GEOLOGICAL SURVEY OF CANADA
BULLETIN 559

SURFICIAL GEOLOGY OF THE GLENLYON MAP AREA, YUKON TERRITORY

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2000

Natural Resources Canada
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Catalogue No. M42-559E
ISBN 0-660-18299-8

Available in Canada from
Geological Survey of Canada offices:

601 Booth Street
Ottawa, Ontario K1A 0E8

3303-33rd Street N.W.
Calgary, Alberta T2L 2A7

101-605 Robson Street
Vancouver, B.C. V6B 5J3

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Price subject to change without notice

Cover illustration

Thick sequence of finely bedded to laminated sand, Tay River; ice axe is 90 cm long. Photograph by Brent Ward. GSC 2000-037E

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Original manuscript submitted: 1999-07
Final version approved for publication: 2000-07

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SURFICIAL GEOLOGY OF THE GLENLYON MAP AREA, YUKON TERRITORY

Abstract

Regional Quaternary mapping and stratigraphic and sedimentological studies were undertaken in the Glenlyon map area (NTS 105 L), with stratigraphic studies extending westward into the Carmacks map area (NTS 115-I). Surficial sediments were divided into 23 units, which range from Early Pleistocene to Holocene.

Evidence exists for at least three glaciations: pre-Reid (Early Pleistocene), Reid (Middle Pleistocene), and McConnell (Late Wisconsinan). Deposits of the Pre-Reid glaciation(s) have a very subdued surface morphology. The Reid Glaciation was less extensive and has better preserved landforms. Organic beds of Middle Wisconsinan age were identified, and insect macrofossils and pollen indicate forested conditions at 36 000–37 000 BP. Landforms and sediments of the McConnell Glaciation are well preserved, allowing for better reconstruction of conditions than the previous glaciations. The stratigraphic record suggests that rivers aggraded and an oscillation in the location of the ice front occurred during glacial advance. At glacial maximum, the Selwyn and Cassiar lobes of the Cordilleran Ice Sheet affected the area, with topography strongly controlling ice flow. Because of aridity, local cirques in the Glenlyon Range supported only small glaciers that did not contribute to the Selwyn Lobe.

At the end of the McConnell Glaciation, the retreat of glaciers was very rapid, with the ice sheet downwasting and stagnating in place. Many small lake basins developed in the Pelly River valley and large thicknesses of sediment were deposited on top of stagnant ice. Sediments were derived from the active ice margin, stagnant ice, marginal streams, and recently deglaciated valley sides.

Résumé

On a entrepris la cartographie régionale et des études stratigraphiques et sédimentologiques du Quaternaire dans la région cartographique de Glenlyon (SNRC 105 L). Les études stratigraphiques ont été poursuivies vers l'ouest dans la région cartographique de Carmacks (SNRC 115-I). Les sédiments de surface on été répartis en 23 unités, dont l'âge s'échelonne du Pléistocène inférieur à l'Holocène.

Des manifestations d'au moins trois glaciations ont été relevées, à savoir au moins une glaciation antérieure à la Glaciation de Reid (Pléistocène inférieur), la Glaciation de Reid (Pléistocène moyen) et la Glaciation de McConnell (Wisconsinien supérieur). La morphologie superficielle des dépôts antérieurs à la Glaciation de Reid est très adoucie. La Glaciation de Reid a été moins importante et les formes de relief sont mieux conservées. Des couches organiques du Wisconsinien moyen ont été mises en évidence et la présence de pollen et de macrofossiles d'insectes est indicatrice de conditions forestières de 36 000 à 37 000 BP. Les formes de relief et les sédiments de la Glaciation de McConnell sont bien conservés; de ce fait, il est plus facile de reconstituer les conditions de cette glaciation que celles des glaciations antérieures. Les données stratigraphiques laissent supposer que les cours d'eau se sont alluvionnés et que le front glaciaire a oscillé au cours de l'avancée des glaces. Au pléniglaciaire, les lobes de Selwyn et de Cassiar de l'Inlandsis de la Cordillère ont envahi la région et la topographie a fortement contrôlé l'écoulement glaciaire. En raison de l'aridité du climat, les cirques locaux dans le chaînon Glenlyon n'ont accumulé que de petits glaciers qui n'ont pas contribué au Lobe de Selwyn.

À la fin de la Glaciation de McConnell, les glaciers ont reculé très rapidement et, par endroits, la calotte glaciaire s'est amaigrie et est devenue stagnante. De nombreux petits bassins lacustres se sont formés dans la vallée de la rivière Pelly et des sédiments de fortes épaisseurs se sont déposés au-dessus des glaces stagnantes. Ces sédiments provenaient de la marge glaciaire active, des glaces stagnantes, des cours d'eau marginaux et des versants récemment déglacés des vallées.

SUMMARY

The Glenlyon map area, located in central Yukon Territory, has been repeatedly affected by the northern extension of the Cordilleran Ice Sheet and records at least three glaciations: the Early Pleistocene pre-Reid glaciation(s), the Middle Pleistocene Reid Glaciation, and the Late Wisconsinan McConnell Glaciation. During the Late Wisconsinan, the Selwyn and Cassiar lobes terminated just west of the map area and many upland surfaces were nunataks. These upland surfaces expose deposits of at least two older glaciations. The physiography is a combination of the Yukon Plateaus, a series of broad plateaus with occasional uplands, and the Kaska Mountains, represented by the Glenlyon Range of the Pelly Mountains. Glaciations have modified the landscape, resulting in major and minor drainage anomalies, broad U-shaped valleys, rugged cirques and arêtes, and increasingly subdued surface morphologies associated with the older glaciations.

Surficial sediments were divided into 23 units, based mainly on genesis, landform, and age. Pre-Reid and Reid deposits are found above the Reid and McConnell glacial limits, respectively, in the western portion of the map area. Some Reid deposits were also mapped in the Glenlyon Range. Deposits from these older glaciations have more intense pedogenesis and larger amounts of colluvial deposits than similar deposits of McConnell age.

McConnell glacial deposits occur throughout the map area, with till being the most common. Till veneers (less than 1 m thick) and blankets (greater than 1 m thick) are common, with occasional thicker deposits associated with moraines and streamlined forms. Till matrix ranges from sandy to clayey silt, likely reflecting depositional controls. The structure ranges from massive to stratified with sorted sediment, representing deposition as basal till and proximal subaqueous debris flow, respectively. Till is generally a good bulk fill and foundation material, although some slopes with northern aspects can have segregated ice lenses.

Glaciofluvial deposits consist mainly of sand and gravel, deposited as plains, terraces, deltas, and complexes. They occur throughout the area but are most common in plateaus and valleys. Most have a planar surface expression, except glaciofluvial complexes, whose hummocky, ridged, and kettled surfaces reflect deposition in contact with ice. Planar surfaces are generally good sites for development, since they are usually stable and above any flood hazards. Glaciofluvial deposits are generally good sources of aggregate resources, but proximal deposits can have rapid lateral facies changes and contain significant amounts of diamicton.

SOMMAIRE

La région cartographique de Glenlyon, qui est située dans le centre du Territoire du Yukon, a été affectée à maintes reprises par le prolongement septentrional de l'Inlandsis de la Cordillère. Elle a été soumise à au moins trois glaciations : une ou plusieurs glaciations antérieures à la Glaciation de Reid au Pléistocène inférieur, la Glaciation de Reid au Pléistocène moyen et la Glaciation de McConnell au Wisconsinien supérieur. Au Wisconsinien supérieur, les lobes de Selwyn et de Cassiar se terminaient juste à l'ouest de la région cartographique et de nombreuses hautes terres étaient des nunataks. Des dépôts d'au moins deux glaciations plus anciennes se rencontrent sur ces hautes terres. Les éléments physiographiques comprennent les plateaux du Yukon, un ensemble de vastes plateaux avec, par endroits, des hautes terres, et les monts Kaska représentés par le chaînon Glenlyon des monts Pelly. Les glaciations ont modifié le paysage, produisant de petites et de grandes anomalies de drainage, de larges vallées en auge, des cirques et des arêtes accidentés, et des reliefs de plus en plus adoucis associés aux glaciations plus anciennes.

Les sédiments superficiels ont été répartis en 23 unités en fonction de leur genèse, de leur âge et des formes de relief qui leur sont associées. Les dépôts de la glaciation antérieure à la Glaciation de Reid et de la Glaciation de Reid se trouvent respectivement au-dessus des limites de la Glaciation de Reid et de la Glaciation de McConnell, dans la partie occidentale de la région cartographique. Certains des dépôts de la Glaciation de Reid dans le chaînon Glenlyon ont également été cartographiés. La pédogenèse des dépôts de ces glaciations plus anciennes est plus intense et les sols renferment de plus grandes quantités de colluvions que les dépôts similaires datant de la Glaciation de McConnell.

Les dépôts de la Glaciation de McConnell sont présents dans l'ensemble de la région cartographique; le till prédomine. Les placages (moins de 1 m d'épaisseur) et les nappes de till (plus de 1 m d'épaisseur) sont abondants; ils sont accompagnés localement de dépôts de plus forte épaisseur associés à des moraines et à des formes profilées. La matrice du till va du silt sableux au silt argileux et reflète vraisemblablement des facteurs ayant contrôlé la sédimentation. La structure varie de massive à stratifiée avec des sédiments granoclassés et représente respectivement des dépôts de till de base et des coulées de débris subaquatiques proximaux. Le till constitue généralement un bon matériau à remblai et de fondation bien que certaines pentes à orientation nord puissent contenir des lentilles de glace de ségrégation.

Les dépôts fluvioglaciaires sont formés principalement de sable et de gravier qui se sont déposés sous la forme de plaines, de terrasses, de deltas et de complexes. Ils se rencontrent dans toute la région, mais sont plus abondants sur les plateaux et dans les vallées. La surface de ces dépôts est généralement plane à l'exception des complexes fluvioglaciaires, dont les surfaces bosselées, côtelées et percées de kettles indiquent qu'ils se sont déposés en contact avec la glace. Les surfaces planes constituent de bons terrains pour le développement puisqu'elles sont généralement stables et situées au-dessus de toutes zones inondables. Les dépôts fluvioglaciaires sont en général de bonnes sources d'agrégats. Cependant, les dépôts proximaux peuvent présenter de brusques changements latéraux de faciès et renferment d'importantes quantités de diamictons.

Glaciolacustrine deposits consist mainly of well stratified sand, silt, and clay, but can contain significant amounts of gravel and diamicton, reflecting proximal deposition. They occur mainly in the larger valleys in the Glenlyon area and were mapped as plains, blankets, veneers, and complexes. Folded, faulted, and brecciated glaciolacustrine sediments reflect deposition in supraglacial lakes and deformation following melting of the ice. Silt- and clay-rich deposits commonly have segregated ice lenses and should be avoided for infrastructure development.

Les dépôts glaciolacustres se composent principalement de sable, de silt et d'argile bien stratifiés. Cependant, ils peuvent contenir d'importantes quantités de graviers et de diamictons, indicateurs d'un dépôt proximal. Dans la région de Glenlyon, ils se rencontrent principalement dans les vallées les plus vastes; ils sont représentés sur la carte comme des plaines, des nappes, des placages et des complexes. Les sédiments glaciolacustres plissés, faillés et bréchifiés se sont accumulés dans des lacs supraglaciaires et ont été déformés après la fusion des glaces. Les dépôts à forte teneur en silt et en argile renferment fréquemment des lentilles de glace de ségrégation; ils sont déconseillés pour le développement d'infrastructures.

Holocene deposits consist mainly of alluvial and colluvial deposits, with lesser amounts of organic and eolian materials. Fluvial deposits occur along all major streams and rivers, and consist of sand and gravel, deposited as floodplains, terraces, and fans. Modern floodplains can contain organic and lacustrine deposits with segregated ice lenses and have low bearing strength, thus limiting their value as sites for development. Development on floodplains can be further curtailed by flood hazard from snowmelt runoff, rainstorm events, and ice jams. Alluvial fans range from low-relief features dominated by fluvial processes to steeper features dominated by debris-flow processes. Care must be taken with development on both types of fans, since fluvial avulsions and debris flows can potentially affect infrastructure.

Les dépôts de l'Holocène sont principalement des alluvions et des colluvions avec des matériaux organiques et éoliens en plus petites quantités. Les dépôts fluviatiles se rencontrent en bordure de tous les principaux cours d'eau. Ils sont formés de sable et de gravier déposés sous la forme de plaines d'inondation, de terrasses et de cônes. Les plaines d'inondation actuelles peuvent contenir des dépôts organiques et lacustres avec des lentilles de glace de ségrégation; leur résistance à la charge est faible, ce qui limite leur utilité comme terrain d'aménagement. Les risques d'inondation associés aux pluies d'orages, aux embâcles et au ruissellement nival sont d'autres obstacles à l'exécution de travaux de développement sur ces plaines d'inondation. Les cônes alluviaux épousent des formes de relief émoussées dominées par des processus fluviatiles et des reliefs plus escarpés dominés par des processus de coulées de débris. Des précautions doivent être prises si l'on doit exécuter des travaux de développement sur ces deux types de cônes, car les avulsions et les coulées de débris sont susceptibles d'affecter les infrastructures.

Colluvial deposits are generally poorly sorted and are deposited by processes ranging from high-velocity rock falls to low-velocity solifluction and creep. They occur as blankets, veneers, and aprons throughout the area on slopes steeper than 20–30°, and can consist of remobilized surficial deposits or weathering products from bedrock. Although landslides occur in both surficial material and bedrock, they are more common in surficial material. Since many colluvial deposits are metastable, they are not recommended for development.

Les colluvions sont généralement mal classées et se sont déposées par l'intermédiaire de divers processus allant de chutes de pierres très rapides à des solifluxions et à des reptations. Elles sont présentes dans l'ensemble de la région sous la forme de nappes, de placages et de tabliers, tous situés sur des pentes supérieures à 20–30°. Elles correspondent à des dépôts superficiels remobilisés ou à des produits de l'altération du substratum rocheux. Bien que des glissements de terrain se produisent dans les matériaux superficiels et dans le substratum rocheux, ils sont plus nombreux dans les matériaux de surface. Puisque de nombreuses colluvions sont métastables, elles ne sont pas recommandées pour l'exécution de travaux de développement.

Stratigraphic sections were examined in the Glenlyon map area and the eastern portion of the Carmacks map area. The oldest sediments exposed were at the base of the Bradens Canyon section. These normally magnetized alluvial sediments reflect cold periglacial conditions prior to the Reid Glaciation.

Reid glaciolacustrine and glaciofluvial deposits are exposed along the Pelly River downstream from the McConnell limit. Within the McConnell limit, the Lyon Creek section exposes sediments of possible Reid age that record advance and retreat of an ice sheet prior to the McConnell Glaciation.

Three sites, Granite Canyon, Pelly farm, and section 26, have deposits that predate the McConnell Glaciation and postdate the Koy–Yukon thermal event. Granite Canyon records spruce forest conditions at 37 000–36 000 BP.

Des coupes stratigraphiques ont été examinées dans le chaînon Glenlyon et dans la partie orientale de la région cartographique de Carmacks. Les sédiments les plus anciens sont exposés à la base de la coupe du canyon Bradens. Ces alluvions à aimantation normale reflètent les conditions périglaciaires froides qui sévissaient avant la Glaciation de Reid.

Des dépôts glaciolacustres et fluvioglaciaires de la Glaciation de Reid sont exposés le long de la rivière Pelly en aval de la limite de la Glaciation de McConnell. À l'intérieur de cette limite, la coupe du ruisseau Lyon renferme des sédiments pouvant dater de la Glaciation de Reid qui témoignent de l'avancée et du retrait d'une calotte glaciaire avant la Glaciation de McConnell.

Trois sites, à savoir le canyon Granite, Pelly farm et la coupe 26, contiennent des dépôts antérieurs à la Glaciation de McConnell et postérieurs à l'événement thermique de Koy–Yukon. Le site du canyon Granite atteste de conditions de pessière à 37 000–36 000 BP. Le

Pelly farm records alluvial fan formation caused by climatic deterioration associated with the onset of the McConnell Glaciation. Section 26 records interstadial alluvial deposits, followed by river aggradation and a ponding event as McConnell ice advanced into the area.

Deposits of the McConnell Glaciation occur throughout the map area and reflect deposition by two lobes of the Cordilleran Ice Sheet, which originated in mountainous areas to the west (Selwyn Lobe) and south (Cassiar Lobe). Conversely, local cirques in the Glenlyon Range were not extensive because of aridity and did not contribute to the Selwyn Lobe. The Selwyn Lobe flowed into the valleys of the Glenlyon Range, blocked drainage, and formed lakes. The Safety Pin Bend section records a significant oscillation of the ice front during advance.

Ice flow during the maximum of the McConnell Glaciation consisted of anastomosing ice streams, with ice deflecting around high mountains (nunataks). The Selwyn Lobe flowed generally westward and the Cassiar Lobe flowed generally northward across the area.

After initial retreat, marked by recessional moraines within a few tens of kilometres of the ice front, the Selwyn Lobe stagnated and downwasted in place. Lake deposits in tributary valleys indicate that higher areas became ice-free first, with decaying ice occupying trunk valleys. Glacial lake levels were controlled by downwasting ice that persisted in the main valleys. Regional stagnation is also reflected in the pattern of sedimentation during deglaciation. Detailed analysis of sections along the Pelly River indicates that sedimentation processes were complex, with material being deposited into lakes from melting ice, adjacent valleys, and mass wasting from valley slopes. Some of these sediments are highly disturbed due to melting of the supporting ice. The timing of deglaciation is poorly constrained and predates 9140 ± 540 BP.

Important Holocene events reflect the transition from glacial to nonglacial conditions: upland vegetation became established by 9140 ± 540 BP; rivers downcut to their present level; and the White River tephra was erupted ca. 1250 BP and covered the southern three-quarters of the map area.

site de Pelly farm témoignent de la formation de cônes alluviaux par suite d'un refroidissement climatique associé au début de la Glaciation de McConnell. Le site de la coupe 26 met en évidence des dépôts alluviaux interstadiaires suivis de l'exhaussement des rivières et d'une retenue au fur et à mesure que les glaces de McConnell progressaient dans la région.

Les dépôts de la Glaciation de McConnell se rencontrent dans l'ensemble de la région cartographique et reflètent une sédimentation par deux lobes de l'Inlandsis de la Cordillère en provenance de zones montagneuses à l'ouest (Lobe de Selwyn) et au sud (Lobe de Cassiar). À l'opposé, les cirques locaux du chaînon Glenlyon n'étaient pas vastes en raison de l'aridité qui sévissait et n'ont pas contribué au Lobe de Selwyn. Ce lobe s'est avancé dans les vallées du chaînon Glenlyon, a obstrué le drainage et a formé des lacs. La coupe de Safety Pin Bend montre que le front glaciaire a considérablement oscillé au cours de l'avancée.

Durant le pléniglaciaire de la Glaciation de McConnell, l'écoulement glaciaire comportait des courants glaciaires anastomosés, les glaces étant déviées autour des hautes montagnes (nunataks). Les lobes de Selwyn et de Cassiar s'écoulaient respectivement vers l'ouest et vers le nord dans la région.

Après le retrait initial, marqué par la présence de moraines de retrait à quelques dizaines de kilomètres du front glaciaire, le Lobe de Selwyn s'est immobilisé et a fondu. Les dépôts lacustres dans les vallées tributaires indiquent que les zones plus élevées se sont déglacées les premières et que les glaces en fusion occupaient les vallées principales. Le niveau des lacs glaciaires était contrôlé par l'amaigrissement des glaces dans les vallées principales. Cette stagnation régionale se traduit également par le régime de sédimentation qui sévissait durant la déglaciation. Une analyse détaillée des coupes le long de la rivière Pelly révèle que les processus de sédimentation étaient complexes, les matériaux déposés dans les lacs provenant de glaces en fusion, de vallées adjacentes et de mouvements de masse sur les versants des vallées. Certains de ces sédiments ont été excessivement perturbés par la fusion des glaces qui les supportaient. La chronologie de la déglaciation est mal définie et est antérieure à 9140 ± 540 BP.

Des événements importants à l'Holocène reflètent le passage des conditions glaciaires aux conditions non glaciaires : la végétation des hautes terres s'est fixée vers 9140 ± 540 BP, les rivières ont creusé leur lit pour atteindre leur niveau actuel et le téphra de White River a été éjecté vers 1250 BP et a couvert les trois quarts méridionaux de la région cartographique.

INTRODUCTION

Surficial mapping and geological studies were conducted in the Glenlyon map area (NTS 105 L), located between 62° and 63°N and 134° and 136°W in central Yukon Territory. Stratigraphic studies were also carried out westward along the Pelly River into the adjacent Carmacks map area (NTS 115-I; Fig. 1, 2), where the limits of the Reid and McConnell glaciations are located.

Physiography

The Glenlyon map area lies within the broad physiographic regions of the Kaska Mountains and the Yukon Plateaus (Fig. 3; Mathews, 1986). In the map area, the Kaska Mountains consist of the Glenlyon Range, which is the northwesternmost extension of the Pelly Mountains (Fig. 3). Peaks above 2000 m in elevation occur within the Glenlyon Range (Fig. 4). The Yukon Plateaus are a broad upland area consisting of low, rolling hills and some mountain ranges, notably the Macmillan, Kalzas, Big Salmon, Little Salmon, and Wilkinson ranges. Peaks with elevations greater than 1700 m occur within these ranges, but the Yukon Plateaus generally have elevations of 600–1200 m.

Several valleys incise the Yukon Plateaus. The largest of these is the Tintina Trench (Fig. 5), a linear, structurally controlled depression that extends north-northwest across Yukon Territory from northwest of Watson Lake into Alaska (Fig. 3). In the Glenlyon map area, the Tintina Trench is 4–10 km wide and lies below 600 m. It contains Detour Lakes, the Little Kalzas River, Little Kalzas Lake, and

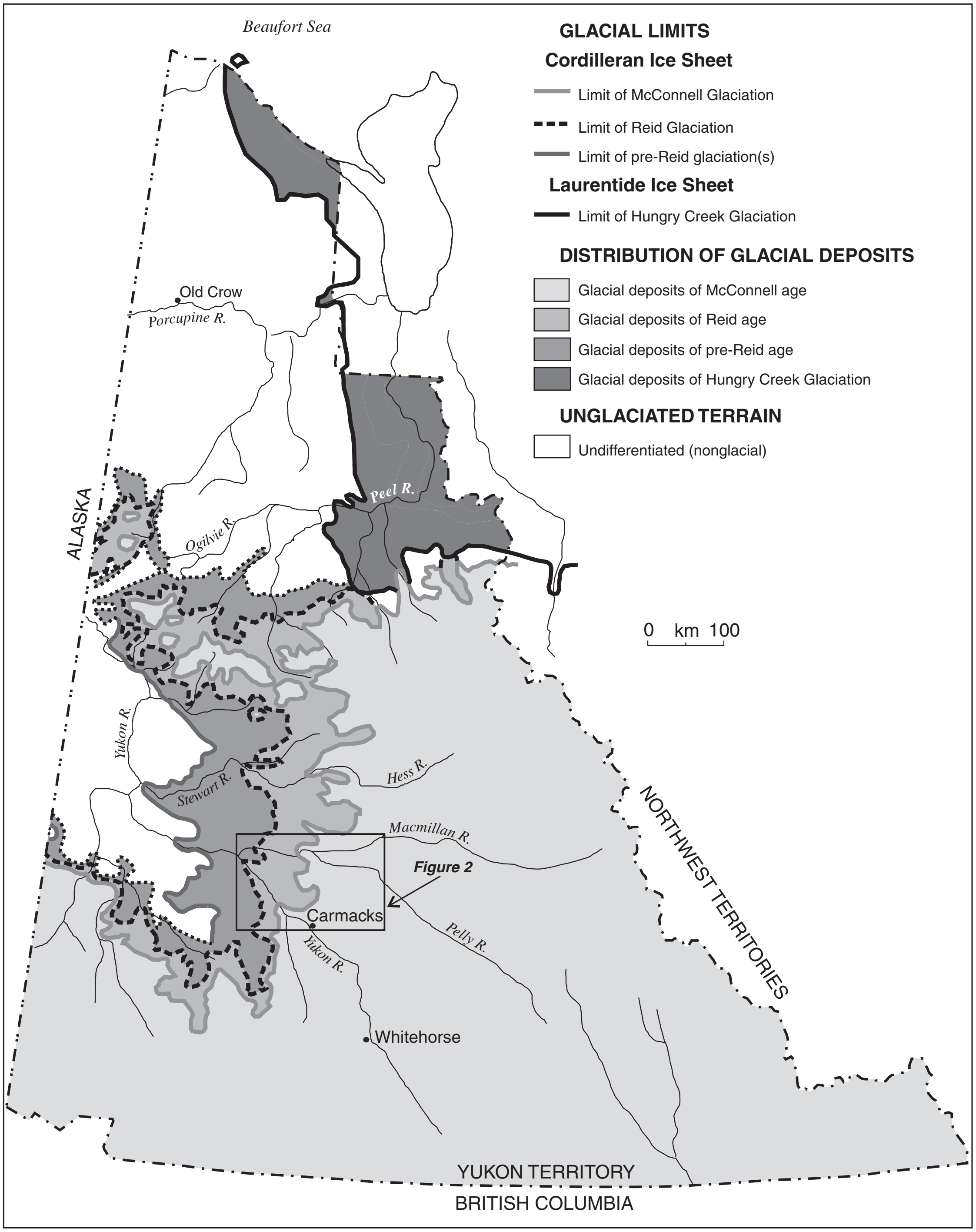


Figure 1. *Glacial limits and distribution of glacial deposits in Yukon Territory (*modified from *Duk-Rodkin, 1999, Fig. 1). Location of Figure 2 is indicated.*

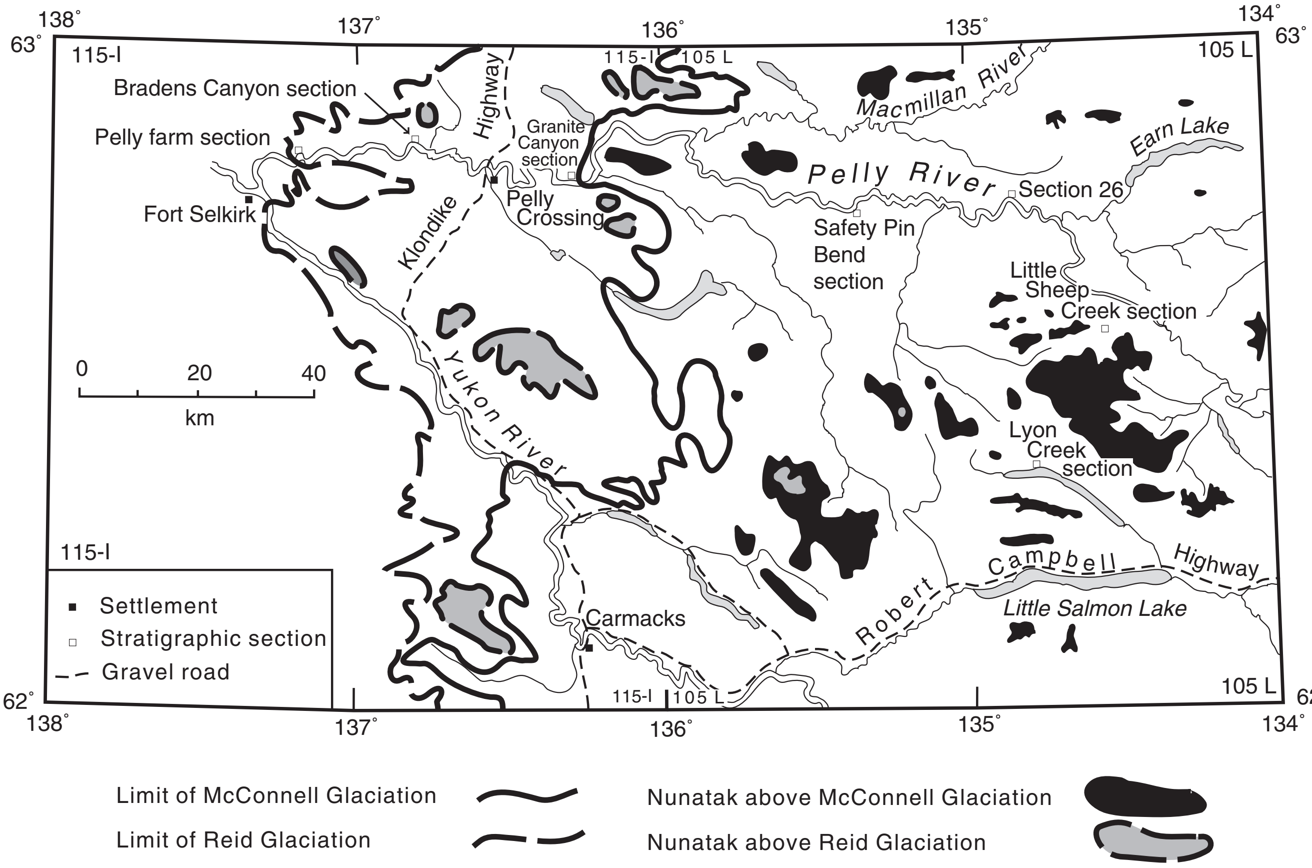


Figure 2. *Glacial limits, nunataks, and stratigraphic sections mentioned in the text, Glenlyon map area (NTS 105 L) and portion of Carmacks map area (NTS 115-I)* (modified from *Duk-Rodkin et al., 1986, Fig. 28.1).*

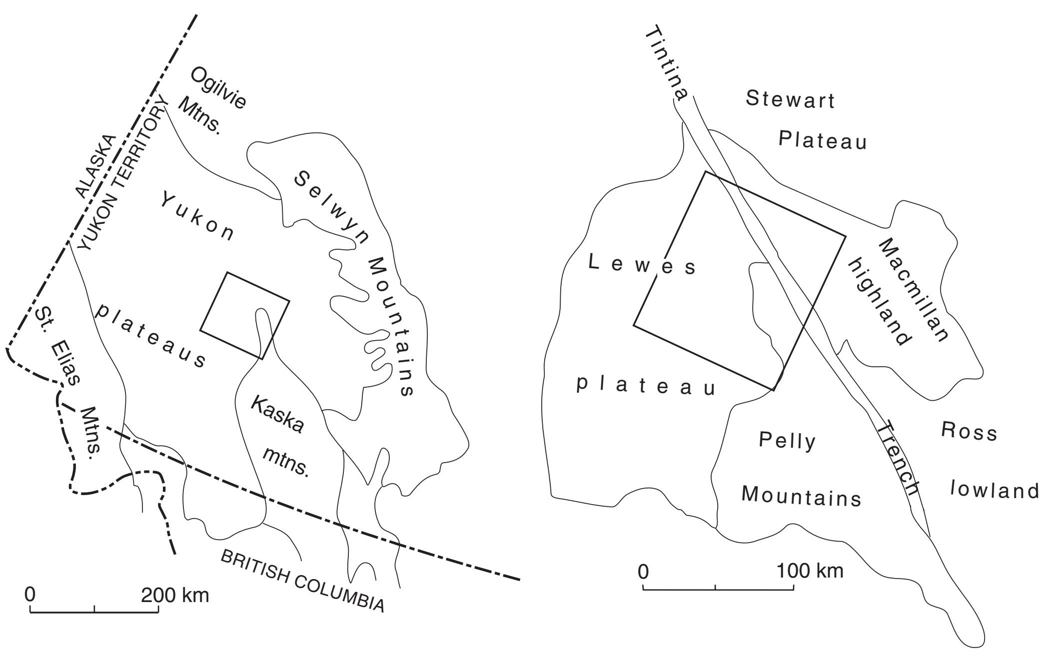


Figure 3. *Major physiographic regions of southern Yukon Territory (*modified from *Mathews, 1986). Glenlyon map area shown by rectangle.*

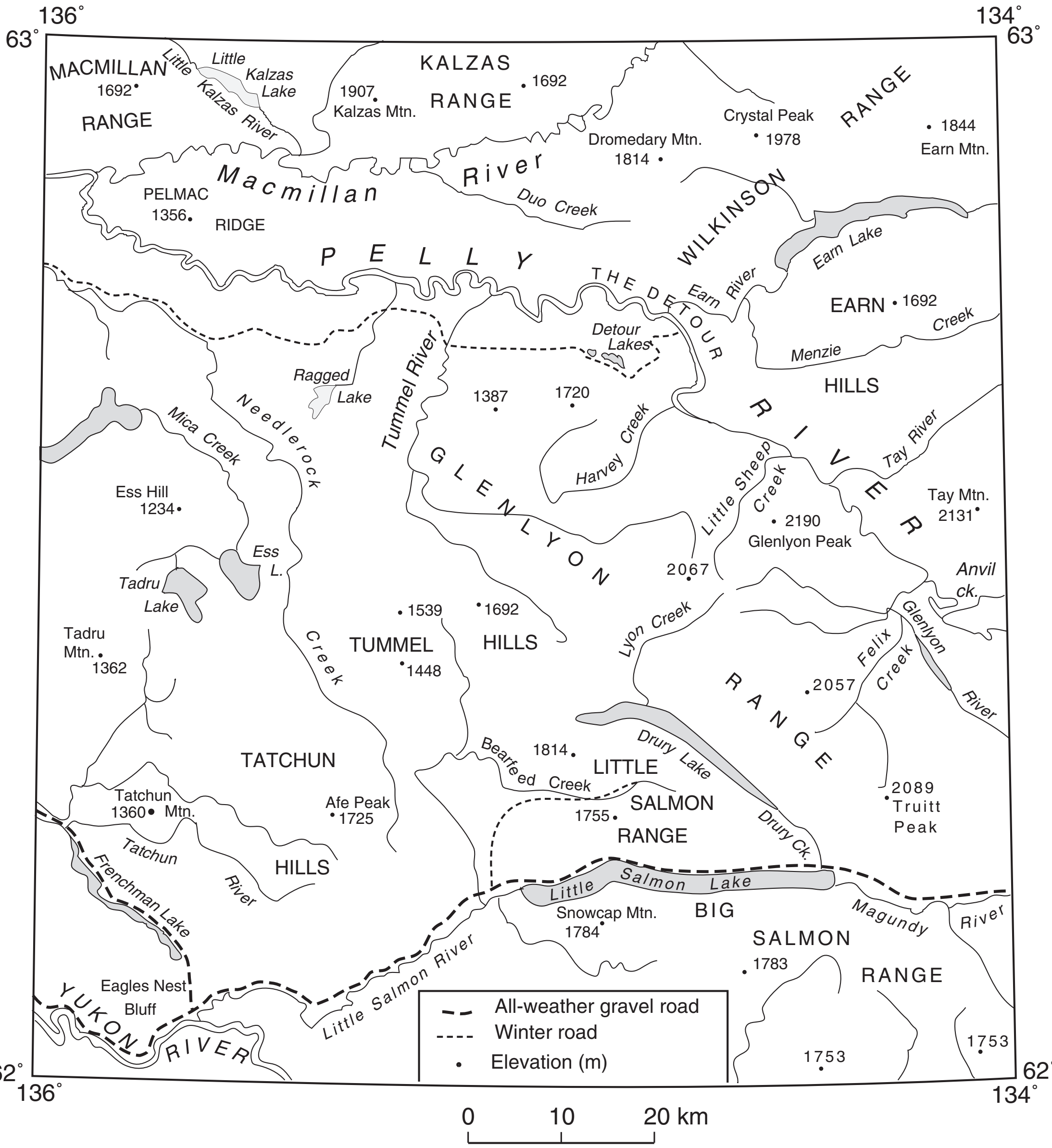


***Figure 4**. Physiographic features in the Glenlyon map area.*

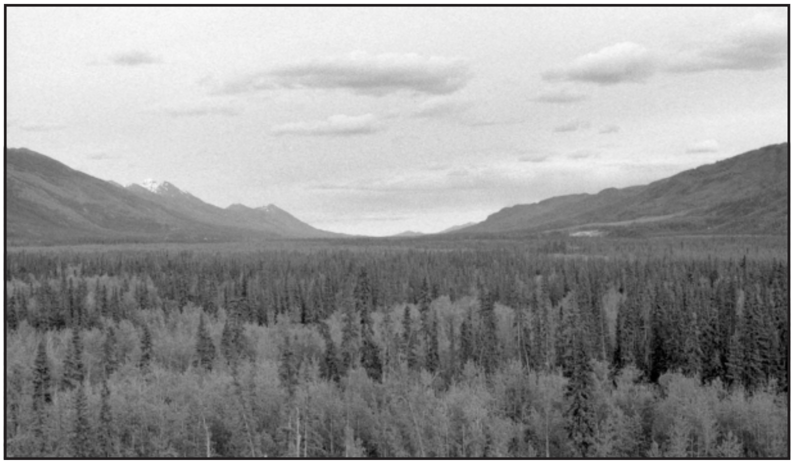


Figure 5.

View southeast along the Tintina Trench from Anvil Creek, near the eastern edge of the map area (see Map 1789A). Photograph by B. Ward. GSC 2000-037A segments of the Pelly River. Other main valleys in the area are those containing the Macmillan River, Earn Lake, Drury Lake and the headwaters of the Tummel River, the Little Salmon River and Little Salmon Lake, the Yukon River, and Frenchman Lake.

Drainage

The entire study area is part of the Yukon River drainage system. The Yukon and Little Salmon rivers drain the southern third of the area, and the Pelly River and its tributaries drain the northern two-thirds. The Macmillan River, the largest tributary of the Pelly River, flows along the northern edge of the map area. Other notable tributaries are the Tummel, Earn, Tay, and Glenlyon rivers. This drainage system terminates to the west in the Bering Sea.

Data on the discharge, freeze-up, and breakup of the Pelly River have been recorded. At the Pelly Crossing gauging station, the river has an average daily discharge of 394 m^3/s and a maximum recorded discharge of 4304 m^3/s (Inland Waters Directorate, 1984). Average freeze-up and breakup of the Pelly River occur on October 28 and May 12, respectively.

River morphology in the Glenlyon map area ranges from meandering and braided-meandering to braided with occasional anastomosing reaches. Most of the Macmillan River meanders with few midchannel bars. The Pelly River and the short segment of the Yukon River in the map area can be classified as braided-meandering; they have a single dominant channel with many midchannel bars and abundant secondary channels. The Pelly and Macmillan rivers contain anastomosing reaches in areas where the banks consist of very fine grained glaciolacustrine sediments and are relatively stable. Braided streams are common in mountainous areas where steep gradients and flashy discharge cause channels to shift frequently.

Drainage evolution and anomalies

Drainage pattern evolution has been markedly affected by tectonics. Tempelman-Kluit (1980) proposed that the Southern Yukon Basin drained southwest to the Pacific in the mid-Tertiary. He further suggested that the drainage began to shift to the northwest due to differential uplift of the St. Elias Mountains in the late Tertiary. A complete shift would have occurred sometime after the onset of glaciation, as ice in the St. Elias Mountains would have blocked drainage to the southwest.

Other glacially induced modifications to the drainage system are apparent in the study area. U-shaped valleys (Fig. 5) that resulted from glacial scouring, and glacially overdeepened valleys that now contain lakes, such as Little Salmon and Drury lakes, are common. In addition, the presence of underfit streams in many valleys indicates that glacial meltwater has modified the drainage. This modification can occur when meltwater follows pre-existing streams, eroding and enlarging valleys, or when meltwater scours new valleys.

Preglacial drainage modified by glaciation has resulted in significant large- and small-scale drainage anomalies. Large-scale anomalies are the result of tectonism and multiple glaciations. Examples of these are the deflection of the Pelly River out of the Tintina Trench and the possible deflection of the Yukon River out of the valley now occupied by Frenchman Lake. Both examples can be explained by glacial blockage and diversion that likely occurred prior to the Late Wisconsinan McConnell Glaciation.

Many small-scale drainage anomalies were created during the Late Wisconsinan glaciation and the Holocene. Stagnant ice caused shifts of the Pelly and Little Salmon rivers at the end of the Pleistocene. The Detour, along the Pelly River, begins at the mouth of Harvey Creek, where the river bends abruptly to the northeast, then gradually curves to the northwest around a bedrock high to rejoin the Tintina Trench (Fig. 4, 6). Detour Lakes, which occupy depressions left by melting ice, occur along the old course of the river (Fig. 6). As suggested by Campbell (1967, p. 20), stagnant ice blocked the drainage, impounding a large glacial lake at the end of the McConnell Glaciation. When the lake drained, likely near the outlet of the Earn River, the Pelly River took a new course and incised these glacial sediments. A similar scenario was proposed for the Little Salmon River by Campbell (1967, p. 20). Ice blocked the Little Salmon River near its confluence with the Yukon River. The Little Salmon River was deflected to the northwest, around a bedrock high, and then southwest to the Yukon River.

The headwater of Harvey Creek is an example of postglacial stream capture. The course of Harvey Creek almost circumscribes a bedrock high (Fig. 4). The short segment flowing southwest previously flowed into the Tummel River. Glacial erosion and meltwater action formed a meltwater channel between Harvey Creek and Tummel River, and the development of an alluvial fan has diverted flow into the Harvey Creek drainage.

Climate, soils, and vegetation

The climate of Yukon Territory is classified as sub-Arctic continental (Wahl et al., 1987). It is characterized by long, cold winters and short, mild summers. Yukon Territory is divided into nine climatic regions, two of which are found in the map area: the Pelly–Cassiar Mountains and the Central Yukon Basin (Wahl et al., 1987). These climatic regions correspond generally to the physiographic regions of the Kaska Mountains and the Yukon Plateaus, respectively. The Pelly–Cassiar climatic region has higher winter temperatures, cooler summers, and more precipitation, especially in winter, than the Central Yukon Basin climatic region. Records from meteorological stations at Drury Creek, in the Pelly–Cassiar region, and Carmacks, in Central Yukon Basin region, give a reasonable approximation of the climate of the area (Table 1); however, since the Drury Creek station is in a valley, conditions at higher elevations in the Pelly–Cassiar region are probably closer to those at Anvil (Table 1), 50 km to the northeast in the Anvil Range.

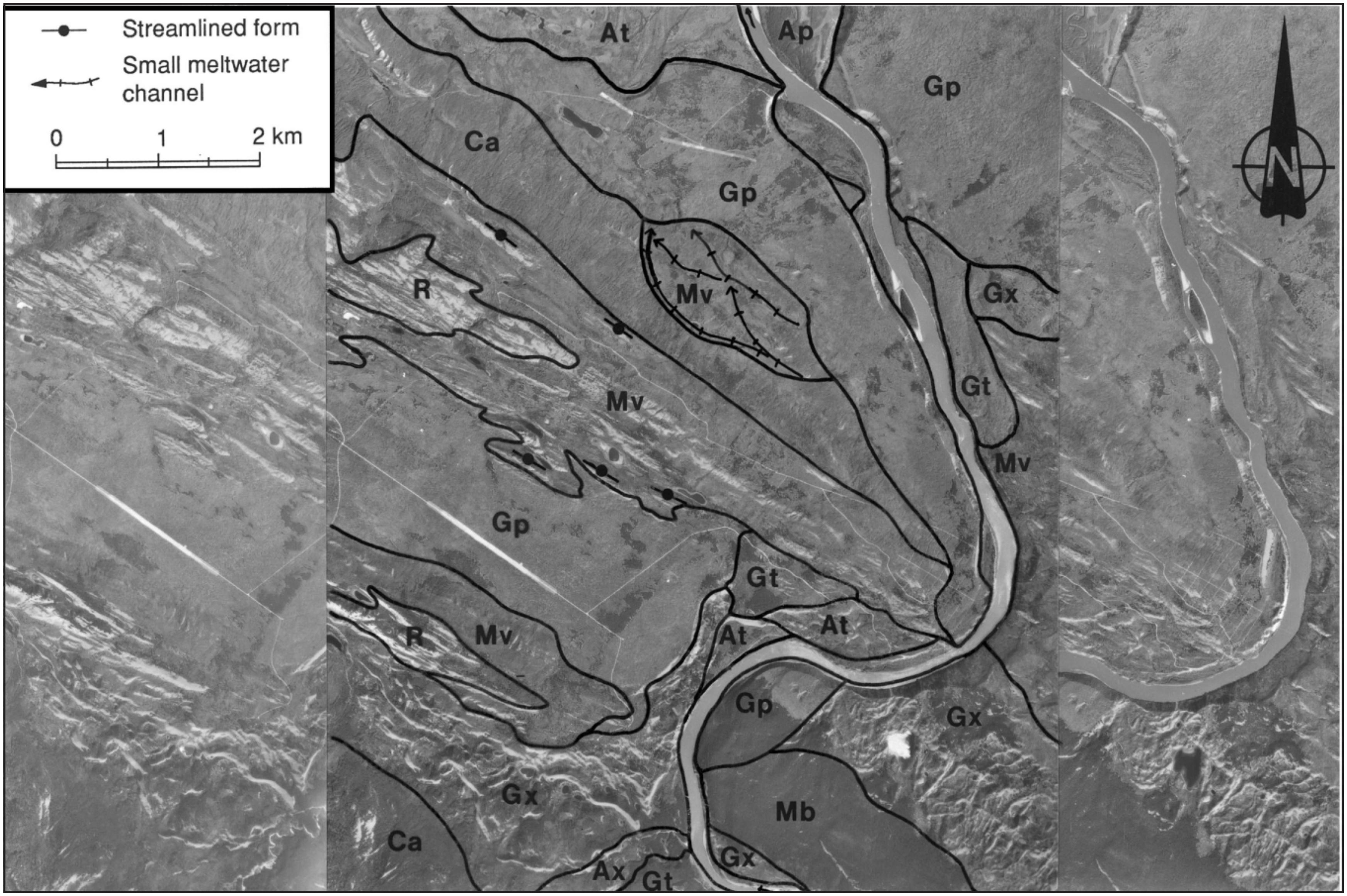


***Figure 6**. Stereotriplet showing ice-stagnation complex (unit Gx) along the Pelly River at The Detour, near the Earn River (*see *Map 1787A). Also present are glaciofluvial plain (unit Gp), glaciofluvial terrace (unit Gt), morainal veneer and blanket (units Mv, Mb), alluvial terrace (unit At), alluvial plain (unit Ap), alluvial complex (unit Ax), colluvial apron (unit Ca), and bedrock (unit R). NAPL A20059-167, -168, -169 (photograph taken 1967).*

Table 1. Selected climatic data for Carmacks, Drury Creek, and Anvil, central Yukon Territory (Wahl et al., 1987).

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
CARMACKS (62°6′N, 136°18′W; NTS 115-I; 523 m a.s.l.):													
Daily temperature (°C)	**-28.2**	**-19.4**	**-11.6**	**-0.1**	**7.1**	**12.5**	**14.5**	**12.4**	**6.7**	**-2.0**	**-13.8**	**-24.0**	**-3.8**
Extreme maximum temperature (°C)	6.0	12.8	14.4	23.4	25.0	35.0	31.7	31.3	26.7	18.3	12.8	5.6	35.0
Extreme minimum temperature (°C)	-57.8	-57.2	-50.0	-31.1	-12.2	-3.9	-1.1	-5.0	-15.6	-28.9	-46.7	-54.4	-57.8
Rainfall (mm)	0.0	0.0	0.2	0.7	12.9	37.5	42.3	34.6	23.3	5.5	0.7	0.0	157.7
Snowfall (mm)	17.6	10.7	9.4	7.1	1.8	0.0	0.0	0.0	1.3	12.8	17.1	17.2	95.0
Total precipitation (mm)	**18.4**	**12.5**	**10.6**	**7.2**	**15.5**	**37.4**	**42.3**	**34.1**	**25.1**	**17.7**	**18.6**	**14.9**	**254.3**
DRURY CREEK (62°12′N, 134°23′W; NTS 105 L; 609 m a.s.l.):													
Daily temperature (°C)	**-23.7**	**-16.5**	**-9.9**	**0.0**	**6.6**	**12.1**	**14.3**	**11.8**	**6.8**	**-0.8**	**-11.1**	**-19.7**	**-2.5**
Extreme maximum temperature (°C)	7.0	7.8	9.4	22.2	22.8	30.0	30.6	30.6	25.6	16.7	11.1	6.7	30.6
Extreme minimum temperature (°C)	-54.4	-46.1	-41.7	-28.9	-8.3	-2.8	-1.7	-2.8	-15.0	-25.6	-37.8	-51.1	-54.4
Rainfall (mm)	0.0	0.3	0.1	1.3	12.1	27.8	41.7	33.2	38.7	14.0	13.3	0.4	182.9
Snowfall (mm)	25.0	29.6	21.9	15.0	1.4	0.1	0.0	0.0	0.8	17.2	28.8	35.9	175.7
Total precipitation (mm)	**25.6**	**29.3**	**23.0**	**15.8**	**13.7**	**28.0**	**41.7**	**33.2**	**38.8**	**31.3**	**32.9**	**36.1**	**349.4**
ANVIL (62°22′N, 133°23′W; NTS 105 K; 1158 m a.s.l.):													
Daily temperature (°C)	**-19.8**	**-13.9**	**-11.2**	**-3.2**	**4.0**	**9.9**	**11.5**	**9.5**	**4.6**	**-3.1**	**-11.6**	**-17.2**	**-3.4**
Extreme maximum temperature (°C)	5.0	9.4	8.0	15.5	20.0	29.4	28.9	26.7	25.0	14.4	11.1	5.6	29.4
Extreme minimum temperature (°C)	-46.6	-43.3	-41.1	-26.5	-14.0	-6.0	-3.3	-7.2	-15.6	-32.2	-39.4	-43.9	-46.1
Rainfall (mm)	0.0	0.2	0.0	0.5	10.2	34.8	45.6	41.6	29.6	2.6	0.1	1.2	166.9
Snowfall (mm)	27.7	16.7	18.3	10.7	13.1	0.0	0.0	0.7	3.8	29.5	30.9	27.8	179.2
Total precipitation (mm)	**26.0**	**22.4**	**30.4**	**15.5**	**16.3**	**41.6**	**49.6**	**41.5**	**32.9**	**36.9**	**29.2**	**24.6**	**367.7**

The Glenlyon map area is in the widespread discontinuous permafrost zone (Brown, 1978). Permafrost is common on north-facing slopes and in fine-grained material. Segregated ice is common in glaciolacustrine sediments exposed along the Pelly and Macmillan rivers. Ice wedges were observed at two sites along the Pelly River in fine-grained fluvial overbank deposits overlain by thick organic deposits. Retrogressive thaw slides are common where stream erosion, forest fire, or anthropogenic disturbance (e.g. road building) has exposed ice-rich sediments.

Most soils in the Glenlyon map area fall into subgroups of the Brunisolic or Cryosolic soil orders (Agriculture Canada Expert Committee on Soil Survey, 1987). Mountainous areas consist mainly of Eutric Brunisols with occasional Turbic Cryosols. Well drained plateaus and valleys contain both Dystric and Eutric Brunisols, while poorly drained areas contain Cryosols and Organic soils; the latter are commonly associated with peat accumulations (Tarnocai, 1987). Regosols occur throughout the map area on fresh or unstable surfaces. Soils examined in detail at studied sections in the valleys are Eutric Brunisols, similar to the Stewart soils described by Tarnocai et al. (1985), Smith et al. (1986), and Tarnocai (1987).

Vegetation varies with elevation, aspect, and forest-fire frequency. Treeline is approximately 1500 m in the Glenlyon Range and descends gradually to 1370 m or slightly lower in the western part of the map area. The forest is dominated by *Picea* (spruce), with *Salix* (willow), *Populus* (poplar), and *Pinus* (pine) also present. *Picea glauca* (white spruce) and *Populus* generally indicate well drained conditions; *Picea mariana* (black spruce) generally indicates poorly drained conditions, which are commonly the result of permafrost. Southern slopes commonly contain more xeric species and can have more grasses and fewer trees, whereas northern slopes commonly have permafrost. Recent forest-fire scars contain an abundance of successional species, such as poplar, alder, birch, and willow, as well as pine and spruce.

Population and industry

Very few people live year-round in the Glenlyon map area. Most of these residents live along the Robert Campbell Highway, mainly near Little Salmon Lake and at the Drury Creek highway maintenance camp. Little Salmon, a former small village at the junction of the Little Salmon and Yukon rivers, is now abandoned. North of the highway, scattered cabins, outfitter establishments, and fish camps are inhabited seasonally.

Industry is presently limited to the highway maintenance camp at Drury Creek, trophy and subsistence hunting and fishing, and trapping. Several power-dam sites have been proposed for the Glenlyon map area, but none are currently being pursued; proposed sites include The Detour along the Pelly River, Eagle Nest bluff along the Yukon River, and Drury Lake.

Extensive mineral exploration has occurred in the past, but there are presently no plans for mineral development in the area. Exploration has concentrated on base metals, such as copper, lead, and zinc, although some claims also contain silver. As well, several barite sites have been staked. A complete listing of claims that have been staked can be found in the Yukon Minfile (Indian and Northern Affairs Canada, 1990). The locations of the most important claims are shown in Figure 7. Most activity has been concentrated along the Tintina Trench and in adjacent areas, with some near Little Salmon Lake. Before 1965, very few claims had been staked. In late 1965 and 1966, however, there was a surge of activity in response to the discovery of the Faro lead-zinc orebody, located 30 km east of the map area (Tempelman-Kluit, 1981). At this time, many copper, lead, and zinc claims were staked along the Tintina Trench. The Clear lake deposit was discovered in 1978. This deposit is located southwest of the Tintina Fault, just north of the Pelly River (Fig. 7). It is estimated to contain 25 000 000 t of massive pyritic mineralization, including galena and sphalerite, containing presently subeconomic concentrations of zinc, lead, and silver. Exploration was limited during most of the 1980s, although several companies restaked many of the more promising claims, as well as several new ones, in 1989.

Previous work

Recorded history and nonaboriginal exploration and settlement began in 1843 when Robert Campbell, an official of the Hudson's Bay Company, explored and named the Pelly River and many of its tributaries, including the Macmillan, Glenlyon, Tay, Earn, and Tummel rivers. The first bedrock and surficial geology observations in the area were made by G.M. Dawson of the Geological Survey of Canada, who travelled down the Pelly River in 1887 (Dawson, 1889). This was followed by a description of bedrock and sediments along the Macmillan River by McConnell (1903). He concluded that the last ice sheet did not cover all the peaks in the area. Cockfield (1929) examined the geology of the Little Salmon and Magundy river valleys, and Johnston (1936) reconnoitred the Pelly River upstream of Macmillan River; both made observations on the glacial history.

More detailed studies of the glacial history of the map area began in the 1960s. Campbell (1967) mapped the bedrock of the Glenlyon map area in detail and produced a glacial geomorphology map of the area. Using mainly airphoto

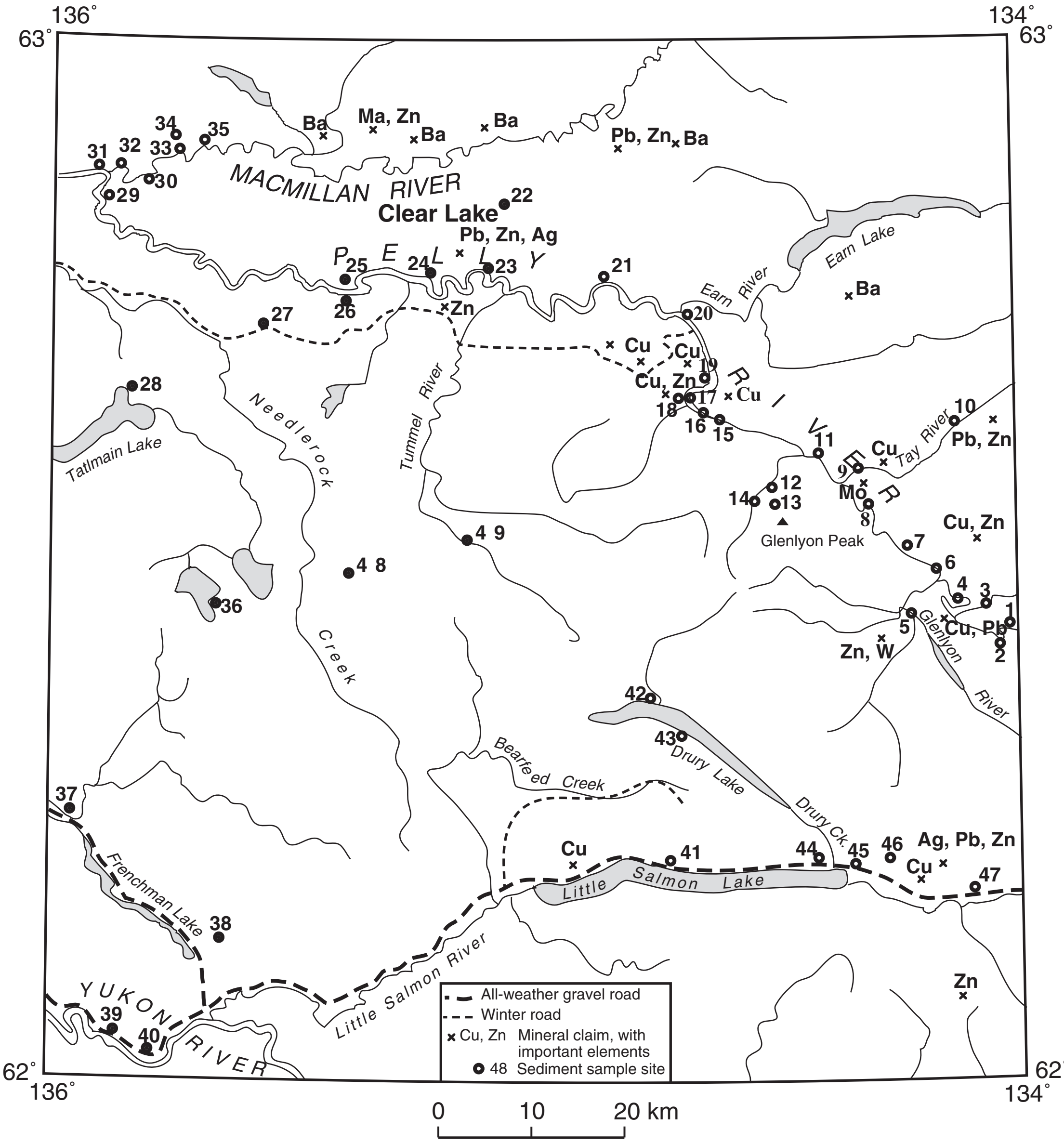


__Figure 7.__ Sediment sample sites and selected mineral claims (Indian and Northern Affairs Canada, 1990), Glenlyon map area. Sample numbers correspond to those in Appendices 1 and 2.

interpretation, he delineated the upper limit of the last ice sheet, determined major ice-flow directions, and demonstrated the interaction of two major lobes of the Cordilleran Ice Sheet, the Selwyn and Cassiar lobes (Campbell, 1967, Map 1222A). Duk-Rodkin et al. (1986) constructed a profile of the Selwyn Lobe during the McConnell Glaciation.

Studies of volcanic rocks and drainage evolution and changes have also been undertaken in the map area. Grond et al. (1984) studied outcrops of the Carmacks Group volcanic rocks to determine whether they had continental or island-arc affinities. Tempelman-Kluit (1980) based his ideas on the evolution of physiography and drainage in southern Yukon Territory, in part, on the physiography of this map area. Holocene evolution of the Yukon River at Eagles Nest bluff was studied by Fuller (1986).

Various Quaternary investigations have been carried out adjacent to the map area. Jackson (1987, 1989, 1994) mapped surficial deposits and conducted stratigraphic studies in five map sheets to the east of the area (NTS 105 F, G, J, K, I), extending to the continental divide. Surficial mapping has also been carried out in map sheets immediately to the north (Hughes, 1983a, b), south (Klassen and Morison, 1987), and west (Klassen et al., 1987) of the Glenlyon map area. Stratigraphic studies include an examination of interbedded volcanic rocks and glacial sediments by Jackson et al. (1990) to obtain relative ages on early Pleistocene glaciations; a study of a Middle Wisconsinan mammal site, by Jackson and Harington (1991), that provides paleoenvironmental information and a maximum age on the Late Wisconsinan glaciation; and an examination of sub-McConnell till sediments, by Matthews et al. (1990a), that provides paleoenvironmental information and a maximum age on the Late Wisconsinan glaciation.

Access

Access for geological investigations is made possible by two roads and two rivers. The Robert Campbell Highway extends across the southern part of the map area, connecting Carmacks and Faro (Fig. 2, 4). Another road in the southwest corner of the map area runs from the Robert Campbell Highway along Frenchman Lake to join the Klondike Highway. The Pelly and Macmillan rivers allowed boat access to river sections. The rest of the region is not easily accessible, but some areas were visited by float plane and helicopter. The area was reconnoitred in 1986. Fieldwork was carried out mainly in the summers of 1987 and 1988, with limited investigations made in 1989.

Laboratory work

Textural and Chittick analyses were completed under the direction of P. Lindsay, Geological Survey of Canada. Radiocarbon ages were obtained from the Geological Survey of Canada (GSC), IsoTrace (TO), and Alberta Environmental Centre Vegreville (AECV), under the direction of R.J. McNeely, R.P. Beukens, and L.D. Arnold, respectively.

Acknowledgments

The writers are indebted to N.W. Rutter and O.L. Hughes. Their support and interest in this project were essential for its completion. The writers benefited from discussions with C. Burn, A. Duk-Rodkin, R.J. Fulton, S.R. Morison, and C.A.S. Smith. A. Duk-Rodkin had previously mapped some of the glacial limits in the Glenlyon map area and made her airphotos available. S. Morison provided notes of his field observations along the Yukon River in 1979. H. Fiebe processed the samples and identified the pollen from the Granite Canyon section. Some logistic support was provided by maintenance personnel at the Drury Creek highway maintenance camp. Field assistance by A. Campbell in 1986, P. Beck in 1987, D. Lye and W. Sutner in 1988, and J. Isobie in 1989 is gratefully acknowledged. Rigorous and constructive reviews of the manuscript by J. Clague and A. Plouffe improved it substantially.

BEDROCK AND TECTONICS

Bedrock

The bedrock of the Glenlyon map area is complex, and includes North American strata, displaced North American strata, pericratonic terranes, accreted terranes, and post-accretion strata (*see* Fig. 8). The reconnaissance geology was done by Campbell (1967), but his work has been reinterpreted by subsequent workers in light of recent geological theories on the tectonic evolution of Yukon Territory (Tempelman-Kluit 1979, 1981; Gabrielse et al., 1980; Wheeler and McFeely, 1991). Colpron (1998) recently mapped, at 1:50 000 scale, the bedrock in the northwest portion of the map area. The following descriptions are based on the sources cited above, as well as work in the adjacent Tay River and Quiet Lake map areas by Gordey and Irwin (1987).

North American strata

North American strata consist of four major groupings of sedimentary and volcanic rocks deposited along the margin of ancestral North America. They range from Hadrynian to Permian, and were deformed during the Jurassic–Cretaceous, producing the northwest-trending thrust faults and folds of the Selwyn Fold Belt.

Displaced North American strata (Cassiar Terrane)

The Cassiar Terrane consists of rocks of North American affinity that have been displaced to the northwest along dextral strike-slip faults. The boundary between the Cassiar Terrane and North American strata is the Tintina Fault, the locus of at least 450 km of strike-slip displacement since the Upper Cretaceous. In the Glenlyon map area, the Cassiar Terrane consists of sedimentary and metasedimentary rocks intruded by large Middle Cretaceous plutons. These rocks have also been deformed by northwest-trending, Jurassic–Cretaceous thrust faults and folds.

Pericratonic terrane (Yukon–Tanana Terrane)

Pericratonic terranes consist of rocks that differ in stratigraphic or structural characteristics from the ancient continental margin but have no record of significant displacement. The Yukon–Tanana Terrane covers an extensive area in Yukon Territory and Alaska. In the Glenlyon map area, it is represented by the Nisutlin Terrane, a combination of sedimentary, volcanic, and plutonic rocks that has been metamorphosed and intensely deformed. These rocks contain the Teslin Suture, a major geological boundary marked by vertical to steeply dipping mylonite, schist, and gneiss. The deformation that produced the suture is thought to have occurred before the Middle Jurassic, during obduction of the exotic terranes (Hansen, 1990).

Accreted terranes

Accreted terranes comprise obducted rocks, of oceanic and island-arc affinities, that are not related to the ancestral North American margin. In the Glenlyon map area, the Slide Mountain, Stikinia, and Quesnellia are exotic terranes.

Postaccretion strata

Postaccretion strata are rocks that have been deposited, extruded, and emplaced after accretion of the exotic terranes. These strata include Middle Cretaceous and Tertiary plutonic rocks, and volcanic rocks of the Upper Cretaceous Carmacks Group and of Tertiary age.

Tectonics

The assemblage of rocks described above and their present distribution have been explained by accretion of distinct terranes onto the ancient North American margin, with associated deformation of rocks of the North American craton (Tempelman-Kluit, 1979, 1981; Gordey and Irwin, 1987). The Jurassic–Cretaceous folding and faulting of the rocks along the North American margin occurred during obduction of the accreted terranes. In the Middle Cretaceous, volcanism and plutonism produced the volcanic rocks of the Carmacks Group and the plutonic suites of various affinities. During the Tertiary, at least 450 km of strike-slip movement occurred along the Tintina Fault, granitic rocks were intruded, and volcanic rocks were extruded.

Bedrock controls on physiography

Many of the major northwest-trending valleys follow faults and other major structural features (Fig. 8). Examples are the Tintina Trench, which follows the Tintina Fault, and the depression occupied by Drury Lake and the headwaters of the Tummel River, which follows the Teslin Suture.

REGIONAL QUATERNARY CONTEXT

Glacial stratigraphy

Central Yukon Territory has been repeatedly affected by the northern part of the Cordilleran Ice Sheet. Portions have never been glaciated because of the aridity caused by the St. Elias Mountains (Fig. 1). This results in a situation that is relatively unique in Canada, in that deposits from glaciations dating back to the Early Pleistocene are exposed at the surface. The glacial stratigraphy was developed by Bostock (1966), based on morphostratigraphic, stratigraphic, and geomorphic evidence. The four glaciations he identified, from oldest to youngest, are the Nansen, Klaza, Reid, and McConnell. Each successive advance was less extensive than the preceding one (Fig. 1). Hughes et al. (1969) were unable to differentiate the deposits and landforms of the two oldest glaciations, Nansen and Klaza, and included them under the term 'pre-Reid.' Ages that provide limits on these glaciations are listed in Tables 2 and 3.

Stratigraphic and paleomagnetic work by Jackson et al. (1990, 1996) in the Fort Selkirk area has confirmed at least two Early Pleistocene pre-Reid glaciations. Interbedded glacial and volcanic deposits have allowed absolute age determinations to be made (Table 2). Basalt underlying the older pre-Reid till yielded a whole-rock K-Ar age of 1.60 ± 0.08 Ma, and the overlying Fort Selkirk tephra yielded an isothermal plateau fission-track age of 1.48 ± 0.19 Ma (Westgate, 1989). Basalt erupted during the younger pre-Reid glaciation yielded K-Ar ages of approximately 1.4 Ma (Westgate, 1989). These absolute ages confirm an early Pleistocene age for the two pre-Reid glaciations.

The age of the Reid Glaciation is uncertain. The subdued nature of Reid landforms, when compared with McConnell landforms, indicates an older age (Bostock, 1966; Hughes et al., 1969). It was originally considered to be Early Wisconsinan (Hughes et al., 1972), but was subsequently considered to be Illinoian because of an interglacial paleosol developed on deposits of Reid age (Hughes, 1987). Further corroboration of Illinoian age has been provided by the fact that the Old Crow tephra occurs above the correlative Mirror Creek Glaciation (Table 4) in the Snag–Klutlan area of southwestern Yukon Territory (Rampton, 1971). Reported ages for the Old Crow tephra range from 0.086 Ma to 0.22 Ma (Table 2). Thermoluminescence ages of 0.086 ± 0.008 Ma (Wintle and Westgate, 1986) and 0.109 ± 0.14 Ma (Berger, 1987) have been determined; however, an isothermal plateau fission-track age of 0.14 ± 0.01 Ma (Westgate, 1989; Westgate et al., 1990, Preece et al., 1999) suggests that the thermoluminescence dates are too young (Wintle, 1990). Magnetic susceptibility suggests an age of 0.220 Ma (Beget and Hawkins, 1989), but the usual stratigraphic position of the tephra, immediately below or associated with deposits correlated to the last interglaciation (Matthews et al., 1990b; Hamilton and Brigham-Grette, 1990), makes this age unlikely. Sheep Creek tephra occurs above deposits of Reid age along the Stewart River at Ash Bend (Hughes et al., 1987). The initial U-series age of 0.080 Ma (Hamilton and Bischoff, 1984) on bones associated with this tephra in Alaska is certainly too young; the Sheep Creek tephra has now been observed 2–3 m below the Old Crow tephra in the Fairbanks area (Preece et al., 1999), and a thermoluminescence age of 0.19 ± 0.002 Ma has been obtained (Berger et al., 1996). Available chronology suggests that the Reid Glaciation is older than oxygen-isotope stage 6. Because of this uncertainty in the age of the Reid Glaciation, it will be referred to as Middle Pleistocene, and the terms 'Sangamonian' and 'Illinoian' will not be used in this report.

The McConnell Glaciation is known to be Late Wisconsinan, based on two finite radiocarbon ages under McConnell glacial deposits: 26 350 ± 350 BP (TO-393; Jackson and Harington, 1991), and 29 600 ± 300 BP (TO-292; Matthews et al., 1990a). A Late Wisconsinan age is supported by the relatively fresh surface morphology of McConnell glacial deposits.

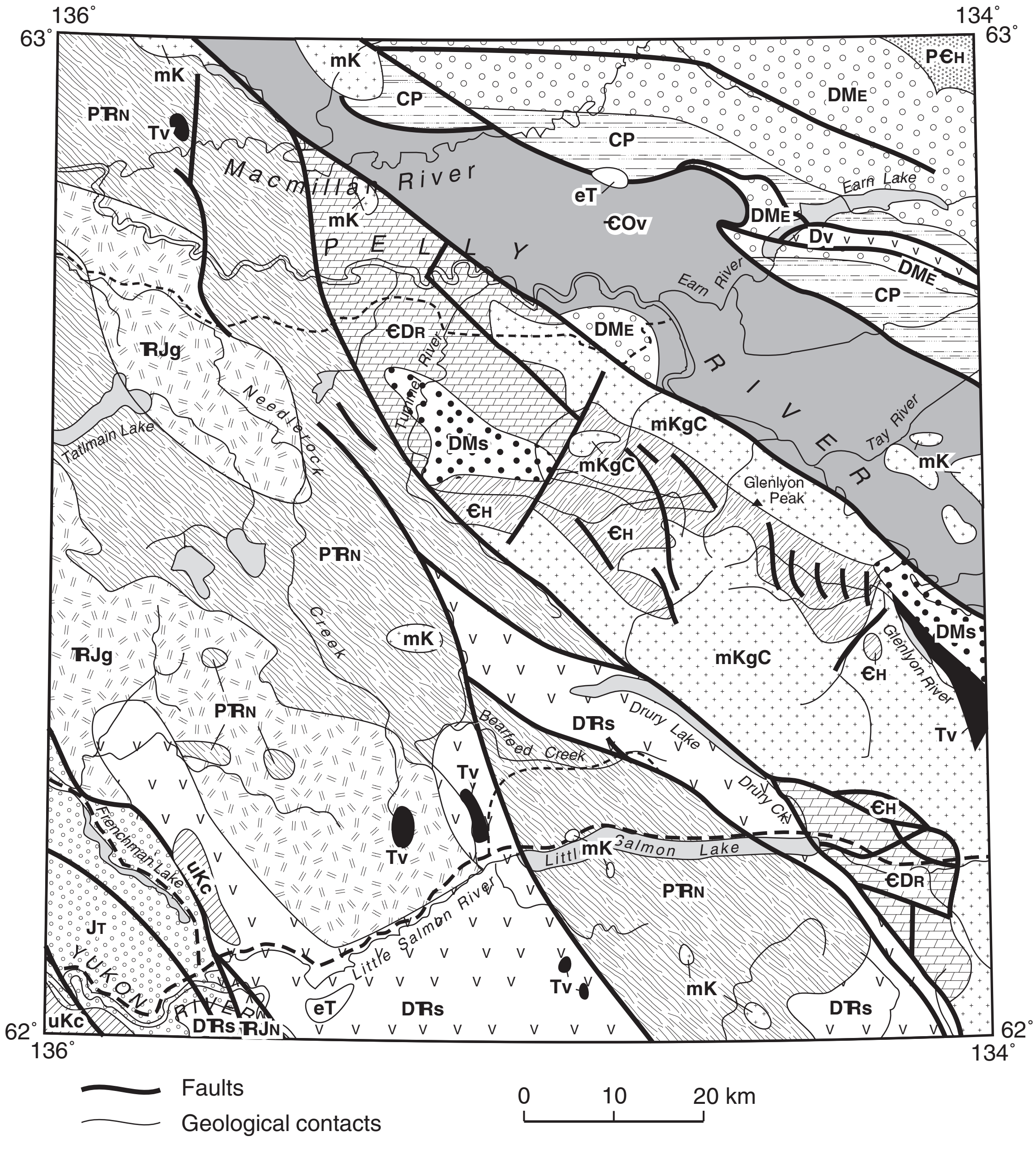


*Figure 8. Bedrock geology of the Glenlyon map area (*modified from *Campbell, 1967; Gabrielse et al., 1980; Wheeler and McFeely, 1991).*

LEGEND FOR FIGURE 8

NORTH AMERICAN STRATA

Outer detrital clastics [Carboniferous–Permian (**CP**)]
Quartzose siltstone and chert

Earn Group [Devonian–Mississippian (**DME**)]
Chert pebble conglomerate, chert, argillite, and quartzite

Volcanic rocks [Devonian (**Dv**)]
Tuff, flow, and/or small intrusions

Anvil Range Group [Cambrian–Ordovician (**ЄOv**)]
Basalt, tuff, and breccia

Hyland Group [Hadrynian–Cambrian (**PЄH**)]
Slate and quartzite

DISPLACED NORTH AMERICAN STRATA

Cassiar Terrane

Earn Group equivalent [Devonian–Mississippian (**DMs**)]
Quartzite, dolomite, slaty limestone, and slate

Askin Group [(?)Cambrian–Devonian (**ЄDR**)]
Dolomite, limestone, quartzite, and shale

Harvey Group [Cambrian (**ЄH**)]
Quartzite, schist, shale, phyllite, and minor limestone

PERICRATONIC TERRANE

Yukon–Tanana Terrane

Nisutlin Terrane [Upper Paleozoic–Triassic (**PTRN**)]
Schist and gneiss

ACCRETED TERRANES

Stikinia

Laberge Group [Lower–Middle Jurassic (**JT**)]
Conglomerate, greywacke, siltstone, shale, and limestone

Tatlmain and Tatchun batholiths [Upper Triassic–Lower Jurassic (**TRJg**)]
Foliated hornblende granodiorite and quartz monzonite

Quesnellia

Nicola Group [Triassic–Jurassic (**TRJN**)]
Andesite, dacite, and rhyolite

Slide Mountain Terrane

Volcanic rocks [Devonian–Triassic (**DTRs**)]
Andesite, basalt, basaltic greenstone, chert, and tuff

POSTACCRETION STRATA

Volcanic rocks [Tertiary (**Tv**)]
Bimodal suite of basalt and rhyolite

Granitic rocks [Tertiary (**eT**)]
Granodiorite and quartz diorite

Carmacks Group [Upper Cretaceous (**uKc**)]
Andesitic and basaltic flows

Granitic batholiths [Mid-Cretaceous (**mK**)]
Various affinities [Glenlyon Batholith (**mKgC**)]

Table 2. Ages for tephra and basalt units mentioned in the text and their relationship to the Reid and pre-Reid glaciations.

Age (Ma)	Method	Reference	Material	Significance
Post-Reid glaciation:				
0.086±0.008	Thermoluminescence	Wintle and Westgate (1986)	Loess	Old Crow tephra
0.109±0.014	Thermoluminescence	Berger (1987)	Loess and tephra	Old Crow tephra
0.14±0.01	Isothermal fission track	Westgate et al. (1990), Preece et al. (1999)	Tephra	Old Crow tephra; provides a minimum age on Mirror Creek (Reid) Glaciation and a maximum age for Koy-Yukon thermal event
ca. 0.220	Magnetic susceptibility	Beget and Hawkins, (1989)	Loess	Old Crow tephra
ca. 0.080	Uranium series	Hamilton and Bischoff (1984)	Bone	Sheep Creek tephra
0.19±0.002	Thermoluminescence	Berger et al. (1996)	Loess and tephra	Sheep Creek tephra, Ash Bend section, Stewart River, provides a minimum on Reid glaciation and a maximum on fossils indicating boreal forest
Reid Glaciation				
Before younger pre-Reid glaciation and after older pre-Reid glaciation:				
1.35±0.08 1.35±0.11 1.47±0.11	K-Ar, whole rock	Westgate (1989)	Basalt	Basalt at Fort Selkirk erupted during the younger pre-Reid glaciation
1.48±0.19	Isothermal fission track, weighted mean	Westgate (1989)	Tephra	Fort Selkirk tephra; provides minimum on older pre-Reid glaciation
Before older pre-Reid glaciation:				
1.60±0.08	K-Ar, whole rock	Westgate (1989)	Basalt	Basalt underlying older pre-Reid deposits at Fort Selkirk; provides a maximum age

Table 3. Radiocarbon ages mentioned in the text and their relationship to the McConnell and Reid glaciations.

Age	Lab	Reference	Material	Significance
Post- McConnell Glaciation:				
1250	GSC	Lerbekmo et al. (1975)	Various	White River tephra; average date from multiple analyses
6570±610	AECV-483C	This paper	Peat	Pelly River, 25 m above present water level
7900±120	AECV-844C	This paper	Peat	Paleosol between units 4 and 5, Bradens Canyon section, Pelly River
8430±60	TO-1279	This paper	Charcoal	Charcoal, 90 cm above TO-951
9140±540	AECV-484C	Ward (1989)	Wood	Minimum for deglaciation and establishment of upland vegetation, Pelly River
12 590±120	TO-951	Ward (1989)	*Psidium sp.* shells	Minimum for deglaciation, Pelly River
Before McConnell Glaciation:				
26 350±280	TO-393	Jackson and Harrington (1991)	Bone (collagen)	Maximum for McConnell Glaciation, mammal assemblage, Pelly Mountains
29 600±300	TO-292	Matthews et al. (1990a)	Seeds	Maximum for McConnell Glaciation, xeric tundra, Stewart River
36 060±2000	AECV-1422C	This paper	Allochthonous peat	Middle Wisconsinan site, spruce forest, Granite Canyon section, Pelly River
37 120±350	TO-1278	This paper	Charcoal	Middle Wisconsinan site, spruce forest, Granite Canyon section, Pelly River
38 100±1330	GSC-4554	Matthews et al. (1990a)	Wood	Middle Wisconsinan site, spruce forest, Mayo Indian Village section, Stewart River
Before Reid Glaciation:				
>41 000	GSC-4510	Ward (1989)	Allochthonous peat	Occurs below deposits of Reid Glaciation, Bradens Canyon section, Pelly River

Table 4. Regional correlation with areas adjacent to central Yukon Territory (*modified from* Hamilton, 1986; Jackson et al., 1991; Vincent, 1992).

General chrono-stratigraphy	Oxygen isotope stage	Central Yukon Territory	Snag-Klutlan area, southwestern Yukon Territory	Northern Yukon basins	Bonnet Plume basin	Brooks Range, Alaska
Late Wisconsinan stage	2	McConnell Glaciation	Macauley Glaciation	Glaciolacustrine sediments from glacial blockage	(?)Hungry Creek Glaciation	Itkillik II/ Walker Lake glaciations
Middle Wisconsinan stage	3					
Early Wisconsinan stage	5d-4			Alternating cold and warm conditions	(?)Hungry Creek Glaciation	Itkillik IB/Chebanikia glaciations (?)Old Crow tephra Itkillik IA/Siruk Creek glaciations
Sangamonian stage	5e	Koy-Yukon thermal event	Koy-Yukon thermal event	Koy-Yukon thermal event	Koy-Yukon thermal event	
Middle Pleistocene		Sheep Creek tephra Reid Glaciation	Old Crow tephra Mirror Creek Glaciation	Old Crow tephra		Sagavanirktok Glaciation
Early Pleistocene		Younger pre-Reid Fort Selkirk tephra Older pre-Reid	undifferentiated pre-Reid glacial features			Anaktuvuk River Glaciation

Nonglacial stratigraphy

Interstadial and interglacial deposits have also been studied in Yukon Territory. The record of pre-Reid interglaciations is represented by paleosols (Foscolos et al., 1977; Rutter et al., 1978; Tarnocai et al., 1985; Smith et al., 1986; Tarnocai and Schweger, 1991), but no nomenclature has been developed. The last interglaciation has been extensively studied in northern Yukon Territory and Alaska, and has been given the informal name ‘Koy–Yukon thermal event’ (Matthews et al., 1990b). Because periods of maximum warmth in northern latitudes may not correspond to those in the south (Matthews et al., 1990b), the term ‘Koy–Yukon thermal event’ is used instead of ‘Sangamonian Interglaciation’. Interstadial conditions from stage 3 are referred to as Middle Wisconsinan.

Cordilleran Ice Sheet in the Glenlyon area

The Glenlyon map area lies very close to the westernmost limit of the Cordilleran Ice Sheet during the McConnell Glaciation, and many upland areas were nunataks (Fig. 1, 2). Deposits of older glaciations are exposed on these more subdued surfaces.

During the McConnell Glaciation, the Selwyn and Cassiar lobes advanced into the Glenlyon map area. Much of the area was overridden by the Selwyn Lobe (Campbell, 1967, p. 11), which generally flowed west from its source in the Selwyn Mountains (Fig. 3, 9). The Cassiar Lobe (Wheeler, 1961, p. 10) flowed north from the Cassiar Mountains and covered the southwestern portion of the map area (Fig. 9).

Regional correlations

Table 4 shows a proposed correlation from central Yukon Territory to adjacent areas in Yukon Territory, the Northwest Territories, and Alaska. The correlation with southwestern Yukon Territory is well established, based on similar preservation of surface features (Hughes et al., 1969). Pre-Reid glacial features have been recently noted in southwestern Yukon Territory (Duk-Rodkin, 1999) but have not been studied in detail.

The lack of glacial deposits in northern Yukon Territory hinders the stratigraphic correlation between that region and the study area; however, northern Yukon Territory provides a wealth of paleoenvironmental information, including information on the last interglaciation, the Koy–Yukon thermal event. A record of alternating warm and cold periods is preserved above deposits representing the Koy–Yukon thermal event. In northern Yukon Territory, glaciolacustrine sediments were deposited during the Late Wisconsinan, when the Laurentide Ice Sheet blocked the drainage of the rivers (Fig. 1).

The Brooks Range in Alaska preserves a record of two Early Wisconsinan glaciations that are not represented in central Yukon Territory. The Itkillik IB drift likely corresponds to oxygen-isotope stage 4 and the Itkillik IA likely corresponds to either stage 5b or 5d. The Old Crow tephra has been reported on Itkillik IA drift (Hamilton, 1986) suggesting a stage 6 age; however, recent fieldwork suggests that the tephra may have been transported by solifluction and that the tephra is actually older than the glaciation, so an Early Wisconsinan age remains a possibility (T. Hamilton, United States Geological Survey, pers. comm., 1992).

A lack of glacial activity in central Yukon Territory during oxygen-isotope stages 4 and 5 is problematic. Other northern sites, such as the western Canadian Arctic (Vincent, 1992), the north shore of Alaska (Carter and Ager, 1989), and the eastern Canadian Arctic and northwestern Greenland (Miller et al., 1992), have a record of more extensive advances during stages 4 and 5 than during stage 2. As suggested by Vincent (1992), the Laurentide Hungry Creek Glaciation in the Mackenzie Mountains could be correlated with stage 4 or 5. Further evidence was given by Schweger and Matthews (1991) when they assigned beds under deposits of the Hungry Creek Glaciation to the last interglaciation, although there is one spurious finite date of 36 900 ± 300. However, there is no distinctive flooding event associated with a stage 4 or 5 glaciation in the Northern Yukon Basins, as there is for the stage 2 event (Matthews et al., 1990b;

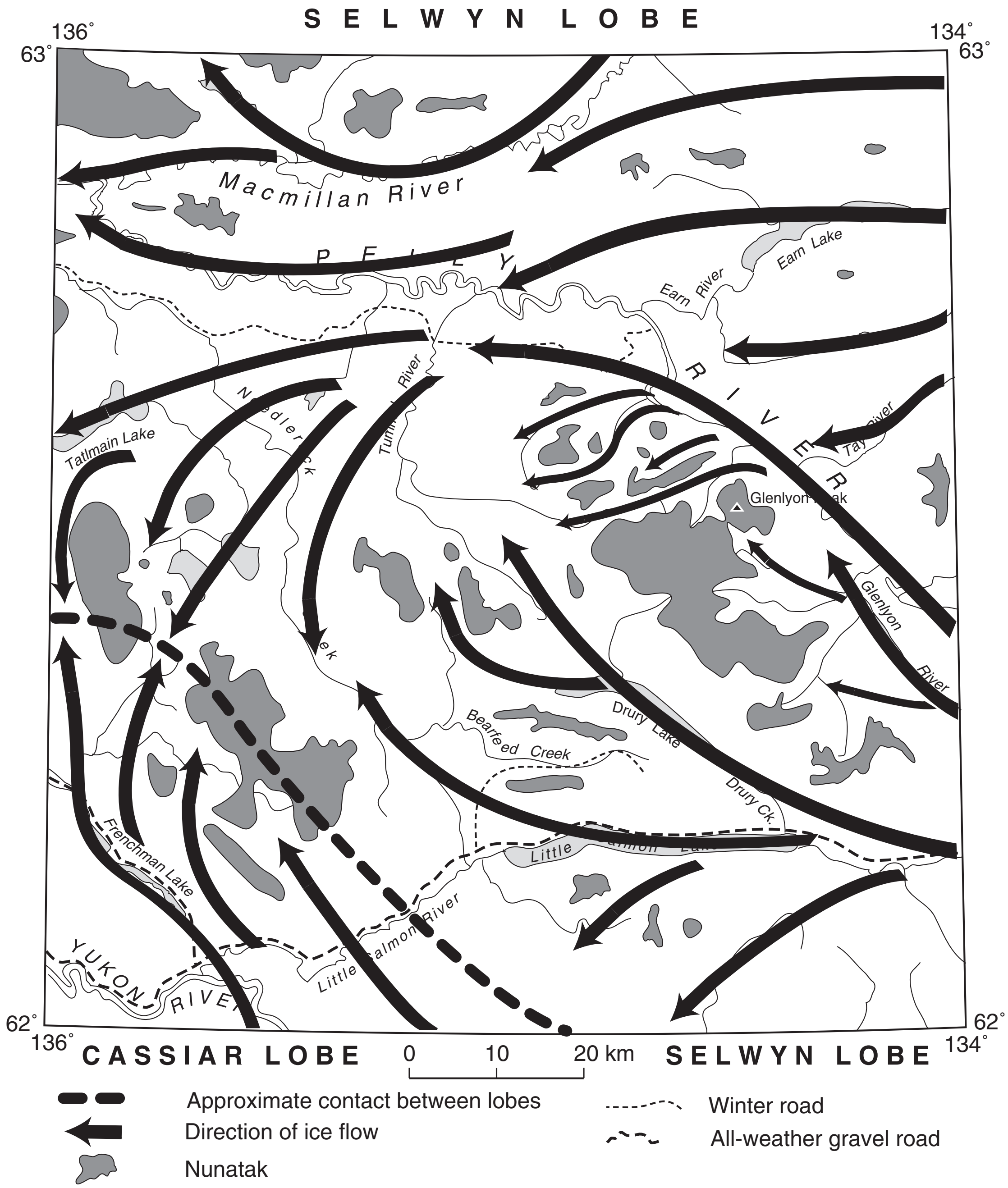


Figure 9. Ice-flow directions, nunatak areas, and contact between the Selwyn and Cassiar lobes during the maximum of the McConnell Glaciation.

Schweger and Matthews, 1991). The reason for the dichotomy between the glacial record of oxygen-isotope stage 4 or 5 of central Yukon Territory and the adjacent areas has not been determined.

CLASSIFICATION OF LANDFORMS AND SURFICIAL MATERIALS

The surficial geology of the Glenlyon map area has been mapped using a simplified version of the British Columbia Terrain Classification System (Howes and Kenk, 1997). For the purposes of this report, geological materials have been divided into two major groups: consolidated material (bedrock) and unconsolidated materials (Quaternary sediments). Surficial materials have been subdivided according to their genesis (e.g. glaciofluvial, fluvial), surface expression (e.g. blanket, veneer, fan), and occasionally, stratigraphic age, texture, and modifying process.

Genesis

The mode of deposition of sediments has a major influence on their physical properties. Genesis is therefore the most important means of classifying surficial deposits. The upper-case letter that represents each genetic type in the unit designators on the surficial geology maps (Maps 1786A–1789A, in pocket) is given in parentheses after the name of the genetic type.

Bedrock ('R')

Areas mapped as bedrock consist of exposed rock or rock with only a patchy covering of morainal deposits or colluvium. These areas may include periglacial landforms, such as blockfields, sorted stone polygons, and solifluction lobes, that are too small to show at the scale of mapping.

Morainal deposits ('M')

Morainal deposits consist dominantly of diamicton deposited either directly by glacier ice or in close proximity to glacier ice. Morainal deposits have been commonly mapped as till. Till is a dominantly unsorted and unstratified sediment deposited directly by a glacier without subsequent reworking. It usually consists of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape (Bates and Jackson, 1980, p. 653). Studies of the marginal areas of active glaciers, however, show that much of the material deposited directly from ice is subsequently remobilized and no longer represents a true 'till' (Lawson, 1979, 1981). When surficial materials are mapped, the term 'till' is used to describe these sediments and it pertains to all diamictons formed in a proximal glacial environment.

The texture of till is highly variable (Fig. 10; Appendix A). The relationship between till texture and bedrock composition, commonly observed in many areas (Haldorsen, 1977, 1978), is not evident in the Glenlyon map area. This likely reflects the highly complex spatial distribution of different bedrock types in the map area (Fig. 8). Depositional processes also influence matrix grain size: abrasion during lodgment produces abundant silt, whereas meltwater can remove fine-grained material during melt-out (Haldorsen, 1981, 1983a, 1983b). In addition, diamicton deposited by subaqueous debris flows may include previously deposited fine-grained material, resulting in a finer grained matrix. Wide ranges in grain size were observed, even at the same site. The thick till sequence at sample site 21 (stratigraphic section 13, Map 1787A) was sampled extensively for particle-size analysis. These samples range in grain size from 55% sand, 33% silt, and 12% clay to 6% sand, 42% silt, and 52% clay (Appendix A). This variation likely reflects depositional controls.

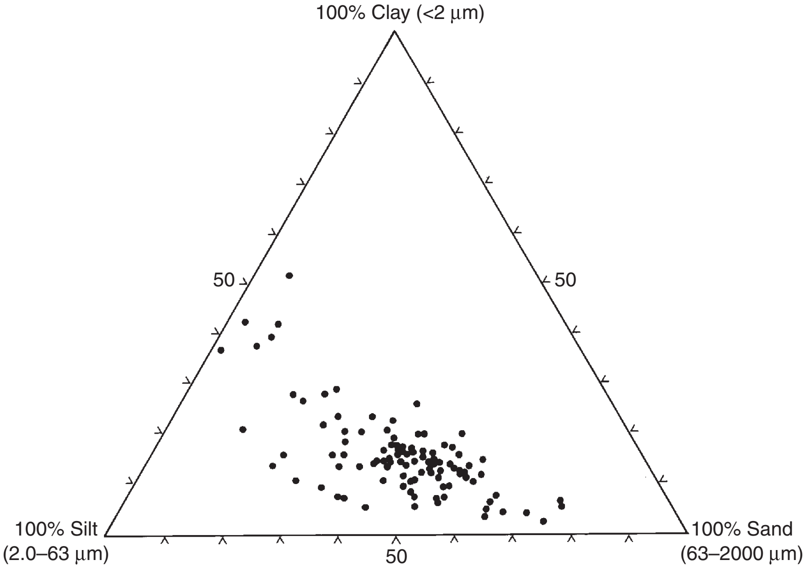


Figure 10.

Particle size of 104 till samples. Data are tabulated in Appendix A.

The concentration of clasts greater than 2 mm in glacial diamictons ranges from 10 to 40%, and averages 25 to 30%. Clasts range from pebbles to boulders, and their shape ranges from angular to rounded, with most being subrounded. Many of these clasts are striated and faceted.

Till ranges from massive (Fig. 11A) to stratified (Fig. 11B), and lenses of sorted material may also occur. Stratification, where present, is usually marked by sorted layers but is also displayed by slight changes in colour, grain size of matrix, or concentration of clasts greater than 2 mm. The massive and stratified diamicton represent two contrasting types of proximal glacial diamicton.

Massive diamicton can form in a variety of environments, both nonglacial and glacial (Dreimanis, 1988; Levson and Rutter, 1989; Mills, 1991). Massive diamicton in the study area is interpreted to consist primarily of basal till, mainly based on its striated and faceted clast content, its strong clast fabric (principal eigenvalues >0.75, Fig. 12), and its dense, massive nature. These same criteria indicate little or no reworking (Levson and Rutter, 1986, 1989) and that it is likely a primary or orthotill (Dreimanis, 1988). Striated and faceted clasts indicate a period of basal transport. Strong unimodal fabrics generally indicate glacial deposition (Mills, 1991, and references therein). These basal tills likely formed from a combination of melt-out and lodgment processes, but it is usually difficult to determine which process dominated (Haldorsen and Shaw, 1982). Where present, the sorted lenses preclude particle-by-particle lodgment.

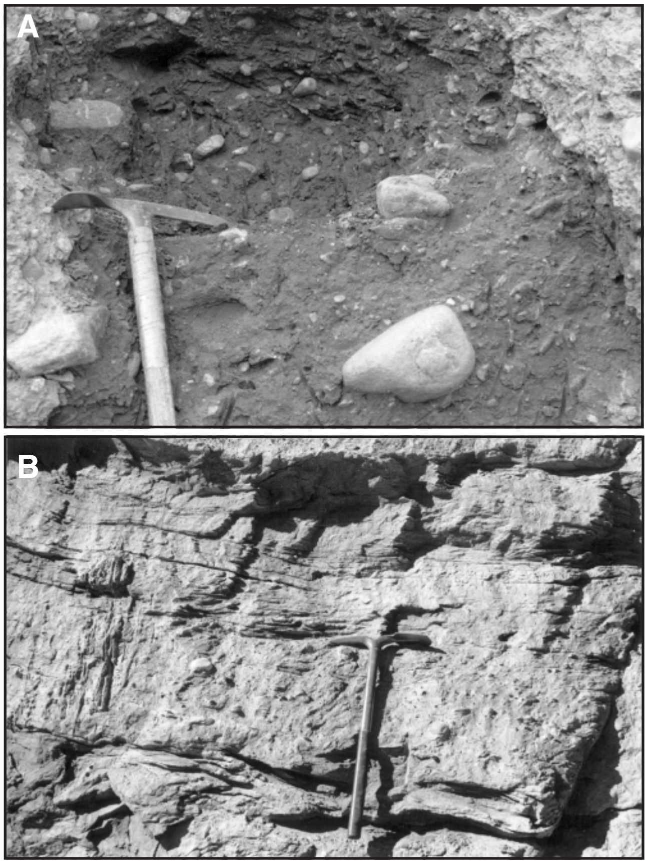


***Figure 11.** A) Massive till at the base of section 10, Map 1787A; head of ice axe is 30 cm long. GSC 2000-037B. **B**) Stratified till at section 11, Map 1786A; pick is 65 cm long. GSC 2000-037C. Photographs by B. Ward.*

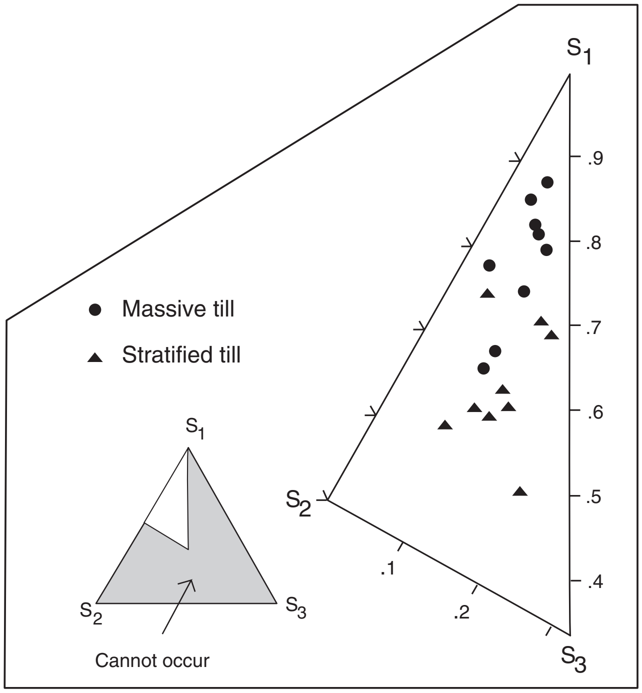


***Figure 12.** Ternary plot of fabric strengths for massive and stratified till along the Pelly River (*modified after *Lawson, 1979).*

Diamicton interbedded with sorted sediments has been interpreted to form by 1) basal melt-out, with stratification formed by meltwater from debris-poor bands in the ice (Shaw, 1979); 2) basal melting and quiet-water sedimentation beneath floating ice (Gibbard, 1980); 3) subaerial debris flow followed by pore-water expulsion and overland flow (Lawson, 1979); or 4) subaqueous debris flow followed by deposition as sorted sediment (Evenson et al., 1977; Eyles and Eyles, 1983; Shaw, 1987). The stratified diamicton examined in the study area is interpreted as having formed by cohesive debris flows in a subaqueous environment, based mainly on the weak fabric strengths and the nature of the interbedded sorted sediment. Fabrics obtained from stratified diamictons are generally weaker and have girdle patterns, in contrast to those from the massive diamicton (Fig. 12). Both characteristics have been observed in debris flows (Lawson, 1979; Mills, 1991). The striated clasts indicate a glacial origin for the material, either directly from the glacier or from previously deposited glacial diamicton. The well stratified nature is caused by sorted material being deposited between diamicton flow events. Along the Pelly and lower Macmillan rivers, the stratified diamicton is more common than the massive diamicton, implying that reworking of till was a major process in the Glenlyon map area.

The morphology of morainal deposits is variable. They commonly form blankets and veneers; thus, their morphology is usually controlled by that of the underlying deposit or bedrock. Some morainal deposits, however, form flutings, drumlins, moraines, and thick units in major valleys.

Glaciofluvial deposits (‘G’)

Glaciofluvial sediments are transported by meltwater from glaciers and deposited in ice-contact, proglacial, and paraglacial environments. Deposits include outwash plains, terraces, fans, deltas, and ice-stagnation complexes.

Glaciofluvial deposits generally comprise gravel and sand, although minor amounts of silt and diamicton are common. Grain-size data for some glaciofluvial deposits are tabulated in Appendix B. The gravel is generally clast supported, poorly to moderately sorted, and massive to well stratified, and commonly has weak to strong imbrication. The amount of interstratified sand, silt, and diamicton is variable. Rapid facies changes are common where deposition occurred in an ice-proximal position. The melting of buried or marginal ice can produce deposits that are folded and faulted.

Glaciofluvial deposits have a variable morphology. They can underlie irregular, hummocky, and pitted terrain, and form ridged landforms such as eskers and crevasse fillings (Fig. 6). Where deposition occurred in more distal environments with respect to the ice, deposits show fewer facies changes and are less disturbed. They form planar to gently rolling terrain that can be terraced or have kettles (Fig. 6).

In many cases, outwash is difficult to distinguish from alluvium. Terrace deposits are considered glaciofluvial in origin if formed by rivers with a more braided form than at present. Braided rivers result from high sediment loads derived, in part, by the erosion of glacial sediment on recently deglaciated slopes and as rivers cut down through thick, deglacial valley fills. The term ‘paraglacial effect’ was introduced by Church and Ryder (1972, p. 3059) to define the period, immediately following glaciation, that is characterized by a high sediment supply directly conditioned by glaciation and resulting in braided rivers. These paraglacial deposits are mapped as glaciofluvial because the sedimentation more closely approaches that of glaciofluvial than alluvial conditions. The distinction is rather arbitrary, however: terraces that are more than approximately 25 m above the present river level are mapped as glaciofluvial, whereas those below this are mapped as alluvial.

Glaciolacustrine deposits (‘L’)

Glaciolacustrine sediments are deposited in lakes dammed by glaciers or stagnant ice. Sources of sediment include meltwater streams, stagnant ice, the glacier margin, icebergs, and deposits along the lake margin. Deposition is dominated by suspension and tractional currents, sediment gravity flows, and iceberg rafting. Sedimentation rates are commonly high, resulting in soft-sediment deformation features, such as load casts and folds, and dewatering structures, such as dish and pillar structures.

Sediment texture and structure are determined largely by the location of the major sediment source(s). Grain-size data for some glaciolacustrine deposits are tabulated in Appendix B. In those parts of the lake distal from meltwater inflow and the ice margin, deposition is mainly from suspension and distal underflow, and deposits consist of well bedded to laminated sand, silt, and clay (Fig. 13A, B). Coarser deposits, such as gravel and diamicton from debris flows or icebergs, may be common locally. In more proximal areas, sediment gravity-flow processes are important and the deposits are coarser, consisting mainly of sand, gravel, and diamicton. Extensive exposures of glaciolacustrine deposits were observed to have been disrupted by syndepositional and postdepositional processes. Sediments can be faulted, folded (Fig. 13C), brecciated, and sheared (Fig. 13D), contain large intraclasts in a highly disrupted matrix (Fig. 13E), and contain synclinal stratification (Fig. 13F). These sediments are interpreted as having been deposited on top of or adjacent to stagnant ice, the disruption being due to removal of support when the ice melted.

Thickness, depositional history, and presence of permafrost all exert control on the morphology of glaciolacustrine deposits. Thick deposits of glaciolacustrine material have planar to gently rolling surfaces, or ridged, hummocked, or pitted surfaces caused by the melting of buried ice. Thinner deposits drape and conform to underlying topography. Fine-grained glaciolacustrine deposits commonly contain segregated ice lenses that can form palsen and pingos. Permafrost can degrade, producing thermokarst lakes and retrogressive thaw slides (Fig. 14).

Alluvial deposits (‘A’)

Alluvial sediments are deposited by rivers and streams under nonglacial conditions. The characteristics of the deposits are related to the specific depositional environment. Gravel beds deposited in channels and on bars are generally moderately sorted, well stratified (locally with cross-stratification), and well imbricated, and contain well to moderately rounded clasts. Conversely, gravel beds deposited in alluvial fans are moderately to poorly sorted, poorly to weakly stratified, and poorly to moderately imbricated, and contain angular to moderately rounded clasts. As well, alluvial fans can contain significant amounts of diamicton, deposited by debris flows and avalanches. Sand and silt deposited in overbank environments are generally well stratified and can contain ripple and ripple-drift stratification; this stratification may be locally disrupted by ice-push during spring breakup.

Alluvial deposits also have a range of topographic expression. Streams with steep gradients deposit mainly coarse gravel beds with little overbank material, forming an irregular topography of small terraces and fans. Alluvial fans form where steep, high-energy streams enter valleys with lower gradients. Deposits of low-gradient rivers and streams underlie planar to slightly undulatory, gently dipping surfaces, either terraces or plains. They consist of gravel and sand, overlain by silty overbank deposits.

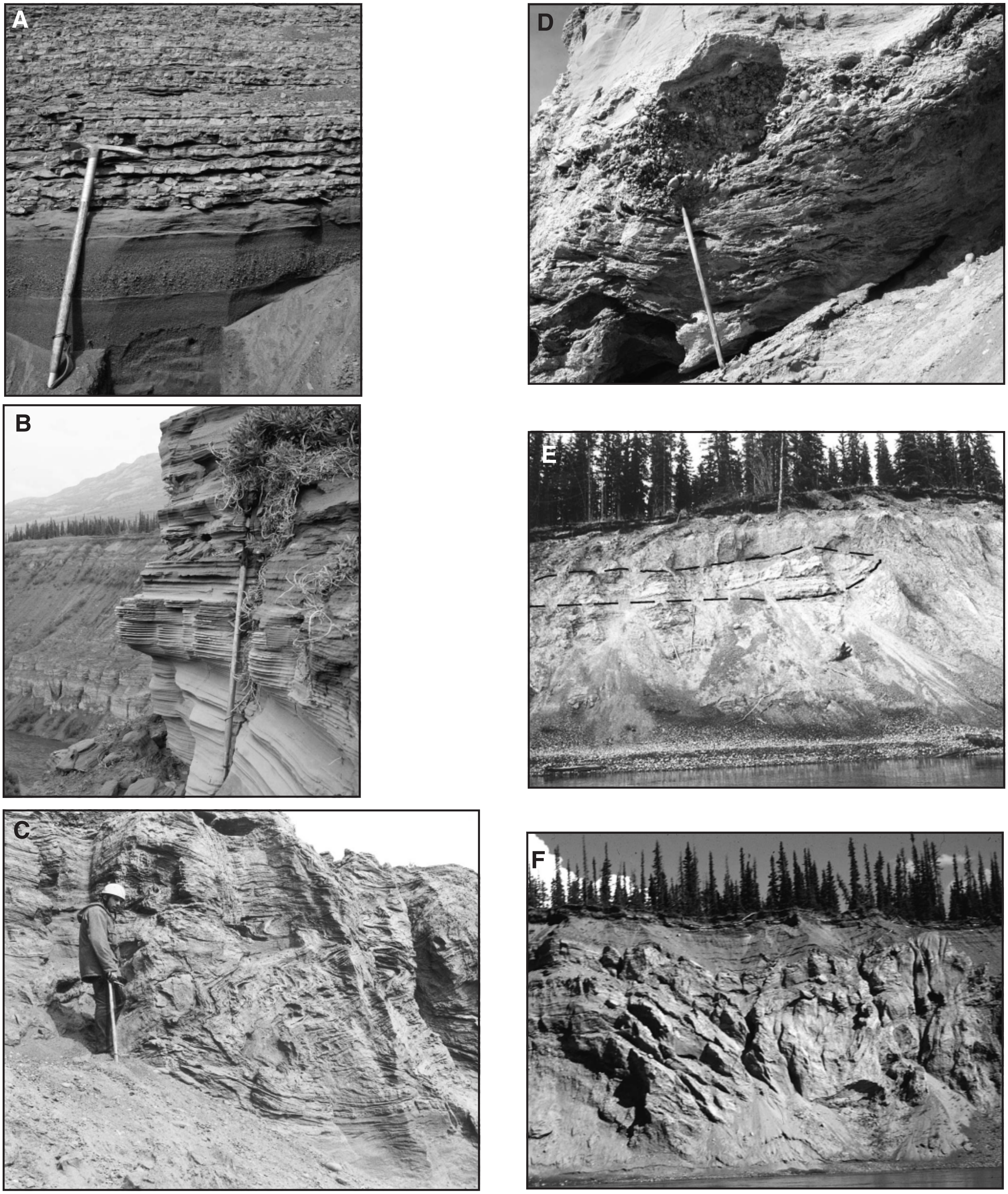


Figure 13. *Examples of glaciolacustrine sediments:* ***A****) normally graded granules to medium sand abruptly capped by laminated sand, silt, and clay; ice axe is 90 cm long; GSC 2000-037D;* ***B****) thick sequence of finely bedded to laminated sand, Tay River; ice axe is 90 cm long; GSC 2000-037E;* ***C****) recumbent folds; GSC 2000-037F;* ***D****) shear zone with coarser sand clasts highlighted as hollows eroded by wind; visible portion of ice axe is 75 cm long; GSC 2000-037G;* ***E****) large intraclast (outlined), 3.5 m thick with bedding preserved, in a sequence of disrupted glaciolacustrine sediments; GSC 2000-037H;* ***F****) large synclinal structure; height of section approximately 40 m; GSC 2000-037I. Photographs by B. Ward.*

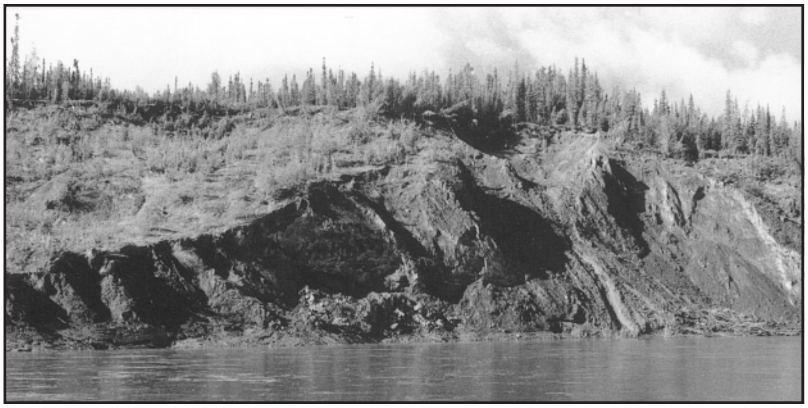


Figure 14.

Retrogressive thaw slide in fine-grained glaciolacustrine sediments (section 9, Map 1786A). The section is 32 m high. Photograph by B. Ward. GSC 2000-037J

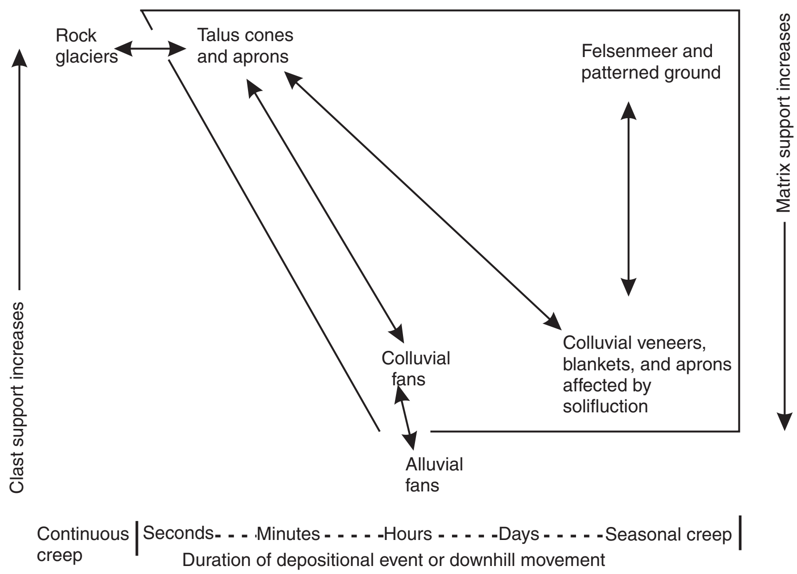


Figure 15.

*Genetic classification of colluvial landforms based on the duration of the formative event or ongoing gravitational transport (*from *Jackson, 1987, Fig. 9).*

Colluvial deposits ('C')

Colluvium consists of material that has been transported and deposited by subaerial gravitational processes (Fig. 15). These processes range from high-velocity rock falls and topples to low-velocity soil creep and solifluction (downslope creep caused by seasonal thaw and saturation).

Colluvial deposits are commonly poorly sorted and consist of diamicton or rubble, deposited as veneers, blankets, fans, aprons, or landslides (*see* 'Landforms' section). The nature of the deposit depends on the source material and the style of transport. Blocky talus cones and aprons with little fine-grained sediment form by rockfall and snow avalanching in steep mountainous areas underlain by coarse-grained bedrock. In areas where weathering products build up and/or extensive till is available for mobilization, debris flows can form levees, fans, and cones. Blockfields and sorted stone polygons form on gentle slopes in alpine areas underlain by coarse-grained bedrock. Steeper slopes with finer grained bedrock and/or surficial materials are commonly mantled with diamicton that has been transported by solifluction and forms a complex of overlapping lobes. Colluvial aprons and cones form in alpine areas through the processes of snow avalanching, rock falls, and debris flows.

Eolian deposits ('E')

Eolian sediments are transported and deposited by wind. In the map area, eolian deposits consist of loess, dune sand, and tephra. They can form a thin veneer or blanket, or distinctive dunes (Fig. 16). Deposits generally consist of well sorted, fine sand and silt. The sediments range from weakly stratified to massive in blankets and veneers, to stratified in dunes.

Many of the eolian blankets and veneers are composed of loess (wind-blown silt), which was deposited at the end of the last glaciation and during early postglacial time as vegetation became established (Tarnocai et al., 1985). White River tephra, deposited ca. 1250 BP during the cataclysmic eruption of Mount Bana near the Alaska–Yukon Territory boundary (Lerbekmo et al., 1975), covers much of southern and central Yukon Territory and occurs throughout the southern three-quarters of the map area. The tephra is locally overlain by eolian sediments, indicating that eolian activity is continuing. Eolian veneers less than 50 cm thick are widespread in low-lying and moderately sloping areas, but are too thin to map.

Thicker eolian deposits consist of dunes and cliff-top deposits. Parabolic dunes (Fig. 16) most likely formed at the end of the last glaciation (Campbell, 1967), whereas 'cliff-top

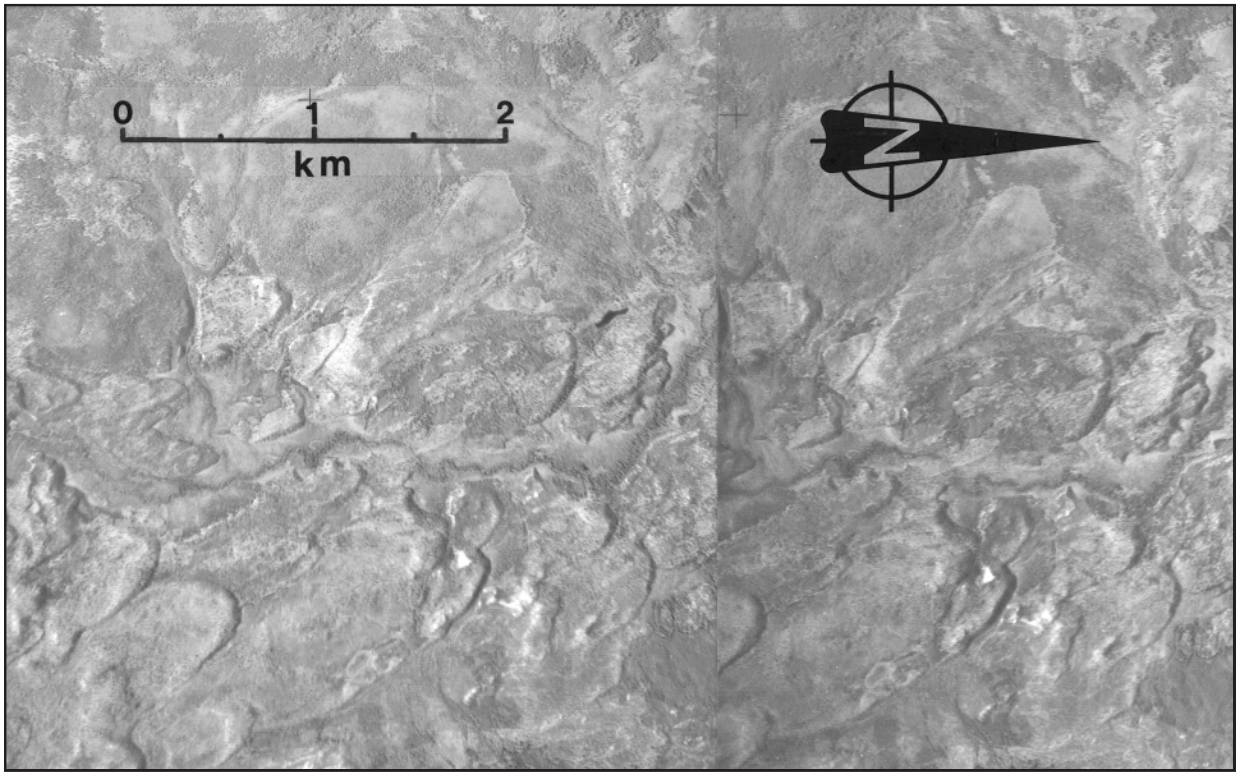


Figure 16. *Stereopair showing parabolic dunes on the south-central edge of the map area (Map 1788A). NAPL A12174-24, -25 (photograph taken 1949).*

deposits' (David, 1972), which resemble dunes, were formed at the tops of river bluffs by winds eroding material from below. Cliff-top deposits are too small to map, but they are shown on some measured sections.

Organic deposits ('O')

Organic deposits are accumulations of dead vegetation in areas of poor drainage (perched water table) or where the water table intersects the ground surface. This water is essentially stagnant and becomes anoxic; thus, the dead vegetation does not fully decompose. Organic deposits include peat and gyttja with occasional layers and lenses of mineral material. They accumulate in bogs, fens, and lakes, which occur on floodplains and in valleys and shallow depressions. In addition, blanket bogs are common on poorly drained slopes underlain by permafrost. Permafrost is commonly present in surface organic deposits. Organic deposits are commonly hummocky, containing tussocks with less than 1 m of relief. Palsen with relief greater than 1 m occur if segregated ice lenses are present. Organic deposits less than 1 m thick are indicated by a symbol on the maps.

Landforms

Landforms are geomorphic features that are recognizable and definable, based on slope, shape, and spatial distribution. Landforms in this study can be divided into two types: large features that can be depicted as map units, and small features that are shown with a symbol on the maps and occur within or along the margins of map units.

Large landforms

Large-scale landforms are used to subdivide the genetic categories on the surficial geology maps (Maps 1786A–1789A). The following descriptions are modified after Clague (1984). The lower-case letter that represents each landform in the unit designators on the maps is given in parentheses after the name of the landform.

Apron ('a')

An apron is a constructional landform that has a planar to semiplanar upper surface with a relatively steep gradient, generally greater than 20–25°. Aprons form by colluvial and fluvial processes at the break in slope where steep valley sides meet valley bottoms (Fig. 17A). Aprons are thickest (commonly >10 m) at mid-slope, and decrease in thickness upslope and downslope.

Blanket ('b')

A blanket is a continuous or nearly continuous mantle of sediment that drapes the underlying material (Fig. 17B). Blankets are generally greater than 1 m thick but can locally be thinner.

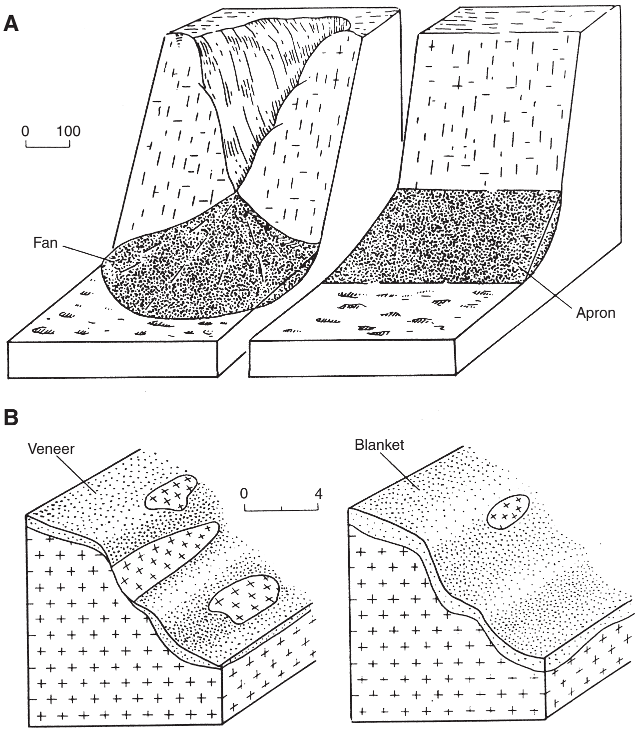


Figure 17. *Representative landforms:* ***A****) fan and apron,* ***B****) veneer and blanket (*from *Clague, 1984).*

Delta ('d')

A delta is a constructional landform that forms where a stream or river enters a standing body of water. It has a triangular plan shape with a flat to gently sloping upper surface, terminated by a steeper scarp (Fig. 18).

Fan ('f')

A fan is a constructional landform with an inverted conical shape and slopes that are generally less than 15° but locally as high as 30° (Fig. 17A). They form where high-gradient streams become unconfined, commonly at the mouths of tributary valleys.

Plain ('p')

A plain is a flat or gently sloping surface with less than 1 m of relief (Fig. 6). It represents an accumulation of fluvial, glaciofluvial, or glaciolacustrine sediments.

Terrace ('t')

A terrace is a flat or gently sloping surface truncated by steeper slopes (Fig. 6). Terraces can be depositional or erosional in origin.

Undivided ('u')

Undivided refers to two or more landform types that cannot be differentiated at the scale of mapping (1:100 000).

Veneer ('v')

A veneer is a thin (<1 m), typically discontinuous mantle of surficial material (Fig. 17B). It conforms to the underlying bedrock or surficial unit, having little or no surficial expression of its own.

Complex ('x')

A complex has highly variable relief, and consists of several of the following surface expressions: hummocks, ridges, depressions, plains, terraces, and channels (Fig. 6, 18). It results from deposition in and around stagnant ice, which subsequently melts.

Small landforms

Arête

An arête is a narrow, sharp ridge formed by glacial erosion and frost action. They generally occur in areas of bedrock in alpine regions and can be associated with bouldery colluvial aprons.

Cirque

A cirque is a deep, steep-walled, half-bowl- or armchair-shaped hollow formed by glacial erosion. They occur in bedrock in alpine areas, usually at the heads of valleys. Cirques in the map area were formed by alpine glaciers that are no longer present, although many contain rock glaciers.

Cryoplanation terrace

Cryoplanation terraces are gently sloping, erosional benches or surfaces on summits or hillsides. They are covered with 1 or 2 m of bedrock rubble and blocks, with some finer interstitial material (Washburn, 1979; Hughes, 1990). Large, well developed terraces are generally considered to form over tens of thousands of years by colluvial and permafrost processes, gelifluction being the most important (Washburn, 1979). Their distribution and development in Yukon Territory were discussed by Hughes (1990, p. 14–16). Within the map area, they are only found in the alpine zone above the Reid ice limit (Map 1786A).

Esker

Eskers are long, narrow, steep-sided, usually sinuous ridges composed of sand and gravel. They are formed by water flowing in a supraglacial, englacial, or subglacial environment, and are commonly oriented approximately perpendicular to the ice front. Eskers are associated with glaciofluvial or morainal units.

Glacial limits

Glacial limits delineate the maximum limits of glaciations and are marked by a variety of landforms. The limits may be inconspicuous, indicated by slight changes in topography and weathering, or well defined, marked by moraines and meltwater channels (Fig. 18, 19). Glacial limits, which commonly correspond to map unit boundaries, are indicated on the maps by unique symbols for the McConnell and Reid glaciations.

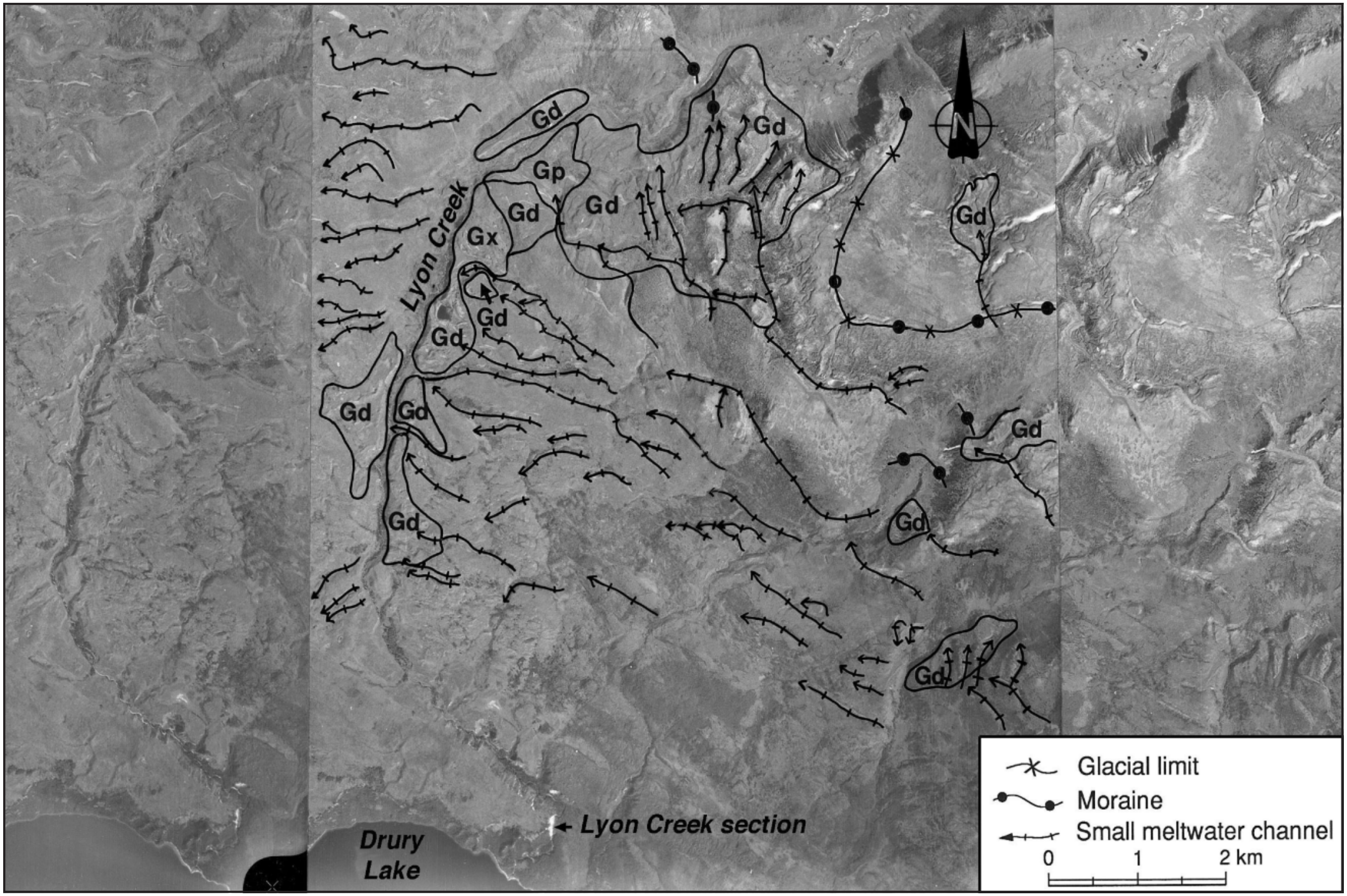


***Figure 18**. Stereotriplet of an area near Lyon Creek (Map 1789A), showing glacial limits, moraines, small meltwater channels, glaciofluvial deltas (unit Gd), glaciofluvial complexes (unit Gx), and till veneers of Reid age (unit M^Rv). Drury Lake is in the southwest corner of the photo. NAPL A20693-128, -129, -130 (photograph taken 1968).*

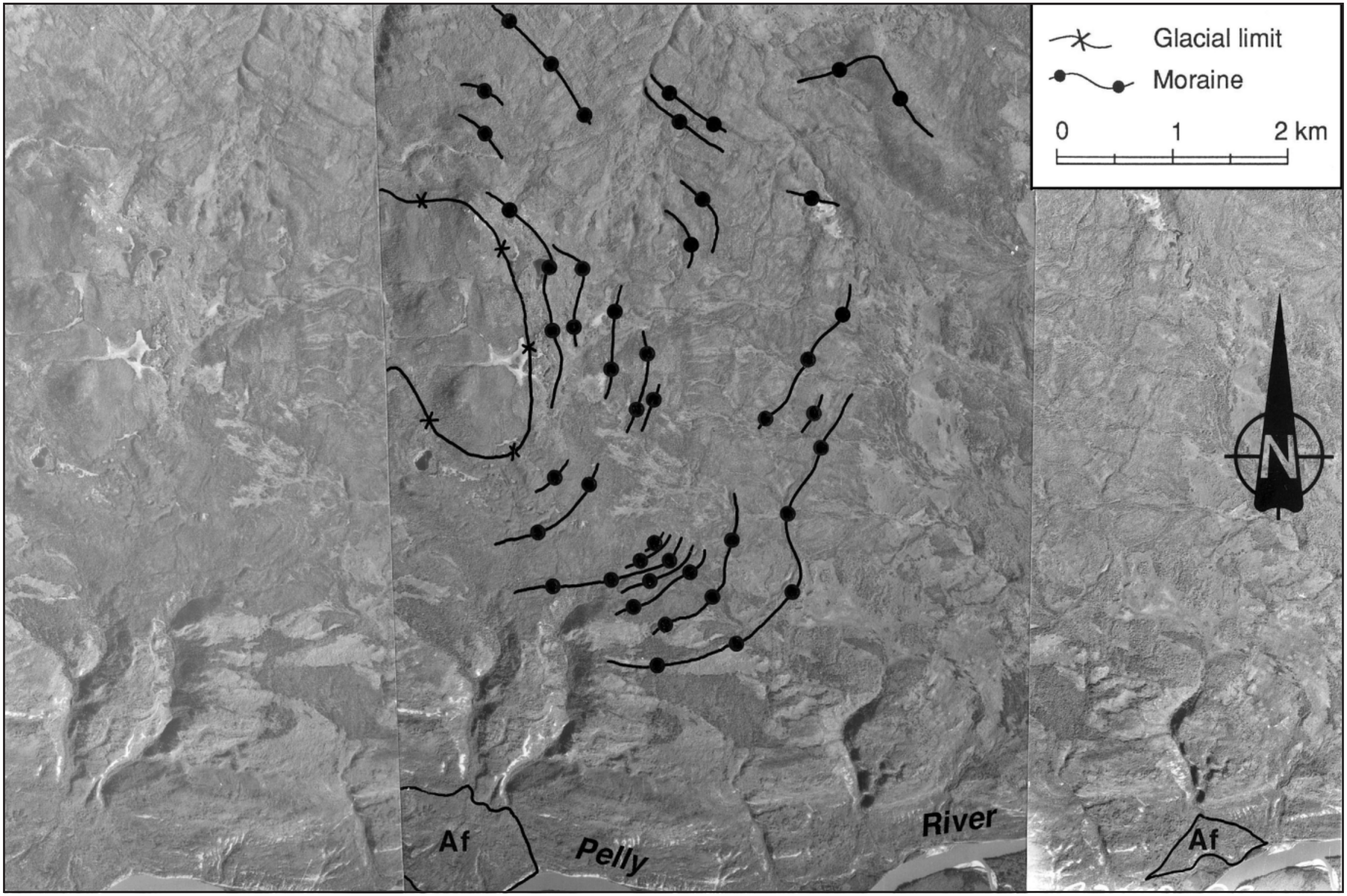


Figure 19. Stereotriplet showing McConnell glacial limit and recessional moraines on Pelmac Ridge (Map 1786A). The area above the McConnell limit has been mapped as Reid till veneer (unit $M^{R}v$). NAPL A20110-97, -98 (photograph taken 1968).

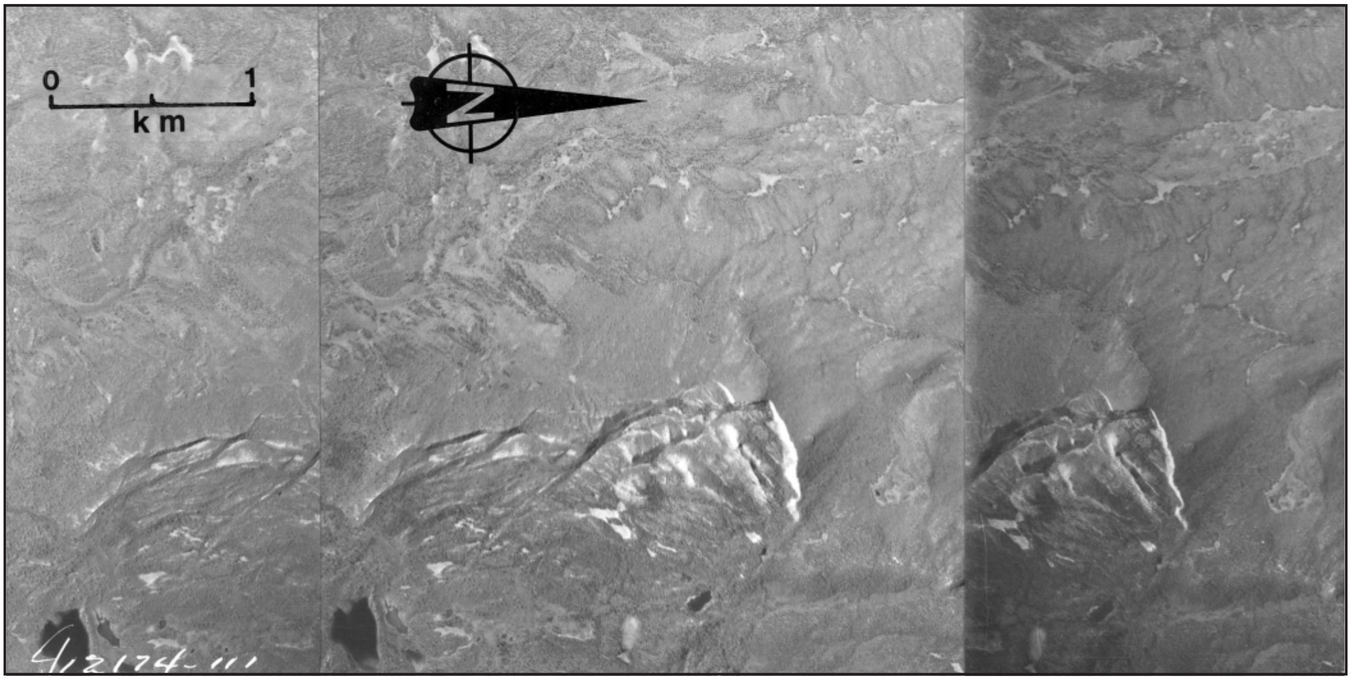


Figure 20. *Stereotriplet showing a landslide in Carmacks Group volcanic rocks (Map 1788A, latitude 62°12′N, longitude 135°13′W). NAPL A12174-109, -110, -111 (photograph taken 1949).*

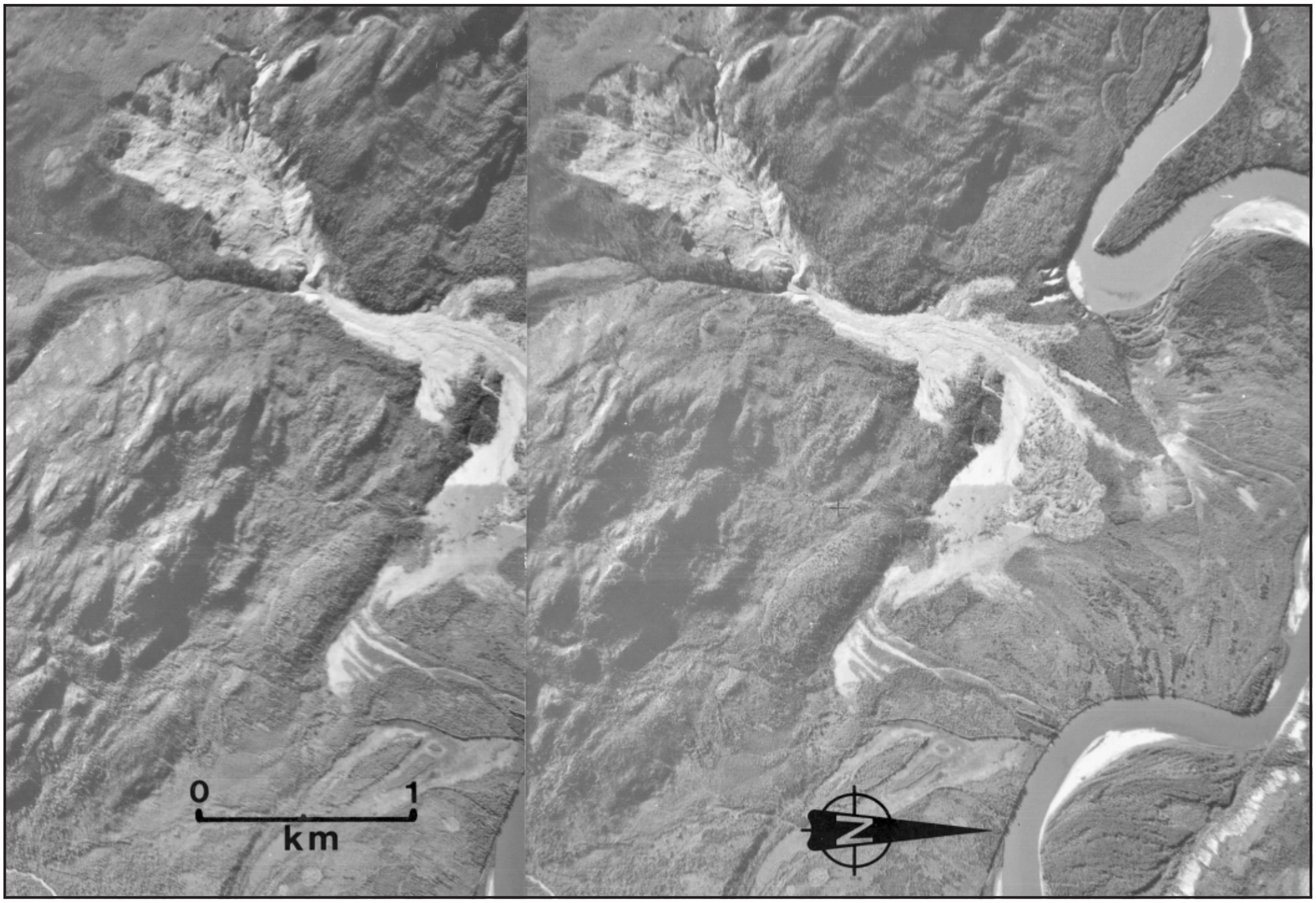


Figure 21. *Stereopair showing landslide in fine-grained till on the eastern margin of the map area (Map 1789A, latitude 134°02′N, longitude 62°24′W). NAPL A12182-127, -128 (photograph taken 1949).*

Landslide

Landslides are mass-movement landforms and processes. The deposits are colluvial and their character is determined primarily by the material that has failed. Landslides involving bedrock are most common in Cretaceous and Tertiary volcanic rocks. The largest landslide in the study area, located at latitude 62°12′N, longitude 135°13′W on Map 1788A, is in Cretaceous volcanic rocks of the Carmacks Group (Fig. 20).

Retrogressive-thaw flow slides, also called bimodal slides or thaw slumps (McRoberts and Morgenstern, 1974; Washburn, 1979; Burn, 1987) commonly occur in fine-grained, ice-rich till or glaciolacustrine deposits (Fig. 14, 21). They are a form of thermokarst (Washburn, 1979). Failure is caused by the exposure of ice-rich sediments due to fluvial erosion, forest fires, or human activities such as road building. Progressive melting during the summer causes liquefaction and flow from a steep headwall (McRoberts and Morgenstern, 1974). Failure is generally slow, but if enough water-saturated sediment accumulates, a debris flow could be generated. Failure usually continues until either the ice-rich ground is exhausted or an insulating material, usually a thick vegetative mat, covers the thaw face (Burn, 1987). Retrogressive thaw slides are common in fine-grained glaciolacustrine sediments along the Pelly and Macmillan rivers.

Meltwater channel

Meltwater channels are cut in either bedrock or surficial sediments by glacial meltwater in an ice-contact or proglacial environment. Small and large channels have been differentiated on the maps. Small meltwater channels are generally less than 100–200 m wide and range from small notches cut in bedrock, representing ice-marginal positions, to more extensive channel systems (Fig. 18). Large channels are up to 3 km wide and represent major discharge paths from ice or glacial lakes (Fig. 22). They can occur within any map unit and can delineate unit boundaries. Both small and large channels may have been ice walled.

Moraine

Moraines are elongate ridges with rounded or steep sides, deposited at the margin of a glacier (Fig. 18, 19). They usually consist of diamicton, but where the glacier terminated in a lake, they may consist of stratified sand and gravel.

Pingo

Pingos are large conical hills formed by the growth of a large body of segregated ice, insulated by fine-grained or organic deposits. If the insulating mat is disrupted by continued ice growth or by fire, degradation can occur, producing a collapsed centre. The pingos in the study area are open-system pingos, the most common form of pingo in Yukon Territory (Hughes, 1969). They are fed by groundwater flow down hillsides and have a relatively long growth cycle, lasting many years (Washburn, 1979, p. 183).

Rock glacier

Rock glaciers are spoon- or tongue-shaped masses of poorly sorted rubble and blocks that deform and flow downhill under the influence of gravity. They are either cored by ice or have an ice matrix. They have steep fronts when active and many have transverse ridges. Rock glaciers are commonly found in cirques or at the base of steep slopes where avalanche and rockfall debris contributes to their formation. They are commonly associated with bouldery colluvial aprons.

Streamlined glacial bedforms

Streamlined glacial bedforms include flutes (parallel ridges with constant width and height) and drumlins (smooth, low, oval hills with the morphology of inverted spoons or whalebacks; Fig. 6, 22). Although the origin of drumlins is controversial (Shaw and Kvill, 1984; Shaw and Gilbert, 1990), the long axes of these and other streamlined forms are assumed to be parallel to the direction of glacial movement. These features are developed in both bedrock (rock drumlins or drumlinoids) and surficial material.

Terrace

In some instances, individual terraces can be identified within a single polygon (e.g. two levels of terraces within an alluvial terrace polygon (unit At)). If this is the case, then individual terraces are differentiated using the standard landform symbol.

Thermokarst lake

Thermokarst refers to topographic depressions formed by the melting of ground ice (Washburn, 1979). Thermokarst lakes are circular or elliptical in plan view and commonly have scalloped edges (Fig. 22). Climatic warming or disturbance of the insulating vegetative mat causes thickening of the active layer, resulting in ground subsidence and ponding of water (Burn, 1987). Thermokarst lakes indicate the presence of permafrost, and are common in fine-grained glaciolacustrine and alluvial deposits, as well as in organic deposits.

Tor

Tors are exposures of rock that stand up from the surrounding slopes (Fig. 23) and form by differential weathering and removal of the debris by mass movement (Washburn, 1979, p. 78). They occur mainly in alpine areas and, as has been noted in other parts of Yukon Territory (Hughes, 1990), usually above the Reid Glaciation limit.

Texture

Texture refers to the size, shape, and arrangement of the constituent elements in a sedimentary deposit (Bates and Jackson, 1980). Common textural terms used in this report are listed in Table 5. Textures of map units are summarized in the 'Description of map units' section.

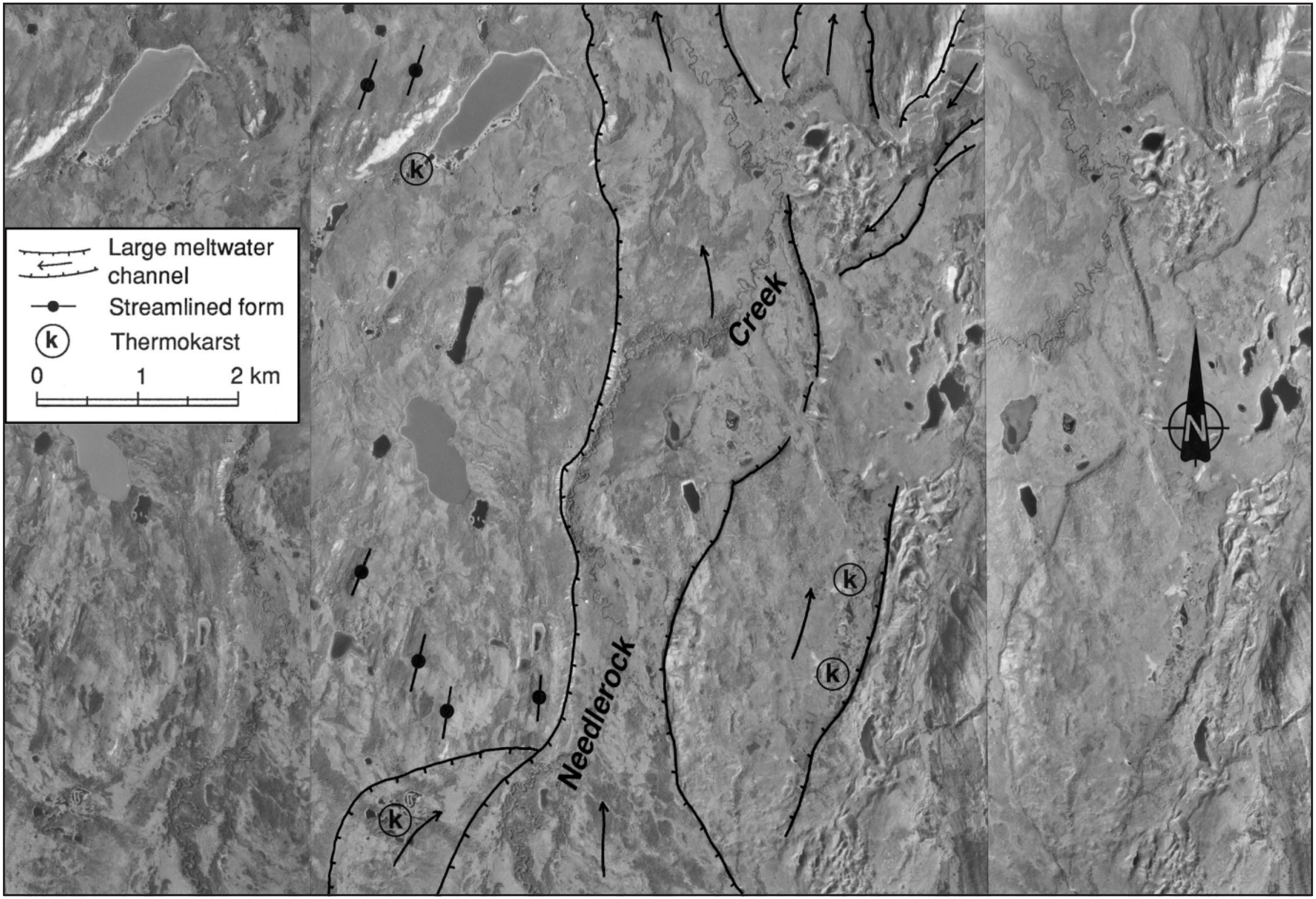


***Figure 22.** Stereotriplet of an area immediately east of Ess Lake (Map 1788A), showing large meltwater channels, thermokarst, and streamlined forms. NAPL A20059-97, -98, -99 (photograph taken 1967).*

Geomorphic processes

There are three important geomorphic processes currently active in the study area: avalanching, mass movement (landslides), and permafrost (pingos, retrogressive thaw slides, and thermokarst lakes). Each is indicated either by a letter modifier added to the unit designator, or by an on-site symbol.

Avalanching is the rapid downslope movement of snow. Avalanches can incorporate abundant bedrock blocks and surficial material, and deposit them at the base of the slope as bouldery colluvial fans or colluvial aprons. Avalanching is indicated on the maps by the letter 'A' being added to the bedrock map unit designator ('R').

Figure 23.

Tors on Glenlyon Peak, Glenlyon Range (Map 1787A, latitude 62°31′N, longitude 134°30′W). Photograph by B. Ward. GSC 2000-037K

Table 5. Common textural terms used in this report (*modified from* Bates and Jackson, 1980; Clague, 1984).

Term	Explanation
Matrix	Finer-grained material (<2 mm) between the larger grains
Clast	Individual constituent, grain or fragment of a sedimentary deposit (>2 mm), produced by mechanical weathering
Matrix-supported	Sedimentary texture where the larger particles are not in contact but are separated by finer particles
Clast-supported	Sedimentary texture where the larger particles are in contact
Boulders	Rounded particles >256 mm
Blocks	Angular particles >256 mm
Cobbles	Rounded particles 64–256 mm
Pebbles	Rounded particles 2–64 mm
Rubble	Angular particles 2–256 mm
Sand	Particles 0.062–2 mm
Silt	Particles 0.002–62 mm
Clay	Particles <0.002 mm
Gravel	Accumulation of rounded particles that are generally larger than sand; can be clast- or matrix-supported, with the matrix generally being sand
Diamicton	Unsorted, matrix-supported mixture of clay, silt, sand, pebbles, cobbles, and, in some cases, boulders
Peat	Deposit of fibrous, partly decayed fragments of vascular plants
Gyttja	Fine-grained organic matter deposited or precipitated in a lake

Individual landslides, pingos, retrogressive thaw slides, and thermokarst lakes are shown by on-site symbols on the maps and were described in more detail in the 'Landforms' section.

Age of glacial events

Glacial deposits older than the McConnell Glaciation are indicated by a superscript after the genesis designator. Deposits of the Reid Glaciation are denoted by the superscript 'R' (e.g. MRv) and those of the pre-Reid glaciations with the superscript 'PR' (e.g. MPRv).

DESCRIPTION OF MAP UNITS

The map units were delineated mainly on the basis of genesis and large landforms. Some further subdivision was made according to texture, modifying process, and age of glacial event. Map units are grouped generally in order of decreasing age.

Pre-Quaternary

Bedrock (units R, R-A)

Bedrock is exposed in alpine areas, on steep slopes where surficial materials have been removed by colluvial processes, and in channels cut by streams. Most bedrock exposures occur in the Glenlyon, Little Salmon, Big Salmon, Macmillan, and Kalzas ranges. Areas mapped as bedrock also include variable amounts of surficial sediment, mainly till and colluvium, that are either too small or too patchy to be shown at the scale of mapping. Areas of bedrock above the limit of the McConnell Glaciation contain a higher percentage of colluvium, felsenmeer, and rubble transported by solifluction than those below this limit.

Early Pleistocene pre-Reid glaciation(s)

Pre-Reid till veneer (unit $M^{PR}v$)

Till veneer of pre-Reid glaciations is similar to that of the McConnell Glaciation (see 'Late Wisconsinan McConnell Glaciation'); however, it contains larger amounts of colluvium and has very subdued landforms because there has been more time for colluvial processes to modify it. Detailed soil studies to the north and northeast of the map area indicate that the pre-Reid deposits can contain a paleosol (Wounded Moose paleosol); although truncated, this paleosol is much more developed than the present soil on comparable materials of McConnell age (Tarnocai et al., 1985; Smith et al., 1986). Deposits of pre-Reid glaciations occur in the western part of the map area, above the limit of the Reid Glaciation (Maps 1786A, 1788A).

Middle Pleistocene Reid Glaciation

Reid till veneer (unit $M^{R}v$)

Till veneer of the Reid Glaciation is similar to that of the McConnell Glaciation (see 'Late Wisconsinan McConnell Glaciation'), but contains larger amounts of colluvial material and has more subdued landforms (Fig. 19). It can contain a paleosol (Diversion Creek paleosol) that is intermediate in development between those developed on McConnell and pre-Reid deposits (Tarnocai et al., 1985; Smith et al., 1986). Reid till occurs above the limit of the McConnell Glaciation, mainly in the western part of the map area (Fig. 19; Maps 1786A, 1788A); there are also small occurrences in the Glenlyon Range (Maps 1787A, 1789A). Areas above the McConnell glacial limits have been mapped as Reid till veneer.

Reid glaciofluvial delta (unit $G^{R}d$)

Glaciofluvial deltas of the Reid Glaciation are similar to those of the McConnell Glaciation; however, as mentioned above, they commonly show evidence of greater colluvial reworking and deeper pedogenesis than similar McConnell deposits. They occur mainly in the western part of the map area (Maps 1786A, 1788A).

Late Wisconsinan McConnell Glaciation

Till blanket (unit Mb) and till veneer (unit Mv)

Till blanket and veneer are greater than 1 m and less than 1 m thick, respectively, and occur throughout the map area. These units locally include thicker deposits associated with moraines. Till blanket and veneer usually drape bedrock and display a streamlined to gently undulatory surface form (Fig. 6). In some larger valleys, they cover older sediments. Till blanket occurs most commonly in areas of low relief in the western part of the map area. Throughout the rest of the map area, with its higher relief and steeper slopes, till veneer is more common. Areas mapped as till veneer commonly contain small patches of till blanket, and vice versa. Till veneer is commonly reworked into colluvial veneers or aprons on slopes greater than 20°. Both till blanket and veneer may contain patches and areas of bedrock, colluvium, and, in places, glaciolacustrine and fluvial sediments too small or thin to be shown at the scale of mapping.

Glaciofluvial plain and fan (unit Gp)

Glaciofluvial plain sediments are greater than 2 m thick and were deposited as outwash in front of retreating ice or when glacial lakes drained and braided streams deposited gravel beds (Fig. 6). Glaciofluvial plains occur in many main valleys and within large meltwater channels (Fig. 22). The sediments consist mainly of moderately stratified, approximately horizontal gravel, commonly capped by thin sand and silt.

Glaciofluvial fan sediments, which are rare in the map area, are greater than 5 m thick. They formed when water from a confined meltwater stream entered a large valley, forming a low-gradient fan. They consist of interstratified gravel and sand. One formed where Menzie Creek flowed into the low area between Earn Lake and the Pelly River (Map 1787A).

Glaciofluvial terrace (unit Gt)

Sediments of glaciofluvial terraces are generally less than 2 m thick and were deposited when glacial streams incised thick valley-fill sequences (Fig. 6). Glaciofluvial terraces are common along the main valleys and in large meltwater channels. The associated sediment is moderately stratified gravel capped by sand.

Glaciofluvial delta (unit Gd)

Sediments of glaciofluvial deltas, generally greater than 5 m thick, are common throughout the map area because many glacial lakes existed during deglaciation. They consist of dipping, well stratified sand and gravel capped by horizontally bedded gravel. When deposited in close association with ice, these sediments are typically deformed, usually by faulting and slumping. They are differentiated from glaciofluvial terraces on the basis of their geomorphic expression and, in exposed sections, by the presence of foreset bedding. Lake levels commonly dropped during delta formation, so that several deltas can be incised or 'telescoped' into each other (Fig. 18). On the map, some of these telescoped deltas are shown as one unit, since they are too small to differentiate and are part of the same delta system.

Glaciofluvial complex (unit Gx)

Sediments of glaciofluvial complexes are generally greater than 5 m thick and form terraces, kettle holes, crevasse fillings, and eskers. A typical example is the complex along the Pelly River at The Detour (Fig. 6; Map 1787A). These deposits occur throughout the map area, reflecting the regional stagnation style of deglaciation, but are most common in valley bottoms and on plateaus. The sediments are dominantly poorly sorted, weakly stratified to unstratified gravel and sand, but may contain diamicton and silt.

Glaciolacustrine plain (unit Lp)

Glaciolacustrine plain sediments are generally greater than 5 m thick and were deposited in relatively long lived glacial lakes. This unit is widespread in the Macmillan River valley (Map 1786A) and along the west side of Little Salmon Lake (Map 1789A), and is exposed in sections along the Pelly, Tay, and Little Salmon rivers. The unit is dominated by well stratified sand, silt, and clay (Fig. 13A, B), and can be capped by thin, discontinuous gravel deposited after the lakes drained. Some deposits have been disturbed by folding, faulting, and brecciation caused by the melting of supporting ice (Fig. 13C–F). Segregated ice lenses, retrogressive thaw slides (Fig. 14), and thermokarst lakes are abundant in glaciolacustrine plain sediments.

Glaciolacustrine blanket (unit Lb) and glaciolacustrine veneer (unit Lv)

Glaciolacustrine blanket and veneer are greater than 1 m and less than 1 m thick, respectively. The sediments were deposited either in short-lived lakes or at low sedimentation rates. These units are found throughout the map area and are especially common in the southern and western sectors, and along creeks in the Glenlyon Range where the drainage was blocked during deglaciation. The sediments are similar in character to those of glaciolacustrine plains.

Glaciolacustrine complex (unit Lx)

Sediments mapped as glaciolacustrine complex are generally greater than 5 m thick. They are much more disturbed than other glaciolacustrine deposits, showing ample evidence of slumping, folding, and faulting (Fig. 13D–F) caused by being deposited on top of stagnant ice. They also contain more gravel and diamicton intrabeds than other glaciolacustrine units, since they were deposited in ice-proximal settings. This unit commonly occurs in the larger valleys where stagnant ice dammed large glacial lakes.

Holocene

Alluvial plain (unit Ap)

Alluvial plain sediments are greater than 1 m thick and can reach thicknesses of 5–10 m. They occur as floodplains along rivers and streams. The width of the floodplain is controlled by the overall width of the valley. The Pelly River floodplain ranges from just over 200 m at The Detour (Map 1787A), where a thick sequence of late-glacial sediments confines the channel, to more than 3.5 km at Safety Pin Bend (Map 1786A).

Sediments in channel bars and channel bottoms consist mainly of sand and gravel. Floodplains are generally underlain by sand and silt deposited during floods. Overbank areas can also contain minor amounts of nonalluvial deposits, such as lacustrine and organic sediments. Alluvial plains are subject to periodic flooding, and areas along active channels of rivers may be affected by ice-push during spring breakup.

Alluvial terrace (unit At)

Alluvial terrace sediments are 1–5 m thick and represent old river-channel deposits. They border all rivers and streams in the map area, but are best developed along the larger rivers (Fig. 6); on smaller rivers and streams, they are generally combined with the present floodplains as 'alluvial undivided' (unit Au). Alluvial terrace sediments generally consist of moderately stratified, well imbricated gravel, which either grades into, or is abruptly capped by, sand and silt.

Alluvial fan (unit Af)

Alluvial fan sediments are more than 2 m thick and can be considerably thicker. They are found throughout the map area but are especially common in mountainous areas. The steepest fans are dominated by debris flow and avalanche processes, while more gently sloping fans are dominated by fluvial deposition. Alluvial fans can coalesce, so that one map unit may comprise two or three individual fans. Both active and inactive alluvial fans occur. Paraglacial fans formed immediately after deglaciation when nonvegetated slopes were covered with abundant, unstable, unconsolidated material (cf. Church and Ryder, 1972). These fans are generally inactive now and have commonly been incised by a stream flowing across them (Fig. 19).

Steep alluvial fans are dominated by diamicton and poorly sorted gravel deposited by debris flows and avalanches. As the fan gradient decreases, the proportion of fluvial sediment increases and is represented by better sorted gravel with minor sand.

Alluvial undivided (unit Au)

Alluvial undivided sediments are thicker than 1 m. This unit was applied along streams and confined river valleys where it is not possible to separate the present floodplain from terraces and fans at the scale of mapping. Sediment types are similar to those found in alluvial plains, terraces, and fans, but the unit can contain significant amounts of colluvial sediment along valley sides in steep terrain.

Colluvial blanket (unit Cb) and colluvial veneer (unit Cv)

Colluvial blankets and veneers are greater than 1 m and less than 1 m thick, respectively. Although rare in the map area, they occur predominantly in alpine areas, commonly above the limit of McConnell Glaciation on slopes that are not steep or extensive enough to form colluvial aprons. They generally consist of solifluction lobes or other permafrost-related features, and are composed of stony diamicton or rubble.

Colluvial apron (unit Ca) and bouldery colluvial apron (unit bCa)

Colluvial apron sediments, up to 10 m thick, are very common in the map area, occurring on most sediment-covered slopes steeper than 20°. They commonly consist of till transported by colluvial processes. The diamicton is weakly stratified parallel to the slope and more porous than glacial diamicton; it may contain organic material and angular bedrock incorporated during downslope movement, and sorted material deposited by slope wash.

Bouldery colluvial apron sediments, up to 10 m thick, are the only map unit separated on the basis of texture. They occur exclusively in alpine areas, usually at the base of steep bedrock slopes mapped as unit R-A, and consist of blocks and rubble derived from local bedrock.

Eolian deposits (unit E)

Eolian deposits greater than 1 m thick are rare in the map area. An extensive field of presently stabilized and vegetated parabolic dunes occurs on the south-central edge of the area (Fig. 16; Map 1788A). Gently undulating eolian sand deposits are present on a glaciofluvial terrace along the Yukon River (Map 1788A). There are many cliff-top dunes above sections along streams and rivers, but these are too small to show on the maps.

Organic deposits (unit O)

Organic deposits range from 1 m to 5 m in thickness. They are common throughout the map area on low-lying or gently sloping surfaces such as floodplains, lake margins, shallow depressions, and some poorly drained slopes. Permafrost is very common in these deposits, as indicated by associated peat palsen and thermokarst lakes.

STRATIGRAPHY

The stratigraphic framework for glaciations in central Yukon Territory is described in the 'Regional Quaternary context' section. In summary, the stratigraphic framework is related to the McConnell, Reid, and pre-Reid glaciations, and the nonglacial intervals that separate them. Stratigraphic relationships and relative ages can be inferred from the spatial distribution of deposits of different glaciations; however, most of the stratigraphy reported here was obtained from natural sections along streams and rivers. The age of sediments underlying McConnell glacial deposits in these sections is difficult to determine because contacts are commonly erosive and because material suitable for dating is rare. The locations of sections from the Glenlyon map area are shown on the surficial geology maps (Maps 1786A–1789A), and exposures to the west of this area are shown in Figure 2.

Pre-Reid glaciations

Surficial deposits correlated with at least one of the pre-Reid glaciations are exposed at the surface in the western part of the map area (Maps 1786A, 1788A). They are characterized by a very subdued landscape, indicative of their antiquity. No deposits examined in sections were correlated with any of the pre-Reid glaciations.

Sediments predating the Reid Glaciation

The oldest sediments identified in section are units 1 and 2 at the Bradens Canyon section (Fig. 2, 24; Ward, 1989). This site is beyond the limit of the McConnell Glaciation but within the limit of the Reid Glaciation (Fig. 2).

Unit 1 is a moderately to poorly sorted, medium to coarse sand containing scattered pebbles and gravelly and silty lenses. It contains two large (up to 140 cm wide and >150 cm in depth), composite wedge casts (cf. French, 1976, p. 239), overlain by interstratified sand, gravel, and organic layers (Fig. 25A). There is no evidence of pedogenesis associated with any bedding surfaces in this unit (S. Smith, Agriculture Canada, pers. comm., 1991). The detrital organic layers yielded a radiocarbon age of greater than 41 000 BP (GSC-4510). Pollen recovered from these sediments is poorly preserved and consists mainly of indeterminate grains

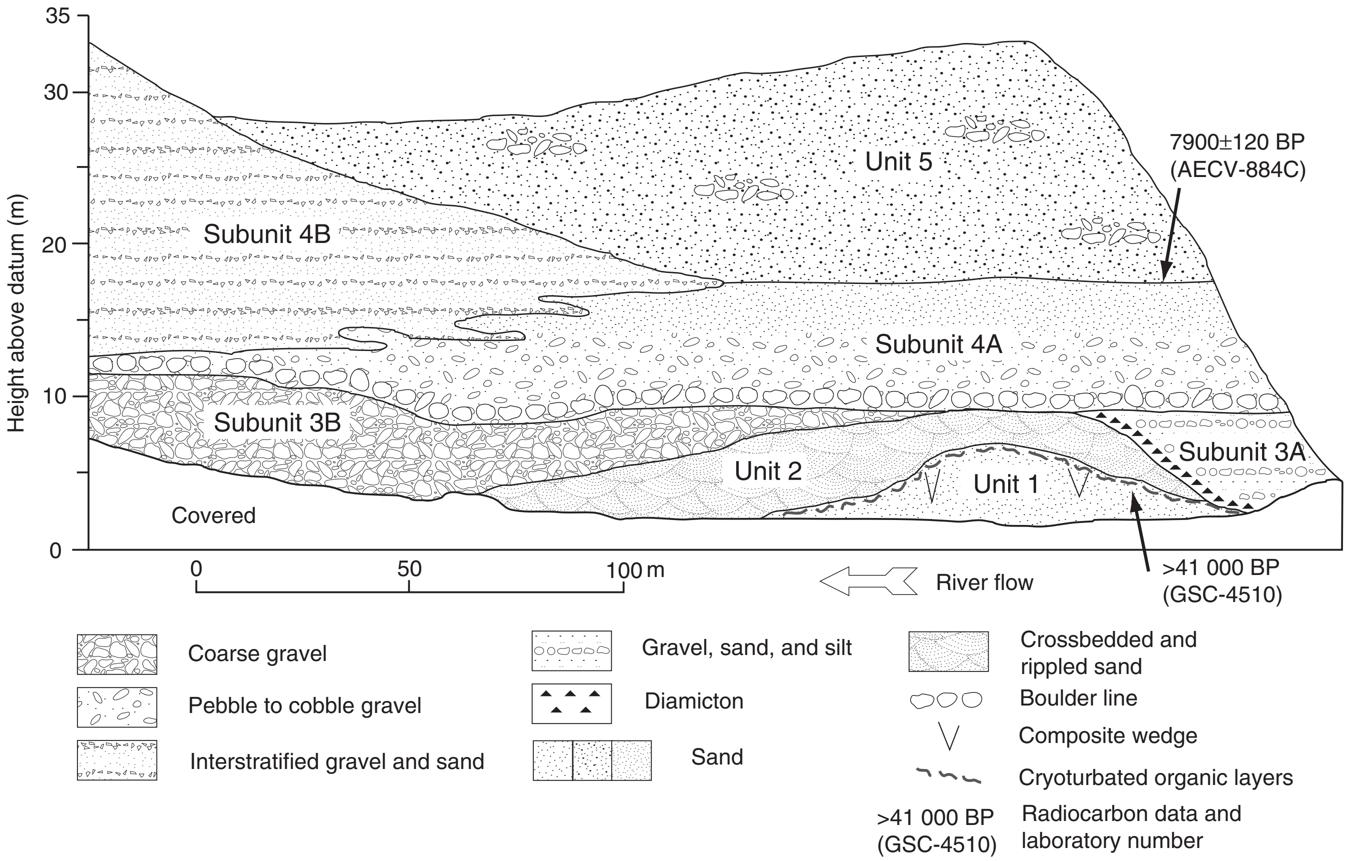


Figure 24. *Bradens Canyon section (*see *Figure 2 for location). Elevation datum is Pelly River.*

with minor amounts of *Picea* (spruce), *Betula* (birch), Chenopodiaceae (goosefoot), and Gramineae (grasses). Macrofossils, consisting mainly of small wood fragments and fungal sclerotia, are also poorly preserved and could not be identified. The organic deposits and associated mineral sediments are convoluted and cut by at least two small, composite wedge casts (Fig. 25B). Paleomagnetic data indicate that unit 1 was deposited during the Brunhes Normal Polarity Chron (Jackson et al., 1990).

Unit 2 consists of well stratified, ripple- and trough-crossbedded, fine to medium sand. The lower contact is sharp and erosive, truncating some of the organic layers in unit 1 and marked by a 2–9 cm thick pebble gravel layer. No obvious permafrost features or organic deposits were observed.

At the upstream end, units 1 and 2 are truncated by a thin diamicton (subunit 3A). Associated with this contact are drag folding and thrust faults, with organic deposits from unit 1 having been thrust over unit 2. The orientation of these folds and faults indicates deformation toward the west.

The units are interpreted to indicate the following sequence of events. Unit 1 was deposited by fluvial processes. Its upper surface was exposed during a periglacial climate, causing the development of the large composite wedges. Their large size suggests a considerable period of subaerial exposure (cf. French, 1976, p. 87). Floods deposited fine-grained detritus and organic material that were subsequently cryoturbated and cut by small composite wedges. Subaerial exposure is also indicated by the presence of fungal sclerotia (J. Matthews, Geological Survey of Canada, pers. comm., 1991); however, the climate was harsh enough that little or no pedogenesis took place. With the deposition of unit 2, river aggradation apparently was sufficiently rapid that permafrost did not have time to affect the unit. The thrust faults and folds are attributed to glacial deformation by a glacier flowing to the west (Ward, 1989). Based on the paleomagnetic data (Jackson et al., 1990) and the location of the section, Reid ice overran the two units and caused the deformation.

Reid Glaciation

Deposits of the Reid Glaciation are exposed at the surface at higher elevations and beyond the limit of the McConnell Glaciation. Reid deposits occur along the Pelly River, downstream from the McConnell limit, in sections including the Bradens Canyon, Pelly farm, and Granite Canyon sections, and at one site within the McConnell limit, the Lyon Creek section (stratigraphic section 8, Map 1789A).

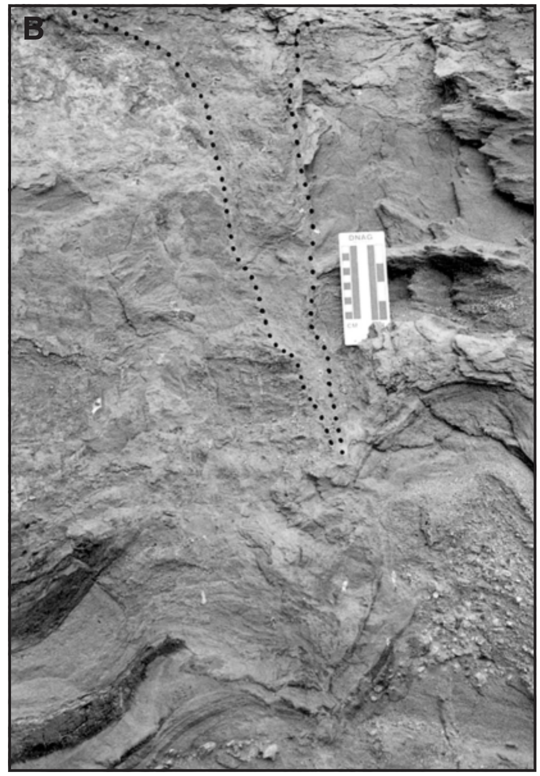


*Figure 25. Cryogenic features in unit 1 at the Bradens Canyon section: **A**) large composite wedge (outlined), overlain by cryoturbated organic layers (arrows), sand, and gravel; visible portion of the ice axe is 90 cm long; GSC 2000-037L; **B**) small composite wedge in the upper part of unit 1; GSC 2000-037M. Photographs by B. Ward.*

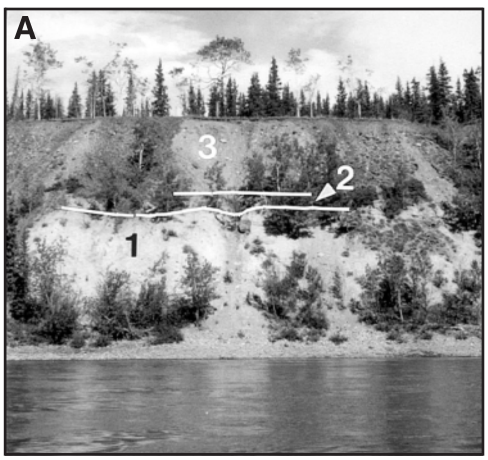
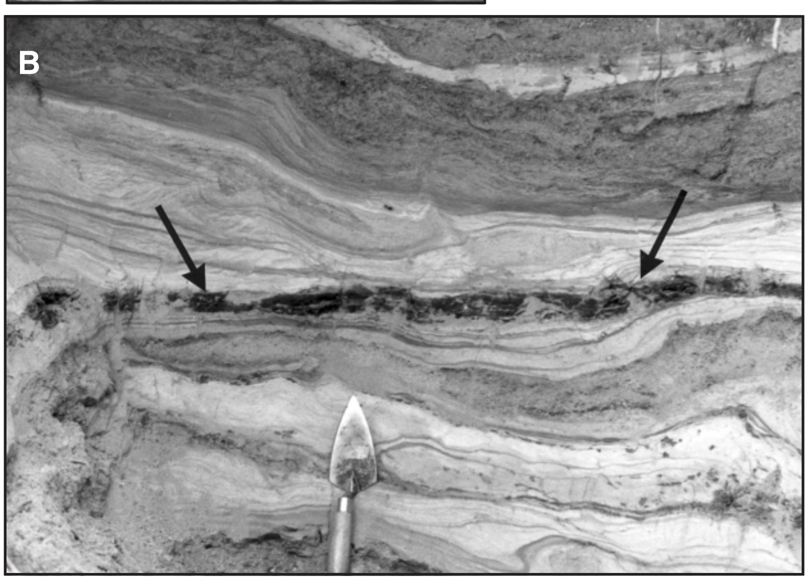


Figure 26.

*Granite Canyon section (see Fig. 2 for location): **A**) unit contacts are highlighted in the 29 m high section; GSC 2000-037N; **B**) detail of upper portion of unit 2 (arrows indicate the organic layer, RC-1); trowel is 25 cm long; GSC 2000-037O. Photographs by B. Ward.*



Bradens Canyon section

The deposition of unit 3 has been attributed to the Reid Glaciation. Unit 3 was divided into two subunits, based on inferred similar age. Subunit 3A consists of a thin diamicton overlain by interstratified sand, silt, and gravel (Fig. 24). The thin diamicton is interpreted as a till, based on its association with underlying glaciotectonic features; the overlying sand, silt, and gravel likely represent glaciolacustrine sedimentation (Ward, 1989). Subunit 3B consists of moderately stratified cobble and boulder gravel, and is interpreted as glaciofluvial. Units 4 and 5 are described in the 'McConnell glaciation' and 'Holocene' sections, respectively.

Granite Canyon section

Several exposures of silt and sand occur below gravel deposits of McConnell and Holocene age downstream of Granite Canyon, including a site at Granite Canyon. (Fig. 2, 26A). Unit 1 at the Granite Canyon section consists of approximately 15 m of thinly bedded to laminated, fine sand, silt, and minor clay. Based on the location, this unit is interpreted as Reid glaciolacustrine sediment deposited during deglaciation.

Pelly farm section

The Pelly farm section occurs in a high terrace, near the limit of the Reid Glaciation (Fig. 2, 27A), that has been mapped as Reid glaciofluvial (Klassen et al., 1987). Most of the section consists of a thick sequence of gravel with minor sand. A paleosol is developed at the top of this gravel sequence. The soil has a well developed Bm horizon, 10–15 cm thick, with hues of 7.5YR to 10YR. Some metamorphic and volcanic pebbles in the uppermost metre of the gravel unit show slight chemical weathering. Other clasts, including some sedimentary, are fractured, likely due to frost shattering, although no ice-wedge pseudomorphs were observed. This soil appears similar to the Diversion Creek paleosols (S. Smith, Agriculture Canada, pers. comm., 1991). Based on the composition of the sediments, the location, and the presence of a paleosol similar to the Diversion Creek paleosols, the section is interpreted as representing Reid glaciofluvial deposition.

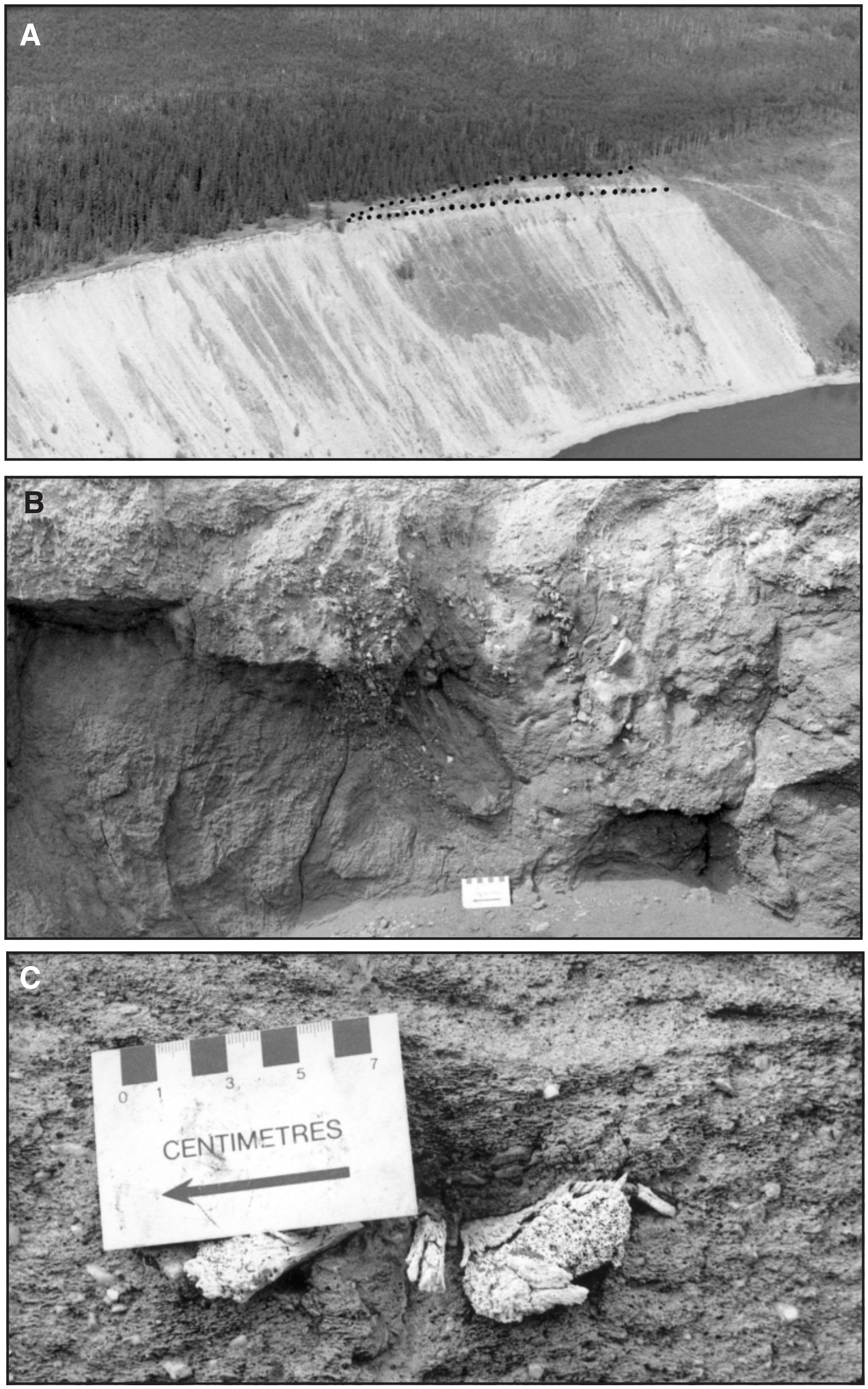


Figure 27.

***A**) Pelly farm section (*see *Fig. 2 for location): alluvial unit is outlined in the 75 m high section; GSC 2000-037P; **B**) detail of cryogenic features in alluvial unit (scale card is 9 cm); GSC 2000-037Q; **C**) detail of bones in alluvial unit. GSC 2000-037R. Photographs by B. Ward.*

Lyon Creek section

Deposits that have been tentatively assigned to the Reid Glaciation have been identified at Lyon Creek (stratigraphic section 8, Map 1789A), north of Drury Lake, well inside the limit of McConnell Glaciation (Fig. 2, 18). A brief description of the units at the Lyon Creek section is given in Figure 28. Subunit 1A (Fig. 29A) consists of well stratified silt and fine sand. Imprints of stems and leaves were found in the lower 5 m. Subunit 1B consists mainly of sand and gravel exhibiting large-scale foreset bedding (Fig. 29B), although the upper 4–5 m are highly disrupted and brecciated. More than 95% of the clasts in the gravel are granitic, many of these being weathered and some having disintegrated in situ (grus). The diamicton of unit 2 is dense and massive; clasts, although dominantly granitic, also include sedimentary and volcanic rock types. The clast fabric (F_1, S_1=0.5) appears random. The lower contact is irregular, with clastic dykes of diamicton and sorted sediment extending down, with a northwesterly dip, into unit 1 (Fig. 29C). Unit 3 consists of interstratified diamicton, gravel, and sand, and unit 4 is a coarse gravel. Unit 5 consists of dense, massive diamicton that forms the upland surface in the area (Fig. 18). A clast fabric from this diamicton has a pronounced clustering (F_2, S_1=0.75) oriented northwest-southeast. The lower contact of unit 5 is sharp and erosive, and truncates weathered pebbles and cobbles in unit 4.

Units 1 to 4 are interpreted to represent the following sequence of events during the Reid Glaciation, although, in the absence of dating control, an even older age is possible. Subunit 1B is interpreted as a deltaic sequence, deposited during advance in an ice-dammed lake in which subunit 1A was deposited. This lake was at least 62 m higher than the present Drury Lake. The clastic dykes at the base of unit 2 are interpreted as till wedges, and their orientation indicates glacier flow toward the northwest (cf. Aber et al., 1989). These wedges and the dense, massive nature of unit 2 suggest that it is a till; however, the weak strength of the fabric could indicate that it has been remobilized. Units 3 and 4 likely represent glaciolacustrine and glaciofluvial deglacial sedimentation, respectively. The highly weathered nature of the granitic boulders and the extensive iron staining indicate that these

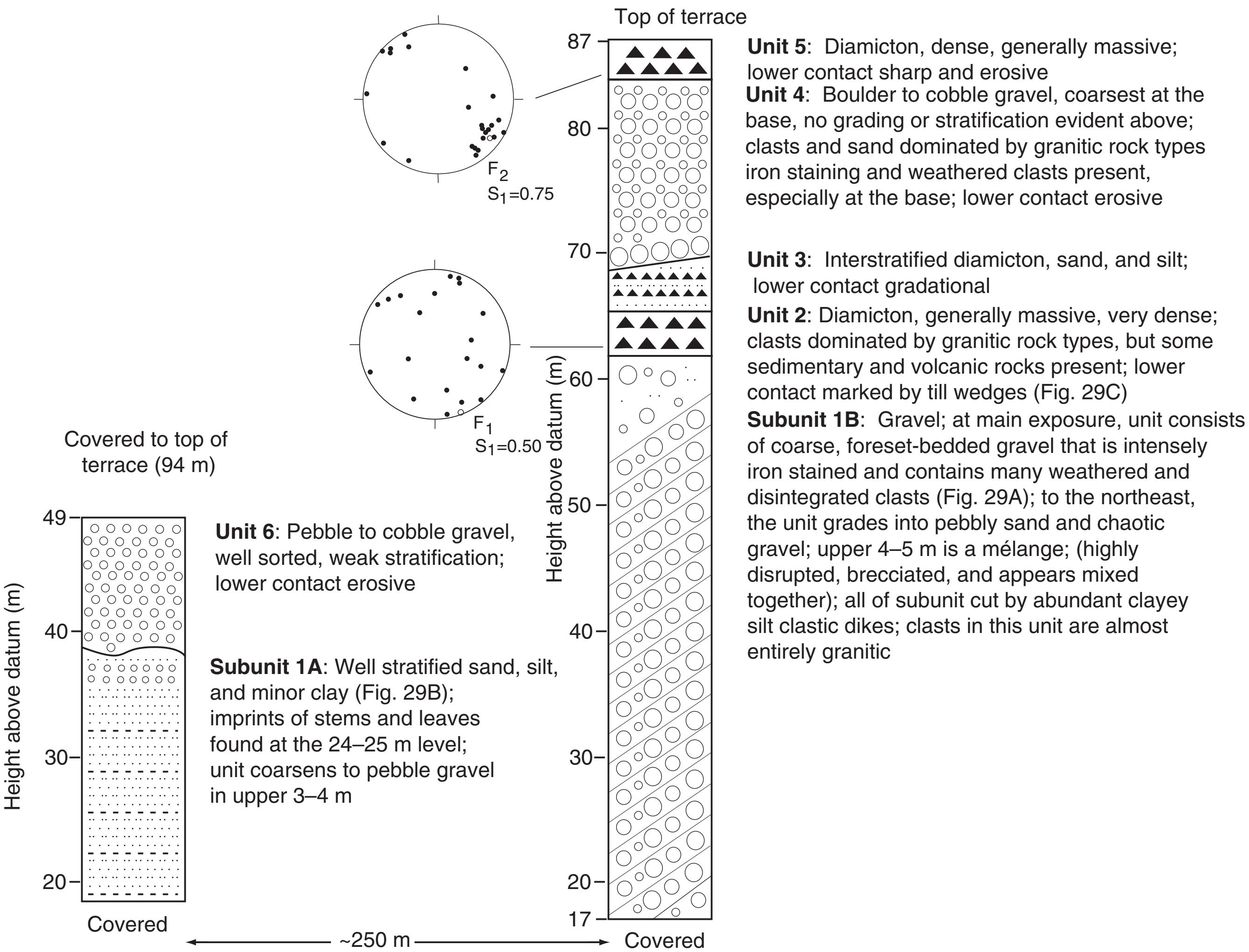


Figure 28. Lyon Creek section (stratigraphic section 8, Map 1789A; see *Fig. 2, 18 for location). Elevation datum is Drury Lake.*

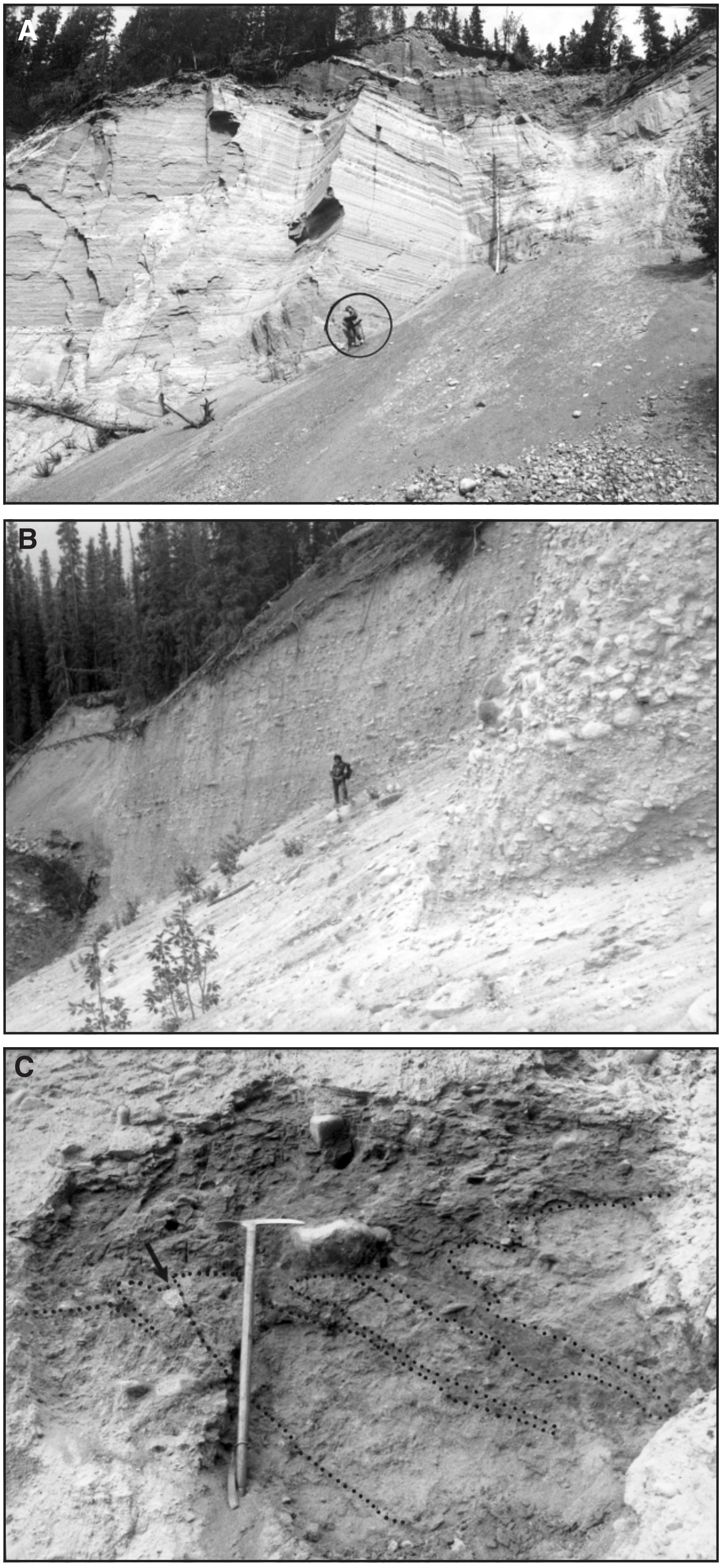


Figure 29.

Lyon Creek section (stratigraphic section 8, Map 1789A; see *Fig. 2, 18 for location):* ***A****) well stratified glaciolacustrine sediments (subunit 1A); scale provided by person (circled); GSC 2000-037S;* ***B****) large foreset beds (subunit 1B); GSC 2000-037T;* ***C****) detail of lower contact of unit 2, along which clastic dykes of diamicton and sorted material have been injected into underlying sediments; clast indicated by arrow has been fractured and infilled; ice axe is 90 cm long; GSC 2000-037U. Photographs by B. Ward.*

units are older than the McConnell Glaciation. There are differences in the degree of weathering between units 1 and 4; unit 1 has more extensive iron staining and contains more gravel clasts that have disintegrated in situ (grus). This could be caused by differences in groundwater flow or by a significant difference in the ages of the two units. Unit 5 is interpreted as till from the McConnell Glaciation, based on its stratigraphic and geomorphic position, the erosive lower contact, and the strong pebble fabric.

Koy–Yukon thermal event

No deposits attributed to the Koy–Yukon thermal event were identified in the study area. The truncated paleosol at the top of the Pelly farm section, however, appears similar to the Diversion Creek paleosols (S. Smith, Agriculture Canada, pers. comm., 1991), which likely formed during the last interglaciation (Tarnocai et al., 1985; Smith et al., 1986).

Table 6. Insect macrofossils identified from unit 2, Granite Canyon section (John Matthews, unpublished Geological Survey of Canada Fossil Arthropod Report 91-24, 1991).

Fossil classification	15789-RC-1	15789-M-7
TUBELLARIA – ('flatworms')	(?)Cocoons	
ARTHROPODA		
INSECTA		
HOMOPTERA		
Cicadellidae ('leafhoppers')		
(?)Genus	Head	
Fulgoridae ('planthoppers')		
(?)Genus	Heads	
COLEOPTERA – "beetles"		
Carrabidae ('ground beetles')		
Elaphrus lapponicus Gyll.	Pronota, elytra	
Bembidion morulum Lec.	Elytra, pronota	
Pterostichus (Cryobius) hudsonicus Lec.	Pronota	
Pterostichus (Cryobius) sp.	Elytra	
Dytiscidae ('predaceous diving beetles')		
(?)Genus	Elytra and pronota fragments	
Hydrophilidae ('water scavenger beetles')		
Hydrobius sp.	Head fragment	
(?)Genus		Thoracic fragment
Staphylinidae ('rove beetles')		
Olophrum rotundicolle (Sahlb.)	Elytra, pronota	
Olophrum latum Makl.	Pronota	
Holoboreaphilus nordenskioeldi (Makl.)	Cf. (elytron)	
Stenus sp.	Head, pronota	
Quedius sp.	Head, pronota	
Aleocharinae	Pronota, head	
Scarabaeidae ('scarab beetles')		
(?)Genus		Elytral fragment
Coccinellidae ('ladybird beetles')		
(?)Genus	Poorly preserved pronotum	
Chrysomelidae ('leaf beetles')		
(?)Genus	Elytral fragment	
Curculionidae ('weevils')		
(?)Genus	Leg	
Scolytidae ('bark beetles')		
Genus (several)	Heads, pronota, elytra	
DIPTERA ('flies')		
(?)Family	Puparial fragments	
HYMENOPTERA ('wasps and ants')		
Symphyta ('sawflies')		
Tenthredinidae	Head	
Apocrita		
(?)Genus	Head and propodeal fragment	
Formicidae ('ants')		
Formica typ.	Head	
ARACHNIDA		
Acari ('mites and ticks')		
Oribatei ('oribatid mites')		
(?)Family	Trace amounts	
Araneae ('spiders')		
(?)Family	Trace amounts	

Middle Wisconsinan interstade

Deposits that predate the McConnell Glaciation and postdate the Koy–Yukon thermal event are exposed at three sites (*see* Fig. 2 for locations): Granite Canyon, Pelly farm, and section 26 (stratigraphic section 13, Map 1787A).

Granite Canyon section

At the Granite Canyon section, glaciolacustrine sediments (unit 1) are overlain by 3.5 m of a fining-upward sequence of gravel, sand, and silt that dips gently toward the present river (unit 2) (Fig. 2, 26A). The upper approximately 1.5 m of unit 2 contains two organic layers and sand that is extensively iron stained (Fig. 26B). A bulk sample from the upper organic bed, bed RC-1, yielded a conventional radiocarbon age of 36 060 ± 2000 BP (AECV-1422C). Charcoal from the sand bed immediately below gave an accelerator radiocarbon age of 37 120 ± 350 BP (TO-1278). This upper organic layer, bed RC-1, contains abundant insect macrofossils (Table 6), and both beds RC-1 and M-7, approximately 1 m below bed RC-1, contain abundant pollen (Table 7). Unit 2 is truncated by the coarse gravel of unit 3, interpreted to have been deposited by a catastrophic flood that occurred during McConnell deglaciation (Lye et al., 1990).

Unit 2 is interpreted as a Middle Wisconsinan alluvial deposit, based on the radiocarbon ages and its stratigraphic position below McConnell gravel. A cautionary note is required about the radiocarbon ages, since the ages obtained are close to the radiocarbon dating limit. These ages could be minima and the sediments could predate the Middle Wisconsinan; however, a Middle Wisconsinan age is currently thought to be the most likely interpretation.

The insect macrofossils and pollen allow for paleoenvironmental reconstruction. The insect assemblage includes several genera of bark beetles and planthoppers, suggesting the presence of forest, although plant macrofossils are lacking. Also, the ground beetles present in the assemblage are found south of treeline, and ants extend only slightly beyond the treeline today. As well, the sample lacks fossils that are found only in tundra regions. The pollen assemblages of samples RC-1 and M-7 are dominated by *Picea* (spruce), which also indicates forested conditions, likely a boggy/muskeg community consisting of *Picea mariana* (black spruce) and Cyperaceae (sedge) according to H. Friebe (University of Alberta, per. comm., 1991). These data therefore indicate forested conditions during the Middle Wisconsinan in the Pelly River basin.

Table 7. Pollen data for unit 2, Granite Canyon section (identified and interpreted by H. Friebe, University of Alberta, pers. comm., 1991).

Pollen classification	RC-1	M-7
Picea (spruce)	66.4%	82.8%
Cyperacea (sedge)	29.9%	8.2%
Salix (willow)		4.7%
Graminea (grasses)	2.1%	1.3%
Betula (birch)	0.4%	0.9%
Valerianacea (Valerian)		1.7%
Ericaceae (heather)		0.4%
Compositeae	1.2%	
Number of grains counted (n)	241	232

Pelly farm section

The Pelly farm section (Fig. 2) is capped by a wedge of disturbed, pebbly sand that covers the Koy–Yukon thermal event paleosol at the upstream end of the section (Fig. 27A). This wedge of sediment forms a fan-like feature. The disturbances of the sediment include warped strata and vertically oriented, wedge-shaped inclusions of pebbles (Fig. 27B). Fragmented bones of a large ungulate (Fig. 27C), possibly *Bison* sp. (C.R. Harington, National Museum of Canada, pers. comm., 1987) were recovered from these sediments. This wedge of disturbed, pebbly sand is sharply overlain by massive, very fine sand and silt, with ventifact (sandblasted) pebbles occurring along the contact. These deposits are interpreted as loess.

This deposit is interpreted as an alluvial fan deposited after the Koy–Yukon thermal event and before the McConnell Glaciation. This interpretation is based on the morphology of the deposit, its stratigraphic position above the paleosol, the wedge-shaped disturbances, and the ventifacts along the upper contact. The wedge-shaped disturbances are interpreted to be cryogenic structures, the ventifact pebbles are interpreted as representing eolian erosion, possibly by katabatic winds, and both are thought to have formed during the McConnell Glaciation. Thus, the sediments were deposited sometime during the Wisconsinan, either before or during the initiation of the McConnell Glaciation.

Section 26

Section 26 (stratigraphic section 13, Map 1787A; Ward, 1989) occurs well within the McConnell limit (Fig. 2). Units 1 to 4 underlie the McConnell succession (Fig. 30). Units 1 and 2 were only exposed in an excavation at the downstream end of the section. Unit 1 consists of gravel, sand, and minor silt, and unit 2 consists of a stony diamicton with some striated clasts. Unit 3 is a well stratified, cobble to pebble gravel that generally fines upward. Unit 4 consists of a thick sequence of sand with minor gravel. Some of the sand contains trough crossbeds that indicate flow generally downvalley. Poorly preserved detrital wood was found in the sand, but there was insufficient carbon for a radiocarbon date. A silt and clay subunit occurs near the top of the unit.

Based on stratigraphic position, units 1 to 4 predate the McConnell Glaciation. Interpretation of units 1 and 2 is problematic because their lateral extent in unknown. The striated clasts in unit 2 suggest a glacial origin, but the unit could be reworked from an older glacial deposit. Unit 3 is interpreted as interstadial fluvial gravel, based on its stratified nature and stratigraphic position. The thick sand of unit 4 provides evidence of river aggradation, likely as McConnell glaciers advanced into the area. The fine sand and silt layer near the top of the sand represent a ponding event before the site was overrun by the ice. This ponding event has been interpreted as the result of ice advancing down the Macmillan River valley and blocking the Pelly River (Ward, 1989).

McConnell Glaciation

Deposits of the McConnell Glaciation occur throughout the study area. Although most of these sediments were deposited during deglaciation, some were deposited during the advance; examples of the latter include stratigraphic section 5 on Map 1787A, the Safety Pin Bend section (stratigraphic section 8, Map 1786A), section 26 (stratigraphic section 13, Map 1787A), and the Bradens Canyon section (*see* Fig. 2 for locations).

Two glaciolacustrine units separated by a till are exposed along Little Sheep Creek in the Glenlyon Range (Fig. 2, 31; stratigraphic section 5, Map 1787A). The lower glaciolacustrine unit (unit 1) was deposited when the Selwyn Lobe in the Tintina Trench blocked the drainage, forming a glacial

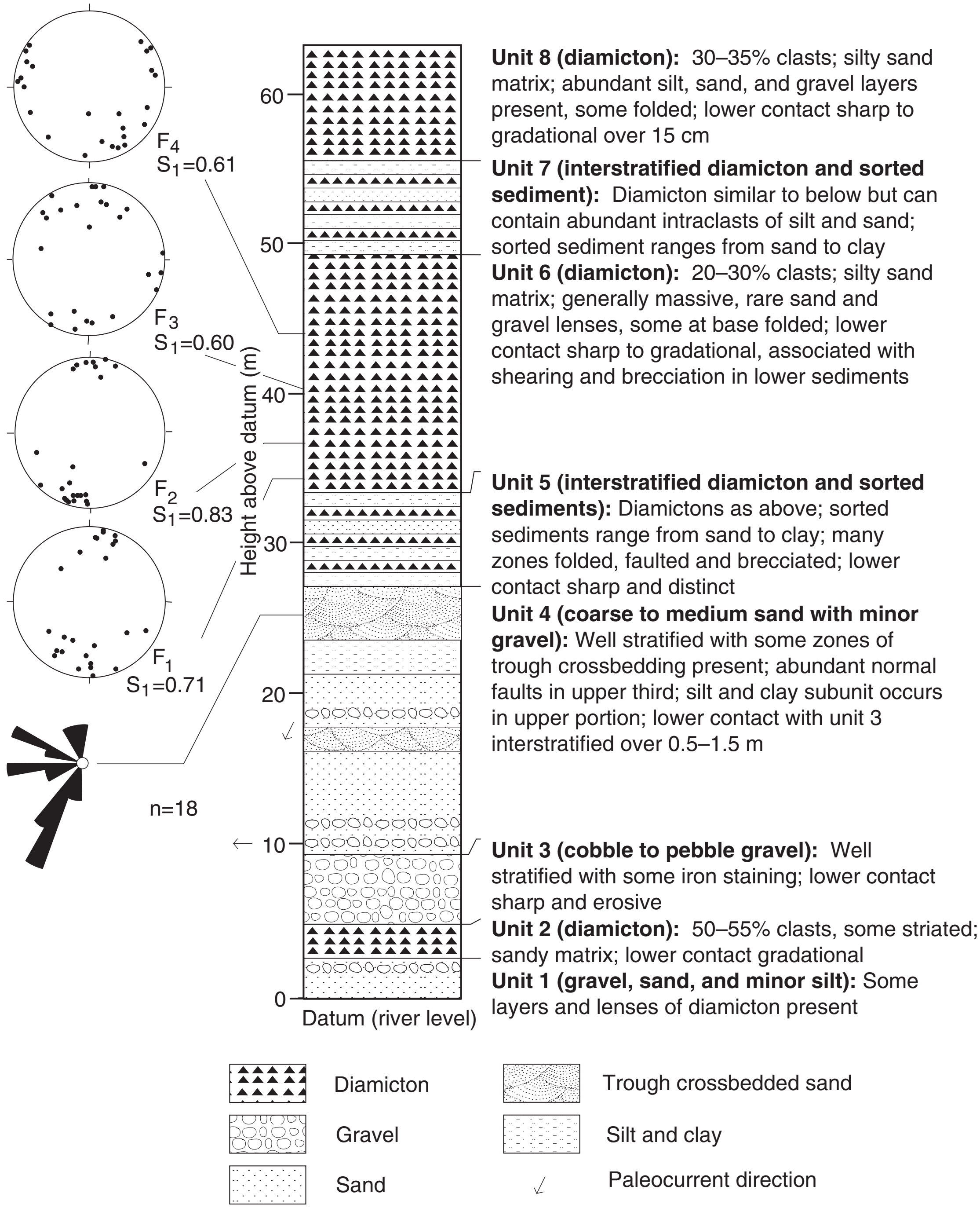


Figure 30. *Section 26 (*see *Fig 2 for location); stereonets are for fabric data from unit 6 and rose diagram is for current indicators from unit 4.*

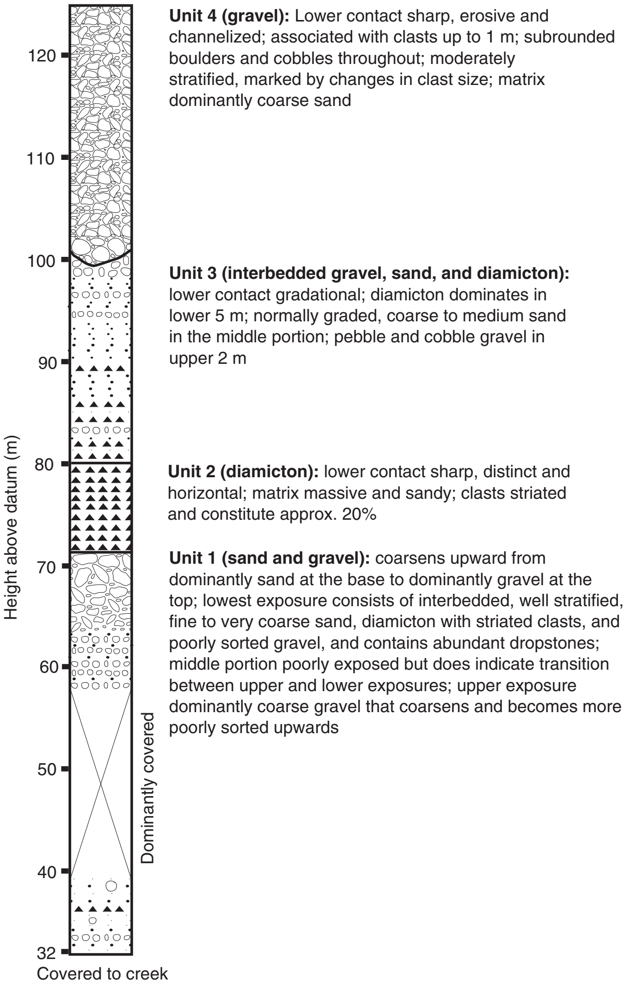


Figure 31. *Stratigraphic section (section 5, Map 1787A) along Little Sheep Creek.*

lake. The site was later covered by ice that deposited a till (unit 2). During deglaciation, ice persisted in the Tintina Trench after Little Sheep Creek was deglaciated, forming a second glacial lake (unit 3). Unit 4 represents glaciofluvial gravel deposited after this lake drained.

Stratigraphic section 8 (Map 1786A), located at Safety Pin Bend on the Pelly River, exposes five units, including two tills separated by thick stratified sediments (Fig. 32; Ward, 1989). Unit 1 consists of interstratified sand and gravel that are poorly exposed. Unit 2 is a thick (17 m) diamicton with a sharp, approximately planar lower contact. It contains striated and faceted clasts whose compositions are dominated by igneous and sedimentary rocks, indicating provenance to the north or northeast (Campbell, 1967, Map 1221A). The lower 5 m is dominantly massive with only occasional sand and silt layers present. Upward, the diamicton becomes more stratified, generally on the 5–50 cm scale, with sand and silt layers being present. Two pebble fabrics taken from the lower 1 m are strong (principal eigenvalues, 0.774 and 0.822) and have principal eigenvectors to the south at a low plunge (183° at 8°, and 181° at 12°).

Unit 3 is a thick (40 m), complex mélange of diamicton, gravel, sand, and silt. Soft-sediment deformation structures, such as convolute bedding and loading structures, are common. The unit fines upward from dominantly diamicton and cobble gravel to dominantly sand and pebble gravel. Unit 4 is a coarsening-upward sequence from fine and medium sand to cobble gravel. The dip increases upward from subhorizontal to approximately 10° to the south. The lower contact is gradational over 1–2 m. Unit 5 is a diamicton that is dense and partially cemented by $CaCO_3$. It has a sharp, generally planar lower contact that truncates cross-strata in unit 4. Clasts in this diamicton are striated and faceted, and some are flat-iron shaped. Pebble compositions are similar to those of unit 1, indicating a source in the Macmillan River drainage. This diamicton forms the upland surface that has northeast-trending drumlins on it. Extending from the diamicton into unit 4 is a sorted dyke, 40–80 cm wide and greater than 4 m

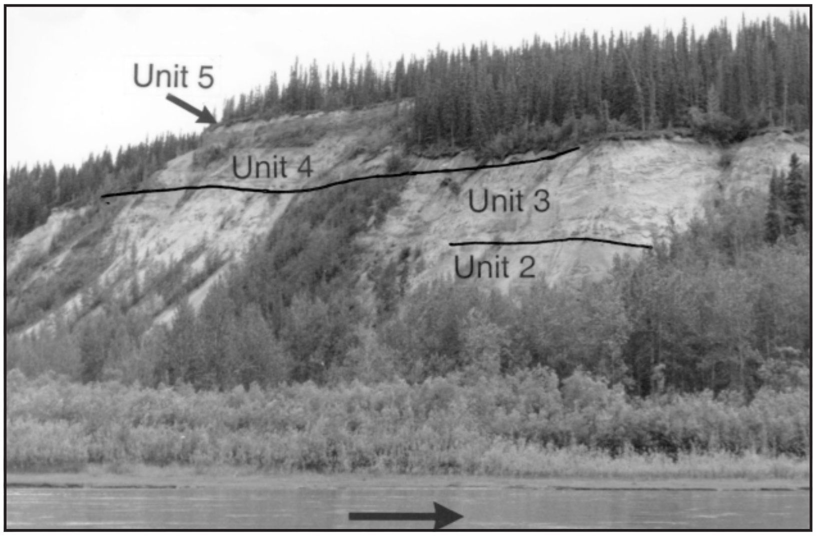


Figure 32.

View looking west at the Safety Pin Bend section (stratigraphic section 8, Map 1786A); units 2 and 5 are diamictons interpreted as tills; upper surface is 120 m above the river; arrow indicates river flow. Photograph by B. Ward. GSC 2000-037V long, composed of laminated to finely bedded diamicton, sand, and pebbly sand and silt (Fig. 33, 34). It strikes 115° and is nearly vertical.

Unit 1 likely represents glacial-advance sediments, deposited either as outwash or in a glacial lake. Unit 2 is interpreted as a till, based on its striated and faceted clasts, dense massive nature, and strong pebble fabrics. It indicates flow from the north along the Macmillan River valley. Unit 3 represents a deglacial sequence into a glacial lake. Unit 4 is interpreted as a glacial-advance sequence. The diamicton of unit 5 is also interpreted as a basal till and indicates flow from the Macmillan River drainage. The sorted dyke (Fig. 33, 34) is interpreted as forming subglacially, injected downward into unit 4. It is also oriented approximately perpendicular to glacier flow.

The Safety Pin Bend section is thought to represent deposits of McConnell age, based on stratigraphic position and relationship to geomorphic features. The gradational contact between units 3 and 4 is not thought to represent a major unconformity. Thus, the Safety Pin bend section is interpreted as depicting two distinct phases of the McConnell Glaciation, representing a significant oscillation of the ice front. The fact that unit 5 forms the upland topography characterized by drumlins, which likely formed during the McConnell maximum, suggests that this oscillation of the ice front occurred during advance rather than during retreat.

Figure 33. *Unit 5 and upper portion of unit 4 at Safety Pin Bend section (stratigraphic section 8, Map 1786A), with a large clastic dyke extending from unit 5 down into unit 4; ice axe is 90 cm long. Photograph by B. Ward. GSC 2000-037W*

Figure 34. *Detail of clastic dyke at Safety Pin Bend section (stratigraphic section 8, Map 1786A), showing stratification of diamicton and sorted layers; ice axe is 90 cm long. Photograph by B. Ward. GSC 2000-037X*

Subunits 4A and B at the Bradens Canyon section (Fig. 2, 24) were deposited during the McConnell Glaciation (Ward, 1989). They were subdivided because the sediment types are significantly different, but they are thought to represent deposition during the same time period. Subunit 4A has a lower contact marked by a boulder line and consists of an overall fining-upward sequence from cobble gravel to sand and silt. The elevation of the upper contact corresponds well to the gradient of McConnell terraces measured between Bradens Canyon and the McConnell limit at Granite Canyon. Subunit 4B consists of interstratified, poorly sorted gravel and sand with minor diamicton, the stratification dipping toward the river. The contact between the two subunits is interfingering and the upper surfaces of both are marked by a weak Brunisolic paleosol. Peat layers associated with this paleosol at its lowest elevation yielded a radiocarbon age of 7900 ± 120 BP (AECV-884C). Subunit 4A is interpreted as distal outwash deposited from the maximum ice-front position at Granite Canyon, based on the elevation of its upper surface, the presence of the paleosol, and the radiocarbon age. Subunit 4B is a coeval alluvial fan that prograded into the river that deposited subunit 4A.

McConnell deglaciation

Although the Cordilleran Ice Sheet rapidly downwasted and stagnated during deglaciation (Jackson, 1994), there is evidence for at least one minor readvance. Sediments at stratigraphic sections 6 and 7 on Map 1789A (Fig. 35) indicate a minor readvance during deglaciation that is described in more detail in Ward (1993). These sections, with two tills separated by stratified sediments, indicate a fluctuating ice front within the Tintina Trench. Clast composition suggests that the till of unit 1 at section 6 represents ice flow along the Glenlyon River valley. The subsequent readvance was from ice that flowed down the Tintina Trench rather than the Glenlyon River valley. If the till of unit 4 at both sections represents the same event, it indicates a readvance of at least 3 km. These two sections are thought to represent an oscillation of the ice front during deglaciation, rather than during advance as was the case at the Safety Pin Bend section. This conclusion is based on the location of these two tills relative to other tills thought to represent the maximum of the McConnell Glaciation.

Most of the thick valley-fill sequences in the area were deposited during deglaciation. Detailed sedimentological analysis of McConnell deglacial sediments exposed along the Pelly River and lower reaches of the Macmillan River was undertaken to determine their pattern and character (*see* Ward (1993) and Ward and Rutter (2000) for a more detailed description). Extensive glacial lakes existed in other parts of the Glenlyon map area during deglaciation, but their study was hindered by the lack of exposures and access. The approximate aerial distribution of deglacial lakes along the Pelly River was determined by airphoto interpretation and the distribution of sediments (Fig. 36). Areas with a surface expression of interlocking crevasse-fill ridges and esker-like features are interpreted as representing subaerially exposed

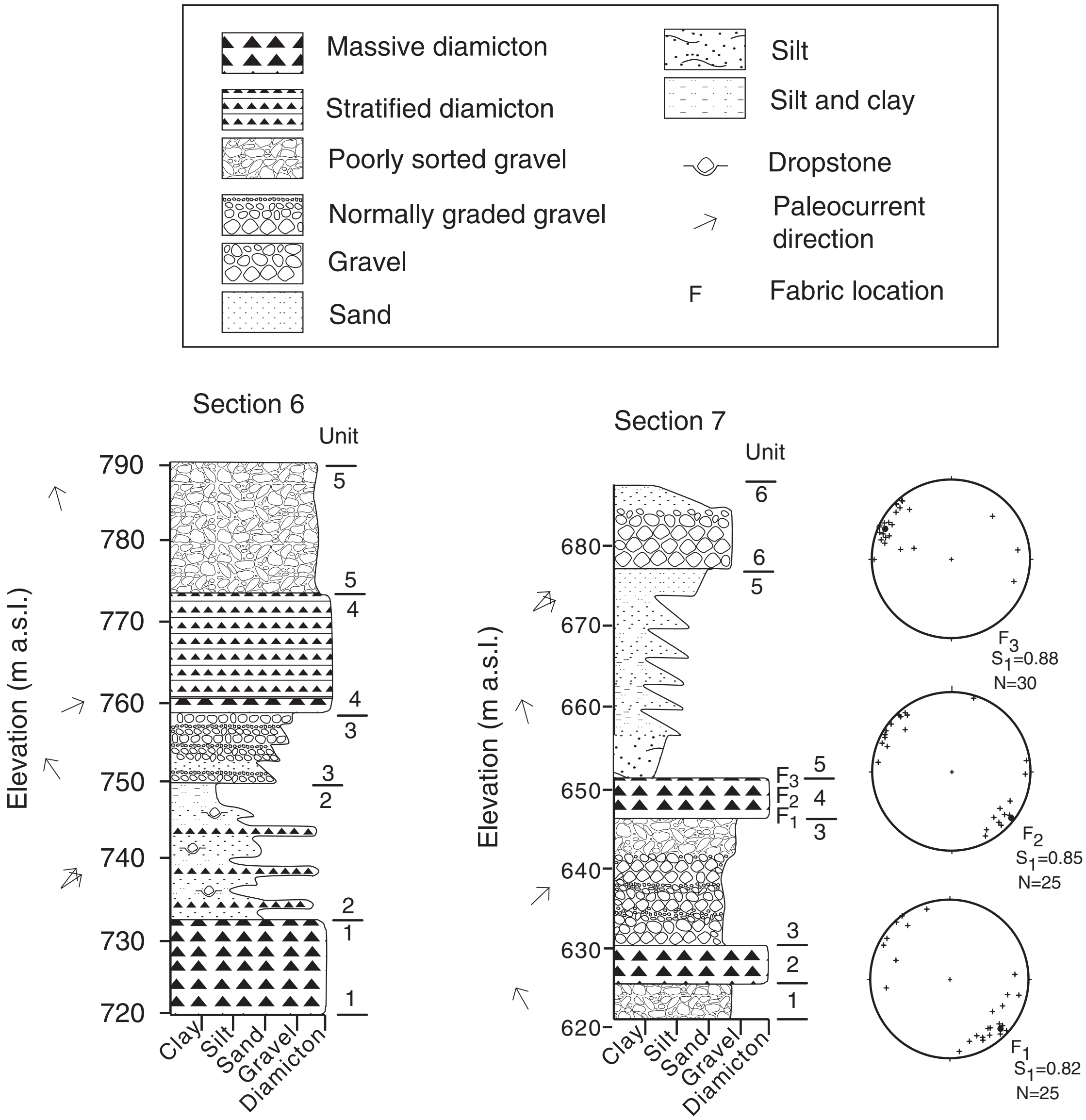


Figure 35. *Stratigraphic sections 6 and 7, Map 1789A; note elevation difference between sections.*

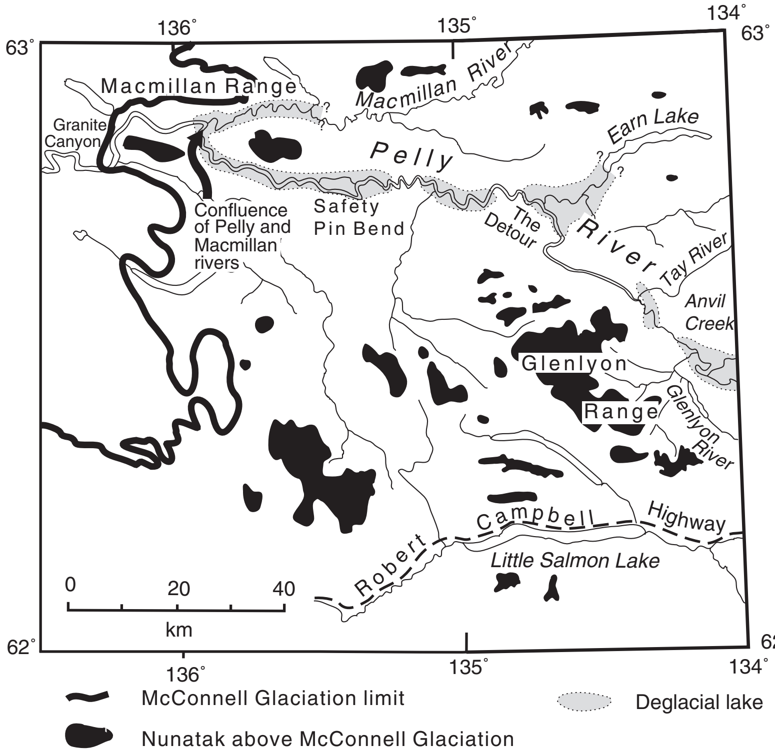


Figure 36.

Location of deglacial lakes along the Pelly River.

stagnant ice, which likely acted as dams for lakes. The measured sections on Maps 1786A, 1787A, and 1789A contain brief descriptions of these sediments.

Sediments were grouped into facies, and depositional environments were reconstructed to explain Late Wisconsinan deposition in the Pelly River valley. The distribution of sediment reflects control by several systems: 1) till deposited under ice, 2) diamicton deposited by debris flows in glacial lakes, 3) sorted sediment deposited by meltwater streams, and 4) sediment remobilized and deformed by the melting of underlying ice. A series of lake basins was present, separated by bedrock highs and stagnant ice. Sediments in these lake basins display an overall transition in grain size from coarser material adjacent to the Glenlyon Range to finer material within the area of the Yukon Plateaus. This transition is probably controlled by the amount of glacial material available from adjacent slopes for resedimentation. Adjacent to the steep slopes of the Macmillan Range at the confluence of the Pelly and Macmillan rivers, the low elevation of the glacial limit reduced sediment availability. This resulted in a fining-upward sequence being deposited in association with ice retreat.

Figure 37 shows the complex situation adjacent to the Glenlyon Range, where sediments are coarser grained. The importance of resedimented material is demonstrated by the abundant slope failures into the lake. Lateral meltwater streams, sub- and englacial streams, side valleys, and gully erosion provided gravel, sand, and silt for sedimentation. The presence of large thicknesses of highly disturbed sediments (Fig. 13) indicates that sediments were deposited onto ice and subsequently slumped and failed. Undisturbed glaciolacustrine sediments were either deposited in more distal parts of the basin or after most of the ice had ablated. The abundance of deformed sediment indicates that the style of deglaciation was by regional stagnation. A more orderly retreat of the ice sheet would have resulted in a simpler sequence of sediments, namely till overlain by outwash.

The extensive occurrence of disturbed glaciolacustrine sediment indicates deposition in supraglacial lakes. Melting of supporting ice caused sediments to be remobilized into slump and slide deposits, and others to be tilted, folded, and faulted (Fig. 13C–F).

Holocene

Holocene deposits, which occur throughout the map area, consist of colluvial deposits along present slopes, alluvial deposits along present streams and rivers, organic deposits in low-lying areas, and eolian deposits. Holocene deposits are present at the tops of some sections. For example, unit 5 at the Bradens Canyon section (Fig. 2, 24) consists mainly of sand with occasional gravelly lenses. It is interpreted as having been deposited by a low-gradient alluvial fan, sometime after 7900 ± 120 BP (AECV-884C). The White River tephra (ca. 1250 BP) was observed over the southern three-quarters of the map area. Along the Pelly River, it thinned rapidly downstream of Safety Pin Bend and was not observed from the confluence of the Pelly and Macmillan Rivers to the Pelly farm section.

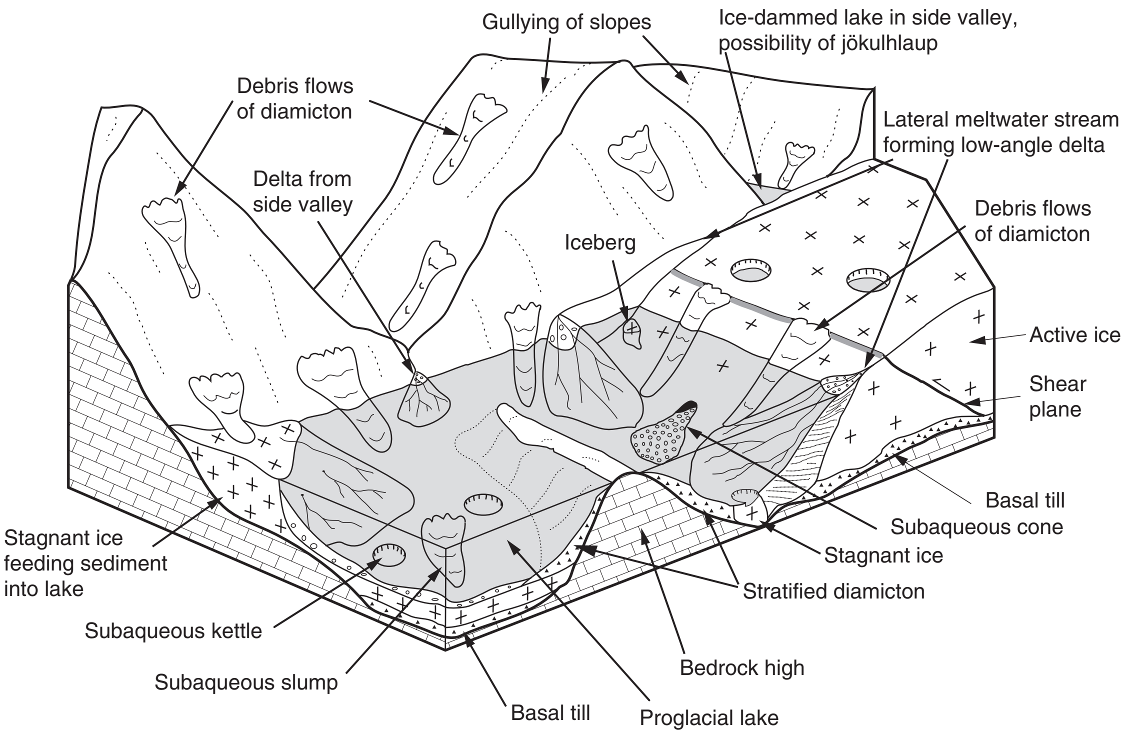


Figure 37. *Proposed depositional environment of lakes adjacent to the Glenlyon Range.*

QUATERNARY HISTORY

The landscape of the Glenlyon map area formed in response to geological events in the Tertiary and has subsequently been modified by Quaternary glaciations. The Pleistocene included nonglacial periods, during which conditions were broadly similar to the present, and glacial periods, when conditions were colder than today and glaciers covered much of southern and central Yukon Territory.

Pre-Reid glaciations

Pre-Reid deposits in central Yukon Territory are Early Pleistocene (Jackson et al., 1990, 1996). Little is known of conditions during these glaciations, but it can be assumed that ice originated from similar sources and had similar flow directions as during younger glaciations. The greater extent of ice cover during these early glaciations, compared to the Reid and McConnell glaciations (Fig. 1), may have been caused by greater precipitation in the source areas of the Selwyn, Pelly, and Cassiar mountains. This, in turn, may have been due to the lower elevations of the St. Elias Mountains during the Early Pleistocene (Jackson et al., 1991).

There is uncertainty about the number of pre-Reid glaciations. At least two occurred in the Fort Selkirk area of central Yukon Territory (Jackson et al., 1990, 1996). Paleomagnetic studies, together with K-Ar dates on interstratified basalt units and isothermal-plateau fission-track ages on the Fort Selkirk tephra, indicate a middle Matuyama age of between 1.6 ± 0.19 Ma and 1.19 ± 0.11 Ma for the older pre-Reid glaciation (Jackson et al., 1996). The younger pre-Reid glaciation occurred in the late Matuyama between 0.99 Ma and 0.78 Ma. It has also been proposed that there were possibly three pre-Reid glaciations that affected central Yukon Territory, but absolute ages were not determined (Tarnocai and Schweger, 1991). Three pre-Reid glaciations have been reported from the Liard Plain of southwestern Yukon Territory (Klassen, 1987); these are younger than the pre-Reid glaciations of central Yukon Territory (Jackson et al., 1991). There have been at least four pre-Reid glaciations in the Mackenzie Mountains of the Northwest Territories (Tarnocai and Schweger, 1991).

Pre-Reid glaciers likely covered most, if not all, of the peaks in the Glenlyon Range and the lower hills in the western portion of the map area. The presence of highly weathered bedrock in the Glenlyon Range (Fig. 23) can be explained by the great antiquity of the pre-Reid glaciations: almost one million years separated the youngest pre-Reid and the Reid glaciations.

Pre-Reid interglaciations

Most of the data on pre-Reid interglaciations comes from paleosols developed on glacial deposits of pre-Reid age. Wounded Moose paleosols (Tarnocai et al., 1985; Smith et al., 1986) are found on pre-Reid glacial deposits in the Stewart River valley. This soil may be the product of pedogenesis during several interglaciations. The presence of montmorillonite indicates an initial period of warm subhumid climate with grassland shrub vegetation (Foscolos et al., 1977; Rutter et al., 1978). Later, the climate was more temperate and humid, causing the montmorillonite to degrade to kaolinite. The presence of in situ hematite indicates a mean air temperature of at least 7°C and annual precipitation of 500 mm (Tarnocai and Schweger, 1991). Paleosols developed on mountain tills in the Little Bear River section in the Mackenzie Mountains to the east and on colluvial sediments in the Dawson Range to the southwest also indicate warmer-than-present climates during pre-Reid interglaciations (Tarnocai and Schweger, 1991; Jackson et al., 2000).

Reid Glaciation

Landforms of the Reid Glaciation are relatively well preserved, allowing accurate determination of the Reid glacial limit (Fig. 1, 2; Hughes et al., 1969). Drumlins and flutings beyond the limit of the McConnell Glaciation indicate that a similar pattern of flow prevailed during the Reid and McConnell glaciations, implying similar source areas. Unit 1 at Bradens Canyon indicates that climatic conditions were severe before the site was overrun by Reid ice.

Sediments deposited at the end of the Reid Glaciation have not been extensively studied. The thick sequence of gravel at the upstream end of the Pelly farm section was likely deposited as outwash during the initial stages of deglaciation. The presence of abundant Reid glaciolacustrine sediments along the lower reaches of the Pelly River implies that regional deglaciation could have been similar to that of the McConnell Glaciation.

Post-Reid Glaciation to pre-Koy–Yukon thermal event

The Ash Bend section on the Stewart River was mentioned in the 'Regional Quaternary context' section because it contains the Sheep Creek tephra, which provides a minimum date on the Reid Glaciation (Table 2), and the section also yields paleoclimatic information. The section has been described in detail by Hughes et al. (1987), Schweger and Matthews (1991), and Clague et al. (1992). A thick sequence of organic-rich silt, containing wood, minor peat, mammal bones, and the tephra, infills a gully incised into Reid glaciofluvial gravel. Analysis of plant and insect macrofossils and pollen below and above the tephra indicates an upward transition from boreal forest to arid tundra conditions. Based on the stratigraphic position of the boreal forest fossils below the Sheep Creek tephra, they could correspond to isotope events 7.1 or 7.3 (C. Schweger, University of Alberta, pers. comm., 1992), which have ages of 0.193 Ma and 0.220 Ma, respectively (Martinson et al., 1987).

Koy–Yukon thermal event

During this interglaciation, Diversion Creek paleosols formed on deposits of the Reid Glaciation (Tarnocai et al., 1985; Smith et al., 1986). A soil correlated with the Diversion Creek paleosol occurs at the Pelly farm section. Based on a comparison with soils forming at present, the Diversion Creek paleosols indicate a climate approximately 1°C warmer and slightly more humid than at present (Tarnocai, 1990).

Other interglacial sites in Yukon Territory indicate that conditions were warmer than at present during the Koy–Yukon thermal event. At Ch'ijee's bluff in northern Yukon Territory, a complex of interstratified fluvial, lacustrine, and organic deposits, which contains Old Crow tephra, has provided abundant paleoecological information, indicating that conditions were warmer during the Koy–Yukon thermal event than at present (Matthews et al., 1990b).

Middle Wisconsinan interstade

Several Middle Wisconsinan sites have been reported from central Yukon Territory. The most important of these are the Mayo and Mayo Indian village sections (Matthews et al., 1990a), the Ketza River site (Jackson and Harington, 1991), and the Granite Canyon section (reported here).

The Mayo and Mayo Indian village sections are located along the Stewart River just downstream from Mayo (Matthews et al., 1990a). Plant and insect macrofossils and pollen from these sections, supported by radiocarbon ages, allow a reconstruction of conditions from the Middle Wisconsinan to the beginning of the McConnell Glaciation. Spruce forest existed in this area at 38 100 ± 1330 BP (GSC-4554), but the vegetation had changed to xeric tundra by 29 600 ± 300 BP (TO-292). Sedimentological studies indicate that the Stewart River had changed from a wandering to a more braided planform over this time period (T. Giles, University of Alberta, pers. comm., 1992). These data indicate climatic deterioration and possibly the advance of McConnell ice into the area.

The Ketza River site, located southwest of the Glenlyon map area, 30 km southeast of Ross River, has yielded abundant mammal remains that include *Mammuthus* sp., *Equus lambei, Bison* sp., and *Lepus* sp. (Jackson and Harington, 1991). The mammal assemblage indicates a dry-steppe grassland environment. The assemblage can be assigned to the Middle Wisconsinan, based on a radiocarbon age of 26 350 ± 280 BP (TO-393). This age is also a maximum for the advance of McConnell ice into the area.

The Granite Canyon section (*see* 'Middle Wisconsinan interstade' in 'Stratigraphy' section) confirms the presence of spruce forest in the region 36 000–37 000 years ago, as indicated by the Mayo section.

McConnell Glaciation

Onset of the McConnell Glaciation

Little is known of the pattern of ice flow during the early phase of the McConnell Glaciation. Precipitation patterns similar to those at present apparently controlled glacier growth (Jackson et al., 1991). The present 600 mm isohyet conforms closely to the source areas of the Cordilleran Ice Sheet (Fig. 38). Initiation likely followed the model of Davis

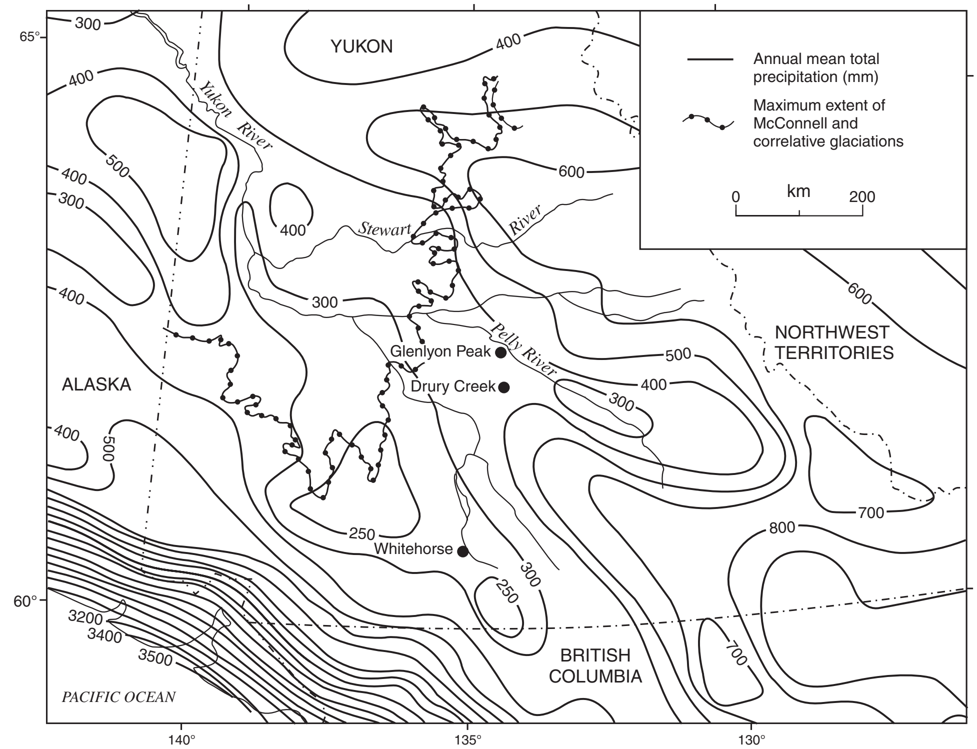


*Figure 38. Annual mean total precipitation for southern Yukon Territory (*modified from *Wahl et al. (1987, Fig. 9.5); glacial limits* from *Hughes (1987, Fig. 7)).*

and Mathews (1944): valley glaciers grew in the high areas of the Pelly, Selwyn, and Cassiar mountains, and then advanced down the main valleys (Jackson, 1989). This scenario has been confirmed by Plouffe (1989), who demonstrated with fabric data and pebble rock types that ice initially flowed out of the main ranges of the Pelly Mountains and subsequently flowed along the Tintina Trench. In contrast, the distribution of erratics, examination of sections, and detailed airphoto analysis in the Glenlyon Range indicate that local cirque glaciers were small and made no significant contribution to the Selwyn Lobe (Ward and Jackson, 1992). Rather, the Selwyn Lobe flowed into the valleys of the Glenlyon Range, blocking the drainage and forming lakes (stratigraphic section 5, Map 1787A). The limited size of the cirque glaciers in the Glenlyon Range is attributed to aridity. Present precipitation patterns show that the area receives low precipitation (Fig. 38); this situation was apparently exacerbated during the McConnell Glaciation. Paleoclimatic information from Beringia, the large unglaciated land mass to the west of the study area, indicates that the period of the last glaciation was more arid than at present (Hopkins, 1982). Other evidence for aridity is the occurrence of ventifacts (sand-blasted clasts) beyond the limit of the McConnell Glaciation, lying between a truncated paleosol on Reid deposits and loess deposited during McConnell deglaciation (Hughes et al., 1972; Tarnocai et al., 1985). In addition, lakes adjacent to the ice sheet dried up (C. Schweger, University of Alberta, pers. comm., 1992). Further corroborating evidence of aridity is provided by a computer simulation model (Barnosky et al., 1987).

The radiocarbon age of 26 350 ± 280 BP (TO-393) from the Ketza River site is a maximum for glacier growth in the main ranges of the Pelly Mountains. As glaciers advanced down the main valleys, rivers likely changed from a wandering to a braided pattern. Section 26 indicates that the ancestral Pelly River aggraded its bed before McConnell ice overran the site, and that ice from the Macmillan River drainage blocked the Pelly River, forming a lake. The presence of two tills at the Safety Pin Bend section (stratigraphic section 8, Map 1786A demonstrates an oscillation of the Selwyn Lobe sometime during the McConnell Glaciation, likely during advance.

Ice flow at the McConnell Glaciation maximum

Figure 9 shows ice-flow directions and interaction of the Selwyn and Cassiar lobes at the maximum of the McConnell Glaciation, as determined from streamlined forms, glacial limits, pebble rock types, and fabric data. Topography had a strong control on ice flow, since topographic relief was approximately equal to or greater than ice thickness. The ice sheet in this area is best described as a series of anastomosing ice streams (Jackson, 1989), with ice dividing around nunataks and subsequently recoalescing. The Selwyn Lobe flowed generally westward across the map area. Ice flowing along the Tintina Trench bifurcated and then coalesced around the Glenlyon Range (Fig. 9) with ice from the Tay, Menzie, and Earn river valleys. This caused some of the ice in the Tintina Trench to be deflected southwest into the main valleys of the Glenlyon Range, as indicated by the descending elevations of glacial limits in these valleys (Maps 1787A, 1789A). The Cassiar Lobe flowed generally northward into the area, mainly along the Yukon River and Frenchman Lake valleys, coalescing with the Selwyn Lobe. The zone of coalescence between Cassiar and Selwyn lobes is thought to be further to the southwest than reported by Campbell (1967, Map 1222A).

McConnell deglaciation

After initial retreat, marked by recessional moraines within a few tens of kilometres of the McConnell glacial limit (Fig. 19; Maps 1786A, 1788A), the Selwyn Lobe stagnated and downwasted in place. Evidence for this includes ice-stagnation features to elevations of 1830 m in source cirques within the Pelly and Selwyn mountains (Jackson, 1989, 1994; Jackson et al., 1991). In addition, the sequence of lake deposits in tributary valleys shows that higher sites became ice-free first, and that lake levels were controlled by downwasting ice in the main valley (Jackson, 1989, 1994; Jackson et al., 1991).

Evidence for this type of tributary-valley glaciolacustrine deposition during deglaciation is found in sections along the Glenlyon River (stratigraphic section 6, Map 1789A), the Tay River (stratigraphic section 4, Map 1787A), and Little Sheep Creek (stratigraphic section 5, Map 1787A). Airphoto interpretation indicates that glaciolacustrine sediments are also present along Felix and Jar creeks and at Drury Lake (Map 1789A), and along Harvey and Menzie creeks (Map 1787A). No glaciolacustrine sediments were mapped in the case of Menzie Creek, but the occurrence of retrogressive thaw slides indicates the presence of fine-grained sediments under glaciofluvial deposits. This evidence further corroborates the regional model of deglaciation of Jackson (1989).

The pattern of sedimentation during deglaciation also indicates regional stagnation of the ice sheet. The presence of large thicknesses of highly disturbed sediments shows that material was deposited onto the ice, and subsequently slumped and failed. The abundance of supraglacial sedimentation indicates that the style of deglaciation was by regional stagnation. A more orderly retreat of the ice sheet would have resulted in a simpler sequence of sediments, namely till overlain by outwash.

The time of retreat of the Selwyn Lobe is not well known. A radiocarbon age of 12 590 ± 120 BP (TO-931) on *Pisidium* sp. has been reported from the Tintina Trench adjacent to the Glenlyon Range, but possible hard-water effects likely render this age too old (Ward, 1989). The shells were obtained from a silty marl at the base of a kettle. Charcoal, situated 90 cm above sample TO-931, gave an age of 8430 ± 60 BP (TO-1279). Another minimum deglaciation age is 9140 ± 540 BP (AECV-484C) on willow wood from a paraglacial fan near the confluence of the Pelly and Macmillan rivers (Ward, 1989). This age also yields a minimum for the establishment of upland vegetation.

The initiation of deglaciation in mountainous areas of Yukon Territory and Alaska has been correlated with the Birch Zone (Hopkins, 1982). This is a pollen zone, recorded throughout Beringia, whose onset is marked by a rapid rise in *Betula* (birch) pollen. It records an abrupt climatic change from cold arid conditions to warmer and moister conditions (Hopkins, 1982; Ritchie, 1984, 1987; Anderson, 1985, 1988; Edwards and Dunwiddie, 1985; Ager, 1989). The onset of the Birch Zone is time transgressive across Beringia and occurred approximately 12 000 years ago adjacent to the study area (Ritchie, 1987; Anderson, 1988). Basal lake sediment ages from Big Reid and Barlow lakes, within the Stewart River drainage to the north of the study area, indicate that the beginning of the Birch Zone preceded 9 800 ± 120 BP (GSC-2548) and 10 100 ± 90 BP (GSC-2538), respectively (McNeely, 1989, p. 50–51). It is likely that this period of climatic warming corresponds to the rapid decay of the Selwyn Lobe.

Holocene

Important Holocene events, such as the re-establishment of vegetation in the map area and rivers cutting down to their present levels, reflect the transition from glacial to nonglacial conditions. The re-establishment of vegetation has not been well studied in the map area. Only the age of 9140 ± 540 BP (AECV-484C) on willow wood from a paraglacial fan gives a minimum age for the establishment of upland vegetation (Ward, 1989). Detailed paleovegetation studies are lacking from lakes that have been cored. Limited palynological studies from Big Reid and Barrow lakes, to the north of the study area, indicate vegetation dominated by birch, willow, and Cyperaceae at 9800 ± 120 BP (GSC-2548) and 10 100 ± 90 BP (GSC-2538), respectively (McNeely, 1989, p. 50–51). After deglaciation, the present rivers began to cut down through thick (up to 125 m) deglacial valley-fill sediments. A radiocarbon age from sample site 8 (Fig. 7) of 6570 ± 610 BP (AECV-483C) indicates that the Pelly River was approximately 25 m above its present level at this time. White River tephra was deposited in the southern portion of the study area at ca. 1250 BP, following the cataclysmic eruption of Mount Bana near the Alaska–Yukon Territory boundary (Lerbekmo et al., 1975). The presence of the White River tephra along the present floodplain of the Pelly and Yukon rivers indicates that these rivers had reached their present level by 1250 years ago.

APPLICATIONS

Foundation conditions

Bedrock in the map area is generally excellent foundation material, although some Cretaceous volcanic rocks are incompetent (Fig. 20). The presence or absence of permafrost is one of the most important controls on the suitability of surficial materials for foundations. The following discussion of foundation conditions is adapted from Jackson (1994).

Colluvial deposits are generally unsuitable for foundations. Coarse deposits, such as bouldery colluvial aprons (unit bCa), are commonly at or near the angle of repose, and are thus metastable and subject to creep (Gardner, 1969). As well, the frequent occurrence of rockfalls or avalanches may render them hazardous as building sites. Colluvial aprons (unit Ca) are also subject to creep and may contain abundant organic material that can decompose and cause settling. Colluvial aprons with fine-grained matrices may contain segregated ice.

The texture of alluvial deposits is highly variable, so their suitability as foundation materials varies considerably. Floodplains (units Ap, Au) may be underlain by well drained gravel, which is a good foundation material, or by organic-rich silt containing segregated ice lenses, which is unsuitable for foundations. Alluvial terraces (unit At) are generally well drained and therefore good building sites. Alluvial fans (unit Af) may be suitable for foundations, depending on the texture of the sediment and the presence or absence of permafrost.

Till (units Mv, Mb) is generally a good foundation material. It contains less segregated ice than finer material, although some slopes with northern aspects can have abundant permafrost. If segregated ice is present, moisture contents upon thawing will exceed the liquid limit and failure can occur on slopes with very low angles.

Fine-grained glaciolacustrine deposits (units Lp, Lv, Lb) commonly contain segregated ice lenses, making them highly prone to retrogressive thaw sliding and thermokarst formation. Care should be taken to ensure that areas of extensive permafrost in such sediments are avoided during development. Areas with evidence of previous retrogressive thaw slides or containing thermokarst lakes should be avoided; if this is impossible, then special precautions, such as overlanding, must be taken.

Organic deposits (unit O) are unsatisfactory foundation substrates because of their low bearing strength and compressibility, and the common occurrence of segregated ice.

Rock glaciers should be avoided for development because their slow, creep-like movement renders them unstable.

Granular materials

Bulk fill

Till (units Mb, Mv) is found throughout the map area and can be easily exploited for low-permeability bulk fill. It has been used extensively as fill and as surface material along the Robert Campbell Highway. Till performs well as bulk fill, as long as in situ moisture contents are low. Glaciolacustrine sediments can also be exploited for bulk fill, but the high moisture content can cause segregated ice to form.

Sand and gravel

Sand and gravel are common throughout the map area. All glaciofluvial (unit G) and alluvial deposits (unit A) can be exploited for aggregate, but the quality will differ according to the texture and sorting of the specific deposit. Present floodplains (units Ap, Au) should be avoided, since extraction will likely disrupt stream courses and degrade fishery values. In addition, a high water table is common on the floodplain, thus hindering gravel extraction. Glaciofluvial deposits are widespread, but may be characterized by rapid lateral facies changes and may contain significant amounts of diamicton.

Natural hazards

Many natural processes can pose hazards to human activity. The following discussion of natural hazards is modified from Clague (1984) and Jackson (1994).

Earthquakes

The Glenlyon map area is located in an area of relatively low seismicity; most earthquakes are concentrated along the Tintina Trench and other major structures in the area (Fig. 39). Since 1980, no earthquakes greater than magnitude 4 have occurred in the map area however, because the instrumented seismic record is short, there remains the possibility that large-magnitude events could occur.

Floods and debris flows

Flood hazards in the Pelly River basin have been examined as part of a larger study by the Inland Waters Directorate (1983) of Environment Canada. Flooding can be caused by snowmelt runoff, rainstorm events, and ice jams. Snowmelt floods occur in early summer on the Pelly and Yukon rivers and their larger tributaries. The Pelly River at Pelly Crossing has a mean annual peak discharge of 2430 m^3/s and a predicted 100-year flood of 5590 m^3/s. Rainstorm events have their greatest effect on smaller watersheds and generally produce floods in the summer. These floods usually occur in remote areas, so there are few data on their magnitude and frequency. They pose serious hazards in high-elevation or steeply sloping terrain where flooding or debris flows can occur rapidly and with little warning. Ice jams can develop in any river or stream during breakup. Although they usually only affect short reaches, they are difficult to predict and can cause rapid increases in water level.

Hazards are greatest along the lowest parts of floodplains, but no part of the floodplain can be considered immune. Only alluvial terraces (unit At) and glaciofluvial terraces (units Gt, Gp) are normally high enough to escape inundation. Active alluvial fans are prone to floods and debris flows, and the streams are capable of avulsion.

As development proceeds in the Glenlyon map area, the dangers of building on floodplains should be recognized and effective land-use planning undertaken. The following planning guidelines have been recommended by the Inland Waters Directorate (1983): 1) determine the level of protection required, for example, for the predicted 100- or 200-year flood; 2) define a floodway, including the channel and those parts of the floodplain that must remain free of development; and 3) define which types of development to allow on other parts of the floodplain.

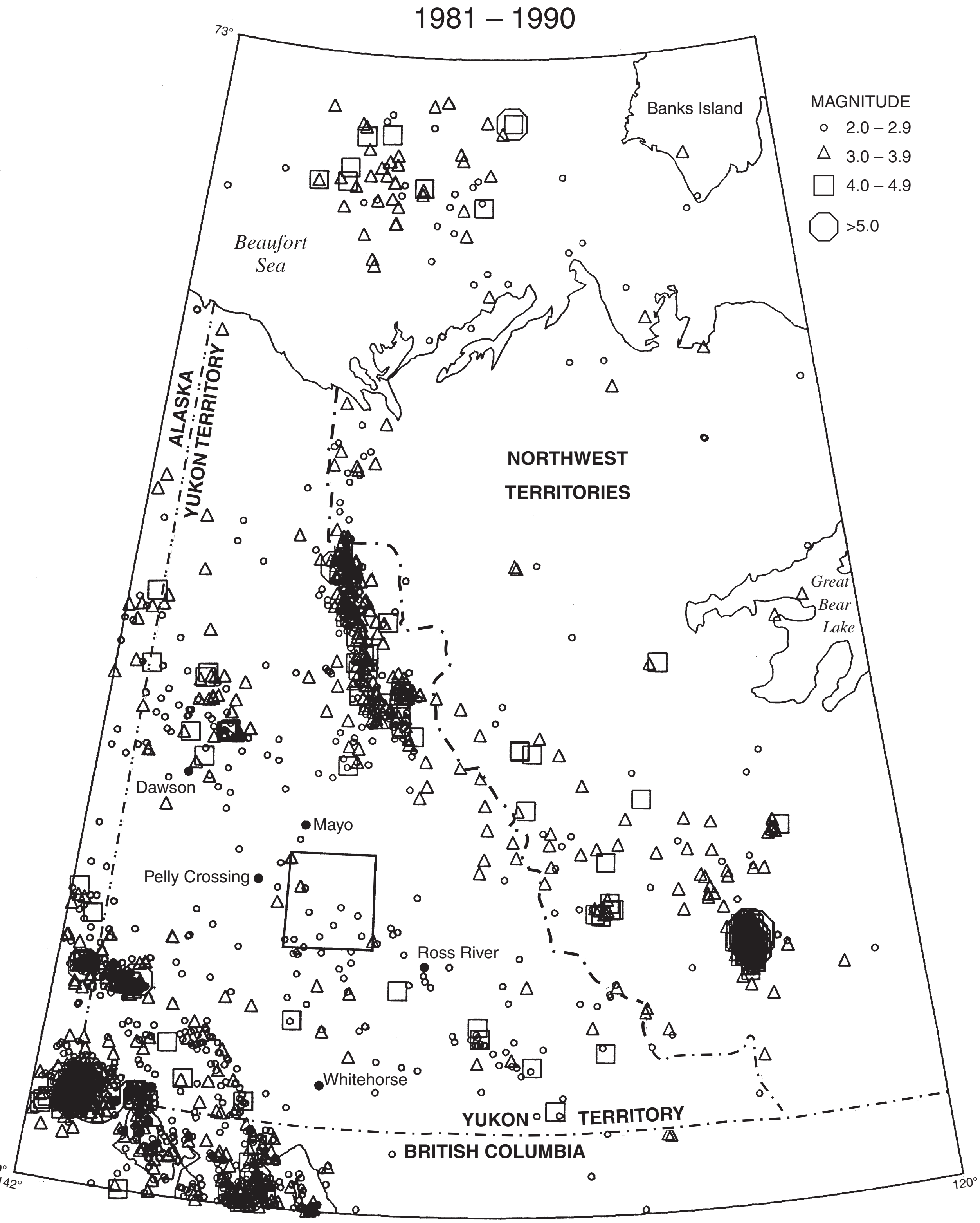


Figure 39. *Earthquake epicentres for Yukon Territory and adjacent areas, 1981–1990. Provided by Pacific Geoscience Centre, Sidney, British Columbia. Square outline indicates Glenlyon map area.*

Landslides

Landslides have occurred throughout the map area in both bedrock and unconsolidated sediments (Fig. 14, 20, 21). Although several large, catastrophic slides involving bedrock have been reported from the Pelly Mountains (Jackson and Isobe, 1990; Jackson, 1994), only one large rockslide has been discovered in the map area. This appears to be a slower, more complex type of failure (Fig. 20). There is a possibility of recurrent failure at this site; therefore, development is not recommended.

Small rockfalls and debris avalanches are common, although they are restricted to alpine areas with steep slopes. Areas mapped as units R-A and bCa should be avoided for development.

Most of the large landslides in the area are in unconsolidated material (Fig. 21), and are likely triggered by the degradation of permafrost. Most of these are in fine-grained glaciolacustrine sediment and till. The largest failure in the map area is in fine-grained till. It occurred on a slope with a northern aspect and is similar to the well studied Surprise rapids slide in the Tay River map area (Ward et al., 1992), which covers an area of more than 3 km^2 and is less than 100 years old. Initial dendrochronological work and airphoto examination suggest that the failure shown in Figure 21 formed in an equally brief period of time. Failure was initiated by some disturbance of the insulating organic cover, causing degradation of ground ice. Development on north-facing slopes underlain by fine-grained diamicton should be done with caution, since similar failures could be triggered by disturbance of permafrost.

Smaller failures are common in glaciolacustrine sediments throughout the map area where fluvial erosion has exposed ice-rich permafrost (Fig. 14). Development, such as road building, should be avoided in areas of glaciolacustrine sediments unless special precautions are taken.

Snow avalanching

Snow avalanching is one of the most widespread and destructive natural processes in the Canadian Cordillera (Evans and Gardner, 1989) and is potentially a serious hazard in the alpine part of the Glenlyon map area. Avalanche tracks are common in the alpine zone and should be avoided.

CONCLUSIONS

The objective of this study was to document the Quaternary geology of the Glenlyon map area (NTS 105 L). Surficial sediments were subdivided into 23 units, based on their genesis, surface expression, stratigraphic age, texture, and modifying process, and range in age from Holocene to Early Pleistocene. Glacial sediments related to the pre-Reid, Reid, and McConnell glaciations, and Middle Pleistocene and Middle Wisconsinan nonglacial deposits were identified in section.

The oldest deposits, consisting of pebbly sand with detrital organic sediments at the Bradens Canyon section, record cold periglacial conditions prior to the Reid Glaciation but still within the Bruhnes normal polarity chron. Abundant deposits from the Reid Glaciation are exposed along the Pelly River beyond the limit of the McConnell Glaciation. These include till and glaciofluvial deposits at the Bradens Canyon section, glaciofluvial deposits at the Pelly farm section, and glaciolacustrine deposits at the Granite Canyon section. At Drury Lake, well within the limit of the McConnell Glaciation, a sediment sequence reflecting the advance and retreat of the Reid Glaciation is preserved beneath McConnell till. A truncated paleosol at the Pelly farm section likely represents pedogenesis during the Koy–Yukon thermal event and correlates with the Diversion Creek paleosols.

Deposits postdating the Koy–Yukon thermal event and predating the McConnell Glaciation were identified at three sites: Granite Canyon, Pelly farm, and section 26. Mid-Wisconsinan organic beds were identified at the Granite Canyon section; a study of insect macrofossils and pollen indicates forested conditions at 37 000–36 000 BP. A low-gradient alluvial fan at the Pelly farm section occurs above a truncated soil from the Koy–Yukon thermal event and contains cryoturbation features attributed to glacial conditions during the McConnell Glaciation. At section 26, a gravel capped by thick sand is preserved under McConnell till. The gravel and some of the sand likely represent interstadial conditions before McConnell ice advanced into the area.

The landforms and sediments of the McConnell Glaciation are well preserved and allow for better reconstruction of conditions than those of the previous glaciations. The area was affected by the Selwyn and Cassiar lobes of the Cordilleran Ice Sheet, which flowed generally westward and northwestward into the map area. With many areas as nunataks, ice flow at the maximum of the McConnell Glaciation was strongly controlled by topography. Deglaciation of the area was rapid and marked by vertical wastage of the ice sheet rather than frontal retreat. Many of the upland valleys became ice-free first, and large lakes formed in them due to blocked drainage.

During the Holocene, rivers cut down to their present base level. Upland vegetation was established around 9000 BP. Streams had downcut to approximately 25 m above their present level by 7000–6000 BP. The White River tephra was deposited within the study area at ca 1250 BP. Its presence in floodplain sediments of the Pelly River indicates that rivers had downcut to their present level by 1250 BP. Permafrost invaded the sediments, and its growth and degradation affected the landscape, forming pingos, palsen, thermokarst lakes, and retrogressive thaw slides.

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APPENDIX A

Particle-size data for matrix of till

Location of sample sites given in Figure 7. Depth indicates depth below present surface as exposed in section.

Site	Sample number	Lab number	Depth (m)	Sand (%)	Silt (%)	Clay (%)
1	24687-T1	30611	10	49.4	37.7	12.9
2	10687-T1	30600	20	38.2	44.3	17.5
2	10687-T2	30601	20	38.2	46	15.8
2	18687-T1	30604	3.5	28.6	52.8	18.6
3	17687-T1	30602	42	48.7	36.7	14.6
3	17687-T2	30603	20	55.8	32.1	12.1
3	19687-T1	30605	60	27.5	61.6	10.9
5	25688-T1	32204	70	40.4	33.6	26
5	25688-T2	32205	40	49.7	32.5	17.8
6	22687-T1	30606	20	49.9	35.4	14.7
6	22687-T2	30607	40	41.7	44.8	13.5
6	21687-T1	30609	35	74	23.5	2.5
6	12688-T1	32193	45	46.2	36.9	16.9
6	12688-T2	32194	45	49.6	36.5	13.9
6	12688-T3	32195	45	47.1	37.4	15.5
6	14688-T1	32196	65	70	25.3	4.7
6	14688-T2	32197	65	56	30.5	13.5
6	14688-T3	32198	65	51.3	35.8	12.9
7	23687-T1	30608	41	42.6	40.1	17.3
7	23687-T2	30610	30	31	48.7	20.3
9	05787-T1	30614	19	45.8	42.9	11.3
9	05787-T2	60615	10	53.6	39.6	6.9
9	05787-T3	60616	3	53.7	39	7.2
10	16788-T1	32222	120	22.8	61.5	15.7
10	16788-T1	32223	114	57.4	27.7	14.9
11	5787-T4	30617	33	48.2	36.3	15.5
12	18788-T2	32225	20	51.2	28.7	20
13	19788-T1	32226	5	51.1	31.7	17.2
14	18788-T1	32224	50	57.4	27.7	14.9
17	07787-T1	30618	43	51.8	37	11.3
17	07787-T2	30619	42	55.1	32.1	12.8
17	03787-T1	30612	12	52.6	33.5	13.9
17	03787-T2	30613	8	53.9	33.4	12.8
17	07787-T3	30920	4	42.2	41.2	16.6
18	09787-T4	30629	70	43.7	38.9	17.4
18	28688-T4	32210	60	42.5	40.7	16.8
18	28688-T5	32211	58	41.2	40.9	17.9
18	08787-T1	30623	50	43.6	40.2	16.2
18	08787-T2	30624	40	23.8	47.9	28.3
18	08787-T3	30625	30	9.2	51	39.8
18	09787-T1	30626	27	44.1	40.3	15.6
18	09787-T2	30627	26	9	49.2	41.8
18	09787-T3	30628	25.5	0.8	61.8	37.4
18	28688-T6	32212	20	40.4	41.7	17.9
19	28688-T1	32207	40	49.5	36.1	14.4
19	28688-T2	32208	35	75.5	18.8	5.7
19	28688-T3	32209	28	41.9	43.8	14.3
19	07787-T4	60621	20	39.5	46.1	14.5
19	07787-T3	30620	4	42.2	41.2	16.6
21	29688-T1	32213	60	74.8	19	6.3
21	15787-T1	60633	40	53.1	31.3	15.6
21	30688-T1	32214	40	34	45.5	20.5

Site	Sample number	Lab number	Depth (m)	Sand (%)	Silt (%)	Clay (%)
21	15787-T6	30637	39	45.6	39.6	14.8
21	15787-T2	30634	39	32.8	51.3	15.9
21	30688-T2	32215	37	45.1	41	13.9
21	15787-T4	30636	35	26.5	51.1	22.4
21	30688-T3	32216	35	34.6	42.1	23.3
21	13787-T1	30630	30	18.6	53.5	27.9
21	14787-T1	30632	30	44.7	38.7	16.6
21	13787-T2	30631	25	25.4	45.2	29.4
21	01788-T1	32217	15	39.9	43.8	16.3
21	01788-T2	32218	15	43.8	41.7	14.5
21	16787-T1	30638	10	54.7	33.5	11.8
22	22688-T1	32203	1	50.7	44	5.3
23	29787-T1	30639	18	37.5	49.3	13.2
24	31787-T1	30640	55	31.2	53	15.8
24	31787-T2	30641	44	22.1	64.7	13.3
24	31787-T3	30642	32	46.3	44	9.7
26	02887-T2	30644	68	33.3	5352.9	13.8
26	02887-T3	30645	66	47.2	42.4	10.4
26	04788-T1	32220	60	13.1	65.6	21.3
26	04788-T2	32221	40	37.4	55.3	7.3
26	02887-T1	30643	4	62	33	5
26	03788-T1	32219	4	49.9	37.4	12.8
27	JJ-20688-S3	32172	1	40.5	44.8	14.7
28	JJ-20688-S2	32171	1	54.8	37.9	7.3
29	11887-S1	30571	40	44.4	51	4.7
29	11887-S2	30572	40	51.4	45.8	2.7
29	11887-S3	30573	40	44.3	50	5.7
29	11887-S4	30574	40	59.3	37.2	3.4
29	08887-T1	30648	40	63.8	28.9	7.3
29	08887-T2	30649	35	53.8	37	9.2
29	08887-T3	30575	30	41.9	52.8	5.2
31	06887-T1	30646	45	49.6	42.8	7.5
31	06888-T2	30647	40	63.6	32.8	3.6
32	12887-S1	30579	17	7.31	54.9	37.8
34	10887-T1	30578	14	48.3	43.3	8.4
35	09887-T1	30576	32	36.1	56.2	7.7
35	09887-T2	30577	31	32.4	57.9	9.7
36	JJ-02688-S1	32170	1	46.1	39.2	14.7
37	JJ-18688-S1	32168	9	56.2	32.4	11.4
38	JJ-19688-S1	32169	1	54	36.1	9.9
39	JJ-16688-S1	32166	3	40	41	19
40	JJ-16688-S2	32167	2	42.4	41.6	16.1
41	JJ-11688-S4	32165	10	39.2	46.6	14.2
42	JJ-21688-S2	32174	22	48.2	39.7	12.1
42	JJ-21688-S3	32175	1	58.2	31.2	10.7
42	19789-T1	34840	3	63	30.7	6.3
42	20789-T1	34841	1	58.6	29.5	11.7
43	17789-T1	34839	2	42.9	46.7	10.4
44	JJ-10688-S1	32160	4	66.7	29.1	4.3
45	JJ-11688-S1	32162	3	41.3	43.8	14.9
46	JJ-11688-S2	32163	5	47.6	41.6	10.6
47	JJ-11688-S3	32164	4	45	35	20

APPENDIX B

Particle-size data for glaciofluvial and glaciolacustrine sediments

Location of sample sites given in Figure 7. Depth indicates depth below present surface as exposed in section.

Site	Type	Sample number	Lab number	Depth (m)	Sand (%)	Silt (%)	Clay (%)
1	GL	24687-S1	30589	15	0.9	91.5	7.6
2	GL	24687-S2	30591	20	0.5	85.1	14.4
3	GL	17687-S2	30582	40	4.2	63.1	32.7
3	GL	17687-S4	30584	25	7.2	61.3	31.5
3	GL	17687-S5	30585	19	1	69.2	29.8
3	GD	17687-S1	30581	40	63.7	35.6	0.7
3	MG	17687-S3	30583	33	89.1	6.6	4.3
4	GL	23687-S1	30590	16	19.1	79.1	1.8
6	GM	21687-S1	30587	70	60.9	25.4	13.7
6	GL	22687-S1	30588	40	4.6	91.7	3.7
6	GL	21687-S2	30586	50	14.9	82.4	2.7
6	GL	14688-S3	32201	50	17.2	79.7	3.1
6	MG	14688-S1	32199	50	91.3	8.7	0
6	MG	14688-S2	32200	50	97.9	2.1	0
8	GL	28687-S2	30594	40	1.4	53.6	45
8	GL	29687-S1	30599	38	17	74.5	8.5
8	MG	27687-S1	30592	35	82.2	16	1.8
8	GD	28687-S1	30593	35	89.9	9.1	1
8	GL	28687-S3	30595	37	0.6	92.9	6.5
8	GD	28687-S5	30597	27	92.8	3.6	3.6
8	GD	28687-S6	30598	29	82.6	11.4	6
15	GM	27688-S1	32206	10	94.2	5.8	0
20	GL	12787-SI	30557	21	3.6	93.3	3.1
20	GL	12787-S2	30558	20.5	9.3	87.7	3
20	GL	12787-S3	30559	19.5	1	51.2	47.8
20	GL	12787-S4	30560	6	2.3	95.1	2.6
20	GL	12787-S5	30561	10	1.2	91.7	7.1
20	GL	12787-S6	30562	9.5	1.2	94.4	4.4
25	GL	01887-S1	30653	25	0	53.1	46.9
25	GL	01887-S2	30564	25	0.9	96.5	2.6
30	GL	09887-S1	30566	1.5	0	45	55
30	GL	09887-S2	30567	9	0.2	80	19.8
30	GL	09887-S3	30568	21	0.9	82.6	16.5
30	GL	09887-S4	30569	29	0	88.2	11.8
31	GL	07887-S1	30565	5	6	40.1	53.9
33	GL	09887-S5	30570	4	21.2	74.4	4.4

Key for sediment types:
GL, Glaciolacustrine
GD, Glaciofluvial deltaic
MG, Matrix of glaciolacustrine and glaciofluvial gravel