Preliminary surficial geology of the northern Hogem batholith area, north-central British Columbia

T. Ferbey[1, a] and E.A. Elia[1]

[1] British Columbia Geological Survey, Ministry of Energy, Mines and Low Carbon Innovation, Victoria, BC, V8W 9N3
[a] corresponding author: Travis.Ferbey@gov.bc.ca

Recommended citation: Ferbey, T., and Elia, E.A., 2021. Preliminary surficial geology of the northern Hogem batholith area, north-central British Columbia. In: Geological Fieldwork 2020, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey Paper 2021-01, pp. 57-64.

Abstract

The Cordilleran Ice Sheet covered the Hogem batholith area during the Late Wisconsinan glacial maximum when ice flowed east and southeast across the region from an ice divide above the Skeena Mountains. During this stage, ice-flow was independent of local topography and glaciers were able to move across valleys. However, for most of the Late Wisconsinan, ice flow was controlled by topography, as recorded by glacially streamlined or eroded landform- and outcrop-scale indicators that are commonly aligned valley parallel. Valley glaciers were not entirely controlled by local topography, flowing over low-elevation, through-valley, topographic divides, transporting glacial debris into adjacent drainages. During full-glacial conditions, glaciers deposited overconsolidated subglacial tills. During deglaciation, hummocky, and less consolidated, melt-out tills were deposited. Significant volumes of glacial meltwater flowed through the valleys during deglaciation, transporting coarse-grained sands and gravels. Much of this transport and deposition was subaerial (forming extensive outwash plains and terraces), but a component was subglacial (forming eskers) or in contact with stagnant ice blocks (producing hummocky sands and gravels). Colluvial deposits are common along the base of steep slopes and are now vegetated and stable, but talus aprons and cones are still actively being constructed. Organic deposits occur throughout the study area, mostly as narrow transition zones between tree stands and water bodies. These deposits can also be extensive along the floors of retreat-phase glaciofluvial meltwater channels. Subglacial till, the ideal sample medium for till geochemistry and mineralogy surveys in mineral exploration, is common in valley bottoms and lower hillslopes. Although bedrock is well-exposed at high elevation, small isolated outcrops are common along valley bottoms and on forested hill flanks but may be overlooked.

Keywords: Surficial geology, Quaternary geology, ice-flow history, Hogem batholith, Cordilleran Ice Sheet

1. Introduction

The Hogem batholith, which is prospective for syngenetic porphyry Cu (±Au, Ag, Mo) and quartz vein-hosted precious and base-metal mineralization, is in the Omineca Mountains, a remote part of north-central British Columbia (Fig. 1). In 2018, the British Columbia Geological Survey initiated a multi-year program integrating 1:50,000-scale bedrock and surficial geological mapping of northern Hogem batholith as it has not been investigated at this scale. Results from bedrock mapping, including detailed geochemical and geochronologic work to better understand the origin and timing of batholith emplacement and base- and precious-metal mineralization, are presented by Ootes et al. (2019a, b, 2020a, b) and Jones et al. (2021). Herein we present a preliminary overview of the surficial geology component by describing map units, landforms, and the ice-flow history of the area.

2. Setting and previous work

The northern Hogem batholith area is in north-central British Columbia, approximately 200 km northwest of Mackenzie, British Columbia (Fig. 1). Topography here consists of steep mountains with northward-facing cirques, and deep U-shaped valleys (Holland, 1976).

The Hogem batholith (Jurassic to Early Cretaceous) is a composite felsic to mafic plutonic body in Quesnel terrane.

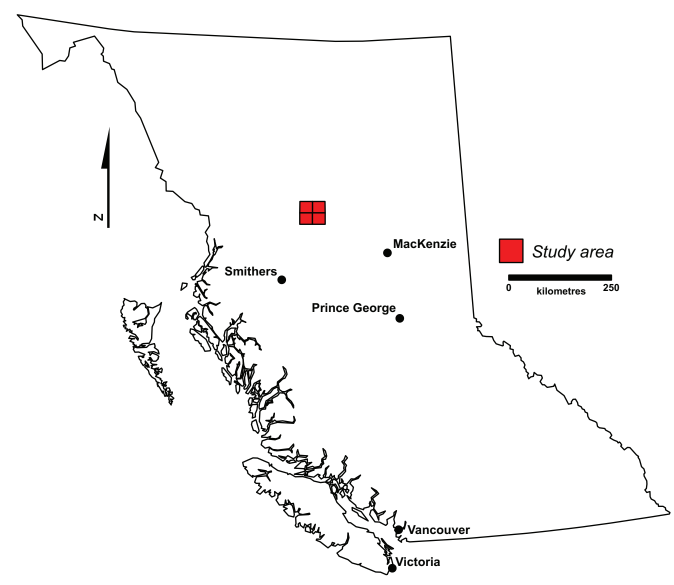

Fig. 1. Study area location.

These rocks have a high potential to host syngenetic porphyry-style Cu (±Au, Ag, Mo) mineralization and quartz vein-hosted concentrations of precious and base-metals. There are 112 MINFILE mineral occurrences in the study area, and an additional 19 have been discovered as part of regional bedrock mapping by Ootes et al. (2019a, b, 2020a, b). Seventy kilometres northwest of the study area is the past-producing Kemess mine (calc-alkaline porphyry Cu-Mo-Au; MINFILE 094E 094) and 10 km south is the Lorraine developed prospect (alkalic Cu-Au porphyry; MINFILE 093N 002).

Roots (1954) and Armstrong and Roots (1954) provided detailed Quaternary geology observations while investigating the bedrock geology and mineral deposits of the Aiken Lake map-area (NTS 94C west). Plouffe (2000) studied the surficial geology and Quaternary history of the Manson River map sheet south of the present study area at 1:250,000-scale and, to the east, Rutter (1974a, b) mapped the surficial geology of the Finlay River valley at 1:125,000-scale before the flooding of Williston Lake behind the W.A.C. Bennet Dam. Ryder and Maynard (1991), Bobrowsky and Rutter (1992), Clague and Ward (2011), and Margold et al. (2013) included the area in their broader summaries of Quaternary history and Cordilleran Ice Sheet dynamics.

3. Methods

Before entering the field, we made preliminary surficial geology maps for NTS 094C/04, 05, 094D/01, and 08 using digital, black and white 1:40,000-scale, air photo stereo pairs. Once in the field, we modified these maps by recording observations at natural (e.g., stream cuts, gullies, up-rooted trees) and anthropogenic (e.g., road cuts, clear cuts, hand-dug pits) exposures. We traversed using truck and all-terrain vehicle in those parts of NTS 094/C04 and 05 with road access (Fig. 2). In areas without roads, we conducted short ground traverses above treeline using a helicopter for access. We made observations from the air where a helicopter was prevented from landing, either because of excessively rugged topography (at elevation) or excessive tree cover (valley bottoms). We supplemented ground observations with high resolution (<10 cm/pixel) photogrammetric DEMs generated in the field using a remotely piloted aircraft system and the structure from motion technique (Elia and Ferbey, 2020).

4. Surficial geology map units

The following is a preliminary summary of the major surficial geology map units of the study area. Detailed descriptions of most sediment types are from exposures in 094C/04 and 05. Observations on bedrock and colluvial units were made in all four map sheets.

4.1. Bedrock

Bedrock is exposed in all topographic positions. It is most common above treeline where it forms extensive coherent exposures (Fig. 3a) or is mantled by felsenmeer consisting of frost-shattered angular fragments derived from immediately subjacent bedrock (Fig. 3b). Felsenmeer is most common in saddles, but can also occur in rounded, high-elevation, ridges or plateaus. At mid-slope positions (Fig. 3c), it can be difficult to distinguish between coherent bedrock and felsenmeer in air photos because exposures are small and discontinuous or hidden by vegetation. Bedrock is exposed discontinuously at isolated exposures distributed along the length of valley bottoms and in adjacent benches (Fig. 3d). Bedrock outcrop below treeline is likely under-represented in surficial geology mapping because of masking by tree canopy or because exposures are too small to resolve in air photos. Nonetheless, bedrock can occur in mappable features such as modern stream banks, and glaciofluvial meltwater channels, and does occur in the stoss (up-ice) end of crag and tail ridges.

4.2. Till

Till forms a cover of variable thickness in many topographic positions. At lower elevations, tills are commonly part of a thicker sediment package that obscures underlying bedrock topography. Tills are generally thinner on benches elevated above a valley, where surface topography is bedrock controlled. Streamlined tills (e.g., drumlins, flutes, crag and tails) also occur locally in the study area.

Tills in the study area contain subangular to subrounded clasts, typically pebble to cobble sizes (<10% boulders), that are set in a silty-sand matrix that typically ranges from 60 to 65% but can be as low as 20%. A massive, matrix-supported, weakly fissile, and moderately consolidated to overconsolidated variety, interpreted as a subglacial till, can be found throughout the study area (Fig. 4a). These subglacial tills locally form veneers <2 m thick overlying bedrock (Fig. 4b). The tills are commonly olive green, brown, or grey, but iron oxide staining may appear at transitions from tills to overlying B-horizon soils. Iron oxides can be restricted to individual clasts suspended in the till matrix or can be pervasive through the till matrix.

Subglacial tills of the Mesilinka River valley are predominantly sandy even though the valley appears to be underlain by mudrocks of the Takla Group (Ferri et al., 2001). This abundance of sand could represent earlier valley-fill deposits being reworked during Late Wisconsinan glacier advance and then incorporated into these tills. Alternatively, it is conceivable that unmapped crystalline intrusive or other coarse-grained rocks, that could yield sand-sized material, underlie parts of the valley. Quartz diorite rubble in a road cut near the center of Mesilinka River valley, 5 km east of Aiken Lake (Fig. 5), might point to such as yet unmapped bedrock.

Some tills have an undulating or hummocky surface expression (1 to 10 m high, 100s m long). This variety is weakly consolidated and is commonly near or adjacent to hummocky or ridged glaciofluvial sediments in valley bottoms. A sandy, weakly consolidated till is overlain by a poorly sorted, boulder-sized, glaciofluvial gravel north of Aiken Lake (Fig. 4c). We interpret these deposits to have formed by melt-out, either supraglacial or subglacial. East of Aiken Lake, tills at surface have a higher gravel content and larger clasts, but are moderately consolidated (Fig. 4d), possibly indicating subglacial deposition.

4.3. Glaciofluvial

Glaciofluvial sands and gravels occur at surface in most

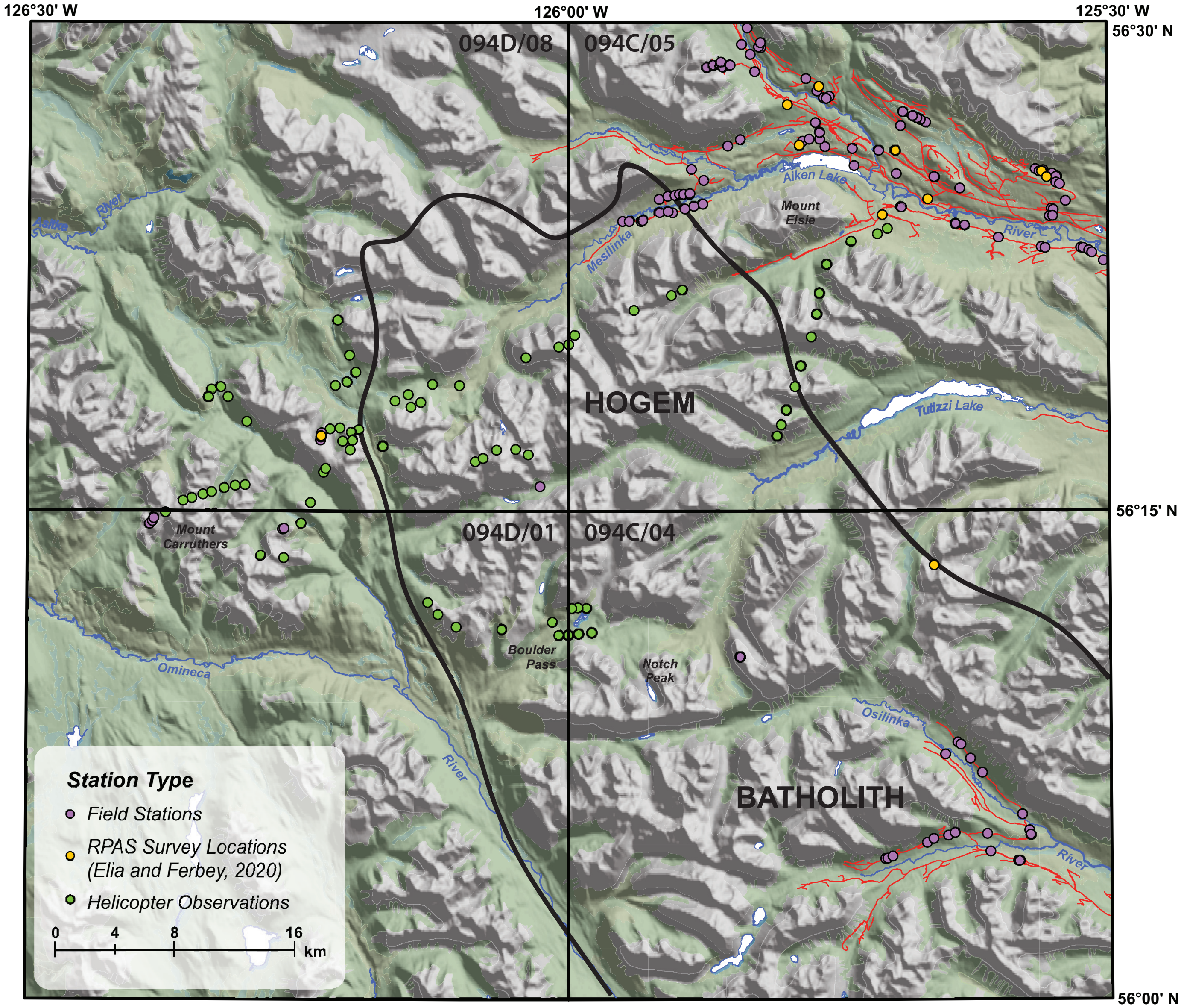

Fig. 2. Station types and locations. Field stations are ground observations. RPAS survey locations are where <10 cm/pixel photogrammetric DEMs were produced (see Elia and Ferbey, 2020). Helicopter observations are geolocated photographs taken from the air. The approximate extent of the Hogem batholith is after Ootes et al. (2020b).

valleys of the study area. They can extend the width of narrow, high-elevation valleys, where they are bounded by colluvial slopes, or occupy the central portions of broader valleys where they are commonly flanked by tills. These deposits can be terraced, show a hummocky or ridged (i.e., esker) surface expression, or form outwash plains or fans. Terrace gravels exposed in a 5 m road cut on the north side of Mesilinka River valley, near Aiken Lake, are typical for the study area (Fig. 6). Here, a cobble to boulder gravel fines up to a pebble to cobble gravel. The gravels are predominantly clast supported but locally can be matrix supported. The matrix throughout is a silty, medium to coarse sand and clasts are subrounded to rounded. These gravels are massive but in the upper 1.5 m, oblate clasts are weakly imbricated.

4.4. Colluvium

Colluvium blankets (>2 m thick) or veneers (<2 m thick) cover most slopes of this high-relief area. In many instances, these slopes are vegetated and the bedrock- or till-sourced sediment is now stable to metastable. Talus aprons or cones, consisting of loose angular pebbles and boulders accumulating directly below a steep-faced bedrock source, are the most visually prominent gravity deposits. Clasts are self-supporting and may be matrix filled or display an open framework. The lack of vegetation on these slopes indicates that talus is still forming (Fig. 7).

4.5. Organics

Peat and plant material in various stages of decomposition

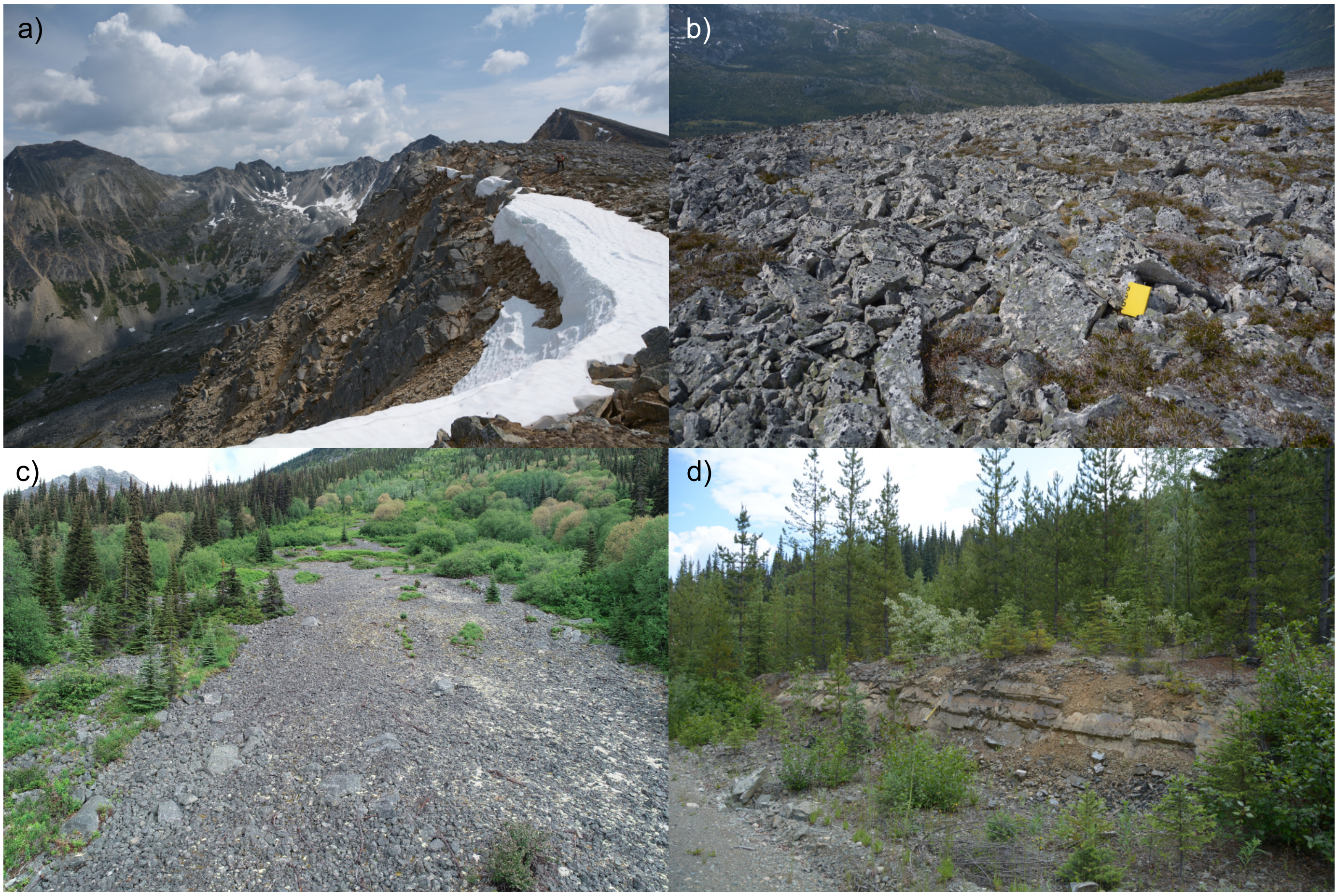

Fig. 3. Representative photographs of bedrock exposures. **a)** Granite ridges of the Osilinka intrusive suite (Late Jurassic; Ootes et al., 2020b), east of Notch Peak. **b)** Felsenmeer at elevation, above immediately subjacent in-situ Osilinka intrusive suite bedrock east of Notch Peak. **c)** Felsenmeer on the southwest-facing slope of the Osilinka River valley above diorite to quartz monzonite of the Thane Creek intrusive suite (Early Jurassic, Ootes et al., 2020b). **d)** A road cut through layered mudrocks mapped by Ferri et al. (2001) as Takla Group (Upper Triassic), east of Aiken Lake on the south side of Mesilinka River valley.

are found along the shorelines of small ponds and lakes and at the margins of low-gradient streams. They form accumulations typically >1 m thick, with a planar surface expression, creating a transition zone (5 to 50 m wide) between tree stands and water bodies. Organic material also occupies the lows in hummocky, undulating, or ridged glaciofluvial terrain, or in the troughs of streamlined tills. The most extensive organic deposits are next to deglacial sands and gravels in the central portion of 094D/08, where they are in well-defined, 100- to 150 m-wide corridors that can continue for 1000s of m. In plan view, these corridors vary from anabranching to dendritic and delineate the floors of glaciofluvial meltwater systems. Today, the corridors are either abandoned or contain underfit streams.

5. Ice-flow history

During the most recent Quaternary glaciation (Late Wisconsinan, or marine isotope stage 2, approximately 29 to 11.7 ka), the Cordilleran Ice Sheet covered the study area (Roots, 1954; Ryder and Maynard, 1991; Clague and Ward, 2011). Ice generally flowed through the area towards the east and southeast (Fig. 8) from an ice divide over the Skeena Mountains, ~100 km to the northwest (Ryder and Maynard, 1991; Clague and Ward, 2011). The ice sheet stage is attained once ice thickness is significantly greater than underlying topography (Kerr, 1934; Davis and Mathews, 1944); ice then flows unconstrained by topography and in the direction dictated by the surface slope of the ice sheet. Field evidence for this ice sheet stage is scarce, but 10 km northeast of Mount Carruthers, on a rounded ridge that forms the eastern boundary of a cirque basin, rat tails at 1750 m ASL are oriented towards 158° (Fig. 9). These glacially eroded features indicate that ice flow was independent of topography and that ice moved up the local slope, towards the cirque headwall. Striation data presented by Ootes et al. (2019b, 2020b), which indicate ice movement across alpine ridges (at 1700 to 2000 m ASL), confirm that the ice sheet stage was achieved in the study area. However, Roots (1954) and Ryder and Maynard (1991) considered that the ice sheet stage in this sector of the Cordilleran Ice Sheet was short lived, which would imply that inter- or cross-valley transport of glacial debris at higher elevations was minimal.

For most of the Late Wisconsinan, topography-controlled glacier flow was typical, as attested to by the well-developed

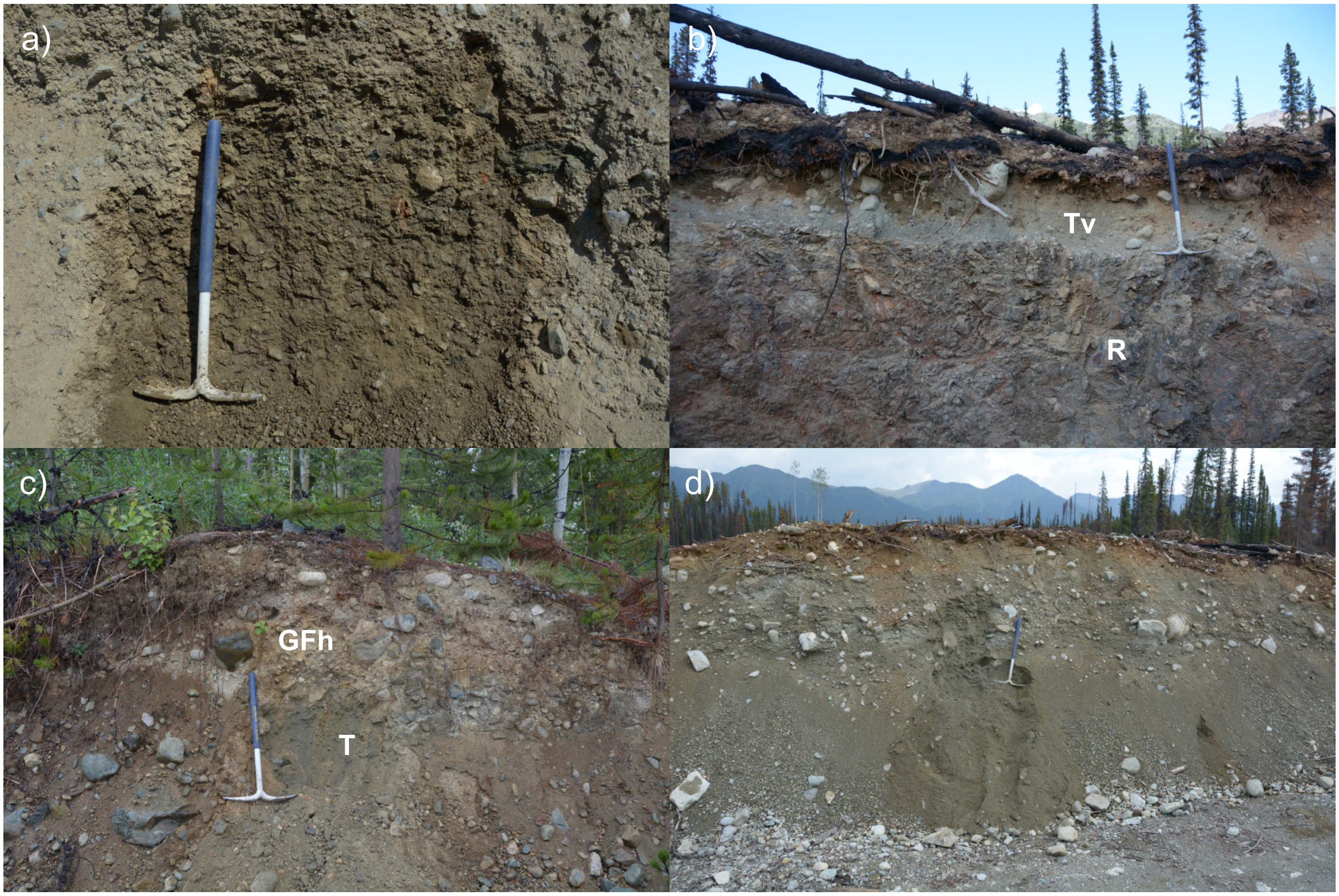

Fig. 4. Representative photographs of tills. **a)** A blocky, massive, overconsolidated subglacial till with a silty-sand matrix exposed on the north side of Mesilinka River valley, east of Aiken Lake. **b)** Subglacial till veneer (Tv) overlying Takla Group (Upper Triassic) mudrocks (R) northwest of Aiken Lake. **c)** A sandy, weakly consolidated, meltout till (T) overlain by hummocky glaciofluvial gravels (GFh) north of Aiken Lake. **d)** Moderately consolidated gravelly meltout till east of Aiken Lake.

Fig. 5. Angular blocks of quartz diorite of uncertain origin in a road cut east of Aiken Lake might signify that intrusive bodies in the Mesilinka River valley remain unmapped.

Fig. 6. Representative glaciofluvial terrace gravels with rounded clasts, east of Aiken Lake.

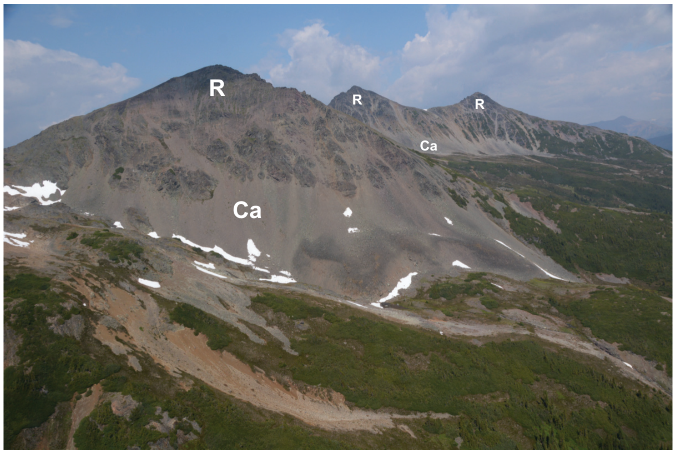

Fig. 7. Talus apron (Ca) and bedrock (R) on the north flank of Mount Carruthers.

Fig. 9. Rat tails preserved in a mafic lapilli tuff of the Asitka Group (Carboniferous to Permian). The long axes are oriented towards 158° indicating ice flow towards the cirque headwall (see Figure 8 for location).

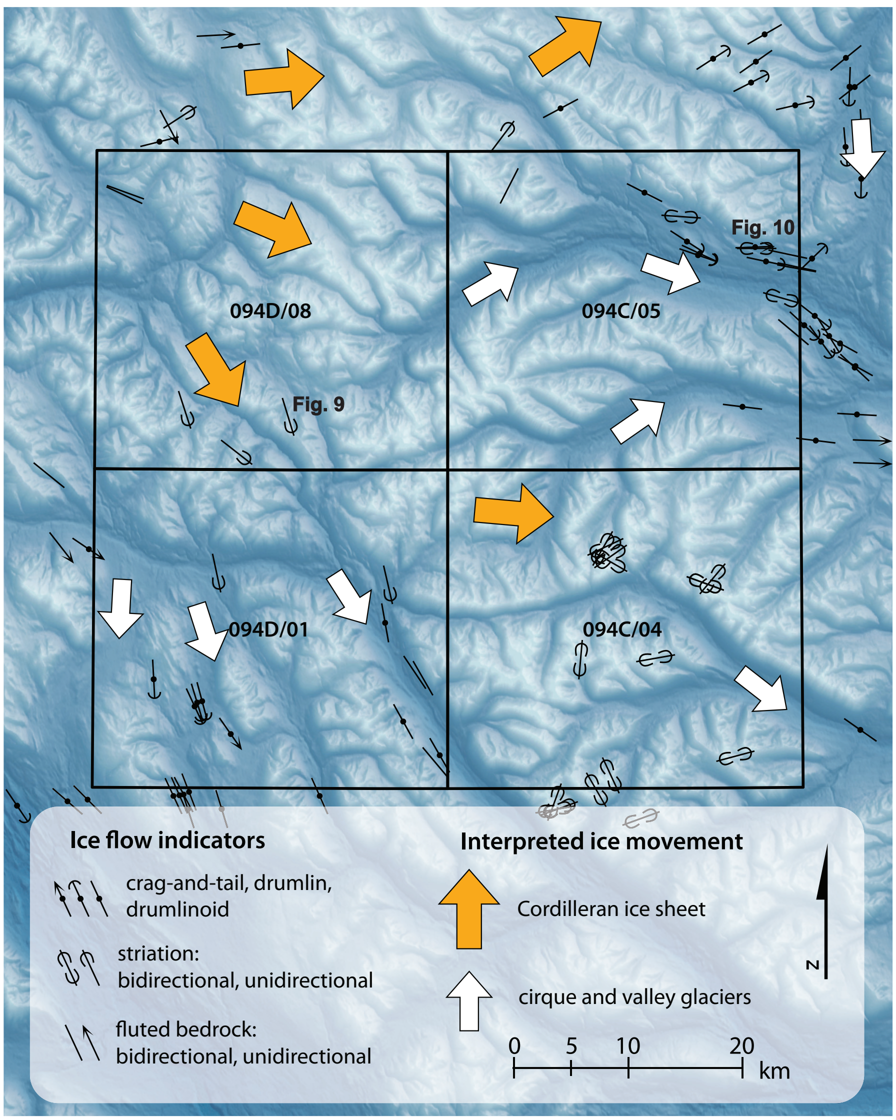

Fig. 8. Ice flow history of the study area. Ice flow indicators are modified from Arnold and Ferbey (2019) and Ootes et al. (2020b). Locations of Figures 9 and 10 are provided.

cirques and arêtes that define the mountains of the northern Hogem batholith area. In valleys, glacially streamlined landforms such as flutes, drumlins, and crag and tail ridges are consistently oriented with valley-parallel long axes (Fig. 8). Well-developed streamlined topography (oriented towards 095°) occurs in the Mesilinka River valley near the eastern side of 094C/05. Elia and Ferbey (2020) focussed on a subset of crag and tail ridges in this area for their investigation into the utility of high-resolution photogrammetric DEMs in surficial geology mapping (Fig. 10). Although outcrop-scale data like striations, rat tails, and roches mountonnées are sparse (Fig. 8) they agree with the landform record. For example, striations oriented 259°/079° to 270°/090° were observed on a bench on the south side of Mesilinka River valley.

The study area has a reticulate drainage pattern at a regional scale that is defined by an interconnected system of through valleys (Roots, 1954). These U-shaped valleys were cut by valley glaciers and contain subtle drainage divides that are below the treeline (Davis and Mathews, 1944). Modern fluvial systems are constrained by these drainage divides, but valley glaciers during the Late Wisconsinan were not. These glaciers flowed over these subtle divides, transporting glacial debris into neighbouring or adjacent drainages.

6. Summary and discussion

The Cordilleran Ice Sheet covered the Hogem batholith area during the Late Wisconsinan glacial maximum. At this time, ice flowed east and southeast through the study area from an ice divide over the Skeena Mountains, ~100 km to the northwest. The ice sheet stage was short-lived for this sector of the Cordilleran Ice Sheet, and inter-valley transport of glacial debris at higher elevations was likely minimal. For most of the Late Wisconsinan, ice flow was controlled by topography, as recorded by landform- and outcrop-scale indicators, which are commonly aligned parallel to valleys. However, valley glaciers certainly flowed over subtle through-valley topographic divides (that are now below the tree line), transporting glacial debris into adjacent drainages.

Glaciers deposited subglacial tills as they moved through the study area and hummocky melt-out tills during deglaciation. Although subglacial tills typically have a silty matrix, local sand-rich tills above mudstones in the Mesilinka Valley suggest that pre-glacial sands were glacially reworked and redeposited. Alternatively, the sand-rich tills may reflect nearby, as yet unmapped, crystalline intrusions or other coarse-grained bedrock capable of yielding sand-sized material. Significant volumes of glacial meltwater moved through the

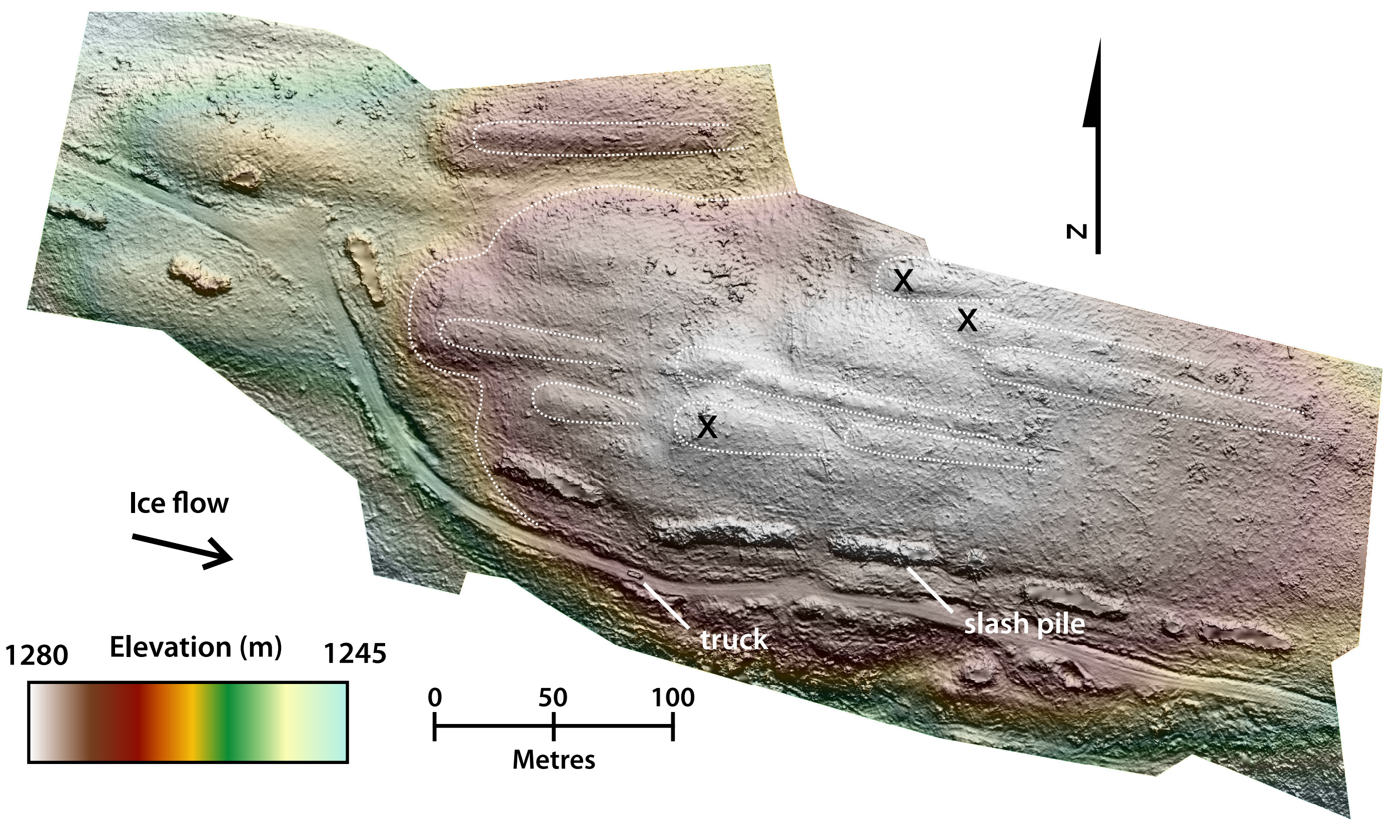

Fig. 10. Photogrammetric DEM of crag and tail ridges from the north side of Mesilinka River valley near the eastern boundary of 093C/05 (see Figure 8 for location). This image was generated in the field using a remotely piloted aircraft system imagery (Elia and Ferbey, 2020). These glacially streamlined ridges indicate ice flow towards the east-southeast. Bedrock outcrops observed in the field are identified by 'X'.

valleys of the study area during deglaciation, transporting coarse-grained sands and gravels. Much of this transport and deposition was subaerial (e.g., extensive outwash plains and terraces) but a component was also subglacial (e.g., eskers) or in contact with stagnant ice blocks (e.g., hummocky sands and gravels). Preliminary mapping shows that retreat-phase glaciolacustrine sediments in valley bottoms are conspicuously absent. Although some valley slopes are now vegetated and are stable, many are still actively building talus aprons and cones. Organic deposits occur throughout the study area, mostly as a transition zone between tree stands and water bodies. These deposits are also in well-defined and continuous anabranching to dendritic corridors that delineate retreat-phase glaciofluvial meltwater systems.

From a mineral exploration perspective, drift prospecting is a viable tool for assessing mineral potential in the study area. Subglacial till, the ideal sample medium for till geochemistry and mineralogy surveys, is common in valley bottoms and lower hillslopes. This glacially transported sediment is most easily observed along existing road and stream cuts but could also be sampled in hand-dug pits. Bedrock exposures are not limited to higher elevation or alpine sites. Local, discontinuous bedrock outcrop is common in valley bottoms and on hill flanks and direct prospecting and mapping are possible. Below treeline, bedrock exposures can be difficult to predict and so are typically underrepresented in surficial geology mapping. However, outcrops can be found in mappable features such as modern stream banks and glaciofluvial meltwater channels, and are found in the stoss (up-ice) ends of crag and tail ridges.

Acknowledgments

We thank I. Grady (IGI Consulting Ltd.) for generating mapping-ready digital air photos and the Abraham family for accommodation. L. Ootes and D. Milidragovic are thanked for their insights into the bedrock geology of the Hogem batholith area. A review by A.S. Hickin improved the manuscript.

References cited

Arnold, H., Ferbey, T., and Hickin, A.S., 2016. Ice-flow indicator compilation, British Columbia and Yukon. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2016-04, Geological Survey of Canada Open File 8083, scale 1:1,750,000.

Armstrong, J.E., and Roots, E.F., 1954. Aiken Lake, Cassiar district, British Columbia. Geological Survey of Canada, Map 1030A, scale 1:253,440.

Bobrowsky, P., and Rutter, N.W., 1992. The Quaternary geologic history of the Canadian Rocky Mountains. Géographie physique et Quaternaire, 46, 5-50.

Clague, J.J., and Ward, B.C., 2011. Pleistocene Glaciation of British Columbia. In: Ehlers, J., Gibbard, P.L., and Hughes, P.D., (Eds.), Developments in Quaternary Science, 15, Amsterdam, pp. 563-573.

Davis, N.F.G., and Mathews, W.H., 1944. Four phases of glaciation with illustrations from southwestern British Columbia. Journal of Geology, 52, 403-413.

Elia, E.A., and Ferbey, T., 2020. Generating photogrammetric DEMs in the field from remotely piloted aircraft systems. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-1, pp. 189-200.

Ferri, F., Dudka, S.F., Rees, C., and Meldrum, D., 2001. Geology of the Aiken Lake area, north-central British Columbia, NTS 94C/5, 6 and 12. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Geoscience Map 2001-10, scale 1:50,000.

Holland, S.S., 1976. Landforms of British Columbia: A physiographic outline. British Columbia Ministry of Energy, Mines and Petroleum Resources, Bulletin 48, 138 p.

Jones, G., Ootes, L., Milidragovic, D., Friedman, R., Camacho, A., Luo, Y., Vezinet, A., Pearson, D.G., and Schiarizza, P., 2021. Geochronology of northern Hogem batholith, Quesnel terrane, north-central British Columbia. In: Geological Fieldwork 2020, British Columbia Ministry of Energy, Mines and Low Carbon Innovation, British Columbia Geological Survey Paper 2021-01, pp. 37-56.

Kerr, F.A., 1934. Glaciation in northern British Columbia. Royal Society of Canada, Transactions, 28, 17-31.

Margold, M., Jansson, K.N., Kleman, J., Stroeven A.P., and Clague, C., 2013. Retreat pattern of the Cordilleran Ice Sheet in central British Columbia at the end of the last glaciation reconstructed from glacial meltwater landforms. Boreas, 42, 830-847.

Ootes, L., Bergen, A., Milidragovic, D., Graham, B., and Simmonds, R., 2019a. Preliminary geology of northern Hogem batholith, Quesnel terrane, north-central British Columbia. In: Geological Fieldwork 2018, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2019-01, pp. 31-53.

Ootes, L., Bergen, A.L., Milidragovic, D., and Graham, B., 2019b. Bedrock geology of Notch Peak and Ogden Creek (parts of NTS 094C/04 and 093N/13), northern Hogem batholith, Quesnel terrane, north-central British Columbia. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2019-02, scale 1:50,000.

Ootes, L., Bergen, A.L., Milidragovic, D., Jones, G.O., Camacho, A., and Friedman, R., 2020a. An update on the geology of northern Hogem batholith and its surroundings, north-central British Columbia. In: Geological Fieldwork 2019, British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Paper 2020-01, pp. 25-47.

Ootes, L., Bergen, A.L., Milidragovic, D., and Jones, G.O., 2020b. Bedrock geology of northern Hogem batholith and its surroundings, north-central British Columbia. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2020-02, scale 1:50,000.

Plouffe, A., 2000. Quaternary geology of the Fort Fraser and Manson River map areas, central British Columbia. Geological Survey of Canada, Bulletin 554, 62 p.

Roots, E.F., 1954. Geology and mineral deposits of Aiken Lake map-area, British Columbia. Geological Survey of Canada, Memoir 274, 246 p.

Rutter, N.W., 1974a. Surficial geology and landforms of Williston Lake area (map 1), British Columbia. Geological Survey of Canada, Map 1381A, scale 1:125,000.

Rutter, N.W., 1974b. Surficial geology and landforms of Williston Lake area (map 2), British Columbia. Geological Survey of Canada, Map 1382A, scale 1:125,000.

Ryder, J.M., and Maynard, D., 1991. The Cordilleran Ice Sheet in northern British Colombia. Géographie physique et Quaternaire, 45, 355-363.