collagen, mammoth	Hills and Harington 2003, Churcher 1972
Lower Burstall Lake	50.56	-115.19	9180±60	CAMS-20358	wood, lodgepole pine needle	Beirerle and Smith 1998
Kananaskis Valley	50.52	-115.10	10400±60	GSC-2965	wood, poplar	Lowdon and Blake 1980
			9400±220	GX-6767	wood, taxon unidentified	
Toboggan Lake	50.46	-114.36	10400±70	TO-149	wood, taxon unidentified	MacDonald et al. 1991
			9100±360	TO-211	wood, spruce needle fragments	

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Princess Dinosaur Provincial Park	50.46	-111.30	16790±270	AECV-681C	bone, taxon unidentified	Evans and Campbell 1992
Cartwright Lake	50.24	-114.29	15670±960	TO-5190	wood, taxon unidentified	Beirerle and Smith 1998
Lindoe, EaPo-100	50.08	-110.36	9790±190	GaK-5097	collagen, probably bison	Byran 1980; Morlan 2001
Lindoe Bluff	50.04.50	-110.39.20	11280±110	GSC-805	collagen, bone (bison or horse, which taxon used unidentified)	Lowdon and Blake 1968
Medicine Hat, Reservoir Gully	50.01.55	-110.44.05	15200±130	GSC-1399	collagen, bison	Lowdon and Blake 1975
Pashley Gravel Pit	49.59	-110.29.40	10870±45	CAMS-82411	collagen, horse	Hills and Harington 2003; Churcher and Stalker 1970
Oldman Drainage DlPm-VP	49.56.58	-114.09.04	11220±60	Beta-79915	collagen, mammoth	Morlan 2001
The Gap, DlPo-20	49.51.05	-114.22.05	9600±240	GX-0956	collagen, bison	Reeves and Dormaar 1972
Taber Provincial Park	49.48.30	-112.10.30	10520±120	GSC-3	wood, willow	Dyck and Fyles 1962
Oldman River	49.48.30	-112.10	11020±260	S-68	wood, taxon unidentified	McCallum and Dyck 1960
Oldman River Dam, DjPm-16	49.36	-114.05	9600±210	AECV-746C	bone, taxon unidentified	Van Dyke 1994; Beaudoin 1991
Wally's Beach	49.20.	-113.12	10980±80	TO-7691	collagen, muskoxen	Kooyman et al. 2001; Kooyman pers. com. 2001
			11350±80	TO-8972	collagen, caribou	
			11330±70	TO-7696	collagen, horse	
			11130±90	TO-7693	collagen, bison	
Fletcher Site, DjOw-1	49.06	-111.49	9380±110	TO-1097	seeds, sedge	Wilson et al. 1991; Vickers and Beaudoin 1989
Saskatchewan						
Denholm 2 Testhole	52.35.45	-108.04.45	10890±660	S-1374	wood, taxon unidentified	Christiansen 1983
Eagle 10 Testhole	52.32.00	-106.54.00	10780±780	S-2097	wood, taxon unidentified	

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Sutherland	52.12	-106.35	14120±470	S-685	bone, taxon unidentified	Rutherford et al. 1979; Christiansen 1979
Saskatoon Site	52.10	-106.35	12080±320	S-482	collagen, tusk fragment	Rutherford et al. 1984
			20280±500	S-499	collagen, bison	
			14730±360	S-498	collagen, tusk fragment	
Riddell series	52.09	-106.36	15420±500	S-1305	bone, horse species	Rutherford et al. 1979
Green	51.36	-109.57	10820±180	S-227	charcoal, taxon unidentified	McCallum and Wittenberg 1965
Kenaston	51.33	-106.01	10170±210	S-97	wood, taxon unidentified	McCallum and Wittenberg 1962
Wiseton	51.19	-107.39	10680±140	S-232	whole bone, mammoth	Rutherford et al. 1973
Gunworth	51.18.08	-108.12.30	12160±250	S-198	charcoal, taxon unidentified	McCallum and Wittenberg 1965
Kelliher	51.08	-103.38	9620±140	S-182	wood, taxon unidentified	
Dinsmore	51.06.40	-107.29.30	10320±160	S-110	wood, conifer species	McCallum and Wittenberg 1962
Kyle	50.50	-108.07	12080±200	S-246	whole bone, mammoth	McCallum and Wittenberg 1968
Sioux Crossing	50.48	-103.54	10130±200	S-1304	wood, taxon unidentified	Rutherford et al. 1979
Earl Grey	50.46.20	-104.37.30	10290±240	S-165	wood, taxon unidentified	McCallum and Wittenberg 1965
Heron Eden Site, EeOi-11	50.45	-109.22	9010±120	S-3114	collagen, bison	Morlan 2001
			9000±130	S-3309	collagen, bison	
			10210±100	S-3118	collagen, bison	Linnamae 1990
Heron Eden Site, EeOi-11	50.45	-109.22	9290±110	S-3308	collagen, bison	Morlan 2001
Marieval	50.35	-102.39	12040±220	S-553	wood, taxon unidentified	Christiansen 1979
Camp Mackay	50.31	-102.18	11120±150	S-793	wood, taxon unidentified	Rutherford et al. 1979
Esterhazy	50.31	-102.09	11260±150	S-794	wood, taxon unidentified	Rutherford et al. 1979
Herbert	50.25	-107.15	10020±310	S-41	wood, willow	McCallum and Dyck 1960
Crane Valley	49.48	-105.32	10820±310	S-128	charcoal, taxon unidentified	McCallum and Wittenberg 1962
Scrimbit	49.46	-105.11	11520±310	S-80	wood, conifer trunk	Rutherford et al. 1979

Table 1. Final accepted and provisionally accepted radiocarbon dates

Site Name	Latitude d . m. s.	Longitude d . m . s	^{14}C Date B.P.	Lab. No.	Material	Reference
Scrimbit	49.46	-105.11	11720±310	S-83	wood, conifer cones and needles	Rutherford et al. 1979
			10420±260	S-85	wood, taxon unidentified	
			10020±260	S-81	wood, taxon unidentified	
			10420±100	GSC-21	wood, taxon unidentified	McNeely 1989
Frenchman Valley	49.29	-109.22	9240±340	S-2931	wood, taxon unidentified	Christiansen and Sauer 1988; Klassen 1993
Robsart (Horsemen Site) Kongeview	49.13.20	-109.10.40	9500±40	GSC-4098	wood, willow	McNeely and McCuaig 1991; Klassen 1993
Frenchman Valley	49.13	-107.49	11480±260	S-2932	wood, taxon unidentified	Christiansen and Sauer 1988; Klassen 1993
Val Marie site	49.06.30	-107.41.50	9880±110	TO-2212	seeds, taxon unidentified	Klassen 1993
			9910±80	TO-1711	seeds, taxon unidentified	

CHAPTER 6

SITE DISTRIBUTION AND ENVIRONMENTAL INFERENCES

This chapter interprets the results from Chapter 5, using the remaining radiocarbon dates to show when a biogeographical corridor was present. The distribution of acceptable radiocarbon dates will be viewed by latitude, temporal period and environmental conditions. The distribution by latitude will involve grouping sites by units of 2° latitude (e.g., 49°00'00" - 50°59'59"). This allows for a manageable number of groupings (11 versus 21 if units of 1° latitude were used) without sacrificing a significant amount of detailed information. For the temporal distributions, the dates are divided into four equal time periods as defined above. The site distributions and associated tables for each period are presented, with a brief description of the stratigraphic provenance or context of each sample. Environmental reconstructions follow in tabulated form for each period.

Latitudinal Distributions

Figure 11 displays the distribution of accepted and rejected dates by latitude. The distribution shows few acceptable dates around 60° latitude, with the number of dates increasing both north and south. It suggests that this area was not as productive or did not support flora and fauna for as long as those areas to the north and south. Alternatively, this distribution could reflect the amount of research conducted between 57° and 63° latitude. To determine if this alternative explanation is valid all the radiocarbon dates from this study can be compared to the number of dates older (>20000 BP) and younger

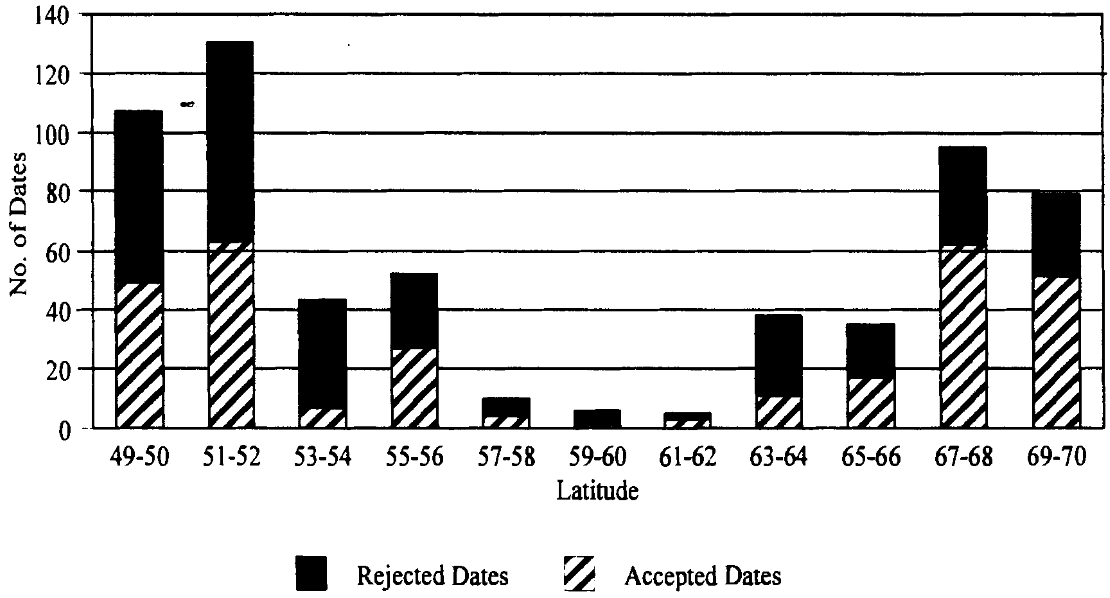


Figure 11. Number of accepted and rejected dates by latitude

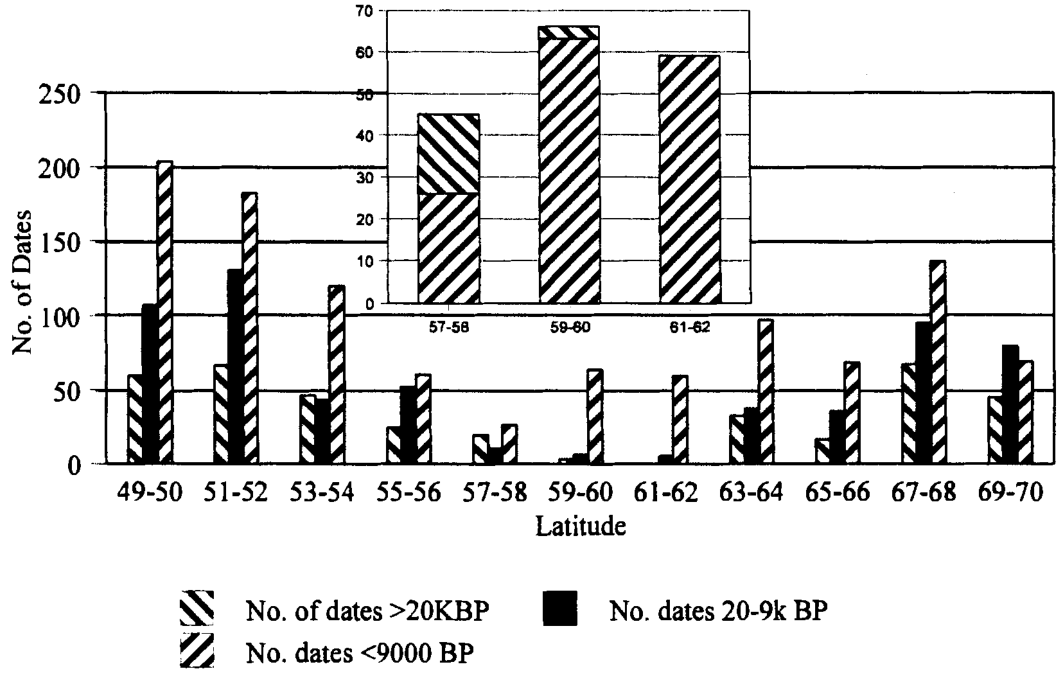


Figure 12. Comparison of radiocarbon datesfrom ≈50 ka to 0 B.P. (Insert: Summed total of other dates between 57° and 63° latitude).

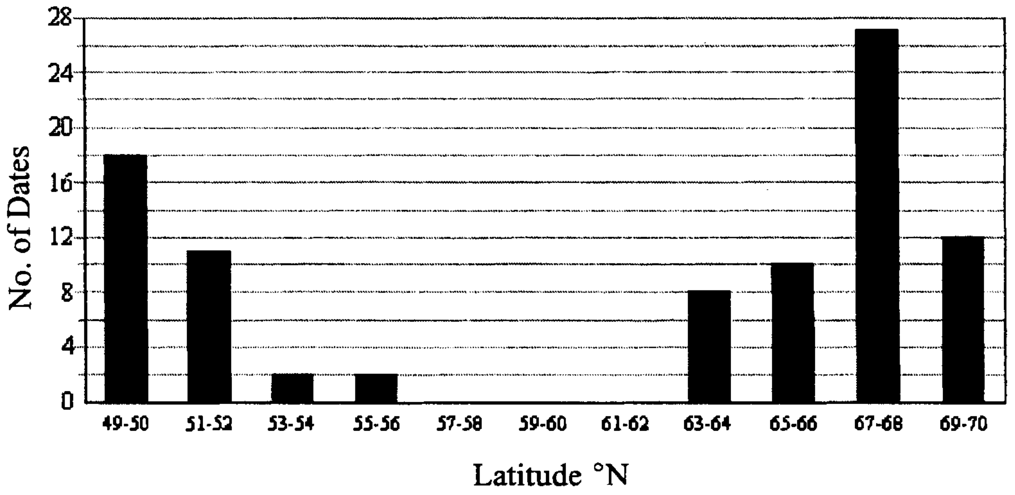


Figure 13. Number of accepted dates ≥ 11000 B.P. by latitude.

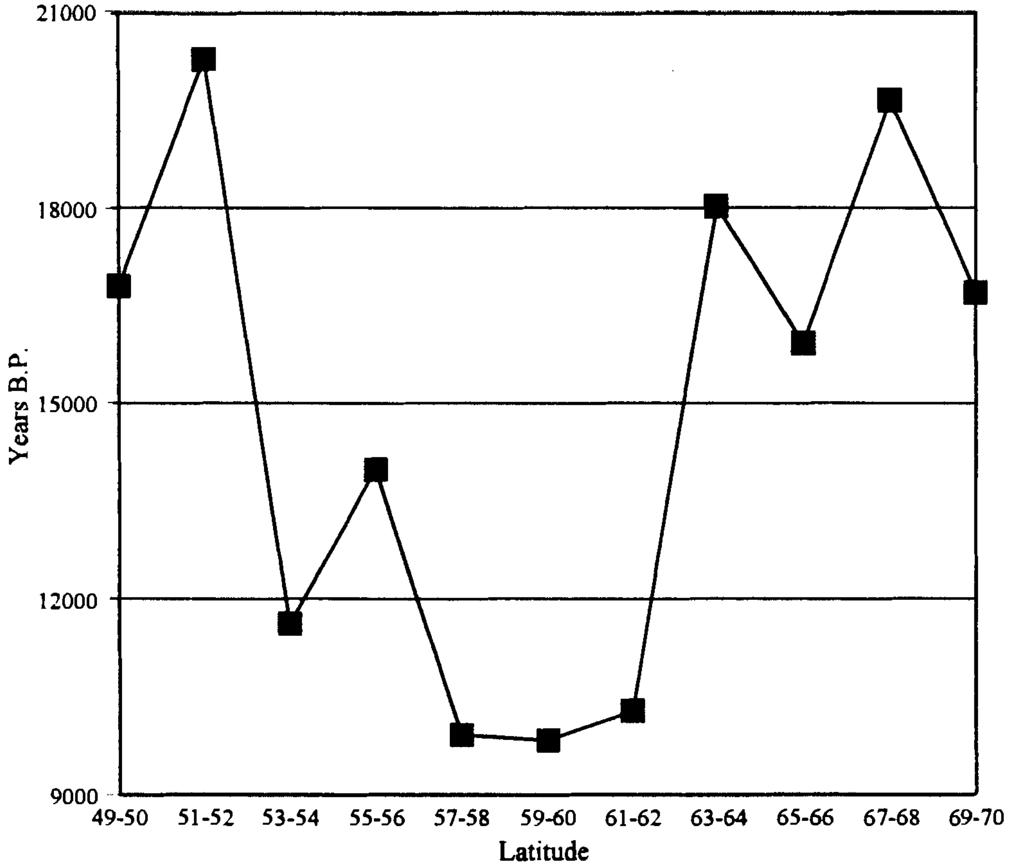


Figure 14. Maximum age of accepted dates by latitude.

(<9000) as a proxy for the intensity of research within the study area. These additional dates are located in a Microsoft Access 2000 file on the accompanying CD-ROM (access the README file first).

Figure 12 compares older and younger dates with those from this study. Each period shows a common pattern of significantly more dates north and south of the area between 57° and 63° latitude. The insert graph sums the older and younger dates between 57° and 63° latitude and indicates that significantly more dates are present from these other periods, with counts ranging from about 40 to 70, than from the period of this study. In fact, the counts are similar in magnitude to areas immediately south (between 53° and 57° latitude) and north (between 63° and 67° latitude) of this crucial central area for the period of this study. These additional dates indicate that the alternative interpretation is not supported and that the intensity of research does not explain the lack of dates between 57° and 63° latitude.

Figure 13 graphs the number of accepted dates older than 11000 B.P. The younger age limit was chosen because it includes the time when Clovis ancestors might have used the corridor. Again, the distribution shows no dates older than 11000 B.P. between 57° and 63° latitudes. Figure 14 indicates the oldest accepted date in each latitude grouping. This graph suggests that area between 56° and 63° latitudes could not support significant amounts of life until after 11000 B.P. Figures 11 to 14 all support the conclusion that a biogeographical corridor was not present in the ice-free corridor until after 11000 B.P.

and that the ice-free corridor could not have been used as a human migration route until then.

Temporal Distributions

Period 1: 20000 - 17001 B.P.

This period is represented by six dates from three sites, ranging from 20280 B.P. to 17440 B.P. Table 2 lists these dates and Figure 15 plots their distribution. Five of the dates are from the Yukon and show that plant and animal life present in these areas throughout the Last Glacial Maximum. The mammoth bone samples from Bluefish Cave are construed as having been intentionally brought to the cave by humans, and had marks interpreted as butchering cut marks. If correct, this indicates the presence of humans in eastern Beringia at that time. It should be noted, that both these dates are found only in the Canadian Archaeological Radiocarbon Database (CARD) (Morlan 2001), which provides no detailed information concerning their recovery or interpretation (i.e., proof of butchery). In the south, the Saskatoon Site in Saskatchewan shows that environmental conditions around 20000 B.P. could still support mammoths. This is expected since the Last Glacial Maximum is thought to have occurred around 18000 B.P.

Period 2: 17000-14001 B.P.

Seventeen dates are included in this period, 10 from the northern end and seven from the southern end of the study area (Table 3, Figure 16). In the north, three dates are from

Table 2. Radiocarbon dates From Period 1

Site Name	Date B.P.	Lab No	Material	Provenance/Description
Yukon				
Bluefish Cave 1	17440±220	RIDDL-278	collagen, horse	No description of provenance
Bluefish Cave 2	19640±170	RIDDL-330	collagen, mammoth	Butchered bone from lower loess, unit
	17880±330	CRNL-1221	collagen, mammoth	Butchered bone from lower loess Unit
Bluefish Cave 3	19000±1500	TO-1266	collagen, cougar	From lower loess, TP1-F-63
Gold Run Creek	18030±120	BETA-70099	bone, mammoth	From placer mine
Saskachewan				
Saskatoon Site	20280±500	S-499	bone, mammoth	From sand deposit within tills of Floral

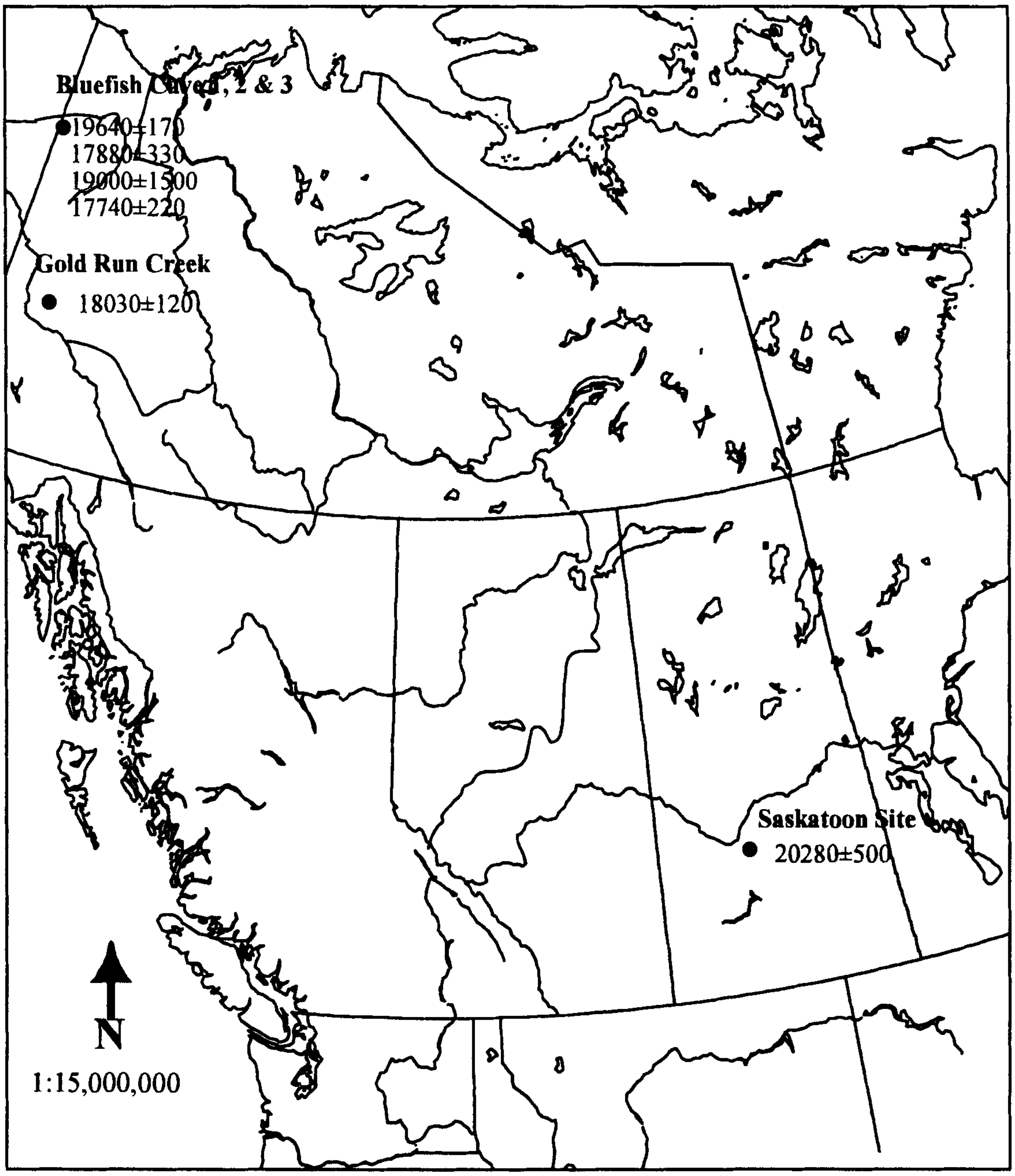


Figure 15. Period 1 site locations, 20000 - 17001 B.P.

two sites along the northern coast. The two dates from Herschel Island (16700±200 B.P., RIDDL-766, 16200±150 B.P., RIDDL-765) are on the same horse bone and the single date from Baillie Island (14920±160, Beta-25119/ETH-3898) is on saiga bone. They indicate that conditions in northern Beringia had improved to the point that horse and saiga were supported.

Wood dates, like the one from the Old Crow Basin (14390 ± 80, GSC-730-2), indicate an environment that supported trees, at least along the rivers. Nevertheless, this date (on a sample of twigs) is problematic since an additional date on another wood sample from the same layer was 41280 ± 1600 B.P. (GSC-730). Irving and Harington (1973:335-336) believe that both samples were in secondary contexts and that neither correctly date the context from which they were recovered. Bone dates from Table 4 indicate large herbivores, including mammoths, muskox and horse existed in Beringia. The presence of mammoth, horse and muskox support Guthrie's mammoth steppe interpretation but the recovery of wood and badger, even if in secondary stratigraphic context, suggests an environment that differed in some manner from this interpretation.

The dated sites from the Plains are more problematic. The Sutherland, Riddell and Saskatoon dates (14040±560 B.P., S-685; 15340±500 B.P., S-1305; 14730±360 B.P., S-498 respectively) from central Saskatchewan do not support the current interpretation that suggests the ice front was farther south at this time (Christiansen 1979:925).

Table 3. Radiocarbon dates from Period 2

Site Name	Date B.P.	Lab No.	Material	Description
Yukon/Northwest Territories				
Herschel Island	16700±200	RIDDL-766	collagen, horse	Sand colluvium resting on glacially deformed marine and terrestrial bed, partly exposed at top of eroding coastal scarp.
	16200±150	RIDDL-765	collagen, horse	Sand colluvium resting on glacially deformed marine and terrestrial bed, partly exposed at top of eroding coastal scarp.
Baillie Island	14920±160	Beta-25119/ETH-3898	collagen, saiga	Thought to have washed out of the silty sand of a nearby bank.
Old Crow River	14410±110	GSC-730-2	wood, twigs	1.5 m above the main bone bearing stratum.
Bluefish Cave 2	15540±70	GSC-3053	bone, mammoth	From excavation pit D6 in Bluefish Cave 2.
Bluefish Cave 3, MgVo-3	14370±130	RIDDL-557	collagen, muskox	From lower loess, TP1-F-31
Upper Porcupine River	15920±110	GSC-2431	wood, taxon unidentified	From silt 2.74 m below the surface, bark was on twigs.
Dominion Creek	14950±260	I-3659	collagen, horse	Found near contact of silts and gold bearing gravels.
	15240±130	Beta-81133	collagen, badger	Found near contact of silts and gold bearing gravels.
Scroggie Creek	16200±70	GSC-1893	collagen, mammoth tusk	From a gravel floor of a glade on a tributary to Scroggie Creek.
Alberta				
Princess-Dinosaur Provincial Park	16790±270	AECV-681C	collagen, taxon unidentified	From immediately above the third lowest stained band.
Cartwright Lake	15670±960	TO-5190	wood, taxon unidentified	From base of zone 1.
Medicine Hat, Reservoir Gully	15200±130	GSC-1399	collagen, bison	Taken from 7 m below the youngest till sheet and 11 m below prairie level.

Table 3. Radiocarbon dates from Period 2

Site Name	Date B.P.	Lab No.	Material	Description
Empress, CPR Pit	14200±560	GSC-1199	collagen, mammoth	From a sand and gravel terrace, 2 to 4 m below surface, 100 m below the general prairie level and 15 m above the river at low water.
Saskatchewan				
Sutherland	14120±470	S-685	collagen, taxon unidentified	In gravel under boulders of Battleford Formation.
Saskatoon Site	14730±360	S-498	collagen, tusk taxon unidentified	From sand deposit within tills of Floral Formation, Units 1 and 4.
Riddell series	15420±500	S-1305	collagen, horse	From sands 1.5 m below Floral-Battleford Formation contact.

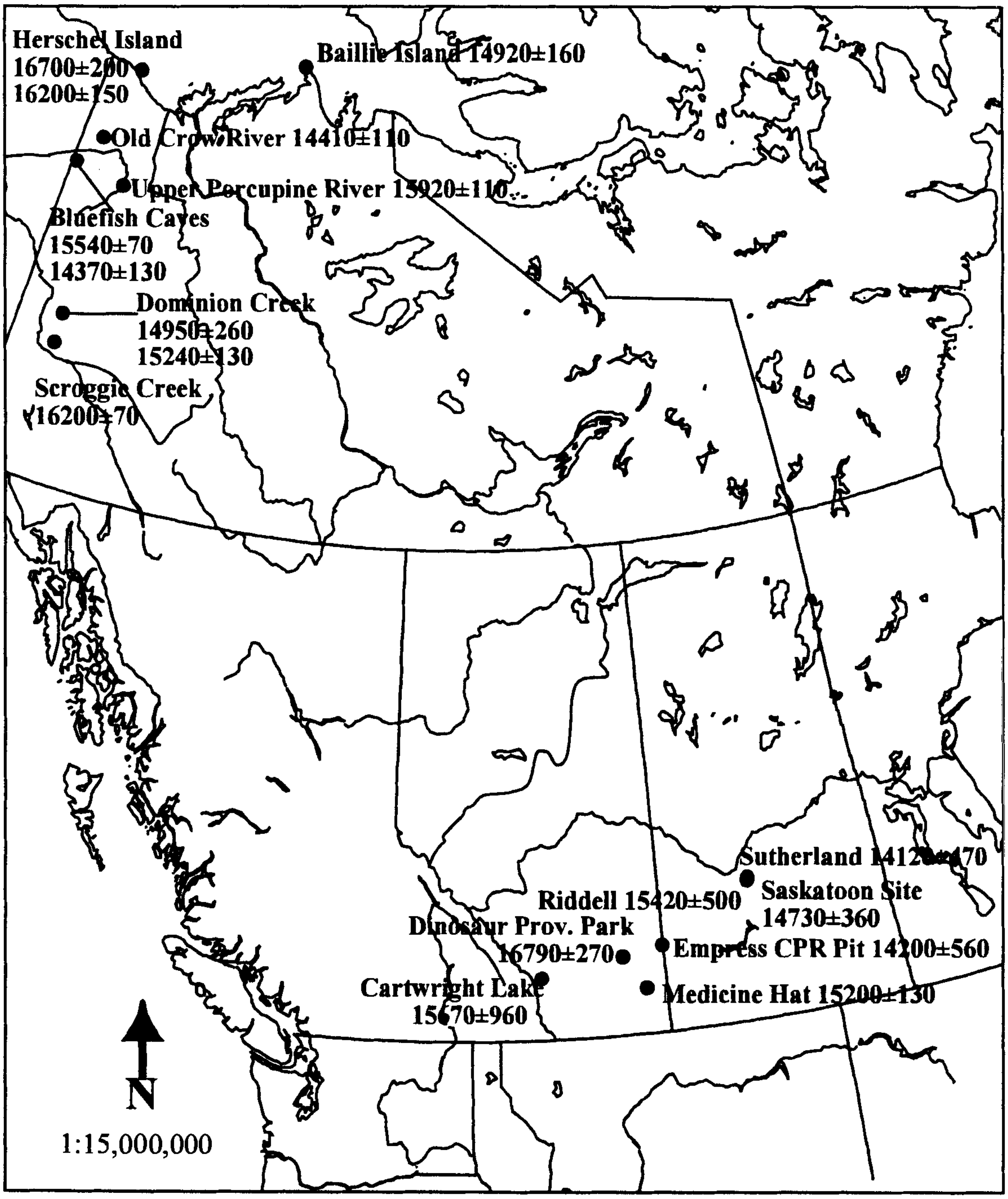


Figure 16. Period 2 site locations, 17000 - 14001 B.P.

The Sutherland sample consisted of unidentified bone from a gravel bed. The geological context was described as "...from 4.6 m gravel bed below 0.6 m boulders and overlying Floral Formation till..." (Rutherford et al. 1979:48). Christiansen comments that the gravel was deposited at the same time as the Battleford Formation and that the boulder layer is a lag deposit from the erosion of that formation (Rutherford et al. 1979:48). The Riddell sample was also an isolated unidentified bone, but was from "...sands 1.5 m below the Floral-Battleford Formation contact..." (Rutherford et al. 1979:54). Similarly, the Saskatoon Site sample was described as originating from sands within the Floral Formation till. Like the Old Crow date in the north, these samples might have been in secondary deposits. No apparent reason is given for the rejection of these dates other than their failure to fit the current reconstruction of deglaciation. Although these three dated samples probably do not accurately date the deposits from which they were recovered, they do indicate that these species was supported in the southern Saskatchewan around 15000 B.P.

The other problematic date is AECV-681C from Dinosaur Provincial Park, Alberta. The sample consisted of deeply weathered unidentified bone that could have been contaminated. Researchers initially considered the date potentially too young, since the enclosing matrix had no crystalline or Shield clasts, indicating a pre-Late Wisconsinan age (Evens and Campbell 1992:540-541). More recently, Evens (2000: 940, 954) has noted that the stratigraphic evidence that these sediments are pre-glacial is not clear. Thus, the date may reflect the earliest age for proglacial lake sediments in this area (Evens 2000:940).

Even if these problem dates are removed, the three remaining dates, two on bone and one on wood, suggest deglaciation occurred in southern Alberta (south of the North Saskatchewan River) around 16000 B.P. It also suggests that environmental conditions were such that mammals flourished during the warmer seasons of the year and trees or shrubs could grow. There is no evidence, however, for a habitable corridor north of approximately 50° latitude at this time.

Period 3: 14000 - 11001 B.P.

Sixty-six dates from 45 different sites (Bluefish Cave 1 and 3 counted as one because they have the same latitude and longitude) are in this period. The sites can be divided into two groups, with internal clustering in each (Figure 17 and Table 4). The definition of internal clusters is to allow for easier discussion of the distribution, but they also may reflect aspects of post-glacial landscape development.

The Northern Group is made up of three clusters: 1. a Coastal Cluster, along the present northern coast of the study area and lower reaches of the Mackenzie River; 2. a Northeastern Cluster, along the middle stretches of the Mackenzie River and; 3. a Northwestern Cluster, located in the present day interior Yukon. The Northwestern Cluster was separated from the Coastal Cluster by the British and Richardson Mountains, and from the Northeastern Cluster by the Mackenzie Mountains.

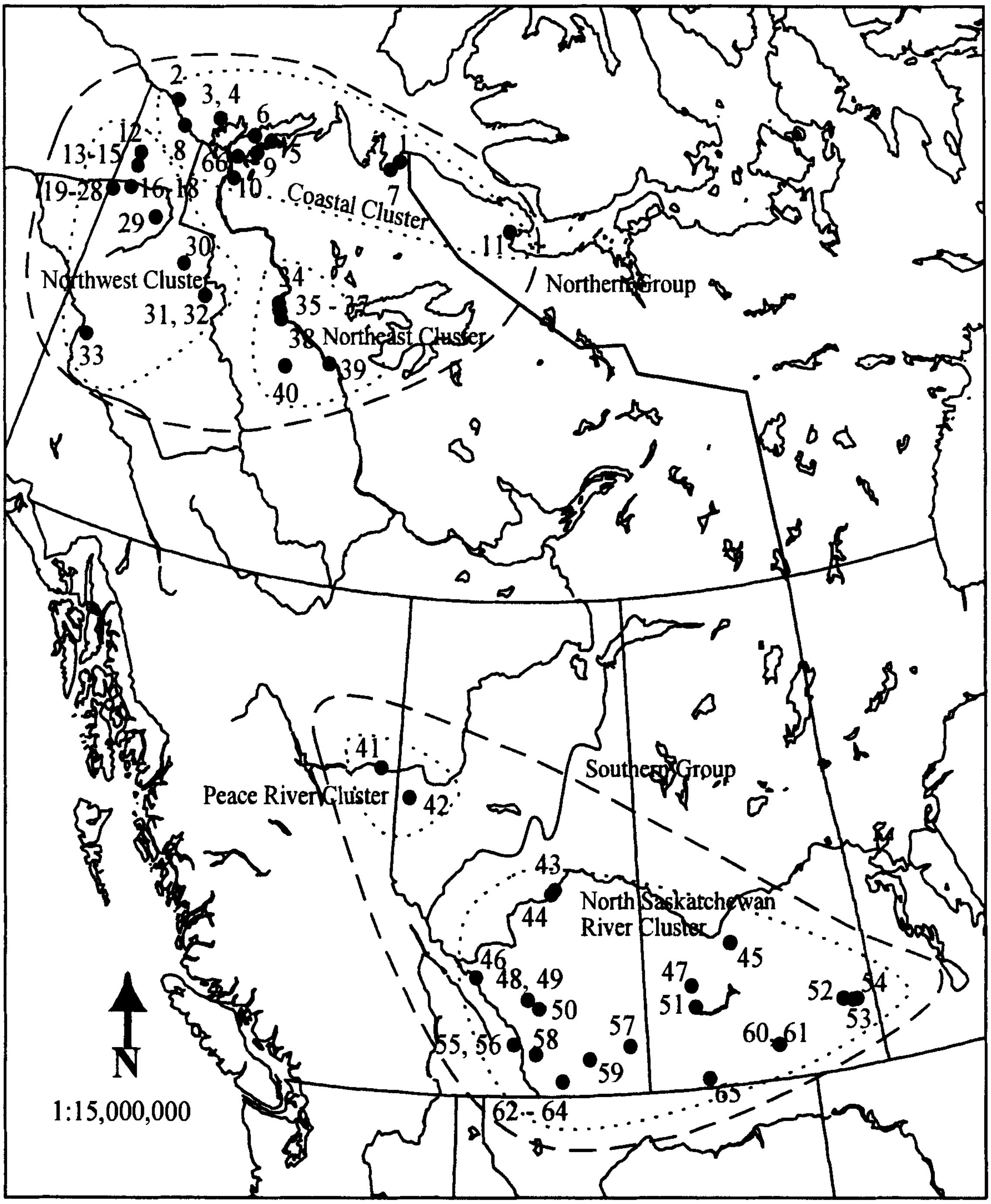


Figure 17. Period 3 site locations, 14000 - 11001 B.P.

Table 4. Radiocarbon dates from Period 3.

Figure 13 No.	Name	Date B.P.	Lab No.	Material	Stratigraphic Provenance
Yukon					
2	Herschel Island	13300±60	BETA-71232	collagen, muskox	Surface
8	King Point	11270±110	GSC-3982	peat, taxon unidentified	From 2 m thick section. Sample from base of the unit, overlying sandy silt.
12	Old Crow, CRH-87	13420±390	CRNL-1218	collagen, mammoth	Surface of point bar.
13	Old Crow, MkVl-12	12360±180	I-7764	collagen, bison horn core	
14		12740±280	QU-782	collagen, bison	
15		11530±200	QU-780	collagen, bison	
16	Old Crow, MkVl-9	11990±90	I-7765	collagen, bison	From high bluff in redeposted context.
17		12300±750	QU-783	collagen, bison	
18		12540±220	I-3574	collagen, bison	
19	Bluefish Cave 1, MgVo-1	12900±50	GSC-2881	collagen, horse	From upper portion of Unit VII of North Trench.
20		12845±250	CRNL-1220	collagen, mammoth	Butchered bone from lower loess, unit J7, part of bone pile feature.
21		12830±60	CAMS-23468	collagen, caribou	Bone pile in front of cave 1, J8-1-136.
22		11570±60	CAMS-23472	collagen, moose	From lower loess layer.
23		12210±210	RIDDL-277	collagen, caribou	Butchered bone from lower loess.
24		13580±80	CAMS-23473	collagen, sheep	From lower loess, E7-20-3.
25		13940±160	RIDDL-559	collagen, mammoth	From lower loess, j7-1-79.
26	Bluefish Cave 3, MgVo-3	13390±180	RIDDL-279	collagen, saiga horn core	A poorly differentiated loess unit overlain by Holocene cyroclastic rubble and humus.
27		12370±440	CRNL-1236	collagen, horse	From lower loess, test pit 1-F-1.
28		13350±100	BETA-129151	collagen, owl	From loess, TP1-E-81.

Table 4. Radiocarbon dates from Period 3.

Figure 13 No.	Name	Date B.P.	Lab No.	Material	Stratigraphic Provenance
29	Upper Porcupine River	13520±170	GSC-2553	wood, willow	From an organic lens 2.2 m below the surface in the main bluff exposure.
30	Caribou River	12370±110	GSC-3691	peat, taxon unidentified	From the base of a 1.32 m thick peat layer.
31	Snake River	11820±100	GSC-2745	wood. willow	From 15 cm above the base of the upper unit.
32		11720±90	GSC-2693	wood, willow	No individual description but probably the same as GSC-2745 (Samples are labled 'HH 62-69 (1976) 35.5 m -B' and 'HH 62-69(1976) 35.5 m-A'.
33	Hunker Creek	11350±110	BETA-27512	collagen, caribou	Placer deposits, provenance unknown.
Northwest Territories/Nunavut					
1	Pearce Point	11800±110	AECV-643Cc	marine shells, *H. arctica*	Enclosed in sandy clay from an elevation of 5 m.
3	Garry Island	11320±200	S-278	wood, taxon unidentified	From a 3.3 m peat section overlying lake silt and ice thrust sediments. From a depth of 2.3 m from top of peat.
4		11720±250	S-277	wood, taxon unidentified	From silt overlain by 3.3 m peat section and underlain by ice thrust sediments. From a depth of 3.7 m from peat/silt interface.
5	Eskimo Lakes Outwash	13200±100	GSC-1995	plant material, grass	From 9 m below surface of outwash plain.
6	Peninsula Point	12770±130	GSC-1214	peat, taxon unidentified	Near base of 1.5 m thick mud flow colluvium overlying sand.
7	Darnley Bay	11280±100	TO-217	marine shells, taxon unidentified	Unknown
9	Eskimo Lakes Outwash	12900±80	GSC-1784-2	plant material, grass	From 9 m below surface of outwash plain.
66	Parsons Lake	11380±140	GSC1160	wood, twigs and peat, taxon unidenitified	From base of 5.5 m exposure of peat and lacustrine sediments at southend of Parsons Lake.

Table 4. Radiocarbon dates from Period 3.

Figure 13 No.	Name	Date B.P.	Lab No.	Material	Stratigraphic Provenance
10	Twin Lakes	11470±120	GSC-1514	peat, brown moss	Basal layer 3.3 m below surface above glaciofluvial gravels or till.
11	Coppermine	11170±80	TO-1231	marine shell, *P. arctica*	From an elevation 125 m. In fine grained marine sediments.
34	Mountain River	11440±90	TO-1191	wood, taxon unidentified	In deltaic sand 10 m below surface and 40 m above river.
35		11530±170	I-3734	wood, taxon unidentified	Below 16 m of deltaic sand and over 30 m of clay, from deposition into Lake Mackenzie.
36		11140±160	I-3913	wood, taxon unidentified	In finely bedded sand, deltaic deposits.
37	San Sault Rapid	11220±130	GSC-1573	wood, willow	From stratified sand 13.25 m below surface and 50 m above river level.
38	Mountain River	11760±90	TO-1190	wood, taxon unidentified	In deltaic sand 6 m below surface and 42 m above river.
39	Little Bear River	11550±180	I-15,020	wood, taxon unidentified	From deltaic sands, 10 m below surface or 28 m above river level.
40	Andy Lake	12060±80	TO-2295	wood, taxon unidentified	From a depth of 2.4 m in core.
British Columbia and Alberta					
41	Fort St. John	13970±170	TO-2742	wood, taxon unidentified	Wood recovered at the contact between Laurentide provenance till and overlying glaciolacustrine sediments.
42	Boone Lake	11700±260	SFU-223	wood, poplar	Taken from organic clay deposits (gyttja) from an uncertain depth somewhere between 5.24-5.40 m from core "d".
43	Clover Bar Sand and Gravel Ltd.	11620±170	AECV-1203C	bone, bison	From Saskatechwan Sands and Gravels. The sands and gravels contained reworked Mid-Wisconsin fossils as well as post-glacial fossils.

Table 4. Radiocarbon dates from Period 3.

Figure 13 No.	Name	Date B.P.	Lab No.	Material	Stratigraphic Provenance
44	North Saskatchewan River	11430±420	S-2385	bone, taxon unidentified	Recovered from current bedded sands a few cm above interface with underlying deposit of alluvial gravels of Laurentide till origin.
46	Crowfoot Lake	11330±220	CAMS-3065	wood, willow twig	From between a depth of 235-238 cm in core CRW6., about 3.5 cm above the diamicton.
48	Clarke Gravel Pit, Cochrane	11450±100	GSC-613	collagen, bison	Bones are from middle terrace of 3 postglacial terraces of Bow River near Cochrane. Surface of terrace lies 22.8 m above river and ca. 7.6 m below highest terrace. Collected from cross-bedded sandy alluvium ca. 2.1 m below terrace surface.
49		11180±90	GSC-989	collagen, bison	
50	Gallelli Gravel Pit	11380±290	RL-757	collagen, bison	From Terrace 4 gravels in Galleli gravel pit, about 10 m above the river.
55	Elk Valley	11940±80	GSC-2142	wood, conifer	A horizontal organic layer, 1 cm thick, was discovered in a 5 m high silt cutbank.
56		12220±110	GSC-2275	wood, conifer	
57	Lindo Bluff	11280±110	GSC-805	collagen, bone (bison or horse, taxon used unidentified)	Bison and horses in gravel laid down when river bed was 7.6 to 15.2 m lower.
58	Oldman Drainage DIPm-VP	11220±60	Beta-79915	collagen, mammoth	Located on glaciolacustrine silt.
59	Oldman River	11020±260	S-68	wood, taxon unidentified	From 12 m below surface in crossbedded sand, from glacial outwash.
62	Wally's Beach	11130±90	TO-7693	collagen, bison	Bone was obtained from a 50 cm thick aeolian sand layer below a paleosol with a good A, B and C horizons. A Folsom like point was found in B horizon of paleosol.
63		11330±70	TO-7696	collagen, horse	Bone was obtained from a 50 cm thick aeolian sand layer below a paleosol with a good A, B and C horizons. This sample was lower then TO-7693.

Table 4. Radiocarbon dates from Period 3.

Figure 13 No.	Name	Date B.P.	Lab No.	Material	Stratigraphic Provenance
64	Wally's Beach	11350±80	TO-8972	collagen, caribou	Bone was obtained from a 50 cm thick aeolian sand layer below a paleosol with a good A, B and C horizons. This sample was lower then TO-7693 and TO -7696.
Saskatchewan					
45	Saskatoon Site	12080±320	S-482	bone, taxon unidentified	From sand deposit within tills of Floral Formation, Units 1 and 4.
47	Gunworth	12160±250	S-198	charcoal, taxon unidentified	From organic zone in 60.9 cm thick alluvial deposit.
51	Kyle	12080±200	S-246	whole bone, mammoth bone	From 0 to 1.22 m below surface contorted pond deposits.
52	Marieval	12040±220	S-553	wood, taxon unidentified	Depth of 50 m in Qu'Appelle alluvium.
53	Camp Mackay	11120±150	S-793	wood, taxon unidentified	From testhole, 43.6 to 44.2 m below valley bottom in Qu'Appelle alluvium.
54	Esterhazy	11260±150	S-794	wood, taxon unidentified	From brecciated shale overlain by 21.3 m of till and 2.4 m sand.
60	Scrimbit	11720±310	S-83	wood, conifer cones and needles	From cones and needles horizon 5.2 m below surface.
61		11520±310	S-80	wood, conifer trunk	A 10 cm diameter conifer trunk found in horizontal position 3.9 m below surface.
65	Frenchman Valley	11480±260	S-2932	wood, taxon unidentified	Wood was obtained from a bore hole. This piece was from test hole 6 (Val Marie) from a depth of between 35-37 m *in* fill of 44 m of alluvial and colluvial material lying on top of landslide material.

The Southern Group is divided into two clusters: a small Peace River cluster, consisting of three sites; and a North Saskatchewan River Cluster, consisting of all sites south of the North Saskatchewan River. These two clusters are separated by about 300 km in which . no dated sites occur. It is undetermined if this blank area is a product of sampling, or if it indicates some real environmental occurrence. This is discussed below.

Northern Group

Coastal Cluster

The Coastal Cluster is made up of 12 dates ranging from 13300 to 11170 B.P. Samples from the three eastern sites (Pearce Point, Darnley Bay and Coppermine) consisted of marine shells (*Hiatella arctica* and *Portlandia arctica*) indicating that this area was still submerged after deglaciation. Pearce Point was nearly 600 radiocarbon years older than Coppermine, suggesting a west to east progression of deglaciation and salt water incursion prior to isostatic rebound. Farther west, the grass samples recovered and dated (GSC-1995 and GSC-1784-2) from Eskimo Lakes suggested a dry, grassy environment as early as 12900 B.P. With the lone exception of the provisional date from Peninsula Point (GSC-1214), peat and wood deposits do not appear until after 12000 B.P., suggesting a wetter environment developed in this area only near the end of the period.

Northwest Cluster

This group consists of 22 dates west of the Richardson Mountains in the Yukon. Samples from Bluefish Caves 1 and 2 and Old Crow included species of mammoth, horse, bison, antelope, caribou, sheep, owl and moose, and may indicate the development of a woodland environment. Further south, willow trees were present on the Upper Porcupine River by 13500 B.P., and at a higher elevation on the Snake River by 11700 B.P. The presence of peat at Caribou River suggests a wet environment. It should be noted that Bluefish Cave 1 is the only archaeological site in the Northern Group and occurred on the western edge of the study area. This indicates that human populations could have been supported by the environment of eastern Beringia at this time.

Northeast Cluster

This cluster of seven dates all occurred around the middle course of the Mackenzie River. All samples were wood, with only the one from San Sault Rapid being identified more specifically as willow. All samples, except the one from Andy Lake, were found in deltaic sands of Glacial Lake Mackenzie. The Andy Lake sample was from a palynological site in the Mackenzie Mountains to the west of the Mackenzie River. Along the Mackenzie River, wood was being deposited in deltaic sands of Glacial Lake Mackenzie, indicating that the environment upstream (to the west) and along shorelines of the lake could support trees or shrubs.

Southern Group

The Southern Group of sites consists of two clusters: a small (two dated sites) Peace River Cluster and the North Saskatchewan River Cluster that includes all sites south of the North Saskatchewan River. Only one date in the group is older than 13,000 B.P. and is situated in the Peace River Cluster (TO-2742, 13970±170 B.P.). The next oldest sites date older than 12000 B.P. (S-246, 12080±200 B.P.; GSC-2275, 12200±60 B.P.; S-198, 12160±250 B.P.; S-533, 12030±210 B.P.) and they occur in southern Saskatchewan and British Columbia.

Peace River Cluster

This small cluster is located near the Peace River in northeastern British Columbia and northwestern Alberta (Table 5). The dates from this cluster were both from wood, one was identified as poplar (SFU-233, 11700±260), and came from lake deposits. The older date (TO-2747, 13970±170 B.P.), from the contact between till and overlying lacustrine deposits (Catto et al 1996: 24), suggests that trees colonized the area during the early formation of regional glacial lakes.

North Saskatchewan River Cluster

This large group of 23 dates spans a wide geographical area, ranging from the Rocky Mountains to southeastern Saskatchewan (Figure 14, Table 4). Dated and identified animal bones came only from east of the Rocky Mountains and consists of bison, mammoth, horse and caribou. Dated plant materials are all wood with willow (*Salix*), from Crowfoot Lake (CAMS-3065), being the only sample identified as to genus. Most of the samples were recovered from alluvial contexts of sand and gravel, or from pond and lake deposits indicating a wet environment.

Period 4: 11000 - <9000 B.P.

There were 202 dates from in this final period. Figure 18 illustrates the overall distribution of these sites and Table 5 and Figures 19 and 20 identify the samples dated and their stratigraphic provenance. As the distribution shows, sites fall into a northern and southern groups separated by a gap just north of the 60th parallel of latitude.

Northern Group

The Northern Group is divided into two coastal clusters and two interior clusters totalling 88 dates.

East and West Coastal Clusters

Dates in the East Coastal Cluster are from marine shells, reflecting the depressed and submerged nature of the area after deglaciation (Lemmen et al 1995:810-821). In contrast, the dated samples from the West Coastal Cluster are all on terrestrial plant and animal remains. Many identified plant remains from the West Coastal Cluster came from pond and peat deposits, and consist of willow (*Salix*), poplar (*Populus*), birch (*Betula*), spruce (*Picea*) and mosses. The only identifiable terrestrial animal remains were bison from the lone archaeological site in this cluster. These remains suggest a possibly wet, wooded environment, but not necessarily forested (e.g., boreal forest), that was capable of supporting large herbivores.

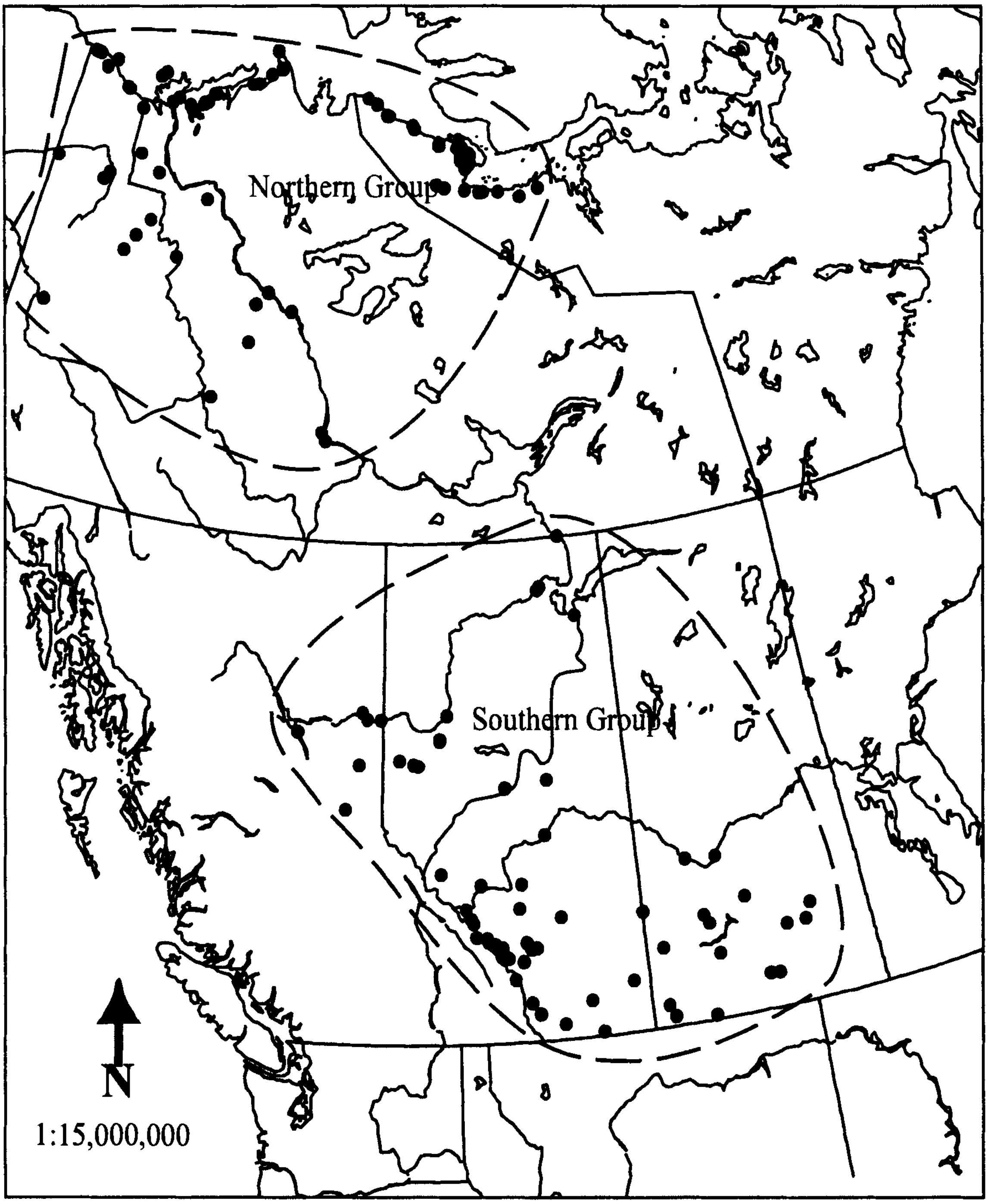


Figure 18. Period 4 site locations, 11000 - 9000 B.P.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
Yukon					
7	Backhouse River	10920±80	GSC-1853	wood, birch	From peaty material in an ice-wedge cast.
8	Komakuk Beach	10220±60	GSC-1838	wood, willow	Obtained from a peaty layer 4 m of silty gravel.
9	Komakuk	9900±100	GSC-4342	wood, willow	Sample enclosed in peat within fine grained tundra pond deposits.
10		10580±190	TO-651	fecal pellets, mammal	
11	Pauline Cove, Herschel Island	9580±110	GSC-1483	peat, sedge	From a 4 m high exposed section of peat, from the base of a thermokarst depression.
15	Engigstciak, NiVk-1	9870±180	RIDDL-362	collagen, bison	From layer 4 of the Buffalo pit, S475 W270-1.
16		9770±180	RIDDL-281	collagen, bison	From layer 4 of the Buffalo pit, NiVk-1:135.
17		9400±230	RIDDL-319	collagen, bison	From layer 4 of the Buffalo pit, NiVk-1:459.
20	Sabine Point	8980±45	GSC-3914	wood, willow	From base of mudflow deposits
22	Sabine Point East	9960±90	GSC-2022	wood, poplar	Wood found near the base of 3 m thick diamicton unit capping a coastal bluff.
70	Bluefish Cave 2, Mgvo-2	10230±140	RIDDL-561	collagen, bison	From lower loess, g5-g-5.
71	Bluefish Cave 3, Mgvo-3	10820±60	CAMS-23467	collagen, wapiti	From lower loess.
72	Whitefish Lake	9550±110	GSC-1829	wood, willow	From between 4.25 to 4.50 m.
74	Upper Porcupine River	9210±80	GSC-2461	wood, spruce	In sand 10 cm above gravel near base of terrace downstream from the main bluff section.
75	Caribou River	9800±90	GSC-3573	wood, willow	Enclosed in sand from an elevation of 260 m asl.
76	Peel River	10620±110	GSC-2393	wood, taxon unidentified	From a silt lens 10.9 m below surface in 20 m thick gravel unit.
78	Hungry Creek, Bonnet Plume	8950±110	GSC-2341	peat, taxon unidentified	From between 23.2 and 23.25 m in section.
79	Hunker Creek	9540±100	GSC-73	wood, taxon unidentified	From base of woody silty unit at a depth of 6.1 m.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
Northwest Territories/Nunavut					
1	Baillie Island	9600±110	GSC-2030	wood, willow	From the base of 3 m of interbedded lacustrine clay and peat.
2	ObRw-1, Qugyuk	9560±60	BETA-79861	collagen, bison	Surface.
3	Cape Monte Casino	9020±80	GSC-1989	wood, poplar	From the base of a 1 m layer of peat containing large chunks of wood.
4	Nicholson Point	9020±80	GSC-4362	wood, birch moss, taxon unidentified	Enclosed in organic silt at an elevation of 10 m.
5	Liverpool Bay	9150±120	GSC-1327	peat, *D. flexicaule*	From 4 m thick pebbly silt, containing pods of peat, twigs.
6	Pelly Island	9180±60	GSC-2197	wood, willow	Obtained from an elevation of 6.5 m just above a thaw unconformity.
12	Garry Island	9520±150	S-276	wood, taxon unidentified	From a depth of 1.9 m in a 3.3 m peat section overlying lake silt and ice thrust sediments.
200		9750±100	GSC-575	iron stained twigs and wood, taxon unidentified	From base of gravel over marl.
13	Eskimo Lakes Postglacial	9200±80	GSC-2023	wood, willow	At the base of a 2 m thick peat unit on the north side of an island in Eskimo Lakes.
14		10320±90	GSC-1936	wood, taxon unidentified	From 3 m from top of bench, taken from midpoint of 3 m of interbedded sand.
18		9150±160	GSC-1653	wood, willow twig	1.5 m from top of bench, at midpoint of 1.8 m thick layer of horizontally bedded sand and gravel.
19		10720±130	GSC-1710	wood, willow twigs with bark	1.8 m below top of exposure.
21	Tuktoyaktuk Peninisula	9560±80	GSC-1169	wood, willow twigs peat, taxon not identified	From 3.13 m thick clayey mudflow debris in exposure.
23	Tununuk	10970±120	GSC-1286	peat, taxon unidentified	From base of a 3 m peat and sand sequence overlying 3+ m of gravel.
24	Zed Lake Series	9640±180	GSC-1469-3	wood, willow	From basal 5 cm of a 4.6 m thick peat layer.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
26	Holmes Creek	9540±150	GSC-1495	peat, mainly sedge	From near the base of 0.8 m of gravel containing peaty layers.
27	Keats Point	10850±110	AECV-644CC	marine shell, *H. arctica*	Enclosed in sandy silt from an elevation of 16.5 m.
28	Clinton Point	10350±100	AECV-642CC	marine shell, *H. arctica*	Enclosed in sandy clay from an elevation of 24 m.
29		10400±160	AECV-645CC	marine shell, taxon unidentified	Enclosed in sandy silt from an elevation of 22 m.
30	Buchanan River	9810±60	GSC-4347	marine shells, *H. arctica*	Enclosed in a sandy clay boil.
31		10700±50	GSC-4318	marine shells, *H. arctica*	Enclosed in sandy clay.
34		10600±60	GSC-4339	marine shells, *H. arctica*	Enclosed in diamicton
32	Tinney Point	10010±70	AECV-462CC	marine shells, *H. arctica*	Enclosed in sandy silt from an elevation of 25 m.
33		10630±90	AECV-444CC	marine shell, taxon unidentified	Enclosed in sandy clay from an elevation of 30 m.
35	Clifton Point	10700±50	GSC-4390	marine shells, *H. arctica*	Collected at 61 m asl, enclosed in medium to course sand, 8.5 km south-southwest of Clifton Point.
36		8890±60	GSC-4425	marine shells , *C. cilatum*	Collected from between 12 and 14 m asl, enclosed in sand, 3 km south-southwest of Clifton Point.
37		10310±50	GSC-4402	marine shell, *H. arctica*	Collected at 47 m asl, enclosed in sandy silt from 9 km south-southeast of Clifton Point.
38		10400±50	GSC-4424	marine shell, *H. arctica*	Collected at 25 m asl, enclosed in silty clay from 6 km southeast of Clifton Point.
39		9310±280	AECV-712CC	marine shell, *H. arctica* and *M. balthica*	Enclosed in sandy clay from an elevation of 45 m.
40		9610±160	AECV-473CC	marine shell, *H. arctica*	Enclosed in sandy clay from an elevation of 30 m.
41	Harding River, Dolphin and Union Strait	10540±280	I(GSC)-25	marine shell, pelecypod	In very fine sand south of Dolphin and Union straits near Harding river.
42	Dolphin and Union Strait	10430±280	AECV-713CC	marine shell, *M. truncata* and *H. arctica*	Enclosed in sandy clay from an elevation of 70 m.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
43	Dolphin and Union Strait	10050±140	AECV-474CC	marine shell, *Macoma* sp.	Enclosed in sand from an elevation of 80 m.
25	Coal Mine Lake	10300±60	GSC-3729	wood, willow and birch	In a pocket of wood-bearing peats underlying reworked till.
44	Kugaryuak River, Coronation Gulf	9110±190	I(GSC)-16	marine shell, pelecypod	From gullied surface on marine clay, from close to upper limit of marine submergence.
45	Coppermine	9550±40	GSC-4696	marine shell, *H. arctica*	From an elevation of 111 m.
46	Basil Bay	9480±60	GSC-4930	marine shell, taxon unidentified	From an elevation of 105 m.
47	Coppermine	10700±50	GSC-4916	marine shell, taxon unidentified	From an elevation of 100 m.
48		9190±80	GSC-4709	marine shell, taxon unidentified	
49	Basil Bay	9130±90	GSC-4845	marine shells, taxon unidentified	From an elevation of 100 m.
50	Richardson River	10300±120	GSC-3663	marine shells, *M. calcarea*	From a gravelly sand raised beach. Many were paired at the time of collection.
51	Coppermine Area	9810±100	AECV-403CC	marine shell, *M. truncata* and *H. arctica*	Enclosed in sandy clay from an elevation of 70 m.
52	Cox Lake, Southwest	9430±60	GSC-3941	marine shell, *M. truncata*	From a sandy clay subtidal deposit in a riverbank exposure.
53	Coppermine River Valley	9820±45	GSC-3327	marine shells, *M. calcarea*	Collected at contact between marine silt and overlying sand.
54	Coronation Gulf	9090±100	AECV-404CC	marine shell, *H. arctica* and *M. truncata*	Enclosed in sand from an elevation of 120 m.
55		9560±130	AECV-472CC	marine shell, *M. truncata*	Enclosed in silty clay from an elevation of 120 m.
56	South Coronation Gulf Coast	9620±70	GSC-3584	marine shells, *H. arctica*	Collected from silty sand, part of an extensive surface of marine sediments.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
57	Tree River, Coronation Gulf	10230±230	I(GSC)-17	marine shells, taxon unidentified	Embedded in erosional remnants of marine clay.
58	Bernard Harbour	9530±40	GSC-4847	marine shells, *H. arctica*	Enclosed in silty clay from an elevation of 97 m.
59		9610±40	GSC-4846	marine shells, *H. arctica*	Enclosed in sandy gravels from an elevation of 100 m.
60		9700±40	GSC-4848	marine shells. *H. arctica*	Enclosed in silty clay from an elevation of 95 m.
61	Coppermine	9920±50	GSC-4727	marine shells, *H. arctica*	From an elevation of 100 m, no description of enclosing sediments.
62		9640±90	GSC-4747	marine shells, *H. arctica* and *M. arenaria*	From an elevation of 105 m, no description of enclosing sediments.
63		9620±45	GSC-4749	marine shells, *H. arctica*	Enclosed in nearshore sand from an elevation of 105 m.
64	Klengenberg Bay	9520±40	GSC-4915	marine shells, *H. arctica*	From an elevation of 115 m, no description of enclosing sediments.
65	Stapylton Bay	9690±80	GSC-4849	marine shells, *H. arctica*	Enclosed in sand and gravels from an elevation of 80 m.
66		9850±40	GSC-4917	marine shells, *H. arctica*	From an elevation of 99 m, no description of enclosing sediments.
67		10100±45	GSC-4926	marine shells, *H. arctica*	From an elevation of 85 m, no description of enclosing sediments.
68	Rat River	9990±110	GSC-147	wood, taxon unidentified	3.65 m below ground on back side of wall of flow slide.
69	West of Frog Creek	9490±90	GSC-1814	wood, poplar	Uncertain, but presumed to be from organic material overlying till in a road cut, rather than from below the till as originally thought.
73	Grandview Hills	9580±90	GSC-2298	wood, poplar	From an organic silt lens at the top of the headwall of a retrogressive thaw flow slide.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
77	Many Beaver Lake	8930±100	GSC-1865	wood, willow	From a 15-20 cm thick transition zone between the till and the overlying gravels from which wood was also recovered but not submitted for dating.
80	Norman Wells	9340±90	GSC-2206	wood, birch and willow twigs	From 7.5 m in 12 m deep borehole, in glaciolacustrine clay.
81	Bell's Lake	10230±150	TO-2375	wood, taxon unidentified	From a depth of 4.06 m in core.
82	Great Bear River	10620±130	GSC-2328	wood, taxon unidentified	From 5 m below ground surface.
83	Keele Lake	9560±70	TO-3989	wood, taxon unidentified	From a depth of 1.95 m in core.
201	Howard's Pass	9610±50	GSC-3532	peat, taxon unidentified	From 1 to 1.1 m depth in a blanket bog.
84	Root River	10290±180	AECV-917C	wood, taxon unidentified	4 m below surface and 7 m above river in fluvial sand.
85	Fort Simpson	9110±240	AECV-916C	wood, taxon unidentified	From deltaic sands 6 m below surface or 5 m above river.
86	Fort Smith	9830±360	S-1507	wood, taxon unidentified	From a test hole, 13.4 m into deltaic sands.
British Columbia					
91	Charlie Lake Cave	10770±120	SFU-454	collagen, bison	From subzone iib, component 1.
92		10380±160	SFU-378	collagen, bison	
93		10290±100	CAMS-2137	collagen, raven	
94		10450±150	SFU-300	collagen, bison	
95		10560±80	CAMS-2134	collagen, bison	
96		10100±210	RIDDL-392	collagen, squirrel	From subzone iic, component 2.
97		9670±150	CAMS-2136	collagen, raven	From subzone iic, component 2.
98		9760±160	SFU-355	collagen, bison	From subzone ii, component 2.
99		9490±140	CAMS-2318	collagen, raven	From subzone iiia, component 3.
100		10500±80	CAMS-2129	collagen, Artiodactyl	Subzone ii component 1.
102	Ostero Gravel Pit	10240±160	AECV-1206C	collagen, bison	From post glacial gravels, 12.8 m below surface(?), 5.5 m above base of pit.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
103	Clayhurst Gravel Pit	10580±210	CAMS-398	collagen, bison	From sediments consisting of 1 to 1.5 m of well rounded medium gravel interbedded with micaceous sand overlying at least 1 m of coarse rounded pebbles.
104		10600±160	AA-1219	collagen, bison	
105		10340±150	CAMS-150	collagen, bison	
106		10230±140	AECV-1558C	collagen, bison	
107		10750±180	RIDDL-220	collagen, bison	
108	Finlay-Parsnip Access	9280±100	GSC-1497	horn core, bighorn sheep	Found about 3 m below normal ground surface from big-horn sheep skull in dry ice-contact fluvial gravels.
115	Tumbler Ridge	10380±100	BETA-44201	collagen, bison	Skull found in 1986 and housed in the Geography Dept, Simon Fraser University until 1990 when it was measured and photographed for the first time. Preservation appeared good.
116	Summit Creek	10020±80	GSC-2964	wood, poplar	Found in stony clay.
139	Lake O'Hara	10100±200	RIDDL-433	wood, conifer needles	Needles extracted from the centre of cores <1 cm above the contact with basal inorganic sediments.
140	Opabin Lake	10060±160	RIDDL-511	wood, conifer needles	Needles extracted from the centre of cores <1 cm above the contact with basal inorganic sediments.
196	Elk Valley, Weary Bog	10130±290	GX-5598	wood, taxon unidentified	Beaver chewed wood from peaty-gyttja contact at 3.3 m in core.
Alberta					
87	Peace Delta	9830±80	WAT-2662	wood, taxon unidentified	From deltaic sand/silt contact and 11 m below surface and 9 m above river.
88		9850±80	WAT-2661	wood, taxon unidentified	From deltaic sand/silt contact from 12m below surface or 7 m above river.
89	Athabasca Delta	9710±70	AECV-1183C	wood, taxon unidentified	From deltaic sand 8 m below surface and 12 m above river.
90		9910±45	GSC-4302	wood, taxon unidentified	

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
101	Peace River	9880±70	GSC-2865	collagen, bison	Collected 8 m below surface but may have originated 5 m higher where other bones were recovered.
109	Watino Series	10200±50	GSC-2895	collagen, bison	Bones came from near the base of the alluvial sand and gravel forming the second terrace.
110		10200±50	GSC-2902	collagen, bison	
111	Wakaluk Quarry	9160±310	S-2614	collagen, antler wapiti	From middle terrace about 50 m above Smoky River high water.
112	Saskatoon Mountain, GhQt-4	9400±370	AECV-1474C	charcoal, taxon unidentified	From hearth at base of site.
113		9360±60	UCR-3275, CAMS 12365	seeds, raspberry and wild rose	
114	Wood Bog, GgQq-7	9730±110	AECV-1620C	wood, poplar	From between 2.10-2.80 m depth towards the base of the section
117	Athabasca River	10200±80	GSC-1205	collagen, bison	Fround 38 to 46 m above current water level, possibly from a bed 4 to 5 m below surface.
118	Freeman River	10920±110	GSC-859	wood, taxon unidentified	From about 6 m depth in contorted calareous sandy silt, pond deposits.
119	Whitemud Creek, Edmonton	8300±1100	S-1798	collagen, bison	From surface of t-2t (terrace 2).
120	North Saskatchewan River	10820±470	S-1923	bone, taxon unidentified	From relatively low position in alluvial sequence.
121	Muskiki Lake peatland	9000±230	AECV-103C	peat	probably brown mosses and other none aquatic types from 4.41-4.50 m.
122	Lorraine Lake	9180±320	AECV-591C	plant remains, charred, taxon unidentified	From between 2.32-2.42 m in core.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
125	Nordegg Pond	8930±150	BETA-252261/ETH-3740	wood, spruce	Twigs came from a depth of 3.20 m in a composite core.
126	Rocky Mountain House	9750±140	I-5677	bone, bison	No description.
127	North Saskatchewan Crossing	9350±110	GSC-332	charcoal, taxon unidentified	From 1.83 m below surface, for lower section of loess layer from 0.61 to 2.44 m thick.
128	James River, EkPp-vp	10320±330	GX-2918D	collagen, mammoth	Terrace deposit, no other description
129	EkPu-8, James Pass Meadow Complex	9750±80	TO-2999	collagen, bison	From base of cultural layer iii about 50 cm below surface.
130		10140±80	TO-3000	collagen, taxon unidentified	From middle of cultural layer ii about 55 cm below surface.
131	Three Hills, Milan Site	9750±160	I-8579	collagen, bison	From bone concentration between about 1.8 m and 3.09 m below surface.
132	Three Hills	9720±150	GSC-1894	collagen, bison	Between 808 m asl and 814 m asl, from bone concentration between about 1.8 m and 3.09 m below surface.
133	Crowfoot Lake	9060±370	CAMS-3064	wood, fir needle	From between a depth of 2.05-2.08 m in core CRW6.,
134		10070±420	CAMS-3177	seed, sedge	From between a depth of 2.27 cm in core CRW6.
135		10020±70	CAMS-3063	wood, pine needle	From a depth of 2.265 m in core CRW6.
136		9470±70	CAMS-6843	wood, pine needle	From a depth of 2.18 m in core CRW6.
142	Copper Lake	10490±160	RIDDL-664	wood, taxon no identified	From core CLC from a depth between 14.37-14.41cm.
143		9650±150	RIDDL-88	wood, spruce needle	From core CLD from a depth between 12.90-12.97cm.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
144	Griffen Gravel Pit, Cochrane	10840±90	GSC-612	bone, bison	Bone from middle terrace of three post-glacial bow river terraces. Surface lies 22.86 m above river and 7.62 m blow highest terrace.
145	Vermilion Lakes	10180±130	RIDDL-73	charcoal, taxon unidentified	Charcoal from base of hearth from unit 12 in occupation 6b. 6b is situated at the base of a silt unit underlying debris-flow stratum 4.
146		9700±130	RIDDL-83	collagen, bison	Bone associated with hearth feature in unit 153r4. From occupation 6a.
147		10040±160	RIDDL-72	collagen, bison	Bone from the main butchering activity area of occupation 8,unit 153r12.
148		10040±200	RIDDL-71	collagen, bone taxon unidentified	
149		10100±210	RIDDL-81	charcoal, taxon unidentified	Charcoal from the main butchering activity area of occupation 8,unit 153r12.
150		10570±150	RIDDL-85	seed, taxon unidentified	From unit 153r12 locale a, component 9a.
151		9570±150	RIDDL-75	wood, taxon unidentified	Carbonized twig from hearth feature in unit 153r4. From occupation 6a.
152		9870±230	RIDDL-317	collagen, bone taxon unidentified	From unit 153r12 locale a, component 9a/8.
153		10310±190	RIDDL-528	seed, taxon unidentified	From unit 153r12 locale a, component 6b.
154		10060±220	RIDDL-84	collagen, bison	Bone from occupation 8, unit 153r7.
155		10010±180	RIDDL-82	charcoal, taxon unidentified	This is from occupation 4, 1.4 m below surface at locality b. Material is from around a hearth like feature in unit 502r.
156		10210±130	RIDDL-282	wood, taxon unidentified	From unit 153r12 locale A, component 9a.
157		10390±140	RIDDL-70	collagen, bison	
158		9840±60	GSC-3804	charcoal, from flowering plant	From occupation 8, feature 103, enclosed in silt and clay.
159		10660±650	RIDDL-216	wood, taxon unidentified	A small sample of charred wood from component (occupation) 9b from excavation unit 153r2.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
160	Vermilion Lakes	9880±140	AECV-121C	charcoal, taxon unidentified	This is from occupation 4, 1.4 m below surface. Material is from around a hearth like feature in unit 502r.
161		9840±200	RIDDL-77	collagen, bison	
162		10310±230	RIDDL-318	collagen, bison	From unit 153r12 locale A, component 9a.
163		10270±100	RIDDL-79	charcoal, taxon unidentified	Charcoal from occupation 9, unit 153r12.
164		10090±130	AECV-124C	collagen, bison	Bone from the main butchering activity area of occupation 8, unit 153r12.
165		10780±180	RIDDL-215	wood, taxon unidentified	From unit 153r2 from component 9b the lowest cultural layer in this unit.
166		11000±1600	RIDDL-217	charcoal, taxon unidentified	Small charcoal sample from a shallow hearth feature uncovered from in unit 153r2, occupation 7.
167	Second Lake Site	9470±460	S-2759	charcoal, taxon unidentified	From the lowest occupation, occupation 8, natural level 22.
170	Johnson Lake	9440±230	TO-5186	wood, taxon unidentified	From zone 1 - 2 boundary.
171	Aquitaine Pit	10200±140	GSC-3065	collagen, bison	The sample consisted of 438 g of bone from a female bison.
172	EgPn-480, 'Stonepine'	9540±70	BETA-127235	collagen, bone taxon unidentified	From second lowest level.
173	Lower Burstall Lake	9180±60	CAMS-20358	wood, lodgepole pine needle	Fragment from 2 cm above zone 1 and 2 transition.
174	Kananaskis Valley	10400±60	GSC-2965	wood, poplar	From 2.95 m below former mud/water interface in afresh face exposed in the course of excavating Wedge Lake.
202		9400±220	GX-6767	wood, taxon unidentified	From 2.25 m below former mud/water interface in a fresh face exposed in the course of excavating Wedge Lake.
177	Toboggan Lake	10400±70	TO-149	wood, taxon unidentified	From a core depth of 5.85 m from top of core.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
178	Toboggan Lake	9100±360	TO-211	wood, spruce needle fragments	From a core depth of 5.1 m from top of core.
183	Lindoe, EaPo-100	9790±190	GAK-5097	collagen, probably bison	From peaty organic layer, same as S-230.
184	The Gap, DlPo-20	9600±240	GX-0956	collagen, bison	From the floor associated with the AH horizon of the buried brunisol.
185	Taber Provincial Park	10520±120	GSC-3	wood, willow	From sandy alluvium containing sticks and erect stumps.
190	Oldman River Dam, DjPm-16	9600±210	AECV-746C	bone, taxon unidentified	From level 24, 2.25 - 2.45 m.
195	Fletcher Site, DjOw-1	9380±110	TO-1097	seeds, sedge	From a depth of 2.8 m.
197	Wally's Beach	10980±80	TO-7691	collagen, muskox	From a 50 cm thick aeolian sand layer below a paleosol with good A, B and C horizons. This sample from near top of the layer. A Folsom-like point was found in B horizon of paleosol.
198	Bindloss Gravel Pit	10930±100	TO-8514	collagen , mammoth	Recovered from gravels 30 m above Red River.
199	Pashley Gravel Pit	10870±45	CAMS-82411	collagen, horse species	Recovered from 45 cm thick buried soil horizon about 30 cm above gravel layer and 1.5 m below surface of sand layer.
Saskatchewan					
123	Denholm 2 Testhole	10890±660	S-1374	wood, taxon unidentified	From 24.4 m below the projection of the top of the river alluvium.
124	Eagle 10 Testhole	10780±780	S-2097	wood, taxon unidentified	From between 24.4 and 30.5 m below the projection of the top of the river alluvium.
137	Green	10820±180	S-227	charcoal, taxon unidentified	From a depth of 77 to 79 cm in contorted lake silt.
138	Kenaston	10170±210	S-97	wood, taxon unidentified	Derived from core depth of 44.2 m.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
141	Wiseton	10680±140	S-232	whole bone, mammoth	From 91.4 cm (presumably below surface) in lacustrine silt.
168	Kelliher	9620±140	S-182	wood, taxon unidentified	From near top of gyttja overlain by 3.35 m of alluvium.
169	Dinsmore	10320±160	S-110	wood, conifer species	Sample from 4.26 m below surface in gyttja above till.
175	Sioux Crossing	10130±200	S-1304	wood, taxon unidentified	From test hole in bottom of Qu'Appelle valley, from the alluvium.
176	Earl Grey	10290±240	S-165	wood, taxon unidentified	From base of gyttja layer 1.47 m thick overlain by 3.96 m of clay.
179	Heron Eden Site, EeOi-11	9290±110	S-3308	collagen, bison	From cultural layer at 28 cm, unit 102.5N 111E.
180		9010±120	S-3114	collagen, bison	From cultural layer between 25 - 30 cm, unit 100N 102E.
203		9000±130	S-3309	collagen, bison	From cultural layer between 24 - 27 cm, unit 102.5N 111E.
181		10210±100	S-3118	collagen, bison	From cultural layer between 22 - 30 cm, unit 100N 112E.
182	Herbert	10020±300	S-41	wood, willow	Found in postglacial lake sediments at depth of 3.35 m.
186	Crane Valley	10820±310	S-128	charcoal, taxon unidentified	From glacial-lake silts and clay.
187	Scrimbit Series	10400±260	S-85	wood, taxon unidentified	Wood from limbs in horizontal position, 3.6 m below surface.
188		10020±260	S-81	wood, taxon unidentified	Root of 1.2 m high stump preserved in upright position. Sample is from a level of cones and needles 4.6 m below surface.
189		10420±100	GSC-21	wood, taxon unidentified	Unknown, presumably from the needle and cone layer.

Table 5. Radiocarbon Dates from Period 4.

Figures 16 & 17 No.	Site Name	Date B.P.	Lab. No.	Material	Provenance/Description
191	Frenchman Valley	9240±340	S-2931	wood, taxon unidentified	Wood obtained from test hole 1 (Cypress Lake) from a depth of 13 m in 50 m of alluvial and colluvial fill covering avalanche deposits of bedrock.
192	Robsart (Horsemen Site) Kongeview	9500±40	GSC-4098	wood, willow	From the middle zone of a peat bed between that lies 4 to 5 m deep in sediments 8 m thick that lie above a till.
193	Val Marie Site	9880±110	TO-2212	seeds, taxon unidentified	Depth of 12 m in clayey loam sediments near till contact.
194		9910±80	TO-1711	seeds, taxon unidentified	Depth of 6 m in clayey loam sediments near till contact.

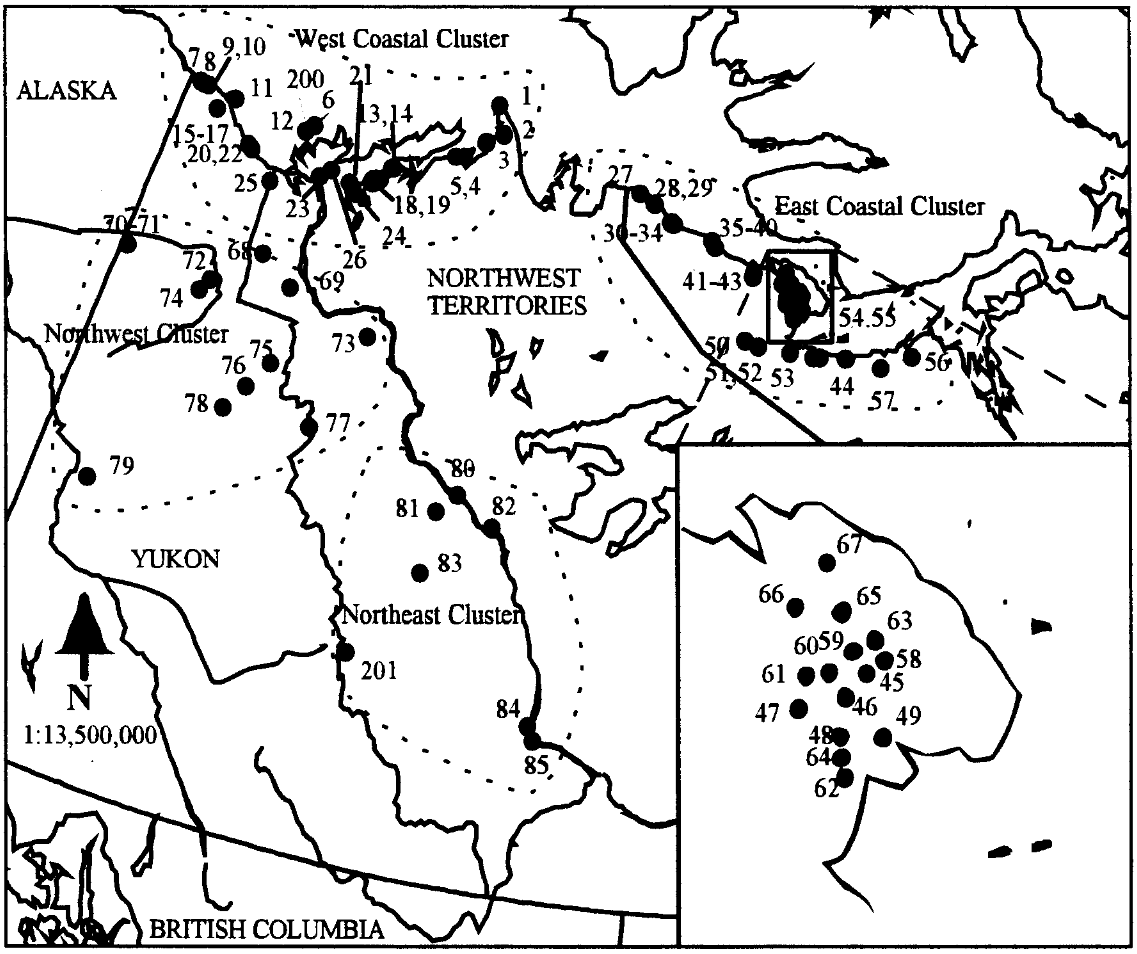


Figure 19. Period 4 Northern Group site locations (see Table 5 for dates identified with each numbered site).

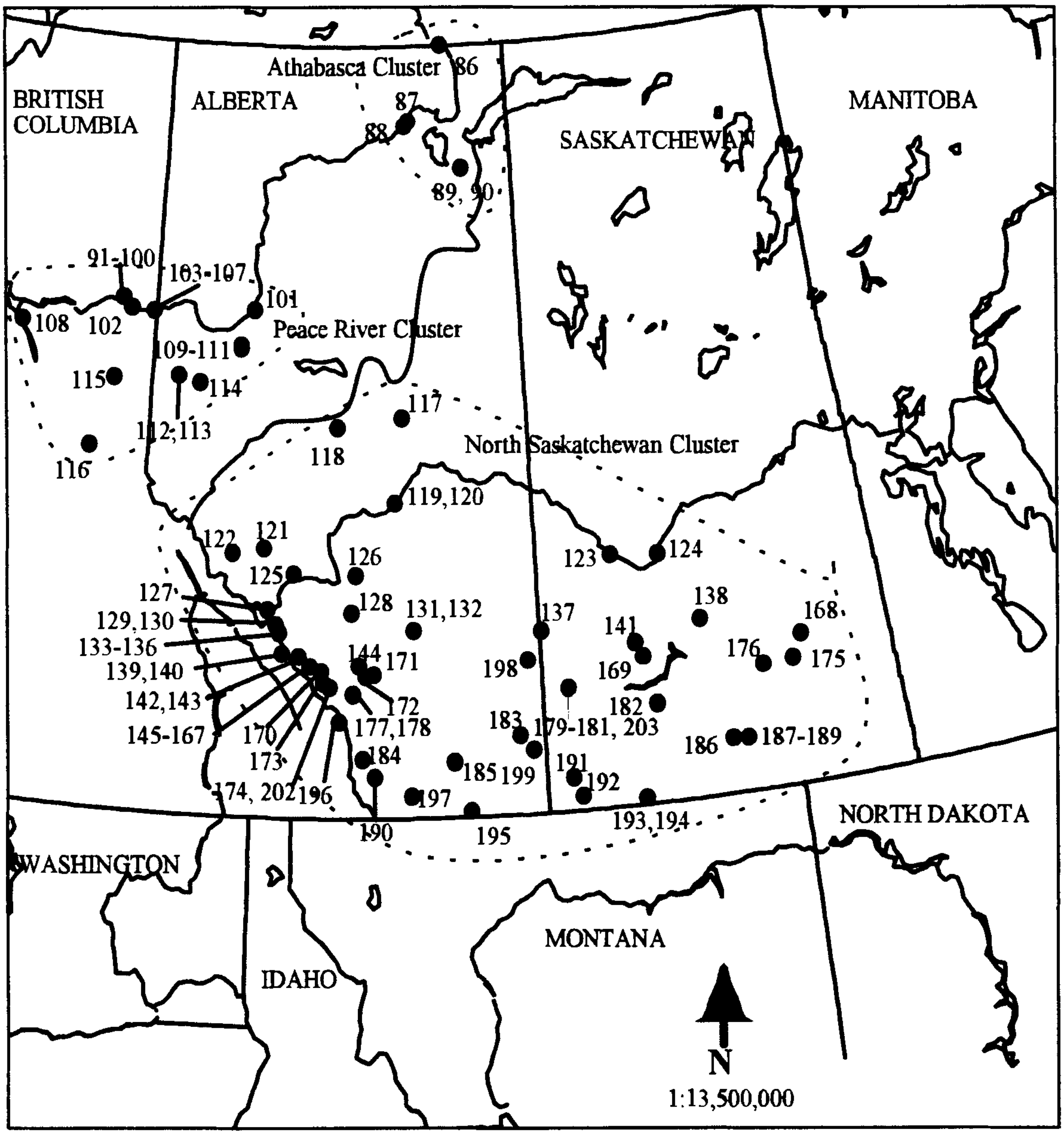


Figure 20. Period 4 Southern Group site locations (see Table 5 for dates identified for each numbered site).

Northeast and Northwest Clusters

These two clusters show an expansion in areal extent of the biota from Period 3. The samples from the Northwest Cluster came from many different contexts, including loess deposits, mudflows, and river and lake deposits. They demonstrate that the environment continued to support large herbivores, such as bison and wapiti. The identifiable plant assemblage included willow, spruce, poplar and moss. In the Northeast Cluster, along the Mackenzie River, no terrestrial animal remains were recovered and the dated plant remains consisted of wood, with birch (*Betula*) and willow (*Salix*) as the only identified taxa.

Southern Group

Three clusters are defined in the south: the small Athabasca Cluster near Lake Athabasca, the Peace River Cluster, around the British Columbia-Alberta border, and the North Saskatchewan River Cluster, which includes all sites south of, or immediately adjacent to the North Saskatchewan River.

Athabasca Cluster

The small Athabasca Cluster consists of five dates from unidentified wood samples in deltaic sand or silt deposits. There are two possible explanations: the area immediately adjacent to these deposits could have supported forests, or, because these samples were found in deltaic deposits, they may have travelled a long distance downstream from the Peace Cluster before deposition.

Peace Cluster

The Peace Cluster consists of 26 dated samples from 10 different locations in northern Alberta and northeastern British Columbia. The contexts of the samples included sand and gravel deposits, lake deposits and two archaeological sites. Samples from terrestrial fauna included bison, raven, ground squirrel, wapiti or deer and bighorn sheep. Identified plant material (poplar) came from only two sites, Summit Creek and Wood Bog. The latter sample of wood also had gnaw marks attributed to beaver, indicating they were present in the area. The two archaeological sites, Charlie Lake Cave and Saskatoon Mountain produced dates ranging from 10500 B.P., in the former (Fladmark et al. 1988:379; Driver et al. 1996:269), to around 9300 B.P. in the latter (Beaudoin et al. 1996:117-118. Dates from higher levels (younger) at Charlie Lake Cave suggests that the area was occupied by humans throughout this period (Driver et al. 1996:269). This implies a comparatively rich environment that could support a range of large and small mammals, including humans, birds, amphibians and fish.

North Saskatchewan River Cluster

The North Saskatchewan River Cluster is the largest, consisting of 80 dates, ranging from the Rocky Mountains to the Saskatchewan/Manitoba border and from the 49th parallel to north of the North Saskatchewan River. Four dates from sites 118, 119, 122 and 123 (Figure 17) occurred north of the North Saskatchewan River suggesting that the area between it and the Peace Cluster became habitable.

The majority of archaeological dates, 22 in all, came from the well stratified Vermilion Lakes archaeological site near Banff, Alberta. Identified plant material at that site included fir, pine, spruce needles, sedge seeds and poplar. Dated identified animal remains included only bison, but other fauna in the local environment included deer, hare and bighorn sheep (Fedje 1986:35-36).

The earliest date from this cluster was 11000±1600 B.P. (RIDDL-217, from Vermilion Lakes), but it should be viewed with caution because of its large uncertainty. The sample was small and other samples dated from the same stratigraphic provenance centred around 9900 B.P. (Fedje 1986:34; Fedje et al. 1995:90). The submitter suggests , based on dates from adjacent stratigraphic layers, that this occupation layer should date to about 10000 B.P. (Fedje 1986:34; Fedje et al. 1995:90).

The remaining sites are scattered across the plains south of the North Saskatchewan River. Identified and dated plant materials include spruce (*Picea*), poplar (*Populus*), willow (*Salix*) and sedge (*Cyperaceae*), and identified dated animal remains include bison, mammoth and muskox. The stratigraphic provenance differs widely, with lake, pond or alluvial deposits dominating (see Table 6).

Environmental Reconstructions

The following environmental reconstructions are based on the identifiable dated samples. The environments discussed in the following tables relate to Figures 15 to 17 and Figures 19 and 20. Tables 6 to 9 are presence and absence tables (following Hills and Harington

2003:Table 1) for Periods 1 to 4. Only dated samples that could be identified to some taxonomic level are discussed (e.g., samples identified simply as bone are not tabulated, but samples identified merely as wood are noted). Other species or environmental information associated with those directly dated samples also will be discussed where such data is present.

It should be noted that areas without dated plant and animals were not necessarily devoid of life, with the possible exception of those regions covered by glacial ice. Those areas existing between the glacial ice and regions of higher biotic richness were so unproductive that, due to taphonomic factors, little evidence has have been preserved. It is unlikely that such regions could have sustained either animal or human populations of any size for anything but the most limited period during the warmer seasons of the year.

Period 1: 20000-17001 B.P.

The results indicated that Period 1 had the severest environment of the four periods. This period, represented by five dates, four in the Yukon and one in Saskatchewan, ranging from 20280 B.P. to 17880 B.P. (Figure 15, Table 2), encompassed the Last Glacial Maximum. Table 6 shows that mammoth, horse and cougar were present in the Yukon and only mammoth in Saskatchewan. The presence of this faunal assemblage would support both Guthrie's mammoth steppe and West's mammoth fauna/tundra steppe (both concepts discussed above). The remainder of the landscape of the study area, however, was either covered by glaciers or environmentally too severe to permit plants or animals to survive.

As noted above, the mammoth bones dated from Bluefish Cave 2 (19640±170 B.P., RIDDL-330; 17880±330 B.P., CRNL-1221) reportedly had butchering marks (Cinq-Mars in Morlan 2001), but, no detailed discussion of these marks has ever been published. No other evidence of human occupation in this area during this time has yet been found. The recovery of cougar bones (19000±1500, TO-1266) from Bluefish Cave suggests that other smaller animals also were present, since it was unlikely that cougars were hunting mammoths.

Table 6. Period 1 dated mammal samples.

Taxa	Localities (see Figure 14 and Table 2)		
	Bluefish Cave 2	Gold Run Creek	Saskatoon Site
mammoth	X	X	X
cougar	X		
horse	X		

Other evidence from the region, but outside the time range of this study, came from the Old Crow River, Yukon. Purportedly, humanly modified bone dating to about 27000 B.P. was recovered from redeposited contexts, which suggested a long human occupation of the region during the Pleistocene (Irving and Harington 1973:336; Bonnichsen 1978:105; 1979:81-147; Nelson et al.1986:749). The most famous of these artifacts was the caribou bone flesher that produced a bone apatite date of 27000^{+3000}_{-2000} B.P. (GX-1640). Since this initial dating, the artifact has been redated to 1350±150 (RIDDL-145) (Nelson et al. 1986:750; Blake 1988:40). Despite this, Morlan (2003) still maintains there is evidence of human occupation in the region stretching into the Mid-Wisconsinan. Morlan (2001) documents 61 dates on presumably humanly modified bone dating earlier than 20000 B.P. in the Canadian Radiocarbon Database from redeposited contexts in the Old Crow region. Unfortunately, no other definite indication of human occupation dating to this age has been discovered that could provide a source for these redeposited bones and the Old Crow assemblage may be a one-of-a-kind situation. It would appear that the most likely explanation is that the "bone artifacts" are in fact "pseudo-artifacts" produced by some yet poorly understood natural fracturing mechanisms. Although, Morlan (2003:126-127) maintains that this explanation has been ruled out.

As expected, the lone date from southern Saskatchewan of 20280±500 B.P. (S-499) falls before the Last Glacial Maximum. After this time environmental conditions for plant and animal life deteriorated until the area was covered by advancing Laurentide ice. As noted above, present geological evidence indicates that Cordilleran and Laurentide glaciers coalesced south of the Athabasca River during this period, but may have been asynchronous to the north in the Peace River area. The deposit from which this sample was recovered also produced gastropod and pelecypod shell fragments, as well as camel, bison and deer bones. It is unclear whether these other faunal remains date to this period since other dated mammoth bones ranged from >34200 BP (S-483, Rutherford et al. 1984:242) to as young as 12000±320 B.P. (S-482, see Table 1).

Period 2: 17000 - 14001 B.P.

The increase in the number of dates and their areal distribution at this time suggests that deglaciation occurred simultaneously at both ends of the corridor, as reflected in Figure

16. Table 7 displays the local presence or absence of the dated identified samples for this period taken from Table 3. In the north, the recovery of mammoth, muskox, horse and saiga samples indicate an environment that could support steppe-grassland species.

Table 7. Period 2 dated plant and animal samples

Localities (see Figure 14 and Table 3)	Taxa						
	trees (unidentified)	mammoth	muskox	horse	badger	saiga	bison
North							
Herschel Island				X			
Baillie Island						X	
Old Crow River	X						
Bluefish Caves 2 and 3		X	X				
Upper Porcupine River	X						
Dominion Creek				X	X		
Scroggie Creek		X					
South							
Cartwright Lake	X						
Medicine Hat, Reservoir Gully							X
Riddell				X			
Empress, CPR Pitt		X					

At Bluefish Cave 3, the samples from the lower loess layer (Cinq-Mars in Morlan 2001) support an interpretation of a dry wind-blown environment that is consistent with Guthrie's mammoth steppe or with a tundra like vegetation. Most likely the source of this loess were the melting glaciers, as discussed by Beget (2001:500-501) for earlier in the Quaternary. The wood samples from Old Crow River (14410±110, GSC-730-2) and the

Upper Porcupine River (15920±110, GSC-2431) show that trees or shrubs were present along rivers. This might indicate that river valleys were wooded on the eastern edge of Beringia that could not support the steppe or tundra animal species that occurred farther west.

In the south, as Table 7 and Figure 16 show, trees or shrubs were present in the foothills, with mammoth, horse and bison on the plains to the east. The bone samples came from possible lacustrine and riverine sands or gravels (Lowdon and Blake 1975:16; Rutherford et al.1979:54). The presence of these herbivores suggests that grassland or steppe conditions also existed in southern Alberta and Saskatchewan during deglaciation. Unfortunately, the Empress, Riddell and Medicine Hat samples were from reworked deposits and were recovered during gravel pit operations. Thus, other faunal remains found in association with these dated samples are not necessarily contemporaneous (Rutherford 1979:54; Lowdon and Blake 1975:16-17).

The dated wood sample (see Table 4, TO-5190, 15670±960 B.P.) from the base of the Cartwright Lake core indicates that trees or shrubs were present in the foothills of the Rocky Mountains by this time (Beierle and Smith 1998:77-79). It was recovered from Zone 1 (the lowest), an inorganic clay that suggests the area had recently become deglaciated, or had not yet become habitable for significant numbers of plants.

Period 3: 14000 - 11001 B.P.

Table 8 presents the presence and absence of dated and identified samples from Period 3 (Figure 17 and Table 4). In the Mackenzie Delta and west along the coast, terrestrial samples of peat, wood, grass and muskox were recovered. These dates suggest an east-to-west temporal trend of grasslands, followed by woodlands with pond deposits. The only bone date (muskox, 13300±60 B.P., BETA-71232) was the most westerly and oldest date in this cluster and suggested that either tundra or steppe-grassland conditions may have been present along the coast early in this period. King Point (11270±110, GSC-3982) and Twin Lakes (11470±120, GSC-1514) provide additional remains and suggest a wetter environment near the end of this period. The former produced fossil insect and plant remains that indicated a meadow environment similar to the present day Yukon lowland coastal plain (Blake 1987:12).

Currently, that coastal plain is underlain by continuous permafrost that allows 25 % to 50 % of the surface to be covered by wetlands that support arctic willow, sphagnum moss and sedge. Dryer areas are covered with dwarf birch, willow, northern Labrador tea, various *Dyras* species and sedge tussocks, while dwarf birch, willow and alder occupy warmer locales. Current land mammals include muskox, snowshoe and arctic hare, caribou, red and arctic fox, wolf and arctic ground squirrel (Environment Canada 2004). Twin Lakes also produced remains of birch, spruce, poplar, bog gale and willow (Lowdon and Blake 1973:31). The eastern sites, at Pearce Point and in the Coppermine

Table 8. Period 3 dated plant and animal samples

Localities (numbers in brackets refer to sites in Figure 14 and Table 4)	Taxon															
	mammoth	horse	bison	moose	caribou	mountain sheep	saiga	muskox	owl	tree (unidentified)	conifer	willow	poplar	peat/moss	grass	marine shell
Yukon																
Herschel Island (2)								X								
King Point (8)														X		
Old Crow CRH-87	X															
Old Crow MkVl-12 (13-15)			X													
Old Crow MkVl-9 (16-18)			X													
Bluefish Caves 1 & 3 (19-28)	X	X		X	X	X	X		X							
Upper Porcupine River (29)												X				
Caribou River (30)														X		

Table 8. Period 3 dated plant and animal samples

Localities (numbers in brackets refer to sites in Figure 14 and Table 4)	Taxon															
	mammoth	horse	bison	moose	caribou	mountain sheep	saiga	muskox	owl	tree (unidentified)	conifer	willow	poplar	peat/moss	grass	marine shell
Snake River (31, 32)												X				
Hunker Creek (33)					X											
Northwest Territories/Nunavit																
Pierce Point (1)																X
Garry Island (3,4)										X						
Eskimo Lakes (5)															X	
Peninsula Point (6)														X		
Darnley Bay (7)																X
Eskimo Lakes (9)															X	
Twin Lakes (10)														X		

Table 8. Period 3 dated plant and animal samples

Localities (numbers in brackets refer to sites in Figure 14 and Table 4)	Taxon															
	mammoth	horse	bison	moose	caribou	mountain sheep	saiga	muskox	owl	tree (unidentified)	conifer	willow	poplar	peat/moss	grass	marine shell
Coppermine (11)																X
Mountain River (34)										X						
Mountain River (35-36)										X						
San Sault Rapid (37)												X				
Mountain River (38)										X						
Little Bear River (39)										X						
Andy Lake (40)										X						
Parsons Lake (66)										X				X		

Table 8. Period 3 dated plant and animal samples

Localities (numbers in brackets refer to sites in Figure 14 and Table 4)	Taxon															
	mammoth	horse	bison	moose	caribou	mountain sheep	saiga	muskox	owl	tree (unidentified)	conifer	willow	poplar	peat/moss	grass	marine shell
British Columbia/Alberta																
Fort St. John (41)										X						
Boone Lake (42)													X			
Clover Bar Sand and Gravel Ltd. (43)			X													
Crowfoot Lake (44)												X				
Clarke Gravel Pit (49)			X													
Gallelli Gravel Pit (50)			X													
Elk Valley (55, 56)										X						
Lindo Bluff (57)		X	X													

Table 8. Period 3 dated plant and animal samples

Localities (numbers in brackets refer to sites in Figure 14 and Table 4)	Taxon															
	mammoth	horse	bison	moose	caribou	mountain sheep	saiga	muskox	owl	tree (unidentified)	conifer	willow	poplar	peat/moss	grass	marine shell
Oldman Drainage DIPm-VP (58)	X															
Oldman River (59)										X						
Wally's Beach (62-64)		X	X		X											
Saskatchewan																
Kyle (51)	X															
Marieval (52)										X						
Camp MacKay (53)										X						
Esterhazy (54)										X						
Scrimbit (60, 61)											X					
Frenchman Valley (65)										X						

area produced only marine shells and showed that glacial ice had retreated from this area by 11800 B.P. These areas were then initially inundated with sea water before isostatic rebound.

In the interior Yukon the dated samples demonstrate an environment that now could support an increasing number of different faunal species. Those listed in Table 8 include mammoth, bison, horse, caribou, moose, sheep, saiga and owl, dating from 13500 to 11500 B.P. At Bluefish Cave, a level dating to about 12900 B.P. also produced rabbits, ground squirrels, lemmings, bison and small unidentified birds (Cinq-Mars 1979:15-17). Most of these finds apparently came from a loess layer, as did samples from Period 2, suggesting that the area remained dry and windy throughout both periods.

Preliminary pollen analysis indicate that the lowest and oldest pollen zone (Zone 1) is dominated by grasses, sages and herbs, with spruce, birch and willow trees also present. This is followed in Zone 2 by an increase in birch and a decrease in grasses, sages and herbs (Cinq-Mars 1979:12,14; Morlan and Cinq-Mars 1982:368). The latter zone, although not directly dated at Bluefish Cave, has been dated elsewhere in the Yukon to about 13000 B.P. (Morlan and Cinq-Mars 1982:368).

Redeposited bison bones, dating between 12500 and 11990 B.P., were found along the Old Crow River and willow and peat samples were recovered from along the Porcupine River. The climate appears to have remained cool and dry enough to support the large mammals on a steppe or plains environment in some areas, but increasing moisture allowed woodland species to become more prevalent. The changing environment may have continually redistributed those areas of Beringia that could support these different faunal species throughout this period.

Along the Mackenzie River all dated samples are wood from deltaic or lacustrine sediments, indicating deglaciation and the formation of proglacial lakes. Willow is the only identified species (11200±130 B.P., GSC-1573). In the mountains to the west, a date (12060±80 B.P., TO-2295) on unidentified wood from Andy Lake indicates that trees/shrubs were present. The pollen diagram from Zone 1 at Andy Lake is described as a sagebrush dominated herb tundra, with shrub willow (Szeicz et al. 1995:364-365). The light pollen accumulation and low organic content of the sediments are interpreted as reflecting washed-in mineral soils and that vegetation in this area was sparse and lake productivity low (Szeicz et al. 1995:364-365). This all indicates that the area had only recently become deglaciated and habitable for plant communities. The recovery of only wood samples along the Mackenzie River also could indicate that the area was not an open steppe or grassland that could have been easily used as a biogeographical corridor by animals. Instead it may have been closed forested environment that would have hindered migration.

The two samples from the upper Peace River Valley consisted of wood (one identified as poplar, 11700±260 B.P., SFU-223). The earliest of the dates (13970±170 B.P., TO-2742) suggests that this area became deglaciated as early as 14000 B.P. Coring at Boone Lake indicates a changing vegetative landscape between 12000 and 11000 B.P., based on the acceptable radiocarbon dates (White and Mathewes 1986:2313; White et al. 1985:184). The vegetation change from one dominated by grasses, sedges and herbs (12000 to 11700 B.P.), similar to Andy Lake, to an open poplar woodland with shrubs and grasses (11700 to 11500 B.P.). Finally, this led to vegetation that was transitional between the early deglaciated environment and the later coniferous boreal forest dominated by pine and spruce (White and Mathewes 1986:2311;2313-2314; White et al 1985:184).

South of the North Saskatchewan River many dated samples came from sands and gravels, or other alluvial deposits, along present river courses. Identified fauna, are dominated by bison, mammoth and horse, while plant remains include willow and conifer needles and cones. The wood samples (most not identified to species) were recovered from throughout the study area and again reflect an increase in environmental productivity. The environment probably had more developed soils (since it had been deglaciated longer) and supported a wider range of herbs, grasses, and shrubs, as well as the herbivores. This evidence would suggest that an open canopy woodland was present across southern Alberta and Saskatchewan at this time.

In the west, the lowest zone from the Crowfoot Lake core near Banff indicates predominately clastic sediments, suggesting a landscape of sparse vegetation between 11300 and 10100 B.P. This thin shrub-herb vegetation cover was dominated by sagebrush, willow and grasses (Reasoner and Humber 1999:485), very similar to the environment around Andy Lake in the Northeast Cluster. The evidence from Crowfoot

Lake and Andy Lakes would suggest that the only steppe or tundra like conditions along the eastern slopes were in the mountains and not at lower elevations.

In addition to bison, the Clarke Gravel Pit near Cochrane and the Gallelli Gravel Pit in Calgary, Alberta, produced additional faunal remains of horse, mountain sheep and wapiti from the former and camel from the latter (Lowdon and Blake 1970:68; Wilson and Churcher 1978:729-740). Since none of these bones appeared to be in primary context their association should be considered provisional. Nevertheless, this assemblage of fauna matches the bone dates from Wally's Beach, which also produced caribou, porcupine, muskrat, ground squirrel, hare, badger, wolverine, otter, weasel, bear, wolf, fox, a small feline, and six bird taxa (McNeil et al. 2004:86), with muskox dating to just after 11000 B.P. Also, horse, camel, bison and mammoth tracks have been preserved in the sediments of this site (Kooyman et al. 2001:687, Kooyman 2006:101-121).

Period 4: 11000 - 8000 B.P.

Period 4 provides the largest and most diverse set of dated sites. Table 9 lists the presence and absence of identified samples from Table 5 and Figures 19 and 20. In the north, coastal sites are divided into distinct eastern and western clusters. The samples from the eastern cluster are all on marine shells, most recovered from sandy marine clays or silts, indicating that isostatic rebound still had not occurred. Compared with Period 3, the number of samples increased in both areal extent and in quantity. The former indicates that deglaciation was continuing and the latter suggests that the area was more productive than in Period 3.

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Yukon																					
Backhouse River (7)												X									
Komakuk Beach (8)										X											
Komakuk (9)										X											
Pauline Cove, Herschel Island																	X				
Engigstciak, NiVk-1 (15-17)			X																		
Sabine Point (20)										X											
Sabine Point East											X										
Coal Mine Lake (25)										X		X									
Bluefish Cave 2 and 3 (70, 71)			X	X																	
Whitefish Lake (72)										X											

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Upper Porcupine River (74)													X								
Caribou River (75)										X											
Hungry Creek, Bonnet Plume (78)																	X				
Hunker Creek (79)									X												
Northwest Territories/Nunavut																					
Baillie Island (1)										X											
ObRw-1, Qugyuk (2)			X																		
Cape Monte Casino (3)											X										
Nicholson Point (4)												X					X				

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Liverpool Bay (5)																	X				
Pelly Island (6)										X											
Garry Island (12)									X												
Eskimo Lakes Postglacial (13, 14, 18, 19)									X	X											
Tuktoyaktuk Peninsula (21)										X							X				
Tununuk (23)																	X				
Zed Lake (24)										X											
Holmes Creek (26)																	X				
Keats Point (27)																					X
																					X
Buchanan River (30, 31, 34)																					X

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Tinney Point (32, 33)																					X
Clifton Point (35-39)																					X
Harding River, Dolphin and Union Strait (41)																					X
Dolphin and Union Strait (42, 43)																					X
Kugaryuak River, Coronation Gulf (44)																					X
Coppermine (45, 48, 61-63)																					X
Basil Bay (49)																					X
Richardson River (50)																					X

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																			
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Coppermine Area (51)																					X
Cox Lake, southwest (52)																					X
Coppermine River Valley																					X
Coronation Gulf (54, 55)																					X
South Coronation Gulf Coast (56)																					X
Tree River, Coronation Gulf (57)																					X
Bernard Harbour (58-60)																					X
Klengenberg Bay (64)																					X

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Stapylton Bay (65- 67)																					X
Rat River (68)									X												
West of Frog Creek (69)										X											
Grandview Hills (73)											X										
Peel River (76)									X												
Many Beaver Lake (77)										X											
Norman Wells (80)										X		X									
Bell's Lake (81)									X												
Great Bear River (82)									X												
Keele Lake (83)									X												

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Root River (84)									X												
Fort Simpson									X												
British Columbia																					
Charlie Lake Cave (91-100)			X				X	X													
Ostero Gravel Pit (102)			X																		
Clayhurst Gravel Pit (103-107)			X																		
Finlay-Parsnip Access (108)					X																
Tumbler Ridge (115)			X																		
Summit Creek (116)											X										
Alberta																					

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Fort Smith (86)									X												
Peace Delta (87, 88)									X												
Athabasca Delta (89, 90)									X												
Peace River			X																		
Watino Series (109, 110)			X																		
Wakaluk Quarry (111)				X																	
Saskatoon Mountain, GhQt-4 (113)																			X		
Wood Bog, GgQq-7											X										
Athabasca River (117)			X																		

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Freeman River (118)									X												
Whitemud Creek, Edmonton (119)			X																		
Muskiki Lake peatland (121)																	X				
Nordegg Pond (125)													X								
James River (128)	X																				
EkPu-8, James Pass Meadow Complex (129)			X																		
Three Hills, Milan Site			X																		
Three Hills			X																		

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Crowfoot Lake (133-136)														X	X			X			
Lake O'Hara (139)																X					
Opabin Lake (140)																X					
Copper Lake (142, 143)									X				X								
Griffen Gravel Pit, Cochrane (144)			X																		
Vermilion Lakes (151, 159, 165)									X												
Johnson Lake (170)									X												
Aquitaine Pit (171)			X																		

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Lower Burstall Lake (173)															X						
Kananaskis Valley (174, 202)									X		X										
Toboggan Lake (177, 178)									X				X								
Lindoe, EaPo-100			X																		
The Gap, DiPo-20			X																		
Taber Provincial Park (185)										X											
Fletcher Site, DjOw-1 (195)																		X			
Elk Valley, Weary Bog (196)									X												

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Wally's Beach (197)						X															
Bindloss Gravel Pit	X																				
Pashley Gravel Pit		X																			
Saskatchewan																					
Denholm 2 Testhole (123)									X												
Eagle 10 Testhole (124)									X												
Kenaston (138)									X												
Wiseton (141)	X																				
Kelliher (168)									X												
Dinsmore (169)																X					

Table 9. Period 4 dated plant and animal samples.

Localities (numbers refer to sites in Figures 15 and 16 and Table 6)	Taxon																				
	mammoth	horse	bison	wapiti	mountain sheep	muskoxen	ground squirrel	raven	generic tree	willow	poplar	birch	spruce	fir	pine	conifer	peat/ moss	grass/sedge	raspberry	wild rose	marine shell
Sioux Crossing (175)									X												
Earl Grey (176)									X												
Heron Eden Site (179-181, 203)			X																		
Herbert (182)										X											
Scrimbit Series (187, 188)									X												
Scrimbit Site (189)									X												
Frenchman Valley (191)									X												
Robsart (Horsemen Site) Kongeview										X											

Samples from western sites were all terrestrial plant or animal remains. The geological contexts of many western samples are described as peat, pond or lake deposits, suggesting a wet or damp surface environment. In addition, the context of several of these samples included thermokarst and solufluction features, suggesting a periglacial environment and permafrost.

Additional information from pollen and other macrofossils (not identified) associated with dated samples from coastal plain locales (e.g., Backhouse River and Komakuk Beach) suggests conditions similar to those present today existed early in this period (Lowdon and Blake 1976:13-14, McNeely and Jorgensen 1992:48). Later dates on bison bone from the Engigstciak and Qugyuk archaeological sites on the coast, indicate that the area could support large grazing mammals and humans.

This occupation level of the Engigstciak site also produced muskox, caribou, hare and Arctic birds, which suggests a more diverse fauna than at present (MacNeish 1959:46; Cinq-Mars 1991:35). Initially, the pollen from this level of the site, which was dominated by grasses, sedges and willows, was interpreted as indicating a colder and wetter climate than present (MacNeish 1959:46). Cinq-Mars (1991:40) notes however, that the diverse faunal assemblage and recent regional vegetation studies suggests that a rapid change in vegetation occurred in that region after 11000 B.P. Now, the pollen is interpreted as evidence of conditions warmer than present. The poplar sample (GSC-2022) from Sabine Point supports this interpretation (Lowdon and Blake 1976:12).

To the east, the coastal area adjacent to the Mackenzie Delta produced only willow and peat in bog or lake deposits prior to 10000 B.P., with no faunal remains, Birch, poplar and bison appear after 10000 B.P. that, with the exception of the bison, also were found in bog or lake deposits, suggesting that these wetter conditions continued.

Only bison and wapiti were recovered from Bluefish Cave in the Yukon interior. This suggests that the environment could no longer support fauna associated with either a steppe or tundra environment. These bones were from loess deposits indicating, that a dry, windy environment was still present in the area of the cave. Trees were not absent, as wood samples recovered from riverine and bog deposits attest, but they may have been restricted to these wetter areas. Dated samples include willow and spruce, with some birch and poplar in the same levels (Lowdon et al. 1977:16; Lowdon and Blake 1980:13-14). This indicates a developing woodland environment that may have been the precursor to modern conditions. Farther east, the geological contexts of two wood samples from the Mackenzie River Valley (# 68 and 69, Figure 16) suggest a wet, cold condition, since both were recovered from flow slides, indicating permafrost and solifluction conditions (Dyck and Fyles 1964:173; Lowdon and Blake 1979:34).

Farther south along the Mackenzie River, dated plant material samples include birch, willow, poplar and moss. Unlike the more northerly sites, no evidence of solifluction or colluvial deposition was present, instead most were recovered in lake (including deltaic) or river deposits. The presence of trees along this segment of the ice-free corridor in a well-watered environment indicates that forest or woodland developed there as early as 10600

B.P. Although no faunal remains were recovered, the poplar samples (GSC-1814, GSC-2298) had both been chewed by beaver, which supports an interpretation of a forest environment. The pollen cores from Bell Lake and Andy Lake (Szeicz et al. 1995:357, 364-365) in the mountains both indicate that the sagebrush dominated herb tundra (Zone 1) lasted till about 10200 B.P., when it was replaced by an environment dominated by birch (Zone 2).

In the Southern Group (Figure 16, Table 10) the dates near Lake Athabasca were on unidentified wood species. All were from deltaic sands or silts of Glacial Lake McConnell. This suggests either that trees or shrubs were growing around glacial lakes in this area, or that these samples came from areas upstream (Peace River Cluster). This development dates about 700 years B.P. later (about 9900 B.P.) than farther north along the Mackenzie River. This is probably explained by the fact that the area is geographically farther east and would have been deglaciated later than the area along the Mackenzie River.

The environment in the Peace River area of northeastern British Columbia and northwestern Alberta became more productive during this period. The dominant animal species from the dated samples was bison, with mountain sheep, ground squirrel and raven also present. The palynological core from Wood Bog produced beaver chewed poplar wood dated to 9730±110 B.P. (AECV-1620C). The macrofossil record from this core suggests a well-vegetated landscape that included trees (Beaudoin et al. 1996:116), but the only tree species identified was poplar.

Two of the sites from the Peace River Cluster are archaeological: Charlie Lake Cave and Saskatoon Mountain. The former shows evidence of multiple occupations from 10500 to 9500 B.P., and the latter had occupations dating between 9300 and 7500 B.P. Subzone IIa, the lowest occupation level dates to between 10700 and 10000 B.P., was associated with a more open environment than present as indicated by the recovery of snowshoe hare, bison, ground squirrel, other large rabbit species, cliff swallow, lemming and short eared owl bones (Driver 1988:1552; Driver 1996:22, Driver 1998b:816-817; Fladmark et al. 1988:375). An analysis of bison mitochondrial DNA indicates that northern and southern bison populations mixed in the Peace River area at about 10500 B.P., showing that a biogeographical corridor was present (Shapiro 2004:1563). This mixing of northern and southern bison populations was short lived and that by about 10000 B.P. this mixing was restricted by the growth of forests over much of northeastern British Columbia and northern Alberta.

This is supported by evidence from Subzone II, at Charlie Lake Cave dating to between 10000 - 9000 B.P., which suggests a more modern faunal assemblage and that a more forested environment was present. The mammalian faunal assemblage now is dominated by species commonly associated with woodland habitats, such as snowshoe hare and several vole species. Avian fauna included western grebe, horned grebe, ruddy duck, coot, a small rail and grouse, all are characteristic of boreal forest marshes or woodland environments. The continued presence of bison may suggest that some grassland was still present in the area (Fladmark et al. 1988:375; Driver 1988:1552; Driver 1996:22), although wood bison occurred in the area historically.

The Saskatoon Mountain dates include a combined date of 9360±60 (UCR-3275/CAMS 12365) on raspberry and rose seeds from a hearth. Other seeds recovered from the same hearth included cherry, strawberry and bearberry. The closest modern habitat in that area, with such a plant community, would be a dry, well-drained mid-to-upper slope locale (Beckingham et al. 1996: 8-16 to 8-22), suggesting that the berries were collected from nearby slopes and transported to the site.

As in earlier periods, the area adjacent to and south of the North Saskatchewan River, had the largest cluster of dates both in number and areal extent. The presence of dated samples recovered from north of the North Saskatchewan River suggests that the area between the North Saskatchewan River and Peace River clusters (Figure 16) was becoming more productive and could support large mammals like bison.

Palynological data from this cluster occur in the mountains and foothills of the Rocky Mountains. It suggests that early in this period (prior to 10000 B.P.) a bare landscape, dominated by grasses and herbs was present (Leonard and Reasoner 1999:6; Reasoner and Hickman 1989:305-307; Beirele and Smith 1998:78-79). A landscape with sparse vegetation is also suggested by the inorganic nature of the sediments early in this period. After about 10000 B.P. sediments became organic and the pollen suggests a forest dominated landscape (Leonard and Reasoner 1999:6; Reasoner and Hickman 1989:308; Beirele and Smith 1998:78-79).

To the south and east on the plains, dated faunal samples include bison, mammoth, horse and muskox (Table 9). Evidence from around Medicine Hat (Blindloss Gravel Pit) suggests that a species of American lion also was present (Hills and Harington 2003:1521; Churcher 1972:1564). Although initial environmental conditions could support this unique combination of fauna, muskox disappeared shortly after 11000 B.P. and mammoth lasted until about 10300 B.P. After this, bison was the only Late Pleistocene species still present. Dated floral samples included spruce, pine, fir, sage, poplar and willow. This suggests the environment was a mixed forest/grassland, as noted by others (Reasoner and Hickman 1989:307; Graham et al. 1996). Additional evidence from the Herbert site, indicates an open mixed forest dominated by spruce and pine but with birch, willow, and probably aspen also present, which suggests a cooler wetter climate (Kupsch 1960:287-291; McCallum and Dyck 1960:74). Thus, both the palynological and fauna data indicate the environment had changed significantly after 10000 B.P.

This southern area also has 10 archaeological sites, more than any other area , in any period. The earliest date from the Vermilion Lake site (Table 5; # 166) of 11000±1600 B.P. (RIDDL-217) was obtained from a small charcoal sample, recovered from the third lowest component. Other dates from this component ranged from 9800 to 10100 B.P., with an average, including RIDDL-217, calculated at 9930±50 B.P. (Fedje et al. 1995:90). Thus, this seemingly early date was probably a result of small sample size. The earliest dated cultural level from this site was dated at less then 10800 B.P., similar to (or a little older than) the earliest archaeological dated level from Charlie Lake Cave in the Peace River Cluster. This leaves the Wally's Beach site dates ranging from about 11300 B.P. to 11000

B.P. as the earliest from an archaeological site in the corridor area(Kooyman et al. 2001:686; Kooyman et al. 2006:101).

Affects of Reassessed Dates

After the initial assessment of radiocarbon dates, 26 were considered complicated and needed more explicit discussion or reassessment to determine their acceptance or rejection. Of these 9 were accepted, 10 were rejected and 7 remained provisional. Figure 21 compares reassessed dates with the maximum age accepted dates by latitude. It shows that these reassessed dates had no influence, so that even if the rejected dates had remained in the database there would have been no affect on this factor. The provisional dates are the most problematic because, as stated above, they should only be considered if other acceptable dates are present. In terms of the overall question of this dissertation none of these dates influence the final conclusion, however, they may influence the interpretation of environmental conditions during each period as are discussed below.

The Garry Island (GSC-575, 9750±100 B.P.) date was conducted on iron stained twigs and wood fragments suggesting multiple radiocarbon events may be present. Although wood samples are dated as early as 11720±250 B.P. (S-277, Period 3) from Garry Island, the only wood date from Period 4 is 9520±150 (S-276). This date overlaps at 1 standard deviation with GSC-575, so we can conclude that the later date does accurately date the presence of trees at this time.

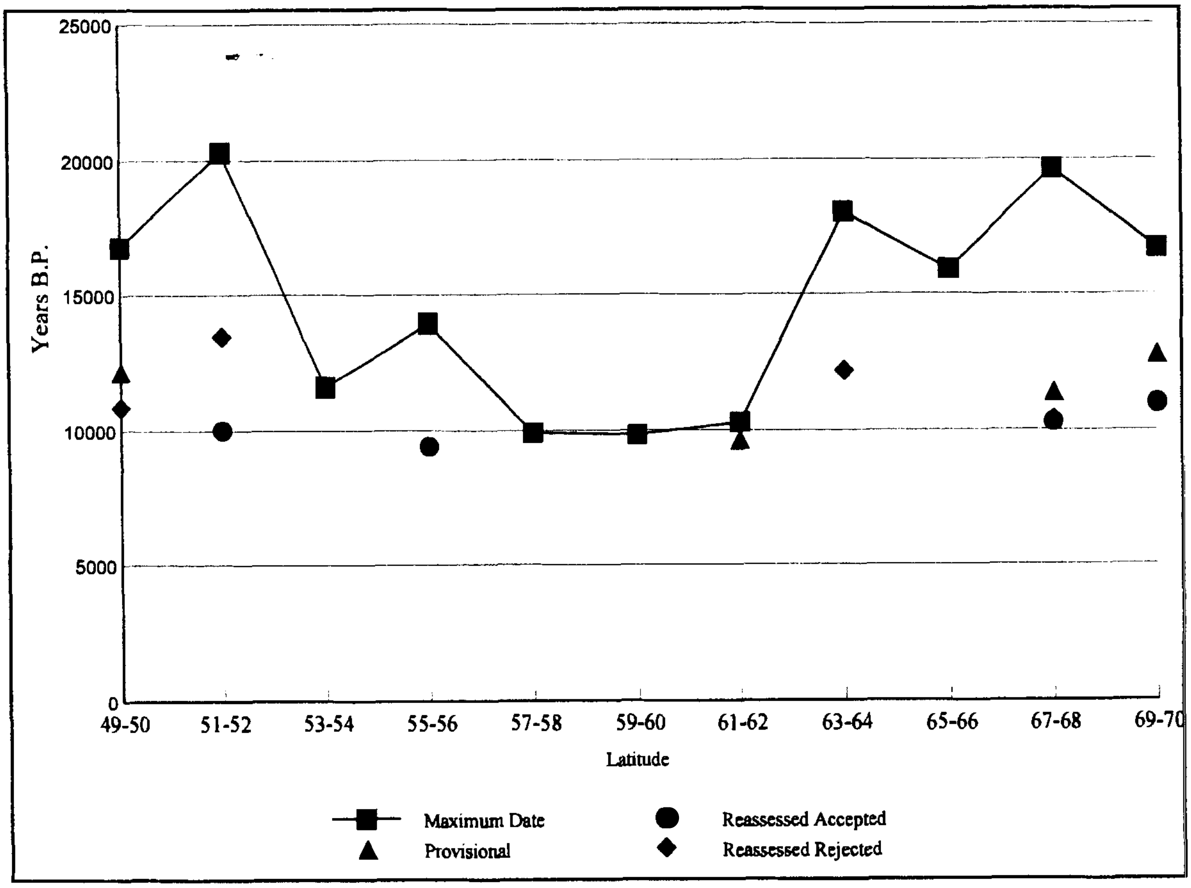


Figure 21. Comparison of reassessed dates with maximum accepted by latitude

Peninsula Point produced a date of 12770±130 B.P. (GSC-1214) on peat, and Parson Lake a date of 11380±140 B.P. (GSC-1160) on a combined sample of wood and peat. That suggests a relatively wet environment during Period 3 at the mouth of the Mackenzie River. The only other peat date from this region during this period is from Twin Lakes (11470±120 B.P., GSC-1514) while the closest wood date is the one noted above for Garry Island. Other wood dates from this period occur further south along the Mountain River and date as early as 11760±90 B.P. (TO-1190). Thus, there is support for an environment that could support peat and trees at Parson Lake around 11400 B.P., but no support as yet for peat development as early as that found at Peninsula Point.

At Holmes Creek a date of 9540±50 B.P. (GSC-1495) was obtained on peat. The peat sample from the Tuktoyaktuk Peninsula produced an almost identical date of 9560±80 B.P. (GSC-1169) on a peat and willow sample. This indicates that the Holmes Creek sample does accurately date an environment where peat could form.

Howard's Pass produced a date of 9610±50 B.P. (GSC-3532) on peat. No other accepted date occurs nearby. The closest is a rejected date from the Natla River area (9400±130 B.P., GSC-3333). It was on a peat sample obtained from a depth of 200 cm in a river dissected bog and was rejected because th sample from 220 cm and 230 cm produced younger dates (8400±80 B.P., GSC-3383 and 8630±160 B.P., GSC-3097, respectively). Thus, there is no supportive evidence for an environment that would have allowed peat formation in this area at this time.

Finally, Elk Valley produced two provisional dates on decomposed conifer wood (11940±80 B.P., GSC-2142 and 12220±110 B.P., GSC-2275), suggesting that deglaciation and forest development occurred around 12000 B.P. A third wood sample, from 31 km farther north (up slope) in Elk Valley, produced a date of 10130±290 B.P. (GX-5598) and does not support this early deglaciation. Since these sites occur in the mountains it is conceivable that deglaciation occurred earlier at the southern locale. Until other dates are recovered that confirm these resultss, their environmental implications must remain tentative.

Conclusions

Based on the current distribution of acceptable radiocarbon dates, there are no archaeological sites within the study area south of eastern Beringia (Yukon) before 11000 B.P. The distribution of dated samples shows that plants and animals were present in the extreme south and north of the study area soon after the glacial maximum at 18000 B.P., and that these habitable areas expanded slowly as deglaciation progressed. Although the study area became time transgressively ice-free after the glacial maximum, there is no evidence for the existence of a biogeographical corridor along the entire length of the corridor, or of a continuous or even sporadic human presence before 11000 B.P.

In the north, the mammoth steppe fauna, so important to West's (1996:556) depiction of the corridor, appears to increase from the Last Glacial Maximum through to Period 3. After 14000 B.P. most of the species that comprised the mammoth steppe fauna disappeared from the geological record. In fact no mammoth steppe fauna, except bison, occur later then

12000 B.P. During this period, trees were present in wetter locales in extreme eastern Beringia and along the Mackenzie River. In the south, the mammoth fauna lasted into Period 4, with muskox present until after 10900 B.P. and mammoth until 10300 B.P.

The earliest dated archaeological sites south of the 60th parallel is at Wally's Beach at between 11300 and 11000 B.P. (Kooyman et al. 2006:101) with Charlie Lake Cave and Vermilion Lakes, both occurring just after 10800 B.P. This small number of well dated archaeological sites is suggestive of a south-to-north migration with Wally's Beach being the most southerly and the oldest (Kooyman et al. 2006:101-121). McNeil et al. (2004:91) note that all the identified species from this site were southern, and no northern species were present. This is supported by recent DNA work that shows that northern and southern bison species met in the Peace River area around 10500 B.P. (Shapiro et al. 2004:1563). This suggests that the lack of an environmentally viable landscape within the study area before this time effectively rules out a north-to-south human migration and leaves a later south-to-north migration as the only feasible alternative.

CHAPTER 7

CONCLUSIONS

The objective of this research was to evaluate the evidence for a Late Pleistocene ice-free corridor that might have provided a human migration route for the first Palaeoindian cultures south of the Late Wisconsinan ice sheets. To assess both the environmental and temporal aspects of this question it was vital that the reliability of radiocarbon dates from archaeological, geological and palynological sites in the corridor area be evaluated. Without such a critical evaluation of these dates, no accurate environmental reconstructions could be undertaken, and the feasibility of the corridor could not be assessed. In order to be feasible as a migration route the ice-free corridor had to meet two conditions, based on the assumption that the earliest Palaeoindian cultures must date to at least 11700 B.P. and are unlikely to pre-date 20000 B.P. These conditions were 1. the area of eastern Beringia must have been able to support or could have supported human populations prior to 11700 B.P., and 2. the corridor must have evidence that it provided a biogeographical corridor between its northern and southern ends.

My approach involved the collection of radiocarbon dates and environmental information from archaeological, geological and palynological sites along the entire length of the corridor. The 600 radiocarbon dates collected were assessed using criteria described by Nelson (1998), resulting in 293 acceptable dates. Distributions were plotted of these remaining radiocarbon dated sites grouped first by latitude and then divided into four temporal periods. Changing environmental conditions were reconstructed for the latter by tabulating those samples identified to an acceptable taxonomic certainty. The results were used to determine if the two conditions were met.

For the first condition, the distributions indicate that humans were present in eastern Beringia prior to 11500 B.P., as made evident by butchered bone from Bluefish Cave. They also show that environmental conditions in that area supported large megafauna through all periods. Thus, the first condition was met: that eastern Beringia could support human populations before 11500 B.P..

To meet the second condition, dated archaeological, geological or palynological sites must be present along the length of the corridor. The distribution of dated plant and animal samples through the four periods indicated that repopulation of such recently deglaciated areas was a discontinuous process involving clusters separated by areas of low plant and animal populations. This mirrors the patchy distribution of animals and plants noted for areas south of the continental glaciers during the last glacial maximum (Graham et al. 1996:1601-1606; Davis 1983:166-181). Other researchers in the study area have suggested similar conclusions (Burns 1996:107-112; Wilson 1996:97-105).

The temporal and areal distributions of site locations show no evidence that dated sites appeared along the length of the corridor during Period 1, Period 2, or Period 3. During Period 4 dated sites do appear along the length of the corridor, but since it dates between 11000 B.P. and 9000 B.P. it can be concluded that there is no evidence of a biogeographical corridor along the corridor's entire length before 11700 B.P. Additional supporting evidence of a biogeographical corridor at this time comes from a study of bison mitochondrial DNA (Shapiro et al. 2004:1563). This study indicates that northern and southern populations of bison only mixed in the Peace River area of northeastern British Columbia around 10500 B.P. It also indicates that after 10000 B.P. genetic exchange between these populations was greatly inhibited by the development of spruce forest. Thus the second condition is not met.

It could be argued that a lack of research in some areas has greatly influenced known site distributions, particularly around the crucial area of the 60th parallel. Figure 10 compares the number of radiocarbon dates older and younger with the period investigated in this study. Their numbers (as indicators of the amount of research conducted) are comparable to those from other portions of the study area for the study period. Thus, this alternative explanation is not supported.

In sum, these results demonstrate that there is no radiocarbon evidence of a biogeographical corridor linking Beringia with the area south of the Laurentide and Cordilleran glaciers prior to 10000 B.P. This negates any possible use of the ice-free corridor as a Late Wisconsinan human migration route into the continent and implies that the earliest inhabitants of the Western Hemisphere arrived some other way, or at another time. Thus, other possible routes must now be considered to account for Late Pleistocene human migration from Beringia. Three possible alternatives are along the northwest coast of North America during the last glaciation, an inter-montane corridor during the initial stages of the last glaciation or a pre-Late Wisconsinan entry. Other routes have been proposed but have received relatively little attention (e.g., such as the hypothetical Late Pleistocene crossing of the North Atlantic) (for discussion see Strauss 2000:219-226, Bradley and Stanford 2003:459-478).

As discussed earlier, Fladmark (1983:19) notes that if human populations had been present in northern Canada during the Mid-Wisconsinan they would have been displaced by the deteriorating environmental conditions and advancing glaciers. If this environmental change was slow enough, these populations may have been displaced in all directions. Those populations that travelled south could have survived south of the maximum glacial extent, and would have had the remainder of the hemisphere to colonize. These populations could have been the founders of the Palaeoindian cultures we know as Clovis and Folsom and could also explain the presence of human populations in South America (e.g., Monte Verde, Monte Alegre) predating or contemporaneous with these North American cultures.

However, the lack of widely accepted sites in North America, dating before the last glacial maximum is problematic to that idea. If this were due to low populations, which would be nearly invisible in the archaeological record, how were they able to survive as viable populations for about 10000 years only to appear suddenly in the record near the end of the Pleistocene as Clovis and Folsom? Another explanation is that, despite archaeologist's best efforts, we have not been looking for such early sites in the correct locations. This could be due to the significant changes in landscape that have occurred since the end of the last glaciation. Such changes may make any archaeological sites dating to before the end of the

Pleistocene less likely to be found by archaeologists trained to look for human occupation in a Holocene or terminal Pleistocene setting. Chlachula may be implying this in defending his purported preglacial Palaeolithic sites in Alberta (Chlachula and Leslie 2001:875-878; Chlachula 1998:455-457). Clearly these problems and more must be addressed before any Mid-Wisconsinan arrival can be accepted.

Jackson and Duk-Rodkin (1996:215, 223) suggest that a possible alternative inter-montane corridor existed and was habitable in the valleys and plateaus of the Cordillera when the Laurentide Ice Sheet was at its maximum extent. They state that the Cordilleran Ice Sheet formed in the Coast Range and began to grow rapidly and spread eastwards after 20000 B.P. (Jackson and Duk-Rodkin 1996:216-217). Thus a possible inter-montane biogeographical corridor existed along the western edge of the Rocky Mountains until that time, that would have allowed humans to migrate south to ice-free areas in the United States. Jackson and Duk-Rodkin (1996:223) note that this could explain the appearance of Clovis between 12000 B.P. and 11000 B.P. allowing for an 8000 year journey down this inter-montane corridor.

As with the ice-free corridor, problems with this alternative corridor involve the dating of the glaciation and deglaciation. The 20000 B.P. date for the formation of the Cordilleran Ice Sheet is a generalization. In fact Jackson and Duk-Rodkin (1996:316) note that southeastern Yukon was blocked by glaciers around 24000 B.P., based on a 23900±1149 B.P. (GSC-2811) radiocarbon date by Klassen (1987:13) in the Liard River Valley silt. They interpret this as a limiting date, thus access to potential routes along valleys and plateaus were in fact cut off several thousand years before 20000 B.P. In addition, as the Cordilleran Ice Sheet grew, environmental conditions would have deteriorated and many of the problems outlined by Fladmark (1983:13-41) for the ice-free corridor would be pertinent to any inter-montane corridor. Also, valleys would have acted as natural spillways for any sudden glacial melt water runoffs, making them less suitable for human occupation and travel. So, until the timing of the Cordilleran Ice Sheet formation is refined, the inter-montane area must remain as one of several possible (and less probable than the ice free corridor) alternative early human migration routes into the Americas.

A third alternative is the coastal route, which involved a Late Wisconsinan entry of humans from Beringia using watercraft. Lower sea levels (at least -100 m) during the last glaciation would have allowed marine adapted migrants to use a series of hypothesized coastal refugia to move south along the northwest coast of North America. These refugia acted as biotic islands between glaciers flowing westward from the mountains. Once south of the glacial ice, this human population began moving inland along river valleys, eventually emerging as the earliest Palaeoindian cultures (Heusser 1960:209-210; Fladmark 1979:58-64; Fedje and Josenhans 2000:99-102; Mandryk et al. 2001:304-310).

Although much of the evidence for these refugia, and any human habitations are now submerged due to rising sea levels, not all has been erased. The Queen Charlotte Islands (Haida Gwaii) and parts of southeastern Alaska have revealed evidence of refugia, including endemic species, such as caribou and black bear, that are unique to these areas, and submerged geologic features. The latter included suspected glacial modified U-shaped valleys that were separated by unglaciated areas and that would have served as refugia (Fladmark 2001:26-29; Mandryk et al. 2001:305-308). Fedje and Josenhans (2000), using high-resolution digital terrain imaging and sea floor sampling, identified drowned landscape that included river channels, deltas and river mouths at over 50 m below current mean sea level.

In addition, the Kilgii Gwaay site on the southern Queen Charlotte Islands, provides faunal evidence of an occupation whose inhabitants were adept at acquiring offshore marine resources as early as 9400 B.P., which suggests watercraft (Fedje et al. 2001:116-117, 119). Also, Pleistocene cave deposits from the Queen Charlotte Islands (Haida Gwaii) indicates that the environment could support bears as early as 14400 B.P. Bears like humans are large terrestrial omnivores suggesting that humans could have survived here as well (Ramsey et al. 2004:107-109). The evidence, in the form of lithic artifacts and a single bone point, from K1 Cave and from Gaadu Din Cave dating from 10900 B.P to 10000 B.P. suggest bear hunting (McLaren et al. 2004:18, 23) at the Pleistocene/Holocene boundary. This circumstantial evidence is the best that presently exits to document the existence of this coastal route. Until more solid evidence of human use, it must remain one of several possible alternatives to the ice-free corridor.

At no time prior to 11000 B.P. did a biogeographical corridor exist along the entire ice-free corridor. Thus, it was unlikely that the corridor was used as a north-to-south migration route for early human populations. It is concluded that the presence of the Charlie Lake Cave, Vermilion Lake and Wally's Beach archaeological sites, south of the 60th parallel, could only be accounted for by human populations moving north through the corridor area. In order for this to have occurred, human populations must have migrated south of the ice sheets prior to this time. Since this research has shown that the corridor could not have been used as a migration route during the last glacial maximum, other logical alternatives must be considered to account for the ancestors of first Palaeoindian cultures.

APPENDIX A

REJECTED RADIOCARBON DATES

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Question 3							
Yukon							
Alaska/Yukon Border	69.38	-140.59.30	10400±80	GSC-1869	peat	Lake sediments. Uncertain what species of moss or other organics made up the peat.	Lowdon and Blake 1976
			10600±80	GSC-1869-2	peat (base soluble solution)	Lake sediments. Uncertain what species of moss or other organics made up the peat.	
Roland Bay	69.22.30	-138.52	9610±90	GSC-1808	peat	Unknown what species of plants (moss) contributed to the peat.	Lowdon and Blake 1976
Kay Point	69.17.30	-138.23.30	9710±140	GSC-480	peat	Submerged species of plant made up the peat because ponds may have formed in the melting ice wedge casts.	Lowdon and Blake 1976
			9030±80	GSC-3737	peat	Submerged species of plant made up the peat because ponds may have formed in the melting ice wedge casts.	McNeely and Jorgenson 1992
Noname	69.15	132.56	10100±130	BGS-197	basal peat	Unknown what species made up the peat.	Zoltai and Tarnocai 1975
Sabine Point east	69.04.30	-137.51	14400±180	GSC-1792	peat	Unknown what type of plants (moss) contributed to the peat.	Lowdon and Blake 1976

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
King Point	69.04.30	-137.5	9510±90	GSC-159	peat	Uncertain what species make up the peat.	Dyck and Fyles 1964
Sabine Point	69.04	-137.48	11000±100	GSC-3986	peat	Peat was recovered from lake sediments and may be composed of aquatic plants affected by hardwater.	Blake 1987
Stokes Point Series	68.39	-138.45	19500±250	GSC-2520	lake sediment	Unidentified radiocarbon event	McNeely 1989
			16800±250	GSC-2521	lake sediment	Unidentified radiocarbon event.	
Little Hanging Lake	68.19	-138.17	10400±140	GSC-2864	lakes sediment, mud	Unidentified radiocarbon event.	
Old Crow River Terrace	68.04	-139.41	10700±150	GSC-1166	shell, periostracum	Shells may be affected by hardwater.	Lowdon and Blake 1979
			10600±150	GSC-1167	shell, carbonate fraction outer	Shells may be affected by hardwater.	
Old Crow Basin, REM 78-3 section	67.55	-139.15.54	10400±90	GSC-2773	woody fragments, taxon not identified	Wood fragments could represent multiple radiocarbon events from different time periods.	Blake 1984
Old Crow Flats	67.51	-139.48	10850±320	I-4224	freshwater shell	Shell may be affected by hardwater.	Clague 1989
Porcupine River	67.28	-139.54	10740±180	GSC-121	peat	Unknown what type of plants (moss) contributed to the peat.	Dyck and Fyles 1964

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Eagle River	67.05.48	-137.03.12	9970±160	GSC-3133	peat	The peat developed in pond environment that became dominated by mosses, presumably submerged varieties. These could have been affected by hardwater.	Blake 1984
Noname	69.1	-138.02	10820±80	BGS-142	basal organic	Unidentified radiocarbon event.	Zoltai and Tarnocai 1975
Palmer Lake	66.05	-136.17	11200±100	GSC-2018	organic silt	Unidentified radiocarbon event.	Lowdon et al. 1977
Tyrrell Lake	66.03	-135.39	8860±270	GSC-2549	silty organic lake mud	Unidentified radiocarbon event.	Lowdon and Blake 1981; Richie 1982
			10200±240	GSC-2607	silty organic lake mud	Unidentified radiocarbon event.	Lowdon and Blake 1981
			11100±500	GSC-2540	silty organic lake mud	Unidentified radiocarbon event.	
			9350±240	GSC-2606	silty organic lake mud	Unidentified radiocarbon event.	
Cwynar Lake, Doll Creek	66.02	-135.42	16000±420	GSC-2690	silty lake mud	Unidentified radiocarbon event.	Lowdon and Blake 1981; Richie 1982
Noname	65.59	-135.03	14410±110	BGS-143	basal organics	Unidentified radiocarbon event.	Zoltai and Tarnocai 1975
			10470±80	BGS-144	basal peat	Unknown what species made up the peat.	
Lateral Pond series	65.57	-135.31	12100±130	GSC-2808	organic mud	Unidentified radiocarbon event.	Lowdon and Blake 1981; Ritchie 1982
			15200±230	GSC-2758	organic mud	Unidentified radiocarbon event.	

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Lateral Pond series	65.57	-135.31	14800±260	GSC-2785	organic mud	Unidentified radiocarbon event.	Lowdon and Blake 1981; Ritchie 1982
Snake River	65.41	-133.26	9750±150	GSC-586	silty peat	Unidentified radiocarbon event.	Lowdon and Blake 1968
Gill Lake	65.28	-139.42	12550±190	GSC-128	silty gyttja	Unidentified radiocarbon event.	Dyck and Fyles 1964
Dempster Highway	64.57	-138.15	9520±110	GSC-3770	lake sediment, organic silt.	Unidentified radiocarbon event.	McNeely and McCuaig 1991
North Fork/Dempster	64.57	-138.24	9840±100	GSC-4058	lake sediment, mud.	Unidentified radiocarbon event.	
Chapman Lake	64.52	-138.18	9890±110	GSC-3756	lake sediment, organic silt	Unidentified radiocarbon event.	McNeely and McCuaig 1991
			10900±90	GSC-3748	mottled organic noncalcareous silt	Unidentified radiocarbon event.	
	64.51.30	-138.19	13870±180	GSC-296	basal organic silt	Unidentified radiocarbon event.	Dyck et al.1966
			9620±140	GSC-310a	peat	From a bog. The peat could be made up of submerged mosses and plants that were affected by hard water.	
			9510±150	GSC-310b	peat	From a bog. The peat could be made up of submerged mosses and plants that were affected by hard water.	
Chapman Lake	64.51.30	-138.19	9620±150	GSC-310c	peat	From a bog. The peat could be made up of submerged mosses and plants that were affected by hard water.	Dyck et al.1966

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
East Blackstone River	64.38	-138.24	13740±190	GSC-515	organic silt	Unidentified radiocarbon event.	Lowdon and Blake 1968
Hart Lake	64.37	-135.1	12900±150	GSC-67	marl (carbonate fraction)	Unidentified radiocarbon event	Dyck and Fyles 1962
			12120±140	GSC-67-2	marl (organic residue)	Unidentified radiocarbon event. Uncertain of the source of the organic residue.	
North Fork Pass	64.35	-138.17.30	11250±80	GSC-470	wood and organic silt, birch twigs	Organic silt may consist of many different radiocarbon events and be partly composed of aquatic plants.	Lowdon. and Blake 1968
Monkshood VII	64.34	-138.15	9440±100	GSC-3847	lake sediments	Unidentified radiocarbon event.	McNeely and McCuaig 1991
Tombstone Range	64.27.00	-138.27	9690±200	GSC-1172	organic silt and twigs	A mixed sample of silt and twigs. The date will be some sort of average of the two.	Lowdon et al. 1971
Hunker Creek	63.58	-138.57	9510±220	I(GSC)-196	organic silt	Unidentified radiocarbon event.	Trautman and Walton 1962
Corkery Creek	63.51.12	-135.38.03	9000 ±45	GSC-4020	moss sedge culms, taxon not identified	Multiple radiocarbon events from broad potential time range. Moss species probably aquatic and could have been effected by hard water.	McNeely. and McCuaig 1991
Gravel Lake	63.48.30	-137.53.30	10930±190	GSC-472	gyttja	Unidentified radiocarbon event.	Lowdon and Blake 1968

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Barlow Lake	63.45	-137.43	10100±90	GSC-2538	basal gyttja	Unidentified radiocarbon event. It is unknown what type of plants made up the gyttja.	McNeely 1989
Twin Buttes	63.30	-135.23.30	10840±150	GSC-365	organic silt	Unidentified radiocarbon event.	Dyck et al.1966
Big Reid Lake	63.23	-137.15	9800±120	GSC-2548	basal gyttja	Unidentified radiocarbon event. It is unknown what type of plants made up the gyttja.	McNeely 1989
Meadowhead Creek	63.19.36	-134.54.06	10300±150	GSC-3901	organic detritus	Unidentified radiocarbon event.	Blake 1986
Northwest Territories/Nunivat							
Hooper Island	69.42	-134.55	11800±170	GSC-1056	organic silt	Unidentified radiocarbon event.	Blake 1987
Bluffer's Pingo series	69.37	-132.2	9540±110	GSC-3446	lake sediment, mud	Unidentified radiocarbon event.	McNeely 1989
Hendrickson pingo	69.32	-133.35	9010±100	GSC-1896	freshwater shells	Shells may be affected by hardwater.	Lowdon et al.1977; Hyvarinen and Ritchie 1975
Hendrickson Island	69.32	-133.35	9340±80	GSC-1896-2	lake mud	Unidentified radiocarbon date	Lowdon et al.1977; Hyvarinen and Ritchie 1975
Garry Island	69.30.05	-135.47.25	10330±150	GSC-516	peat	Lake sediments. Unknown what species of moss or other plants made up the peat.	Lowdon et al. 1971
Mayday Lake	69.27	-134.16	11100±100	GSC-3470	lake sediment, silt	Unidentified radiocarbon event.	McNeely1989
			9670±90	GSC-3473	lake sediment, organic silt	Unidentified radiocarbon event.	

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Tuktoyaktuk, pingo	69.27	-133.01	9460 ±140	GSC-1458	woody peat,	Sample may be made up of aquatic mosses and may contain old carbon. Taxon unidentified.	Lowdon and Blake 1973
Eskimo Lakes Pingo	69.25	-131.40	9690±250	GSC-1671	pond clay unit	Unidentified radiocarbon event.	Lowdon and Blake 1981; Hyvarinen and Ritchie 1975
Eskimo Lakes Pingo	69.25	-131.4	9500±170	GSC-1717	chara gyttja with shells	Chara species sometimes have incrustations of lime and almost always occur in hardwater the shells may be affected by hardwater.	
Ibyuk Pingo	69.24	-133.08	17860±260	GSC-481	peat	Uncertain what species make up the peat.	Lowdon and Blake 1973
			14130±440	GSC-512	organic silt	Unidentified radiocarbon event.	
Kugaluk Estuary	69.20	-130.55	10900±190	GSC-1303	peat	Probably aquatic moss because environmental and geological data suggest a channel environment.	Lowdon. and Blake 1978
Cabin Creek	69.18	-134.19	9390±150	GSC-1031	peat	The peat was from lacustrine sediments, is probably of aquatic origins and could have been affected by hardwater.	Blake 1987
Sleet Lake	69.15	-133.36	12500±110	GSC-3302	lake sediment	Unidentified radiocarbon event.	Blake 1983

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Sleet Lake	69.15	-133.36	10400±110	GSC-3307	lake sediment	Unidentified radiocarbon event.	Blake 1983
Eskimo Lakes Outwash (III)	**69.04**	-132.43	14100±170	GSC-1784	fibrous organic material	Some of plant material may be from submerged plants (i.e., Potamogeton) and thus may be affected by hard water.	Blake 1987
Tuktoyaktuk Peninisula, Lake 5	69.03	-133.27	11500±220	GSC-1237	lake sediments	Unidentified radiocarbon event.	Lowdon and Blake 1973
			12900±170	GSC-1321	lake sediments	Unidentified radiocarbon event.	Lowdon and Blake 1973; Ritchie and Hare 1971
Zed Lake	68.57.30	-133.13.30	9790±90	GSC-1469-2	peat, taxon not identified	Unidentified radiocarbon event.	Lowdon and Blake 1976
			9140±170	GSC-1469	marl	Unidentified radiocarbon event	
Hummocky Lake	68.5	-133.31	9030±80	GSC-3344	basal lake sediments	Unidentified radiocarbon event.	Blake 1983
Kate's Pond	68.22	-133.2	15500±440	GSC-3646	organic silt and clay	Unidentified radiocarbon event	Blake 1987
			9630±110	GSC-3664	firm gyttja	Unidentified radiocarbon event.	
			9130±110	GSC-3668	firm gyttja	Unidentified radiocarbon event.	
			9000±110	GSC-3582	firm gyttja	Unidentified radiocarbon event.	
			13700±190	GSC-3645	organic silt and clay	Unidentified radiocarbon event.	

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Kate's Pond	68.22	-133.2	8910±100	GSC-3554	organic silt and clay	Unidentified radiocarbon event.	Blake 1987
			14100±340	GSC-3570	organic silt and clay	Unidentified radiocarbon event.	
Twin Tamarack Lake	68.18	133.25	11600±140	GSC-3346	organic silt and clay	Unidentified radiocarbon event.	Blake 1983
			13100±150	GSC-3387	organic silt and clay	Unidentified radiocarbon event.	
Inuvik area	68.16	-133.29	12300±120	GSC-2352	lake sediment, mud.	Unidentified radiocarbon event.	McNeely 1989
			10000±180	GSC-2377	lake sediment, mud	Unidentified radiocarbon event.	
			11400±430	GSC-2365	lake sediment, mud	Unidentified radiocarbon event.	
			10500±120	GSC-2360	lake sediment, mud	Unidentified radiocarbon event.	
M Lakes series	68.16	-133.28	10000±110	GSC-2172	silty organic lake mud	Unidentified radiocarbon event.	Lowdon and Blake 1981; Ritchie 1977
			11100±100	GSC-2075	silty organic lake mud	Unidentified radiocarbon event.	
Erly Lake	68.14	-122.38	10800±150	GSC-1139	peaty moss	From lake sediments. Aquatic mosses may be affected by hard water effect.	Lowdon et al. 1971
Sweet Little Lake series	67.39	-132.01	9600±100	GSC-3430	organic lake sediments	Unidentified radiocarbon event.	Blake 1987
			9520±100	GSC-3419	fibrous organics in lake sediments	Unidentified radiocarbon event.	
Noname	67.16	-135.14	9960±80	BGS-139	basal organics	Unidentified radiocarbon event.	Zoltai and Tarnocai 1975

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Reindeer Lake series	67.07.05	-132.17	13500±190	GSC-3488	inorganic gyttja	Unidentified radiocarbon event.	McNeely1989
			14600±200	GSC-3483	inorganic gyttja	Unidentified radiocarbon event.	
Kelly Lake	65.35	-126.19.30	9570±110	GSC-2320	peat	Uncertain what species makes up the peat.	McNeely 1989
			9600±80	GSC-2379	peat	Uncertain what species makes up the peat.	McNeely 1989; Hughes 1987
Lac Meleze	65.13	-126.07	11000±340	GSC-3536	organic lake sediment	Unidentified radiocarbon event.	Blake 1986; MacDonald 1987a; MacDonald and McLeod 1996
			9240±120	GSC-3496	organic lake sediment	Unidentified radiocarbon event	
Andy Lake	64.39	-128.05	10460±390	Beta-54932	clayey gyttja	Unidentified radiocarbon event	Szeicz et al.1995.
Keele Lake	64.10	-127.37	11990±80	TO-2298	shells	Shells may be affected by hardwater.	Szeicz et al.1995
Eildun Lake Series	63.08.36	-122.46.5	10700±230	GSC-2737	organic material in marl and silty clay.	Unidentified radiocarbon event.	Lowdon and Blake 1979
			10300±290	GSC-2743	organic material in marl	Unidentified radiocarbon event.	
Natla River	63.01.00	-128.48.00	9400±130	GSC-3333	peat, taxon unidentified	Unknown what plant species makes up peat and the date is older than two other dates obtained from lower in section	Blake 1982
Lac Demain	62.03	-118.42	10500±200	GSC-3524	organic lake sediments	Unidentified radiocarbon event.	Blake 1986; MacDonald 1987a; MacDonald and McLeod 1996

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Horn Plateau	61.57	-120.06	8920±110	GSC-2396	organic peat	Unknown what species of moss made up peat.	McNeely 1989
John Klondike bog	60.21.24	-123.38.48	9590±320	GSC-1890	very calcareous gyttja (marl)	Unidentified radiocarbon event.	Lowdon and Blake 1980; Matthew 1980
			8700±350	GSC-1871	very calcareous gyttja	Unidentified radiocarbon event.	
British Columbia							
Lac Ciel Blanc	59.31	-122.11	9350±150	GSC-3755	organic lake sediment	Unidentified radiocarbon event.	Blake 1986
			9910±120	GSC-3749	marly gyttja	Unidentified radiocarbon event	
Snowshoe Lake	57.27	-120.40	9550±100	GSC-3708	gyttja	Unidentified radiocarbon event.	MacDonald 1987b
			10400±140	GSC-3704	gyttja	Unidentified radiocarbon event.	
Lower Cache Creek Road Site 1	56.27	-121.16	15800±1300	SFU-387	bulk organic samples	Unidentified radiocarbon event.	Woolf 1993
Dawson Creek	55.59.00	-120.15.40	9960±170	GSC-1548	mollusk shells	Shells may be affected by hardwater.	Lowdon and Blake 1973
Dawson Creek	55.58.50	-120.14.37	10400±170	GSC-1654	mollusk shells	Shells may be affected by hardwater.	Lowdon and Blake 1973
Oldman Creek	54.28.55	-117.13.25	10000±140	GSC-1457	peat	Unknown what species made up the peat.	Lowdon and Blake 1976
Tonquin Pass	52.43	-118.21	9660±280	BGS-465	peat	Unknown what species of plants (moss) contributed to the peat.	Kearney and Luckman 1983; Brock Geological Survey lab form.
Tonquin Pass	52.43	-118.21	9150±150	BETA 1831	peat	Unknown what species of plants (moss) contributed to the peat.	Kearney and Luckman 1983

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Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Elk Valley	50.23	-114.56	13430±450	GX-5599	shell	Fresh water shell may be contaminated by hard water.	Ferguson and Osborn 1991; Bobrowsky and Rutter 1992
Jaffray	49.23.24	-115.18.18	19100±850	GX-2033	peat	from a peat clast within Fraser Glaciation recessional outwash	Clague 1981
Alberta							
Wild Spear Lake	59.15	-114.09	10200±490	GSC-3313	moss	Aquatic moss may be affected by hardwater.	Blake 1986; MacDonald1984; MacDonald 1987b; MacDonald and McLeod 1996
Eaglenest Lake	57.46	-112.06	11280±275	GX-8910	lake sediments?	Unidentified radiocarbon event.	Vance 1986
			10740±150	BETA 8287	lake sediments?	Unidentified radiocarbon event.	
			10085±245	GX-8909	lake sediments?	Unidentified radiocarbon event	
Yesterday Lake	56.46	-119.29	9260±130	GSC-3505	gyttja	Unidentified radiocarbon event.	Macdonald 1987b; Blake 1986
Yesterday Lake	56.46	-119.29	10000±150	GSC-3544	gyttja	Unidentified radiocarbon event	Macdonald 1987b; Blake 1986
Lone Fox Lake	56.43	-119.43	9990±100	GSC-3482	gyttja	Unidentified radiocarbon event.	
			10700±140	GSC-3520	gyttja	Unidentified radiocarbon event.	

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Sulphur Lake	56.43	-118.19	11000±200	GSC-2004	clayey gyttja	Unidentified radiocarbon event..	Lowdon et al. 1977
Mariana Lake	55.57	-112.01	11300±110	GSC-2038	clayey gyttja	Unidentified radiocarbon event. Unknown what plants made up gyttja.	
Boone Lake	55.35	-119.26	12650±320	WAT-408	organic clay	Unidentified radiocarbon event.	White et al. 1979; Berry and Drimmie 1982
			10740±198	WAT-362	organic clay	Unidentified radiocarbon event.	
			17570±325	WAT-406	organic clay	Unidentified radiocarbon event.	
			9250±180	SFU-209	organic clay	Unidentified radiocarbon event.	White and Mathewes 1986
Spring Lake	55.31	-119.35	11200±400	WSU-2557	organic sediment - gyttja?	Unidentified radiocarbon event.	White and Mathewes 1986
			10800±180	SFU-210	organic sediment - gyttja?	Unidentified radiocarbon event.	
Dollar Lakes	55.10	-117.12	10200±110	GSC-1998	organic sediment	Unidentified radiocarbon event.	Lowdon et al.1977
Wood Bog, GgQq-7	55.09	-118.43	8990±360	AECV-723C	organic material	Unidentified radiocarbon event.	Beaudoin 1991
			9270±110	AECV-469C	organic material	Unidentified radiocarbon event.	Beaudoin et al. 1996
Wood Bog, GgQq-7	55.09	-118.43	9630±650	AECV-470C	organic material	Unidentified radiocarbon event.	Beaudoin et al. 1996
			9290±140	AECV-469C	organic material	Unidentified radiocarbon event.	
			9200±130	AECV-724C	organic material	Unidentified radiocarbon event.	Beaudoin 1991

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Alpen Siding Lake	54.45	-113.00	10700±170	GSC-1093	marly gyttja	Unidentified radiocarbon event	Lowdon et al.1971,
Lofty Lake	54.44	-112.29	11400±190	GSC-1049	laminated gyttja	Unidentified radiocarbon event.	Lichti-Federovich 1970; Lowdon et al. 1971
			9130±150	GSC-1240	gyttja	Unidentified radiocarbon event.	
Athabasca	54.42	-113.15.30	10200±280	GSC-1380	freshwater gastropod shells	Shells may have been affected by hardwater.	Lowdon and Blake 1979
Freeman River	54.35	-115.00	12400±600	GSC-903	gastropods shells	Shells may be affected by hardwater.	Lowdon et al. 1971
Little Smoky River	54.21	-117.01	13510±230	GSC-694	fresh water gastropod shell	Shells may be affected by hardwater.	Lowdon and Blake 1968.
			13580±260	GSC-698	fresh water gastropod shell	Shells may be affected by hardwater.	
			12190±350	GSC-508	fresh water gastropod shells	Shells may be affected by hardwater.	Lowdon et al. 1967
Greencourt	54.15	-115.04	10200±170	GSC-861	gastropods	Shells may be affected by hardwater	Lowdon et al.1971
Clear Lake	54.14	-114.47.30	10400±200	GSC-1053	organic, silty clay	Unidentified radiocarbon event.	
Edson	53.59	-117.28	9560±190	S-1308	calcareous tephra	Unidentified radiocarbon event.	Rutherford et al. 1979
Lake Wabamun	53.33.30	-114.42.16	10090±2530	TX-2555	lake sediments	Unidentified radiocarbon event.	Holloway et al.1981; Jackson and Pawson 1984
			9890±2530	TX-2554	lake sediments	Unidentified radiocarbon event.	
			10400±390	TX-2558	lake sediments	Unidentified radiocarbon event.	
			10240±2290	TX-2556	lake sediments	Unidentified radiocarbon event.	

ndix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Lake Wabamun	53.33.30	-114.42.16	9520±1430	TX-2553	lake sediments	Unidentified radiocarbon event.	
			16180±980	TX-2560	lake sediments	Unidentified radiocarbon event.	
			11750±420	TX-2559	lake sediments	Unidentified radiocarbon event.	
			10300±3720	TX-2557	lake sediments	Unidentified radiocarbon event.	
Lake Wabamun	53.33	-114.35	9780±265	S-2051	sediment?	Unidentified radiocarbon event. Rejected by author due to coal contamination and by the fact that it is out of place stratigraphically.	Hickman et al.1984
			9805±550	S-2155	sediment?	Unidentified radiocarbon event.	
			9720±405	S-2050	sediment?	Unidentified radiocarbon event.	
Cooking Lake	53.31	-113.00	10900±190	GSC-2404	freshwater mollusk shells.	Freshwater shell may be affected by hard water.	Lowdon and Blake 1979
Moore Lake Series	53.31	-110.3	11300±170	GSC-2856	lake sediment	Unidentified radiocarbon event.	Blake 1984
Moore Lake Series	53.31	-110.3	9250±80	GSC-2858	lake sediment	Unidentified radiocarbon event.	Blake 1984
			10200±160	GSC-2921	lake sediment	Unidentified radiocarbon event	

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Pocahontas	53.13	-117.55	11900±120	GSC-3885	freshwater gastropod shell	Shells may be affected by hardwater.	Blake 1986
Mary Gregg Lake	53.07	-117.28	11000±120	GSC-2997	fibrous organic mud	Unidentified radiocarbon event. Unsure what plants made up the fibrous organic mud	Blake 1983
			9460±90	GSC-3073	fibrous organic mud	Unidentified radiocarbon event.	
			9690±130	GSC-3029	fibrous organic mud.	Unidentified radiocarbon event.	
			10300±220	GSC-2935	organic mud.	Unidentified radiocarbon event.	
Fairfax Lake	52.58	-116.34	11225±120	S-1705	lake sediment	Unidentified radiocarbon event.	Beaudoin 1983
Watchtower Basin	52.50.00	-117.50.00	9945±275	BETA-1480	peat	Peat was from fresh water lake deposits and may be contain aquatic plants affected by hard water.	Kearny 1981; Jackson and Pawson 1984
Lorraine Lake	52.44	-117.4	12350±440	AECV-431C	unknown	Unidentified radiocarbon event	Beaudoin 1993
Maligne Lake	52.44	-117.37.00	10850±300	BGS-627	wood, taxon unidentified	Sample contaminated by carbonates	Kearny 1981, Jackson and Pawson 1984
			13500±400	BGS-629	wood, taxon unidentified	Sample contaminated by carbonate.	
Lake Isle	52.37	-114.26	9530±120	DIC-917	Unknown	Unidentified material and radiocarbon event.	Hickman and Klarer 1981
Nordegg Pond	52.29	-116.06	10500±140	Beta 251481/ETH-3736	potomogeton seeds	Submerged plants may be affected by hardwater.	Mandryk 1992

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Rocky Mountain House	52.28.16	-114.32.00	10250±165	I-5675	shell	Shells may be affected by hardwater.	Harris and Boydell 1972; Jackson and Pawson 1984
Goldeye Lake	52.27	-116.12	11400±170	GSC-3543	lake sediment	Unidentified radiocarbon event.	McNeely 1989
			14500±180	GSC-3528	lake sediment	Unidentified radiocarbon event.	
North Saskatchewan	52.25.33	-114.16.38	10600±300	S-140	marl	Unidentified radiocarbon event.	McCallum and Wittenberg 1962
Horseshoe Lake Core series	52.21	-110.45	8600±435	S-1189	gyttja	Unidentified radiocarbon event.	Rutherford et al. 1979
			10180±160	S-1190	gyttja	Unidentified radiocarbon event.	Rutherford et al. 1979
Wilcox Pass	52.14.30	-117.13	9600±305	GX-8785	organic material?	Unidentified radiocarbon event.	Beaudoin and King 1990
Mitchell Lake	52.13	-115.00.30	17960±160	TO-574	*Sphaerium* shells	Shells may be affected by hardwater.	Mandryk 1992; Mancryk 1990
			11110±110	TO-572	gyttja	Unidentified radiocarbon event..	
			14740±130	TO-573	*Sphaerium* & *Psidium* shells	Shells may be affected by hardwater.	
Castleguard Meadows	52.08.06	-117.09.14	9600±300	BGS-490	organic sediments	Unidentified radiocarbon event.	Luckman and Osborn 1979; Jackson and Pawson 1984
Castleguard Cave	52	-117	10800±100	SFU-44	soda straw	Unidentified radiocarbon event	Nelson and Hobson 1982
			18090±280	SFU-46	soda straw	Unidentified radiocarbon event	

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Castleguard Cave	52	-117	18200±280	SFU-47	soda straw	Unidentified radiocarbon event	Nelson and Hobson 1982
			15590±200	SFU-49	soda straw	Unidentified radiocarbon event	
			13620±100	SFU-48	soda straw	Unidentified radiocarbon event	
Red Deer River Valley	51.43.00	-114.30.00	10700±150	I-5126	shell	Shell may be affected by hardwater.	Harris and Boydell 1972; Jackson and Pawson 1984
Banff National Park	51.42.30	-115.39.30	11220±680	WSU-881	shell	Shells may be affected by hardwater	
K&T Site	51.32.20	-112.14.19	19730±360	AECV-654C	organic material, containing roots of surface plants.	Uncertain of a specific radiocarbon event since it may contain soil as well as the roots.	Young et al.1999
Seward site	51.32.20	-112.05.30	9170±150	AECV-?	bulk sediments	Unidentified radiocarbon event.	
Courtney East	51.31.00	-112.19.20	12560±150	AECV-631C	bulk organics	Unidentified radiocarbon event.	
Copper Lake	51.18.35	-115.55.20	12870±370	BETA-11647	gyttja	Unidentified radiocarbon event.	White and Osborn 1992
			9740±140	RIDDL-665	monocot	Unknown whether this plant was aquatic or terrestrial.	White and Osborn 1992
			11000±120	GSC-4284	lake sediment, gyttja	Unidentified radiocarbon event.	White and Osborn 1992; McNeely and McCuaig 1991
			11370±180	BETA-11648	gyttja	Unidentified radiocarbon event.	White and Osborn 1992

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Cooper Lake	51.18.35	-115.55.20	8810±210	RIDDL-666	monocot	Unknown whether this plant was aquatic or terrestrial.	
			9430±180	BETA-11646	gyttja	Unidentified radiocarbon event.	
Cochrane	51.10.00	-114.29.00	9650±160	I-5676	shell	Freshwater shell may be affected by hard water.	Harris and Boydell 1972; Jackson and Pawson 1984
Sibbald Creek	51.03	-114.52	9570±320	GX-8808	charcoal, taxon not identified	From compacted soil horizon and consisting of flecks of charcoal from a number of sources. Possibly from forest fires or a hearth or washed in from above (different levels)	Beaudoin 1986
Fish Creek	50.55.40	-114.05.10	13900±700	BGS-619	soil and organic matter	Unidentified radiocarbon event.	Brock Geological Survey laboratory form.
Little Sand Hill Creek	50.5	-111.5	9080±70	TO-959	gastropod shells	Unidentified radiocarbon event.	Evans and Campbell 1992
Toboggan Lake	50.46	-114.36	15490±70	TO-653	*Pisidium* species (snail)	Shell may be affected by hardwater..	MacDonald et al. 1991
			11070±70	TO-652	*Pisidium* species (snail)	Shell may be affected by hardwater..	
			12520±70	TO-654	*Pisidium* species (snail)	Shell may be affected by hardwater..	
			9460±80	TO-1047	organic lake sediments	Unidentified radiocarbon event.	
			16130±80	TO-150	*D. crassicostatus*	Aquatic plant that could have been affected by hardwater.	

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Tobaggan Lake	50.46	-114.36	13620±130	TO-303	organic lake sediment	Unidentified specific radiocarbon event probably made up of aquatic plant that could be affected by hardwater.	MacDonald et al. 1991
			10430±70	TO-655	*D. crassicostatus* (moss)	Freshwater aquatic moss that could have been affected by hardwater.	
Chalmers Bog	50.39	-114.33	18400±1090	GSC-2670	*D. crassicostatus*	Aquatic moss that is affected by hardwater.	Mott and Jackson 1982
			18300±380	GSC-2668	*D. crassicostatus*	Aquatic moss that is affected by hard water.	
Longview	50.32.30	-114.22.30	10600±100	GSC-2162	freshwater gastropod shells (*Stagnicoal elodes*)	Shells may have been affected by hardwater.	Lowdon et al. 1977
Willow Creek	50.09	-113.59	9290±260	GSC-236	freshwater gastropod shells	Shells may be affected by hardwater.	Dyck et al. 1965
Bain Bluff	50.08.05	-110.34.20	10200±240	GSC-1061	shell, terrestrial gastropod	Shells may be affected by limestone bedrock.	Lowdon et al. 1971
Lindoe, EaPo-100	50.08	-110.36	9900±120	S-230	carbonaceous sediments	Unidentified radiocarbon event. Unknown what made up sediment.	Rutherford et al. 1984; Morlan 2001; Bryan 1980
Foremost	49.51.05	-110.25.37	10550±350	I-1877	shell fragments, *Stagnicola palustris*	Shells may be affected by hardwater.	Bik 1968; Jackson and Pawson 1984

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Waldron Ranch	49.48	-114.07	9560±90	GSC-141	charcoal, taxon not identified	Material was collected over 10 foot interval and from below an ash layer (Mazama?). Thus date is an average and may cover considerably more than 3000 years.	Dyck and Fyles 1964
Kipp North Section	49.46.30	-113.01.30	10600±280	GSC-1501	freshwater gastropod shells	Shells may be affected by hardwater.	Lowdon and Blake 1975
Elkwater	49.41	-110.2	10230±150	I-4927	unknown, possibly soil	Unidentified radiocarbon event.	Vreeken 1987
Cowley	49.40	-113.59	10400±200	I(GSC)-211	freshwater gastropod	Shells may be affected by hardwater.	Trautman and Walton 1962
Blood Indian Reserve	49.32.30	-112.56.30	10620±250	GSC-161	organic matter	Unidentified radiocarbon event.	Dyck and Fyles 1964
Southwest Blood Indian Reserve	49.18.30	-113.34	10000±130	GSC-220	humus	Unsure of a specific radiocarbon event is being dated in the soil.	Dyck et al.1965
Saskatchewan							
Fontaine Lake	57.12.52	-109.03.25	9230±120	GSC-4832	woody, sandy gyttja	Lake sediments. Uncertain of what species of plants formed the gyttja.	McNeely and Jorgensen 1993
Long Lake	56.51.40	-108.59.20	11100±150	GSC-4807	basal detritus gyttja	Unidentified radiocarbon event.	
Nipawin Bay	56.24.28	-108.33.00	10600±120	GSC-4821	basal gyttja	Unidentified radiocarbon event.	
La Ronge South	55.03	-105.26	10200±110	S-1588	marl	Unidentified radiocarbon event.	Rutherford et al. 1984

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Waterhen River	54.27	-109.12	9935±65	S-964	peat	Unknown what species of plants (moss) contributed to the peat. Hard water may affect submerged plants	Rutherford et al. 1979
Prince Albert National Park	53.48	-106.04	10260±170	GSC-647	basal organic sediment	Unidentified radiocarbon event.	Lowden et al. 1967
Ladder Valley	53.46	-106.54	11610±450	GX-2254	organic silt	Unidentified radiocarbon event.	Christiansen 1979
Sturgeon Lake series	53.25	-106.00	8950±150	S-253A	marl	Unidentified radiocarbon event	McCallum and Wittenberg 1968
			9100±150	S-243	marl	Unidentified radiocarbon event	
Nipawin	53.18	-104.04	10270±590	S-2166	carbonaceous silt	Unidentified radiocarbon event.	Rutherford et al. 1984
Prince Albert	53.14.15	-105.43.30	11560±640	GSC-648	organic sand	Unidentified radiocarbon event.	Christiansen 1979; Lowden et al. 1967
Marsden	52.53	-109.54	19200±400	S-228b	organic fraction	Unidentified radiocarbon event.	McCallum and Wittenberg 1968
			18000±450	S-228A	carbonate fraction	Unidentified radiocarbon event. Uncertain what plants made up the carbonate fraction.	McCallum and Wittenberg 1968
Cutknife Hill	52.50.30	-108.53	11090±160	GSC-642	basal organic silt and sand	Unidentified radiocarbon event.	Lowden et al. 1967

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Evesham	52.29	-109.57	15850±225	S-300B	carbonaceous silt	Unidentified radiocarbon event	Christiansen 1979; Christiansen 1968; McCallum and Wittenberg 1968
			14670±240	S-300A	carbonaceous silt	Unidentified radiocarbon event.	
			12725±135	S-401A	carbonate sample of silt	Unidentified radiocarbon event	McCallum and Wittenberg 1968
			18000±275	S-401B	organic sample of silt	Unidentified radiocarbon event.	
Saskatoon Gowen site	52.05.45	-106.42.20	8930±320	S-2184	organic clay	Unidentified radiocarbon event.	Rutherford et al.1984
			9460±240	S-2035	organic clay	Unidentified radiocarbon event.	
Goodale Farm	52.03	-106.3	10730±280	S-1180	carbonaceous silt	Unidentified radiocarbon event.	Rutherford et al.1979
			9290±155	S-1179	carbonaceous silt	Unidentified radiocarbon event.	
Agar Slough	52.03	-106.3	10560±255	S-1194	carbonaceous silt	Unidentified radiocarbon event.	
			9630±230	S-1193	carbonaceous silt	Unidentified radiocarbon event.	
			9300±220	S-1192	carbonaceous silt	Unidentified radiocarbon event.	
Agar Slough	52.03	-106.29	9620±210	S-1196	carbonaceous silt	Unidentified radiocarbon event.	Rutherford et al. 1979

Appendix A Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Martens Slough	52.02	-106.29	10240±250	S-1198	carbonaceous silt	Unidentified radiocarbon event.	Rutherford et al. 1979
			11070±245	S-1199	carbonaceous silt	Unidientified radiocarbon event.	
Quill Lake	51.48	-104.19	11000±150	S-292	gyttja	Unidentified radiocarbon event	McCallum and Wittenberg 1968
Biggar	51.27	-107.59	9200±150	S-239	marl	Unidentified radiocarbon event	
Yorkton	51.12.36	-102.28	10300±80	GSC-1356	wood and organics, taxon not identified	Unidentified radiocarbon event. Uncertain of origin of the organics.	Lowdon and Blake 1976
Leader	50.58.54	-109.21.47	20000±850	S-176	organic residue from A horizon	Unidentified radiocarbon event.	McCallum and Wittenberg 1965; Christiansen 1968
Old Wives	50.56	-105.59	9400±160	S-236	organic	Unidentified radiocarbon event.	McCallum and Wittenberg 1968
			12000±180	S-235	marl	Unidentified radiocarbon event	
Clearwater Lake	50.52.25	-107.56	9310±150	GSC-1506	lake sediments (inorganic)	Unidentified radiocarbon event.	Mott 1973
Empress Bluff	**50.50.50**	**-109.58.00**	10500±180	GSC-1332	fresh water gastropod shells *Lymaea elodes* Say)	Shells may be affected by hardwater.	Lowdon et al. 1971

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Lancer	50.48.52	-108.56.14	10250±150	S-174	snail and pelecypod shells	Shell may be affected by hardwater. Calcareous sand suggests hardwater.	McCallum and Wittenberg 1965
Qu'Appelle Valley	50.46	-104.39	12100±160	S-151	travertine	Unidentified radiocarbon event.	
Matador	50.44	-108.02	11620±130	S-248	organic clay	Unidentified radiocarbon event.	McCallum and Wittenberg 1968
Mission Lake series	50.43	-103.46	9735±120	S-1172	carbonaceous silt	Unidentified radiocarbon event.	Rutherford et al. 1979
Boyer	50.23.39	-108.58.26	9250±150	S-175	black organic silt	Unidentified radiocarbon event. Uncertain what went into the organic silt.	McCallum and Wittenberg 1965
Lillestrom	50.20	-105.54	10270±150	S-188	gyttja	Unidentified radiocarbon event. Unknown what made up the gyttja.	
			10630±150	S-189	gyttja	Unidentified radiocarbon event. Unknown what made up the gyttja.	
			11650±150	S-190	gyttja	Unidentified radiocarbon event. Unknown what made up the gyttja.	
Crestwynd	50.06	-105.42	10710±250	GSC-618	carbonaceous material	Unidentified radiocarbon event.	Lowden et al. 1967
Galilee Junction	49.55	-105.33	10900±700	S-123	marl	Unidentified radiocarbon event.	McCallum and Wittenberg 1962
Ormiston	49.54	-105.27	15200±260	S-241	silty marl	Unidentified radiocarbon event.	McCallum and Wittenberg 1968
Fleming Creek	49.49.20	-109.29.00	14000±340	GSC-4675	shells	Shells may be affected by hardwater.	McNeely and McCuaig 1991; Klassen 1993

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Fleming Creek	49.49.20	-109.29.00	13120±80	TO-694	shells	Shells may be affected by hardwater.	Klassen 1993
Niska Site, DkNu-3	49.44	-107.24	10880±70	TO-956	charcoal, taxon not identified	Multiple radiocarbon events.	Meyer and Liboiron 1990
			8480±650	S-2510	charcoal or paleosol	Multiple radiocarbon events.	Meyer and Liboiron 1990; Morlan 2001
Harris Lake	49.4	-109.54	9120±250	S-2908	plant macrofossils	Unknown if plants are terrestrial or submerged aquatic plants.	Sauchyn 1990; Klassen 1993.
Antler	49.35	-103.52	11050±860	S-1801	carbonaceous layer	Unidentified radiocarbon event.	Rutherford et al. 1984
			18140±6610	S-1803	snail shells	Unknown what species of snail shell. Freshwater aquatic snails shells can be affected by hardwater.	
			11310±470	S-1802	carbonaceous layer	Unidentified radiocarbon event.	
Ceylon	49.26	-104.37.30	13000±200	S-173	marl	Unidentified readiocarbon event.	McCallum and Wittenberg 1965
Robsart (Horsemen Site)	49.13.20	-109.10.40	14340±100	TO-310	peat	Unknown what type of plants (moss) contributed to the peat.	Klassen 1993
			10000±130	GSC-4273 or (GSC-4270)	peat	Unknown what type of plants (moss) contributed to the peat.	McNeely and McCuaig 1991; Klassen 1993
			10200±140	GSC-4266	peat	Unknown what type of plants (moss) contributed to the peat.	

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Loomis (Ham site)	49.04.05	-108.45.20	12630±80	TO-216	shells (*Pisidium*)	Shells may have been affected by hardwater.	Klassen 1993
Sites Rejected at Question 5							
Yukon							
Dominion Creek	63.48	-138.41	12200±100	GSC-2641	seeds, plant stems and feces	Plants and seeds not identified so uncertain which fractionation value to add to make date conventional.	Blake 1984
British Columbia							
Rocky Mountain Portage	56.00.00	-122.07	11600±?	I-2244A	collagen, mammoth tusk	sample to small to provide an error estimate. Researcher dismissed it as too young.	Mathews 1978; Mathews 1980
Rocky Mtn Trench	52.07	-118.24	18450±340	WAT-130	wood, spruce	other dates from the same wood sample indicated an age in the range of 25000 BP.	Berry and Drimmie 1982
Alberta							
Seward site	51.32.20	-112.05.30	17060±180	TO-1143	collagen, rodent bone (taxon not identified)	Date was rejected. Sample might have been contaminated with modern carbon from roots or by translocation of organic colloids. Bone was badly preserved producing only 1/20 collagen recovered from the Winter site.	Young et al. 1999

Appendix A. Rejected Radiocarbon Dates

Site Name	Latitude d.m.s	Longitude d.m.s	Date B.P.	Lab. No.	Material	Reasoning	References
Vermilion Lakes	51.10.36	-115.38.40	10900±270	SFU-314	charcoal, taxon not identified	Rejected due to inadequate pretreatment.	Hobson and Nelson 1984; Fedje et al.1995
			11500±300	SFU-316	charcoal, taxon not identified	Rejected due to inadequate pretreatment.	Hobson and Nelson 1984
			9200±1300	SFU-349	wood, taxon not identified	rejected for inadequate pretreatment.	Fedje1986; Fedje et al.1995
			9800±400	SFU-318	charcoal, taxon not identitified	Rejected due to inadequate pretreatment.	
			9400±400	SFU-317	charcoal, taxon not identified	Rejected due to inadequate pretreatment.	
			8950±600	SFU-347	charcoal, taxon not identified	Rejected due to inadequate pretreatment.	
			11000±500	SFU-348	wood, taxon not identified	Rejected due to inadequate pretreatment.	
			11700±290	SFU-346	charcoal, taxon not identified	Rejected due to inadequate pretreatment.	Hobson and Nelson 1984
Crowsnest Pass	49.40.00	114.35.00	14470±610	RL-362	charcoal	rejected, conflicts with other point types and other dates.	Driver 1978; Jackson and Pawson 1984
Bellevue, DjPo-81	49.29	-114.36	9860±320	na-39	collagen, bison bone	Unknown lab so uncertain if it is a conventional date.	Driver 1978

APPENDIX B

CD-ROM OF ADDITIONAL RADIOCARBON DATES

The CD-ROM of Additional Radiocarbon Dates is appended in the pocket on the back cover and is part of this work. The data file requires Access 2000 or compatible software to view and the text files a text editor or word processing software. Files and their size on this CD-ROM are:

• OtherDates.mdb	524 KB
• README.txt	2 KB
• README.rtf	2 KB

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