DESCRIPTIVE NOTES

INTRODUCTION
This Surficial Geology Map of NTS 94-O/12 (Canadian Geoscience Map 122) is the product of collaboration between the Geological Survey of Canada and the British Columbia Ministry of Energy, Mines and Natural Gas as part of the Geo-mapping for Energy and Minerals Program (GEM-Energy Yukon Basins Project. The accompanying geodatabase includes field observation points and field photos, landform features as lines, and surficial geology unit polygons. The map and geodatabase are essential baseline geoscience information for a range of potential end-users including resource explorationists, geotechnical engineers, land-use managers, terrestrial ecologists, archaeologist, geoscientists and communities in northern British Columbia. By providing new insight into the distribution and origins of surficial earth materials, CGM 122 will help to reduce the economic costs and risks associated with the sustainable development of energy and mineral resources in NTS 94-O/12. Environmental impact assessments for new access roads, work camps, well pads, pipeline and power transmission line corridors, water storage and waste management systems and other infrastructure will benefit from the geoscience information presented here. By identifying areas prone to geological hazards (e.g., landslides, permafrost, flooding), CGM 122 will also help to protect natural resources, infrastructure and communities vulnerable to climate change in Canada's north.

APPROACH TO SURFICIAL GEOLOGY MAPPING
Terrain mapping and field-based benchmarking studies have led to a better understanding of the regional distribution of surficial deposits, permafrost, landslides and other geomorphic processes in the NTS 94-O/12 map area (Huntley and Hickin, 2010; Huntley et al., 2011a-b). Surficial earth materials and landforms were interpreted using a combination of stereo-pair air photos (e.g., BCB97010, 15BCB97015, 15BCB97029, 15BCB97075 and 15BCB97088 series), LANDSAT 7 satellite imagery (http://glovis.usgs.gov/ [URL 2011]) and Shuttle Radar Topography Mission digital elevation models (http://dds.cr.usgs.gov/srtm/ [URL 2011]). The base map was generated from CANVEC shape files (http://geogratis.cgdi.gc.ca/geogratis/ [URL 2011]). Terrain polygons and on-site symbols were digitized using commercially available computer software packages (Global Mapper, ArcMap and ArcGIS) and compared to published maps, reports and archived digital data (e.g., Stott and Taylor, 1968; Bednarski, 2003a-d; Clement et al., 2004; Bednarski, 2005a-b). The geodatabase accompanying this map conforms to the Science Language for the Data Management component of the GEM Geological Map Flow process (cf. Huntley and Sidwell, 2010; Huntley et al., 2011a; Deblonde et al., *2012*).

Fieldwork was undertaken in 2009 and 2010 to ground truth surficial geology polygons interpreted from air photos and satellite imagery, and to gather characteristics that could not be determined through remote predictive mapping. Earth materials were defined on the basis of facies and landform associations, texture, sorting, colour, sedimentary structures, degree of consolidation, and stratigraphic contact relationships at field stations and remote observations from helicopters. The distribution of glacial and non-glacial landforms is depicted on the surficial geology map. Map units in the Legend are presented chronostratigraphically and include organic deposits, alluvial, colluvial, eolian, glaciolacustrine and glaciofluvial sediments, tills and areas of bedrock.

INFERRED GEOLOGICAL HISTORY
The distinctive landscape of NTS 94-O/12 is largely a product ofunderlying bedrock and geological structures, with ornamentation by the Late Wisconsinan Laurentide Ice Sheet. La Jolie Butte is underlain by conglomerate, sandstone, carbonaceous shale and coal (Upper Cretaceous Wapiti Formation). Over much map area, shale, siltstone and sandstone (Upper Cretaceous Kotaneelee Formation) lie beneath surficial units (Stott and Taylor, 1968). Topography and drainage patterns were greatly modified during the phase of maximum ice cover (>18 ^{14}C ka BP or >21.4 calendar ka BP). Unconsolidated sediment thicknesses in excess of 2-5 m are observed in valleys and it is suspected that similar drift thicknesses blanket bedrock (unit R) across the map area. Silt- and clay-rich Laurentide tills have low clast contents (<20%) of proximally derived Cretaceous siliciclastic sedimentary rocks and distal igneous and metamorphic clasts from the Canadian Shield, hundreds of kilometres to the northeast. Drumlin ridges up to several hundred metres in length suggest clay-richtills (unit Ts) were deposited beneath active, rapidly flowing warm-based glacial ice (Huntley and Hickin, 2010; Huntley et al., 2011b). Drumlinized till (unit Ts) is most pronounced west of La Jolie Butte where west- and southwest moving ice flowed up-hill, and thick accumulations of till were deposited over soft bedrock and unconsolidated advance-phase sediments. Small lake basins were excavated by erosion and ice-thrusting as Laurentide ice and subglacial meltwater scoured and deformed olderglacial deposits and weak bedrock.

Deglaciation began sometime after 18 ^{14}C ka BP (or >21.4 calendar ka BP) and ended before 10 ^{14}C ka BP (ca. 12 calendar ka BP), with the retreating active Laurentide Ice Sheet, stagnant ice masses in lowlands, glaciofluvial outwash and landslide debris blocking and reordering regional drainage. The mapped distribution of moraine ridges (unit Tm) implies that ice margins receded to the northeast across the map sheet (Huntley and Hickin, 2010). Some large end moraines are deformed and streamlined suggesting that receding lobes remained active during retreat and occasionally rapidly advanced. Minor moraine ridges drape drumlins in cross-cutting patterns and are interpreted as crevasse fillings and squeeze moraines deposited shortly after drumlinization ended, or as ice retreated from the map area (Huntley et al., 2011b). Hummocky till (unit Th) together with short segments of subareal-subglacial meltwater channels and eskers indicate that bodies of stagnant glacier ice remained in lowland areas west of the Maxhamish Escarpment (Huntley et al., 2011a-b). As ice retreated from the map area, a proglacial lake system formed on the Liard Plateau. Proglacial lakes were linked by spillways that drained meltwater northward into the Mackenzie River basin. In the map area, glaciolacustrine deposits (unit GLb), glaciofluvial terraces (unit GFt), and meltwater channels incised into till and bedrock indicate that glacial lake levels fell stepwise through deglaciation, with stable elevations at approximately 420 m, 380 m and <300 m. Fine-grained glacial earth materials have been re-worked by eolian activity and discontinuous loess covers glacial lake and till deposits in some areas.

Post-glaciation (10 ^{14}C ka BP, or ca. 12 calendar ka BP to present), changes in regional base-level led to episodes of channel incision and aggradation, resulting in the formation of erosional alluvial terraces along most stream and river valleys. In the early Holocene, pulses of fluvial terrace building followed initial valley incision by the Liard and other major rivers. Most streams and rivers have alluvial terraces (unit At) <5 m above active floodplains (unit Ap) consisting of gravel overlain by silt and sand. Poorly drained clay-rich till on the plateaux and glaciolacustrine sediments in lowland areas are covered by extensive postglacial peat deposits (unit Owb). Discontinuous permafrost is sporadically encountered in glaciolacustrine and some peat deposits. Charcoal, observed in dug pits on alluvial terraces, suggest forest fires may have contributed to periods of landslide activity on slopes and local fluvial aggradation. Landslides and colluviated deposits (units Cv, Cb) are common where bedrock outcrops form escarpments, and where shale or fine-grained glacial deposits are exposed along steep cutbanks. Stream networks and wetlands draining plateau watersheds are disrupted by beaver activity and, to a lesser extent, by roads and infrastructure where they cross streams, rivers and organic deposits (Huntley and Hickin, 2010; Huntley and Hickin, 2011a-b).

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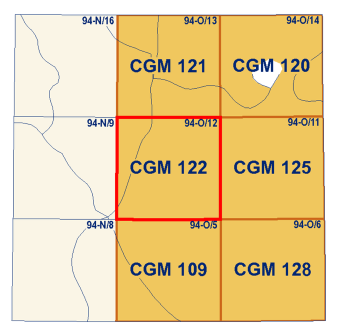
Abstract

Canadian Geoscience Map 122 depicts the surficial geology over some 790 km^2 covered by the La Jolie Butte map sheet (NTS 94-O/12) in northeastern British Columbia. The map area lies at the western limit of the Liard Plateau and is incised by the Liard River and its tributaries. Bedrock is mantled by unconsolidated earth materials dating to the Late Pleistocene (Late Wisconsinan Glaciation, > 25 ka to ca. 10 ka) and non-glacial Holocene (ca. 10 ka to present). Deposits of till, green on the map, are generally suitable for placement of infrastructure. Glaciofluvial and eolian deposits with mineral, aggregate, and groundwater potential are coloured orange and buff. Slopes disturbed by landslides, debris flows, and rock falls appear brown and pink. Glaciolacustrine and organic deposits with sporadically discontinuous permafrost are coloured purple and grey. Alluvial deposits prone to flooding, erosion, and sedimentation appear yellow on the map.

Résumé

La Carte géoscientifique du Canada 122 illustre la géologie des matériaux superficiels d'un territoire d'environ 790 km^2 couvert par le feuillet cartographique de La Jolie Butte (SNRC 94-O/12), dans le nord-est de la Colombie-Britannique. La région cartographique se situe à la bordure occidentale du plateau de Liard et est entaillée par la rivière Liard et ses affluents. Le socle rocheux est couvert de matériaux terrestres non consolidés remontant au Pléistocène supérieur (Glaciation du Wisconsinien supérieur, de > 25 ka à env. 10 ka) ainsi que de matériaux non glaciaires de l'Holocène (d'env. 10 ka jusqu'à nos jours). Les dépôts de till, de couleur verte sur la carte, sont généralement propices à l'établissement de l'infrastructure. Les dépôts fluvioglaciaires et éoliens, qui recèlent un potentiel en minéraux, en agrégats et en eau souterraine, sont figurés par les couleurs orange et chamois. Les versants dérangés par des glissements de terrain, des coulés de débris et des chutes de blocs sont représentés en brun et en rose. Les dépôts glaciolacustres et organiques, qui renferment sporadiquement du pergélisol discontinu, sont représentés en violet et en gris. Les dépôts alluviaux sujets aux inondations, à l'érosion et à la sédimentation apparaissent en jaune sur la carte.



National Topographic System reference and index to adjoining published Geological Survey of Canada maps

Cover illustration
Shales and sandstones exposed along the Liard River in northeast British Columbia, view south toward the confluence with Fort Nelson River. Photograph by D.H. Huntley. 2013-100

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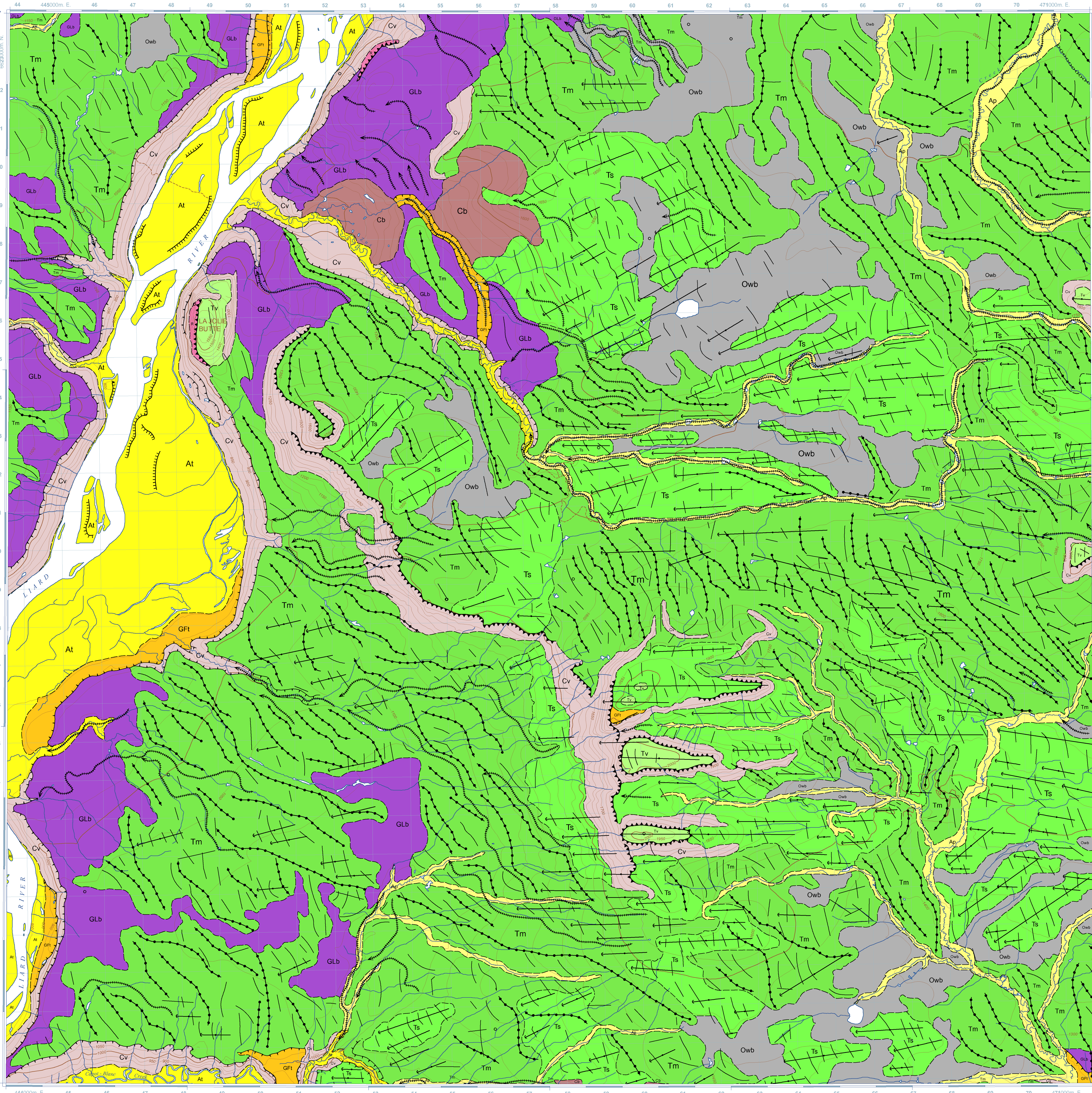
Natural Resources Canada Ressources naturelles du Canada

CANADIAN GEOSCIENCE MAP 122
SURFICIAL GEOLOGY
LA JOLIE BUTTE
British Columbia

1:50 000



Holocene earth materials and landforms

Organic Deposits

Owb — **Peat bogs**: fibric to humic organic matter; massive to stratified accumulations; generally greater than 2 m thick; confined to topographic depressions or level areas; underlain by poorly drained till, glaciolacustrine and other unconsolidated sediments; formed by decomposition of plant material in wetland areas; bogs with sporadically discontinuous permafrost and thermokarst depressions potentially unstable if organic material is disturbed or removed.

Alluvial deposits

At — **Alluvial terraced sediments**: boulders, gravel, sand and silt; generally massive to planar stratified; well to rapidly drained; greater than 2 m thick; may contain interbedded debris flows and buried organic material; underlain by outwash, till or bedrock; transported and deposited by modern rivers, streams and creeks; subject to rare flooding; potential source of aggregate; land use activities may adversely affect stream courses and conditions, and impact fish and wildlife resources.

Ap — **Alluvial floodplain sediments**: gravel, sand and silt; massive, trough cross-bedded, rippled-bedded, planar stratified; well to rapidly drained; greater than 2 m thick; underlain by till or bedrock; transported and deposited by modern rivers, streams and creeks; subject to seasonal flooding; land use activities may adversely affect stream courses and conditions, and impact fish and wildlife resources.

Colluvial deposits

Cv — **Colluvial veneer**: clast-supported diamictons and rubble; massive to stratified, poorly-sorted; well to rapidly drained; deposits less than 2 m thick; landslide headscarps range from 300 m to 10.5 km; formed by the weathering and down-slope movement of earth materials by gravitational processes; bedrock and unconsolidated debris on slopes above 10-15° with greater than 5 m relief prone to mass-wasting; rock falls, topples, rock slides and debris flows occur where shale, sandstone and carbonate strata is exposed close to the surface; retrogressive rotational debris slides, debris flows and slumps occur in glaciolacustrine sediments and outwash containing sporadically discontinuous permafrost; where ground ice is found slope failure can occur on surfaces less than 5°; slope instability could present major problems for construction in some areas.

Cb — **Colluvial blanket**: clast-supported diamictons and rubble; massive to stratified, poorly-sorted; well to rapidly drained; deposits greater than 2 m thick; landslide headscarps range from 300 m to 10.5 km; formed by the weathering and down-slope movement of earth materials by gravitational processes; bedrock and unconsolidated debris on slopes above 10-15° with greater than 5 m relief prone to mass-wasting; rock falls, topples, rock slides and debris flows occur where shale, sandstone and carbonate strata is exposed close to the surface; retrogressive rotational debris slides, debris flows and slumps occur in glaciolacustrine sediments and outwash containing sporadically discontinuous permafrost; where ground ice is found slope failure can occur on surfaces less than 5°; slope instability could present major problems for construction in some areas.

Late Pleistocene earth materials and landforms

Glaciolacustrine deposits

GLb — **Glaciolacustrine blanket**: silt and clay with subordinate sand, gravel and diamicton; massive or rhythmically interbedded; slump structures and dropstones locally present; poor to moderately drained; generally greater than 2 m thick; kettle lakes and irregular topography underlain by bedrock, tills and outwash; transported by and deposited from sediment-laden meltwater, subaqueous gravity flows and thermal melting of ice in proglacial lakes; where sporadically discontinuous permafrost is, or was present, glaciolacustrine sediments may be subject to thermokarst processes; slopes less than 5° are potentially unstable and prone to landslides and debris flows.

Glaciofluvial deposits

GFt — **Outwash terraces**: boulders, cobbles, pebble-gravel, sand, silt and matrix-supported diamicton; generally massive to stratified, some slump structures; moderately to well-drained; greater than 2 m thick; terrace scarps range from 100 m to 8 km in length; in contact with, and overlying other till units, outwash and glaciolacustrine sediments; deposited by meltwater confined to proglacial channels and spillways; potential source of groundwater and granular aggregate when material is gravel rich.

Tm — **Moraine ridges**: sand, silt and clay-rich diamictons; massive, matrix-supported; clast contents less than 20% and contain sub-rounded granitic erratic boulders with sources on the Canadian Shield; moderately to well-drained; greater than 2 m thick; minor moraines less than 1 km long and 5 m high; major moraines up to 12.5 km in length and 10 m high; ridges drape bedrock and older glacial deposits; minor moraines include crevasse-fill ridges and small recessional push moraines; major ridges features are large recessional end moraines and ice-thrust ridges; generally suitable for infrastructure placement.

Ts — **Streamlined till**: silt and clay-rich diamictons; massive, matrix-supported and compact; clast contents less than 20% and contain sub-rounded granitic erratic boulders with sources on the Canadian Shield; moderately well-drained; greater than 2 m thick mantling bedrock and older glacial deposits; drumlins and fluted till ridges typically under 1 km long but can exceed 9 km in length; generally less than 50 m wide and 20 m high; formed beneath the Laurentide Ice Sheet directly through lodgement, basal meltout, glacigenic deformation of sediment beneath rapidly-flowing warm-based ice; generally suitable for infrastructure placement.

Tv — **Till veneer**: sand, silt and clay-rich diamictons; massive, matrix-supported and compact; clast contents less than 20% and contain sub-rounded granitic erratic boulders with sources on the Canadian Shield; moderately to well-drained; less than 2 m thick draping bedrock and older glacial deposits; transported and deposited by the Laurentide Ice Sheet directly through lodgement, basal meltout, glacigenic deformation beneath active, warm-based ice and in situ melting from stagnant cold-based ice; generally suitable for infrastructure placement.

Pre-Quaternary earth materials and landforms

Bedrock

R — **Undifferentiated bedrock**: conglomerate, sandstone, siltstone, shale and limestone; slopes above 10-15° with greater than 5 m relief prone to rock falls, topples rock slides and debris flows; Paleozoic unconformably overlain by Mesozoic sedimentary rocks; limestone and clastic sedimentary rocks are a potential source of crushed granular aggregate.

- Geological boundary (Confidence: approximate)
- Bedrock scarp
- Major moraine ridge (end, interlobate, or unspecified)
- Other moraine ridge (DeGeer, minor lateral, recessional, rogen, washboard, other transverse or unspecified)
- Esker ridge (sense: unknown or unspecified)
- Drumlin ridge
- Major meltwater channel scarp
- Minor meltwater channel central axis (marginal, overflow, subglacial or unspecified; sense: known)
- Terrace scarp (environment: glaciofluvial)
- Terrace scarp (environment: fluvial)
- Station location (ground observation or stratigraphic section)

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Canadian Geoscience Maps

Authors: D.H. Huntley, A.S. Hickin, W. Chow, and M. Mirmohammadi

Geology by D.H. Huntley and A.S. Hickin (2009–2010)

Geological compilation by D.H. Huntley (2009–2011)

Geomatics by D.H. Huntley, W. Chow, and M. Mirmohammadi

Cartography by W. Chow

Initiative of the Geological Survey of Canada, conducted under the auspices of the Yukon Basin Project as part of Natural Resources Canada's Geo-mapping for Energy and Minerals (GEM) program

SURFICIAL GEOLOGY
LA JOLIE BUTTE
British Columbia
1:50 000

1 0 1 2 3 4 km

Map projection Universal Transverse Mercator, zone 10. North American Datum 1983

Base map at the scale of 1:50 000 from Natural Resources Canada, with modifications. Elevations in feet above mean sea level

Magnetic declination 2013, 20°39'E, decreasing 22' annually.

The Geological Survey of Canada welcomes corrections or additional information from users.

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Preliminary publications in this series have not been scientifically edited.

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