Preliminary Quaternary geology of Coal River area (NTS 95D), Yukon

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Kennedy, K., 2010. Preliminary Quaternary geology of Coal River area (NTS 95D), Yukon. *In:* Yukon Exploration and Geology 2009, K.E. MacFarlane, L.H. Weston and L.R. Blackburn (eds.), Yukon Geological Survey, p. 197-212.

ABSTRACT

Quaternary geology investigations in the Coal River map sheet (NTS 95D) during the 2009 field season focused on characterizing surficial materials and their distributions, with attention to the eastern half of the map sheet which has not been previously mapped. Moraine deposits are relatively thin in valley bottoms (<2 m) and become thinner and more intensely colluviated on upland surfaces. Streamlined glacial landforms and till plains are pronounced in the southern half of the map sheet. Surficial deposits are limited in many east-trending meltwater canyons, and in the northeastern corner of the map sheet.

The map area was glaciated most recently by the Cordilleran Ice Sheet, which advanced from the south and west. Meltwater from montane glaciers and the Laurentide Ice Sheet in adjacent map sheets likely contributed to extensive glaciolacustrine, glaciofluvial and glaciodeltaic deposits in north-trending valleys that were dammed by the Cordilleran Ice Sheet.

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INTRODUCTION

The Coal River project in southeast Yukon is a collaborative effort between the Geological Survey of Canada (GSC) and the Yukon Geological Survey (YGS) under the Government of Canada's Geomapping for Energy and Minerals (GEM) program. The Coal River map sheet (Fig. 1; NTS 95D) was selected for mapping because it is considered to have high mineral potential and is under-explored both scientifically and economically. Furthermore, surficial geological mapping has not been completed for the east half of 95D, and existing maps for the west half lack field-based observations and descriptive documentation. The goals of the Coal River GEM project are to provide a revised 1:250 000-scale bedrock geological map (Pigage *et al.*, in prep), an aeromagnetic map of the adjacent Yukon part of the Flat River map sheet (NTS 95E), and new surficial geological mapping for the previously unmapped east half of Coal River map sheet.

Preliminary investigations of the surficial geology of the Coal River map sheet (NTS 95D) have resulted in a broad characterization of the distribution of surficial materials. This paper outlines new observations of glacial geomorphology and provides stratigraphic controls on the regional surficial geology. From these observations, an interpretation of the regional glacial history will be proposed.

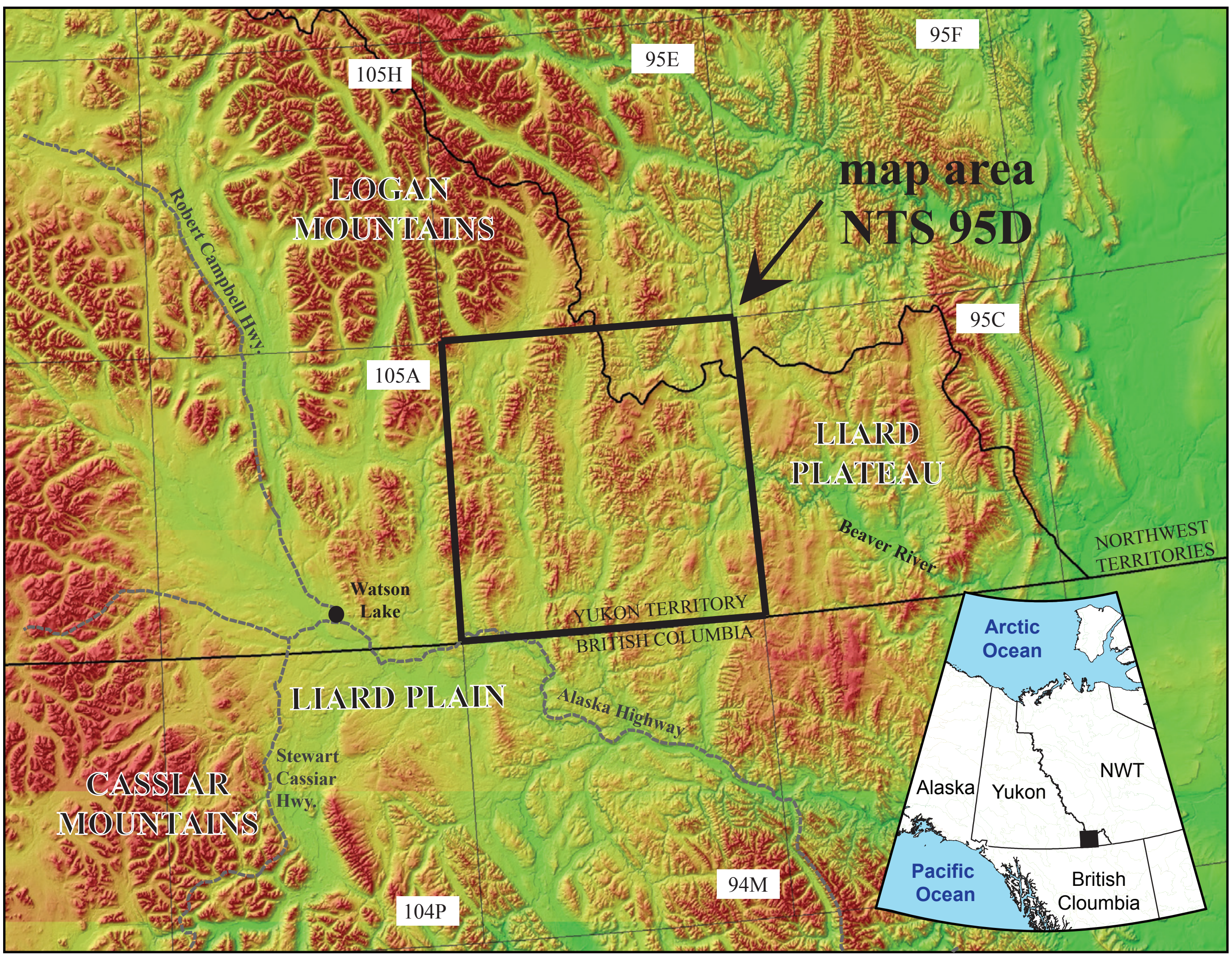

Figure 1. *Coal River map sheet (NTS 95D) is located in southeast Yukon and includes part of southwest Northwest Territories.*

REGIONAL SETTING

The Coal River map sheet is located in southeast Yukon and includes part of southwest Northwest Territories (Fig. 1). The map sheet is predominantly within the Hyland Highland ecoregion (Fig. 2), an elevated area higher than neighbouring plains and plateaus, but lacking the high summits of mountains or ranges (Smith *et al.*, 2004). The highest elevations in the ecoregion are on the Yukon Territory-Northwest Territories border, and between the West Coal and upper Rock rivers at ~1900 m a.s.l.; local relief is generally between 300 m and 750 m a.s.l. The physiography of the Coal River map sheet is characterized by three broad, near-parallel, north-trending valleys extending the length of the map sheet (Fig. 3).

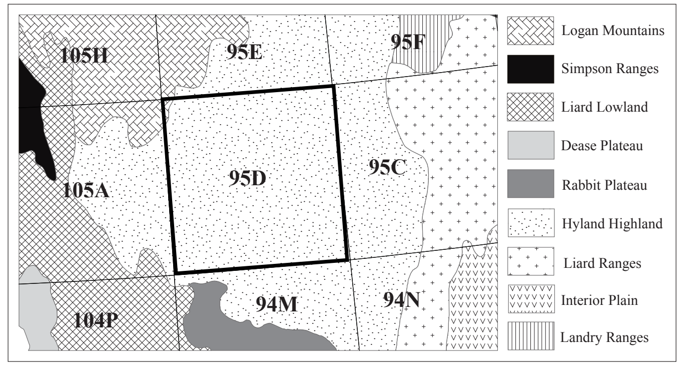

Figure 2. *Physiographic regions of the Coal River map sheet and surrounding area. Map area (95D) falls almost entirely within the Hyland Highland physiographic region (regions from Smith et al., 2004).*

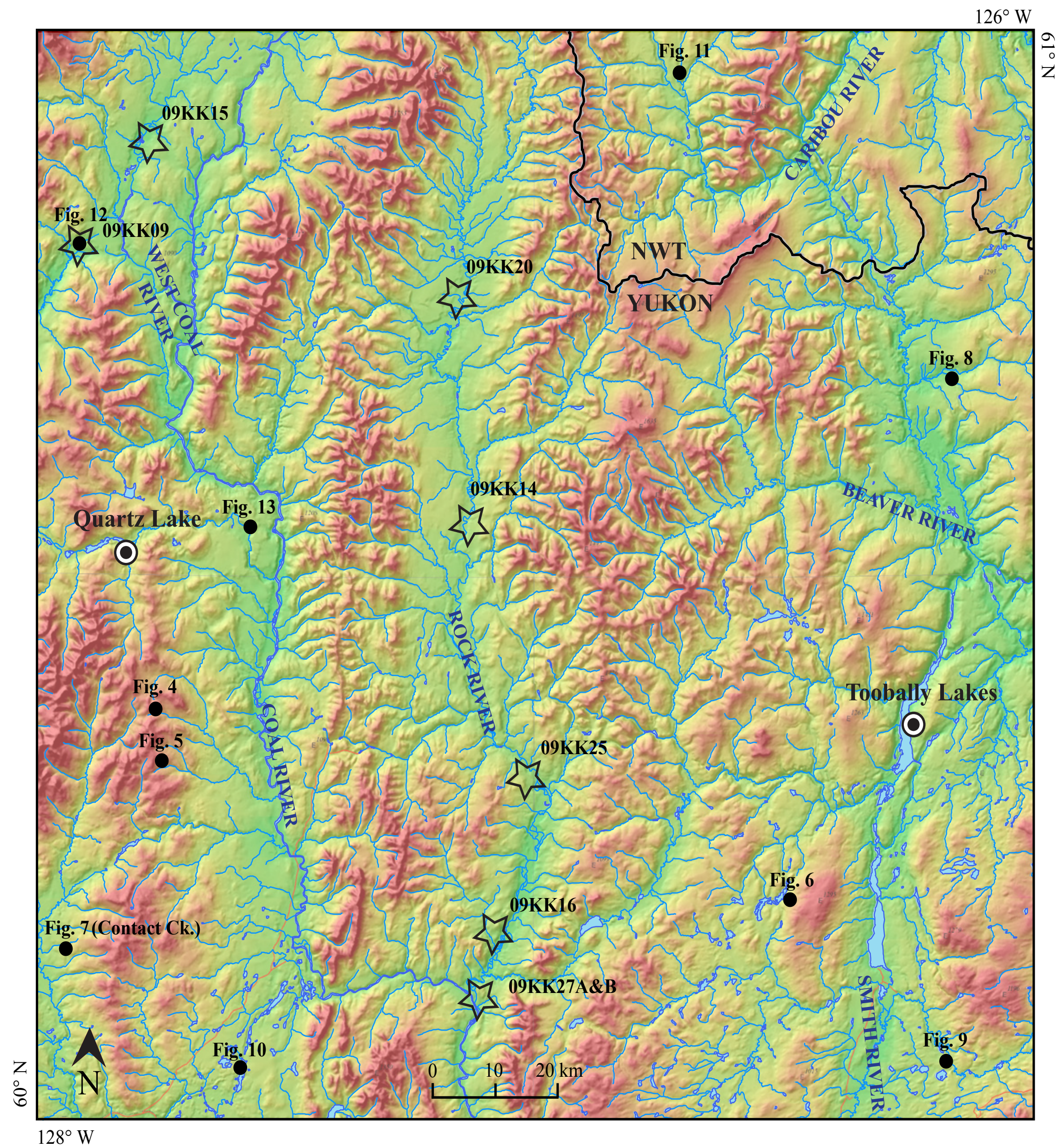

Figure 3. *Hillshade and DEM (Digital Elevation Model) image of the Coal River map sheet. The West Coal River and Coal River valleys are oriented north-south in the western map area. The Rock River valley is in the centre of the map sheet and joins the Coal River near the southern margin of the map area. The Caribou, Beaver and Smith rivers, along with the Toobally Lakes, occupy the eastern north-trending valley in the map area. Stratigraphic sections presented in the paper are indicated with stars, and camp locations are identified with a circle.*

The Coal River originates in the northwest corner of the map sheet and flows south; it has only two minor eastward deviations during its course, which are incised into bedrock. The broad valley in the centre of the map sheet is occupied by the Rock River, which flows south throughout its course. The Rock River frequently exposes bedrock along its banks, including Tertiary deposits, suggesting the valley is a pre-glacial feature, and that its modern drainage route has not changed significantly during the Pleistocene. The valleys of the Rock and Coal rivers are the largest in the map area, and contain the most extensive glacial deposits.

The north-trending valley on the eastern edge of the map sheet is host to three modern drainages: the Smith River draining south, the Caribou River draining north, and the Beaver River draining east. The paleoflow direction of Tertiary fluvial gravel deposits preserved ~150 m above the modern Beaver River suggest pre-glacial drainage of the east Coal River map sheet was to the east (Pigage, 2009). Modern drainage in the Coal River map sheet is predominantly south into the Liard River, and ultimately into the Mackenzie River and Arctic Ocean.

Underlying the unconsolidated sediments in the Coal River map area is a thick sequence of slope, basin, platform and clastic shelf sedimentary and volcanic rocks that range in age from late Proterozoic to Triassic (Pigage *et al.*, in prep).

SURFICIAL GEOLOGY

PREVIOUS WORK

Previous surficial geological mapping of the Coal River map sheet (NTS 95D) is limited to the west half of the sheet, and was mapped between 1978 and 1981 by Klassen (1983) at a scale of 1:250 000. This mapping also included the Watson Lake (NTS 105A) and Wolf Lake (NTS 105B) map sheets to the west (Klassen and Morison, 1982a; Klassen and Morison, 1982b). No ground-truthing locations are noted on Klassen's map for 95D West.

Detailed surficial geological mapping was completed from 1999 to 2001 in the La Biche River map sheet (NTS 95C; Fig. 1). This mapping resulted in seven 1:50 000-scale maps (Smith, 2002a,b; Smith, 2003a,b,c,d; Smith, 2004b); one 1:100 000-scale map (Smith, 2004a); a revised ice-flow map (Duk-Rodkin and Smith, 2002); and a report outlining early findings (Smith, 2000). Most notably, Smith (2000) demonstrated that the Laurentide Ice Sheet advanced further west than previously thought, and coalesced with the Cordilleran Ice Sheet along its western margin. Ice flow directions and meltwater channels in the study area were mapped by Duk-Rodkin (1999) as part of a Yukon-wide glacial limits map.

The Quaternary history of the Coal River map sheet is largely undocumented. South of the map sheet, the Liard Plain (Fig. 1) is thought to have been a major conduit of Cordilleran ice during multiple Pleistocene glaciations (Ryder and Maynard, 1991). The Cordilleran Ice Sheet in this region was likely composed of coalescent valley and piedmont glaciers, which may have thickened enough to over-top ridges and divides, but likely always remained somewhat constrained by topography (Klassen, 1987). Ice advancing southeast across the Liard Plain is thought to have diverted northward into the three main valleys of the Coal River map sheet (Klassen, 1987) and ultimately inundated even the highest points in the map area, establishing southwest to northeast ice flow during glacial maximum (Duk-Rodkin, 1999).

A lengthy Quaternary and Tertiary record was described by Klassen (1987) in the Watson Lake map sheet (105A) where four distinct till units are interbedded with four non-glacial units that include basalt and organic horizons. The till units represent glaciations beginning in the early Pleistocene, with the uppermost till recording glaciation during the late Wisconsinan (Klassen, 1987). The evidence of multiple glaciations fits well with regional reconstructions of repeated northern Cordilleran glaciations throughout the Pleistocene (Jackson *et al.*, 1991; Ryder and Maynard, 1991).

The Coal River map area is situated near the eastern limit of the Cordilleran Ice Sheet and is immediately west of the Laurentide Ice Sheet limit, which reached its maximum position in the adjacent map sheet (95C; Smith, 2000). Regional east-flowing streams that were diverted by the westward-advancing Laurentide Ice Sheet were likely rerouted into the Coal River map sheet. Early advances of both ice sheets may have been valley-constrained and limited to low elevations; however, a mutual buttressing upon coalescence would have allowed the ice sheets to thicken and attain glacial maximum distributions that likely covered all but the highest peaks in the region (I.R. Smith, pers. comm.).

SURFICIAL GEOLOGY

The distribution of surficial materials in the map area can be broadly divided into highland, upland and valley-

Figure 4. *Periglacial and colluvial processes are common on high-elevation surfaces that are covered in thin till and weathered bedrock. Here, on an upland surface near Quartz Lake, cryoturbation has sorted the weathered bedrock colluvium and soil creep has modified the hummocks into linear mounds.*

bottom units. The high rugged topography in the northern part of the map sheet is characterized by cirque development on north-facing aspects, and thin accumulations of weathered bedrock. Other than cirques and limited moraine deposition on cirque floors, evidence of glaciation is rare in this region.

Upland units in lower terrain, which characterizes most of the map sheet, are typically thin veneers of glacial diamict and weathered bedrock. Bedrock is at, or near, surface in most areas above tree line. Colluvial processes such as soil creep, solifluction and slope wash are common at high elevations above tree line (Fig. 4). Upland surfaces, particularly those in the southern part of the map sheet, are scoured and sculpted by glaciation. These surfaces contain streamlined landforms indicating regional ice flow to the northeast, and localized flow directions ranging from north to east (Fig. 5). Colluvial processes are minimized where surface materials are stabilized by the dense forest cover, which is typical of the Coal River map area. On average, the elevation of tree line is ~1400 m a.s.l.

Mid-elevation (~1000-1400 m a.s.l.), forested slopes are covered in mixed colluvial and glacial diamicts that are characterized by predominantly sharp, angular, pebble-cobble clasts with a minor component (~15%) of well-rounded clasts. Matrices are dominantly silty, and contain variable sand and clay fractions. Where there are relatively thin moraine deposits and limited erosion, flights of lateral meltwater channels flanking mid-elevation slopes are the most distinctive evidence of glaciation in the uplands of the Coal River map sheet (Fig. 6). The channels are predominantly erosional features, but also form linear depressions where colluvial and organic deposits accumulate to greater thicknesses than on the surrounding slopes.

Valley-bottom geomorphology is characterized by thick glacial, glaciolacustrine and glaciofluvial deposits. The nature of the valley-bottom geomorphology can be separated into two distinct regions based on landforms. In the southern part of the map sheet, the valley-bottom geomorphology is characterized by bedrock-cored drumlins, or drumlinoid features, glaciofluvial terraces, deltas, eskers, kames and meltwater channels (Figs. 7, 8, 9). Hummocky and ablation moraine, and crevasse-fill type deposits associated with glacier recession are abundant in the southwestern corner of the map sheet (Fig. 10).

Figure 5. *Chatter marks (circled) and striations preserved on polished bedrock surfaces indicate ice flow directions. Compass diameter is ~6 cm and black arm points in direction of ice flow (~004°).*

Alternatively, valley bottoms in the central, eastern and northern parts of the map area lack distinct ice-contact glacial recession features. Instead, they are primarily blanketed by glaciolacustrine and glaciofluvial deposits. Deltas, terraces and streamlined glacial features in the Beaver River and Toobally Lakes areas provide evidence of glaciation and glacial lakes in the south and central parts of the primary north-trending valley in the eastern map area. However, very little evidence for glaciation exists in the northern extension of the valley, where the

Figure 7. *Light-coloured, sinuous ridges in the foreground are eskers in the Contact Creek (Fig. 3) area in the southwest part of the map sheet. These deposits typically contain sand and gravel. Trees on valley floor are ~20-30 m high.*

Figure 6. *Lateral meltwater channels are common features on heavily forested mid-elevation slopes. Meltwater channels flowed to the north (bottom left of photo), indicating the ice margin was retreating to the south (top right of photo).*

Figure 8. *Glaciofluvial delta formed at the outlet of a small meltwater channel in a west-flowing tributary to the Beaver River (Fig. 3). These deposits often consist of well-sorted sand, and mixed sand and gravel. Dashed black line marks the front edge of the delta surface.*

Caribou River occupies a deeply incised bedrock canyon (Fig. 3). Bedrock (strath) terraces are common in this part of the map sheet and provide evidence of high-energy fluvial erosion (Fig. 11).

The Coal and Rock river valleys (Fig. 3), along with many of their tributaries, are filled with thick glaciolacustrine clay, silt and sand deposits (Fig. 12). Ice-rich clay, often located near the bottom of exposures, is prone to slope

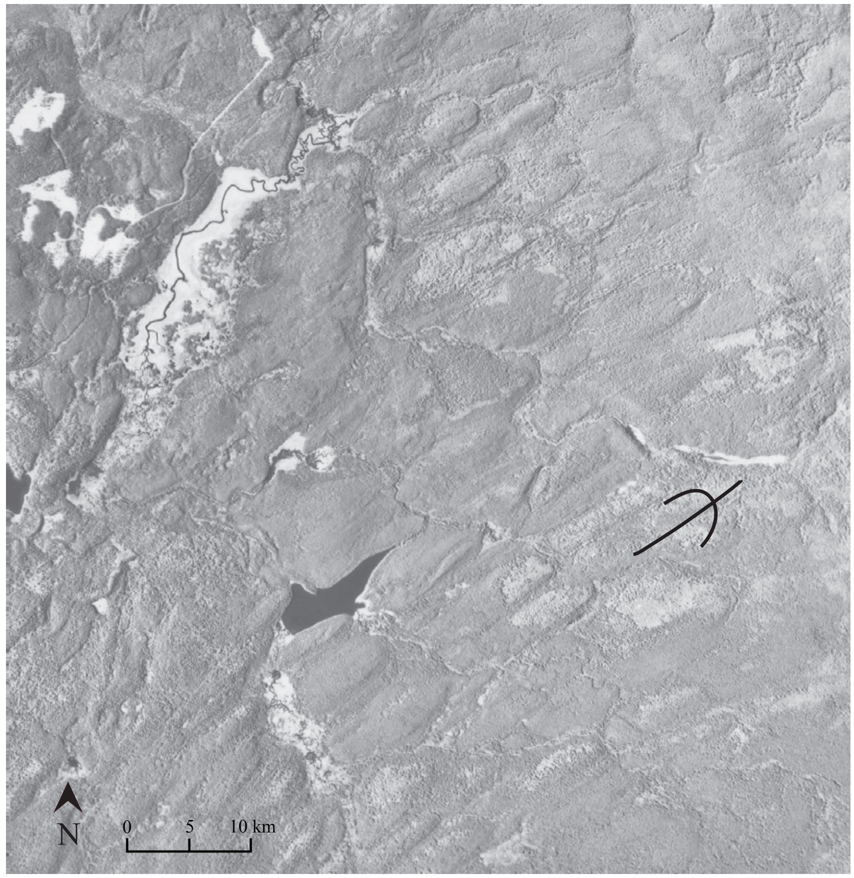

Figure 9. *Streamlined landforms in the southeast part of the map area indicate ice flow from the southwest to the northeast. (National Air Photo Library (NAPL) A28344-106).*

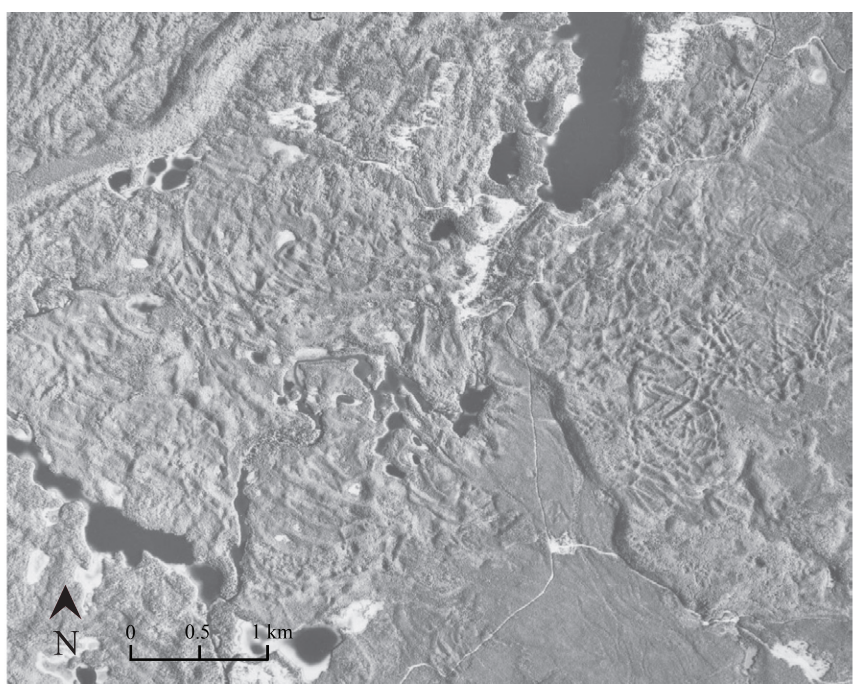

Figure 10. *Recessional moraine deposits in the southwest part of the map area are likely formed in part by buried ice and moraine deposited during retreat of the ice front. (NAPL A28344-52).*

Figure 11. *Bedrock, or strath terrace on the Caribou River in the northeast corner of the map sheet. Outlined area (t) represents the bedrock erosion surface. Modern stream flow is from right to left in the photo.*

Figure 12. *Thick glaciolacustrine deposits in the West Coal River valley. Section is ~30 m high and its stratigraphy is presented in Figure 14 (09KK09). Massive clay at the bottom of the section is ice-rich and prone to slope failure when exposed.*

failure when exposed to fluvial erosion. Glacial lake sequences are frequently capped by coarser grained (sand, pebbles and cobbles) glaciofluvial deposits, and represent glacial lake drainage and subsequent re-establishment of fluvial regimes. The surface expressions of these deposits are relatively flat to gently inclined plains, terraces and deltas. Modern streams have incised through much of the glacial deposition in the Coal and Rock river valleys, reaching bedrock in some locations.

Deeply incised, east-flowing meltwater channels, and associated glaciofluvial deltas at their outlets, are distinctive landforms of the Coal River map sheet (Fig. 13). These meltwater canyons dissect the regional north-trending ridges at regular intervals across the map sheet (Fig. 14). The channels are generally 10-15 km long, but some channels extend to as much as 50 km in length. These meltwater channels form box-shaped canyons that are predominantly erosional features, but in many cases contain extensive accumulations of organic deposits on their channel floors. The primary depositional feature associated with the meltwater channels are large, terraced deltas that formed where the channels debauch into a north-trending valley (Fig. 13).

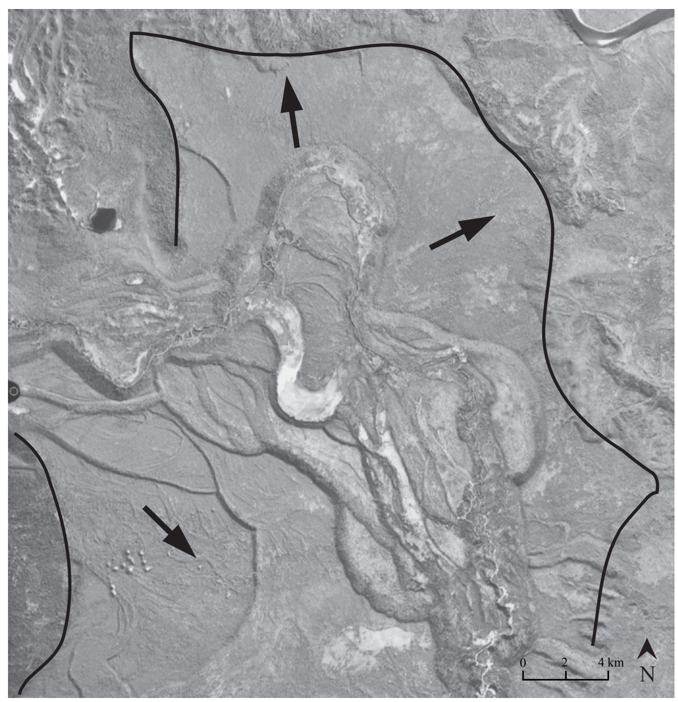

Figure 13. *Large delta at the mouth of an east-flowing meltwater channel in the Coal River valley (NAPL A28425-35). Outside edge of the delta is outlined, and flow direction is indicated with arrows.*

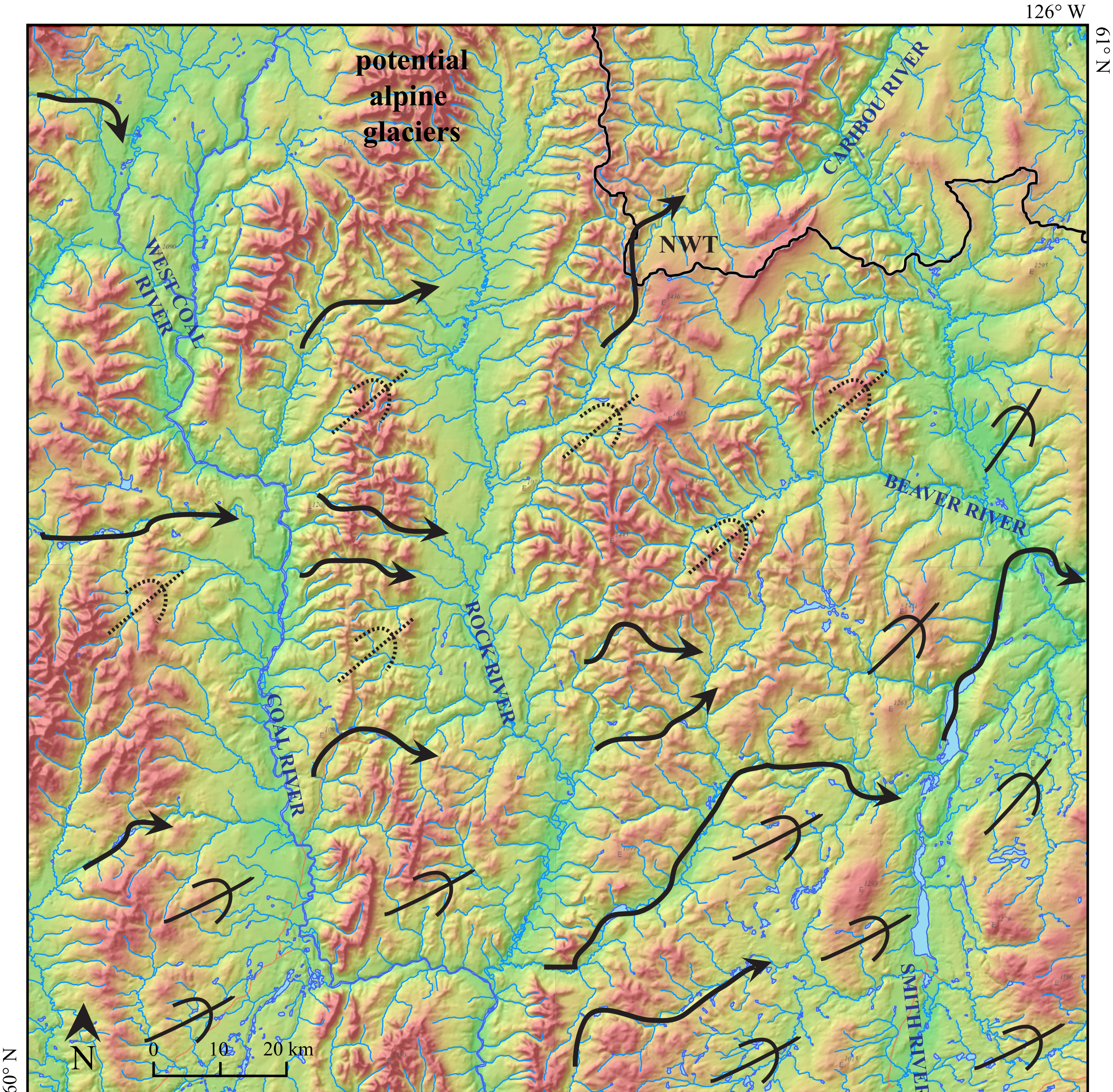

Figure 14. *East-flowing meltwater channels dissect the north-trending ridges of the Coal River map area at regular intervals. Arrows indicate major meltwater channels, and streamlined symbols represent ice-flow directions across the southern part of the map sheet. Dashed streamlined symbols are inferred ice-flow directions.*

STRATIGRAPHY

Stratigraphic sections are illustrated in Figure 15 for the West Coal, Coal and Rock rivers. The locations of the sections are indicated on Figure 3.

09KK15

Section 09KK15 comprises ~40 m of gravel, sand, silt and clay (Fig. 15). The lowermost unit is an ~8-m-thick sequence of highly oxidized, well-sorted, centimetre-sized pebble gravel and crossbedded sand that is unique to the map area. It is overlain by an ~30-m sequence that grades from massive sand, to interbedded sand and cross-stratified silt and clay, to massive clay, and finally back to interbedded cross-stratified sand with silt and clay. The uppermost unit in the exposure is a thin (~2 m) sandy gravel unit with an erosive lower contact.

The highly oxidized fluvial sediments at the bottom of the 09KK15 exposure are interpreted as a pre-glacial fluvial deposit. The overall gradually fining-up stratigraphy of section 09KK15 is interpreted as representing sedimentation from an increasing distal source, or deposition into a deepening lake. Drainage of the lake would have initiated deposition of the uppermost glaciofluvial unit.

09KK09

The stratigraphy at section 09KK09 is largely inverted from that at 09KK15. A thick (~10 m) silty clay unit grades up to a silty sand, and finally into massive to weakly bedded sand at the top of the exposure (see also Figure 12). One thin horizon of cobbles was observed between the silty sand and massive sand units. The lower oxidized unit of section 09KK15 was not observed at the 09KK09 exposure.

The stratigraphy at section 09KK09 is interpreted to represent the progradation of a delta in the West Coal River valley. The delta was likely fed by a meltwater channel flowing from the west. The thin cobble horizon may record shifting channel patterns, or a periodic high-energy flow event. Stratigraphic exposures on the West Coal River provide evidence for extended glaciolacustrine sedimentation in the upper Coal River valley. The fine-grained textures of glaciolacustrine sediments, along with the absence of observed dropstones or other ice-rafted debris, suggest the ice front blocking the regional drainage was at a considerable distance from the West Coal River area.

09KK27A

Two exposures on the lower Coal River, occurring only 100 m apart, have distinctly different stratigraphy. Section 09KK27A is comprised of ~15 m of interbedded silty clay, and silty fine sand. This unit has an erosional upper contact and is overlain by an ~3-m-thick, moderately to well-sorted pebble-cobble gravel unit.

The fine sand, silt and clay comprising the bulk of the 09KK27A exposure is similar to exposures on the West Coal River, and is interpreted as glaciolacustrine deposition. Similar to the sections to the north, the 09KK27A section is also capped by a thin gravel deposit interpreted as post-lacustrine glaciofluvial deposition.

09KK27B

Exposure 09KK27B is located approximately 100 m downstream of section 09KK27A and can be divided into a lower, ~16-m-thick diamict unit, and an upper, ~4-m-thick diamict unit. The lower diamict is well indurated, contains striated, boulder-sized clasts, and has a matrix of silt and clay with minor sand. In contrast, the upper diamict lacks very large boulders (all <1 m in diameter), is less cohesive, contains isolated lenses of sorted sand and gravel, and has a matrix dominated by sand with a lesser component of silt and minor clay.

The lower diamict at section 09KK27B is interpreted as till, while the overlying upper diamict is interpreted as a melt-out, or colluviated till. The juxtaposition of two very different stratigraphic profiles in close proximity makes interpretations of their depositional environments difficult. The lower Coal River exposures have been interpreted as representing a moraine ridge (09KK27B) with later, glaciolacustrine deposits (09KK27A) abutting the moraine margin.

09KK20

Unlike the West Coal River sections, the upper Rock River sections (09KK20 and 09KK14) both contain diamict units. In section 09KK20, the lower, dark grey to almost black, well-indurated diamict is ~9 m thick and has a silty clay matrix (~75%) with a maximum clast size of ~25 cm. The underlying unit of interbedded silty clay and sand display disrupted and faulted bedding planes, indicative of glacio-tectonism.

The upper, tan diamict at exposure 09KK20 is ~4-5 m thick, and has a sharp lower contact with the underlying sand and gravel. The matrix (~40%) is composed

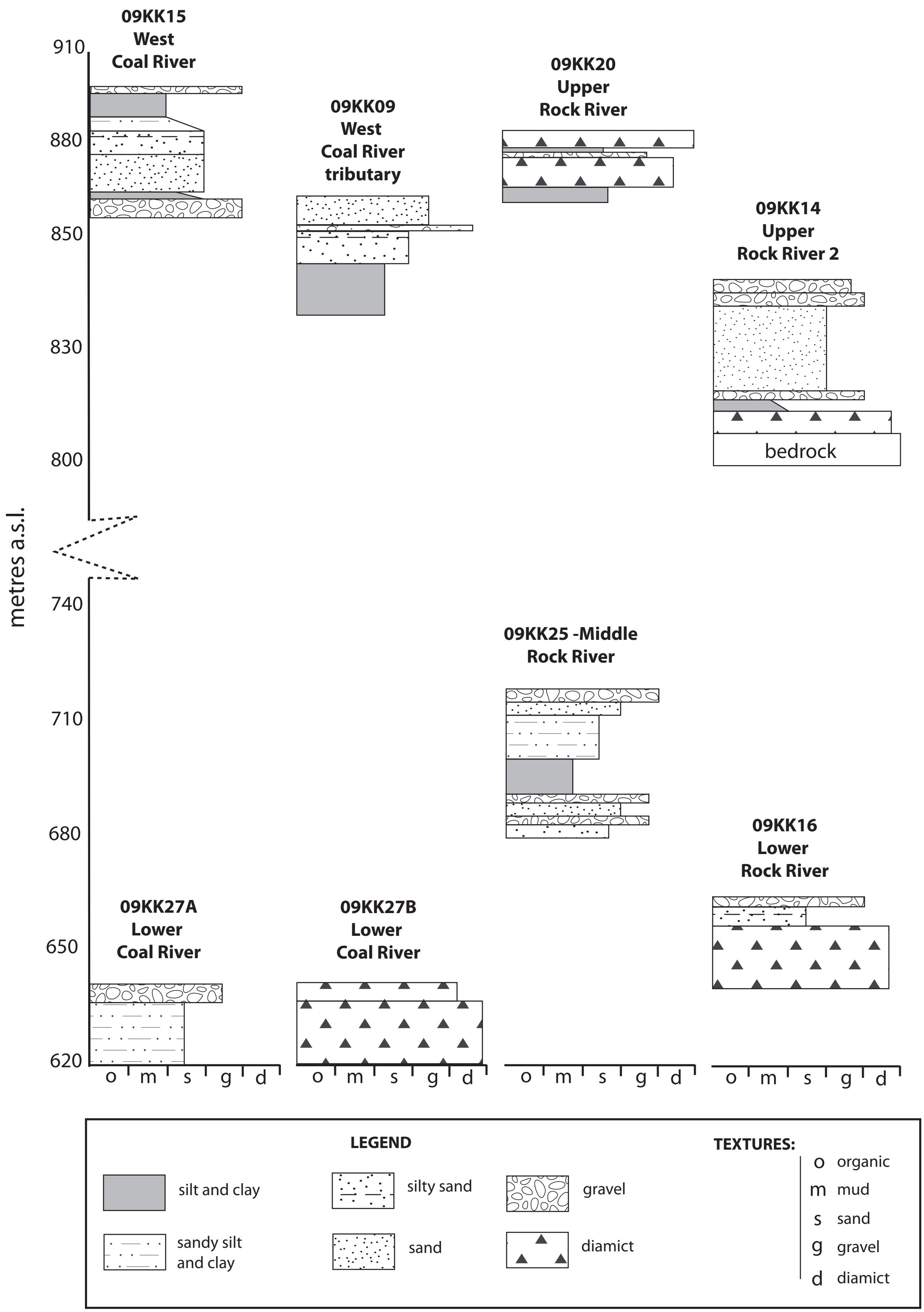

Figure 15. *Stratigraphic logs of sections on the West Coal, Coal and Rock rivers. Unit textures are presented on the x-axis. Lithologies are represented by fill patterns.*

predominantly of silt, and clasts are well rounded with a maximum diameter of ~80 cm.

The uppermost Rock River exposure is unusual in that it preserves significant thicknesses of glacial diamict. The dark, fine-grained lower diamict at 09KK20 is interpreted as till, while the genesis of the upper diamict is uncertain. The upper diamict either represents a different glacial depositional event, or post-glacial reworking of hillslope moraine into the valley bottom.

09KK14

At section 09KK14, ~3 m of matrix-dominated, clay-rich diamict is overlain by a thick package of sand, silt, clay and gravel. The diamict is poorly exposed and overlies bedrock. This is the only section where the underlying bedrock contact was observed.

The diamict unit overlying bedrock at section 09KK14 is interpreted as a till. Fine-grained sediments overlying the diamict are interpreted as glaciolacustrine and glaciofluvial deposits associated with glacial recession.

09KK25

Section 09KK25 consists predominantly of fluvial, or glaciofluvial and glaciolacustrine sediments, without any diamict units. The lower sand and gravel units (~15 m thick) have sedimentary structures indicating northerly, or up-valley paleo-flow (compared to modern southward flow); these units are overlain by ~2 m of massive silt with well-developed compression jointing (Fig. 16). The silt unit has a sharp, conformable contact with an overlying unit of interbedded massive grey clay and thinly laminated fine grey sandy-silt that becomes increasingly clay rich over its ~5 m exposure. This fine-grained grey unit grades upward into a tan-coloured, ripple cross-laminated silty-sand with flow structures that are parallel to present-day flow direction (to the south). The uppermost unit is a sand and gravel deposit with a lower erosive contact and south-trending flow structures.

The north-flow directions (opposite to present-day flow) on the lowest sand and gravel units at section 09KK25 are interpreted as ice-proximal glaciofluvial deposits from a southward-retreating ice front. Loading and compression features in the overlying silt unit suggest this unit represents abrupt deposition and equally abrupt drainage of a small lake or pond in the proglacial environment. Following drainage, the weight of the saturated silt itself could be responsible for forming the compression fractures in this unit. The thick package of fine-grained

Figure 16. *Compression jointing formed in a silt unit of section 09KK25. Ice axe is 75 cm tall.*

sand, silt and clay overlying the compressed silt unit is interpreted as glaciolacustrine sedimentation. The reverse (coarsening-up) grading of this unit is interpreted as the progradation of a sediment source. The section is capped with a coarse, pebble-cobble unit interpreted as glaciofluvial sedimentation following drainage of a glacial lake. The entire sequence was likely formed in a highly dynamic proglacial environment characterized by sudden shifts in drainage and meltwater input.

09KK16

The lowermost exposure on the Rock River (09KK16) is similar to the lower Coal River exposures and comprises ~15-20 m of diamict overlain by sand and gravel. The tan-weathered, silt-rich diamict is ~40% subrounded, pebble to cobble-sized clasts with a maximum diameter of ~30 cm. The overlying massive to weakly bedded sand has a gradational contact with the uppermost imbricated, clast-supported, pebble-cobble gravel. Imbrication indicates southward flow, *i.e*, parallel to modern-day flow. The sequence of diamict and overlying sand and gravel at section 09KK16 is interpreted as a till with overlying recessional glaciofluvial sedimentation.

DISCUSSION

The surficial geology of the Coal River map sheet reflects the history of glaciation in southeastern Yukon. The pre-glacial landscape of north-trending valleys and uplands has been altered by east-flowing meltwater channel incision, by erosion and deposition by proglacial

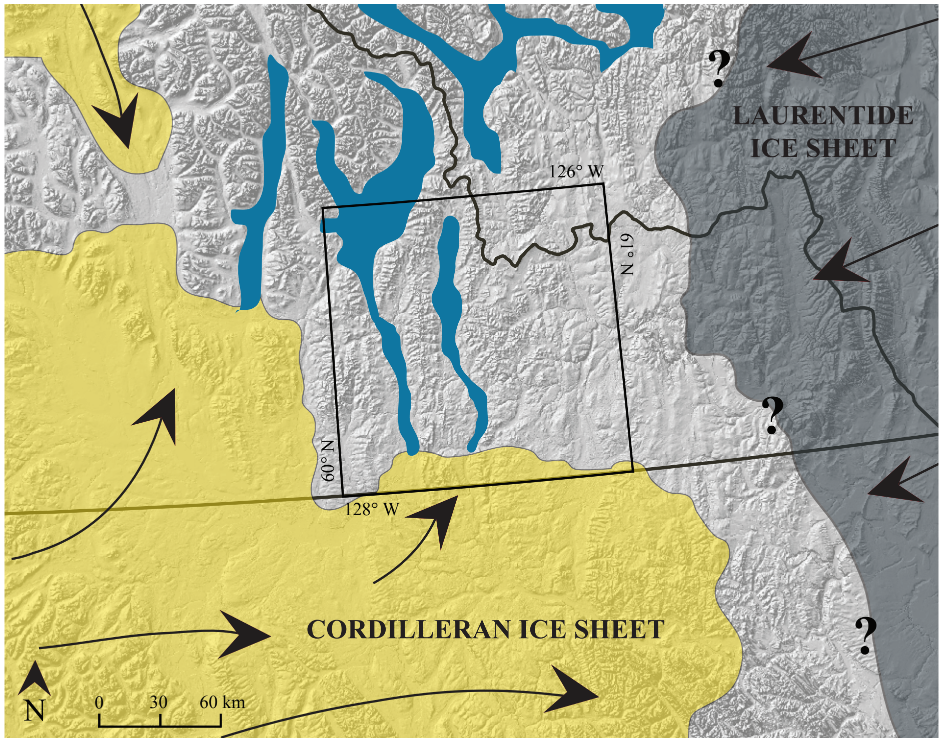

Figure 17. *Early in the Cordilleran Ice Sheet advance, glacial lakes were probably impounded in south-flowing valleys in the Coal River map sheet (outlined). The Laurentide Ice Sheet had probably already advanced near its maximum limit at that time.*

lakes and streams, and by the movement of glaciers across the landscape. Predicting the distribution of surficial materials relies on accurately reconstructing the processes that created the post-glacial landscape. While the observations presented here are only preliminary, they suggest a number of potentially new interpretations for the glacial history of the Coal River map sheet.

GLACIAL ADVANCE

The advance of Cordilleran glaciers from the Cassiar Mountains into the map area was probably in the form of a piedmont glacier flowing southeast across the Liard Plain (Klassen, 1987). Early in the advance phase of glaciation, sublobes of the main piedmont glacier advanced north into regional south-flowing drainages and created proglacial lakes (Fig. 17). Until the Cordilleran Ice Sheet advanced sufficiently to meet the Laurentide Ice Sheet, free drainage to the east likely persisted. Advance-phase proglacial lakes may have overtopped regional divides and incised meltwater channels to establish northern drainage at this time.

As the Laurentide Ice Sheet advanced westward toward the Coal River map sheet, east-flowing drainages were probably diverted west into unglaciated regions. It is possible that diverted Laurentide meltwater flowed south into the Coal River map sheet and was responsible for the extensive erosion in the eastern Caribou River and Toobally Lakes valleys.

GLACIAL MAXIMUM

While the Cordilleran glacial advance was valley-constrained, striations on bedrock along high ridges in the map area suggest the ice eventually thickened sufficiently to overtop topographical highs and establish an east-northeast flow direction. Only one general ice-flow direction from glacial maximum was recorded in the map area, despite other evidence that the region has been glaciated repeatedly during the Pleistocene. This suggests that all advances occurred with the same pattern of growth and maximum flow, or that only one, or a few very similar, glaciations were extensive enough to overtop regional divides. If the latter case is true, the striations found at higher elevations may be artifacts of an early or mid-Pleistocene glaciation, as the most recent Cordilleran advance in Yukon was the least extensive of Pleistocene glaciations (Jackson, 1991).

Cirque landforms developed on north-facing slopes in the northern part of the map sheet provide evidence of montane glaciation. Many cirques are weakly developed and lack the neo-glacial moraines and rock glaciers common to higher regions to the north (*e.g.*, Dyke, 1990). This implies that many of the cirques were formed during

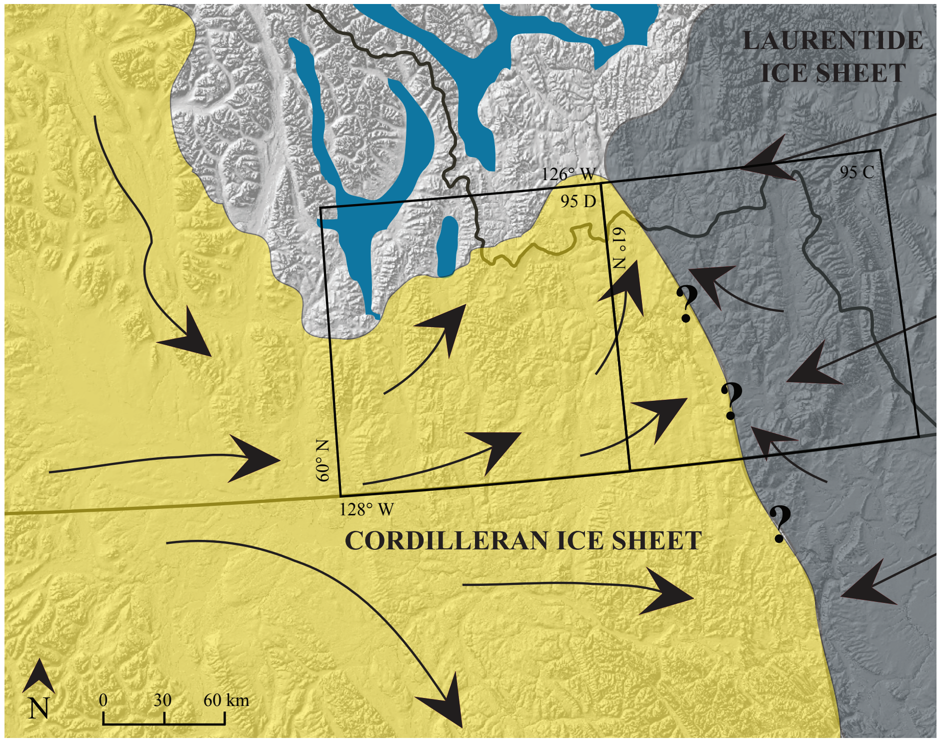

Figure 18. *Potential glacial maximum extent in the Coal River map sheet (outlined). The location where the Cordilleran and Laurentide ice sheets converged is approximate (adapted from Smith, 2000); however, ice-flow indicators from both ice sheets divert northward, just east of the Coal River map sheet.*

pre-late Wisconsinan glaciation(s) that were more conducive to alpine glacier growth in this region. The two distinct diamict units on the upper Rock River (09KK20) are not preserved elsewhere in the map area, and may represent montane ice advances limited to the northern part of the Rock River valley.

The possibility exists that some of the higher topographic regions in the north-central and northwest corner of the map sheet remained unglaciated during Cordilleran glacial advances (Fig. 18). Klassen (1987) initially suggested an ice-free region in the northwest corner of the map sheet based on thick lacustrine sediments and more dissected surfaces without the distinct glacial features evident in the south. The stratigraphy from the West Coal River supports this hypothesis, and it is possible that alpine glaciers originating in the few high cirques in the region were limited in extent since glacial deposits were not observed in the valley bottoms. Similar dissected surfaces without obvious glacial features are found in the high ridges between the Caribou and Rock rivers, suggesting these areas may have remained unglaciated throughout the Pleistocene. Unglaciated regions typically preserve important paleo-ecological records, and further investigation is required to determine potential in the Coal River map sheet for glacial refugia.

Smith (2000) suggests that the Laurentide Ice Sheet advanced at least to the middle of the La Biche River map area (95C; Fig. 18) during its late-Wisconsinan advance, but no clear limit was mapped. Because the late-Wisconsinan advance was the most extensive of the Laurentide glaciations, it has the highest potential to have extended near, or into, the Coal River map sheet. Geomorphic evidence east of Coal River (Smith, 2000) places the Laurentide Ice Sheet into the area before the Cordilleran Ice Sheet advanced, but the advance lacks chronological controls. It is assumed that both ice sheets were present in southeast Yukon during the late-Wisconsinan glacial maximum, and that the Laurentide Ice Sheet began to retreat earlier than the Cordilleran Ice Sheet.

GLACIAL RETREAT

Deglaciation of the Coal River map sheet produced extensive glaciolacustrine and glaciofluvial deposits. As ice retreated south and westward out of the map area, glacial lakes formed in the Coal, Rock, Smith and Beaver river valleys. Eastern drainages became ice-free before western drainages, and the deep meltwater canyons (Fig. 14) within the map area were likely successively incised as these meltwater routes became available. As the meltwater channels became active, the large deltas at the mouths of many channels were deposited (*e.g.,* Fig. 13).

Evidence of ice-front retreat is recorded in the southwestern corner of the map area, where the ice sheet was pulling back from the edge of the Hyland Plateau to the lower elevation Liard Plain. Abundant moraine, eskers, kettled and hummocky landforms reflect large volumes of meltwater and buried ice left by the ice sheet as it retreated west (Fig. 10). This is the only area in the map sheet with abundant features of glacier retreat, and clearly reflects a different style of deglaciation than that which occurred in other regions of the map area. The deposits may record a minor readvance or slowing of active retreat, allowing glacier ice to be buried under thick blankets of debris.

IMPLICATIONS FOR FUTURE DEVELOPMENT

The glacial history and distribution of surficial materials in the Coal River map area has a number of important implications for future development in the region. The distribution of both stable (sand and gravel) and unstable (silt and clay) surficial materials will be important for regional development and land use planning. Thick massive clay deposits in the Coal and Rock river valleys always contain some amount of ground ice and are prone to catastrophic slope failures when the ice melts. However, massive clay deposits are nearly always stratigraphically below well-drained glaciofluvial sand and gravel. Provided the ice-rich clay deposits are not exposed, the ground surface should remain stable. The many flat terraces in the Coal and Rock river valleys provide ideal surfaces for infrastructure development.

Prospecting in the Coal River map sheet should take into account the complex drainage history of the map area. Meltwater channels between drainage divides obscure the distribution and provenance of heavy minerals and stream sediments. Geochemical signatures from the western map sheet are expected to be present at least as far east as the Beaver River in 95C (Fig. 1).

Thin moraine deposits and unidirectional ice flow/dispersion trains can facilitate mineral exploration on high and mid-elevation slopes in the map area. Northern cirques affected by local glaciation are an exception and need to be examined at on an individual basis. At low elevations in the map area, up-valley advancing ice, and thick fine-grained deposits have the potential to make drift prospecting considerably more complicated. Prospectors should keep in mind that the glaciofluvial deposits at surface in the north-trending valleys are far-travelled and likely do not reflect underlying, or exclusively upstream, bedrock sources.

CONCLUSIONS

Glacial meltwater impoundment and drainage are major landscape-forming events in the Coal River map area. These processes have resulted in abrupt drainage diversions, thick accumulations of potentially unstable clay deposits and abundant, flat, gravel-rich terrace surfaces. Environments proximal to the edges of ice sheets are sensitive barometers of changes in ice sheet-climate dynamics, and can record regional climate changes on a local scale. The ice-proximal environments in southeast Yukon lack chronologies or paleoenvironmental descriptions.

Unresolved questions about the Coal River map area include the extent and chronology of Cordilleran and nearby Laurentide glaciations, the effect buttressing and subsequent debutressing would have had on the Cordilleran Ice Sheet in the Coal River map area, and the potential existence and extent of glacial refugia.

Continuing investigations of the surficial geology and Quaternary history of the Coal River map sheet will include mapping of ice-flow patterns and drainage routes (in 2010), the production of new surficial geology maps for the east half of 95D (in 2012), and updated surficial geology maps for the west half of 95D (in 2013).

ACKNOWLEDGEMENTS

Funding for this project was provided by the Yukon Geological Survey and the Geological Survey of Canada's Geomapping for Energy and Minerals (GEM) program. Able assistance in the field was provided by Martina Bezzola, Casey Cardinal, Gavin Clarkson and Kristy Long. Casey Cardinal also assisted with drafting some of the figures provided in this manuscript. Lee Pigage collected and shared alpine striation data that has been a valuable contribution to this study. Charlie Roots is thanked for his generosity in planning, running and sharing what turned out to be a successful and productive field camp. A review by Jeff Bond resulted in a greatly improved manuscript and his many valuable contributions are acknowledged.

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