Late Wisconsinan McConnell glaciation of the Whitehorse map area (105D), Yukon

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ABSTRACT

Ice accumulations in the Coast Mountains of southwestern Yukon and the Cassiar Mountains of south-central Yukon during the late Wisconsinan were responsible for glaciation of the Whitehorse area. Cirques in the Coast Mountains likely supported the first glaciers that advanced out of the mountain valleys ahead of the more distal Cassiar accumulation. Glacial maximum is characterized by topographically unconstrained ice flow trending northwesterly over most of the map area. Ice thickness over the city of Whitehorse exceeded 1350 m during full glacial conditions. Deglaciation is characterized by frontal retreat punctuated by periods of dynamic equilibrium and readvances. Differential retreat of the Cassiar and Coast Mountain ice lobes enabled the Cassiar lobe to penetrate, and at times readvance, up-gradient into Coast Mountain valleys. This pattern of deglaciation created ice dams and a series of proglacial lakes that submerged valleys under as much as 300 m of meltwater.

RÉSUMÉ

Les accumulations de glace dans la chaîne Côtière du sud-ouest du Yukon et les monts Cassiar dans le centre-sud du Yukon au Wisconsinien tardif sont à l'origine de la glaciation de la région de Whitehorse. Les cirques de la chaîne Côtière ont probablement contenu les premiers glaciers qui se sont avancés au-delà des vallées de montagne devant l'accumulation plus distale de Cassiar. Le maximum glaciaire est caractérisé par un écoulement glaciaire sans contraintes topographiques orienté vers le nord-ouest sur presque toute la région cartographique. L'épaisseur de glace au dessus de la ville de Whitehorse dépassait 1350 m lorsque les conditions étaient complètement glaciaires. La déglaciation est caractérisée par un recul frontal ponctué par des périodes d'équilibre dynamique et des réavancées. Le recul différentiel des lobes glaciaires de Cassiar et de la chaîne Côtière a permis au lobe de Cassiar de pénétrer, et parfois de réavancer vers l'aval des vallées de la chaîne Côtière. Ce mode de déglaciation a créé des barrages de glace ainsi qu'une série de lacs proglaciaires qui ont submergé les vallées d'eau de fonte pouvant atteindre 300 m de profondeur.

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INTRODUCTION

During the Late Wisconsinan McConnell Glaciation (~20,000 years ago), the Whitehorse map area (105D) was glaciated by ice lobes originating in the Coast Mountains and the Cassiar Mountains of southern Yukon (Fig. 1). This paper describes the regional interaction and relative influence of these ice lobes, beginning with the onset of glaciation and finishing with final deglaciation. While the chronology of these events is poorly constrained, a reconstruction of glacial stages according to ice-flow indicators, ice-stagnation episodes and glacial-lake history is possible.

PREVIOUS WORK

Much of the early geological work in the Whitehorse map area focused on the mineral deposits at Windy Arm, Wheaton River and Whitehorse (Dawson, 1889; McConnell, 1906, 1909; Cairnes, 1908, 1912, 1916; Bostock, 1941; Wheeler, 1961; Hart and Radloff, 1990). The first surficial geology descriptions were completed by Denny (1952) in a reconnaissance survey of Late Quaternary geology along the Alaska highway. Wheeler (1961) described the style of glaciation in the Whitehorse map area and produced the first geomorphological map.

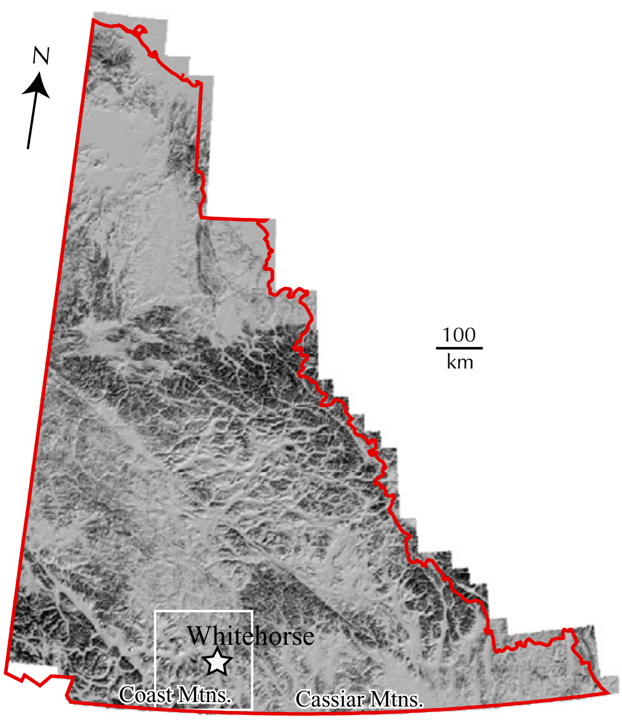


Figure 1. *Map of Yukon showing the location of the Coast Mountains, Cassiar Mountains and study area (outlined box).*

Surficial geology and soils mapping by Morison and McKenna (1980) at 1:100 000 scale provided the first Quaternary geology maps of the region. Morison and Klassen (1990) completed the surficial geology of the Whitehorse map (105D) at 1:250 000 scale. Soils mapping by Mougeot and Smith (1992, 1994) at 1:20 000 scale in the Takhini River valley and the Carcross valley provide detailed descriptions of soil parent materials. Thesis investigations into the sedimentology and paleogeography of Glacial Lake Champagne, in the vicinity of Whitehorse, were completed by Barnes (1997), and the glacial geomorphology of Whitehorse was studied by Ayers (2000). Finally, Mougeot et al. (1998) mapped the terrain and surficial geology of the city of Whitehorse (1:30 000 scale).

PHYSIOGRAPHY

The Whitehorse map area encompasses the physiographic transition between the southern portion of the Yukon Plateau and the northeastern extent of the Coast Mountains (Fig. 2). The eastern half of the region, including the area north of the Takhini River, lies within the Yukon Plateau, a region of accordant uplands ranging between 800 and 2000 m in elevation (Bostock, 1948). The western half, south of the Takhini River, lies within the Coast Mountains. Wheeler (1961) referred to this portion of the Coast Mountains as a transitional zone between the two regional physiographic subdivisions. The characteristic cirque- and horn-strewn topography associated with the Coast Mountains is found only in the southern portion of the map area west of Bennett Lake. The remainder of the 'transitional zone' is an upland plateau dissected by relatively narrow and deep river valleys. In this paper, the Coast Mountains occurring in the Whitehorse map area will be referred to as the 'Coast Mountains transitional zone'.

DRAINAGE

The Whitehorse map area lies within the Yukon River drainage basin. The larger drainages include the Primrose, Wheaton, Watson and Ibex rivers in the Coast Mountains transitional zone, and the Yukon and M'Clintock rivers in the Yukon Plateau. The Yukon River flows northerly through a system of interconnected valley-bound lakes in the southeast corner of the map area. North of the city of Whitehorse, the Yukon River flows into Lake Laberge, a 50-km-long lake that extends north into the Lake Laberge map sheet (105E).

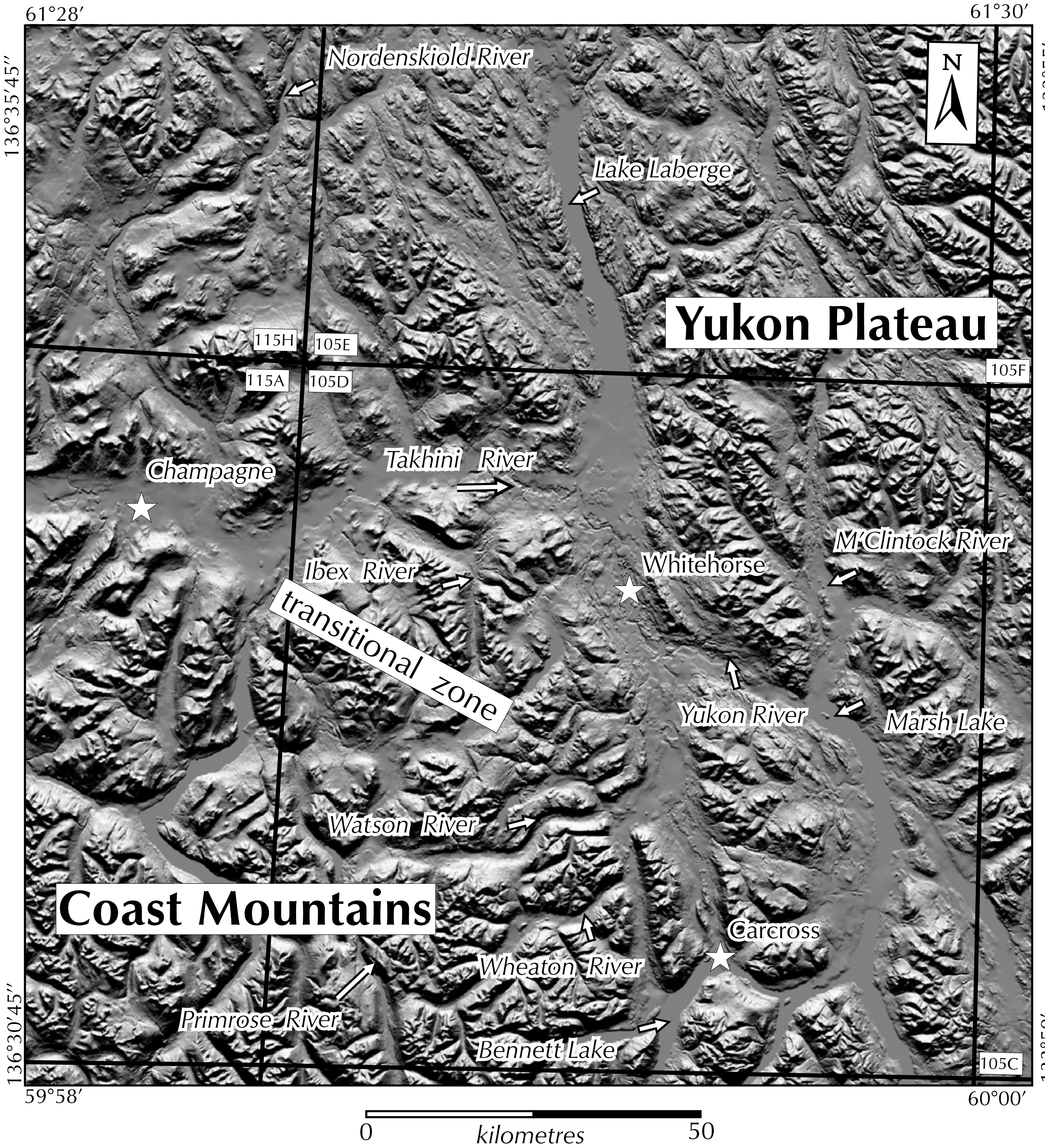


Figure 2. *Detailed location map of the study area showing major physiographic divisions.*

YUKON GLACIAL HISTORY

The long Quaternary glacial and interglacial history of Yukon is preserved in the stratigraphic record found at the margins of glaciation and in unglaciated terrain. The preservation of this record is due to aridity in central Yukon, which inhibited the extent of glaciers in this region (Armentrout, 1983; Jackson et al., 1991). As a result of limited glacial erosion, long stratigraphic records and multiple glacial margins are preserved in central Yukon, which has enabled researchers to piece together the Quaternary history (Fig. 3). The first Cordilleran glaciation in Yukon occurred between 2.6-2.9 Ma years ago (Froese et al., 2000; Duk-Rodkin and Barendregt, 1997; Duk-Rodkin et al., 2001). This first glaciation is thought to have been the most extensive; subsequent Pleistocene glacial advances were less extensive. As many as six glaciations during the Pleistocene are recorded in the stratigraphy of Tintina Trench near Dawson City (Duk-Rodkin and Barendregt, 1997; Duk-Rodkin et al., 2001). In the Whitehorse area, pre-McConnell deposits have not been observed, which suggests that sediments associated with previous advances were eroded or buried during the last glaciation (Wheeler, 1961).

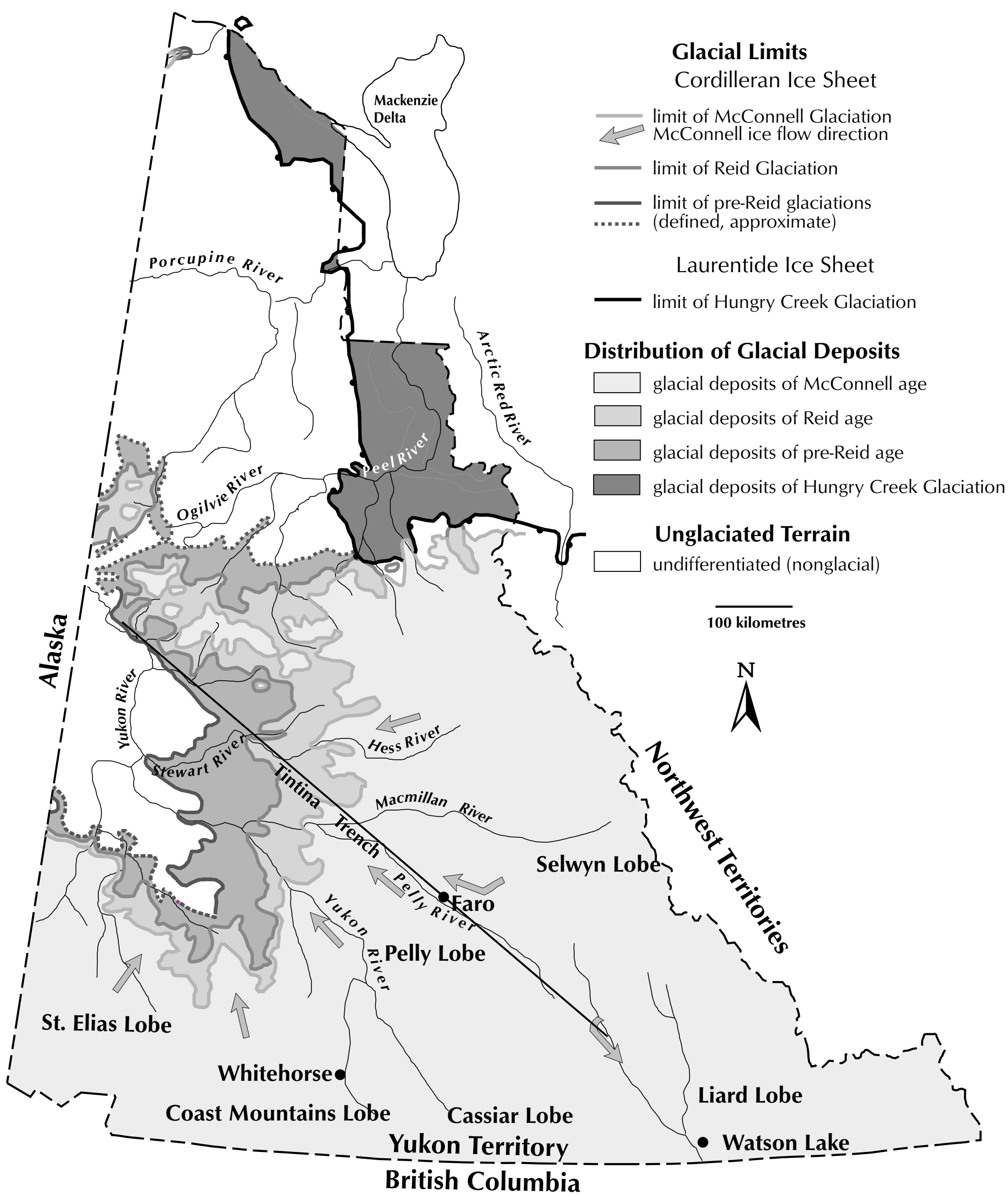


Figure 3. Glacial limits map of Yukon (after Duk-Rodkin, 1999).

The onset of climatic cooling associated with the late Wisconsinan McConnell Glaciation had begun by 29.6 ka BP according to organic deposits containing arctic floral assemblages under McConnell drift in the Stewart River valley near Mayo (TO-292, University of Toronto Laboratory; Matthews et al., 1990). By that time, alpine glaciers likely started to form in the higher accumulation zones of Yukon. However, the timing of the great ice sheets emanating from southern and eastern Yukon is poorly constrained. Ice-free conditions at 26 ka BP in the Tintina Trench near Ross River suggest that glaciers had not advanced out of the Pelly Mountains accumulation zone (TO-393; Jackson and Harington, 1991). In addition, ice-free conditions persisted near Watson Lake until 23.9 ka BP (GSC-2811; Klassen, 1987). Glacial maximum, ice retreat, and the re-establishment of vegetation in the Whitehorse area was complete by 10.7 ka BP according to terrestrial and aquatic macrofossils from lacustrine sediments in Marcella Lake (Kettlehole Pond) in southern Yukon (Anderson et al., 2002). From the radiocarbon chronology, the Late Wisconsinan McConnell Glaciation of Yukon occurred from approximately 23.9 ka to 10.7 ka BP.

MCCONNELL GLACIATION

STAGE 1: ONSET OF GLACIATION

Evidence of the McConnell glacial advance in the Whitehorse map area is absent and was likely removed or buried during later periods of the glaciation. Therefore, the reconstruction of the onset of glaciation is speculative and based on modern glacier analogues such as the St. Elias ice cap. It is assumed that ice first accumulated in cirques of the Coast Mountains, while at lower elevations tundra environments expanded with a descending tree-line elevation (Fig. 4 and 5). Alpine glaciers eventually

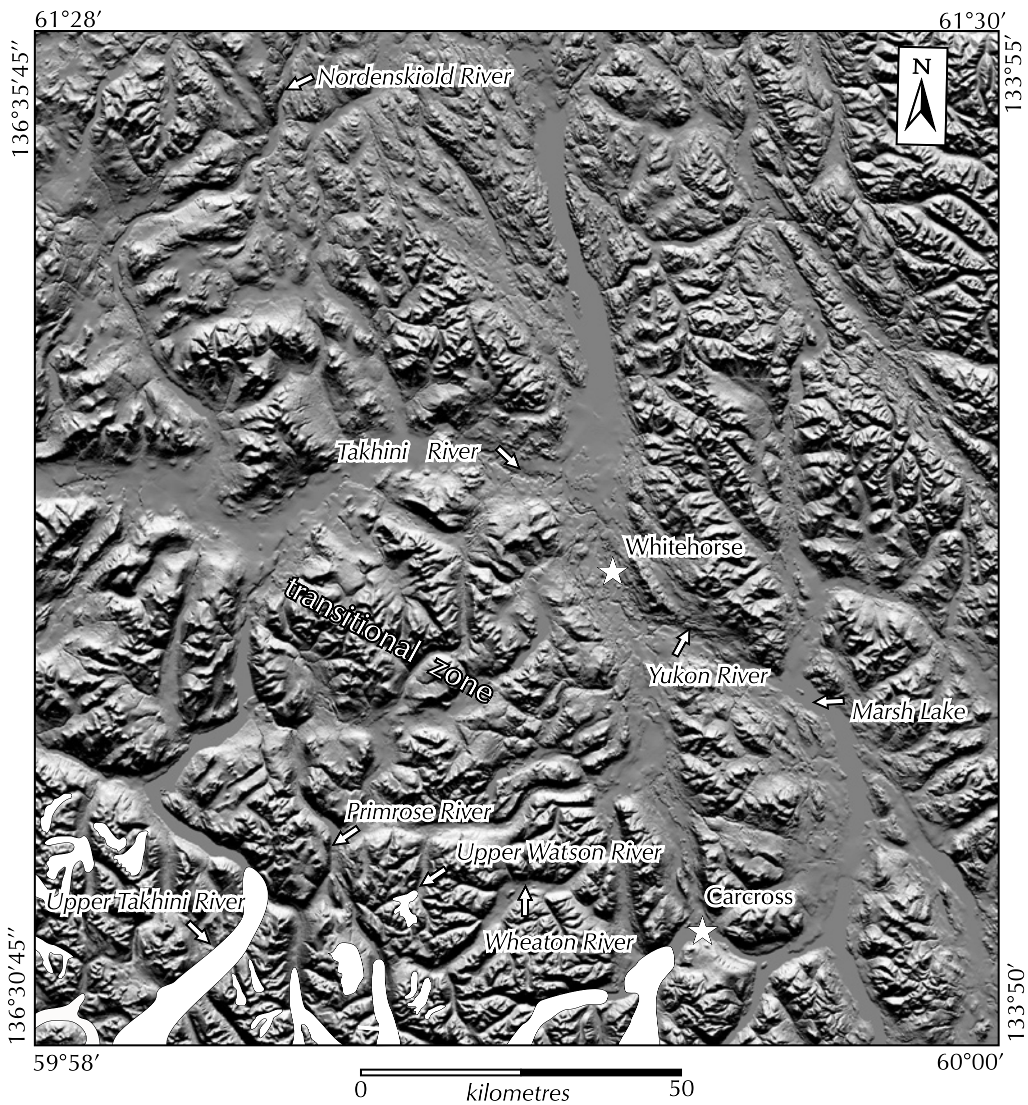


Figure 4. *Stage 1 – McConnell glacial advance. A schematic depiction of ice accumulations in the Coast Mountains (white glacial lobes in southern map area).*

Figure 5. A modern glacier on the upper reaches of the Wheaton River. Cirques at high elevation in the Coast Mountains were occupied by similar glaciers at the onset of the McConnell Glaciation.

coalesced to form valley glaciers in the Wheaton River, Bennett Lake and upper Watson River valleys. With continued glaciation, a Coast Mountain ice cap developed with radiating valley glaciers occupying major valleys such as the upper Takhini, Primrose, Wheaton and Watson rivers. These were the precursors of the Coast Mountains Lobe.

Ice accumulation had also begun in the Cassiar Mountains of south-central Yukon and Atlin District of northern British Columbia. The leading edge of this ice cap advanced northwestward into the Whitehorse map area via the Marsh Lake valley and continued north down the Yukon River valley. This portion of the Cordilleran Ice Sheet is referred to as the Cassiar Lobe (Wheeler, 1961).

The chronology of the onset of glaciation is uncertain. Evidence from central Yukon, near the McConnell glacial limit, indicates that tundra expansion may have preceded actual glaciation by anywhere from 5000 to 8000 years (Matthews et al., 1990; Jackson and Harington, 1991). In the Whitehorse area, it is estimated that the initial advance had begun by 29 ka BP, however significant ice accumulations may not have developed until after 26 ka BP.

STAGE 2: GLACIAL MAXIMUM

At the climax of the McConnell Glaciation, a continuous carapace of ice covered southern and eastern Yukon (Fig. 3 and 6). Ice thickness over the city of Whitehorse (700 m above sea level (a.s.l.)) exceeded 1350 m during glacial maximum according to the elevation of an erratic on the summit of Mount Granger (Fig. 7; 2087 m a.s.l.). Nunataks would have been scarce in this area and probably only present at the headwaters of the Wheaton River where summits reach 2460 m (Fig. 5). The northwest trajectory of the Cassiar Lobe was maintained through glacial maximum according to striae trending at 325° on Grey (Canyon) Mountain. The influence of the Cassiar Lobe also extended onto the Coast Mountains transitional zone west of Whitehorse, where striae and flutings having a northwest trajectory were observed near Alligator Lake, Mount Granger and Skukum Creek. The Coast Mountains Lobe, according to scanty evidence gathered by Wheeler (1961), moved in a northerly direction. The boundary between the Coast Mountains

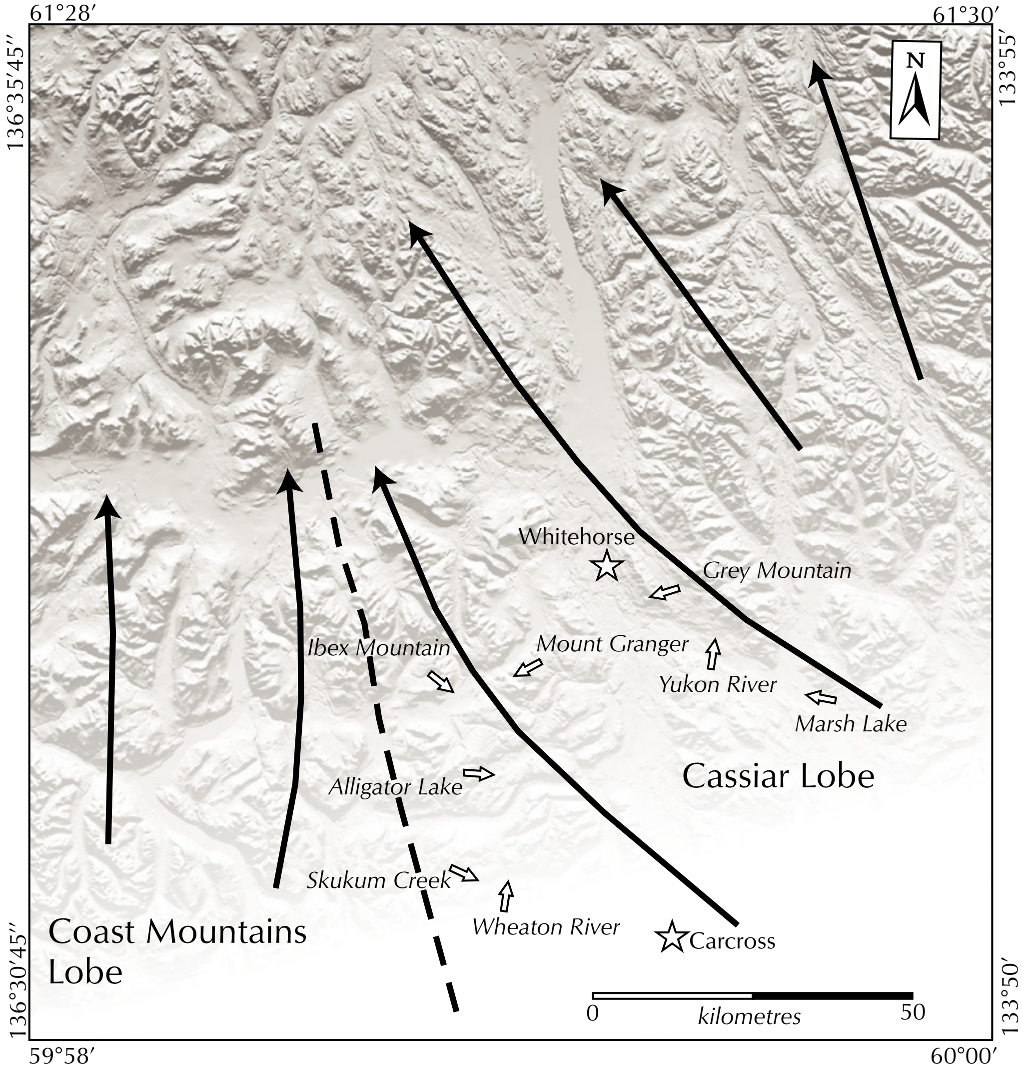


Figure 6. *Stage 2 – McConnell glacial maximum. The dashed line represents the approximate boundary between the Coast Mountains and Cassiar lobes. Long arrows indicate direction of ice flow.*

Figure 7. *A granitic erratic on the summit of Mount Granger (2087 m) west of the city of Whitehorse.*

and the Cassiar lobes is not well defined but was most likely located over the transitional zone west of Alligator Lake and Ibex Mountain (Fig. 6).

STAGE 3: DEGLACIATION

McConnell deglaciation in the Whitehorse map area is divided into seven stages and presented in a series of schematic diagrams. These stages were identified based on changes in ice flow, glacial readvances, periods of dynamic equilibrium, or glacial lake development.

Stage 3a: Early deglaciation

Deglaciation brought a wholesale reduction of the ice thickness in the Whitehorse map area. As a result, more nunataks would have been exposed above the ice surface. Movement of a thinner ice sheet would also have become more susceptible to topographic control. For example, multiple striae observed in the Takhini River valley indicate that ice flow became increasingly controlled by topography. Ice flow readjustments also occurred at the margin between the Coast Mountains and Cassiar lobes. High-elevation northeast-descending meltwater channels, west and north of Alligator Lake, suggest the western margin of the Cassiar Lobe retreated before the Coast Mountains Lobe, allowing the Coast Mountains Lobe to occupy parts of the transitional zone (Fig. 6).

Stage 3b: Cassiar re-advance

A large magnitude re-advance of the Cassiar Lobe occurred in the Whitehorse map area after early deglaciation (Fig. 8). Up-valley descending moraines and meltwater channels in the Wheaton and Watson river valleys suggest that the Cassiar Lobe re-advanced into the transitional zone after the Coast Mountains Lobe had retreated to the west. The climatic force responsible for

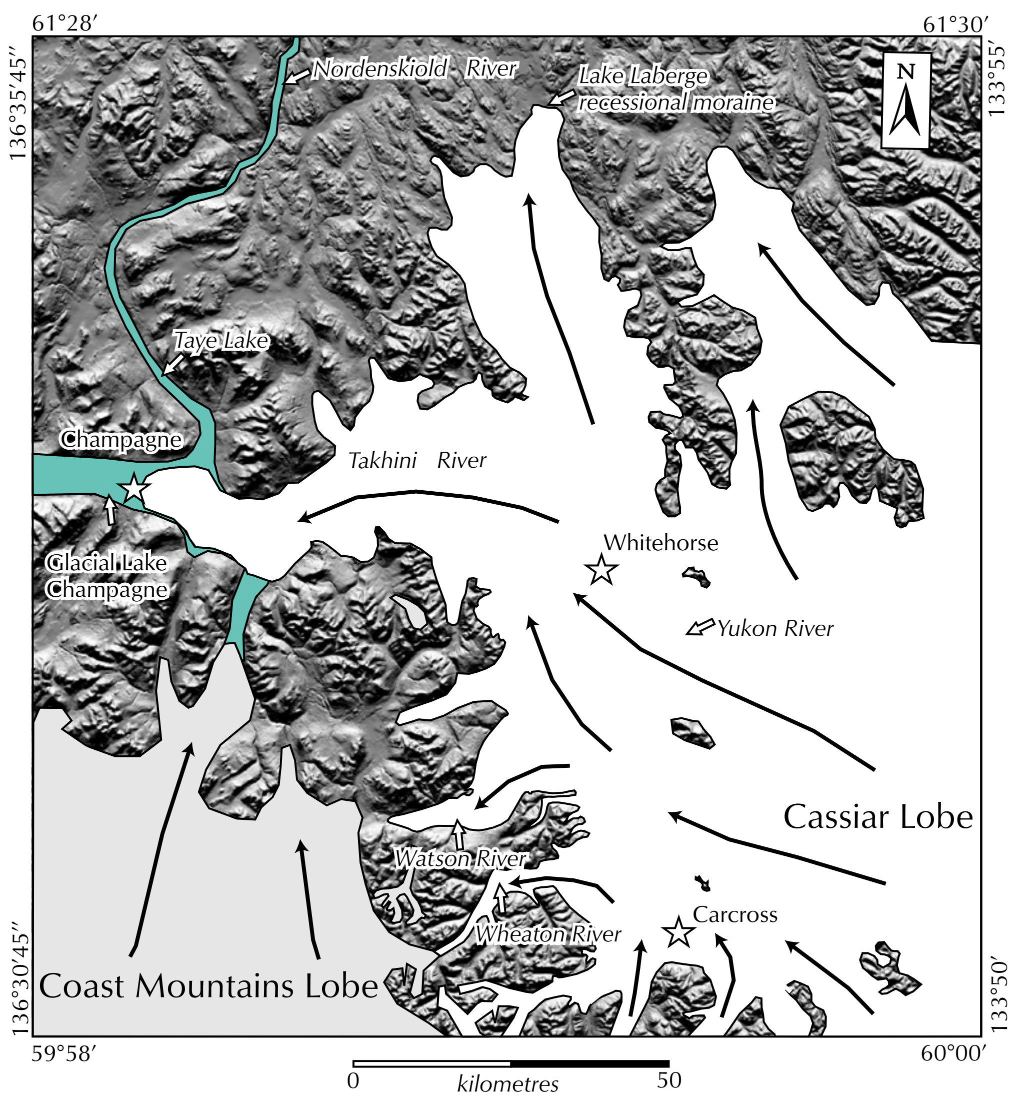


Figure 8. *Stage 3b – Cassiar re-advance. A schematic diagram showing the approximate limit of the Cassiar re-advance during deglaciation. Up-valley ice flow in the Takhini River valley dammed the westward drainage and created Glacial Lake Champagne.*

the re-advance appears to have had less influence on ice accumulations in the Coast Mountains. Reasons for this apparent precipitation deficit are unclear.

The limit of the re-advance in the Takhini River and the Yukon River valleys is poorly defined. This limit is drawn along the boundary of ice stagnation moraines which are thought to be concordant in both of these valleys.

At the village of Champagne, in the Takhini River valley, a well developed up-valley-oriented moraine may mark the limit of the Cassiar re-advance. Glacial Lake Champagne is thought to have been created by the retreat of the Cassiar Lobe from the Takhini River valley in the east and blockage of the Dezadeash River drainage by St. Elias ice to the west. Drainage for this lake occurred through the Taye Lake – Nordenskiold River divide. This outlet maintained a maximum water level of 746 m a.s.l. for drainage of Glacial Lake Champagne.

At the north end of Lake Laberge in the Yukon River valley, a large recessional moraine complex is preserved (Fig. 8). The magnitude of this stagnation complex suggests a significant pause occurred in the glacier's recession and is thought to correlate with the limit of the Cassiar Lobe re-advance. As the ice receded from this moraine, Glacial Lake Laberge developed behind the moraine of stagnating ice and sediment. Elevations of a fluvial terrace within the moraine and the upper-most strandline indicate that the highest outlet was at 699 m (a.s.l.) which is 65 m above the modern outlet. Flights of strandlines below the 699 m elevation suggest that erosion of the outlet was relatively constant during deglaciation.

Stage 3c: Ibex

The Ibex recessional stage is recognized from well developed morainal deposits extending from Fish Lake to the Ibex River valley (Fig. 9). The ice margin at this stage

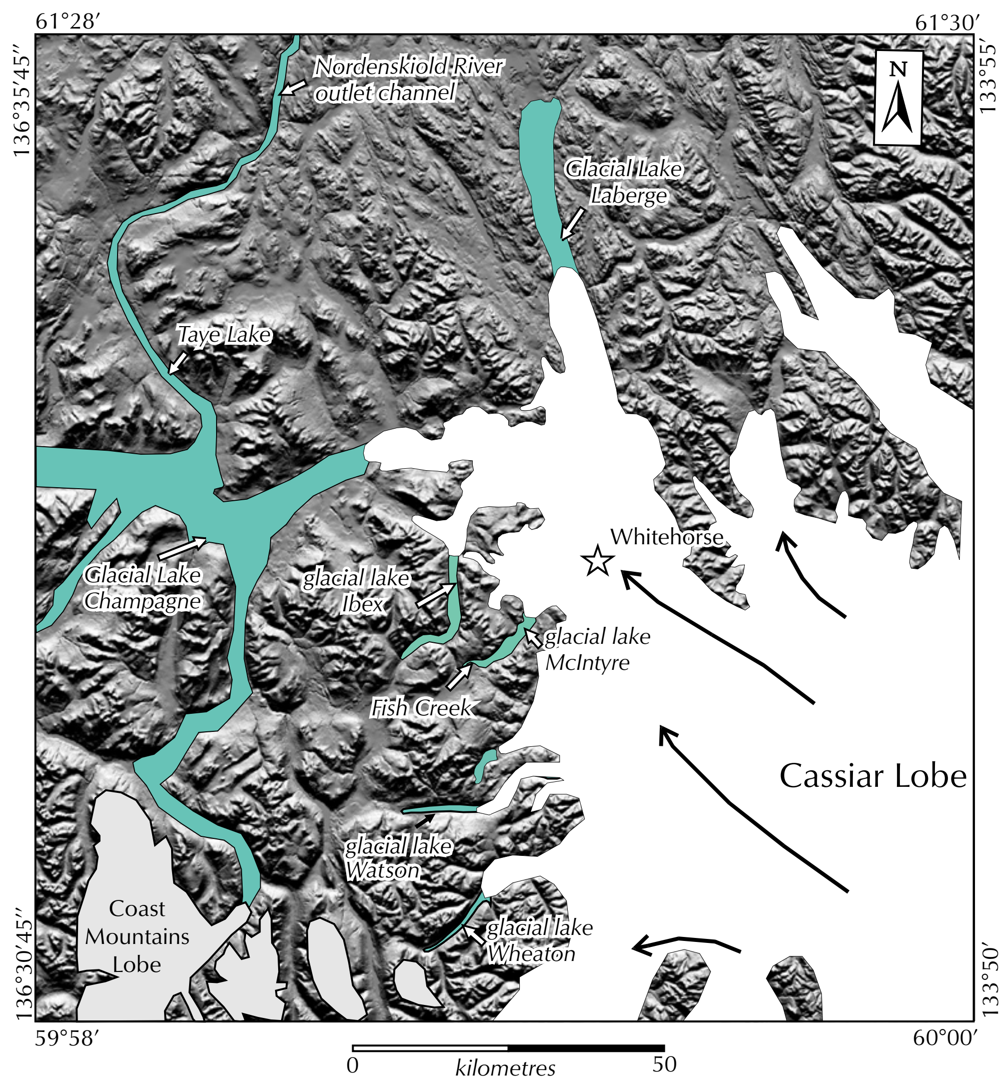


Figure 9. *Stage 3c – Ibex stage. This stage is defined by a recessional glacial limit that blocked the mouths of the Ibex River valley and Fish Lake. Ice tongues in the Yukon and Takhini river valleys retreated from the Cassiar re-advance limit, enlarging the glacial lakes in these valleys.*

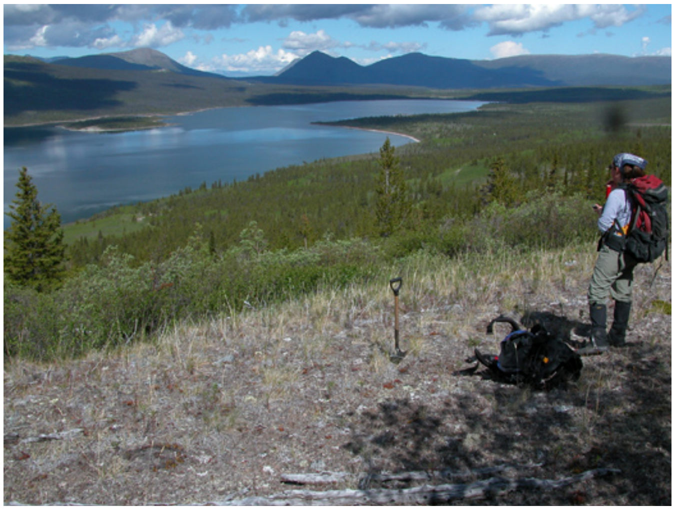


Figure 10. *View looking northwest across Fish Lake. The photograph is taken from the upper-most strandline of glacial lake McIntyre in Fish Lake valley (1250 m a.s.l.). This shoreline lies 120 m above the present shoreline of Fish Lake.*

Figure 11. *Scoured granite canyons in Ibex River valley formed from the draining of glacial lake Ibex.*

dammed both the Ibex River and Fish Lake valleys resulting in the development of two glacial lakes. The pro-glacial lake in Fish Lake valley, informally termed glacial lake McIntyre, reached an elevation of 1250 m a.s.l., that is, 120 m above modern Fish Lake (Fig. 10). The outlet for this glacial lake was located at the headwaters of Fish Creek and drained into the Ibex River valley. Upper strandline elevations in the Ibex River valley indicate that the water level reached an elevation of 1080 m a.s.l. The level of glacial lake Ibex was controlled by an outlet along the ice margin and possibly through sub-glacial channels, as evidenced by scoured granite bedrock in this area (Fig. 11).

During the Ibex stage, Glacial Lake Champagne would have increased in size as the Cassiar Lobe retreated to the east. Likewise, in the Yukon River valley, Glacial Lake Laberge would have increased in size as the ice receded to the south. Smaller pro-glacial lakes developed in the Wheaton and Watson river valleys.

Stage 3d: Chadburn

The Chadburn stage marks a significant pause in the retreat of the Cassiar Lobe from the Whitehorse area (Fig. 12). Large volumes of stagnation moraine in the vicinity of Whitehorse (Chadburn Lake area), Lewes Lake and Annie Lake all correlate to this period of dynamic equilibrium (Fig. 13). Further south, in the Wheaton River valley, glacial lake Wheaton would have persisted behind the ice front at Annie Lake (Fig. 12). Similarly, glacial lake Watson was impounded by the ice fronts at Lewes Lake and in the Yukon River valley at Cowley Creek. Each of these glacial lakes drained via outlets at their respective headwaters. The multiple ice fronts impounding glacial lake Watson acted as important sediment sources resulting in thick accumulation of glaciolacustrine deposits in that valley. To the north of the city of Whitehorse, glacial lakes Champagne and Laberge had joined following retreat of the Cassiar Lobe from the Takhini River valley. Drainage for the combined waters was through the Glacial Lake Laberge outlet, resulting in abandonment of the Nordenskiold outlet.

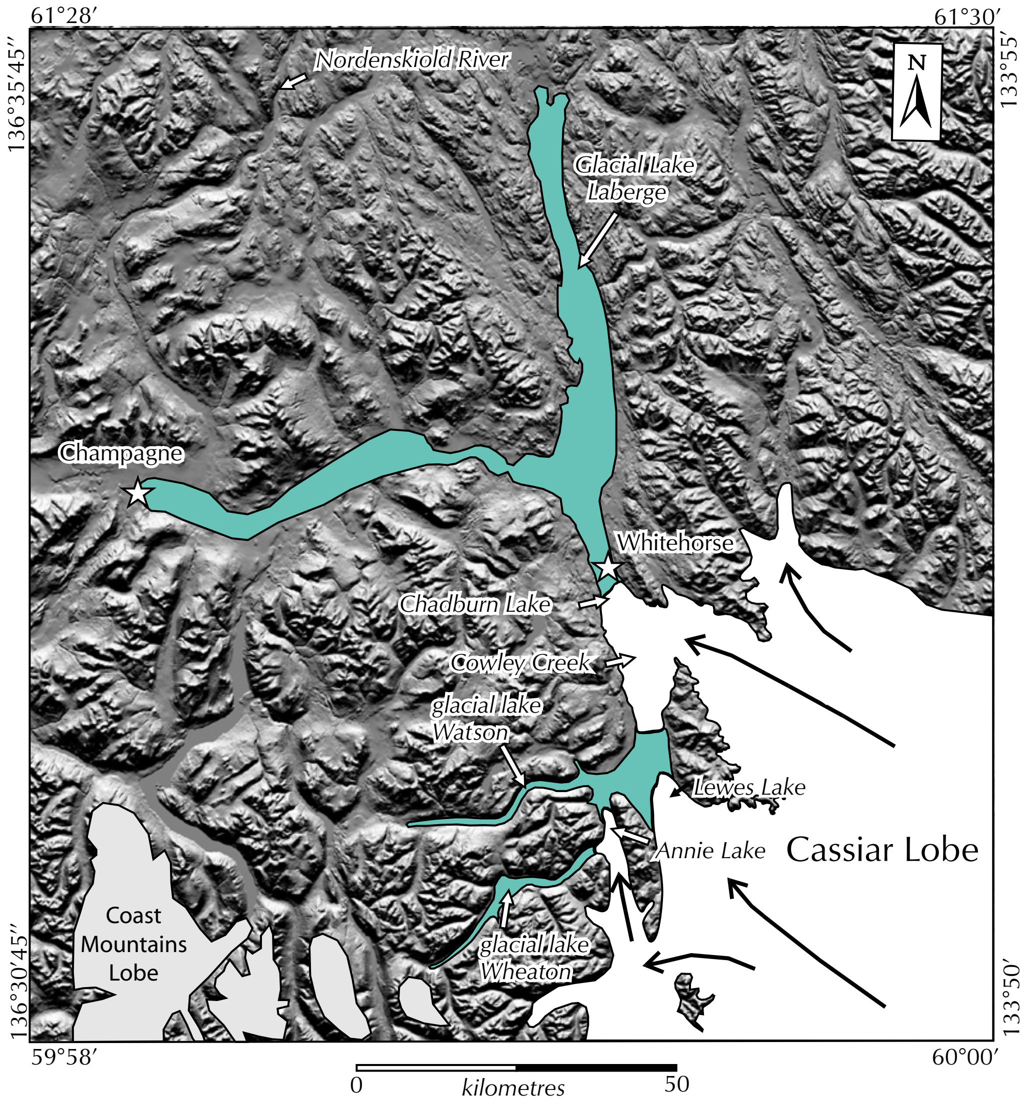


Figure 12. *Stage 3d – Chadburn stage. The Chadburn stage is a well defined recessional limit in the Whitehorse area.*

Figure 13. *A view to the north of Chadburn Lake near the city of Whitehorse. The rolling stagnation moraine topography is a remnant of the Chadburn recessional stage.*

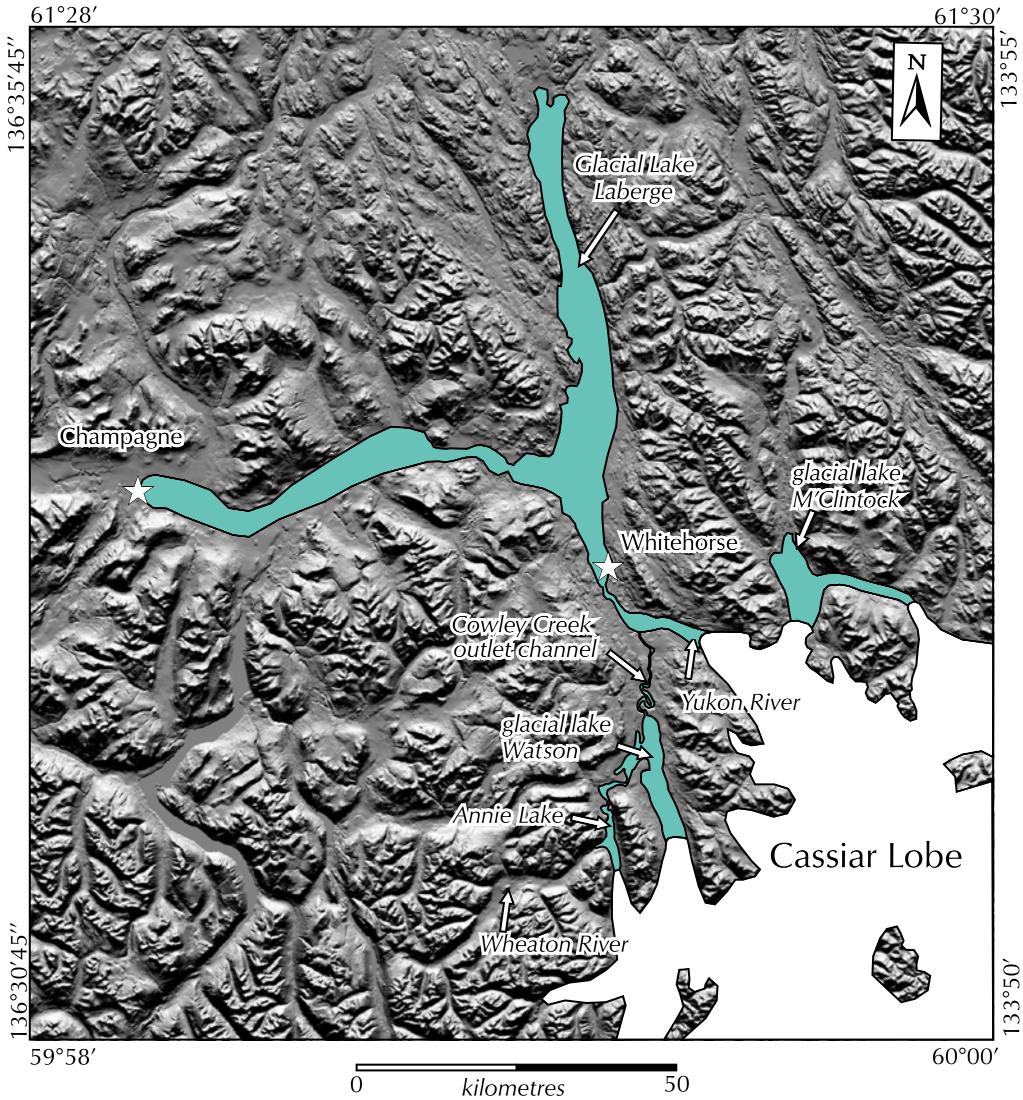


Figure 14. *Stage 3e – Cowley stage. This stage is defined by the activation of the Cowley Creek outlet channel for glacial lake Watson.*

Stage 3e: Cowley

The Cowley stage marked a rearrangement of drainage for glacial lake Watson (Fig. 14). The eastward retreat of ice near Whitehorse permitted glacial lake Watson to drain northward into the Yukon River valley via the Cowley Creek outlet channel. The channel cuts through a sediment dam deposited during the Chadburn stage. Also at this time, the Wheaton River ice lobe would have retreated south from Annie Lake, permitting water from the upper Wheaton River to drain into glacial lake Watson (Fig. 15). A glacial lake would have also developed in the M'Clintock River valley as ice receded south in that drainage.

Figure 15. *A paleo-outwash channel at the north end of Annie Lake. This channel carried northward-flowing waters from the Wheaton River valley and a nearby melting ice tongue into glacial lake Watson.*

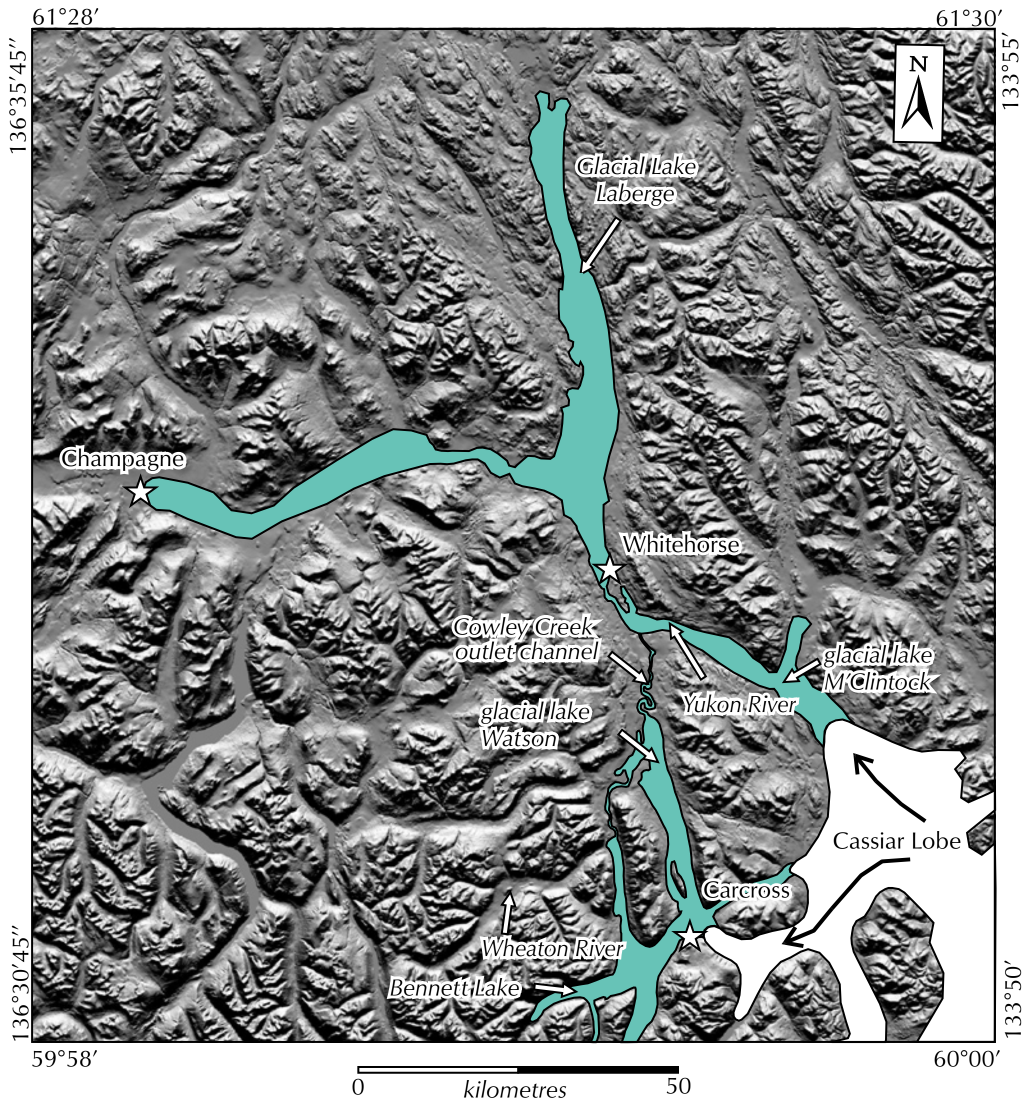


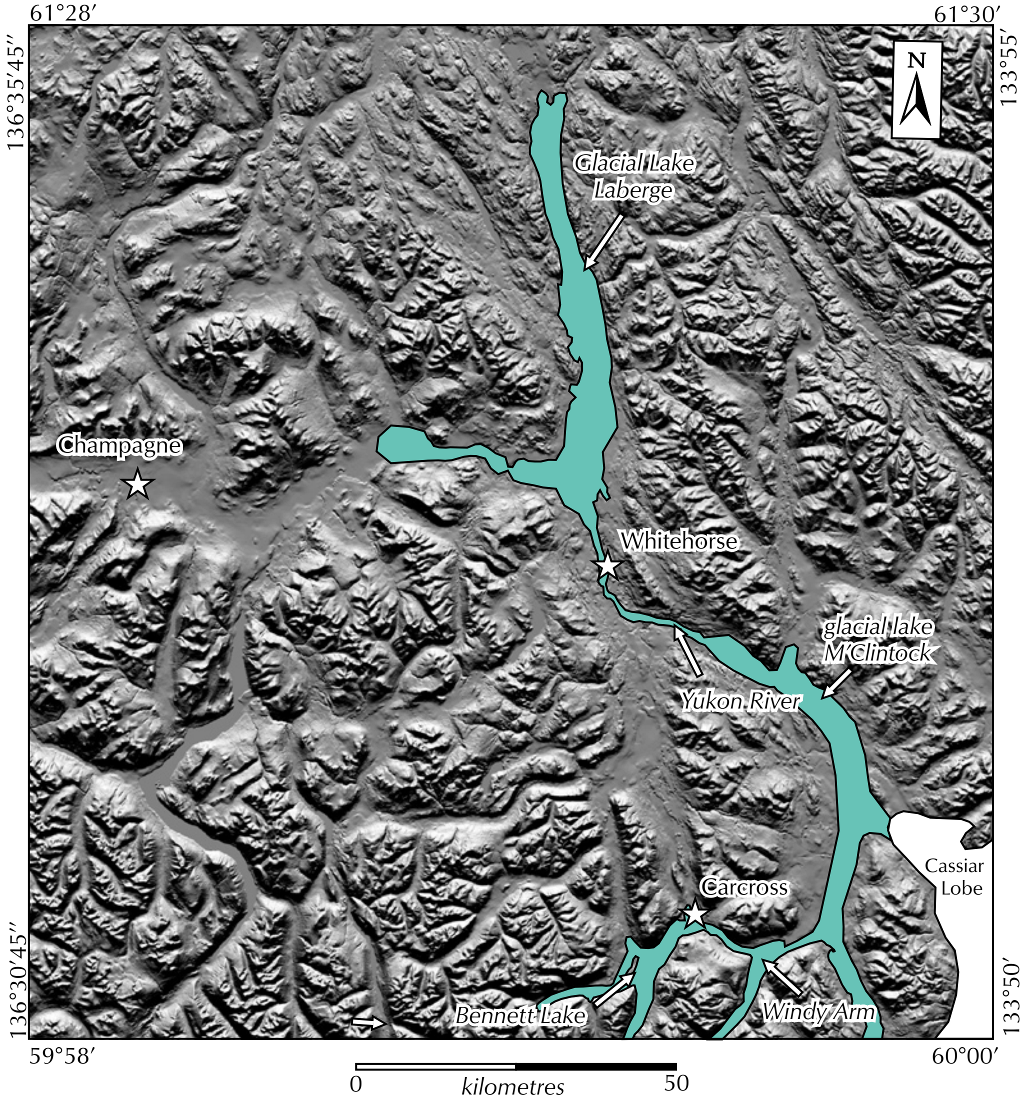
Figure 16. *Stage 3f – Bennett stage. This recessional stage is defined by an ice limit near the village of Carcross at the east end of Bennett Lake. Glacial lake ponding in Bennett Lake would have been part of glacial lake Watson.*

Stage 3f: Bennett

Continued retreat of the Cassiar Lobe from the Watson, Wheaton and Yukon river valleys allowed glacial lakes to expand in the Whitehorse map area (Fig. 16). The Bennett stage contained the most extensive glacial lake coverage during deglaciation. To the south of Whitehorse, the Cowley Creek outlet maintained drainage from an expanded glacial lake Watson as ice retreated south and east. Strandlines along Bennett Lake at 778 m a.s.l. correlate with the Cowley Creek outlet elevation which means the Carcross area was once submerged under 120 m of lake water (Fig. 17). In the Yukon River valley, glacial lake ponding extended into the Marsh Lake area and M'Clintock River watershed. This is informally referred to as glacial lake M'Clintock. Drainage of glacial lake M'Clintock was through a short section of river or narrow lake connecting it with Glacial Lake Laberge. The water level of this large system of glacial lakes was maintained through the outlet of Glacial Lake Laberge.

Figure 17. *Strandlines above Bennett Lake (see arrows). These former shorelines are wave-modified landforms that consist mostly of winnowed till deposits.*

Figure 18. Stage 3g – M'Clintock stage. The last stage of McConnell ice in the Whitehorse map area.



Stage 3g: M'Clintock

The final stage of deglaciation in the Whitehorse area is marked by a withdrawal of ice from the Bennett Lake/ Windy arm area causing the abandonment of the Cowley Creek outlet channel (Fig. 18). Water from glacial lake Watson was incorporated into glacial lake M'Clintock. This vastly increased the size of glacial lake M'Clintock. Thin deposits of glaciolacustrine sediment bordering Marsh Lake suggest that glacial lake M'Clintock was relatively short lived. This may have been attributed to rapid incision into the sediment constriction controlling the glacial lake drainage.

STAGE 4: EARLY HOLOCENE

On-going fluvial incision of the sediment dam on Lake Laberge, into the Holocene, continued to affect the geography of the Yukon River valley near Whitehorse. The decreasing level of Lake Laberge caused the Yukon River to downcut into the glaciolacustrine and morainal deposits to the south. The retreating waters of Lake Laberge also caused the southern shoreline and the Yukon River delta to migrate northward, thus depositing deltaic sands over the lacustrine fill. Once subaerially exposed, the deltaic sand was reworked by aeolian processes to form the Whitehorse dune field (immediately north of the city). Optical dating of the aeolian sediments is currently in progress to improve the chronology of the deglaciation history of the Whitehorse region.

SUMMARY

During the McConnell Glaciation, the Whitehorse map area was situated at the boundary of two ice lobes of the Cordilleran Ice Sheet: the Cassiar and Coast Mountains lobes. Initial ice accumulations in the map area probably began in the higher regions of the Coast Mountains. It was not until localized ice caps had formed that the more distal Cassiar Lobe advanced into the map area from the southeast. The convergence of the two lobes at glacial maximum occurred over the Coast Mountains transitional zone west of the city of Whitehorse. Movement of the Cassiar Lobe over this portion of the map area was to the northwest and was unobstructed by underlying topography. Movement of the Coast Mountains Lobe was northward. The pattern of deglaciation is highlighted by periods of differential retreat and fluctuating ice fronts. A large re-advance of the Cassiar Lobe occurred into the already deglaciated Coast Mountains transitional zone. This had a significant influence on sediment deposition within the map area. In particular, systems of pro-glacial lakes developed marginally to the Cassiar Lobe as it retreated. Deposition within these lakes is evident in many of the major valleys in the map area. The early Holocene is highlighted by drainage of the glacial lakes, incision into the glaciolacustrine fill and aeolian activity.

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