Supplementary Materials

Descriptive notes

The Kinaskan Lake map area, within which is the currently active Red Chris porphyry Cu-Au-Ag mine (see summary in Clarke et al., 2024), was covered by the Cordilleran ice sheet during the Late Wisconsinan (MIS 2) Fraser Glaciation (Clague and Ward, 2011). The map area is mainly in the Klastline Plateau, a subdivision of the Stikine Plateau (Holland, 1976), and in the ancestral territory of the Tahltan Nation. Generally lower in elevation than surrounding mountain ranges, the Stikine Plateau is an erosional surface that experienced differential uplift and dissection throughout the late Pliocene (Holland, 1976). The upland surfaces in the map area (Fig. 1) are generally above 1500 m; the main valley systems are incised to below 900 m. Our current understanding of the surficial sediments and landforms and thus glacial history in the area near the Red Chris Mine is limited. Ryder (1984) completed a terrain inventory report to accompany 1:250,000-scale mapping of the Stikine and Iskut River watersheds. Spooner (1994), Spooner and Osborn (2000), and Spooner at al. (1996, 2002) examined Quaternary environments in the Stikine Plateau region and stratigraphic units in the Stikine River valley, approximately 40 km northwest of the Kinaskan Lake area. Presented herein are the results of mapping (1:50,000 scale) and fieldwork completed using a combination of modern and traditional methods, adding to our current understanding. New data from this work serve to help interpret the glacial history of an area in northern British Columbia with active resource development that can be used to test models of glaciation and deglaciation largely developed for southern parts of the province (e.g. Fulton (1991)).

A lidar dataset that included most of the study area with a bare earth point density of 12 pts/m^2 and colour orthoimagery with a 0.2 m resolution were acquired in 2021 (McElhanney Ltd, 2021, unpublished data). These data were used to generate digital pseudo-stereo imagery, which are stereo images generated by shifting a single orthoimage over a digital elevation model. Digital black and white 1:60,000-scale air photo images, from flight lines flown in 1982, were used for mapping in the Kinaskan Lake valley where digital pseudo-stereo images were lacking (see ‘data source boundary’). The Canadian Digital Elevation Model (CDEM), a 0.75 arcsecond (12 m) resolution surface (Natural Resources Canada, 2013) was used to support interpretation of air photo images. Map features and boundaries were drawn on the digital stereo images from both datasets using 3D visualization software (DAT/EM Summit Evolution) linked to a GIS (ESRI ArcGIS). Truck- and helicopter-supported ground truthing was completed during the summers of 2022 and 2023.

In the uplands of the map area, discontinuous veneers of till and colluvium overlie Stikine terrane bedrock (e.g., Nelson et al., 2013; Nelson, 2019); in the valley bottoms are thick sediment accumulations. Bedrock is exposed at surface on steep slopes and ridges. Valley bottom deposits include glacial and non-glacial sediments resulting from at least two regional glacial advances (Fig. 2). Organic material recovered in a sonic drill hole from between two till units near the base of the section produced radiocarbon ages of >54,000 C^{14} years BP (Sauvé, in progress, Lab ID UCIAMS-271934), significantly older than the Late Wisconsinan till exposed at or near surface across much of the area.

Late Wisconsinan till on top of the plateaus is commonly a discontinuous veneer (<2 m) of poorly consolidated silt- and sand-rich diamicton. In the valley bottoms, tills are thick (>2 m) accumulations of silt- and clay-rich diamicton interpreted as subglacial deposits because of their high density and fissility. Well-developed streamlined tills (Ts) are at low and moderate elevations in the Little Iskut River, Iskut River, and Klappan River valleys. In the Little Iskut River valley are particularly well-developed streamlined landforms comprising till and bedrock with indicated ice-flow directions apparently aligning with orientations of structures in bedrock.

We established the ice-flow history of the area by combining our landform- and outcrop-scale (Fig. 3) data with previous studies by Stumpf et al. (2000) and Spooner et al. (2000). At the onset of the Fraser Glaciation, ice-flow was directed to the northeast from glaciers sourced in the Coast Mountains to the west. As glaciation progressed and the Cordilleran ice sheet became established in northern British Columbia, ice-flow shifted towards the northwest indicating the existence of an ice divide southeast of the map area, likely in the Skeena or Omineca mountains. During deglaciation, glaciers generally flowed north within the confines of existing valley systems, in some instances moving upslope (e.g., in the Kanaskan Lake and Little Iskut River valleys).

At the end of the Fraser Glaciation, ice melted from the top down resulting in the plateau tops being ice-free before the lower elevation valleys, broadly following the deglacial model proposed by Fulton (1991). On the plateau surface in the northwest part of the map area, very well sorted horizontally bedded sands and silts (GLv) are locally developed, probably recording sedimentation in ice-dammed retreat-phase lakes. These deposits were recognized during fieldwork but were unidentifiable in the digital pseudo-stereo imagery. Thus, it is likely that additional retreat-phase lake sediments remain unmapped in similar topographic settings. On the plateau in the eastern part of the map area, meltwater sourced from stagnant ice in valleys to the south, cut across the plateau surface, as indicated by meltwater channels.

During deglaciation, active ice occupied the Kinaskan Lake valley. This ice retreated towards the south, down the slope gradient of the valley, and an extensive ice-dammed proglacial lake formed. We identified four distinct lake levels using subtle shoreline features and sporadic deltaic deposits (GLd) mapped in the Kinaskan Lake and Ealue Lake valleys (Fig. 4). Glaciolacustrine (GLv, GLb, GLn, GLp and GLh) sediments deposited during this retreat phase lake are generally limited to the Little Iskut River valley at the southern extent of the map area, but the mapped shorelines and outlet locations (red arrows, Fig. 4) indicate the lake was much more extensive. Undulating till (Tu) and till blankets (Tb), with lesser ice-contact glaciofluvial deposits (GFc) and glaciolacustrine sediments (GL), are common in lower elevation valleys, indicating a combination of active retreat and ice stagnation at the end of the Fraser Glaciation.

Holocene processes have modified the post-glacial landscape. Large landslides seated in bedrock developed at the southeastern edge of Todagin Mountain and at the southwestern edge of the plateau west of Kanaskan Lake. Smaller landslides, mostly seated in Quaternary sediments, are scattered across the modern landscape. Cirques containing active rock glaciers are in the northwest and southwest. On the plateau surfaces at higher elevations, patterned ground in the form of mud boils, solifluction lobes, boulder stripes, and discontinuous ground ice indicate active periglacial processes and likely permafrost. Beyond the limits of the map area, Ryder (1987) recognized Little Ice Age moraines.

Figures

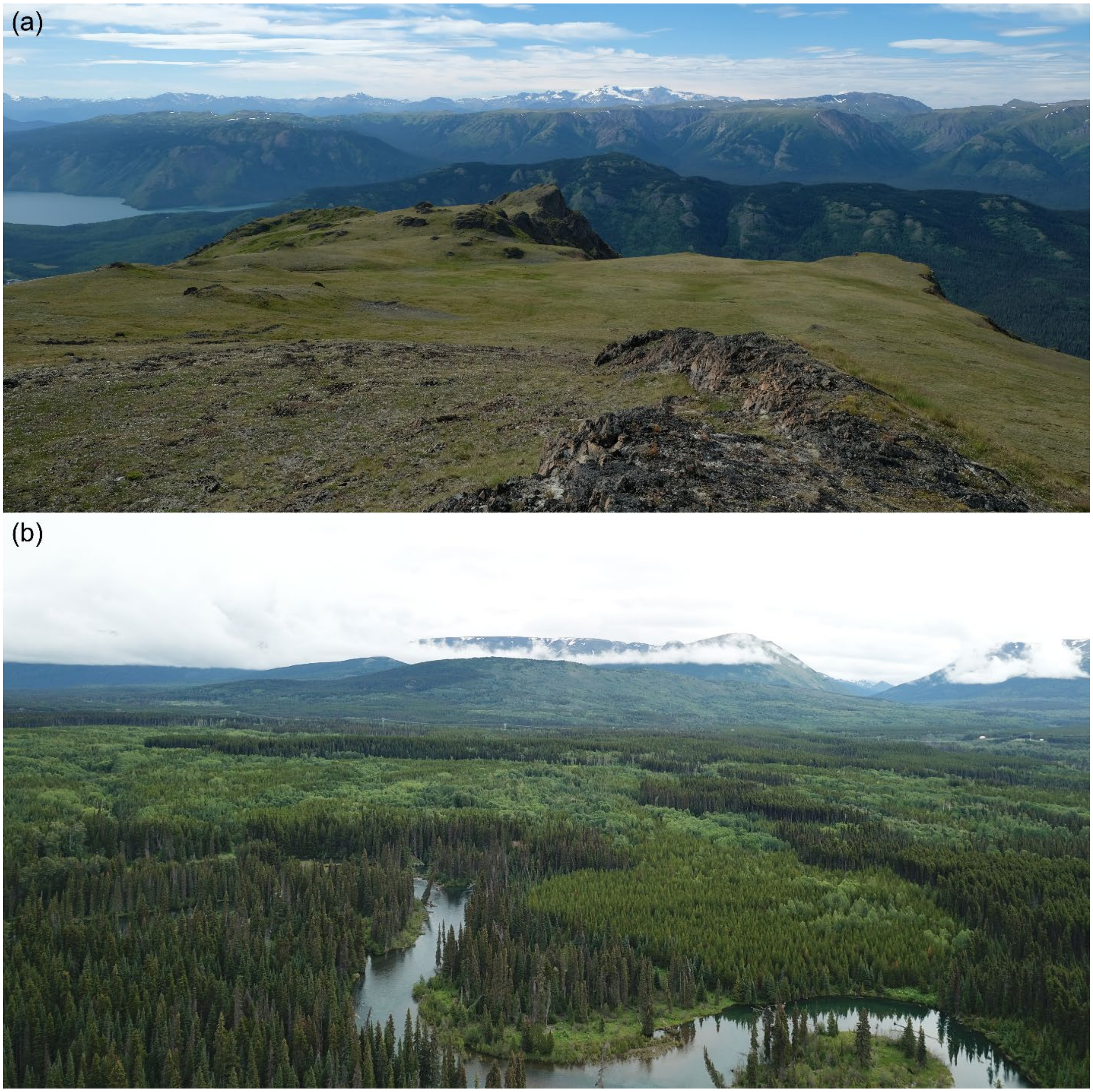

Figure 1: *Representative photos of map area.* ***a)*** *Upland surface dissected by valleys. View looking southwest toward Kinaskan Lake at the southern portion of the Klastline Plateau. Mount Edziza and the Spectrum Range are visible in the background.* ***b)*** *Low-relief terrain in a valley bottom with extensive glaciolacustrine and alluvial sediments. In the foreground is a meandering part of the Iskut River immediately north of its confluence with the Little Iskut River. Round Mountain and the plateaus surrounding Tsatia Mountain are visible in the background. View looking northeast.*

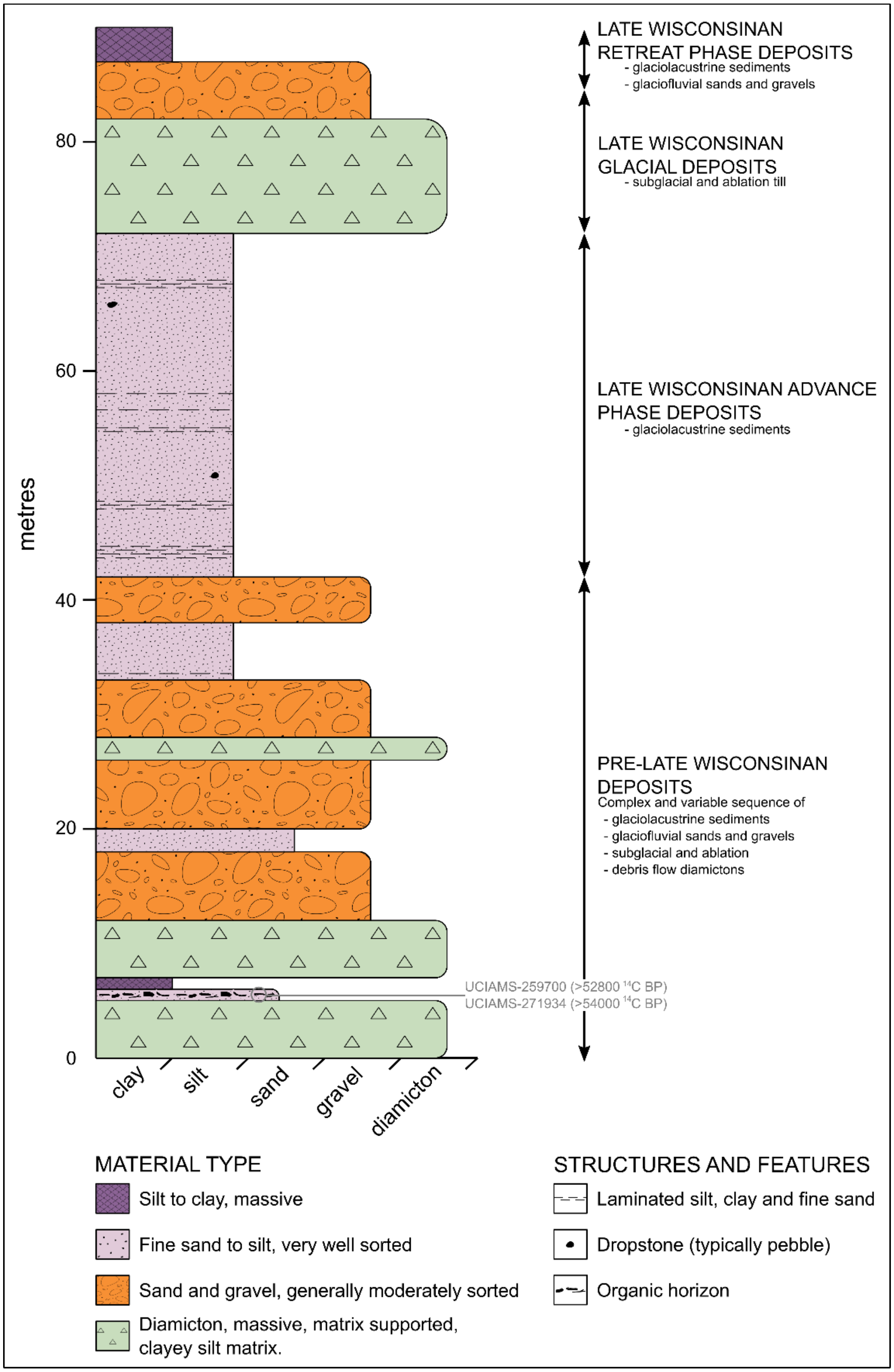

Figure 2: *Composite stratigraphic section of valley bottom sediments based on field observations from the map area and sonic drill hole logs from the Red Chris mine site. Thicknesses are approximate, and units display significant variability. The section does not include Holocene deposits.*

Figure 3: *Rat tails on pebble conglomerate outcrop surface southeast of the Red Chris mine site. Flow towards 255°, indicated by white arrow. Scale card is 8 cm long.*

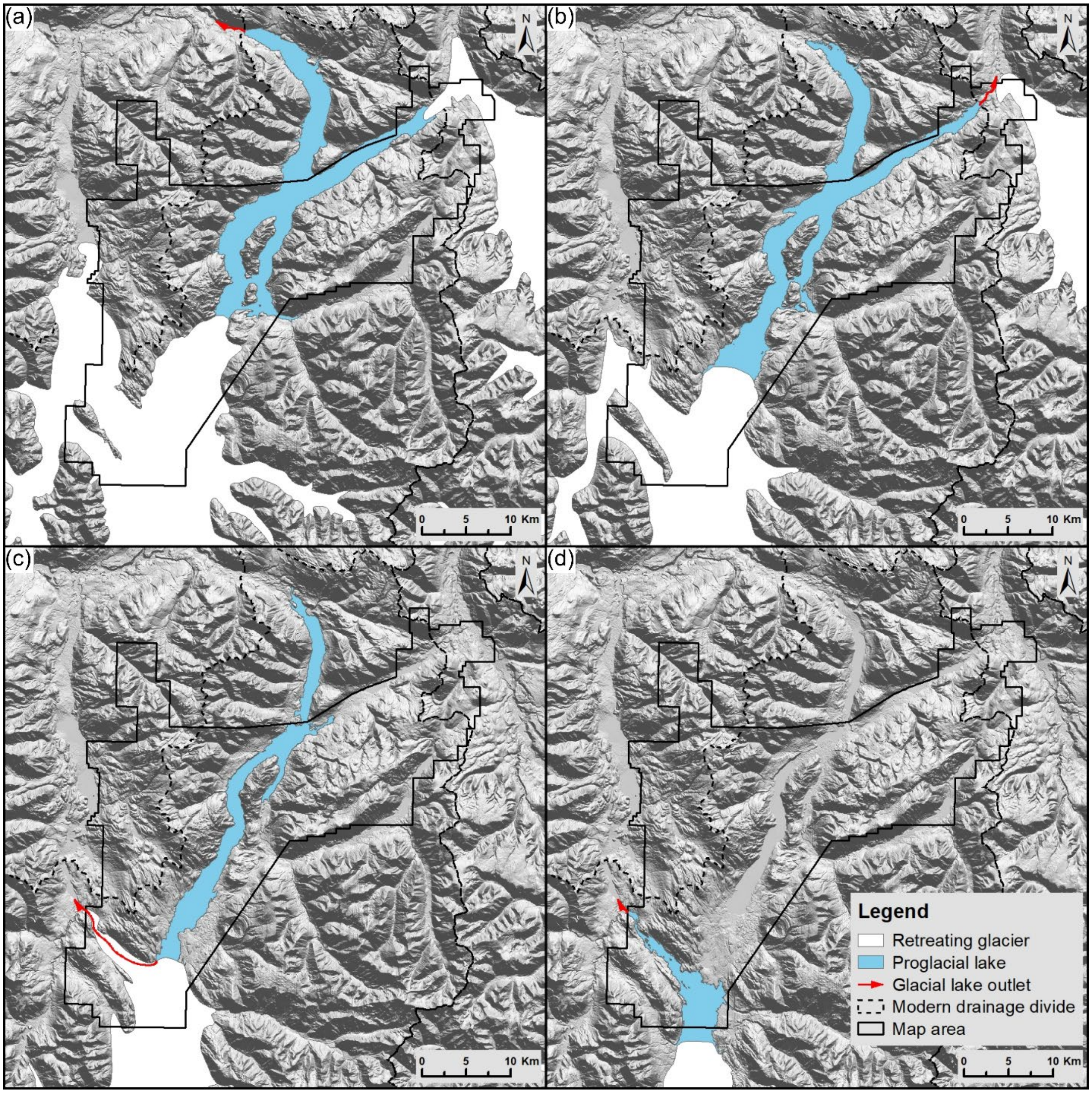

Figure 4: *Sequence of proglacial lake development during the retreat phase of the MIS 2 Fraser Glaciation defined by shorelines, deltas, and outlets. The lake level dropped sequentially from **a)** 930 m, **b)** 900 m, **c)** 850 m to **d)** 810 m as ice retreating in the valley bottom exposed lower elevation outlets. Lake outlets in **a)** and **b)** are evidenced by outsized gullies cut into the valley fill sequences. Lake outlet in **c)** is interpreted to be supraglacial or subglacial, with ice in the valley bottom having partially blocked drainage. Lake outlet in **d)** is interpreted to have been controlled by topography but modern depositional processes have obscured the channel location. Differential isostatic depression at time of lake formation is not accounted for here. Digital elevation model is a hillshade render of the 0.75 arcsecond resolution CDEM (Natural Resources Canada, 2013).*

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