Evidence for a late-McConnell readvance of the Cassiar Lobe in Seagull Creek, Pelly Mountains, central Yukon

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ABSTRACT

Drift prospecting in high relief areas of the Cordillera requires consideration of paleo-ice-flow reversals. This means rethinking the manner and degree to which glacial ice eroded, transported and deposited surficial sediments. The regional context, geomorphic landforms and sediment stratigraphy identified in the Seagull Creek valley suggest that late-glacial up-valley ice flow, although relatively short in duration, may have been the controlling process for glacial transport and deposition in this area. This interpretation has important implications for mineral exploration programs that utilize glacially transported materials for various forms of geochemical analysis. Geomorphic landforms and glacial dynamics responsible for reverse (up-valley) ice flow in Seagull Creek valley have important implications for mineral exploration on the Ross River Minerals Tay LP gold-copper property.

RÉSUMÉ

La prospection des sédiments glaciaires dans les zones montagneuses de la Cordillère exige une analyse des inversions de paléo-courant glaciaire. En d'autres termes, il s'agit de repenser la façon dont la glace a érodé, transporté et déposé les sédiments superficiels et réévaluer son importance. Le contexte régional, les formes de relief et la stratigraphie des sédiments de la vallée du ruisseau Seagull font supposer que l'écoulement tardiglaciaire vers l'amont, même s'il a été de courte durée, a pu être le processus de contrôle du transport et de la sédimentation glaciaire dans cette zone. Cette interprétation a des répercussions importantes sur les programmes de prospection minérale qui utilisent les matériaux transportés par les glaciers pour effectuer diverses analyses géochimiques. Les formes de relief et la dynamique glaciaire qui sont responsables de l'écoulement glaciaire inverse (amont) dans la vallée du ruisseau Seagull ont des conséquences de taille sur l'exploration minérale dans la propriété d'or-cuivre Tay LP de la société Ross River Minerals.

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INTRODUCTION

Till geochemistry and ice-flow reconstruction have been used in regions of thick glacial deposits to trace mineral occurrences in underlying bedrock (Shilts, 1993). This type of 'drift prospecting' is generally straightforward in regions where the dominant ice flow was relatively constant and unidirectional. Due to the nature of deglaciation in the Cordillera, however, drift transport in mountainous regions may be more complex than previously thought. The possibility of reverse (up-valley) ice flow in Seagull Creek valley has significant implications for ongoing mineral exploration, particularly on the Ross River Minerals Tay LP property. The objective of this paper is to document the late glacial history of Seagull Creek and relate this to the present search for mineralization in the valley.

Quaternary deposits obscure much of the bedrock in Seagull Creek valley (Fig. 1), and the nature of underlying mineralization is not fully understood (Tolbert, 2000). Surface exposure of bedrock occurs primarily within Seagull Creek and above the upper limit of till preservation at approximately 1300 m elevation on the surrounding hillsides. Samples containing some of the highest gold values on the property are from mineralized float boulders found along the valley sides and bottom (Tolbert, 2000). Historically, exploration in the valley bottom has focused on geochemical investigations. Although soil sampling programs, limited drilling, and electromagnetic surveys undertaken by a number of exploration programs have located some gold-bearing rocks, the source of high-grade mineralization observed in float has yet to be discovered. It is proposed that a possible error in interpreting this data is the assumption of

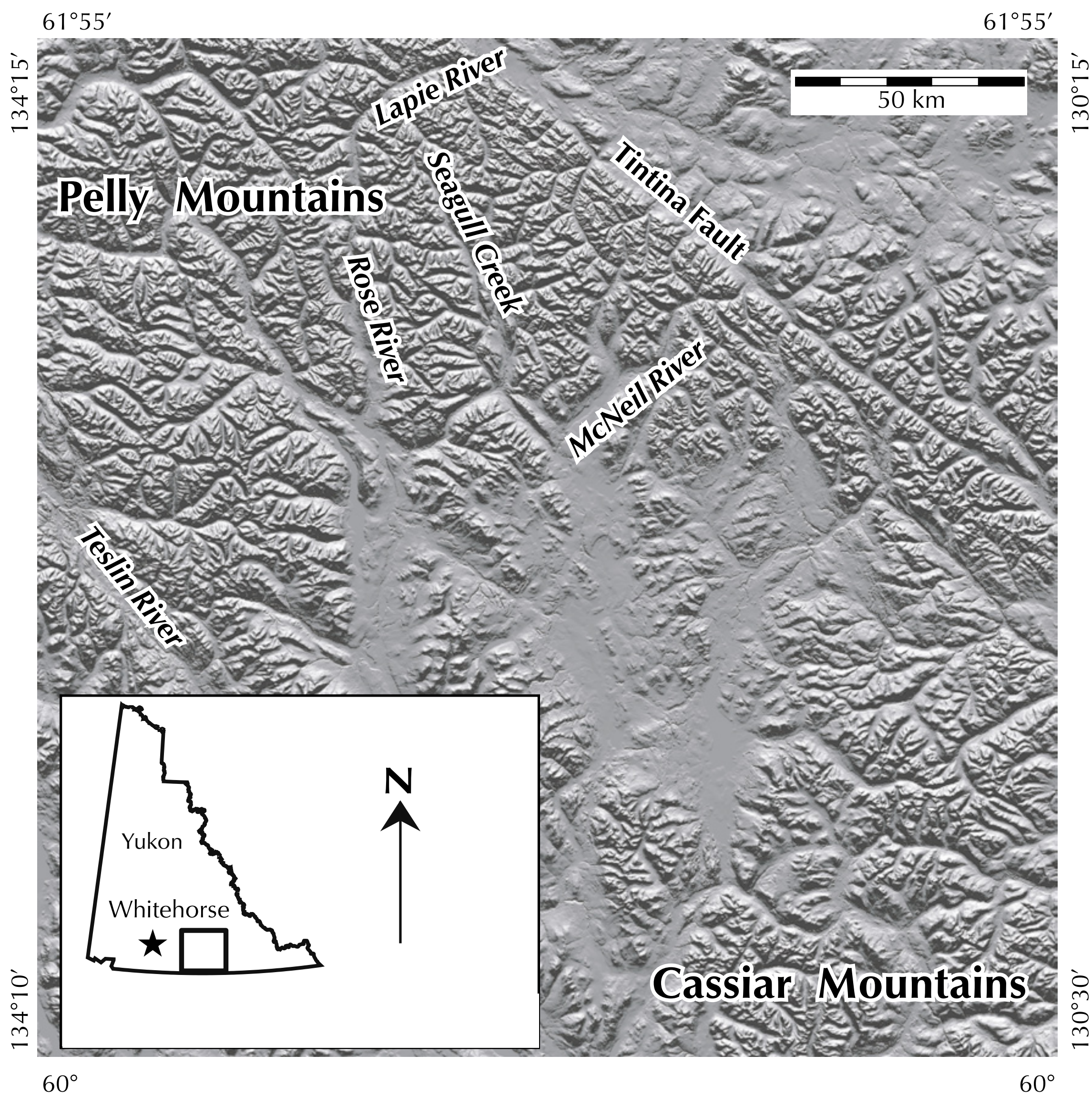

Figure 1. *Seagull Creek is located along the continental divide of the Pelly Mountains in central Yukon.*

down-valley ice flow as the dominant transport mechanism of valley-bottom sediments.

The importance of drift prospecting in glaciated terrain in mountainous regions of central Yukon has been well established by till geochemistry programs conducted in the nearby Anvil, Finlayson and Glenlyon regions (Bond, 1999, 2001; Bond and Plouffe, 2002, 2003). However, before applying this methodology, some basic assumptions relating to the nature and history of glacial transport need to be verified. Previous research near Lapie River (Plouffe and Jackson, 1992) and Anvil Range (Bond, 1999), as well as ongoing investigations in the Wheaton River valley by the authors have shown that reversals of ice flow in mountainous regions have occurred during the late-glacial phase of the McConnell Glaciation and can be the dominant sedimentation-controlling event for some valleys. The regional context, topographic landforms and sediment stratigraphy of Seagull Creek suggest that up-valley ice flow was likely the controlling process on glacial transport of surficial materials.

PHYSIOGRAPHY AND BEDROCK GEOLOGY

Seagull Creek is located in the St. Cyr Range of the Pelly Mountains in central Yukon (Fig. 1). The physiography of this region is characterized by high (up to 2162 m) cirques, arêtes and horn peaks above broad, sediment-filled valley bottoms ranging in elevation from 900-1200 m. Tertiary drainage trended to the southwest and is preserved only in major valleys such as the Ross and Nisutlin (Jackson, 1994). Narrower northwest-trending valleys follow the orientation of ice expansion during the Pleistocene.

The Tay LP gold-copper property is located within the Pelly-Cassiar Platform, a region of northwest-trending platform carbonates ranging in age from Cambrian through Mississippian (Gordey and Makepeace, 1999). This shallow marine miogeoclinal sequence has been folded and faulted into the 70-km-wide and 600-km-long massif of the Pelly Mountains. Mid-Cretaceous granitic rocks extensively intrude the entire foreshortened assemblage, and Late Cretaceous right-lateral movement of 450 km along the Tintina Fault has displaced tectonic elements relative to each other. In the Seagull Creek valley garnet-diopside skarn rocks are found in close association with limestone and intrusions of quartz monzonite (Tolbert, 2000). Known mineralization on the property consists of veins and replacement of calcareous schists with variable amounts of tourmaline, pyrrhotite, pyrite and chalcopyrite, and trace to minor amounts of marcasite, arsenopyrite, galena, bismuthinite, tellurobismuth, bismuth and gold (Tolbert, 2000).

Falling within the 'Tintina Gold Belt' (British Columbia and Yukon Chamber of Mines, 2000) of the Cordillera, there has been active mineral exploration in Seagull Creek valley since the 1970s. The 9524-hectare Tay-LP claims were staked in 1984 and have been optioned to both Cominco Ltd. and Comox Resources Ltd. before Ross River Minerals Ltd. acquired interest in 1999. Thick glacial deposits in the valley bottom have hindered prospecting, and the scarcity of basal till has made traditional drift prospecting techniques ineffective. In 1999, a reconnaissance program of selective leach soil sampling was undertaken to test the viability of this method for locating mineralization beneath deep, transported overburden (Tolbert, 2000). Although this more sensitive analysis improved soil geochemistry results, high-grade mineralization in Seagull Creek has yet to be located.

GLACIAL HISTORY

The last glaciation to affect central Yukon is the late Wisconsinan McConnell Glaciation, which began sometime after 26 ka BP (Jackson and Harington, 1991; Matthews et al., 1990). The Pelly Mountains acted as a regional divide for the northern sector of the Cordilleran Ice Sheet, supporting numerous divides and ice-cap complexes that shed ice north-northeast to the Selwyn Lobe, and south-southwest to the Cassiar Lobe. It is likely that an ice divide or ice cap existed near the current hydrological divide at the headwaters of Seagull Creek. Ice sheet thickness in this region never greatly exceeded relief and the radial flow from the Pelly Mountain ice complexes remained topographically controlled throughout the McConnell Glaciation (Jackson, 1994).

Deglaciation of the Pelly Mountains likely began by a rapid rise in the equilibrium-line altitude causing thinner ice in high mountains and cirques to stagnate and melt before the thick accumulations in adjacent valleys (Jackson, 1994). This pattern of downwasting and stagnation is common in much of the Cordillera and is responsible for blockages to down-valley drainage and extensive ice-stagnation landforms in cirques and valley bottoms (Fulton, 1991). Deglaciation of the Pelly Mountains was complete by around 10 ka BP (Jackson, 1994).

Late-glacial readvances in Yukon are evidenced primarily by depositional and erosional landforms indicative of ice surface gradients and flow directions. Up-valley ice flows have been documented in many areas of central Yukon. In the Anvil Range district, Bond (1999) used flights of valley-bottom kame terraces and laterally continuous meltwater channels and moraines to provide evidence of invading ice fronts from down-valley sources. Closer to Seagull Creek valley, at the confluence of the Lapie and Pelly rivers, Plouffe and Jackson (1992) supplemented geomorphic evidence with detailed till fabrics and erratic tracing to infer a late-glacial readvance of the Selwyn Lobe up-gradient into the Lapie River valley. Current work by the authors in the Wheaton and Watson river valleys near Whitehorse has revealed a similar scenario for the coast mountain transitional zone. A six-phase model has been developed to explain the regional glacial dynamics of up-valley ice flow for mountainous regions (Fig. 2):

Stage 1: Onset of glaciation and the initial advance of ice from high-elevation accumulation zones.

Stage 2: Continued advance of ice out of the mountainous regions into low-lying plains.

Stage 3: Development of a regional ice sheet, marking glacial maximum.

Stage 4: Initial retreat of ice at the onset of deglaciation. The reduction in ice is most noticeable in the mountainous areas where ice was relatively thin.

Stage 5: Readvance of glaciers during a period of climatic deterioration. Ice sheets advance readily into the already deglaciated mountains. This allows for 'up-valley ice flow'.

Stage 6: Final ice retreat and the end of the glaciation.

EVIDENCE OF LATE GLACIAL READVANCE

Baseline information for interpreting glacial history in Yukon can be provided by reconnaissance-level surficial geological mapping and an understanding of the processes of deglaciation in the Cordillera. A 1:50 000-scale surficial mapping project of the Tay LP property was undertaken in the summer of 2003 to identify the most reliable areas for geochemical sampling. In general, colluviated bedrock and till above valley bottom stagnation landforms have short transport paths and are reliable sampling mediums for drift prospecting. The degree of transport in valley bottom sediments, however, is not as easily determined and can vary widely.

The evidence for a regionally sourced readvance in Seagull Creek valley consists primarily of lateral meltwater channels and depositional ice-stagnation features. Meltwater channels from the receding alpine glaciers are preserved by erosional troughs descending down-valley from north to south at elevations above 1350 m in upper Seagull Creek (Fig. 3). The longitudinal gradients of meltwater channels approximate that of the former ice-surface profile and are indicative of down-gradient ice flow (Ryder, 1994; Bennett and Glasser, 1996).

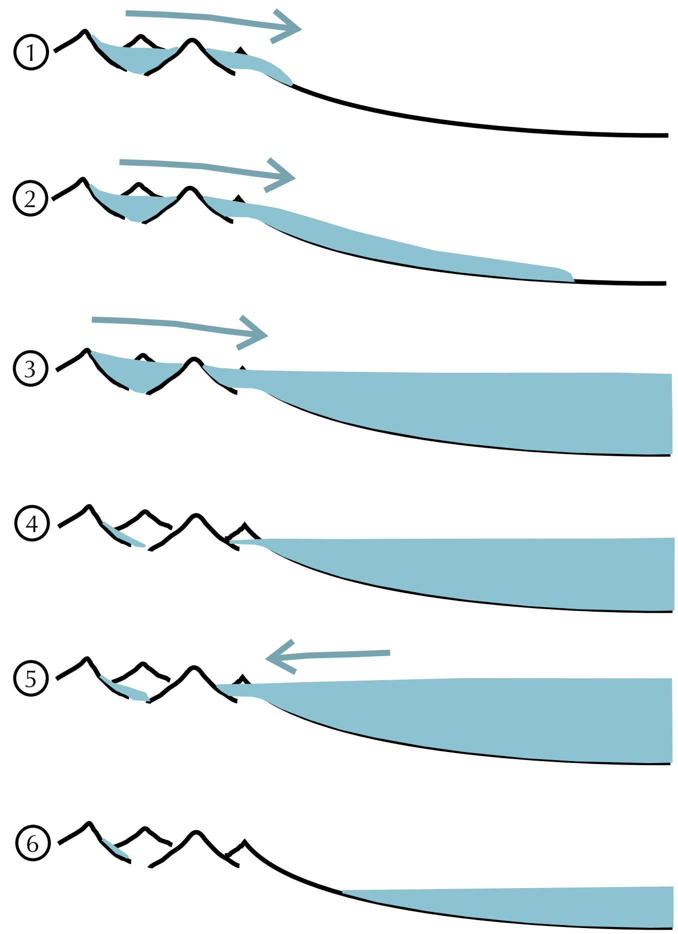

Figure 2. *A six-phase model is used to explain the regional glacial dynamics of up-valley ice flow for mountainous regions. Stage (1) is the onset of glaciation and initial ice advance from high elevations, (2) continued ice advance from mountains into low-lying plains, (3) glacial maximum and development of a regional ice sheet, (4) onset of deglaciation, initial retreat is most noticeable in high mountains where ice is thin, (5) climatic deterioration causes a readvance of the ice sheet into already deglaciated mountain valleys (up-valley ice flow), and (6) final ice retreat at the end of the glaciation.*

During retreat, while thick valley-bottom ice accumulations persisted to some extent, renewed nourishment of the Cassiar Lobe caused an expansion of the ice sheet margin and forced ice up-valley into the Pelly Mountains (Fig. 4). By contrast, local ice re-accumulation was limited in cirques of the Seagull Creek drainage. This apparent precipitation deficit in the Pelly Mountains may have been caused by the Cassiar Lobe intercepting moisture from Pacific air masses and thus enabling Cassiar ice to flow freely up the southward draining Pelly Mountain valleys.

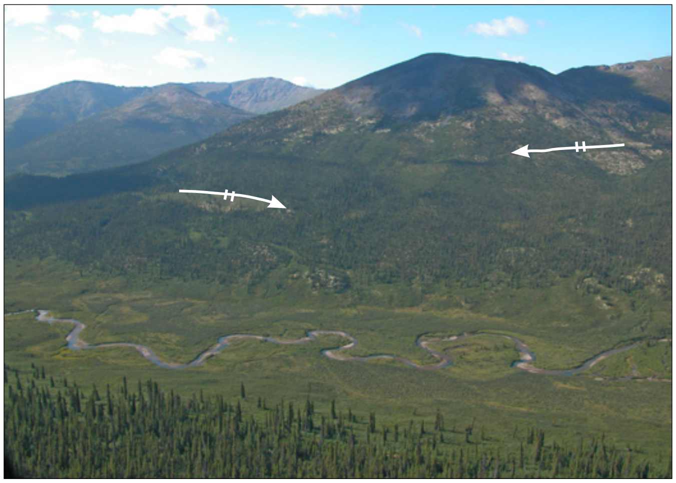

Figure 3. *Upper meltwater channels, descending from right (up-valley) to left (down-valley), preserve the profile of retreating alpine ice after glacial maximum. Lower meltwater channels, descending from left (down-valley) to right (up-valley), represent the ice surface profile during the Cassiar readvance.*

Previously stagnating ice tongues in the Rose, Seagull and McNeil valleys (Fig. 1) would have been reincorporated into the northward-advancing Cassiar valley glaciers. Ice flow advanced up to, and in places breached, alpine divides. In the study area, Cassiar ice reached its maximum limit at the south end of Seagull Lakes (Fig. 4). The northward ice movement is well documented by up-valley descending, lateral ice-marginal channels (Fig. 3) and the outlet channel at the Seagull Lakes divide. Similar meltwater channels were mapped in the Rose and McNeil drainages (Jackson, 1994) and include correlative ice-stagnation deposits in the low divides.

The recessional phase of the ice lobe is marked by periods of dynamic equilibrium between up-valley flow and ice-front ablation. This step-wise retreat is noted at a number of locations in the valley and best displayed at the kame deposit in Figures 5 and 6. The well developed

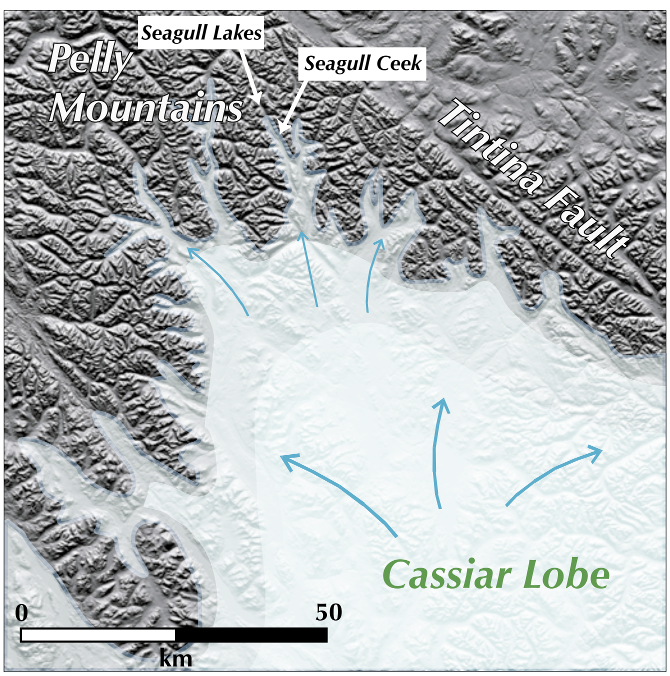

Figure 4. *Expansion of the Cassiar Lobe forced ice up-valley into the Pelly Mountains. Local alpine accumulations were not significant enough to interfere with the regional readvance. The Selwyn Lobe, located north of the Tintina Fault, is not shown in this diagram.*

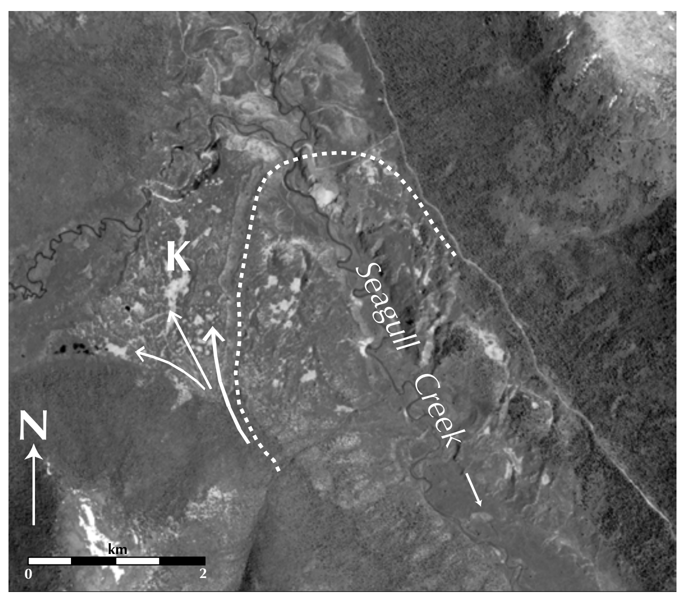

Figure 5. *An aerial view of the confluence of an unnamed tributary valley with Seagull Creek shows the former ice front (dashed line) preserved on the south side of the kame terrace (K). The shape of the ice front and the direction of meltwater flow over the kame (arrows) indicate up-valley flow. Seagull Creek is presently flowing south-southeast.*

Figure 6. *Nearly 50 m of glaciofluvial sand and gravel were deposited along the ice front (dashed line) during the recessional pause that created the kame terrace. View is down-valley toward the southeast.*

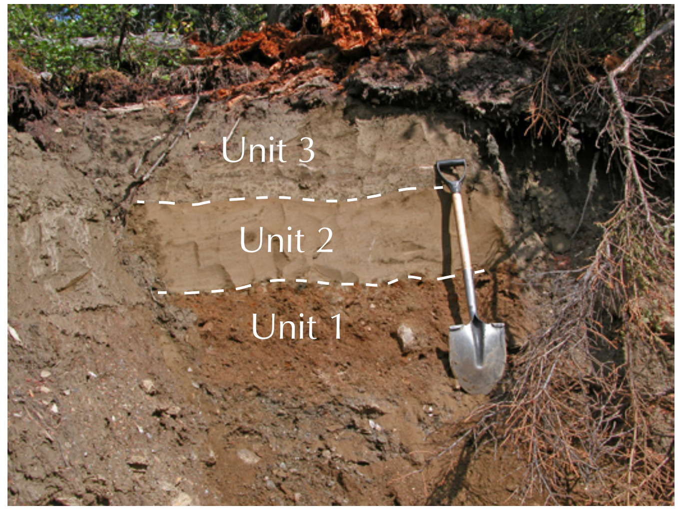

Figure 7. *The valley-bottom stratigraphy of the study area is well preserved in this hillslope section above the valley floor. Unit 1 is an angular, clast-dominated ablation till. Unit 2 is a medium-fine sand that grades upward into a thin (~ 5-10 cm) silty clay bed. This unit represents the short-lived lacustrine event between the kame and the southward-retreating ice front after maximum readvance into Seagull Creek. Unit 3 is composed of Holocene ash and colluviated hillslope sediments.*

morphology of this kame, and the associated deposition in the adjacent tributary valley, signifies a considerable standstill. The rapid rate of up-valley transport and sedimentation at this ice front is inferred by nearly 50 m of stratified coarse sand and gravel exposed in section on Seagull Creek (Fig. 6). Lateral extension of the kame sediment into a proglacial lake north of the ice front is suspected according to the elevation of the outlet channel near Seagull Lakes. However, there is very little evidence of glaciolacustrine sedimentation preserved north of the kame deposit. This, and the lack of northward continuity of the kame front, suggests that deposition beyond the active ice front may have occurred onto buried or stagnating ice.

Following the deposition of the kame terrace, deterioration of valley ice was relatively rapid and characterized by stagnation and in-situ downwasting of the ice surface. Before southward drainage of Seagull Creek resumed, ponding of supra-glacial meltwater was limited and short-lived. Approximately 30 cm of a discontinuous sandy lacustrine unit overlies valley bottom sediments south of the kame terrace (Fig. 7). The extent of this glacial lake would have been restricted between the kame terrace to the north and the retreating ice front to the south. As the ice mass melted, down-valley drainage of Seagull Creek resumed, creating a series of paraglacial terraces below the kame, as sediment was reworked toward baselevel (Fig. 8).

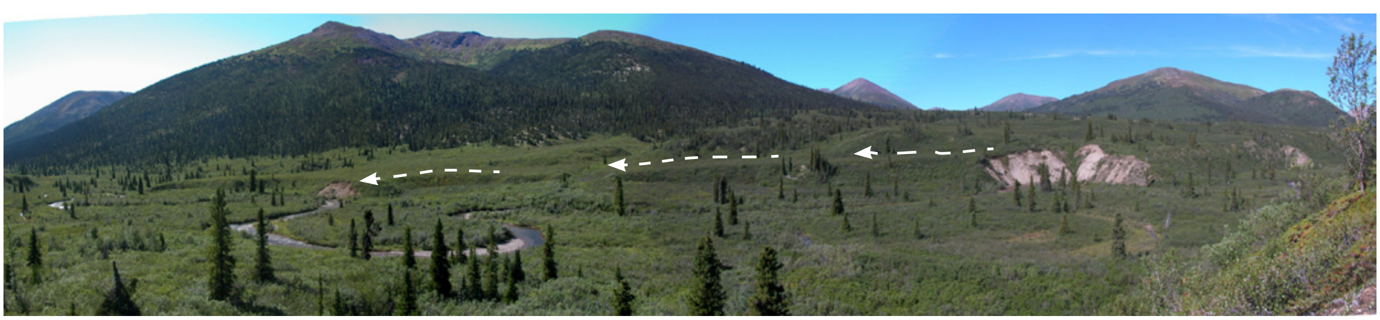

Figure 8. *The resumption of down-valley drainage in Seagull Creek created a series of downstream-descending paraglacial terraces (dashed line).*

IMPLICATIONS FOR DRIFT PROSPECTING

The ice-flow reversal and nature of sedimentation recorded in the Seagull Creek valley has profound implications for drift prospecting in the area. All previous studies assumed a dominantly down-valley ice flow in regard to the origin of mineralized float. Also, the ubiquity of glacio-fluvial sediments makes most soil survey techniques impractical. Down-valley of the kame deposit, where glacial drift is thick, care must be taken to sample from till that has a relatively high silt and clay fraction. This is best found at elevations above 1150 m and also at depth below ablation material in the valley bottom (Fig. 9).

The rapid stagnation of ice in Seagull Creek valley resulted in extensive and well-washed ablation till overlain by somewhat chaotic glaciofluvial deposits. Although ablation till is not ideal for geochemical analysis, it is a closer derivative of bedrock than glaciofluvial sediments and therefore can provide a more reliable geochemical signal. Till deposition in this region is relatively thin, and it is likely that a readvancing ice front from the Cassiar Lobe was able to remobilize the majority of valley bottom sediments and further eroded bedrock in Seagull Creek.

The spatial characteristics of a dispersal train in Seagull Creek may exhibit both down-valley and up-valley indicators depending on the degree of reworking by the later phase ice flow. A basic ribbon-shaped dispersal train would have developed during the onset of glaciation and glacial maximum conditions (d_1) when down-valley ice flow dominated (Fig. 10a). A reversal of ice movement (d_2) would have partly re-entrained the initial dispersion train and established a new up-valley-trending geochemical anomaly from the mineralized outcrop (Fig. 10b). This of course assumes the readvancing glacier erodes to and incorporates the mineralized bedrock. The length of transport associated with d_2 ice movement may be shorter due to a decrease in basal sliding associated with up-gradient ice flow. The remnant d_1 dispersion train will have a diluted geochemical signature.

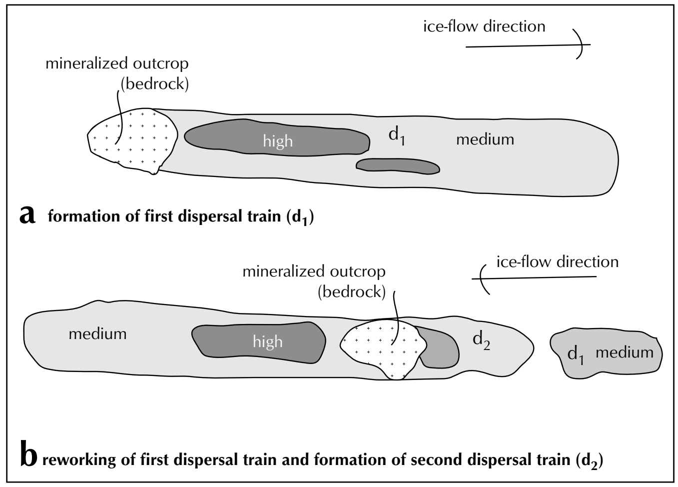

Figure 10. *Spatial characteristics of a dispersal train in Seagull Creek may exhibit both down-valley and up-valley indicators:* ***(a)*** *down-valley ice flow and* ***(b)*** *up-valley ice flow. High and medium indicate level of hypothetical geochemical concentration.*

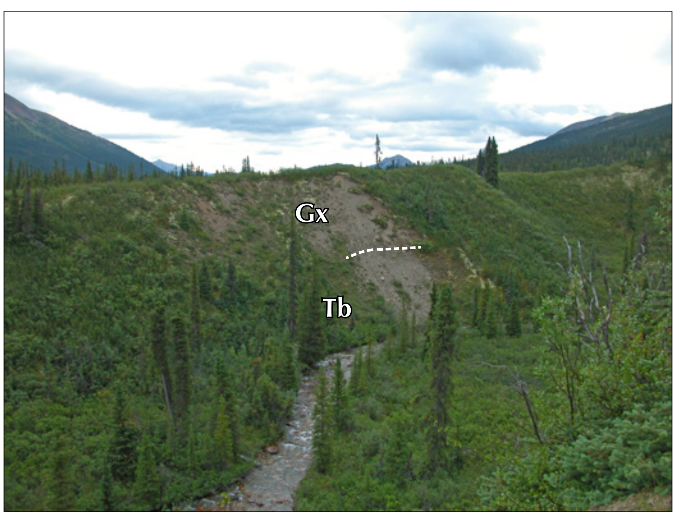

Figure 9. *Approximately 13 m of basal till (Tb) is exposed in section below a glaciofluvial complex (Gx) of water-washed sand and gravel along a tributary to Seagull Creek (view is southeast).*

CONCLUSIONS

The distribution of sediments in Seagull Creek is determined primarily by late-glacial recessional processes. Therefore, geoscientists cannot rely on overly simplistic models of high-to-low elevation, down-valley ice flow when drift prospecting in high relief areas of Pelly Mountains. Future exploration should work with a deglacial model that incorporates the possibility of large magnitude late-glacial ice-flow reversals at the margins of the Cassiar ice lobe. Ice-flow directions near a receding ice margin can differ considerably from flow directions during earlier stages of a glaciation. Thus, investing the resources to properly interpret surficial landforms can aid in creating a sound till geochemistry program reflective of the most recent mechanism of glacial transport.

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