

**RADIOCARBON CHRONOLOGY FOR  
GLACIAL LAKE PEACE**

by

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## ABSTRACT

The Peace River area of northeastern British Columbia and northwestern Alberta lies astride the hypothesized "ice-free corridor." Recent research has shown that it is likely the corridor was open in this area during the Late Wisconsinan period. The area, however, was inundated by proglacial lakes impounded by retreating Laurentide ice. The nature and duration of these water bodies is largely unknown, as relict shorelines are fragmentary and distorted by post-glacial rebound. Direct  $^{14}\text{C}$  dates from these features are rare.

This thesis examines eleven new radiocarbon dates from glacio-lacustrine deposits in the area. Two sets of dates from the Charlie Lake region argue for ice-free conditions being terminated by an expanding pro-glacial lake which was impounded by continental ice sometime before 22,000 years B.P. This encroachment may have been much earlier, perhaps 33,000 years ago, but the evidence for this remains equivocal. The area may have been overridden by ice sometime after 15,800 years B.P.

A Holocene lake, perhaps equivalent to Charlie lake, existed in the upper reaches of the Red Creek drainage near Fort. St. John. The lake would have been left as a remnant following the draining of glacial Lake Peace circa 10,380 years B.P. The lake drained sometime after 4245 years B.P.

A  $^{14}\text{C}$  date from Tumbler Ridge coming from the lowest of three terraces relating to ice retreat, indicates that deglacial conditions were well under way by 10,380 years B.P. An arm of glacial Lake Peace probably extended up to the head of the Murray River Valley. Possible correlations with two early phases (Bessborough and the "unnamed") of glacial Lake Peace are noted. Such correlations would indicate that the existence of lower phases of Lake Peace must have extended into the Holocene.

It is also hypothesized that the Clayhurst phase of Lake Peace correlates with the lowest terrace at Tumbler Ridge. This indicates the last high phase of Lake Peace drained sometime after circa 10,380 years B.P. and that a north to south component of isostatic rebound, dominated by western ice, is evidenced on the order of 0.6m/km.

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## CHAPTER ONE

### INTRODUCTION

The study area generally lies within the Peace River District of northwestern Alberta and northeastern British Columbia. The term "generally" is considered one as the glacial lakes with which this thesis is concerned, covered much of the area at times, but exact temporal and areal limits remain unknown. The radiocarbon dates this thesis presented here define a more specific area extending along the 121° W meridian from Fort St. John to Tumbler Ridge B.C. (Figure 1).

The Peace River region of northwestern Alberta and northeastern British Columbia has an interesting and complex glacial history. The location sits astride a zone where both coalescence of Cordilleran and Laurentide ice, as well as the "ice-free corridor" have been hypothesized (Mathews, 1980; Liverman, 1989). Recent research has followed an evolutionary trend away from multiple coalescing western and eastern glaciations to two western glaciations asynchronous with one Laurentide glaciation, resulting in an ice-free corridor (Bobrowsky, 1988; Liverman, 1989).

This theorized corridor has important implications for both paleontological and archaeological research. Many researchers suspect this was the entry route for humans and Old World faunas to the New World during glacial periods (Reeves, 1973, Harington, 1980). Although the corridor was probably ice-free, large lakes impounded by the ice masses, may have constrained migration through the corridor for large periods of time.

The ice-impounded or proglacial lakes may have an even more complicated history than that of the associated ice sheets. The lakes seldom existed as a stable water body, instead they constantly changed both shoreline elevations and limits as new outlets were formed by advances or retreats of the impounding glacial margins. The abandoned shorelines or strandlines of these

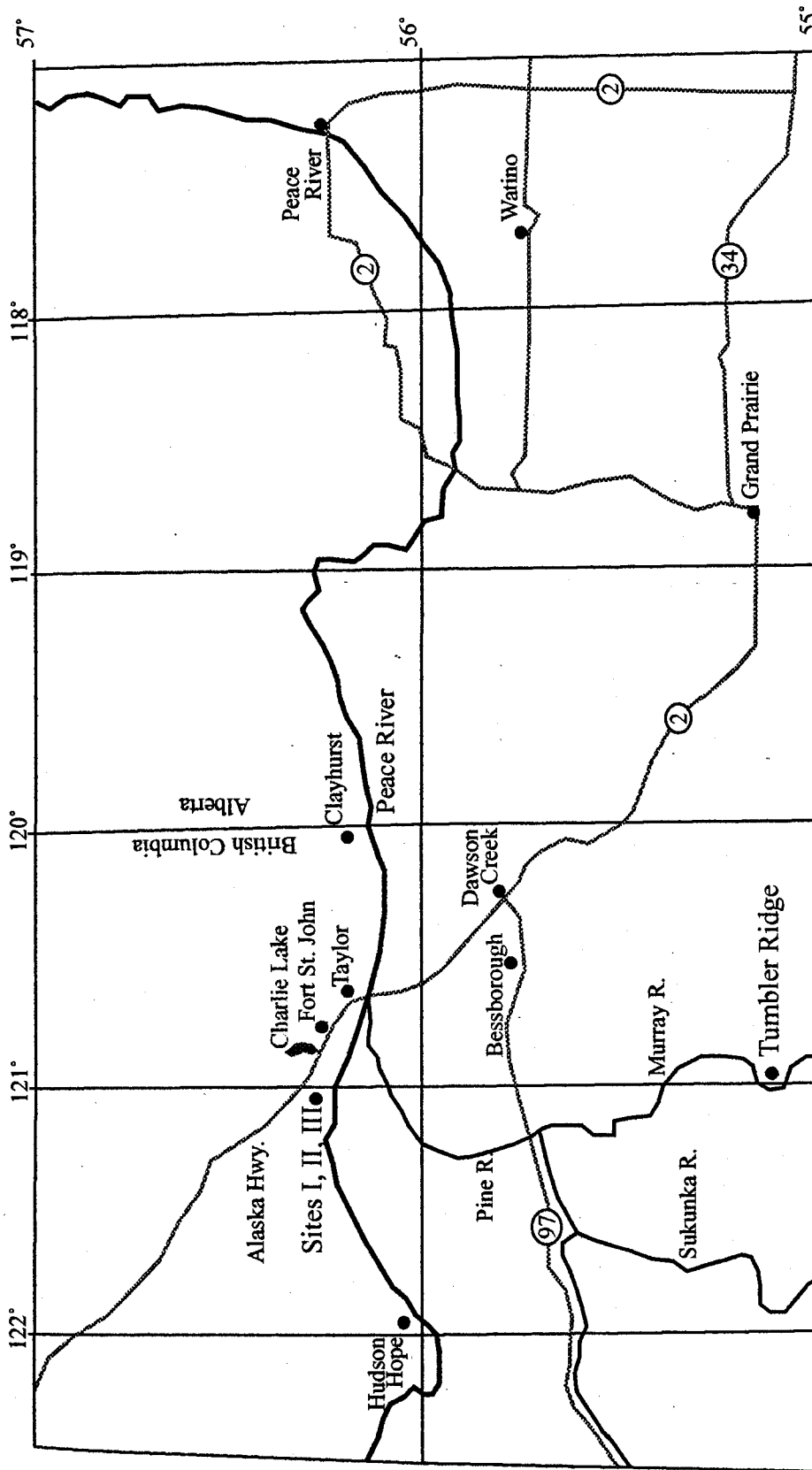


Figure 1  
 Location Map,  
 northeastern British Columbia  
 and  
 northwestern Alberta

proglacial lakes record the various water-levels and limits. Interpretation, however, is made difficult by the fragmentary nature of this record and a post-glacial distortion that results in originally horizontal strandlines becoming tilted with the upward side of this tilt trending towards the retreating ice mass.

This deformation is termed glacio-isostasy. The term refers to the deformation of the earth's crust due to the presence of an ice-mass constituting a load greater than the strength of the underlying material in the upper mantle. During glaciation, the equilibrium between the crust and the mantle is upset, resulting in crustal subsidence with both plastic and elastic deformation taking place (Flint, 1971). Deglaciation removes the overlying burden and the pre-existing equilibrium condition attempts to re-establish itself. The amount of uplift or recovery is regulated by the degree to which the original land surface was depressed, consequently those areas near the ice-sheet's periphery rebound less than those areas closer to the center. Isostatic deformation, in the Peace River region of British Columbia, seems to have been dominated by western ice as relict shorelines are higher in the west (Mathews, 1978a).

Local glacial terminology has also undergone an evolution. Specifically, the term Cordilleran has taken on new meaning as new research recognized the three glacial systems which have affected the area. The majority of published research previous to Mathews (1978a) had assumed that all ice emanating from the west was part of the Cordilleran Ice Sheet. Mathews (1978a) showed that local "Rocky Mountain Ice" should be considered a separate entity.

Bobrowsky and Rutter (1992), following Mathews (1978a, 1978b), made a clear distinction between "Montane" and "Cordilleran" ice. Montane ice referred to local ice centers to the east of the Rocky Mountain Trench, while Cordilleran refers to ice originating from centers to the west of the Rocky Mountain Trench. Therefore, Cordilleran ice east of the Trench must be associated

with a coalescent ice mass during periods of extensive glaciation. In general the non-Laurentide glacial evidence in the glacial Lake Peace area, although often referred to as Cordilleran in the literature may have been Montane and maybe associated with local ice centers and smaller events.

This thesis adopts the original term as given by the author of the work being discussed especially those writing prior to Mathews (1978a) regardless of the glaciation's origin. Some of the glaciations discussed as Cordilleran could be Montane, however it would be incorrect to re-interpret past field work on this basis. In addition the point is somewhat moot, as many of the sediments from early works interpreted as "Cordilleran glaciations" have been shown to be non-glacial in origin. The term "Montane", therefore, is used only when discussing glaciations referred to in the original work as "Montane" or "Rocky Mountain."

## **Methods**

The intent of this thesis was to:

- 1) Measure, map and describe the trend of the isostatically deformed shorelines of glacial Lake Peace.
- 2) Critically evaluate the area's late glacial history (as evidenced by a literature review) as it pertains to the abandoned lake levels (shorelines).

The proposed procedure involved using standard stereoscopic aerial photography in combination with ground truth measurements and topographic maps to: 1) identify abandoned shorelines and 2) measure elevations at points along these structures and ascertain the trend of uplift (isostasy) of the proglacial strandlines relating to glacial Lake Peace.

Strandline elevations were proposed to be determined via a modified Zeiss G-2 analytical stereoplotter. This instrument relies on a precise set of ground truth measurements input to allow construction of a "stereo model" allowing precise elevational measurements to be determined. Distortions inherent in aerial photography are identified and corrected.

In addition to the photometric study an examination of a series of unpublished radiocarbon dates obtained by Dr. A. C. B. Roberts in 1984 from lacustrine sediments in the Fort St. John area was accomplished. The dates are controversial as they range from approximately 16,000 to 33,000 years B.P. suggesting that glacial Lake Peace, or it's predecessor, was extant from the Mid-Wisconsinan to the early Late Wisconsinan. In an effort to reexamine and redate the section from which these sediments were taken a field excursion was undertaken in fall 1990. It was determined the original section had probably been destroyed by slumping or road excavation but a similar organic rich sediment in the same area was located from which samples were taken and dated.

Lastly, an examination of a bison skull found in a glacial lake delta at Tumbler Ridge B.C. was accomplished. Measurement of the well preserved skull, would allow speciation of the animal and radiocarbon assay would date the glaciogenic deltaic sediments from which it was derived.

Unfortunately, all these objectives were not achieved . The photometric examination, mapping and determination of the areas strandlines and associated isostatic deformation was abandoned. This was due, in part, to the fact that a field manual containing the ground truth data was lost somewhere between a previous graduate student, who had collected the data, and this researcher. This factor alone, although a significant setback, did not make the photometric study impossible. Height determinations of strandlines could have continued through the use of published shoreline locations and elevations in conjunction with topographic maps using bench marks and



photographically recognizable contour line crossings. The determining factor proved to be the lack of confidence this researcher had in photo-interpretation of strandlines without a field component to back up the observations.

Much of the Fort St. John/Peace River area is underlain by sandstones known as the Dunvegan Formation (Mathews, 1963). The sandstones frequently outcrop near surface displaying linear features similar in appearance to wave cut structures, which combined with the subtlety of previously mapped and published shoreline traces as displayed on aerial photographs convinced this researcher that any data so gathered would be largely spurious.

This study, therefore, examines a series of eleven new radiocarbon dates from the Peace River area of northeastern British Columbia. These determinations directly date lacustrine events ranging from the Mid-Wisconsinan to the middle Holocene period. The following literature review provides the geomorphological context into which these dates are placed.

## CHAPTER TWO

### HISTORY OF QUATERNARY RESEARCH ON PROGLACIAL LAKES AND RELATED PHENOMENA IN NORTHEASTERN B.C. AND NORTHWESTERN ALBERTA

#### Early Research

The first recorded European exploration of the area was undertaken by Alexander Mackenzie (1801) in 1792/93. Simon Fraser (1808) established fur trading posts in 1805. The Hudson's Bay Company and the North West Company were actively trading in this area throughout the Nineteenth Century (McLean, 1849; Simpson, 1872).

Selwyn (1877) was the first Geological Survey of Canada geologist to traverse and examine this area. In 1875 Selwyn, accompanied by Macoun and Webster, travelled from Quesnel, *via* McLeod Lake, the Pine and Smoky rivers, to Fort St. John and back to Quesnel. From the point of view of surficial geology their comments were restricted to observations of "drift" throughout the Peace River basin often including thick deposits of sand, gravel and clay, upon occasions interbedded.

Dawson (1881) travelled through this area in 1879/80 and made detailed observations regarding the surficial geology and the nature and sources of these deposits. Dawson was the first to formally recognize the lacustrine nature of these extensive deposits and to associate them with a large proglacial lake throughout this area. He also made several observations concerning deposits from the Montane and Laurentide ice sheets. He believed that the presence of both Laurentian and Montane gravels and boulders was a result of floating ice from these two sheets calving into this glacial lake and therefore being deposited in the same area as a result of their drifting and melting.

Hage (1944) made several observations on Pleistocene material and reported extensive lacustrine deposits in many of the river valleys between Fort St. John and Fort Nelson. He cites several well-logs showing thick glacial and lacustrine deposits and suggested that differences in the lithology of the tills show Montane and Laurentide influences.

McLearn and Kindle also reported extensive glacial deposits in many valleys in northeastern British Columbia including lacustrine deposits that were "laid down in the numerous temporary lakes that formed near the melting ice fronts" (McLearn and Kindle, 1950:18). They also speculate regarding ice coalescence but were not able to specify any locations on the Peace River basin although they cite Williams (1944) as suggesting that the Laurentide ice extended into the foothills to the west of Fort Nelson. Williams also made reference to a general depression of the land by 183 to 213 m (600 to 700 feet) from the weight of the ice and the subsequent erosion caused by regrading of the landscape.

Holland (1964) briefly referred to two stages of Lake Peace. One at 838 m (2,750 feet) and a lower, younger stage controlled by an outlet at 689 m (2,260 feet). He also pointed out that unequal ice-loading and time differences during melt resulted in differential isostatic uplift of glacial Lake Peace shorelines of as much as a few feet per mile. He did not however, specify locations where this was observed, procedures used for the observations or references.

Much of the research on proglacial lakes and the Quaternary history of the Peace River region of British Columbia has occurred across the border in Alberta. Rutherford (1930) discussed the nature of the lacustrine deposits in the Lesser Slave Lake area. He suggested that the Peace River drained to the east through Lesser Slave Lake during the retreat of continental ice from the region.

Taylor (1958 republished 1960) contains a composite shoreline map of a body of water named Lake Peace, occupying a large area of north-central Alberta, with a comparatively small area in B.C. This is the first formal use of the name Lake Peace, although Hage had informally used it in reports prepared for the Shell Oil Co. (Mathews, 1980)

Further work on lake deposits in the area, as reported by Taylor (1960), was accomplished by Beach and Spivak (1943), Hage (1944), and Allan and Carr (1946). The Alberta Soil Survey was responsible for a large body of work wherein the soils of the Alberta portion of the Peace River Area were mapped and their water-laid character reported. These include Odnysky and Newton (1950), Odnysky et al. (1952), Wynnyk and Odnysky (1954), Odnysky et al. (1956), Lindsey et al. (1958, 1959, 1960), and Wynnyk et al. (1961) These works report upper limits of (various) Pleistocene lakes to be 938 m (3225 feet) along the Wapiti River, 945 m (3100 feet) on the upper Porcupine River, 792 m (2600 feet) in the Woking area, 762 m (2500 feet) near Grand Prairie, 732 m (2400 feet) to the south of Rahab, 701 m (2300 feet) at Sturgeon Lake, 686 m (2250 feet) in the Lesser Slave Lake region, 671 m (2200 feet) along the Little Cadotte River and lastly, 640 m (2100 feet) south of the junction of the Smokey and Little Smokey Rivers. Odnysky et al. (1952), also reported possible shoreline traces near 640 m and 655 m elevation (2100 and 2150 feet) to the north and south of High Prairie. Bobrowsky et al. (1987) reported that in the Grande Prairie, area the majority of deposits below 800 m (2,625 feet) are post-glacial lacustrine in origin.

Taylor noted that the last stage of Lake Peace had an elevation of about 533 m (1750 feet) after which it underwent confluence with Lake Tyrrell. Lake Tyrrell was a body of water formed first in the Athabasca basin and enlarged by it's confluence with Lake Peace (Taylor, 1960)

Taylor (1960), citing the above data, noted that no allowance for glacio-isostatic deleveling was reported. He cited Upham (1890), who reported a differential uplift on the order of 0.28 m/km (1.5 feet/mile) in western Manitoba along a north to northeast ascent; Johnston (1946), who found a value of greater than 0.22 m/km in southwestern Manitoba along the same north to northeastern axis, and; Kroger (1958), whose work along Great Bear Lake in the Northwest Territories discovered uplift of some 115 feet in 100 miles or 0.28 m/km (1.5 feet/mile) with the greatest uplift in the east.

Henderson (1959) undertook a study examining the surficial geology of the Sturgeon Lake map area in Alberta. He reported evidence of four glacial episodes in his study area, three of which date to the Wisconsinan. Henderson's analysis of the area's proglacial lakes is complicated and relies on several readvances of ice to explain the lacustrine deposits he found. He reported lacustrine sediments extending over a large portion of the study area.

Henderson (1959) stated that he found three till sheets with the possibility of a fourth in the Sturgeon Lake map-area. The poorly defined, and lowest till was termed "ancient" and assigned to either the Nebraskan or Kansan glaciation. The till overlying this ancient unit was referred to by Henderson as the "Lower Till" (Henderson, 1959:68). It is widespread but exposed only in areas of deep gullying. The age of this unit is poorly known, as both early Wisconsinan and pre-Wisconsinan ages are mentioned as a possibility, Henderson favoured the latter.

The "Middle Till" (Henderson, 1959:69) was reported to be continuous over most of the study area. Henderson believed this till was deposited when, "the full flood of Laurentide ice attained a thickness in the order of thousands of feet and extended at least as far as Nose Mountain south of the Wapiti River, more than 70 miles west-southwest of the area.". Henderson reported that the top of Nose Mountain at 1524 m was not covered by the Laurentide ice-sheet but by Cordilleran

ice. He supported his argument with data showing erratics of both eastern and western provenance scattered over the summit of Nose Mountain (Allan and Carr, 1946 in Henderson, 1959). The age of this till sheet was thus dated to the Iowan-Tazewell substage of the Wisconsin stage; today this period of time would more likely be referred to as the Early Wisconsinan (Charlesworth, 1957). Henderson based this age on: depth of leaching, state of stream dissection, comparison of the character of the different till surfaces, and the existence of an overlying upper till.

The "Upper Till" (Henderson, 1959:71) was ascribed to substage magnitude rather than minor readvance. He did this for the following reasons:

- 1) Complete draining of the pro-glacial lake resulting from the antecedent ice had taken place before the last ice entered the area. Henderson stated that this would require retreat of the impounding ice sheet for some distance down the Peace River valley. He also stated that loess derived from the exposed lacustrine deposits was found over the middle till but not over the upper till.
- 2) Between the deposition of the middle and upper till enough time elapsed for "pronounced periglacial modification" (Henderson 1959:72) of the abandoned lake beds and till slopes.
- 3) Depth of leaching. The upper till is leached to only 0.76 m whereas the middle till shows modification down to 1.0 m.
- 4) The end moraine associated with the upper till (Fish Creek moraine) shows little or no evidence of modification, as do the older ground moraines farther south.

In light of the above evidence Henderson assigned the upper till to the Cary substage.

Radiometric dating and more complete stratigraphies have placed the Cary substage within the last 25,000 years (Flint 1971). The Middle Wisconsinan is largely thought of as a time when ice had retreated from most of western and southern Canada (Fulton, 1984), therefore, for the above reasons, Henderson's "Upper Till" is probably better ascribed to the Late Wisconsinan.

Henderson's (1959) history of the glacial lakes in the area, is complicated and must be examined in detail before reasonable correlations can be drawn with the work of other researchers. He adopted the name "Lake Rycroft", which had been proposed by W.H. Mathews at a conference on soil correlation in 1951 (Mathews, 1980). At this conference, Mathews had proposed the name Lake Rycroft to be used for a lake represented by shorelines at 685 m (2250 feet) near Rycroft, Alberta. Similarly, Mathews had proposed that the name Lake Bessborough be used when discussing a lake with shorelines at about 840 m (2750 feet) elevation near the town of Bessborough, British Columbia. The problem arose when Henderson incorrectly adopted "Rycroft" for the water body Mathews intended to be called "Bessborough." This error would see Henderson's "Lake Rycroft" having no shoreline anywhere close to the town after which it was named (Mathews, 1980).

Henderson (1959) stated that the first clear record of a glacial lake in the area, as shown by surficial deposits of silt and clay, came in the form of Lakes Puskwaskau I and Valleyview I. He considered these lakes to have been formed upon advance and retreat of "early Wisconsin" ice. This dating was based on depth of leaching in till, depth of stream dissection, and till surface modification. Beaches of the extinct lakes, he reported, are poorly developed and fragmentary, with the exception of one strandline at 663 m (2175 feet) attributed to Lake Valleyview (no stage number given). The water body occupied the Little Smoky River basin and along with Lake Puskwaskau I are attributed to the early Wisconsinan.

Ice retreat eventually opened the lower elevations of the Peace River Valley and Lake Falherl was formed (Henderson, 1959). The evidence for this must be considered equivocal, however, as Henderson stated that the shorelines and bottom deposits were "largely or perhaps totally destroyed" (Henderson, 1959:76), with evidence for the lake's existence presumably being based upon the large amount of silt and clay incorporated into the overlying till. St.Onge (1972),

however, uses the term Lake Fahler when discussing Late Wisconsinan ice retreat in the same area. The overriding till sheet, although not expressly stated, must have been Henderson's "Upper Till" of the Late Wisconsinan.

The readvance of ice up the Peace and into the Lower Smoky basin, Henderson (1959) maintained, brought about the formation of Lake Falher 2. Continued ice advance contributed to the development of lakes Puskawskau 2 and Valleyview 2, with the final stage being named Lake Falher 3 (which formed upon the ice's final retreat.) All stages of Lake Falher, according to Henderson, could have had western limits extending through the Peace River basin possibly into British Columbia. He noted three poorly developed shorelines correlated with this waterbody; the first, and most westerly is at 584 m (1915 feet), a second shoreline at 593 m (1945 feet) and a third at 599 m (1965 feet).

Henderson (1959) also noted that the shoreline elevations are distorted due to post-glacial isostasy. Based on the elevations of correlative clay-till contacts, Henderson quoted figures ranging from 2.0 m to 3.75 m per 8 km (1.4 to 2.5 feet per mile) rising northeasterly. He went on to say that one possible shoreline correlation would give figures in the range of 2.45 m to 6.1 m per 8 km (2 to 4 feet per mile) northeasterly.

St. Onge (1972) examined glacial lakes occurring in north central Alberta from Red Deer northwest to Watino. His interpretation closely followed the ideas of W.H. Mathews (1978a, 1980). St. Onge (1972) cited a series of radiocarbon determinations supporting his chronology. He stated that the entire sequence of glacial lakes in Alberta were in existence for approximately 2000 radiocarbon years. The older limiting date is  $13,510 \pm 230$  years B.P. (GSC-694) and the younger is  $11,400 \pm 190$  years B.P. (GSC-1049). It should be noted, however, that these two dates were run on very disparate materials [freshwater shells (Lowdon and Blake, 1967) and basal



gyttja respectively (Lichi-Federovich, 1970) ] and are not corrected for  $C^{13}/C^{12}$  ratios; in addition GSC-694 was run on the carbonate not the conchiolin fraction of the shell, making the date somewhat suspect.

White et al. (1979) working in the Saddle Hills of Alberta dated organic detritus from lake cores of which the oldest date was >30,000 years B.P. (WAT-361) indicating the hills had not been overridden by Late Wisconsinan ice. These dates were later shown to likely be contaminated with reworked Cretaceous coal (White, 1983, White et al. 1985).

#### **Fort St. John/Charlie Lake area**

The earliest substantial understanding of the Quaternary history of the Fort St. John area of northeastern British Columbia came in 1954 when Mathews (1954) reported on the area's glacial sediments. He found a twice repeated succession of sediments beginning with gravels overlain by lacustrine sands, silts, and clays, which in turn were overlain by till. He interpreted the gravels to be non-glacial in origin, the former being tentatively attributed to a pre-glacial Peace River and the latter having been laid down at the close of an interglacial. The lacustrine materials were credited to water ponded by advancing Laurentide ice with the overlying till deposited by the same ice. The lower till was tentatively assigned to the early Wisconsinan, the latter, by implication, to the Late Wisconsinan.

Mathews (1954) also reported that Cordilleran ice came within 24 km (15 miles) of Fort St. John overriding areas from which the early eastern ice had already withdrawn. This ice sheet deposited a till into the proglacial environment still in place from retreating eastern ice. He later (Mathews, 1962) amended the Cordilleran ice limit, extending its influence to within 15 km (9

miles) of Fort St. John. At the same time he reported proglacial shoreline traces at elevations of 838 m (2750 feet), 689 m (2260 feet), and 625 m (2050 feet).

Mathews (1963) described in detail the glacial stratigraphy of the Fort St. John area. The model he put forward remained essentially unchanged from his earlier assertions (Mathews 1954). He reported that the clay deposits he characterized as late glacial lacustrine, extend almost continuously over the study area lying between the 579 m and 686 m contour. The nature of the clay deposit changes character towards its upper limit. The deposit becomes silty, then sandy, and finally grades upslope into a thin gravel deposit marking a former shoreline. The best example of this, on the east bank of Tea Creek, shows the gravel rests unconformably on bedrock between elevations of 689 m and 698 m (Mathews, 1963). Mathews also reported that evidence of a deeper lake is present at this site in the form of a clay bed 3 to 4.6 m thick which displays no facies change at the 686 m (2250 foot) level. The clay bed is overlain and locally truncated by the deposit related to the 689 m (2260 foot) shoreline and is therefore older. Mathews also stated that there is a shoreline present at the 800 m (2625 foot) contour and up to four shorelines near the 838 m (2750 foot) contour.

Mathews(1963) restated his earlier assertions on geomorphic history, adding that the advance of the second continental ice sheet, is clearly marked by a younger till, and associated glacial grooves. He cites the Glacial Map of Canada 1958 (Geological Association of Canada 1958) as showing Laurentide ice flowing into the Fort St. John area from the northeast and extending into, "a broad sweeping curve southwest, south, then southeast as if deflected by the front of the Rocky Mountains or by ice tongues issuing from it" (Mathews, 1963:14).

He goes on to point out that erratics from the Canadian Shield have been found at elevations of more than 914 m (3000 feet) near Fellers Heights, 71 km south of the Fort St. John area. This

observation would seem to be at odds with his description of a fan shaped pattern of drumlins and glacial grooves between Fort St. John and the mountain front. The pattern, he said, was clearly caused by ice moving across the Rocky Mountains onto the plains. He noted that the pattern truncates and therefore postdates the pattern of ice moving southwesterly from the Canadian Shield. The drumlin field shows no sign of deflection which lead Mathews to suggest that the two ice sheets were not coalescent. This apparent contradiction is better explained by his later statement that this pattern is "developed or maintained after Laurentide ice had melted back from the line of contact" (Mathews, 1978a:15).

A history of the stages of the late glacial water body is also given in Mathews (1963). The retreating stages of the last ice sheet gave rise to a series of ice-dammed lakes named Lake Peace. The highest and oldest lake stage is marked by the 838 m (2750 foot) shoreline. The type locality is reported as Bessborough, where four closely spaced shorelines are clustered. The Bessborough stage, was postulated as being continuous from the town of Bessborough northwest at least 80 km and southeast at least 32 km (Mathews, 1963). Mathews reported that no significant variation of shoreline elevation is measurable over this distance but this is complicated by the fact that the northwest extent of the stage is marked by only two, not four closely spaced shorelines. The limits of the lake to the northeast and southwest were not defined.

A second level of Lake Peace is marked by a relict shoreline near Wilder Creek, 10 km west of Fort St. John. The relict shoreline elevation is unreported but must be only slightly less than 838 m (2750 feet) as Mathews notes the extent of the younger stage "can scarcely be less limited in extent than the Bessborough stage" (Mathews, 1963:14).

A lower and younger stage is marked by a gravel deposit at the 689 m (2260 foot) level. This gravel has been noted throughout the Fort St John area as are extensive bottom clays below this

level (Mathews, 1963). The lowest shoreline is at the 655 m (2150 foot) level near Indian Creek about 14 km north and 20 degrees east of Fort St. John.

The same moraine at The Portage, 77 km west of Fort. St. John, was believed by Mathews (1963) to be a recessional moraine to which, barring steep isostatic tilting, the Cordilleran ice had withdrawn following draining of the higher stages of Lake Peace. Mathews (1963) also noted that a lower stage of Lake Peace seems to have persisted during and after the pause of the Cordilleran ice at The Portage. He cited Beach and Spivak (1943), who discovered evidence of a lake dammed by eastern ice extending west to Johnson Creek, some 11 km south and 15 degrees west of The Portage. In addition, data from Mathews (1947) argued for the existence of such a lake at the 732 m (2400 foot) level near the mouth of Carbon Creek, 40 km west of The Portage. Mathews (1963) believed this lake might correspond with the 689 m (2260 foot) level found near Fort St. John. Thus, the influence of eastern ice persisted even after the Cordilleran ice had withdrawn some 97 km west of its maximum extent.

Mathews (1972) noted a single Late Wisconsinan till sheet containing eastern and western lithologies occurring in the Charlie Lake area of northeastern British Columbia. He found that counts of diagnostic eastern and western lithologies increased in the directions of their respective provenances. These data were interpreted as evidence that Montane and Laurentide ice had coalesced in the Late Wisconsinan.

Mathews (1972) believed little postglacial rebound was indicated by a narrow belt of shoreline gravels at the 686 m (2250 feet) level, running from the Alberta border west 80 km to Upper Cache Creek, in the Charlie Lake area. He did find evidence of rebound, farther west, in similar gravels running from 716 m (2350 feet) to 732 m (2400 feet) elevation. This considered along with the rise of glacio-lacustrine sediments from 838 m (2750 feet), near Fort St. John, to greater

than 3000 feet (914m) near 122 degrees longitude, suggested a differential uplift in the west. He also noted that the eastern one third of the Charlie Lake map sheet showed a general lack of glacio-lacustrine sediments. This, he maintained, was caused by glaciers lingering until drainage was available at the 686 m (2250 feet) level; he also believed that this would have occurred after the accumulation of the Portage Mountain kame moraine which was dated to 11,600 years B.P. (I-2244A).

Mathews (1973) noted lenses of a coarse Cordilleran diamicton in a "three to four hundred foot thick lacustrine bed" (Mathews, 1973:210), underlying a till sheet from the Late Wisconsinan ice advance. Roughly synchronous, but somewhat later than the above pre-Late Wisconsinan advance of western ice, Mathews discovered an outwash deposit of Laurentide provenance suggesting a pre-Late Wisconsinan advance coming close to the area. He repeated his view of a single continuous till sheet deposited during the Late Wisconsinan maximum, but went on to say that counts of clast lithology suggested that the boundary between the coalescing eastern and western ice was approximately 21 km east of Attachie, British Columbia. The breadth of this zone (several km) may record shifts in the position of this boundary.

Mathews (1973) again reported shorelines at 838, 808, 701, and 655 metres. These shorelines exhibited "very weak topographic expression" and were concentrated in "swarms" (Mathews, 1973:211). It was the "swarm" of shorelines at the 701 m (2300 feet) level upon which Mathew was able to determine an east to west isostatic rise. A 126 km segment was traced and the differential uplift was determined to be "no less than 1.2 and perhaps 2.0 feet per mile" (Mathews, 1973,:211). This suggested that the area's rebound is dominated by loading from Cordilleran ice as opposed to Laurentide ice. It was also noted that a 35 km segment of shorelines running north-south along the Alberta border could be interpreted to indicate a similar southward rise on the order of 0.4 m/km. Mathews went on to state, however, that another interpretation of shoreline

correlations gives no indicated southward isostatic rise. Lastly Mathews described a deposit of glaciofluvial sands from a stand of Montane ice post-dating the draining of the last Laurentide dammed pro-glacial lakes.

Mathews (1978a) continued in his work on the Quaternary stratigraphy and geomorphology of the Charlie Lake area of British Columbia. This document was a synthesis of much of the earlier information but made some important new observations. Mathews recognized a third eastern glaciation preceding what he had referred to as the "old till." This early glaciation is documented in the form of red granite and gneiss pebbles, presumably from outwash, contained in the early Peace River gravels exposed at Golata Creek some 42 kilometres east of Charlie Lake. This initial glaciation was followed by the two already reported Early and Late Wisconsinan Laurentide glaciations which were interspersed with corresponding Early and Late Cordilleran advances with a last very late Rocky Mountain advance. This last point is significant as it recognizes, for the first time, that the area has been influenced by three glacier systems, ie. Laurentide Ice Sheet, Cordilleran Ice Sheet, and local coalescent valley glaciers from the northern Rocky Mountains.

Mathews (1978a) updated his view on ice positions by discussing the Portage Mountain moraine saying that the topset and forset bedding on the kame moraine indicates it was built into a proglacial environment, most probably the Bessborough stage of glacial Lake Peace. The melt water channel that subsequently cut through the moraine terminates at an elevation of 737 m (2420 feet), Mathews believed that for this channel to function, Cordilleran ice could not have been more than 5.6 km to the west (Mathews 1978a). Ice contact features at Carbon Creek mark the position of Cordilleran ice contemporaneous with a Laurentide ice dam at the eastern end of Lake Peace near the Alberta-British Columbia border.

Mathews (1978a) formally introduced the terms "Clayhurst Stage" and "Indian Creek Stage" to refer to glacial Lake Peace phases occurring at 664 m (2180 feet) to 692 m (2270 feet) and 646 m (2120 feet) respectively. He also pointed out that as measured isostatic uplift is greater in the west than it is in the east, coupled with the fact that the lake outlets are in the east, the lake-traces should show a continuous decrease in elevation with time since deglaciation. He went on to say, that most shorelines adhere to this pattern. The one exception to this is a deltaic gravel deposit at 861 m (2825 feet) 1.6 km north of Inga Lake which was buried by approximately 1.2 m of lacustrine silt (Mathews 1978a). The explanation for this exception, Mathew said, may have been a minor readvance.

Mathews (1978a) used a series of 14 C dates to support his chronology. Much of the ancient lakes bottom deposits now display a mounded topography whose development is thought to either post-date the draining of their parent water bodies or had developed after many feet of fine sediment had accumulated on the lake bottom. Radiocarbon dates (Lowdon and Blake, 1973:28) on snail shells taken from associated swamp and pond deposits topping this mounded topography seem to support the argument;  $9960 \pm 170$  (GSC-1548), and  $10,400 \pm 170$  years B. P. (GSC-1654). The only radiocarbon date directly from the area was from what Mathews reports as a "postglacial terrace" (Mathews, 1978a:17) at the Ostero gravel pit near Taylor. This specimen yielded a date of  $27,400 \pm 580$  years B. P. (GSC-2034). Mathews (1978a) mentioned he believed that the till overlying the Watino fossiliferous beds (Westgate et al, 1972) dated to the Late Wisconsinan.

Mathews (1978a) cited dates from Westgate et al, (1972), to define the chronology of the Charlie Lake area; these dates are  $43,500 \pm 620$  (GSC-1020),  $>38,000$  (GX-1207) and  $27,400 \pm 850$  years B.P. (I-4878). The dates are thought to represent an interglacial lacustrine succession. The

date of  $27,400 \pm 850$  years B.P. (I-4878) from near the top of the succession provides a maximum date for Late Wisconsinan glaciation in the Watino area.

Mathews (1978a) also discussed the dating of a mammoth tusk found in the Portage Mountain moraine. The carbonate fraction of the tusk was originally dated at  $7670 \pm 170$  years B.P. (I-2244) (Buckley et al., 1968). Later it was argued that the date was contaminated by young carbonates (D.D. Cambell, personal communication *in* Mathews, 1978a), and a small collagen fraction was subsequently dated. The subsequent date (I-2244A) yielded a figure of 11,600 years B.P. but since the organic portion dated was small, no estimate of counting precision was reported. Mathews (1978a) considered this a good estimate of the age of the Bessborough stage of glacial Lake Peace and an indication Laurentide ice had not then retreated as far as Swan Hills, Alberta. Mathews (1978a) believed that the Portage Mountain moraine represented an recessional kame moraine built into the standing water of glacial Lake Peace. Rutter et al. (1972) came to a similar conclusion concerning this 11,600 year old date.

In 1978 the tusk was dated again, yielding a date of  $25,800 \pm 320$  years B.P. (GSC-2859) (Mathews, 1980). This much older age is difficult to accept for a number of reasons. Most importantly the tusk had been treated with a preservative, possibly petroleum based, thus increasing the likelihood of contamination with ancient carbon. Mathews (1980) also stated that this age was difficult to reconcile with a nearly contemporaneous non-glacial date of  $25,940 \pm 380$  (GSC-573) coming from sand underlying "till-like" lenses and lacustrine sediments (Rutter, 1977:19). If the tusk date is to be believed, however, it would see the Cordilleran climax at Portage Mountain in the "early" Late Wisconsinan and date Cordilleran deposits to the east much older (Mathews 1980).



The final contribution from Mathews (1980) was a detailed study of the various phases of glacial Lake Peace, see Appendix 3, (Figure 7). This work provided a series of figures outlining ice positions and corresponding lake levels. Mathews recognized two new low stages of glacial Lake Peace. The lowest and last left a shoreline close to 335 m (1100 feet) in the Hay Valley area of Alberta. The second last, slightly higher stage was termed the "Keg River stage" (Mathews, 1980:18), had left traces near the 427 m (1400 foot) level at Keg River, Alberta. Although not categorically stated the inference may be drawn from comments in the paper (Mathews, 1980:13, 19) that Mathews then believed that the Portage Mountain structure was not a recessional moraine but instead an end moraine.

Evidence of human occupation along the shoreline of a late stage of glacial Lake Peace was presented in Driver (1988) and Fladmark et al. (1988). The archaeological investigation at Charlie Lake Cave, a rock shelter directly south of Charlie Lake, B.C. A fluted point, and other cultural material, was found in the lowest levels of the stratified site. The point is diagnostic of the Paleo-Indian culture thought by many to represent the earliest human presence in North America. The stratum in which artifact was found and closely associated strata contained North American bison bones, which were radiocarbon dated. These determinations,  $10,450 \pm 150$  years B.P. (SFU 300),  $10,380 \pm 160$  years B.P. (SFU 378), and  $10,770 \pm 120$  years B.P. (SFU 454), suggested the cultural material was deposited approximately 10,500 years before present. The connection to glacial Lake Peace results not only from the timing but also from a shoreline deposit that occurs slightly below the cave mouth. The cave is situated at approximately 730 metres a.s.l., the beach deposit may be some 15 m lower. A personal communication with W.H. Mathews was cited (Driver, 1988) which suggested a correlation with the Clayhurst stage of Lake Peace. Based on the timing coincident with Mathews' assertion that the Clayhurst stage terminated prior to 10,000 years B.P. plus the fact that the cave floor displays no lacustrine

deposits, led the authors to conclude the occupation and the nearby lake level may have been coeval.

### **Pine Valley/Dawson Creek/Murray River**

The surficial and hardrock geology of the Pine Valley was investigated by Hughes (1967). He reported that the flat valley floor of the Pine River was due to glacio-lacustrine processes. Indistinct terraces at elevations ranging between 747 m (2450 feet) and 808 m (2650 feet) were noted. The genesis of these features is reported as being either glacial (lateral moraines) or lacustrine (former shorelines). The valley lake would have been part of glacial Lake Peace, particularly when it stood at 747 m (2450 feet) or higher (Hughes, 1967). Eventually the preglacial course of the Pine River was blocked and deglacial drainage was diverted to the southeast to the Pine River's present confluence with the Sukunka River. This large outwash deposit marks a stillstand in the westward retreat of the Pine Valley glacier. Hughes theorized this event represented a regional phenomenon for which another example was the Portage Mountain moraine on the Peace River. Lastly Hughes noted that high mountain ice in at least two tributary creek basins had melted and formed high level glacial lakes impounded by the then still present valley glacier.

The area of NTS 93P map sheet has been extensively investigated by N.W. Rutter and his colleagues. An early example of these works (Rutter, 1970) ranged from the headwaters of the Murray River to the Pine River, and along Bull Moose Creek and the Wolverine River. The present day community of Tumbler Ridge is situated at the confluence of Bull Moose Creek, the Wolverine River, and the Murray River.

In the Pine Pass area, Rutter found a paucity of glacial deposits within the valleys, he cited postglacial stream erosion as having removed much of this material (Rutter, 1970). Rutter reported that the exception to this lack of glaciogenic deposits was found up the valley system towards the headwaters of the different rivers and creeks. A good example of this was found near the headwaters of the Sukunka River, where late glacial lacustrine silts are found on the valley floor to elevations of over 1067 m (3500 feet) (Rutter, 1970). Continuing downstream, Rutter found lacustrine sands on the valley sides present at elevations of over 1219 m (4000 feet), and 457 m (1500 feet) above the present valley bottom.

The northward flowing Murray River also provided similar extensive glacier deposits. Rutter reported that a section near Lone Prairie has at least 12 m of Cordilleran till overlain by another 12 m of oxidized sands and gravels (Rutter, 1970). Rutter theorized that these sand and gravel sediments may be equivalent to similar deposits found throughout the Rocky Mountains; thought to be interglacial in origin. The sands and gravels near Lone Prairie are overlain by 3 to 5 m of lacustrine silts and no tills of Laurentide provenance were reported.

An examination of the Dawson Creek area of British Columbia was undertaken by Reimchen and Rutter (1972). They reported that their preliminary examination of the area showed the western part was covered by three Cordilleran glaciations and the eastern part by one, or possibly two, Laurentide advances. The earliest glacial deposit classed as Early Wisconsinan or possibly Illinoian, may have been laid down synchronously with an early Laurentide glaciation which was inferred from the presence of Canadian Shield erratics. Following the glaciations an extensive period of lacustrine deposition, referred to as, "lacustrine phase I," began. Lacustrine deposits are theorized to have resulted from Laurentide ice blocking northeasterly drainage from the area. The lacustrine phase contains interfingering drift and outwash from both the second Cordilleran and Laurentide advances. Lacustrine phase I is thought to have been ended by extensive Late

Wisconsinan glaciation from both east and west. The western and eastern glaciers, it was reported, seem to have overlapped a common area by 15 km which is evidenced by a strip of mixed Cordilleran and Laurentide till. Coalescence was not reported, instead the western ice seems to have truncated and overridden deposits from the Laurentide ice. Cordilleran outwash was reported to have blocked the northerly drainage of the Pine River north of Chetwynd, diverting flow into the Murray River to the east.

### **Rocky Mountain Trench**

Rutter investigated the Williston Lake area to the west of Fort St. John including the Peace, Parsnip, and Finlay River valleys (Rutter, 1967, 1968, 1969a, 1969b, 1976, 1977). Initially concentrating on the Peace and Parsnip valleys, Rutter (1967) reported two advances with the possibility of a third affecting the Parsnip River valley. Evidence in the Peace River valley indicated one and possibly two advances had occurred in the area. The above data led Rutter to believe that a minimum of one glacial advance had extended from the Rocky Mountain Trench into the Peace River Valley. Continued study of the Parsnip and Finlay valleys (Rutter, 1968) brought about the conclusion that four advances had affected the Finlay River valley, with two of these units possibly being correlative with the two advances in the Parsnip River valley. The possibility of a third advance in the Parsnip valley was more strongly advocated in Rutter (1969a), and it was noted that extensive western glaciations crossing drainage divides would only have occurred early in the area's glacial history, ie. Early Wisconsinan or pre-Wisconsinan (Rutter, 1969b).

Rutter (1976, 1977) formalized by naming the four western glacial episodes. The earliest was named, "Early advance." an event that may have reached as far east as the Alberta Plateau near Fort St. John. Rutter reported lacustrine deposits correlated with retreat of the Early phase. The

water body was probably dammed by Laurentide ice to the east, although landslides or moraine construction were also listed as possibilities (Rutter, 1977). The timing of this event is known only indirectly, but was interpreted as being Early Wisconsinan or older. Infinite dates of >28,000 years B.P. (GSC-1057), >41,000 years B.P. (GSC-841), and >44,000 years B.P. (GSC-837) from underlying interglacial sediments provided a minimum age for the interglacial deposit while the  $25,940 \pm 380$  years B.P. (GSC-573) material, found in sands interpreted as underlying the Portage Mountain advance, gave a maximum age for the Early Portage Mountain advance (Rutter, 1976).

The next glacial event was labelled the "Early Portage Mountain" advance (Rutter, 1976). This glacial episode, like the former, originated in the Rocky Mountain Trench and probably advanced well out from the mountain front onto the Alberta Plateau (Rutter, 1977). This extensive advance also had a proglacial lake blocked by eastern ice associated with its retreat. Silts deposits at an elevation of 945 m (3100 feet) are cited as possibly correlating with this lake phase.

The "Late Portage Mountain" advance was the third western glaciation to effect the Williston Lake area (Rutter, 1976). This advance, Rutter stated, was responsible for building the Portage Mountain moraine which was dated at  $11,600 \pm 1000$  years B.P. (I-2244A). This date's veracity is now questioned (see discussion Mathews, 1978a). Interestingly Rutter et al. (1972), following Bryan (1969), considered the Portage Mountain moraine a recessional feature; as reported above, this view had changed by his publication of 1976 (Rutter, 1976). Rutter also cited dates of  $9,960 \pm 170$  (GSC-1548), and  $10,400 \pm 170$  (GSC-1654) on freshwater mollusc shells found in the "upper lake deposits east of the mountain front" (Rutter, 1977:21) as providing approximate timing on the final deglaciation of the area. A Bighorn sheep skull was recovered in the Parsnip River valley near its confluence with the Finlay River (Rutter et al. 1972). The specimen was found in ice-contact fluvial sediments and the subsequent radiocarbon determination provided a

date of  $9280 \pm 200$  years B.P. (GSC-1497) also indicating the timing of final deglaciation. Peat and wood found on river terraces along the Ospika River were dated at  $7,470 \pm 140$  years B.P. and  $7470 \pm 150$  years B.P. These terraces overlie the last lacustrine sediments in the area and so provide a minimum age for these lacustrine deposits.

The final advance was named the "Deserters Canyon" advance (Rutter, 1976). This advance was minor and never proceeded farther than the Finlay River valley now occupied by Williston Lake.

Rutter reported shoreline deposits and upper limits of glacial lakes in the Williston Lake area. He correlated these with relict shorelines reported by Mathews (1963, 1972, 1973) using a glacio-isostatic adjustment with a range of 1 to 6 feet/mile rising to the west. A personal communication from Mathews is cited using the term "Hudson Hope" phase for what Mathews would later refer to as his "unnamed" phase. Possible damming of the upper Peace valley by landslide or morainic deposits resulting in the formation of two separate lakes forming (Clayhurst phase?) was discussed, but the evidence and rationale for this argument is unclear.

### **Lake Correlations**

Henderson (1959) reported that Lake Valleyview I was a low stage of an earlier, higher water body. The earlier lake was named Lake Rycroft by Mathews (1980) with high early strandlines found on both sides of the Alberta-British Columbia border. Henderson continued that at their greatest extent, Lake Rycroft and Lake Valleyview 1, must have formed one large body of water. Lake Puskwaskau I and Lake Valleyview I were also shown as being contemporaneous (Figure 7B, Henderson, 1959). As noted earlier Mathews had intended the term "Rycroft" to pertain only to a lake with an elevation of about 838 m (2750 feet). Mathews considered his Bessborough stage to be correlated with Henderson's "Lake Rycroft" (Mathews, 1980).

St. Onge's (1972) examination of glacial lakes in north-central Alberta showed a very specific series of water bodies following retreating Late Wisconsinan ice out of the area. His sequence of lakes largely agrees with the scenario as outlined by Mathews (1963). Lake Iosegun I and II are the first water bodies which seem to be correlated with glacial Lake Peace. These lakes are reported having an elevation of 846 m (2775 feet) and 823 m (2700 feet) respectively (St. Onge, 1972). St. Onge reported that Iosegun I and Henderson's (1959) "Lake Rycroft" were synonymous. Mathews (1980) suggests that this lake stage be referred to as "Bessborough" and that the common use of the Pass Creek outlet in Alberta of Lakes Iosegun I, II and the Bessborough stage of glacial Lake Peace imply an overall correlation. It should be noted that earlier, Mathews (1978a) had held that the correlation was between his Bessborough phase and Lake Iosegun I. At the same time he had proposed a correlation between his unnamed stage at 800 m (2625 feet) and Lakes Iosegun II or III. Mathews (1980) would see the suggestion that only St. Onge's Iosegun III may correspond with his "glacial Lake Peace, unnamed stage." (Mathews, 1980:17). As previously mentioned, St. Onge uses the term "Lake Fahler I" to describe the lake at elevation 686 m (2250 feet). This elevation may imply a correlation with the Clayhurst phase of glacial Lake Peace, although Mathews noted that his Indian Creek stage may be a more likely correlation (Mathews, 1978a). Published lake phase correlations are shown in Figure 2. These are arranged geographically from west to east (left to right).

WEST.....

.....EAST

|  |  |  |  |   |
|--|--|--|--|---|
|  | >3100 feet<br>(>940 m)<br>"silt on Bull<br>Mtn."<br>(Rutter,<br>1977:12)   | 3000 feet<br>(910 m)<br>(Mathews,<br>1963)<br>[Rutter, 1977]             |  |   |
|  | 2820 feet<br>(855 m)<br>"flat top of<br>Portage Mtn.<br>moraine"<br>(Rutter,<br>1977:12)                         |  | 2750 feet<br>(835 m)<br><b>Bessborough</b><br>(Mathews<br>1978a),<br><b>Lake Rycroft</b><br>(Henderson<br>1959)                                      | 2700-2775<br>feet<br>(833-845 m)<br><b>Iosegun I, II</b><br>(St. Onge,<br>1972)<br>[Mathews,<br>1978a]  |
|  | 2700-2800<br>feet<br>(818 m)<br>"Beaches on<br>north side of<br>Portage Mtn.<br>moraine"<br>(Rutter,<br>1977:12) |  | 2650 feet<br>(803 m)<br><b>unnamed</b><br><b>stage 2625</b><br>feet<br>(Mathews,<br>1978a)<br><b>"Hudson</b><br><b>Hope stage"</b><br>[Rutter, 1977] | 2600-2700<br>feet<br>(792-833m)<br><b>Iosegun II, III</b><br>(St. Onge,<br>1972)<br>[Mathews,<br>1978a]   |
| > 2500 feet<br>(> 760 m)<br>"upper limit of<br>lacustrine<br>seds"<br>Rocky Mtn.<br>Trench<br>(Rutter,<br>1977:12) | 2350 feet<br>(710 m)<br>"break-in<br>slope<br>east of Bull<br>Mtn."<br>(Rutter,<br>1977:12)                      | 2350-2400<br>feet<br>(710-725 m)<br>(Mathews,<br>1963)<br>[Rutter, 1977] | 2250 feet<br>(680 m)<br><b>Clayhurst</b><br>(Mathews<br>1978a, 1980)   | 2175-2280<br>feet<br>(663-695m)<br><b>Lake</b><br><b>Puskwaskau</b><br><b>I, II</b><br><b>Lake</b><br><b>Valleyview I,</b><br><b>II</b><br>(Henderson,<br>1959) |
|  |  |  | 2120 feet<br>(646.m)<br><b>Indian Creek</b><br>(Mathews,<br>1978a)   | 2075-2250<br>feet<br>(632-686m)<br><b>Lake Fahler</b><br><b>I</b><br>(Henderson,<br>1959)<br><b>Lake Fawcett</b><br>(St. Onge,<br>1972)                         |

Figure 2  
after Rutter (1977)

Published proglacial lake correlations in northeastern B.C. and northwestern Alberta  
(author) = original reporter of glacial lake phase or strandline elevation  
[author] = reporter of correlation if different from above



## **Recent research: Model II**

Much of the previously discussed research exemplifies glacial timing adhering to what Bobrowsky et al. (1991) have referred to as "Model I" that is, multiple Laurentide glaciations, usually Early and Late Wisconsinan, contemporaneous, or coalescing with, two to four Cordilleran (or Montane) glaciations. Recent research suggests that this view may require revision. In what has been called the "Model II" scenario, (Bobrowsky et al. 1991) Laurentide glaciation is restricted to one Late Wisconsinan advance asynchronous with two ice advances of western provenance.

Work in the northern Finlay River valley by Bobrowsky et al. (1987) provided evidence for three Cordilleran glacial advances which were named Early advance Till, Early Portage Mountain, and Late Portage Mountain, following Rutter (1977). The Deserter's Canyon till (Rutter, 1977), it was determined, was not evidence of a separate glacial advance but more probably an resedimented diamicton relating to an earlier advance.

The timing of the above glacial events was also reexamined and reported in Bobrowsky et al. (1987). Instead of Rutter's (1977) scheme of three Late Wisconsinan events (Early Portage Mountain, Late Portage Mountain and the deleted Deserter's Canyon) and one Early Wisconsinan (Early Advance Till), Bobrowsky moved the Early Portage Mountain advance to the Early Wisconsinan and the Early Advance Till to a Pre-Sangamonian time period. Hence the Late Portage Mountain advance would be the only Late Wisconsinan event remaining.

This evolution away from multiple glaciations rapidly continued in other studies with the glacial history of the northern Rocky Mountain Trench reported as containing only two ice advances (Bobrowsky, 1987, 1988, 1989a, 1989b). A facies analysis approach suggested that the genesis of

the Early Advance Till was more likely a sediment gravity flow deposit rather than a till. This left only two western glaciations (Early and Late Portage Mountain) affecting the area. The Early Portage Mountain glaciation was interpreted as occurring previous to the Middle Wisconsinan and was an extensive Cordilleran glaciation crossing the Rocky Mountain Trench from the west and possibly debouching onto the plains to the east (Bobrowsky and Rutter, 1992). The Late Portage Mountain advance was seen to be a Montane glaciation of restricted extent building the end moraine at Portage Mountain, therefore, the authors reported, no evidence for coalescence of continental and western ice was seen in the Late Wisconsinan in the Peace River area (Bobrowsky, 1989a).

The argument that the Late Wisconsinan glaciation was a short lived event is supported by a series of reported radiocarbon determinations that bracket the last western ice advance. Dates as young as  $15,280 \pm 100$  years B.P., (TO-708) and  $18,750 \pm 120$  years B.P. (TO-709). on non-glacial sub-till sediments occur in the Rocky Mountain trench (Bobrowsky, 1989a). Bobrowsky cited GSC-2036 ( $10,100 \pm 90$  years B.P (Alley and Young, 1978) and GSC-2036-2 ( $10,000 \pm 140$  years B.P) (Blake, 1986) as reliably dating the postglacial interval.

On the plains of Alberta, investigations by Liverman et al. (1989) and Liverman (1989) have suggested that only one Laurentide glaciation may have affected the Watino area of west-central Alberta. This would mean that the Late Wisconsinan glaciation represented the Quaternary glacial maximum in this area. The authors stated that sections at Watino and Simonette, Alberta, no Canadian Shield stones were present in sediments dating to the Mid-Wisconsinan and they support this claim with the statement that chemical weathering would not be strong enough to decompose granitic clasts in the elapsed period of time. The maximum Early Wisconsinan ice limit must have been at least 200 kilometres northeast of the limit proposed by Vincent and Prest (1987). With ice advances in this area trending generally from north to south (Mathews, 1980)

the areas to the south and west should display similar records, that is, not glaciated prior to the Late Wisconsinan (Liverman et al. 1989).

This differs from the work of Mathews (1962, 1978, 1980) who found evidence for three distinct Laurentide glaciations at Charlie Lake, British Columbia; an area which should display only a single Late Wisconsinan glaciation according to Liverman et al. (1989). Mathews based his claim for three distinct Laurentide glaciations on rare Canadian Shield clasts present in gravels underlying two tills (Mathews, 1976) gravels considered to be interglacial. The third till was inferred by the stratigraphy at another location, where Mathews found two additional tills separated by a silt layer that he also considered to be interglacial in origin.

Liverman et al. (1989) explained the evidence from Charlie Lake in the following manner. Mathew's early glacial sediments were deposited by ice that failed to reach the Watino study area which would imply a lobate margin associated with the Early Wisconsinan ice complex. The other possibility, according to Liverman et al. (1989), is that the tills in the Charlie Lake area are all Late Wisconsinan. They state that Mathews provided no paleo-environmental or chronological evidence to support his view that the basal gravels and the intertill silts are interglacial sediments. They maintained that it is conceivable that the gravels were deposited during a Late Wisconsinan advance and the silt during a minor retreat followed by an advance (Liverman et al. 1989). They stated that the "ice-free corridor" of west-central Alberta was open prior to the Late Wisconsinan period. In his doctoral thesis Liverman (1990) acknowledges the multiple till sections reported by Henderson (1959) in the Watino area, although no explanation for the difference is offered.

Bobrowsky et al. (1987) reported evidence of a single Cordilleran and Laurentide advances in the Grand Prairie region. They reported that flutings developed by the Cordilleran ice suggested that

no coalescence had taken place and the timing could be either pre-late Wisconsinan to early in the Late Wisconsinan, to post Laurentide ice retreat.

Earlier work by Westgate et al. (1971, 1972), in the Watino area, tended to support the Model II scenario. This work reported a six metre thick fine-grained alluvial succession sandwiched between over and underlying proglacial lake sediments (Early and Late Wisconsinan by inference). The alluvial sediments contained abundant organic material for radiocarbon dating; dates ranging from  $43,500 \pm 620$  (GSC-1020) to  $27,400 \pm 850$  (I-4878), placed the alluvial sediment in the Mid-Wisconsinan. In combination with Liverman's, (1989) findings of a single overlying till, these data suggest the only advance into the Watino area occurred in the Late Wisconsinan and the eastern and western ice masses were widely separated during the Middle Wisconsinan

### **Radiocarbon Chronology**

Problems in understanding the glacial history of northeastern B.C. stem in part from a paucity of absolute radiocarbon dates from sediments spanning the Quaternary/Holocene border. Many of the existing dates suffer from poor stratigraphic control or possible contamination. Presented below is a list of some of the more important dates.

Table 1  
Late Pleistocene radiocarbon dates from northeastern B.C. and northwestern Alberta  
Modified after Bobrowsky et al. (1992)

| <u>Lab. Number</u> | <u>Age</u> | <u>Location</u>    | <u>Material</u> | <u>Reference</u>            |
|--------------------|------------|--------------------|-----------------|-----------------------------|
| GSC-2036-2         | 10,000±140 | Omineca            | marl            | Blake 1986                  |
| RIDDL-392          | 10,100±210 | Charlie L.         | bone            | Driver 1988                 |
| AECV-1206C         | 10,240±160 | Taylor             | bone            | Bobrowsky et al.<br>1991    |
| SFU-378            | 10,380±160 | Charlie Lake       | bone            | Driver 1988                 |
| GSC-1654           | 10,400±170 | Dawson Creek       | shell           | Rutter 1977                 |
| SFU-300            | 10,450±150 | Charlie Lake       | bone            | Driver 1988                 |
| GSC-3520           | 10,700±140 | Lone Fox Lake      | organics        | MacDonald 1987              |
| WAT-362            | 10,740±395 | Boone Lake         | organics        | White et al.<br>1979*       |
| SFU-454            | 10,770±120 | Charlie Lake       | bone            | Driver 1988                 |
| SFU-210            | 10,800±180 | Spring Lake        | organics        | White and<br>Mathewes 1986* |
| WSU-2557           | 11,200±400 | Spring Lake        | organics        | White and<br>Mathewes 1986* |
| SFU-223            | 11,700±260 | Boone Lake         | wood            | White et al.<br>1985*       |
| WAT-408            | 12,650±320 | Boone Lake         | organics        | White et al.<br>1985*       |
| GSC-694            | 13,510±230 | Little Smoky River | shell           | Lowdon and<br>Blake 1968    |
| GSC-698            | 13,580±260 | Little Smoky River | shell           | Lowdon and<br>Blake 1968    |
| TO-708             | 15,180±100 | Finlay             | wood            | Bobrowsky<br>1989a          |
| WAT-406            | 17,570±650 | Boone Lake         | organics        | White et al.<br>1979*       |
| TO-709             | 18,750±120 | Finlay             | wood            | Bobrowsky<br>1989a          |

Table 1 con't

| Lab. Number | Age                  | Location     | Material      | Reference                |
|-------------|----------------------|--------------|---------------|--------------------------|
| AECV-351C   | 23,280±750           | Finlay       | wood          | Bobrowsky<br>1989a       |
| GSC-2859    | 25,800±320           | Portage Mtn. | tusk collagen | Mathews 1978a*           |
| GSC-573     | 25,940±380           | Finlay       | plants        | Rutter 1977              |
| AECV379C    | 26,800±1450          | Finlay       | wood          | Bobrowsky<br>1989a       |
| GSC-2034    | 27,400±580           | Taylor       | mammoth tooth | Mathews 1978a            |
| I-4878      | 27,400±850           | Watino       | wood          | Clague 1981              |
| AECV-352C   | 29,280±1230          | Finlay       | wood          | Bobrowsky<br>1989a       |
| AECV-349C   | 29,880±1680          | Finlay       | wood          | Bobrowsky<br>1989a       |
| AECV-416C   | 31,530±1440          | Watino       | wood          | Liverman et al<br>1989   |
| AECV-382C   | 32,750±3180          | Finlay       | wood          | Bobrowsky<br>1989a       |
| AECV-380C   | 33,490±1780          | Finlay       | peat          | Bobrowsky<br>1989a*      |
| I-2626      | 34,900+3000<br>-2000 | Watino       | wood          | Lowdon and Blake<br>1970 |
| I-2516      | 35,500+2300<br>-1800 | Watino       | wood          | Lowdon and Blake<br>1970 |
| I-2615      | 35,500+3300<br>-2300 | Watino       | wood          | Lowdon and Blake<br>1970 |
| AECV-415C   | 36,220±2520          | Watino       | wood          | Liverman et al.<br>1989  |
| AECV-350C   | 36,510±2570          | Finlay       | wood          | Bobrowsky<br>1989a       |
| AECV-353C   | 37,190±2870          | Finlay       | wood          | Bobrowsky<br>1989a       |
| I-2244A     | >11600               | Portage Mtn. | tusk collagen | Rutter 1977              |

Table 1 con't

| <u>Lab. Number</u> | <u>Age</u> | <u>Location</u> | <u>Material</u> | <u>Reference</u>         |
|--------------------|------------|-----------------|-----------------|--------------------------|
| GSC-1057           | >28000     | Finlay          | wood            | Rutter 1977              |
| WAT-361            | >30000     | Boone Lake      | organics        | White et al.<br>1979*    |
| GX--1207           | >38000     | Watino          | wood            | Lowdon and Blake<br>1970 |
| AECV-348C          | >40000     | Finlay          | wood            | Bobrowsky<br>1989a       |
| I-2259             | >40000     | Peace           | charcoal        | Buckley et al.<br>1968   |
| AECV-386C          | >40130     | Finlay          | wood            | Bobrowsky<br>1989a       |
| AECV-414C          | >40170     | Watino          | wood            | Liverman et al.<br>1989  |
| AECV-385C          | >40180     | Finlay          | wood            | Bobrowsky<br>1989a       |
| AECV-381C          | >40330     | Finlay          | wood            | Bobrowsky<br>1989a       |
| AECV-383C          | >40400     | Finlay          | wood            | Bobrowsky<br>1989a       |
| GSC-841            | >41000     | Finlay          | peat            | Rutter 1977              |
| GSC-837            | >44000     | Finlay          | wood            | Rutter 1977              |

\* probable sample contamination

## CHAPTER THREE

### SITE DESCRIPTIONS AND RADIOCARBON RESULTS

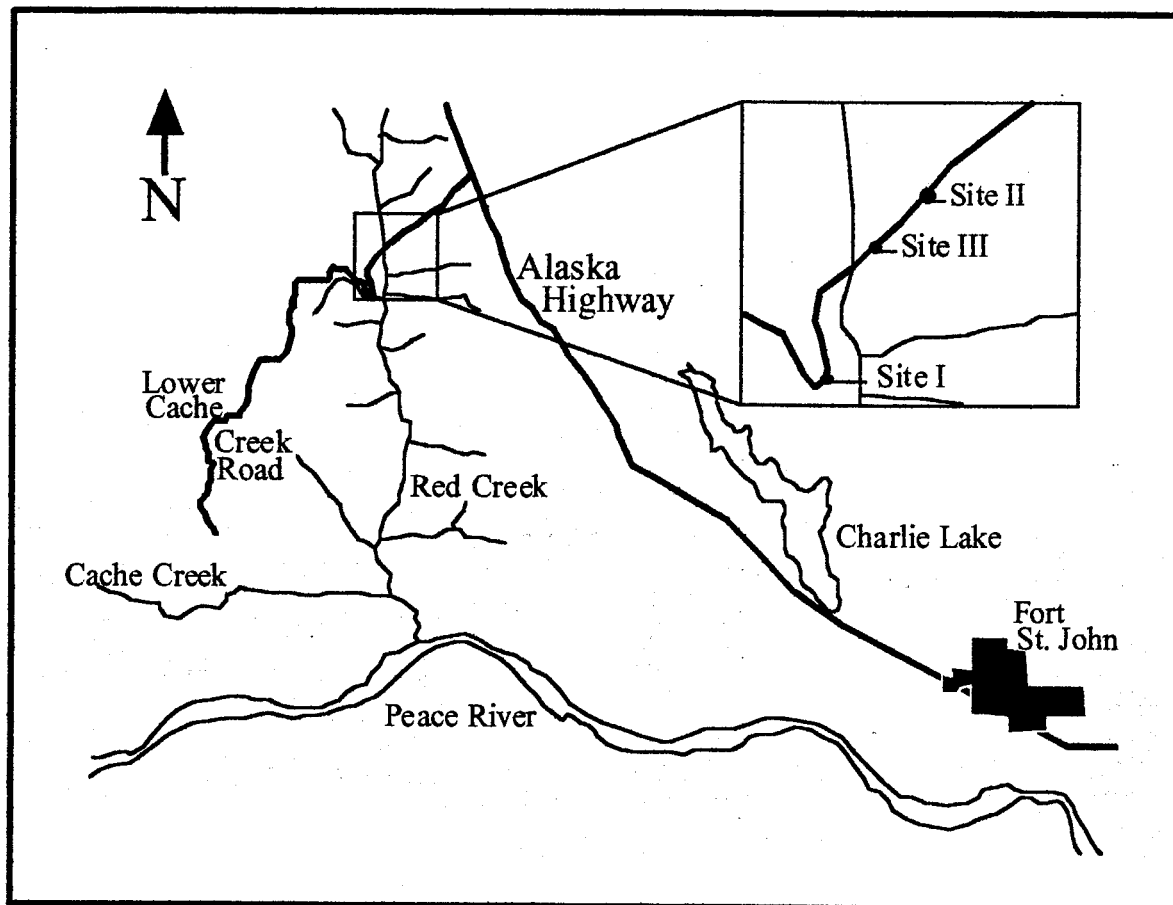


Figure 3  
Locations of Sites  
I, II, III

The four sections from which datable materials were taken are all located in northeastern British Columbia. Three (Sites I, II, and III) are located close to the city of Fort St. John on the Lower Cache Creek road northwest of the town, approximately seven km southwest of the Alaska highway,  $56^{\circ} 27'$  north latitude  $121^{\circ} 16'$  west longitude (Figure 3 and aerial photograph in Appendix 3). The fourth is located just north of the town of Tumbler Ridge  $55^{\circ} 09'$  north latitude



121° 00' west longitude (Figure 6). Site II is a section near Sites I and III which is briefly discussed but is not immediately relevant to this study. Future dating of the material collected from Site II will then make further elaboration appropriate.

#### **Lower Cache Creek Road/Red Creek Sites:**

##### **Original Site: (Site I)**

Information on the original site is limited because much of the primary data were lost. We are left with the site description as given to the S.F.U. radiocarbon lab and the resulting radiocarbon dates as well as the memory of the original researchers.

In 1986 Dr. Arthur Roberts and Mr. Mark Hilton (then a graduate student) located a section of lacustrine sediments containing at least three well defined bands of organic debris at an elevation of 728 m (2387 feet). The section was located at UTM 10VFT064550 (Map Sheet 94/A6) on the Lower Cache Creek road along Red Creek, approximately 7 kilometres southwest from Highway 97 (Alaska Highway). Mr. Hilton sketched the section and organic samples were taken for later radiocarbon analysis. The section consisted of three organic layers which received a designation of B, D, and E2 from top to bottom, samples were taken from each of these sediments. These organics were interbedded in lacustrine sands, silts and clays (Figure 4). The organic layers were described as occurring in a "bed of dark compacted material approximately 2 feet thick and eleven feet below the top of the section (unpublished S.F.U. radiocarbon lab data sheet). The upper part of the section was interpreted as a sandy till with a blocky, "ice pressed" form (A. C. B. Roberts, personal communication 1990). In addition the organic layers and lacustrine sediments below the till displayed imbricate structure suggesting that either the area was overridden by ice or had undergone some post-depositional slumping.

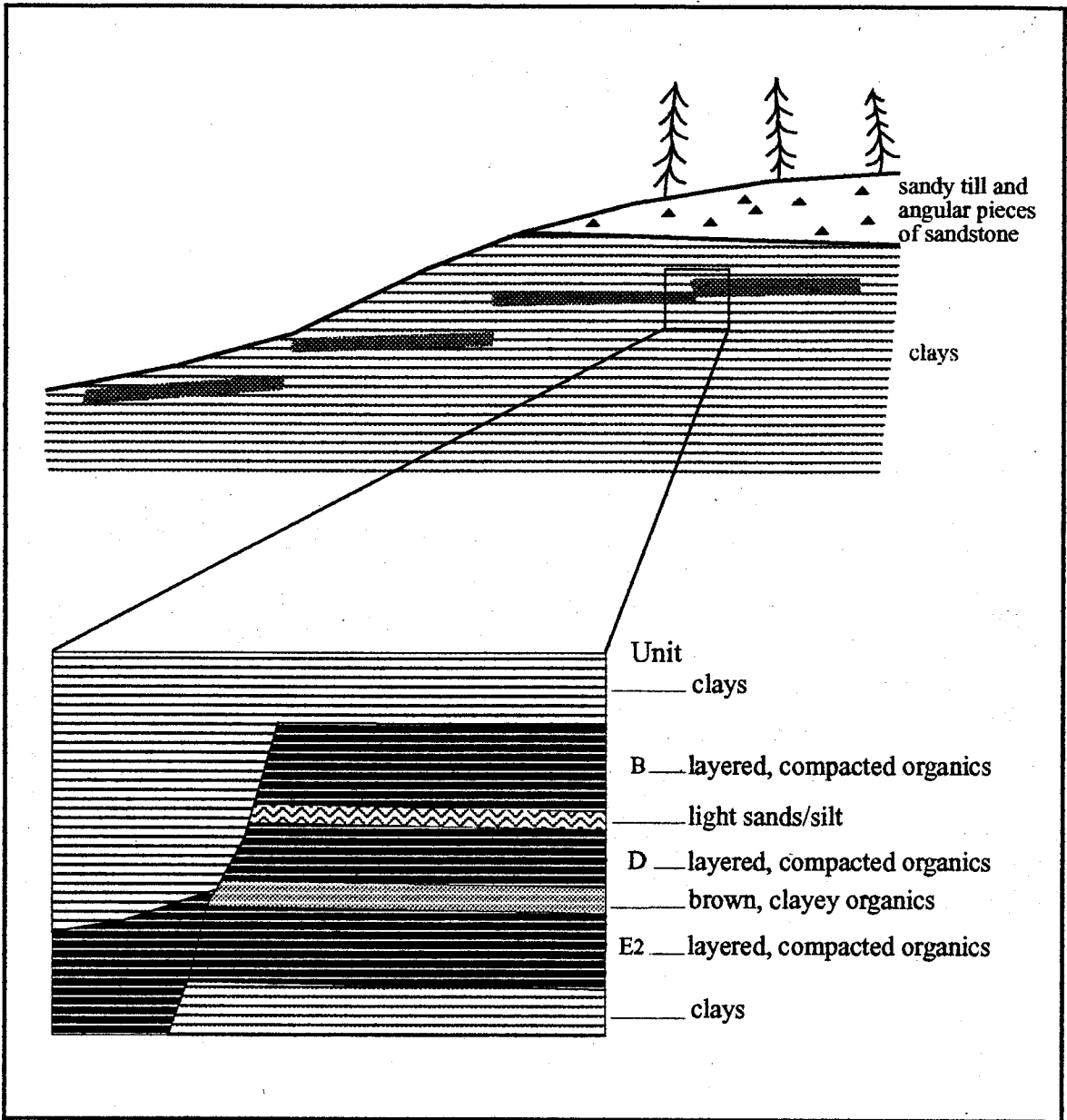


Figure 4  
Section diagram  
Site 1

## Radiocarbon Dating

The bulk organic samples were submitted to the S.F.U. radiocarbon dating lab, sample numbers: SFU 387 (unit B) and SFU 380 (unit E2). These samples received standard mechanical and acid pretreatment procedures. The base rinse following the acid rinse was not attempted because of the lab's mistaken assumption that the organic samples were compressed peat. Organic sediments and peat as standard procedure are only subjected to treatment with 0.2N HCl, the base treatment being deemed too likely to dissolve the sample (Nelson and Hobson, 1982). The two samples yielded dates of  $33,100 \pm 1800$  (SFU 380), and  $15,800 \pm 1300$  (SFU 387). No mass spectrometer was available, hence, no  $\delta^{13}\text{C}$  measurements were derived. Estimates of the probable  $\delta^{13}\text{C}$ , if the material dated was wood, provides a correction within the range of 0 and 15 years older, if the material was carbonized grasses or sedges, the correction would be in the order of 245 years older. Likewise, if the material consisted of tree leaves or peat/humus deposits, the correction would be approximately 35 years younger (Stuiver and Polach, 1977).

Problems in the administration of the S.F.U. radiocarbon lab prompted Dr. Erle Nelson of that facility to send the intermediate sediment sample (unit D) to Beta Analytic for radiocarbon assay. This date was run December 4, 1984. The sample was given an acid, alkali (light alkali), acid pretreatment (Dr. Murray Tamers, Beta Analytic, personal communication, 1993). The sample dated  $25,700 \pm 1200$  years B.P. (Beta 11060) and a  $\delta^{13}\text{C}$  value of  $-25.75$  ‰ was determined. The correction resulting from the  $\delta^{13}\text{C}$  measurement made the date 10 years older.

Table 2  
Radiocarbon Dates from Site I  
Lower Cache Creek Road

| Horizon | Lab No.    | $\delta^{13}C$ ‰ | Date (C-14 Y.B.P.) |
|---------|------------|------------------|--------------------|
| B       | SFU-387    | ∅                | 15,800±1300        |
| D       | BETA-11060 | -25.75           | 25,700±1200        |
| E2      | SFU-380    | ∅                | 33,100±1800        |

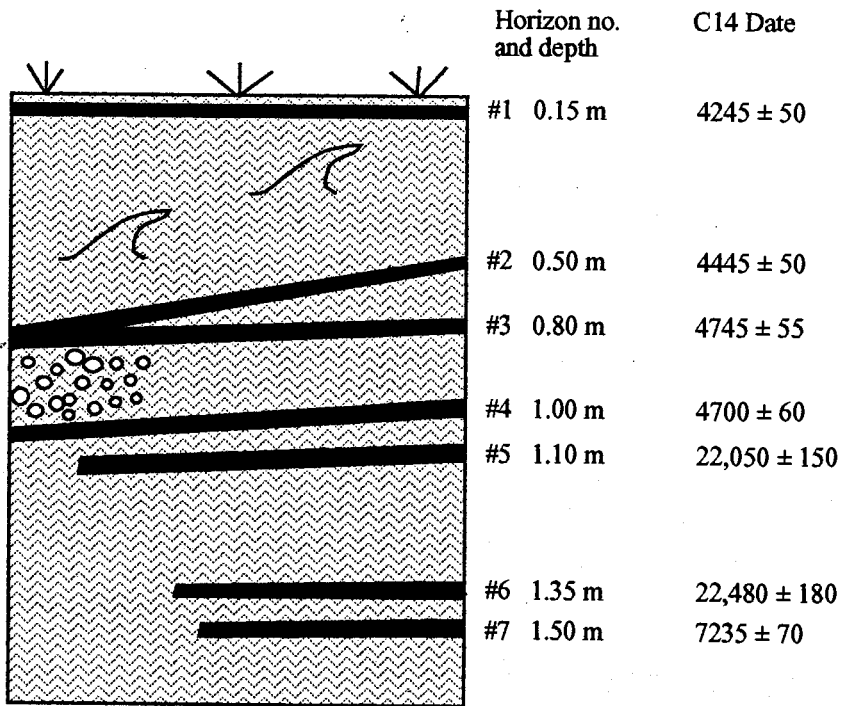
### Site II

The controversial nature of these dates prompted Dr. Roberts to undertake a reexamination and re-sampling of the site in 1986. It was determined during this trip that the original site had either been destroyed through road work or slumping. An examination of the road cut near the original section (UTM 10VFT074567) resulted in the discovery of a similar sediment with interbedded lacustrine silts and organic debris at an approximate elevation of 689 m (2260 feet). This material has yet to be radiocarbon dated.

### Site III

In the fall of 1990 a third trip was mounted to the area to relocate and collect samples from the previous sites. Neither the original site or the second site was located but a third site was discovered a few hundred metres away from the previous locations at UTM 10VFT073568. Site III displayed seven organic horizons within 1.5 metres of the surface which was roughly 686 m

SECTION III



LEGEND

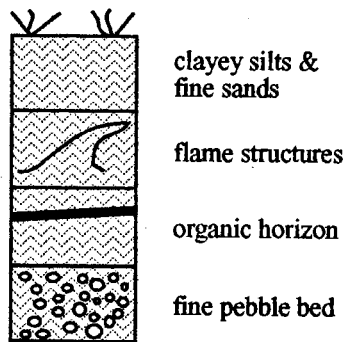


Figure 5  
Section Diagram  
Site III

(2250 feet) a.s.l. (Figure 5). The organic sediments were interbedded with sand and some minor gravel. The section showed deformation due to loading including flame structures, diapirs and minor scour and fill. There were no Canadian Shield stones visible with sandstones and limestones of western provenance predominating. The depositional environment was interpreted as lacustrine and fluvial and might represent a series of sediment gravity flow deposits into a standing body of water (Bobrowsky, personal communication, 1990).

### **Radiocarbon Dating**

The sediments supported fairly large pieces of organic debris which appeared to be charcoal. Organic samples from each unit were manually separated and weighed. Initially one sample from organic horizon number 4 was sent for radiocarbon assay to determine the efficacy of more dates. This was performed as a palynological examination had shown Cretaceous aged spores were present and therefore coal contamination was suspected (Dr. Bob Vance personal communication, 1990). The date resulting from this test was  $4700 \pm 60$  years B.P. (BETA-44202). The six other organic horizons were then dated. The results are reported in Table 3. Details on specific samples can be found in Appendix No. 1.

Table 3

C-14 Dates from Site III  
 Lower Cache Creek Road (Fort St. John)  
 and  
 Tumbler Ridge, B.C.

| Horizon No.                                  | Lab. No.   | $\delta$ C-13 0/00 | Date (C-14 Y.B.P.) |
|--|------------|--------------------|--------------------|
| 1  | BETA-50790 | -23.5              | 4245 $\pm$ 50      |
| 2  | BETA-50791 | -22.9              | 4445 $\pm$ 50      |
| 3  | BETA-50792 | -21.7              | 4745 $\pm$ 55      |
| 4  | BETA-44202 | -25.4              | 4700 $\pm$ 60      |
| 5  | BETA-50793 | -24.4              | 22,050 $\pm$ 150   |
| 6  | BETA-50794 | -26.7              | 22,480 $\pm$ 180   |
| 7  | BETA-50795 | -28.2              | 7235 $\pm$ 70      |
| bison bone<br>Lower Terrace<br>Tumbler Ridge | BETA-44201 | -15.4              | 10,380 $\pm$ 100   |

**Tumbler Ridge Site: (Figure 6)**

Mathews (Figure 5E, 1980:12) illustrated an arm of glacial Lake Peace extending down the Murray River Valley with an indeterminate border in the vicinity of Lone Prairie accompanied by the annotation of "southwestern limit of lake uncertain." Rutter (1970) found glacial lacustrine sediments extending south to the headwaters of the Sukunka River. He also reported glacial lacustrine sediments in the Murray River Valley near Lone Prairie. Engineering reports drafted prior to the construction of the town of Tumbler Ridge mention the glacial deltaic deposits underlying the present day townsite (Thompson et al., 1978). All of these studies suggested that an arm of glacial Lake Peace extended south at least to Tumbler Ridge. A serendipitous

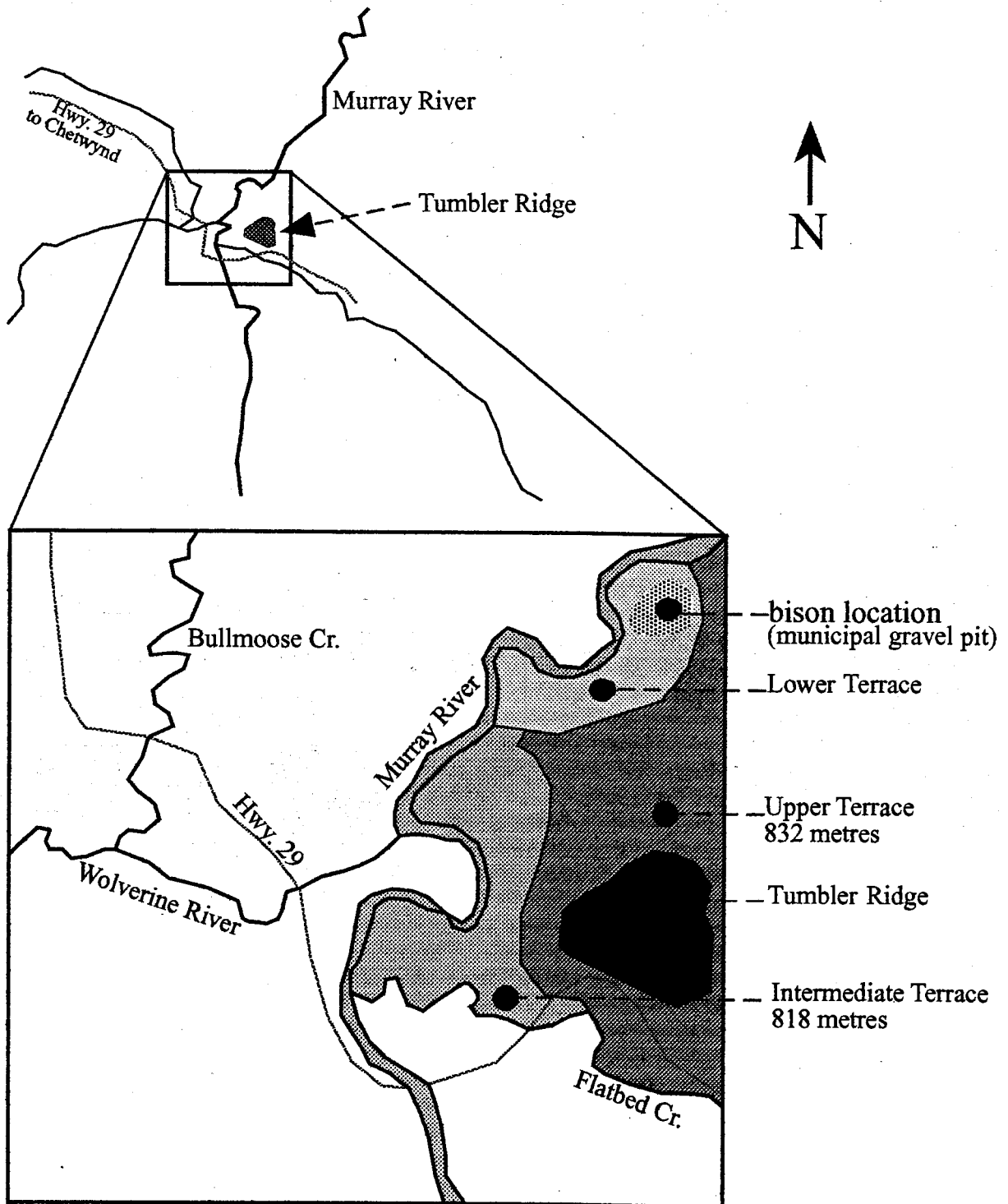


Figure 6  
Tumbler Ridge location map



discovery of datable bone material from the deltaic deposits provided a means to investigate this possibility.

The history of this site began when Dr. Arthur Roberts was contacted by a municipal employee who reported a bison skeleton had been recovered from the gravel pit operation at the new settlement of Tumbler Ridge, British Columbia, located at 121° 00' west longitude and 55° 08' north latitude. The sediments from which the bison was taken were reported as an 8 foot thick sand lens within a deltaic gravel deposit at an elevation of approximately  $792 \pm 1.5$  m ( $2600 \pm 5$  feet) at UTM 10U FS 269125. These facts were confirmed in person by Dr. Roberts soon after the skeleton's exhumation.

The deltaic sediments occur at the confluence of the northerly flowing Murray River, northeasterly flowing Wolverine River, southeasterly flowing Bullmoose Creek, and the northwesterly flowing Flatbed Creek. This complex confluence supplied the deltaic sediments which occur on both sides of the Murray River (Thompson et al. 1978). The eastern side of the river exhibits three terraces which have been referred to as the upper, intermediate, and lower townsite terraces (Figure 6). The deltaic sediments were studied by a consulting firm prior to the construction of the then new settlement of Tumbler Ridge.

Thompson et al. (1978) described the deltaic sediments and their genesis as follows:

- 1) The valley of the Murray River had been eroded to 670 metres elevation during the Pleistocene epoch.
- 2) The stagnation of the last ice in the area facilitated the formation of the Flatbed terrace; an ice-contact deposit formed by Flatbed Creek.

- 3) Disappearance of the stagnant ice was followed by the formation of a lake (presumably pro-glacial) which deposited stratified silts and sands to an elevation of 850 metres.
- 4) Gravel deltas were built into this standing water body by the Murray and Wolverine rivers, and by Flatbed Creek. The deltas coalesced to form a continuous surface of which the upper townsite terrace is a remnant.
- 5) Downcutting by local streams began as the water level of the lake dropped. The upper townsite terrace was eroded and its material redeposited as the intermediate and lower townsite terraces.

The bison skeleton was found in the lower townsite terrace and, therefore, dates a lower stage of the glacial water body then occupying the Murray Valley.

The bison was reported as articulated when found but much of the skeleton had been scavenged or discarded by the gravel pit workers. The value of the large skull was recognized and it was sent to Dr. Roberts in August, 1986. The bison skull resided in the S.F.U. Geography Department until the winter of 1990, when it was measured and photographed for the first time. The skull was identified as probably representing a mature male B. occidentalis. The state of preservation of the skull was good, discounting transport and secondary deposition and since it is likely the specimen was articulated when found, the resulting date is, therefore, assumed to be an excellent approximation of the age of the delta and the attendant lake level. Details of the measuring and identification process are found in Appendix No. 2

The site was revisited in the fall of 1990. The original section had been destroyed by gravel pit operations but a nearby section was located where a sand lens clearly displayed topset and foreset bedding, confirming the deltaic nature of the sediments.

The occipital portion of the skull, weighing approximately 643 grams was sent for radiocarbon assay. The collagen fraction was retrieved and underwent a standard radiocarbon count (non-AMS). The C-13 adjusted age is  $10,380 \pm 100$  years B. P. (BETA-44201) Table 3.

## CHAPTER FOUR

### DISCUSSION

A summary of the data follows:

- 1) Site I: three radiocarbon dates from 33,100 through 25,700 to 15,800 years B.P. near Fort St. John originating from lacustrine sediments underlying a till at an elevation of 728 m.a.s.l (2387 feet).
- 2) Site III: seven radiocarbon dates near Site I at an elevation of approximately 686 m.a.s.l (2250 feet) in lacustrine sediments spanning the mid-Holocene with an apparent discrepancy near the section base dating to circa 22,000 years B.P.
- 3) Tumbler Ridge: a bone date from deltaic sediments at an elevation of 792 m.a.s.l (2600 feet) near Tumbler Ridge B.C. dating to 10,380 years B.P.

All of these dates present significant problems in interpretation. The data sets will be discussed separately followed by conclusions.

#### Site I

The dates,  $33,100 \pm 1800$  (SFU-380),  $25,700 \pm 1200$  (BETA-11060), and  $15,800 \pm 1300$  years B.P (SFU-387), and the context in which they were found, are perhaps the most difficult to reconcile with contemporary geomorphic theory of the area. They seem to represent a record of a comparatively high level lake (non-glacial conditions) extending through the Middle and Late-Wisconsinan period ending with an overriding glaciation. The period determined for the lakes existence is intriguing in that it follows closely the interglacial period,  $37,190 \pm 2870$  (AECV-353C) through  $15,180 \pm 100$  (TO-708), proposed by Bobrowsky (1989a) in the Rocky Mountain

Trench. This correlation is interesting as it argues that neither Cordilleran or Montane ice can be responsible for impounding the theorized body of water.

Recent dates from the Alberta Plateau indicate ice free conditions throughout the Mid-Wisconsinan ending sometime after 22,000 years B.P. with the advance of Late Wisconsinan Laurentide ice onto the Alberta Plateau (Liverman et al. 1989; Bobrowsky, 1992). Westgate et al. (1971) also shows ice-free conditions throughout the Mid-Wisconsinan period. If these series of dates are correct it becomes difficult to implicate Laurentide ice as the damming mechanism for a lake throughout the entire Mid-Wisconsinan.

Alternatively, Reimchen and Rutter (1972) found evidence of a long lived lake phase existing in the area (93P map sheet) throughout the majority of the Mid-Wisconsinan. This timing was based on glacial stratigraphy and one late-glacial date of  $16,300 \pm 180$  (GSC-1548) from sediments below a 689 m (2260 foot) relict lake shoreline. The lake was shown as being impounded by a lengthy Laurentide advance. This conforms to the Model I scenario which postulates two Laurentide glaciations entering the area, the earliest of which was thought to be either Illinoian or Early Wisconsinan.

### **Date Reliability**

The reliability of the three radiocarbon dates suffer from two potential problems. It has been argued that the absence of the alkaline wash, on two of the dates, make the outcome questionable. The function of this wash is to remove humic acids, potentially present in a sample, which would tend to, but not always, skew the determinations towards a figure younger than their true age. Additionally it has been argued that because the samples were bulk dates, coal contamination could make the determinations appear older than their true age.

The problem concerning the lack of the alkaline pretreatment is mediated by the fact that one of the series, Beta-11060, did receive full acid and alkaline pretreatment. The determination of  $25,700 \pm 1200$  years B.P. seems to fall naturally into place between the dates of  $15,800 \pm 1300$  years B.P. (SFU-387) and  $33,100 \pm 1800$  years B.P. (SFU-380). If the two SFU dates suffer from significant contamination which could have been removed by the alkaline treatment, it is not evident.

However, it is possible that the dates could be affected by ancient carbon giving an erroneously old determination. Since it is known that coal does exist in the area and could, therefore, have been incorporated into lake sediments. The  $\delta C^{13}$  reading of  $-25.75$  ‰ is of some value as this figure is very close to the value for recent wood or charcoal ( $-25.00$  ‰), unfortunately, it is also close to the figure commonly obtained from coal of approximately  $-23.00$  ‰.

The most likely form of contamination is a scenario where the dated material consists largely of infinitely old carbon (coal), of actual age 1,000,000 years B.P., only 7 to 8 percent modern carbon contamination would be required to date the sediments to 26,000 years B.P. (personal communication, Earl Nelson.). This is obviously significant, but in the end uninformative, without further data it is impossible to comment further on this possibility.

Perhaps the best argument in favour of retaining the dates as valid, is the fact that the three dates fall naturally in place along a near linear time scale and the dated material originated from a suitable context (under a till). If contamination is seen as significantly affecting the dates then the question must be asked; what is the nature of this contamination? If the dated material is really much younger, dating to 10,000 years B.P., significant amounts of ancient contaminants, greater than 85 percent in fact, would be necessary to achieve the measured values.

Another factor, arguing for the retention of the dates as valid, questions the likelihood that essentially random processes of contamination could proceed in such a manner as to generate seemingly non-random dates. This is especially true of ancient carbon as the most common vector of contamination would be the simple washing in of materials containing significant amounts of dead carbon (coal). The process should proceed according to precipitation and availability of contaminant parent material, with an outcome of totally random amounts of contamination deposited. Contamination by young carbon might conceivably follow some mathematic function with soluble contaminants percolating either downward or upward.

Another possibility, is that the dates are not contaminated and reflect real radiocarbon events, but these events are not contemporaneous with the deposition of the sediment (redeposition). Other than acknowledging that this is a possibility there is little else can be said, without further investigation.

Given the above it is still a possible that the radiocarbon dates from Site I accurately record a lake stand above 732 m (2400 feet) throughout part of the Mid-Wisconsinan.

The mechanism for impounding this water body is likely continental ice but remains open to speculation because, with the these dated lake sediments recognized only in this locale, it is impossible to surmise the extent of the water body. Invoking large landslides as a damming mechanism for such a water body is an ad hoc hypothesis at best.

Without further study, especially fieldwork, it is difficult to speculate on the possibility of local damming of a small tributary producing the sediments. Local relief at the site places the lake sediments some 200 feet above the present stream bed. The local topography of the area some thousands of years ago, before glaciation, is difficult to surmise. However, many transient

mechanisms such as spring break-up ice-damming, or small landslides could have affected an ancient creek in the area and contributed to the development of the sediments.

Still, if the dates are correct, they provide evidence that the area was ice free through parts of the Mid-Wisconsinan and that there may have been an ice-advance into the area sometime after 15,800 B.P. A single granitic clast found in nearby Red Creek argues that Laurentide ice was in the area at some time, whether this was previous or antecedent to the lacustrine sediments deposition is unknown.

The influence of Late Wisconsinan Laurentide glaciation is now thought to have entered the area sometime after 22,000 years B.P. (Bobrowsky and Rutter, 1992) and remained until sometime before  $13,580 \pm 260$  (GSC-698) (Lowdon and Blake, 1968). The youngest date of  $15,800 \pm 1800$  (SFU-387) from unit B, could represent water impounded behind the retreating continental ice mass. Additionally, it is conceivable that advancing Laurentide ice was close enough to account for damming leading to the deposition of the sediments from unit D ( $25,700 \pm 1200$  years B.P.) (BETA-11060). The oldest date from the lowest unit (E2) ( $33,100 \pm 1800$ ) does seem firmly rooted in the Mid-Wisconsinan. It seems unlikely, given the range of non-glacial dates from Watino (Liverman et al. 1989 and Westgate et al. 1971) that Laurentide ice could be responsible for impounding easterly drainage 33,000 years ago.

Liverman's (Liverman et al. 1989) explanation of the non congruence of their data with Mathews (1978a) data may help to explain this early date. Liverman and his colleagues explained that Mathews evidence of multiple Laurentide glaciations entering the Charlie Lake area could be explained if early Wisconsinan ice exhibited a lobate margin, bypassing the Watino area while entering the Charlie Lake area. If this scenario is possible for Early Wisconsinan ice, perhaps it is also possible that the influence of early Late Wisconsinan ice bypassed Watino to the north. The



pattern of ice-flow during glacial onset (Mathews, 1978a, 1980) was determined to be generally aligned on a north south axis. It may be conceivable that an early Late-Wisconsinan advance developed a very lobate margin extending south as to block the Peace River drainage near the mountain front but allowing eastwardly drainage to continue towards Watino.

### **Summary**

There are some problems with the dates from Site I. If the dates are correct they provide evidence of ice-free conditions in the Charlie Lake area through-out the Mid-Wisconsinan. The sediments from which the  $15,800 \pm 1300$  and the  $25,700 \pm 1200$  dates were taken record a water body which was probably impounded by advancing Laurentide ice. The earliest date of  $33,100 \pm 1800$  is more difficult to explain but might represent a lobate margin on the continental sheet blocking drainage of the Peace River while leaving the Watino area basically unaffected.

### **Site III**

The dates from Site III are similar to Site I in that they present some difficulties in interpretation. The four uppermost levels gave dates clustering in the mid-Holocene:  $4245 \pm 50$  (BETA-50790),  $4445 \pm 50$  (BETA-50791),  $4745 \pm 55$  (BETA-50792),  $4700 \pm 60$  (BETA-44202). Levels 5 and 6 date to  $22,050 \pm 150$  (BETA-50793) and  $22,480 \pm 180$  (BETA-50794). The stratigraphically lowest determination comes from level 7 which dates to  $7235 \pm 70$  (BETA-50795).

## **Date Reliability**

The main problem is to explain the apparent dating inversion at the bottom of the section. Three hypotheses logically offer themselves: 1) the oldest dates from levels 5 and 6 are contaminated or are out of place, 2) the date from level 7 is contaminated or out of place, and 3) all the dates are contaminated or out of place.

Examination of the third hypothesis shows that it is unlikely. Firstly, there is little evidence which argues for this other than the fact that the organics were found in sediments that showed evidence of deformation possibly due to loading. The dates are not out of sequence and the upper four levels almost certainly date a small post-glacial lake, analogous to the present day Charlie Lake, impounded in the upper reaches of Red Creek.

Sediments from this extinct water body form the basis for local agriculture in the area and are shown as being glacio-lacustrine by Mathews (1978a) on Map 1460A. Elevational measurements show that a dam just below the bridge crossing of Red Creek would require approximately 15 metres of additional relief to impound a water body above 686 metres (2250 feet). The dam may have been a small landslide or perhaps more likely, stagnant ice deposits. Kettles and ablation moraine are abundant near the valley mouth at Peace River, whereas none are visible further up valley, near the postulated dam location, these sediments could have been draped by colluvium or mostly removed by fluvial action.

The first scenario wherein the circa 22,000 year old dates are spurious and the younger Holocene dates are correct is unlikely for the following reasons. The material dated was identifiable organic remains; identifiable, in that the material was distinct pieces of woody material, not stained sediments. This lessens the chances of ancient carbon (coal) skewing young material to

date much older. Radiocarbon statistics show that it would require 80 percent of the dated material being dead carbon to date a sample of 6000 years true age to 22,000 years old (personal communication Nelson, 1993). Conversely the obverse of this statistic is not a mirror image, it would require more than 45 percent modern material to date a 22,000 year old carbon sample to 6000 years (personal communication, Nelson, 1993). Additionally, the chances of contamination regardless of it's origin bringing about essentially contemporaneous dates in two distinct strata are small (personal communication, Beta Analytic, 1993). It seems therefore, that probability argues the older dates record a distinct, real radiocarbon event occurring about 22,000 years B.P. The question of whether this radiocarbon event is contemporaneous with the deposition of levels 5 and 6 prompts an examination of the second scenario wherein the  $7235 \pm 70$  date is spurious.

Again radiocarbon statistical measures tell us that it would require similar amounts of young carbon, approximately 50 percent, to skew a 22,000 year old date to a 7000 year old determination (personal communication, Nelson, 1993). The probability of this occurring is related to the depositional environment and without further field study is difficult to quantify. However, the fit of the lowest date with the other Holocene dates higher in the section suggests it is in place and uncontaminated. This then suggests the overlying 22,000 year old dates may be out of place. The obverse of this is perhaps equally likely, the lowest date is contaminated and the sediments above date a late Mid-Wisconsinan water body.

The result of this is that two possible scenarios are presented:

- 1) The section dates a Holocene lake which formed before  $7235 \pm 70$  years B.P. and drained sometime after  $4245 \pm 50$  years B.P. The circa 22,000 year old dates are out of place and do not date the deposition of the sediment.
- 2) The section dates a Holocene lake which formed sometime before 4700 years B.P. and drained after 4200 years B.P. These sediments overlie older lake sediments laid probably in relation to

advancing continental glaciers approximately 22,000 years B.P. The underlying date of 7235 ± 70 (BETA-50795) is out of place or contaminated and does not accurately date the including sediments deposition.

Site III, like Site I, lacks lacustrine sediments dating to classic Laurentide deglacial periods circa 10,000 years B.P.; the reasons for this are unknown. Both sections may have lost younger sediments to erosion or the record may have been destroyed by farming activities at Site III. It is also possible that the sediments dating to the turn of the Holocene are thin, include no organic debris and therefore, are not recognized. The suggestion that Site III sediments might be gravity flow deposits (Bobrowsky, personal communication, 1990), could indicate deposition was periodic and no significant accumulation of sediments took place during the early Holocene.

Periodic deposition may have occurred for many reasons, but one theory might be that the sediments record forest fires. The sediments would have been mobilized by heavy runoff following denudation of the landscape by fire. This would explain the dark organic layers associated with each sediment.

Lastly, a comment on the fact that Site III strata were interpreted to show evidence of loading (flame structures, diapirs, minor scour and fill). If true, this might help explain the dating reversal at the bottom of the section. Although the organic units appeared essentially horizontally bedded, it may be possible that organic layers near the bottom of the section record emplacement of contaminate carbon migrating from elsewhere in the section. Given the facts that the majority of the deformed strata dates to the mid-Holocene, and that no overlying till is found at the section, the conclusion must be that Site III was not overridden by an ice sheet.

## Summary

The upper, Mid-Holocene dates represent a small post-glacial lake analogous to Charlie lake impounded in the upper reaches of Red Creek. Two scenarios are presented to account for the section base:

- 1) The two 22,000 year old dates are contaminated or out of place and the entire section including the underlying  $7235 \pm 70$  determination, record the post-glacial water body discussed above.
- 2) The lowest stratigraphic date ( $7235 \pm 70$ ) is contaminated or out of place and the overlying 22,000 year old dates represent a body of water impounded by ice or sediment

## Tumbler Ridge Site

Rutter (1970) reported extensive late glacial lacustrine deposits up to 4000 feet elevation near the head of the Sukunka River valley west of the Murray River. Similarly, he reported extensive lacustrine deposits in the Murray River Valley, although he did not provide the elevation to which these extended. The presence of these sediments indicates a glacial lake was impounded within the Murray River valley and it is possible that this lake was an arm of glacial Lake Peace.

The late-glacial date of  $10,380 \pm 100$  (Beta-44201) from deltaic deposits near Tumbler Ridge B.C. falls into the deglacial time period commonly used in the literature. The elevation at which the bison bone material was found, the "lower terrace" (Thompson et al. 1978) suggests that this radiocarbon determination dates the last stage of the delta's development. As mentioned earlier, the delta is comprised of three levels, the highest representing the initial deposition with the lower two terraces dating to the lowering of the incoming streams base level as the receiving glacial

lake receded. Although the lower two levels should contain mostly redeposited gravels eroded from the higher terrace, the bone material probably represents a primary deposition.

The bison was reported as being articulated when exhumed. Although none of the postcranial bones were recovered for study, evidence from the skull supports a primary burial and attendant articulation. Small, fragile bone protrusions or burrs between the horn core base and the side of the skull were intact. Indeed, the skull as a whole displayed many fragile bone structures which could not have survived any amount of tumbling prior to deposition. This evidence in conjunction with testimony of articulation offers the logical scenario of the bison carcass entering a stream course and being deposited basically intact, decaying in situ. Therefore, the skull and its attendant date have excellent correlation with the sediments from which they originated.

The reliability of the date is not in question. Dates on bone collagen are now thought to be very reliable (personal communication, Dr. Erle Nelson, 1993). Rigorous pretreatment procedures were followed and the quality of the resulting collagen was termed good by the radiocarbon laboratory (Dr. M. Tamers, Beta Analytic, personal communication, 1993). The nitrogen content of the bone was tested at the SFU radiocarbon lab. This determination showed that there had been good amino acid preservation, lessening the chances of contamination.

### **Terrace/Lake Correlations**

Values of isostatic rebound are not known for the Tumbler Ridge area. The question of possible correlations between the three terraces and known lake levels is difficult to evaluate with so little additional information. The following suggestions towards a correlation are open to question and should be viewed with circumspection.

Table 4  
 Measured terrace elevations at Tumbler Ridge B.C.  
 versus  
 observed and isostatically adjusted paleo-lake levels

| Observed Terrace Elevations (1) | Scenario I                     | Scenario II                             |   |                                       |
|---------------------------------|--------------------------------|---|---|---------------------------------------|
|                                 | Observed Lake Elevations (2)   | PREDICTED east/west component (0.4m/km) | ISOSTATIC north/south component (0.4m/km) | ELEVATIONS both east/west north/south |
| HIGH<br>832<br>metres           | Bessborough<br>838<br>metres   | 851<br>metres                           | 868<br>metres                             | 881<br>metres                         |
| MIDDLE<br>818<br>metres         | "unnamed"<br>800-808<br>metres | 786<br>metres                           | 847<br>metres                             | 825<br>metres                         |
| LOW<br>790<br>metres            | Clayhurst<br>689<br>metres     | 713<br>metres                           | 735<br>metres                             | 759<br>metres                         |

(1) (Thompson et al., 1978)

(2) (Mathews, 1962)

**Scenario I**

The elevations of the terraces, as they exist, suggest at least two possible correlations. The 792 m (2600 feet) elevation of the lower terrace, as well as the 818 m (2684 feet) elevation of the middle terrace suggests the glacial lake into which they were deposited was the "unnamed phase" of Mathews (1978a) or what Rutter referred to as the "Hudson Hope phase" (Rutter, 1977) known to occur near Hudson Hope between 800 and 808 metres elevation. Limits of lacustrine silts mantling the Alberta plateau suggested this phase may have extended between 792 and 823 metres (Mathews, 1978a; St. Onge, 1972).

The lower and middle terraces exist at equal distances from the observed range of "unnamed phase" shoreline elevations near Hudson Hope. The lower terrace (790 m elevation) is 10 metres

lower than the lowest observed shoreline elevation of 800 metres. Similarly, the middle terrace (818m) is 10 metres higher than the upper observed shoreline at Hudson Hope (808 m). The range of observed elevations on the Alberta plateau (792 m and 823 m) suggests that this lake underwent extensive elevational changes. The lower two terraces fit well within this expanded framework. The Clayhurst phase of glacial Lake Peace does seem to be too low to have existed this far south (see Scenario III below).

Mathews (1980) noted the lack of shorelines at elevations intermediate to the higher Bessborough stage and the lower "unnamed stage." He believed this absence might represent a rapid drop in level associated with the cutting of a new outlet. The middle terrace at Tumbler Ridge might represent evidence of such a water body existing at these intermediate elevations.

The suggestion that the dated lower terrace is correlative with Mathews "unnamed phase" agrees reasonably well with the radiocarbon chronology given by St. Onge (1972) from glacial Lake Iosegun (Iosegun II or III at elevations between 792 m and 823 m correlative with Mathews "unnamed phase") at elevations ranging from 833 m to 747 m with a corresponding radiocarbon range of  $13,510 \pm 230$  to  $10,900 \pm 170$  years B.P. (GSC-694, and GSC-859 respectively).

If it is true that the lowest two terraces correlate with the lake phase between 792 and 823 metres then it might be supposed that the upper terrace is correlative with older, higher lake levels identified farther north around Fort St. John. The elevation of the uppermost level (832 m) suggests an affiliation with the Bessborough stage of Mathews (1978a) the water body known to exist at elevations around 838m (2750 feet) near the community of Bessborough.

If the above correlations are true this would suggest that lower, younger phases of glacial Lake Peace have temporal limits extending well into the Holocene. Dates on the final phases of Lake Peace are rare, but two shell dates from the Dawson Creek area at  $9960 \pm 170$  (GSC-1548) and



10,400 ± 170 (GSC-1654) suggested that the Clayhurst phase dates to the beginning of the Holocene (Lowdon and Blake, 1973).

If true, these dates are at odds with the correlation of the "unnamed" phase of Lake Peace with the bone date from Tumbler Ridge (Beta-44201). In the past shell dates have been viewed with some suspicion due to the non-stable carbon exchange from shell's carbonate fraction. It is not clear whether these samples used the carbonate or conchiolon fraction and so their reliability is difficult to evaluate.

Dates on another bison (10,300, 10,500, 10,700, 10,400) (lab numbers and errors unavaible) recovered from a gravel pit at Clayhurst crossing elevation 544 m a.s.l. also argue that the Clayhurst phase of Lake Peace ended before 10,500 years B.P. (Apland, personal communication, 1992).

The above set of hypotheses concerning glacial lake correlations with the Tumbler Ridge delta support the measure of the north-south component of isostasy noted by Mathews (1978a) in which one possible shoreline correlation was determined to be zero. Mathews (1978a) also noted that another shoreline correlation showed a north to south rise of 0.4 m/km (2 feet/mile) rise. This value as well an east-west isostatic component are examined below in Scenario II.

## **Scenario II**

This exercise attempted to apply known directional and magnitudunal values for east to west isostatic rebound from type sections of major phases of glacial Lake Peace and extend the predicted water planes to the terraces at Tumbler Ridge. This was done by normalizing known lake levels (at their type sections) to the longitude at Tumbler Ridge (121° west longitude) using the value of isostatic rebound (0.4 m/km) noted by Mathews (1978a) and Rutter (1977). The

values would predict that correlative terraces for the Bessborough, "unnamed," and Clayhurst phases should exist at elevations of 851 m, 786 m, and 713 m respectively at 121° west longitude see Table 4. The exercise demonstrates that the differences between isostatically predicted terrace elevations and actual terrace elevations increase substantially when compared to known lake-phase elevations.

Similarly, postulated values for a north-south isostatic component were examined using the same procedure. These calculations predicted the terraces at Tumbler Ridge should exist at 868 m, 847 m, and 735 m for three phases, Bessborough, "unnamed," and Clayhurst respectively, see Table 4. The values attained through this procedure also increased the differences between predicted terrace elevations and the actual measured values at Tumbler Ridge.

Finally, both east-west and north-south components were combined to compare the predicted fit with the measured terrace elevations. These computed values continued the trend and increased the poorness of the fit between predicted and measured values. The single exception in this case was the fit from the shoreline associated with the Hudson Hope or unnamed phase. Applying both isostatic components made the fit slightly better, but only because the east-west versus the north-south values are different in sign for this calculation. The fit is still inferior to the actual lake elevations compared to the observed terrace elevations see Table 4.

It is apparent the differences between the measured terrace elevations and the isostatically predicted elevations are greater than those from the measured terrace elevations and the measured relict shoreline type sections farther north (Scenario I). This suggests that either the magnitude or direction of isostatic rebound as given in Mathews (1978a) and Rutter (1977) are incorrect or non-applicable to areas to the south. The lack of applicability should probably not be a surprise, as correlation of the Tumbler Ridge terraces with major phases of glacial Lake Peace have not been

established. Additionally, values of isostasy are known to vary with linear distance from the ice sheet as well as temporal distance from deglaciation (Flint, 1971). Since the terraces and their respective parent water bodies represent a time-transgressive process, it should be expected that the complexity of isostatic rebound would prevent a single value from having predictive ability.

### **Scenario III**

The two scenarios for terrace/lake correlations presented above are, in the final analysis, somewhat moot. Regardless of the hypotheses about what specific lake level is associated with an individual terrace the fact remains that the simplest explanation is that one of the final phases of glacial Lake Peace in the Tumbler Ridge area took place circa 10,380 years B.P. Published accounts of Charlie Lake Cave near Fort St. John suggests three dates, all circa 10,500 years B.P. from the strata including in situ Paleo-Indian material might be correlated (within a few hundred radiocarbon years) with the shoreline at an elevation of 730 metres a.s.l., some 15 metres below the cave mouth (Fladmark et al., 1988). Although the relation of dated cave material to the lake phase is tenuous at best, if true would argue that the lake below the caves mouth may have extended it's southern shores to Tumbler Ridge resulting in the deposition of the lowest terrace level at the latter location.

This leads to one final speculation. To attain the above correlation the lake plain at Charlie Lake Cave at elevation 715 metres a.s.l. would have to have rise upwards to the south some 77 metres to correlate with the lowest terrace elevation at Tumbler Ridge of 792 metres a.s.l. The intervening distance between these two locations is approximately 129 kilometres. This then would require an isostatic uplift trending from north to south on the order of 0.6 m/km or 3.2 feet/mile. As mentioned earlier, rates of 0.4 m/km are observed running east to west in the Peace River Valley and rates of similar magnitude have been postulated running north to south

(Mathews, 1978a; Rutter, 1977). Rates of uplift at this new figure do seem slightly excessive given published figures from the Great Lakes region with maximum figures around 0.4 m/km (Roberts, 1985)

### **Summary**

A late-glacial lake occupied the Murray River Valley for a significant period of time, sometime before 10,380 years B.P. This water body may have been contiguous with glacial Lake Peace. Isostatic values measured to the north in the Peace River Valley may not be applicable to the Tumbler Ridge area. If the correlation with the "unnamed" stage is correct, lower stages of glacial Lake Peace must have remained well into the Holocene. Correlation of the lowest terrace with the Clayhurst stage of Lake Peace suggests a rate of isostatic uplift trending from north to south on the order of 0.6 m/km or 3.2 ft/mile.

## CHAPTER FIVE

### CONCLUSIONS

The literature is full of new data which seem to argue that the "classical" idea of many continental glaciations interfingering with equal numbers of Cordilleran glaciations is suspect. The data presented here provides some support for the newer paradigm advanced by Bobrowsky and others. Both sets of dates from the Charlie Lake area argue, somewhat equivocally, for ice-free conditions ending with an expanding pro-glacial lake impounded by continental ice sometime before 22,000 years B.P. This encroachment may have been much earlier circa 33,000 years ago, but the evidence for this remains equivocal. The area may have been overridden by ice sometime after 15,800 years B.P.

A Holocene lake, perhaps equivalent to Charlie lake, existed in the upper reaches of the Red Creek drainage near Fort. St. John. Two minimum dates relating to its formation are available. The lake would represent a remnant feature following the draining of glacial Lake Peace circa 10,380 years B.P. The lake drained sometime after 4245 years B.P.

The Tumbler Ridge date from the lowest of three terraces relating to ice retreat indicates that deglacial conditions were well under way by  $10,380 \pm 100$  years B.P. An arm of glacial Lake Peace probably extended up to the head of Murray River Valley. Possible correlations with two early phases (Bessborough and the "unnamed") of glacial Lake Peace are noted. Such correlations would indicate that the existence of lower phases of Lake Peace must have extended into the Holocene.

Alternatively, it may also be possible that the Clayhurst phase of Lake Peace correlates with the lowest terrace at Tumbler Ridge. This would mean the last high phase of Lake Peace drained

sometime after circa 10,380 years, that a north to south component of isostatic rebound is evidenced on the order of 0.6m/km and that the area was dominated by western ice.

**APPENDIX I**  
**ORGANIC REMOVAL**  
**Site III**

This section outlines the details noted while manually separating the organic samples from the matrix from the section at Site III. All samples were collected by trowel and wrapped in tin foil. Separation of organics occurred soon thereafter. Organic separation was accomplished through the use of a magnifying lamp to aid location and stainless steel and copper implements to collect the organics. All implements and sample jars were thoroughly washed with distilled deionized water prior to use.

**Horizon #1**

- grey silt
  - some orangish staining of small sand clumps (oxidation?)
- lots of rootlets
- spiders nest
- organics poorly defined
  - mostly confined to dark staining of sediments
  - some intact larger pieces
- numerous small pieces of wood sent
  - homogenous (from one larger piece)
  - total sample weight of 0.33 grams

**Horizon #2**

- silt with orangish staining of sand inclusions
  - silt is almost completely black (organic staining)
- lots of rootlets
- numerous large pieces of organic debris (charcoal)
  - some show orangish staining
- one large organic piece sent for dating
  - total sample weight of 0.5 grams

### Horizon #3

- sample consists of about equal parts silt found throughout an orange stained sand
- lots of rootlets
- large pieces of organic debris (charcoal) are common
  - seem to be concentrated in silts although a few smaller pieces in sand
  - may be concentrated at the silt/sand interface
  - wood grain visible in many larger pieces
- non-homogenous sample
  - 4 large pieces sent
  - total sample weight of 0.35 grams

### Horizon #4

- not noted

### Horizon #5

- mostly silt with some fine sand
- very little orange staining
- some very small rootlet present
- organics relatively rare
  - usually in hard silt clumps
- also a small amount of bone present
  - small rodent?
- some hard black rock present
  - flat cleavage (gneiss?) (coal?)
- two samples taken
  - first sample is homogenous but small
    - retained for future use
  - second sample sent (non-homogenous)
    - 3 large organic pieces
    - total sample weight of 0.43 grams

### Horizon #6

- sample is silt with small amount of sand
- very few small rootlets visible



- upon opening package noted orangish staining not noticed when sample was collected (oxidation?)
- organic portion seems to consist largely of staining only
  - some small pieces of charcoal visible
  - removal is therefore difficult consists of scratching darkened silts off with copper probe
  - some organics seem slightly indurated and are included as flakes (these samples discarded)
- finding lots of bone fragments
  - very dark organics seemingly in association with bone fragments (burned bone?)
  - these samples not sent.
- a few small teeth (rodents?)
- numerous small pieces sent (non-homogenous)
- total sample weight of 0.55 grams

#### Horizon 7

- fine silt with a little sand
  - sand seems slightly indurated
- lots of large organics
  - grain visible in most
- no oxidation visible
- two pieces sent (non-homogenous)
  - total sample weight of 0.32 grams

## APPENDIX II

### BISON MEASUREMENT AND IDENTIFICATION TO SPECIES

One of the more interesting features of this research is the ancient bison skull obtained from a delta at Tumbler Ridge B.C. The skull was exceptional in that it was among the rare physical evidence available for consideration from the study area. This fact made an attempt to speciate the animal of great interest and some importance.

#### **Bison Taxonomy**

Speciation and taxonomy of fossil bison are matters of some complexity if not outright notoriety. The basic controversy has revolved around two taxonomic paradigms which have been referred to as "lumping" vs "splitting." The terms are self-explanatory. "Splitters" see new combinations of bone characters as representative of different species; individual variation, poor fossil preservation, or stratigraphic confusion can and have played a part in generating new specific names. Taxonomists of the 18th, 19th, and early 20th centuries were largely splitters and generated new species and even genera in significant numbers. In fact during the late 19th century this evolved into a contest between two taxonomists who tried to outdo each other by naming more new species than his rival. "Lumpers" see fossil and living bison as representing a continua and species designations are assigned on this basis resulting in fewer named species. Contemporary taxonomists largely adhere to the "lumper" paradigm. McDonald (1981) and Wilson (1975) give excellent summaries of the taxonomic history of North American fossil bison.

One reason the study of fossil bison has enjoyed so much attention is that bison skulls present a series of measurable features that have a generally agreed upon role in species identification, by far the most commonly used of these features are "horn core characters" and measurements of the adjoining portions of the skull. This has arisen in part because horn cores are probably the most

commonly recovered portion of bison skulls (McDonald, 1981). But not only high relative occurrence make horn cores useful for speciation, much of the evolutionary change bison have undergone since their arrival in North America, perhaps as early as the Yarmouthian Interglacial (Wilson, 1975), has been reflected in the size and shape of their horn cores (Guthrie, 1980, McDonald, 1981).

Skull character and horn core character measurements are generally agreed upon, being delineated by two major studies, Skinner and Kaison (1947) and McDonald (1981). McDonald (1981) arose directly from Skinner and Kaison (1947) with some changes and was the schema used for speciation of the Tumbler Ridge bison.

Taxonomically of interest to this study is the question of what species name should the Tumbler Ridge specimen be assigned. The question was difficult to answer. The skull was reasonably well preserved although significant post-exhumation abrasion and damage had occurred. This damage had eroded much of the fragile tips of the horn cores, making length estimates necessary.

Additionally, the skull had been broken into three large pieces; left and right halves along the sagittal suture and through portions of the lamdoidal suture separating the occipital from the rest of the skull. The nasals, maxillas, and mandible were also missing although it appeared these had been separated early after the skulls deposition probably through settling and consequent crushing by overlying sediments. The traumas, however, did not make measurement impossible as many of the essential characters were preserved.

Further complicating the process is the fact that Late Pleistocene/Early Holocene bison taxonomy is still a somewhat convoluted issue. Fortunately, of the many fossil species still recognized only two phenotypes present themselves with both correct temporal correlation and appropriate anatomical size to be considered. Unfortunately, even the taxonomy between these two forms is

not agreed upon. The Tumbler Ridge specimen fell into either an B. antiquus or an B. occidentalis form. These represent the major two phenotypes present on the Great Plains during the Pleistocene/Holocene transition (Wilson, 1975).

I have chosen to refer to these two phenotypes as either B. antiquus or occidentalis as current taxonomy is still unresolved. B. antiquus specimens could be referred to either as Bison antiquus (Leidy, 1852), Bison antiquus antiquus (Leidy, 1852), or Bison bison antiquus (Wilson, 1975). Similarly the other taxa could be formally referred to as either, Bison antiquus occidentalis (Lucas 1898), Bison occidentalis (Lucas, 1898) or Bison bison occidentalis (Fuller and Bayrock, 1965). Rather than wade into the field of taxonomy and synonymy I have chosen to describe the specimen in terms of characteristics common with B. occidentalis or B. antiquus specimens, ignoring whether they are species or subspecies.

Although not entirely agreed upon, the ranges of these animals are thought to have generally occurred in a north-south pattern. The southern form (California, Texas, Mexico and surroundings areas) were the B. antiquus, the northern form (central and Great Plains) the B. occidentalis (McDonald, 1981). It has been proposed that intermediate ranges, such as the northern Great Plains should display bison forms intermediate between the two phenotypes (Wilson, 1975). The nature of the phenotypic variation is complex but it is sufficient for this discussion to limit our remarks to those characters affecting the skull.

### **Measurements**

Because the skull was missing the distal portions of the horn cores it was necessary to estimate some of the horn core characters, specifically measurement numbers 1, 3, and 5 relating to different length measurements surrounding the horn cores. Estimation was accomplished via the

statement that, "The length along the upper curve is about equal to the circumference of the (horn) core at the base." (McDonald, 1981:86). This statement, made in reference to the B. occidentalis bison, is also generally true of the B. antiquus taxa as well. Estimation also involved the use of "Flexi-curves," flexible drafting instruments similar to a "french curve" in function. These flexible pieces of plastic were affixed along the intact upper curve of the horn cores and manipulated until the curve was reproduced and a good extrapolation of the core's original size was possible. This approach was deemed possible as the horn cores exhibited very strong occidentalis characteristics (discussed below under 'horn core characters') which suggested that curvature should follow a "curve upward in a continuous arc that begins at or near the base" (McDonald 1981:86). This technique combined with the knowledge that core circumference is roughly equal to distance along the upper curve led to the estimated measurement to 320 mm, which in turn allowed approximations of the horn core spread from tip to tip (940 mm) and the straight line distance from the core tip to burr, (310 mm). It is worthy of note that these figures are somewhat conservative, as the horn core circumference (average of 370.5 mm) suggests a somewhat larger animal. It should also be noted that if the cores were true to antiquus curvatures the orientation of the cores would be more strongly affected than would estimations of length.

The two other estimated measures are very good in that they may differ from the actual size by a maximum of one or two millimetres. Portions of the dextral half of the occipital were missing. This break continued down through the dextral condyle which was also missing a small distal portion. Estimation of these two measures involved measuring from the medial line to the lateral portions of the intact sinistral side and multiplying this figure by two.

Table 5 compares measurements from the Tumbler Ridge specimen with a set of measurements from identified B. occidentalis and B. antiquus specimens compiled by (McDonald, 1981). He presented these measurements to assist the process of speciation, although it should be noted

Table 5  
Tumbler Ridge Bison Measurements  
*occidentalis* vs *antiquus*

| Standard Measurement (Males)                            | Tumbler Ridge bison | Bison <i>Antiquus</i> range* | Bison <i>Antiquus</i> mean*<br>13.7mm | Standard Deviation* | Bison <i>Occidentalis</i> range* | Bison <i>Occidentalis</i> mean* | Standard Deviation* |
|---|---------------------|------------------------------|---------------------------------------|---------------------|----------------------------------|---------------------------------|---------------------|
| Spread of horn cores tip to tip                         | 940mm (est)         | 765-1067mm                   | 870.0 ± 13.7mm                        | 71.0mm              | 626-1055mm                       | 779.3 ± 8.8mm                   | 76.9mm              |
| horn core length, upper curve, tip to burr              | 320mm (est)         | 203-364mm                    | 279.2 ± 6.2mm                         | 35.1mm              | 186-392mm                        | 277.8 ± 4.2mm                   | 39.1mm              |
| straight line distance, tip to burr, dorsal horn core   | 310mm (est)         | 185-330mm                    | 249.7 ± 5.3mm                         | 29.2mm              | 175-350mm                        | 248.1 ± 3.5mm                   | 31.8mm              |
| dorso-ventral diameter, horn core base                  | 123mm               | 81-126mm                     | 101.9 ± 1.6mm                         | 9.7mm               | 70-114mm                         | 94.6 ± 0.9mm                    | 8.4mm               |
| minimum circumference, horn core base                   | 370mm               | 233-392mm                    | 324.4 ± 5.3mm                         | 32.6mm              | 237-355mm                        | 300.3 ± 2.9mm                   | 27.7mm              |
| width of occipital at auditory openings                 | 284mm (est)         | 251-318mm                    | 287.9 ± 4.2mm                         | 18.6mm              | 238-294mm                        | 262.0 ± 1.4mm                   | 13.2mm              |
| width of occipital condyles                             | 142mm (est)         | 132-161mm                    | 143.7 ± 1.9mm                         | 8.4mm               | 111-151mm                        | 135.0 ± 0.9mm                   | 7.7mm               |
| depth, nuchal line to dorsal margin of foramen magnum   | 105mm               | 94-134mm                     | 111.6 ± 2.2mm                         | 9.2mm               | 89-120mm                         | 104.0 ± 0.9mm                   | 7.0mm               |
| antero-posterior diameter, horn core base               | 116mm *             | 76-129mm                     | 105.6 ± 1.9mm                         | 12.2mm              | 77-120mm                         | 98.8 ± 1.1mm                    | 10.0mm              |
| least width of frontals between horn cores and orbits   | 314mm               | 276-352mm                    | 314.7 ± 3.9mm                         | 19.4mm              | 261-348mm                        | 296.6 ± 2.0mm                   | 16.8mm              |
| greatest width of frontals at orbits                    | 410mm               | 338-400mm                    | 371.3 ± 4.6mm                         | 18.6mm              | 311-394mm                        | 348.0 ± 2.1mm                   | 16.7mm              |
| angle of divergence of horn cores forward from sagittal | 74.5°               | 72-86°                       | 79.2 ± 1.0°                           | 4.8°                | 63-83°                           | 72.1 ± 0.7°                     | 5.2°                |

\*(McDonald, 1981)

that there are other skull and horn core character measurements which do not appear in the table of equal or perhaps greater importance. Scanning the table it is readily apparent that measurements from the Tumbler Ridge specimen fall mainly into the B. antiquus set as measured by their proximity to the mean. Only two measurements, number 10 and angle 21 fall closer to the B. occidentalis mean. It should also be noted that all measurements, except number 15, fall within the measured range of both species. Number 15, greatest width of frontals at orbits, is extraordinary in that it falls outside ranges for both phenotypes. Further examination shows that measurements 1 and 12 fall very close to the upper limit of one standard deviation while measurements 3, 5, and 7 are more than one standard deviation larger, than stated B. antiquus limits. Measurements 6 and 15 are two standard deviations larger than measured B. antiquus specimens. These figures are more inflated in regard to the B. occidentalis phenotype as these animals are generally seen as being the smaller of the two phenotypes (McDonald, 1981). The Tumbler Ridge bison then seems to display B. antiquus characteristics and is somewhat extraordinary in it's size.

### **Horn Core Characters**

The essential horn core characteristics of the Tumbler Ridge specimen were intact, although those relating to the horn core tips were lost. The bases of the cores emanated horizontally from the frontals and were directed posteriorly from the sagittal plane at an average angle of 74.5 degrees. The frontals were very mildly domed and formed essentially a continuous plane with the horn cores. The cores themselves exhibited a non-symmetrical, broadly triangular basal section rotated posteriorly from the frontal plane with straight, non-spiralled, or very slightly spiralled growth. The dorso-ventral axis of the cores was arched with a straight anterior-posterior axis.

The above characteristics with the possible exception of the non-symmetrical horn core base present a strong set of diagnostic characters arguing for an B. occidentalis assignment. Especially significant is the fact that B. antiquus forms almost always display strong subhorizontal horn core emanation from the frontal plane unlike the horizontal or suprahorizontal characteristic of B. occidentalis forms (McDonald, 1981). The non-symmetrical horn core base is not significant as McDonald (1981:77, 86) noted that both taxa display antero-posterior diameters "about equal" to dorso-ventral diameters. This is certainly the case in the Tumbler Ridge specimen with a dorso-ventral diameter of 123 millimetres and an antero-posterior diameter of 116 millimetres.

### **Sexing and Maturity**

The Tumbler Ridge specimen was almost certainly a mature male. This is suggested by a number of factors; first of all the animal was large. Fossil bison were similar to contemporary bison in that males grow to larger sizes than do the females (McDonald, 1981). The Tumbler Ridge specimen also exhibited a characteristic sexual dimorphism of the horn cores in which a distinct ridge or burr is present in the males along the neck of the horn cores, this ridge is absent in most females where horn cores blend seamlessly with the frontals (McDonald, 1981).

Maturity is also suggested by the animals large size but is best shown by three other characteristics: the degree of fusion of the sagittal suture, the bone spurs growing along the neck of the horn cores, and the ruggosities evident along the orbits. Although the skull did break along the sagittal suture a close examination showed that in many places the break left intact much of the sagittal suture with the bone failing around the fused suture, additionally breakage of the suture is probably not significant as this would always be the thinnest bone section regardless of the state of fusion. The small burrs or bone spurs along the horn core neck are very indicative of



a mature or even aged animal, this is also shown by the crenellation or rugosity on distal edges of the orbital protrusions (McDonald, 1981).

### **Identification to species**

The Tumbler Ridge bison presents two series of mensural characteristics arguing for two different conclusions. The series of measurements presented in Table 5. show the specimen fits standard size measurements set out in McDonald (1981) for B. antiquus animals. The two exceptions, closer to the B. occidentalis mean, are measurement no. 10, the depth of the nuchal line to the top of the foramen magnum and angle 21, that angle separating the sagittal plane from the longitudinal axis of the horn cores. The second set of characteristics, the horn core characters, strongly agree with those characteristics set out for occidentalis specimens. The question then becomes; what taxonomic association is best representative of this animals phyletic ancestry?

I believe that if the Tumbler Ridge bison were alive today it would undoubtedly be assigned to a B. occidentalis taxa. The outward appearance of the bison would essentially appear modern except for it's great size, the face and orientation of the horn cores would not be unfamiliar. A living representative of B. antiquus animals would present a very different picture. The strongly sub-horizontal emanation of the horns and the near 90 degree angle between the horns axis and the long axis of the face would appear very unlike modern bison morphology.

The outstanding size of the Tumbler Ridge animal is the only factor which argues a B. antiquus association. This may not be all that significant. The mensural basis upon which speciation was accomplished was that set out by McDonald (1981). His data set is based on less than a hundred animals for each taxa examined, additionally the occidentalis specimens examined covered a time-span of approximately 11,000 to 5400 years B.P. It is known that B. occidentalis animals

changed significantly over this time period with the more ancient members being larger with a progression towards a smaller, modern phenotype as time progressed (Wilson, 1974; Guthrie, 1980). The temporal origin of the samples originating from this time line are not discussed, there may be some chronologic skewing of the data. Wilson (1974) also stated that several B. occidentalis skulls of comparable size have been found on the Alberta plains. Lastly, the large size may be a function of the Tumbler Ridge specimens probable advanced age, Wilson (1974) uses this criteria to help explain his referral of a large bison to B. occidentalis.

### **Bison $\delta^{13}\text{C}$ Determination**

One of the interesting components of this date on bison bone is the  $\delta^{13}\text{C}$  determination of  $-15.4$  ‰. This reading is well out of the normal range found in bison from the Peace River area where  $\text{C}_4$  grasses are absent (Moss, 1952) and is similar to readings typical of bison from New Mexico ( $-11.9$  ‰) and Texas ( $-15.7$  ‰) where xeric  $\text{C}_4$  grasses dominate (Speth, 1983 and Bumsted, 1984). Another dated bison from the Peace River area of British Columbia gave a  $\delta^{13}\text{C}$  value of  $-20.6$  ‰ (Chisholm et al. 1986).

A short word of explanation regarding  $\delta^{13}\text{C}$  determinations is warranted. Of the three common isotopes of carbon, two are stable,  $^{12}\text{C}$  and  $^{13}\text{C}$ , one is radioactive and unstable  $^{14}\text{C}$ . The latter isotope is used in radiocarbon dating to provide statistical measures of an organic materials age. Part of this process commonly involves measuring the ratio of  $^{12}\text{C}$  to  $^{13}\text{C}$  to allow a correction to be made for isotopic fractionation. Isotopic fractionation is the process or processes whereby living material (typically photosynthetic plants) discriminate between the heavier or lighter isotope of carbon resulting in different relative amounts of the two isotopes being incorporated into the organism's tissues, as measured relative to the isotope's naturally occurring environmental ratio.

Certain groups of plants show metabolic preferences for one or the other of the two stable isotopes. The metabolic processes associated with this discrimination have been termed the C<sub>3</sub> and C<sub>4</sub> photosynthetic pathways. Herbivorous animals subsisting on either C<sub>3</sub> or C<sub>4</sub> plants reflect the relative isotope abundances of their dietary preference. Research has shown that  $\delta^{13}\text{C}$  determinations allow investigation of the dietary preferences of large ungulate populations (Tieszen et al. 1979 and Vogel, 1978). Additional research done on the Canadian plains suggested that  $\delta^{13}\text{C}$  determinations could be used to examine the question of bison forage and migration (Chisholm et al. 1986). This research simply looked for evidence that an animal had consumed significant quantities of C<sub>4</sub> grasses which were non-available in the area from which the animal's remains were taken.

Bison are known to be primarily grazers, subsisting on gramminoids and some forbes (Guthrie, 1990). Since today these plants are not present in the Peace River area a number of scenarios are presented as possible explanations for the reading from the Tumbler Ridge bison.

Perhaps there was, an unknown population of C<sub>4</sub> grasses in the Peace River area. It may also be possible that unrecognized remnants of this population still exist. Research in this area would be a good test of this hypothesis.

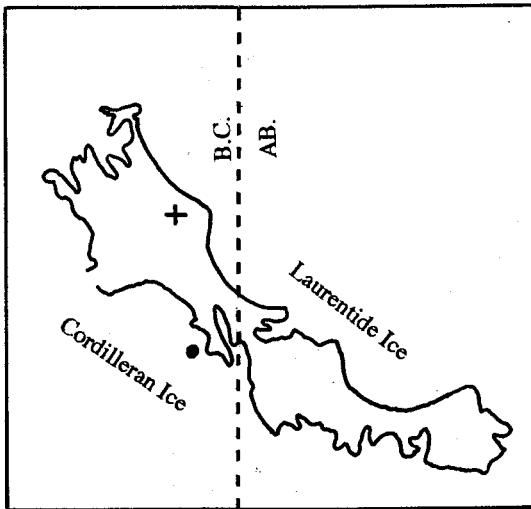
The most tempting scenario but perhaps the least likely is that the bison foraged primarily in areas where C<sub>4</sub> grasses are common. Today these areas are remote from Tumbler Ridge with the closest being southern Manitoba (Chisholm et al. 1986). Evidence from Alaska and the Yukon suggests that the vegetal communities during the last interglacial, ending with deglaciation consisted of large amounts of C<sub>4</sub> grasses, primarily *Bouteloua* sp. (Guthrie, 1980). This then, is the really tempting part: could it be that the Tumbler Ridge bison was an immigrant from farther

north? He was a mature animal and could have made the journey, however I believe this is unlikely given the following reasons.

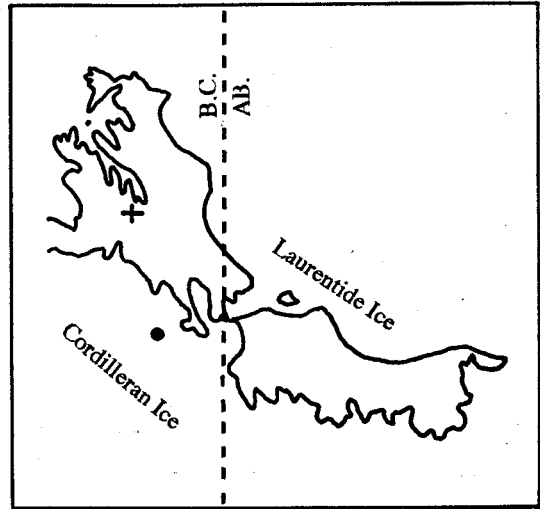
It has been well documented that bison are opportunistic in their foraging habits and will browse on available C<sub>4</sub> sedges, (Guthrie, 1990) which should have been common in the near-mountain foothill environment from which the bison emanated; if that environment reflected current plant communities. I believe that this is likely and constitutes the simplest explanation for the observed data. It may be however, that the extremely low  $\delta^{13}\text{C}$  reading of -15.4 suggests another explanation, perhaps a combination of those above.

APPENDIX III

FIGURE 7 AND AERIAL PHOTOGRAPH



Glacial Lake Peace  
Bessborough stage



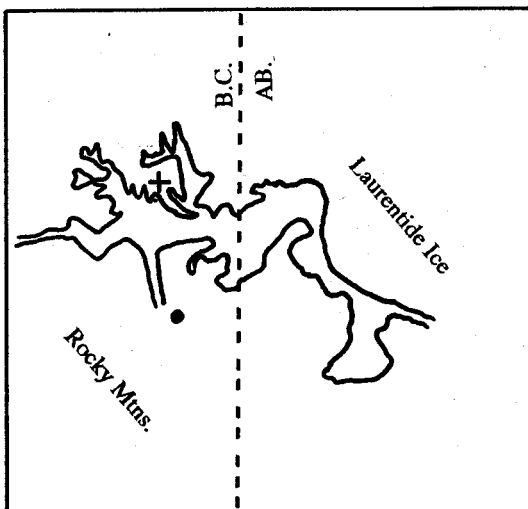
Glacial Lake Peace  
"unnamed" stage

LEGEND:

Site I, II, III +

Tumbler Ridge ●

Glacial Lake Peace  
early Clayhurst stage



Glacial Lake Peace  
late Clayhurst stage

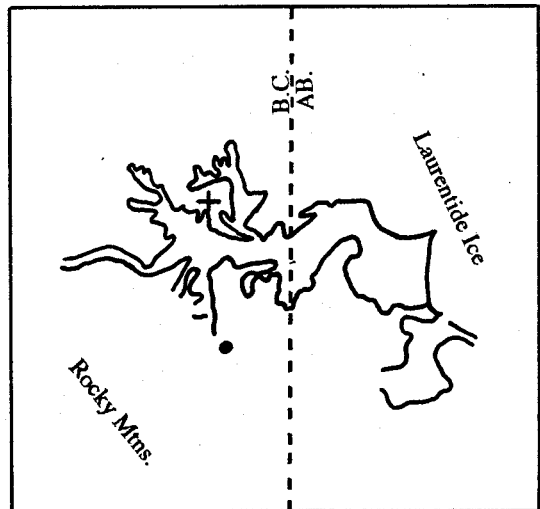
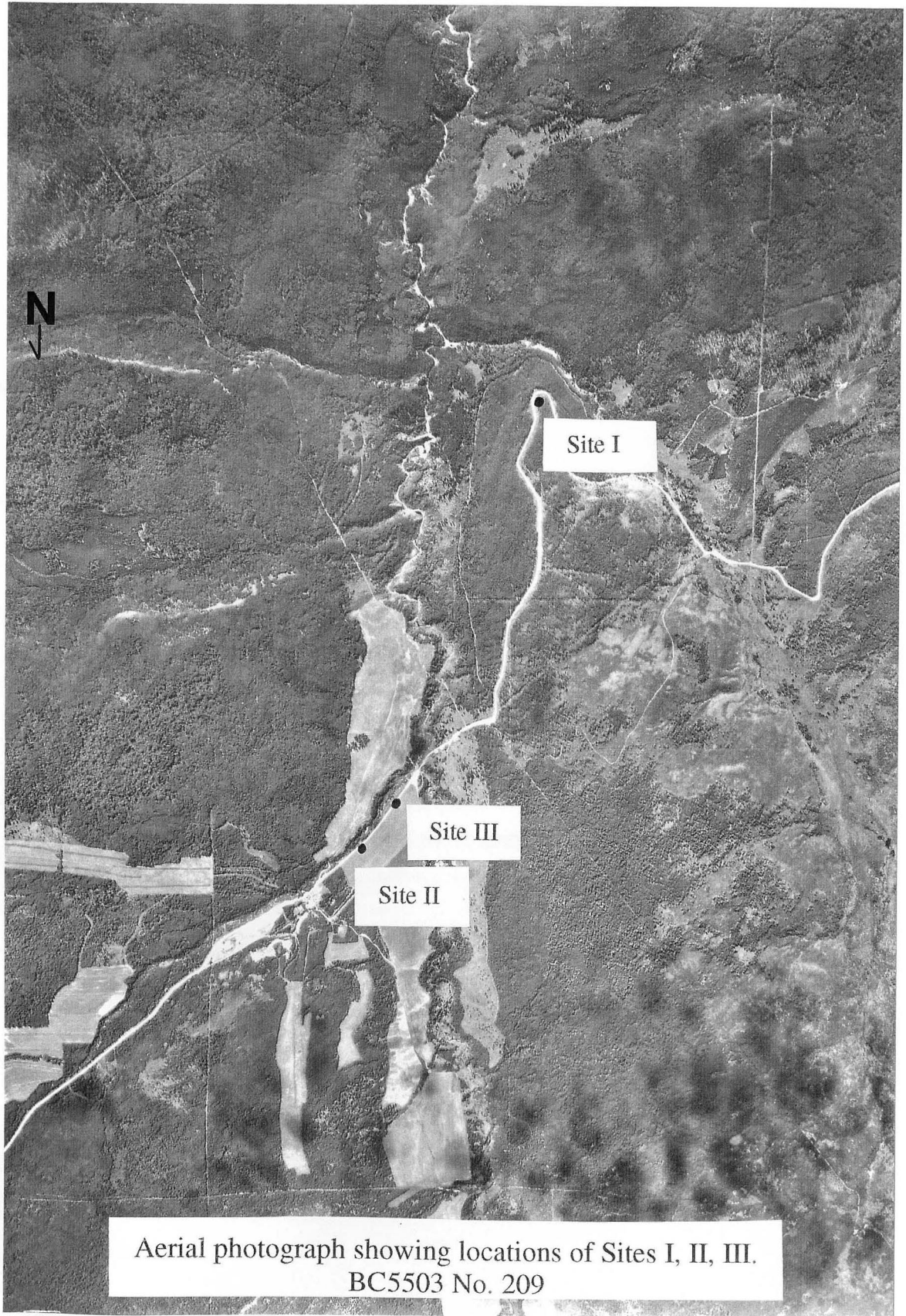


Figure 7  
Various hypothetical lake positions  
(after Mathews, 1980)



Aerial photograph showing locations of Sites I, II, III.  
BC5503 No. 209

## BIBLIOGRAPHY

- Allan, J.A., and Carr, J.L., 1946, "Geology and Coal Occurrences of Wapiti-Cutbank area, Alberta." Research Council of Alberta, Report 48.
- Alley, N.F., and Young, G.K., 1978, "Environmental significance of geomorphic processes in the northern Skeena Mountains and southern Stikine Plateau." British Columbia Ministry of Environment, Resource Analysis Branch, Bulletin No. 3, 83 p.
- Beach, H.H., and Spivak, J., 1943, "The origin of the Peace River Canyon, British Columbia." American Journal of Science, 241, p. 366-376.
- Blake, W. Jr., 1986, "Geological Survey of Canada, radiocarbon dates XXV." Geological Survey of Canada, Paper 85-7, 32 p.
- Bobrowsky, P. T., 1987, "Quaternary stratigraphy of the northern Canadian Cordillera based on new evidence from the Finlay River of northeastern British Columbia." Program with Abstracts, International Quaternary Association, XIIth International Congress, Ottawa, p. 136.
- Bobrowsky, P. T., 1988, "Ice free conditions in the northern Canadian Cordillera at 18 ka and the timing of the Late Wisconsinan." Abstracts and Program, American Quaternary Association, Tenth Biennial Meeting, Amherst, p. 108.
- Bobrowsky, P. T., 1989a, Late Cenozoic geology of the northern Rocky Mountain Trench, British Columbia, Ph.D. thesis, University of Alberta, Edmonton, 463 p.
- Bobrowsky, P. T., 1989b, "Quaternary diamictons in the inter-montane environment of British Columbia." Program with Abstracts, Geological Association of Canada, Montreal, 14 p. 89.
- Bobrowsky, P. T., 1992, "The Quaternary geologic history of the Canadian Rocky Mountains." Geographie physique et Quaternaire, 46, p. 5-50.

- Bobrowsky, P. T., Levson, V., Liverman, D. G. E., and Rutter, N. W., 1987, "Quaternary geology of northwestern Alberta and northeastern British Columbia." Field Excursion A-24. International Quaternary Association, XIIth International Congress, Ottawa, 62 p.
- Bobrowsky, P. T., Catto, N.R. and Levson, V., 1991, "Reconnaissance Quaternary geological investigations in the Peace River District, British Columbia (93P, 94A)." B.C. Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork 1990, Paper 1991-1, p.345-358
- Bobrowsky, P. T., and N. W. Rutter, 1992, "The Quaternary geologic history of the Canadian Rocky Mountains". Geographie physique et Quaternaire, 46 p. 5-50.
- Bryan, A.L., 1969, "Early man in America and the late Pleistocene chronology of Western Canada and Alaska." Current Anthropology, 10, p. 339-365.
- Buckley, J.D., Trautman, M.A., and Willis, E.H., 1968, "Isotopes' radiocarbon measurements VI." Radiocarbon, 10, p. 246-294.
- Bumstead, M.P., 1984, Human variation:  $\delta^{13}C$  in adult bone collagen and the relation to diet in an isochronous C4 (Maize) Archaeological population. Publication LA-10259-T (thesis). Los Alamos National laboratory, Los Alamos, New Mexico.
- Charlesworth, J.K., 1957, The Quaternary Era, Edward Arnold Ltd., London.
- Chisholm, B.S., Driver, J. C., Dube, S., and Schwarcz, H.P., 1986, "Assessment of prehistoric bison foraging and movement patterns via stable-carbon isotopic analysis." Plains Anthropologist, 31, p. 193-205.
- Clague, J. J., 1981, "Late Quaternary geology and geochronology of British Columbia. Part 2: summary and discussion of radiocarbon-dated Quaternary history." Geological Survey of Canada, Paper 80-35, 41 p.



- Dawson, G. M., 1881, "Report on an Exploration from Port Simpson on the Pacific Coast, to Edmonton on the Saskatchewan Embracing a Portion of the Northern Part of British Columbia and the Peace River Country. 1879", Report of Progress for 1879-80, A. R. C. Selwyn ed., section B, Dawson Brothers, Montreal.
- Driver, J.C., 1988, "Late Pleistocene and Holocene vertebrates and palaeoenvironments from Charlie Lake Cave, northeast British Columbia." Canadian Journal of Earth Sciences, 25, p. 1545-1553.
- Fladmark, K., Driver, J.C. and Alexander, D., 1988, "The Paleoindian Component at Charlie Lake Cave (HbRf-39), British Columbia." American Antiquity, 53, p. 371-384.
- Flint, R.F. 1971 Glacial and Quaternary Geology, John Wiley and Sons, New York.
- Fraser, S., 1808, Second Journal of Simon Fraser, Bancroft Collection.
- Fuller, W.A., and Bayrock, L.A., 1965, "Late Pleistocene mammals from central Alberta, Canada." Vertebrate Paleontology in Alberta, ed. R. E. Folinsbee and D. M. Ross, University of Alberta, Edmonton, p. 53-63.
- Fulton, R.J., Fenton, M.M., and Rutter, N.W., 1984, "Summary of Quaternary stratigraphy and history of Western Canada." Geological Survey of Canada, Paper 84-10, R.J. Fulton ed., p. 229-241.
- Geological Association of Canada, 1958, Glacial Map of Canada.
- Guthrie, R.D., 1980, "Bison and Man in North America." Canadian Journal of Anthropology, 1, p. 55-73.
- Guthrie, R.D., 1990, Frozen Fauna of the Mammoth Steppe The Story of Blue Babe, The University of Chicago Press, Chicago and London.
- Hage, C. O., 1944, "Geology Adjacent to the Alaska Highway Between Fort St. John and Fort Nelson, British Columbia." Geological Survey of Canada, Paper 44-30, 22 p.

- Harrington, C.R., 1980, "Faunal exchanges between Siberia and North America-Evidence from Quaternary land mammal remains in Siberia, Alaska and the Yukon Territory." Canadian Journal of Anthropology, 1, p. 45-50.
- Henderson, E. P., 1959, "Surficial geology of the Sturgeon Lake map area, Alberta." Geological Survey of Canada, Memoir 303, 108p.
- Hoffman, R.S., 1980, "Of mice and men: Beringian dispersal and the ice-free corridor." Canadian Journal of Anthropology, 1, p. 51-52.
- Holland, S. S., 1964, "Landforms of British Columbia A Physiographic Outline.", British Columbia Department of Mines and Petroleum Resources, Bulletin No. 48, 138 p.
- Hughes, J. E., 1967, "Geology of the Pine Valley: Mount Wabi to Solitude Mountain northeastern British Columbia." British Columbia Department of Mines and Petroleum Resources, 145 p.
- Johnston, W.A., 1946, "Glacial Lake Agassiz with special reference to the mode of deformation of the beaches." Geological Survey of Canada, Bulletin 7, 20 p.
- Kroger, A., 1958, "Geomorphological work along the north shore of Great Bear Lake." Arctic 11, p. 253.
- Leidy, J., 1852, "Report on Bison from Big Bone Lick and vicinity." Proceedings. Academy of Natural Sciences of Philadelphia, 6, p. 117.
- Lindsey, J.D., Heringa, P.K., Pawluk, S., and Odynsky, W., 1958, "Exploratory Soil Survey of Alberta map sheets 84c (east half), 84B, 84A, and 74D." Research Council of Alberta. Preliminary Soil Report 58-1, 32 p.
- Lindsey, J.D., Pawluk, S., and Odynsky, W., 1959, "Exploratory soil survey of Alberta map sheets 84D (north-half), 84E, 84F, 84G." Research Council of Alberta. Preliminary Soil Survey Report 59-1, 48 p.

- Lindsey, J.D., Pawluk, S., and Odynsky, W., 1960, "Exploratory soil survey of Alberta map sheets 84J, 84K, 84L." Research Council of Alberta, Preliminary Soil Survey Report 60-1, 49 p.
- Lichti-Federovich, S., 1970, "The pollen stratigraphy of a dated section of Late Pleistocene lake sediment from central Alberta;" Canadian Journal of Earth Sciences, 7, no. 3, p. 938-945.
- Liverman, D.G., 1989, "The Laurentide ice sheet in west-central Alberta - implications for the ice free corridor." Program and Abstracts, Canadian Quaternary Association, Edmonton, p. 36.
- Liverman, D.G., 1990, The Quaternary geology of the Grand Prairie area, Alberta. Ph.D. thesis, University of Alberta, 360 p.
- Liverman, D.G., Catto, N.R., Rutter, N.W., 1989, "Laurentide glaciation in west-central Alberta: A single (Late Wisconsinan) event." Canadian Journal of Earth Sciences, 26, p. 266-274.
- Lowdon, J.A., and Blake, W. Jr., 1967, Radiocarbon, 9 p. 170-171.
- Lowdon, J.A., and Blake, W. Jr., 1968, Geological Survey of Canada radiocarbon dates VII. Radiocarbon, 10:207-245. reprinted as Geological Survey of Canada, Paper 68-2B
- Lowdon, J.A., and Blake, W. Jr., 1970, Geological Survey of Canada radiocarbon dates IX. Radiocarbon, 12 p. 46-86.
- Lowdon, J.A., and Blake, W. Jr., 1973, "Geological Survey of Canada radiocarbon dates XIII." Geological Survey of Canada, Paper 73-7, 61 p.
- Lucas, F.A., 1898, (no title). Science 8 p. 678.
- MacDonald, G. M., 1987, "Postglacial vegetation history of the Mackenzie River Basin." Quaternary Research, 28, p. 245-262.

- MacKenzie, Alexander, 1801, Voyages from Montreal on the River St. Lawrence, through the Continent of North America, to The Frozen and Pacific Oceans in the years 1789 and 1793, London.
- McDonald, J.N., 1981, North American Bison. University of California press, Berkeley.
- McLean, J., 1849, Notes on Twenty Five Years Service in the Hudson's Bay Company; Vol I, London.
- McLearn, F. H. and E. D. Kindle, 1950, "Geology of Northeastern British Columbia", Geological Survey of Canada, Memoir 259.
- Mathews, W.H., 1947, "Geology and coal resources of the Carbon Creek-Mount Bickford map-area, British Columbia." British Columbia Department of Mines, Bulletin No. 24
- Mathews, W. H., 1954, "Quaternary stratigraphy and geomorphology of the Fort St. John area, northeastern British Columbia." Geological Society of America. Bulletin No. 65, p. 1345.
- Mathews, W. H., 1962, "Quaternary Geology, Peace River district, British Columbia." Peace River. Edmonton Geological Society, 4th Annual Field Trip. Guide Book, p. 1-4.
- Mathews, W. H., 1963, Quaternary stratigraphy and geomorphology of the Fort St. John area northeastern British Columbia, Department of Mines and Petroleum Resources, British Columbia, 22 p.
- Mathews, W.H., 1972, "Quaternary Geology, Charlie Lake, British Columbia." Report of Activities, Part A, Geological Survey of Canada, Paper 72-1A, p. 169-170.
- Mathews, W. H., 1973, "Quaternary Geology, Charlie Lake, British Columbia." Report of Activities, Part A, Geological Survey of Canada, Paper 73-1A, p. 210-211.
- Mathews, W. H., 1978a, "Quaternary Stratigraphy and Geomorphology of Charlie Lake (94a) Map-Area, British Columbia." Geological Survey of Canada, Paper 76-20, 25 p.

- Mathews, W. H., 1978b, "The Geology of the Ice Free Corridor, Discussion, Northeastern British Columbia and Adjacent Alberta." Program and Abstracts, American Quaternary Association, Fifth Biennial Meeting, Edmonton, p. 16-18.
- Mathews, W. H., 1980, "Retreat of the last ice sheets in northeastern British Columbia and adjacent Alberta." Geological Survey of Canada, Bulletin 331, 22 p.
- Moss, E. H., 1952, "Grassland of the Peace River Region, Western Canada." Canadian Journal of Botany, 30, p. 98-125.
- Nelson, D.E., and Hobson, K. A., 1982, "Simon Fraser University radiocarbon dates I." Radiocarbon, Vol. 24, No. 3, p. 344-351.
- Odnysky, W., and Newton, J.D., 1950, "Soil Survey of the Rycroft and Watino Sheets." Alberta Soil Survey, Report 15, 84 p.
- Odnysky, W., Wynnk, A., and Newton, J.D., 1952, "Soil survey of the High Prairie and McLennan Sheets." Alberta Soil Survey, Report 17, 112 p.
- Odnysky, W., Wynnk, A., and Newton, J.D., 1956, "Soil Survey of the High Prairie and Sturgeon Lake sheets." Alberta Soil Survey, Report 18, 111 p.
- Reeves, B.O.K., 1973, "The nature and age of the contact between the Laurentide and Cordilleran ice sheets in the western interior of North America." Arctic and Alpine Research, 5, p. 1-16.
- Reimchen, T.H.F. and Rutter, N.W., 1972, "Quaternary geology, Dawson Creek, British Columbia (93P)." Report of Activities, Part A, Geological Survey of Canada, Paper 72-1A, p. 176-177.
- Roberts, A.C.B., 1985, "Preceramic occupations along the north shore of Lake Ontario." National Museum of Man Mercury Series: Archaeological Survey of Canada, Paper 132, 228 p.
- Rutherford, R.L., 1930, "Geology and water resources in parts of the Peace River and Grande Prairie Districts, Alberta." Research Council of Alberta, Report 21, 68 p.

- Rutter, N.W., 1967, "Surficial geology of the Peace River dam and reservoir area, British Columbia." Report of Activities, Part A, Geological Survey of Canada, Paper 67-1A, p. 87-88.
- Rutter, N.W., 1968, "Surficial geology of the Peace River dam and reservoir area, British Columbia." Report of Activities, Part A, Geological Survey of Canada, Paper 68-1A, p. 182-183.
- Rutter, N.W., 1969a, "Summary of preliminary work on the Quaternary geology of the Lake Williston area, British Columbia." P. A. Ziegler, ed., Field Conference 1969, Edmonton Geological Society, Field Conference Guidebook, Edmonton Alberta, p. 1-3.
- Rutter, N.W., 1969b, "Surficial geology of the Peace River dam and reservoir area, British Columbia (Parts of 93N, O, 94B,C, E)." Report of Activities, Part A, Geological Survey of Canada, Paper 69-1A, p. 216-217.
- Rutter, N.W., 1970, "Quaternary geology, Pine Pass, British Columbia-Jasper, Alberta (parts of 83, 93)." Report of Activities, Part A, Geological Survey of Canada, Paper 70-1A, p. 183.
- Rutter, N.W., 1976, "Multiple glaciation in the Canadian Rocky Mountains with special emphasis on northeastern British Columbia." W.C. Mahaney, ed., Quaternary Stratigraphy of North America, Dowden, Hutchinson and Ross, Stroudsburg, p. 409-440.
- Rutter, N.W., 1977, "Multiple glaciation in the area of Williston Lake, British Columbia." Geological Survey of Canada, Bulletin 273, 31 p.
- Rutter, N.W., Geist, V. and Shackleton, D. M. 1972, "A Bighorn Sheep skull 9280 years old from British Columbia." Journal of Mammalogy, 53 p. 641-644.
- Selwyn, A. R. C., 1877, "Report on Exploration in British Columbia in 1875." Report of Progress 1875-76, Geological Survey of Canada.
- Simpson, Sir G., 1872, A Canoe Voyage from Hudson's Bay to the Pacific in 1828, Ottawa.

- Skinner, M.F., and Kaisen, O.C., 1947, "The fossil Bison of Alaska and preliminary revision of the genus." American Museum of Natural History, Bulletin 89, p. 123-256.
- Speth, J.D., 1983, Bison kills and bone counts. University of Chicago Press, Chicago.
- St. Onge, D.A., 1972, "Sequence of Glacial Lakes in north-central Alberta." Geological Survey of Canada, Bulletin 213, p. 1-16.
- Stuiver, M., and Polach, H. A., 1977, "Discussion and reporting of C14 data." Radiocarbon, 19, p. 355-363.
- Taylor, R.S., 1960, "Some Pleistocene lakes of northern Alberta and adjacent areas (revised)." Journal of the Alberta Society of Petroleum Geologists, 8, p. 167-177,185.
- Thompson, Berwick, Pratt and Partners., 1978, Physical plan Tumbler Ridge northeast sector, B.C. Ministry of Municipal Affairs and Housing, 661 p.
- Tieszen, L. L., Hein, D., Ovortrup, S. A., and Imbamba, S. K., 1979, "Use of  $\delta^{13}\text{C}$  values to determine vegetation selectively in East African herbivores." Oecologia, 37, p. 351-359.
- Upham, W., 1890, "Report of Exploration of the Glacial Lake Agassiz in Manitoba." Geological Survey of Canada. Annual Report. 1888-1889, Vol. 4, Section E, 156 p.
- Vincent, J.S. and Prest V.K., 1987, "The Early Wisconsinan history of the Laurentide Ice Sheet." Geographie physique et Quaternaire, XLI, p. 199-213.
- Vogel, J.C., 1978, "Isotopic assessment of the dietary habits of ungulates." South African Journal of Science, 74, p. 298-301.
- Westgate, J.A., Fritz, P., Mathews, J.V. Jr., Kalas, L. and Green, R., 1971, "Sediments of mid-Wisconsin age in west-central Alberta: geochronology, insects, ostracodes, mollusca, and the oxygen isotopic composition of molluscan shells." Program with Abstracts. Geological Society of America. Rocky Mountain Section, 3, p. 419.

- Westgate, J.A., Fritz, P., Mathews, J.V. Jr., Kalas, L., Delorme, L.D., Green, R. and Aario, R., 1972, "Geochronology and palaeoecology of mid-Wisconsin sediments in west-central Alberta, Canada." Program with Abstracts, 24th International Geological Congress, Montreal, p. 380.
- White, J.M., 1983, Late Quaternary geochronology and palaeoecology of the upper Peace River District, Canada. Unpublished Ph.D. thesis, Simon Fraser University, B.C., 146 p.
- White, J.M. and Mathewes, R.W., 1986, "Postglacial vegetation and climatic change in the upper Peace River District, Alberta." Canadian Journal of Botany, 64, p. 2305-2318.
- White, J.M., Mathewes, R.W., and Mathews, W.H., 1979, "Radiocarbon dates from Boone Lake and their relation to the "Ice Free Corridor" in the Peace River District of Alberta, Canada." Canadian Journal of Earth Sciences, 16, p. 1870-1874.
- White, J.M., Mathewes, R.W., and Mathews, W.H., 1985, "Late Pleistocene chronology and environment of the "Ice Free Corridor" of northwestern Alberta." Quaternary Research, 24, p. 173-186.
- Williams, M.Y., 1944, "Geological reconnaissance along the Alaska Highway from Fort Nelson, British Columbia, to Watson Lake, Yukon." Geological Survey of Canada, Paper 44-28.
- Wilson, M., 1975, Holocene fossil bison from Wyoming and adjacent areas. unpublished M.A. thesis, University of Wyoming, Laramie.
- Wynnyk, A., Heringa, P.K., and Odnysky, W., 1961, "Exploratory soil survey of Alberta map sheets 83O, 83P, and 73M." Research Council of Alberta Preliminary Soil Report, 32 p. plus 3 maps.
- Wynnyk, A., and Odnysky, W., 1954, Exploratory soil survey report of portion of Valleyview-Whitcourt area. Alberta Soil Survey, 20 p. plus map.