Evidence for limited glaciation in northern Kluane Range, southwestern Yukon, with implications for surficial geochemical exploration

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ABSTRACT

Preliminary investigation of surficial geology in northern Kluane Range has resulted in new interpretations of Pleistocene ice cover including extensive unglaciated terrain and restricted glaciation during the Last Glacial Maximum. Two glacial limits are identified: a higher limit recording the most extensive glaciation of the area; and a lower limit that records younger, less extensive glaciation. This paper describes Pleistocene limits of the Donjek Glacier and the distribution of surficial materials in the upper Quill, Maple, and Wade creek drainages. The source and transport mechanism of surface materials has particular significance for surficial geochemistry sampling programs and implications for mineral exploration are addressed.

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INTRODUCTION

Preliminary results from 1:50 000-scale surficial geologic mapping in northern Kluane Range include new interpretations of glacial limits and descriptions of surficial material textures and distributions. The study area (Fig. 1) is characterized by steep, mountainous terrain and bedrock is commonly well exposed along canyons, ridges and high elevation summits. However, mid to low-elevation slopes of moderate steepness are largely covered with deposits of weathered bedrock, till, glaciofluvial and glaciolacustrine materials. Determining the provenance and composition of these materials can inform new surficial geochemical (e.g., soil, stream sediment, till) exploration programs and help interpret results from earlier programs.

GEOLOGY AND MINERAL DEPOSITS

Northern Kluane Range is a high-relief landscape surrounded by relatively subdued topography in Shakwak Trench to the east and the Duke Depression to the south and west. The range is bound by the Denali fault to the northeast and the Duke River fault to the southwest, forming a wedge of Late Paleozoic to Middle Mesozoic rocks that widens to the northwest (Israel and van Zeyl, 2005). A variety of mineral deposit types likely exist in the study area (Yukon MINFILE, 2017; Fig. 2), with regional occurrences including porphyry Cu-Mo-Au (Amp and Cork), possible Besshi-type massive sulphide (Musketeer and Burwash), and the well-known Ni-Cu-PGE ultramafic complexes (Wellgreen, Linda, Jaquot, Quill). Additionally, placer gold (and minor platinum) deposits are found

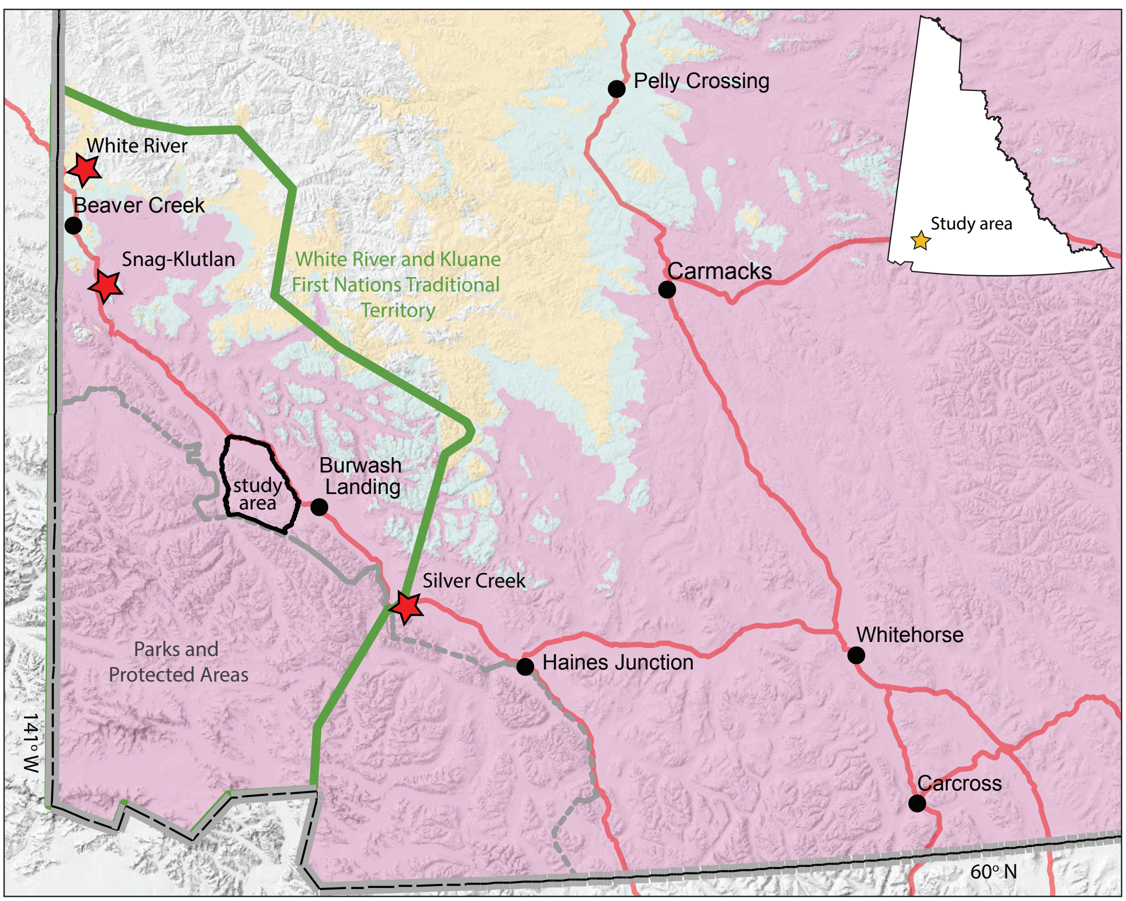

Figure 1. *Location of the study area (outlined in black) in SW Yukon. The study area is in the Traditional Territory of the White River and Kluane First Nations (outlined in green), adjacent to Kluane National Park and Asi Keyi Territorial Park (outlined in grey). Locations of glacial history studies mentioned in text are marked with red stars. Regional glacial limits by Duk-Rodkin (1999) are shown in pink (least extensive), blue (intermediate extent), and yellow (most extensive). Yellow (most extensive) limits of the St. Elias Lobe mapped by Duk-Rodkin (1999) have not been confirmed by subsequent authors (i.e., Turner et al., 2013) working in southwestern Yukon.*

in most streams draining the study area and may be associated with native gold in bedrock, paleo-placer gold in Cenozoic conglomerate units, and/or gold transported by glacial processes (YGS, 2010; van Loon and Bond, 2014; Kennedy and van Loon, 2017).

GLACIAL HISTORY

The Quaternary in southwestern Yukon has been marked by cyclical advance and retreat of valley glaciers originating in the St. Elias Mountains, which have, during extended cold periods, coalesced and filled the broad Shakwak Trench, advancing up to 125 km to the north and northeast (Fig. 1; Duk-Rodkin, 1999). The coalescing glaciers formed the St. Elias lobe within the northern sector of the Cordilleran Ice Sheet (CIS). At Silver Creek, a tributary to the south end of Kluane Lake, Turner *et al.* (2016) identified at least five Middle to Late Pleistocene advances of the northern Cordilleran Ice Sheet. The three most recent advances identified at Silver Creek correlate well with glacial deposits in the Snag-Klutlan and White River areas north of the study area (Fig. 1; Rampton, 1971; Turner *et al.*, 2013).

The build up of the St. Elias lobe appears to have been out of phase with overall global ice volumes and advances of the CIS in central Yukon (Turner *et al.*, 2013). Central Yukon saw maximum advances of ice prior to marine isotope stage (MIS) 6 (Pre-Reid glaciations; Ward *et al.*, 2008; Westgate *et al.*, 2008), and limited advances in MIS 4 (Gladstone Glaciation; Ward *et al.*, 2007). The most

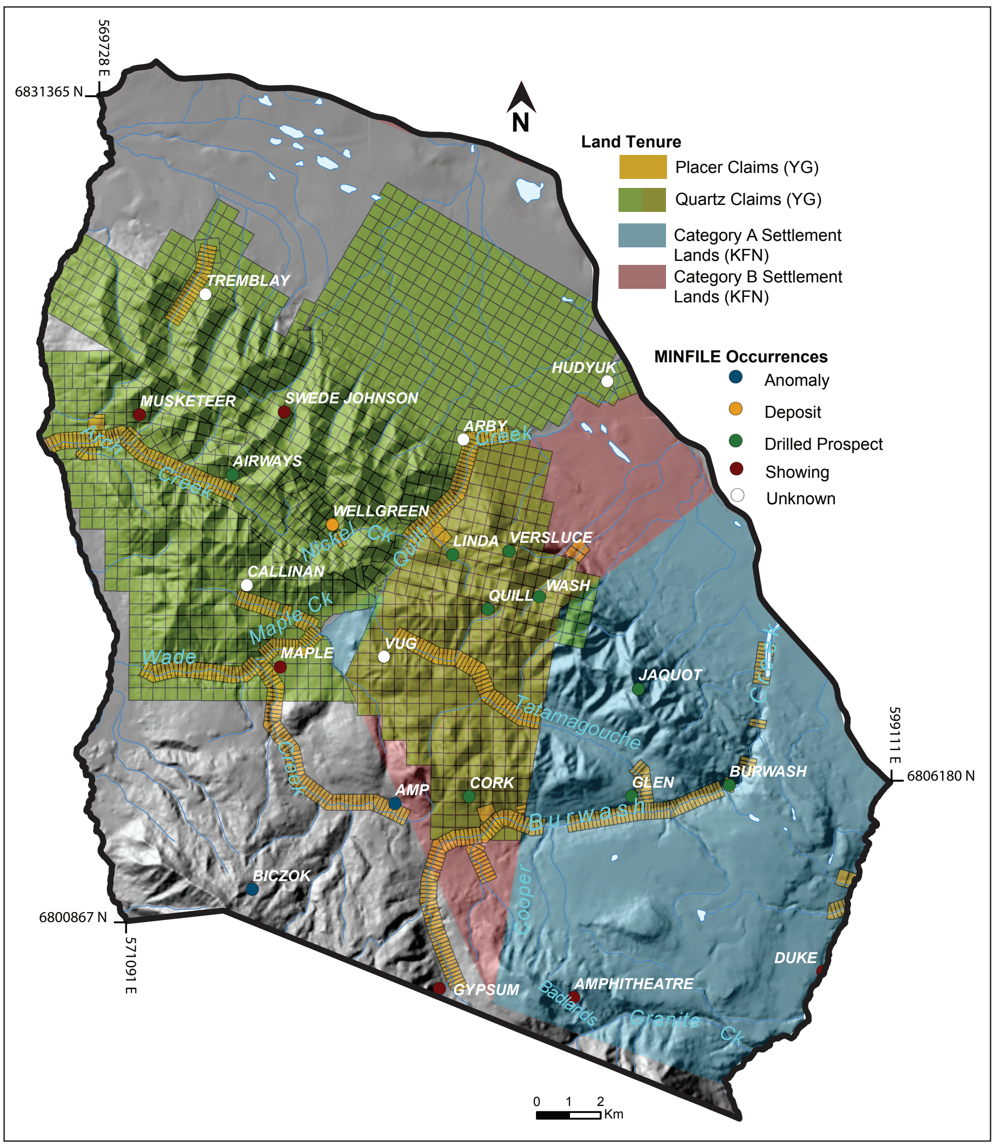

Figure 2. Land tenure and locations of MINFILE occurrences in the study area.

extensive advance of the St. Elias lobe occurred in MIS 6 (Reid Glaciation), with a very similar extent achieved in MIS 4 (Gladstone Glaciation), suggesting constraints on precipitation in the St. Elias Mountains remained similar through the Pleistocene (Turner *et al.*, 2013). The pre-Reid (prior to MIS 6) extent of the St. Elias lobe suggested by Duk-Rodkin (1999; yellow limit in Fig. 1) has not been confirmed by subsequent mapping (Bond *et al.*, 2008; Lipovsky and Bond, 2013) and paleoenvironmental studies (Turner *et al.*, 2013) which found the most extensive limit to correlate with mapped MIS 6 (Reid Glaciation) limits.

PREVIOUS WORK

Regional-scale (1:250 000) glacial limit mapping and compilation work by Duk-Rodkin (1999) used glacial landforms to reconstruct paleo ice-flow directions and suggested three sources of ice during regional glaciations in the study area: (1) locally-sourced alpine glaciers; (2) advances of the Donjek Glacier and its tributaries along the western edge; and (3) advances of glaciers occupying the Shakwak Trench, including a glacier in the Duke River valley which may have advanced over the Burwash Upland (Fig. 3). This mapping suggests high elevation peaks in the study area may have been unglaciated during the most recent advance, but were completely inundated by ice in earlier advances (Duk-Rodkin, 1999). Glacial limits of ~1200-1400 m above sea level (a.s.l.) were suggested in earlier work related to 1:100 000-scale surficial geological mapping of a large part of the study area (Rampton, 1980; 1981), however, no surficial mapping was completed for Arch, Wade, or Maple creeks.

GLACIAL LIMIT MAPPING

Glacial limit mapping in 2017 focused on limits associated with advance of the Donjek Glacier along the northwestern margin of the study area. Glacial limits associated with Duke and Shakwak glaciers will be investigated in 2018. During periods of advance of the St. Elias lobe, the Donjek Glacier thickened considerably, inundating and flowing up valleys draining the northern Kluane Range. Two distinct ice limits are mapped along the eastern margin of the Donjek valley and extend into the drainages of Arch, Wade, Maple and Quill creeks (Fig. 4). The limits are highest in the western part of the map area, where

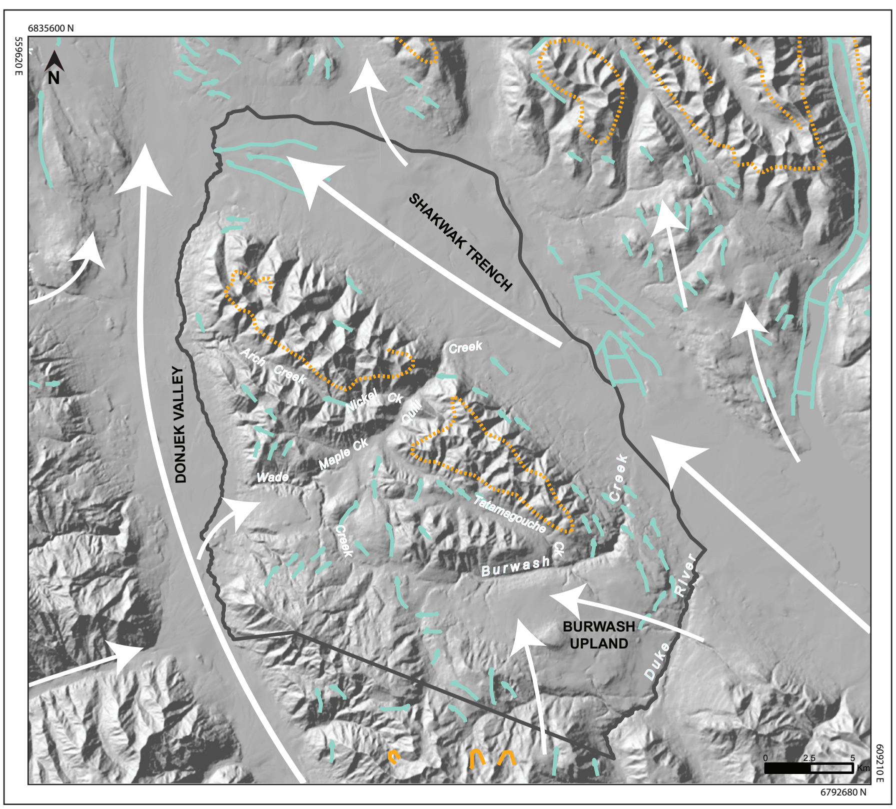

Figure 3. *Regional glacial limits (yellow lines) and meltwater channels (blue arrows) from existing glacial limits mapping (Duk-Rodkin, 1999). Generalized flow directions are represented by white arrows and suggest Donjek Valley and Shakwak Trench glaciers flowed up tributary valleys in the study area.*

the Donjek Glacier flowed along the mountain front, and descend in elevation eastward toward terminus positions in the valley bottoms of the Kluane Range.

Both higher all-time limits and younger lower elevation limits may be composite features consisting of multiple ice advances that reached similar extents, and/or recessional limits. All-time limits in the study area are identified through a combination of erratic and landform mapping. Extra-basinal pebbles and cobbles are identified along ridges and spurs in the study area (Fig. 5), and their elevations are used to correlate discontinuous and subdued landforms. Landforms preserved at the all-time limit are typically rounded in appearance, and have been eroded by subsequent colluvial and/or glaciofluvial processes. The limit is best marked by meltwater channels along spurs (Fig. 6) and rare ice marginal features preserved on high elevation valley floors. There is no age associated with the all-time limit in the study area but it may correlate with one or both of the MIS 6 all-time limit or the similarly extensive MIS 4 limit documented by Turner *et al.* (2013) on the White River and mapped to the north by Lipovsky and Bond (2013).

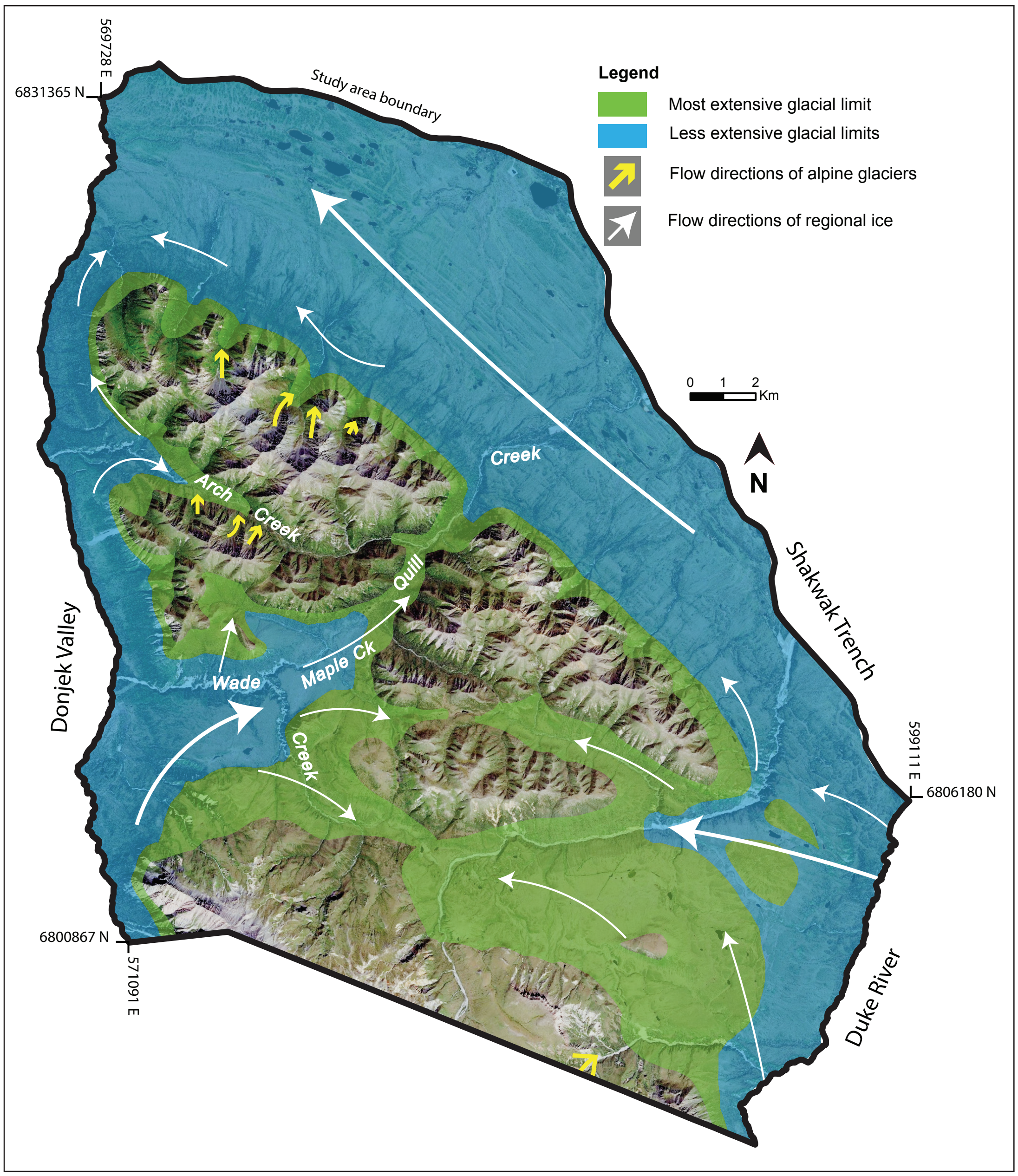

Figure 4. *Preliminary glacial limits for the study area, including draft limits for the Donjek Glacier, and tentative limits for glaciers occupying Shakwak Trench.*

Landforms associated with the lower limit are typically well preserved, and are best marked by glaciofluvial features including kame terraces and meltwater channels (Fig. 6). Up-valley flowing ice from the Donjek Glacier would have impounded the drainages of Wade, Maple and Arch creeks (*see* Fig. 4), creating glacial lakes and redirecting meltwater and stream flow over former drainage divides. Landforms characteristic of glacial lakes and streams include broad glaciofluvial deltas and terraces (Fig. 7), often overlying glaciolacustrine silt and sand. There are no ages associated with low elevation limits in the study area, but they may correlate with one or both of the most recent regional glaciations (MIS 4 or MIS 2).

Figure 5. *Example of an erratic cobble (circled) marking the all-time glacial limit in the study area.*

WADE CREEK GLACIAL LIMITS

In the Wade Creek valley, glacial limits suggest ice during the most extensive glaciation entered the valley as a broad off-shoot of the Donjek Glacier. It would have measured ~8 km across at the mountain front where it entered the Wade Creek valley and narrowed rapidly as it flowed up the valley and across the narrow drainage divide (Fig. 4).

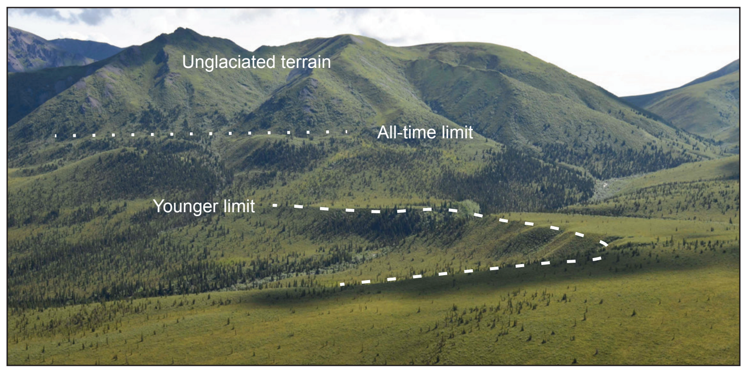

Figure 6. *Both the all-time limit and a more recent glacial limit are visible in this tributary to Maple Creek. The older, higher elevation, limit is marked by a meltwater channel with subdued morphology. The younger limit is marked by an ice-contact, or possibly glaciolacustrine, delta with well-defined morphology.*

Northward flow of the trunk glacier in the Donjek valley resulted in a higher northern limit (~1550 m a.s.l.) and lower southern limit (~1450 m a.s.l.) at the mouth of the Wade Creek valley, with the ice surface achieving a level cross-valley profile ~5 km up valley at an elevation of ~1400 m a.s.l. The main body of ice flowed up the Maple Creek valley, crossing the divide at 1150 m a.s.l., and flowing down Quill Creek valley to its terminus position at the confluence of Nickel and Quill creeks, where it measured ~500 to 700 m wide at an elevation of ~1100 m a.s.l. (Fig. 8). Moraines associated with glaciation in the Shakwak Trench are preserved at the terminus position, and it is possible Donjek ice coalesced with Shakwak ice in this location.

All-time ice also advanced eastward into upper Wade Creek and a NE-flowing unnamed tributary to Maple Creek (Fig. 8). Ice entered these valleys at elevations of ~1450-1500 m a.s.l., and flowed ~3 to 5 km upstream before terminating at ~1350 m a.s.l. It is possible that Donjek ice in these tributaries coalesced with Shakwak ice flowing up Burwash and Tatamagouche valleys during this most extensive glaciation.

Figure 7. *Maple Creek is characterized by a broad flat valley bottom filled with glacial materials (view west toward the Donjek River). The modern stream is cutting through thick surficial sediments (see Fig. 14) before becoming entrenched in a bedrock canyon just above its confluence with Wade Creek.*

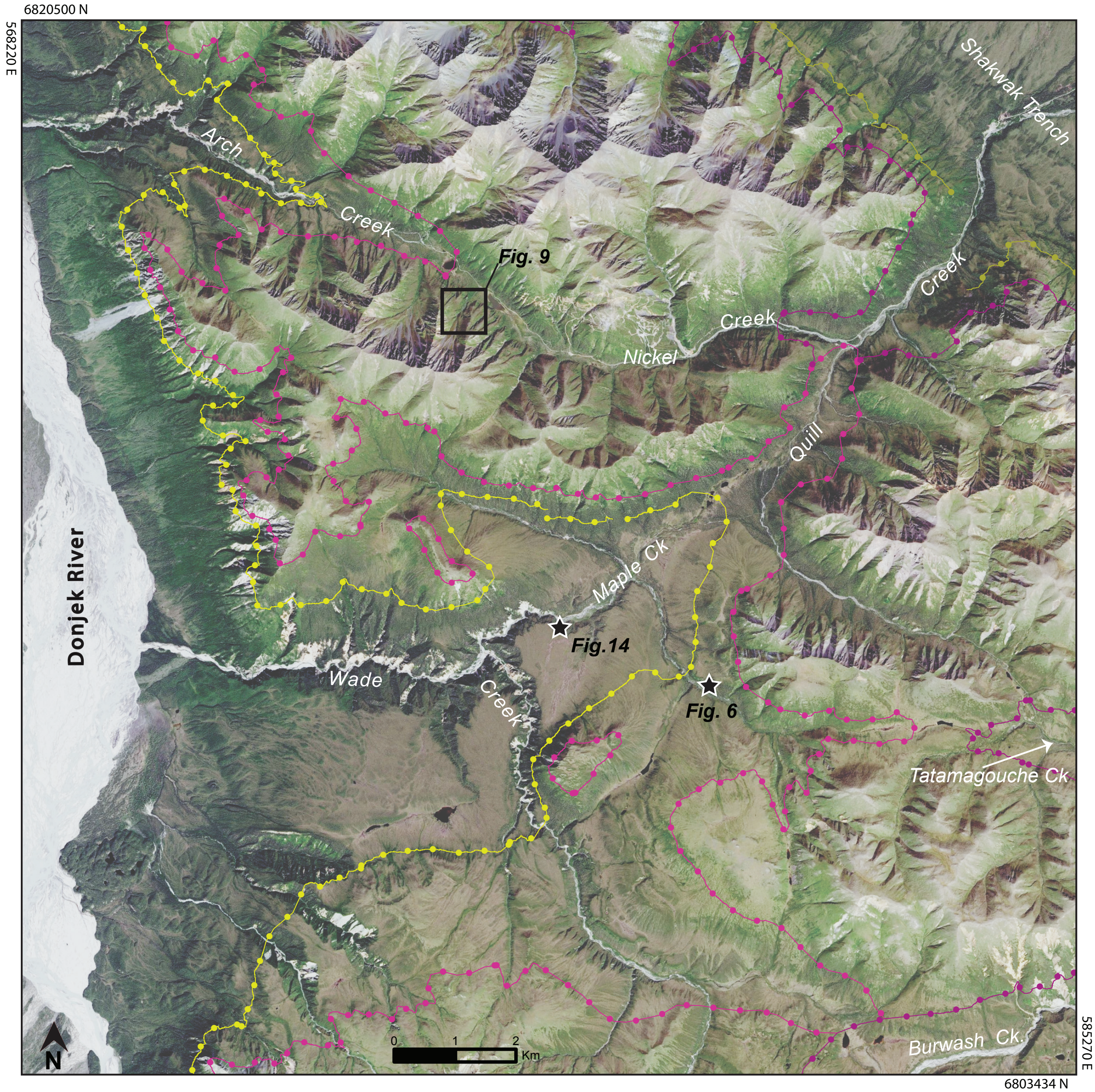

Figure 8. *Glacial limits in the western part of the study area. Pink lines indicate higher, all-time limits, and yellow lines indicate lower, more recent limits. Darker shades of pink and yellow are limits associated with glaciers in the Shakwak Trench.*

Younger, lower elevation limits in Wade Creek valley are considerably less extensive than all-time limits, terminating ~3 km SW of the all-time limit (Fig. 8). The lower limit also has an asymmetrical profile at the mountain front, entering the Wade Creek valley at ~1300-1250 m a.s.l., and descending to its terminus position at 1150 m a.s.l. near the modern divide of the Maple and Quill creek drainages. The lower limit did not advance into tributary valleys, and these limits are marked with large, well-preserved ice-contact glaciofluvial terraces and kames (*i.e.*, Fig. 6).

ARCH CREEK GLACIAL LIMITS

Donjek Glacier ice entering Arch Creek valley during the most extensive glaciation was more constrained than in Wade Creek valley. Only ~3.5 km wide at the mountain front, ice was unable to advance as far into the narrower Arch Creek valley. Surface elevations of ~1400 m a.s.l. at the mouth of Arch Creek descend over ~5 km to a terminus elevation of ~1300 m a.s.l. during the most extensive glaciation (Fig. 8). This left much of the Nickel Creek valley unglaciated, and it likely served as a conduit for glacial meltwater flowing toward Shakwak Trench.

Younger, low elevation limits in the Arch Creek valley are even more restricted compared to earlier glaciations (Fig. 8). Limits are largely found at ~1200-1250 m a.s.l., however stacked moraines from ~1100 to 1200 m a.s.l. may record recessional features, and/or separate advances that achieved very similar limits. Ice thicknesses during the most recent glaciation were likely insufficient to redirect meltwater through Nickel valley, and ice contact features along the limit record ice marginal damming and redirection of flow northward along the margin of the Donjek Glacier.

Alpine glaciers occupied some north and northeast-facing cirques in the Arch Creek valley during the Quaternary (Fig. 4). Moraines are poorly preserved and glaciers appear to have been limited to high alpine valleys. Alpine moraines are preserved in an unglaciated reach of the Arch/Nickel valley where cirque glaciers extended onto the valley floor (Fig. 9).

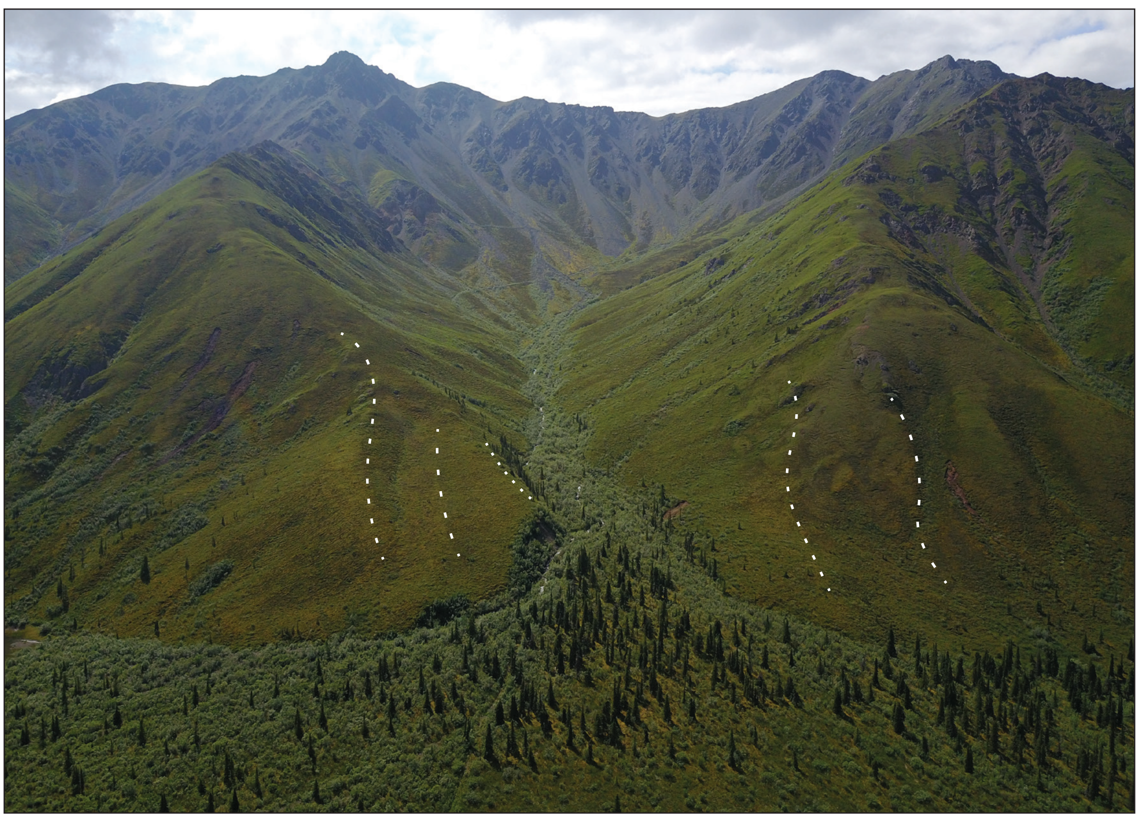

Figure 9. *Alpine moraines (dashed lines) preserved in a small north-facing cirque in the divide between Arch and Nickel creeks, beyond the all-time limits of the Donjek Glacier in Arch Creek (location shown on Fig. 8).*

SURFICIAL MATERIALS

The distribution of surficial materials is controlled by the limits of glaciation and the relative steepness of slopes in any particular setting in the study area. Colluviation (the movement of materials through the action of gravity) is, by far, the most active surficial process on-going today. Together with steep, high-energy streams in the study area, the landscape in the Kluane Ranges is capable of moving unconsolidated surficial materials quickly off slopes and out of the study area.

While many streams currently occupy channels incised into bedrock, thick surficial cover is preserved in the broad, relatively flat-bottomed upper reaches of Arch, Wade, Maple, and Quill creeks (Fig. 7). A typical valley profile, from unglaciated uplands to bedrock entrenched stream, is presented in Figure 10 and described below.

UNGLACIATED TERRAIN

Much of the high elevation terrain in the study area remained unglaciated throughout the Quaternary (*see* Fig. 4). On the steepest slopes, freshly weathered bedrock surfaces may be covered with thin to moderate thicknesses (0-1 m) of weathered bedrock and weathered bedrock colluvium as a veneer or mantle of variable thickness (*see* Fig. 10).

Moderate slope angles typically have distinctive cryoplanation or pediment surfaces that are unique to unglaciated terrain (Fig. 11). These surfaces often have thin veneers or blankets of weathered bedrock colluvium overlying bedrock. In the study area, where rates of erosion and uplift are high, some raised surfaces retain fluvial and colluvial sediments deposited at the time they were formed (Fig. 12).

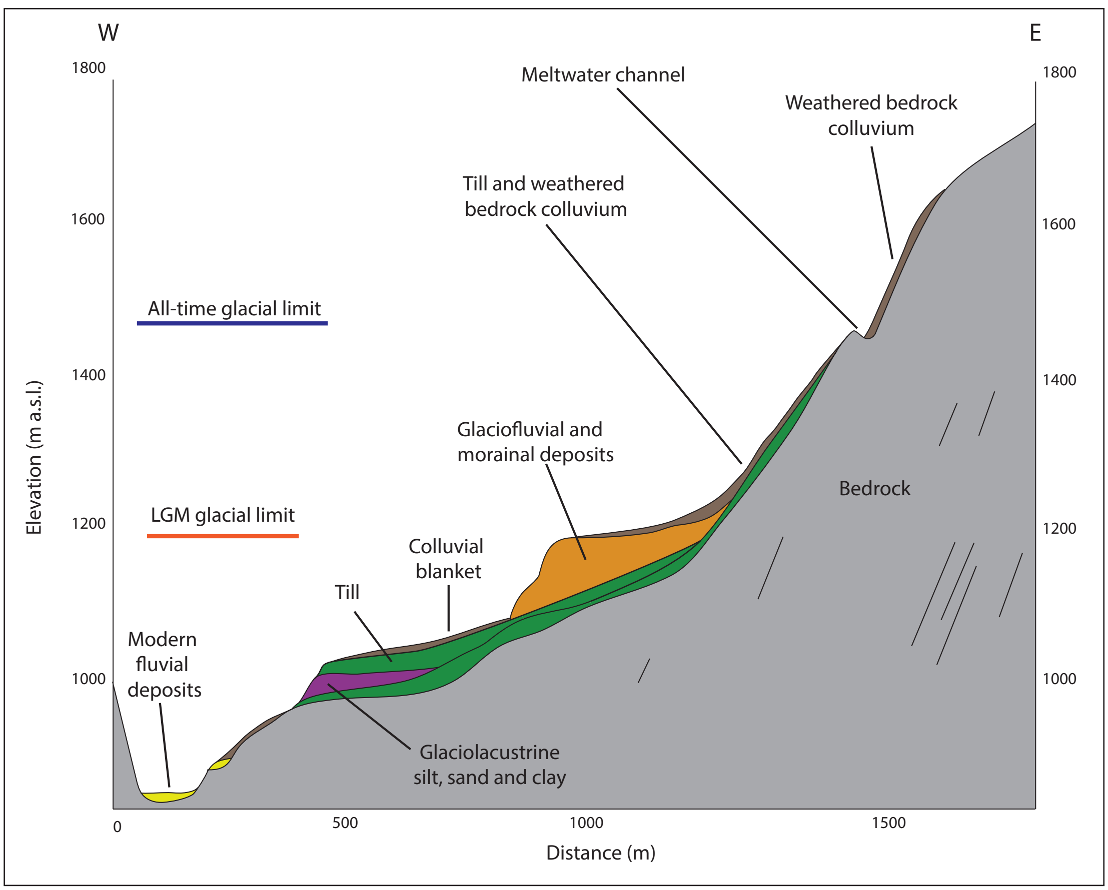

Figure 10. *Idealized valley profile illustrating the distribution of sediments in Maple and Wade creeks.*

Figure 11. *Typical subdued morphology of unglaciated terrain with flat cryoplanation terraces (black arrows) and pediments (white arrows) marking erosional surfaces that likely pre-date the Quaternary period.*

Figure 12. *Paired terraces (arrows) across upper Quill Creek record former base level and retain gravel deposited above the modern valley floor.*

Glaciers and glacial meltwater affected all of the trunk streams in the study area, and glacial meltwater would have flowed through some unglaciated valley bottoms that were outside the limit of glaciation. Modern stream sediments in all these valleys likely contain extra-basinal sediments. In contrast, where fluvial terraces are found along these unglaciated valley bottoms, the sediments are likely representative of the upslope basin and contain no foreign materials.

UPPER GLACIATED SLOPES

Upper glaciated slopes in the study area are defined as being between the all-time glacial limit and the lower glacial limit (*see* Figs. 4 and 10). While glaciogenic materials are present on these slopes, they are typically thin and incorporated into more abundant deposits of locally-derived weathered bedrock colluvium. On moderate to gentle slopes (SE side of the Wade Creek valley, much of Maple and upper Quill creeks) mixed morainal and colluvial materials thicken downslope from thin veneers to blankets (>1 m) of sediment (Fig. 13). On steeper slopes, or where there has been significant base level change (much of Arch Creek valley, NW side of Wade Creek valley) only thin remnants of glaciogenic sediments are preserved.

Materials related to alpine glaciation are limited to high and mid-elevation landscape positions near their source areas. Deposits from alpine glaciers are derived entirely of local bedrock material with little or no input of extra-basinal material. A dissected alpine moraine in the Arch Creek valley (Fig. 9) comprises ~3.5 m of interbedded diamict and fluvial sediments over bedrock in the creek bottom.

LOWER GLACIATED SLOPES AND VALLEY BOTTOMS

Low-elevation slopes and valley bottoms in the study area are defined as being at, or below, the lower glacial limit (*see* Figs. 4 and 10). These landscape positions are likely to have very thick (>40 m) deposits of glaciogenic materials including blankets and ridges of moraine, glaciofluvial terraces and glaciolacustrine blankets, all of which can be covered by,

***Figure 13.** Uniform angular clasts visible in a colluvial apron on an upper glaciated slope. These slopes are within the all-time glacial limit, but very little morainal material is preserved, particularly on north-facing slopes where mass wasting is active.*

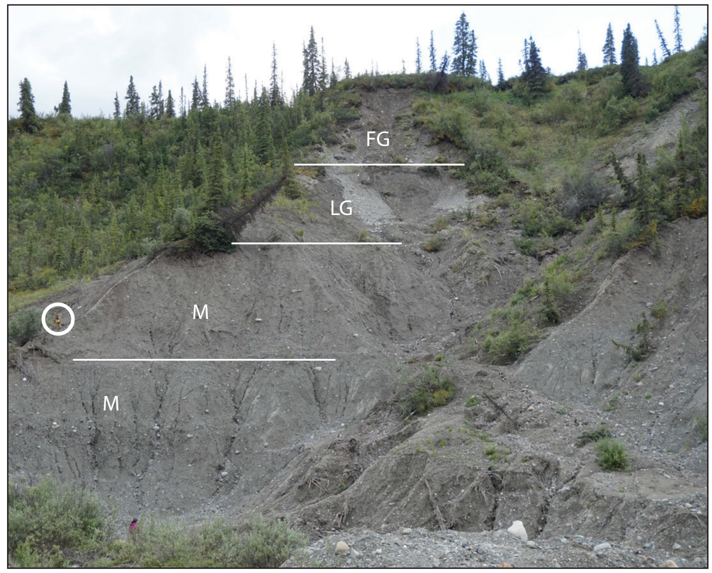

***Figure 14.** Thick deposits of glacial materials recording at least two phases of advance and retreat of the Donjek Glacier into lower Maple Creek (FG – glaciofluvial; LG – glaciolacustrine; M – morainal). Exposed sediments are 60 m thick (person circled for scale) and the location of the exposure is shown in Fig. 8.*

and/or incorporated with locally-derived colluvial and fluvial materials. Permafrost and peat blankets are common in low elevation landscape positions, particularly on north-facing slopes where the permafrost table can be immediately below surface vegetation.

Valleys draining toward the Donjek Glacier were affected by impoundments and diversions of regional streams and meltwater during glaciations. In particular, upper Maple Creek valley is characterized by a wide, flat, valley bottom that likely represents one or more phases of glaciolacustrine deposition (Fig. 7). Valley-fill may record many glacial episodes (Fig. 14), and surface materials are unlikely to be representative of underlying, up-slope, or up-valley bedrock.

While the Donjek Glacier advanced in similar configurations throughout the Quaternary, interglacial streams draining toward the Donjek River likely formed entirely or partially new channels after each glaciation. This migration of paleo-valleys has created significant buried topography in valley bottoms that is largely masked by deposits of the last glaciation (Fig. 15). The lower reaches of Arch, Maple and Wade creeks have bedrock entrenched reaches as well as reaches of thick glaciogenic sediments, resulting in highly mixed stream sediments that aren't representative of bedrock in upstream drainages. Modern stream sediments on the lower, bedrock entrenched, reaches of Arch and Wade creeks comprise extremely coarse-grained (boulders >2 m diametre are common) gravel deposits that overlie bedrock. Gravel deposits are relatively thin (a few metres), but represent significant reworking and concentration of both local bedrock and transported glaciogenic materials.

***Figure 15.** Paleo-topography on lower Wade Creek is masked by thick glacial fill that forms a flat surface above the creek. Dashed line follows the approximate bedrock surface.*

MASS WASTING

Mass wasting of surface materials through detachment slides is prevalent on mid-elevation slopes (Fig. 16). Mass wasting is more active on north-facing slopes where permafrost is common at depths of 0.5 to 1 m below the surface. North-facing slopes typically have a thin cover of colluvium on steep slopes and thicker blankets of well-mixed colluvium and morainal material at breaks in slope where materials accumulate. Bedded colluvial deposits are shown in Figure 17, where thin bands of resedimented tephra mark individual events. Detachments typically occur in the upper ~1 m of seasonally thawed materials (active layer), and underlying perennially frozen (permafrost) sediments comprise local weathered bedrock and minor morainal materials in a silty matrix.

IMPLICATIONS FOR MINERAL EXPLORATION

Weathered bedrock and colluvium in unglaciated terrain are ideal materials for soil geochemical sampling programs (*e.g.*, Fig. 11). The new glacial limits for the study area highlight significant regions of unglaciated terrain marginal to the valleys of Wade, Maple and Arch creeks (Figs. 4 and 8). Some of these unglaciated areas include lower slopes and valley bottoms. On steeper slopes, soil geochemical anomalies may be displaced from their source due to colluvial processes. These same processes can be used advantageously in high-elevation basins when soil sampling. For example, talus aprons can be a used to target upslope mineralization on otherwise difficult to access alpine environments.

Stream sediment geochemistry should work well in high-elevation basins above the glacial limits. When collecting stream sediment samples in the unglaciated region, care should be taken to stay upstream of glacial deposits related to up-valley advancing ice. In addition, glacial meltwater may have emptied into an unglaciated valley resulting in the deposition of foreign sediments. Raised fluvial terraces in the unglaciated area are rare, but could be interesting targets for stream sediment sampling.

Upper glaciated slopes are generally good targets for soil geochemistry sampling. Where slope angles are steep, moraine deposition would have been limited and is likely partially eroded. In regions of mixed moraine and colluvium, slope material thickness and composition should be assessed to determine the degree to which local materials are present. Soil sampling should avoid thicker deposits of moraine where valley slopes become gentler and are susceptible to accumulation of glacial sediment. Stream sediment geochemistry in this environment can be effective depending on the concentration of foreign sediment in a stream bed.

Figure 16. *Surface detachments on a north-facing slope at the divide between Arch and Nickel creeks. Detachments are commonly 0.5-1.5 m thick, 10-30 m wide, and ~200 m long. Detached materials are comprised of weathered bedrock and colluvium that slides on permafrost or bedrock detachment surfaces.*

Figure 17. *Thin white bands of tephra mark individual mass wasting events on this mid-elevation slope. The entire active layer (above the dashed line) comprises bedded colluvial deposits. Below the permafrost table, sediments are comprised of local weathered bedrock and minor morainal materials.*

Lower glaciated slopes and valley bottoms are the most complicated landscape type for designing and undertaking surficial geochemical sampling programs. Significant lateral and vertical changes in surficial cover can introduce far-travelled materials into areas that appear to be dominated by local bedrock. Quaternary fill in valley bottoms comprises primarily glacially-transported material with significant and complex transport vectors that do not represent local bedrock conditions. As a result, soil geochemical sampling should only be conducted where surficial mapping has identified areas of thin morainal or colluviated morainal cover over bedrock. In these areas, ice transport directions need to be factored into geochemical interpretations. Stream sediment geochemistry in valley bottoms should only be considered where significant local bedrock is being eroded into the fluvial system.

Modern stream sediments in bedrock and sediment entrenched reaches of Wade and Arch creek are favourable placer mining targets because of the significant volumes of material that have been concentrated into relatively thin modern deposits, and the potential for modern valleys to intersect with enriched paleo-valleys (Kennedy and van Loon, 2017). Glacial moraine or lacustrine sediments in upper Maple Creek (Fig. 7) can act as false bedrock surfaces where placer gold can accumulate, but entrenchment of the stream (and related concentration of surface materials) decreases quickly toward the drainage divide.

CONCLUSIONS

New glacial limit mapping near the Donjek River in the Kluane Ranges indicates that Quaternary glaciation of the region was restricted. Extensive regions of unglaciated terrain persisted throughout the Quaternary in an area that was formerly thought to be predominantly glaciated. As suggested by Rampton (1981), the lee of the Icefields Range would have received limited moisture during full glacial conditions, and high cirques in the Kluane Ranges were unable to accumulate large volumes of ice.

Extensive glaciers emanating from the Icefields Range fed the St. Elias lobe in southwestern Yukon, and although the Donjek and Shakwak glaciers advanced into Kluane Ranges, most of the ice flowed freely to the Shakwak Trench, and ultimately, Wellesley basin. The combination of restricted moisture in the lee of the Icefields Range, and free (unrestricted) drainage of glaciers into Shakwak Trench likely existed along a large region of the Kluane Ranges, and there may be significantly more unglaciated terrain than has been mapped to date.

The unique ice configuration in the study area resulted in episodes of up-valley flowing glaciation. Thick accumulations of valley-bottom glacial materials, drainage diversions and drainage impoundments are all characteristic of up-valley flowing ice, and are present in the lower drainages of Arch, Maple and Wade creeks.

Mid and high-elevation slopes are dominated by weathered bedrock materials, and glacial deposits on upper slopes may have undergone substantial reworking into local colluvial materials. The permafrost table controls mass wasting on many slopes in the study area, and increases in active layer thicknesses related to climate warming are likely to increase the magnitude of mass wasting events, creating thicker deposits of colluvium on mid-elevation slopes.

Mineral exploration programs undertaking surficial sediment geochemistry sampling programs, or employing existing geochemistry data, need to consider the sediment genesis in the area of investigation. Unglaciated environments are generally mantled by locally sourced weathered bedrock, weathered bedrock colluvium, and fluvial deposits that provide an excellent sampling medium. Within the glacial limits, there is considerable variation in the amount of glaciogenic cover. Much of the variation is associated with topographic position, however, the surficial geology map (*in prep.*) should be referenced to avoid terrain overlain by thick deposits of far-travelled glaciogenic sediment.

ACKNOWLEDGEMENTS

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