GEOLOGICAL SURVEY OF CANADA
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Glacial history and drift prospecting in the Canadian Cordillera: recent developments

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A Contribution to a Session on
The Canadian Cordillera and its Mineral Deposits: A New Look

Presented at the

Prospectors and Developers Association of Canada (PDAC),
International Convention, Trade Show and Investors Exchange, March 6th, 2012

A Targeted Geoscience Initiative 4 Contribution

2012

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Glacial history and drift prospecting in the Canadian Cordillera: recent developments

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2012

doi:10.4095/292101

Recommended citation
Plouffe, A., Ferbey, T., Levson, V.M., and Bond, J.D., 2012. Glacial history and drift prospecting in the Canadian Cordillera: recent developments; Geological Survey of Canada, Open File 7261, 51 p. doi:10.4095/292101

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Summary

For more than 20 years, provincial, territorial and federal geological surveys have implemented surficial geology mapping and glacial sediment (till) sampling surveys within the Canadian Cordillera to evaluate the mineral potential of regions covered by glacial sediments using drift prospecting methods. The chemical composition of the till samples were assessed for anomalous element enrichments which were traced back to the bedrock source in the up-ice flow direction. Several mineral exploration targets have been identified by these surveys and followed-up by mineral exploration companies. The success of these surveys and subsequent follow-up relies on reconstructed ice-flow histories based on mapping of glacial sediments and ice-flow indicators varying from landform (e.g. drumlins) to outcrop (e.g. striations) scales.

During the last glacial maximum (LGM), the Canadian Cordillera was covered by the Cordilleran Ice Sheet (CIS) which was thick enough to flow across high summits in both the Rocky and Coast mountains. The CIS left a clear foot print on the landscape including glacial landforms and thick successions of glacial sediments. The position of ice source regions and ice-divides changed during the last glaciation such that ice-flow directions at LGM were different than in early and late glacial times. However, northwest Yukon did not receive sufficient precipitation for extensive glacial ice build-up.

Recent developments and current research in the application of this drift prospecting methodology include: 1) the recognition of multiple ice-flow directions (including flow reversals) and associated glacial dispersal patterns, 2) the study of indicator minerals in sediments which could be traced to fertile mineralized bedrock sources, 3) recognition of mineral-rich dispersal trains in areas of thick till (> 30 m thick), and 4) the implementation of surficial sediment sampling strategies for the unglaciated landscape of northwest Yukon.

Introduction

The Prospectors and Developers Association of Canada (PDAC) Convention held in Toronto, Ontario, from March 4 to 7, 2012 included one special session entitled "The Canadian Cordillera and its mineral deposits: a new look". The special session comprised a number of presentations on recent developments in our understanding of the mineral potential and the exploration methods applicable in this vast territory of Canada. One of the talks was entitled "Glacial history and drift prospecting in the Canadian Cordillera: recent developments" and provided a summary of the application of drift prospecting in the Cordillera. This open file contains the slides of that talk (second part of this document), their description and relevant references. Because of the evident interest expressed by the audience for this talk, this Open File seeks to provide an annotated archive of the presentation to a wider audience

The talk contains a brief introduction to basic concepts of glacial transport, examples of mineral discoveries in the Canadian Cordillera which benefited from the use and application of drift prospecting, examples of dispersal trains, recent developments in our understanding of the ice-flow history of the last glaciation, basic concepts of soil and surficial sediment sampling in the unglaciated terrain of the Yukon, and an overview of the work in progress on drift prospecting as part of the Targeted Geoscience Initiative 4 (TGI4) of the Geological Survey of Canada (GSC).

Slide 1

Title of the presentation, authors and their affiliation.

Basic concepts

Slide 2

Most of Canada was covered by glaciers during the last glaciation except for west central and northern Yukon where precipitation was lacking because of a dry climate. This resulted in reduced ice accumulation for the formation of glaciers. The lack of precipitation in this part of the northern Canadian Cordillera extended to the present, as seen in a modern precipitation map of Yukon and Alaska where areas with less precipitation are shown in shades of red to yellow (Spatial Climate Analysis Service, Oregon State University, Copyright 2000).

Slide 3

A glacier is a body of ice which moves in the direction of decreasing ice surface slope, as depicted with the blue arrows in this figure of a cross-section through a valley glacier (Boulton, 1996). The glacier is always moving in this forward motion even during ice-front retreat creating the "conveyor belt effect".

Slides 4 and 5

As a glacier advances over a substrate (i.e., bedrock and pre-existing sediments), it erodes this substrate and transport the resultant debris in a down-ice direction. Following the retreat of the glacier, the landscape is left with a mixture of debris derived from sources in the up-ice region. Sediment directly deposited by a glacier is termed till.

A simplified illustration of the development of a dispersal train, modified from Drake (1983), Miller (1984), and McClenaghan and Kjarsgaard (2007), is shown in cross-section (slide 4) and plan view (slide 5). A mineralized zone exposed at the surface before a glaciation is shown in pink (panel 1). During a glaciation, the mineralized zone and the host bedrock (grey) is eroded by the glacier and the resultant debris is transported in the direction of glacier flow or ice movement (panel 2). Following deglaciation, the till (green, slide 4 only) includes a train of debris, the dispersal train, enriched in material derived from the mineralized zone (shaded pink) (panel 3). No precise scale is shown on this diagram since the scale of the dispersal train depends on the size of the mineralized zone, the contrast between the mineralized zone and the host lithologies, the till thickness, the topography and the relative position of the source rock, the physical properties of the glacier (thermal regime, ice velocity), etc. Note on panel 3 of both slides that the dispersal train reaches surface at some distance from the mineralized zone which has important implications for mineral exploration; the search for a buried mineralized bedrock source (e.g. trenching and drilling) should be conducted some distance up-ice from the last anomalies or the cut-off identified in till.

Drift prospecting: exploration targets and mineral discoveries

Slides 6 and 7

These slides list a number of mineral exploration targets and discoveries that were made in the Canadian Cordillera with some support or contribution from drift prospecting. References are also provided.

Regional and property-scale drift prospecting surveys in the Canadian Cordillera

Slide 8

A number of regional and property scale drift prospecting surveys were completed in Yukon since the late 1980’s including:
Tintina Trench and Grew Creek (Plouffe, 1989; Plouffe and Jackson, 1992; 1995);
Anvil district and the Faro Mine (Bond, 2001);
Finlayson Lake region and the Kudz Ze Kayah (KZK; Bond et al., 2002; Bond and Plouffe, 2002);
Glenlyon and Clear Lake (Bond and Plouffe, 2003);
Dawson region (Bond and Sandborn, 2006); and
Selwyn and Anniv (Turner et al., 2008).

Slide 9

Similarly, regional and property scale drift prospecting surveys have been completed in British Columbia. Ferbey (2011) has compiled a map showing the geographic distribution of those surveys along with references to reports on the results and their interpretation.

Examples of dispersal trains in the Cordillera

The following slides are examples of dispersal trains from various deposit types in the Cordillera. Limited access in some of the regions presented below has restricted more detailed investigations of the geographic distribution of glacially dispersed material. The length and shape of the dispersal trains may be inaccurate due to the extent of sampling.

Slide 10

Copper dispersal train from the porphyry copper-gold deposit at Bell Mine located on the Newman Peninsula, on Babine Lake, in central British Columbia (inset) (Levson, 2002). Copper concentrations were determined from the -230 mesh (< 0.0625 mm) size fraction. Ice-flow direction is to the south-southeast as shown with the black arrow. Magenta, pink and orange polygons are representing the mineralized Babine intrusion (MacIntyre, 2001). Dashed lines are representing faults and solid lines alteration halos surrounding mineralization (MacIntyre, 2001).

Slide 11

Copper dispersal train from the Galaxy porphyry copper-gold deposit in the Iron Mask Batholith southwest of Kamloops in south central British Columbia (inset) (Kerr et al., 1993; Levson, 2001; Lett, 2011). Copper concentrations were determined from the -80 mesh (<0.0177 mm) size fraction. Ice-flow direction is to the southeast as indicated by striations and drumlins.

Slide 12

Lead and zinc dispersal trains extending to the northwest of the Faro Mine (SEDEX deposit) in south central Yukon (Bond, 2001). Lead and zinc concentrations were determined on the -230 mesh (<0.0625 mm) size fraction. Regional ice-flow direction is towards the west northwest as shown with the blue arrows.

Slide 13

Lead dispersal westward from the Clear Lake SEDEX deposit in central Yukon (inset) as defined in the <0.063 mm size fraction (Bond and Plouffe, 2003). Ice-flow direction is to the west as shown with the black arrow.

Slide 14

Gold dispersal train from the Wolf epithermal gold-silver prospect located in west central British Columbia (inset) (Levson, 2001). Ice-flow direction is to the northeast. Note in this case that the highest gold concentration in till occurs at some distance (> 4 km) from the mineralized zone.

Recent developments in our understanding of the ice-flow history

From these examples, it becomes clear that knowing the direction of ice movement is key for tracing the bedrock source of anomalous debris (e.g. indicator minerals or mineralized boulders) identified and geochemical anomalies in till.

Slide 15

Important findings regarding ice-flow histories have been achieved in the Canadian Cordillera in the last decade or so. Two examples which follow show that the migration of ice-divide and ice source regions greatly affected ice-flow directions during the last glaciation.

Slide 16

The first example if from west central British Columbia. At the onset of the last glaciation, an ice divide was above the Coast Mountains (panel 1**)**. Ice was flowing east and west from the ice divide, analogous to streams flowing in opposite direction from a drainage divide. At the glacial maximum, the ice divide migrated easterly onto the Interior Plateau (Stumpf et al., 2000; panel 2). During deglaciation, the ice divide returned to the Coast Mountains (panel 3). The implications are that there were major changes in ice-flow directions within the zone of ice divide migration (panel 4): (1) first to the east in the first phase of glaciation, (2) then to the west at glacial maximum, and lastly (3) to the east during ice retreat.

Slide 17

The ice-divide migration shown in plan in slide 16 has had important effect on glacial dispersal and the location of geochemical anomalies in the till stratigraphy. For example, at Huckleberry Mine, evidence of early-eastward, followed by westward, and late-eastward transport was found based on till geochemistry (Ferbey and Levson, 2009) and is schematically depicted in Ferbey et al. (2012).

Slide 18

The second example is from the Bonaparte Lake area (green rectangle) which is delimited on this broad compilation of the extent and ice-flow directions for the southern Cordilleran Ice Sheet (CIS). The Bonaparte Lake are is located south of an ice divide from which ice was generally flowing north and south.

Slide 19

The regional geomorphology of the Bonaparte Lake map area was first mapped and interpreted by Tipper (1971a, b, c). His map is shown in the background of this slide with drumlins and crag-and-tail, pitted terrain, meltwater corridors (green), eskers, moraines, and glacial lake sediments (blue polygon with black outline) in the Canim Lake (CL) area only. (The region underlain by glacial lake sediments should not to be confused with Canim Lake shown as a blue polygon with a dark blue outline.) From the available data, he demonstrated that glaciers first formed in the Cariboo Mountains (slide 18) at the onset of the glaciation and then were flowing generally to the south in the Bonaparte Lake map area, from an ice divide located to the north. The extent of glaciers and the amount of glacial transport from the first ice movement out of the Cariboo Mountains was not known. More recent field mapping by Plouffe et al. (2010; 2011c) indicated that the Cariboo Mountains glaciers reached the Lac la Hache (LlH) and Loon Lake (LL) regions in the western sector of the map area (red arrows). This regional westward flow was followed by progressively more southern ice movements (green and then blue arrows) resulting from the formation of the ice divide to the north of the map area.

Slide 20

The two-fold ice-flow history for the Bonaparte Lake map area has important implications for boulder tracing and the interpretation of till geochemistry. For example, terbium (Tb) concentrations are elevated in heavy mineral concentrates (HMC) from till samples collected in the vicinity of the larger felsic intrusions irrespective of their age (i.e.,. Takomkane, Raft, and Thuya batholiths; Plouffe et al., 2011c). There is evidence of westward glacial transport (first phase of ice flow) to the west of the Takomkane and Raft batholiths (red shaded zone) and southward transport (second phase of ice flow) south of the Raft and Thuya batholiths based on the dispersal patterns of Tb in the HMC.

Slide 21

The newly-discovered two-fold history of ice movement in the Bonaparte Lake map area had a practical application in the tracing of felsic, gold-rich, mineralized rhyolite boulders in the northeastern corner of the area (Plouffe et al., 2011b). Here, boulders overlay mafic phases of the Thuya Batholith (pink unit on slide; Schiarizza et al., 2002) which intruded strata of the mafic Nicola Group (shades of green and greenish-grey on slide; Schiarizza et al., 2002).

The search for the bedrock source of the boulders was originally conducted using a single, southeasterly ice-flow direction and a provenance envelope shown in yellow.

Slide 22

If the newly-identified two-stage ice-flow history for the Bonaparte Lake map area is taken into account (i.e., early movement of the boulders by the newly-discovered west-southwesterly ice flow (red arrow) and subsequent transport to the southeast by later glaciation (blue arrow), the potential exploration envelope (shown in yellow) extends to the east.

Unglaciated terrain in the Yukon

Slide 23

Parts of Yukon were not glaciated during the Pleistocene because of a lack of precipitation and snow accumulation. This map of Yukon shows the maximum extent of glaciers (shaded green area) at the Pleistocene glacial maximum. The dominant ice-flow directions are shown with arrows.

Slide 24

In unglaciated terrain, sediments observed at surface or in the near surface environment have not been transported by glaciers. In this example from the Lone Star property near Dawson City, the weathering product of a mafic dyke was transported downslope by colluvial processes. Such processes can occur on a slope gradient as low as 14°, as in this example. Consequently, colluvial processes, and the geochemical variability of distinct litho-colluvial units have to be taken into consideration when interpreting results of soil geochemical surveys conducted in the unglaciated part of the Yukon (Bond and Lipovsky, 2011).

Slide 25

In the unglaciated part of Yukon, permafrost processes are also present. On north-facing slopes, permafrost is likely present and accumulated organic matter is interstratified with weathered bedrock and loess as the material is reworked by solifluction processes (left hand photo: “cold”). On south-facing slopes, soil creep is the dominant transport mechanism and organic matter accumulation is minimal (right hand photo: “warm”). The absence of permafrost on south- facing slopes facilitates the sampling of surficial sediments via pits excavated by hand.

Work in progress

Slide 26

As part of the GSC’s Targeted Geoscience Initiative 4 (TGI 4; 2010-2015), drift prospecting methods are being developed for the search of porphyry mineralization buried by glacial sediments. Till samples will be collected near four study sites: Highland Valley, Gibraltar, and Mt Polley mines, and Woodjam developed prospect. Till samples will be submitted for geochemical analyses and indicator mineral processing. This research includes the sampling of outer tree bark from lodgepole pine and spruce, and twigs from cedar which will be submitted for biogeochemical analyses. Links between elemental enrichment in plant tissue, the underlying till and the presence of buried mineralization will be investigated (see Anderson et al., (2012a and b and in press) for more information).

Slide 27

Preliminary results of a survey completed near Gibraltar Mine as part of the GSC’s Mountain Pine Beetle Program show elevated copper concentrations in the clay-sized fraction of till near known mineralization (Plouffe et al., 2011a). Although limited spatially, sampling in this region suggests that copper dispersal from Gibraltar mine is of limited extent, probably less than 2 km. The limited detectable extent of this dispersal train could be related to the low-grade of the mineralization but also to the restricted area of mineralized source rock exposed to glacial erosion as explained in the following slides.

Slide 28

In this schematic representation of a glacial dispersal train, it is assumed that mineralization in bedrock (pink) is exposed to glacial erosion. This might not always be the case. For instance, the areal extent of mineralization exposed in open pit mines does not represent the size of the mineralized surface exposed to glacial erosion. The areal extent of mineralization exposed to glacial erosion affects the size and length of the glacial dispersal train in till. As well, work on characterizing potential porphyry indicator minerals associated with mineralization but at depth may have limited applicability to those found in glacial sediments which were eroded from higher-level parts of the porphyry system.

Two examples will be discussed where the lack of exposure of mineralization to glacial erosion might have limited glacial dispersal.

Slide 29

In this first example only an apophysis of an ore body (mineralization shown in pink) was exposed to glacial erosion (panels 1 and 2). This resulted in a limited dispersal train compared to the overall extent of the ore body (panel 3). In other words, in the current open pit mine the extent of exposed mineralization might be misleading and does not reflect the pre-glacial conditions (panel 4).

Slide 30

As an example, the glacial dispersal train at Gibraltar Mine is likely to be more representative of the smaller extent of the mineralized subcrop than the larger economic deposit defined by diamond drilling. In other words, the extent of exposed mineralization in the mine pit is not representative of the areal extent of mineralization exposed to glacial erosion.

Slide 31

A second example demonstrates the influence of pre-glacial sediments (or cover rock) on top of altered and mineralized bedrock. In this example, pre-glacial sediments (orange, yellow and blue) are in large part covering the ore body (pink; panel 1) and are protecting it from glacial erosion (panel 2). Again, the resulting dispersal train is limited in extent compared to the size of the economic deposit defined by diamond drilling (panel 3) and the extent of mineralization exposed in the current open pit mine is not representative of pre-glacial conditions (panel 4).

Slide 32

This scenario is applicable to the Valley Pit at the Highland Valley Mine where some mineralization is covered by pre-glacial sediments (Bobrowsky et al., 1993).

Slide 33

A principal objective of this TGI4 project is to identify and characterise the near surface expression of hidden porphyry mineralization via the geochemical composition of till and tree bark. This surface expression will be further characterised through the use of porphyry indicator minerals (PIM) from the HMC obtained from till.

At the scale of sampling in this study (approximately 1 sample per kilometre along accessible roads), it is more likely that the larger components of porphyry systems will be identified. If we consider the classic porphyry model of Lowell and Guilbert (1970), the propyllitic alteration “footprint” of a typical calc-alkaline porphyry system presents a larger exploration target that is more likely to be identified in our sampling than the areally smaller, inner phyllic, argillic and potassic alteration zones.

Slide 34

Furthermore, given the geological constraints on the source area described above, compared to ore or other minerals from other alteration zones, epidote associated with the propyllitic alteration zone is more likely to be captured as an HMC, is less susceptible to destruction during glacial transport and is more available to the glaciers given its location in the upper part of the porphyry system.

Slide 35

Our work on PIM will complement the research by the Mineral Deposit Research Unit at the University of British Columbia (e.g. Bouzari et al., 2010; 2011a, b) on apatite and other indicator minerals derived from porphyry mineralization.

Conclusion

Slide 36

From the few examples provided in this presentation and from numerous published studies on glacial dispersal of mineralization in the Canadian Cordillera (e.g., Bobrowsky et al., 1995; McClenaghan et al., 2001; Paulen and McMartin, 2009), drift prospecting is a valuable tool for mineral exploration in the Canadian Cordillera. The success of such an exploration methods relies on a detailed understanding of ice-flow directions which may have varied within a single glaciation. In the unglaciated terrain of Yukon, a clear understanding of colluvial and permafrost processes, as opposed to glacial processes, is required for the tracing of mineralized material identified in the near-surface environment. Current research in the field of drift prospecting includes the identification of the best tracers in till: 1) geochemical analyses of specific size fractions of the till matrix and 2) the identification and characterization of porphyry indicator minerals in the sand sized fraction of till.

Acknowledgements

The authors would like to thank R.G. Anderson, D. McDonald and J. Morganti for the invitation and opportunity to present this talk in the special session on the Canadian Cordillera at the Prospectors and Developers Association of Canada Conference in March 2012. The in-progress research presented in this report (slides 26 to 34) is part of the GSC’s TGI 4 Program. This research would not have been possible without the support from the TGI4 personnel and the following exploration and mining companies: Taseko Mines Limited, Fjordland Exploration Inc. (now Consolidated Woodjam Copper), Gold Fields Canada Exploration, and Teck Resources Limited. The original manuscript greatly benefited from the internal GSC review completed by R.G. Anderson. A.J. Stumpf kindly provided the maps shown in slide 16. Yukon Geological Survey contribution 15.

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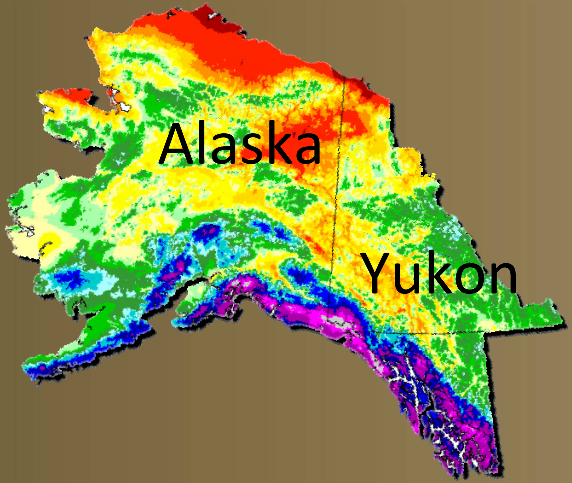
TGI 4 Ore Systems

Glacial history and drift prospecting in the Canadian Cordillera: recent developments

A. Plouffe, T. Ferbey, V.M. Levson, and J.D. Bond

Geological Survey of Canada, Ottawa, ON
British Columbia Geological Survey, Victoria, BC
Quaternary Geosciences Inc., Victoria, BC
Yukon Geological Survey, Whitehorse, YT

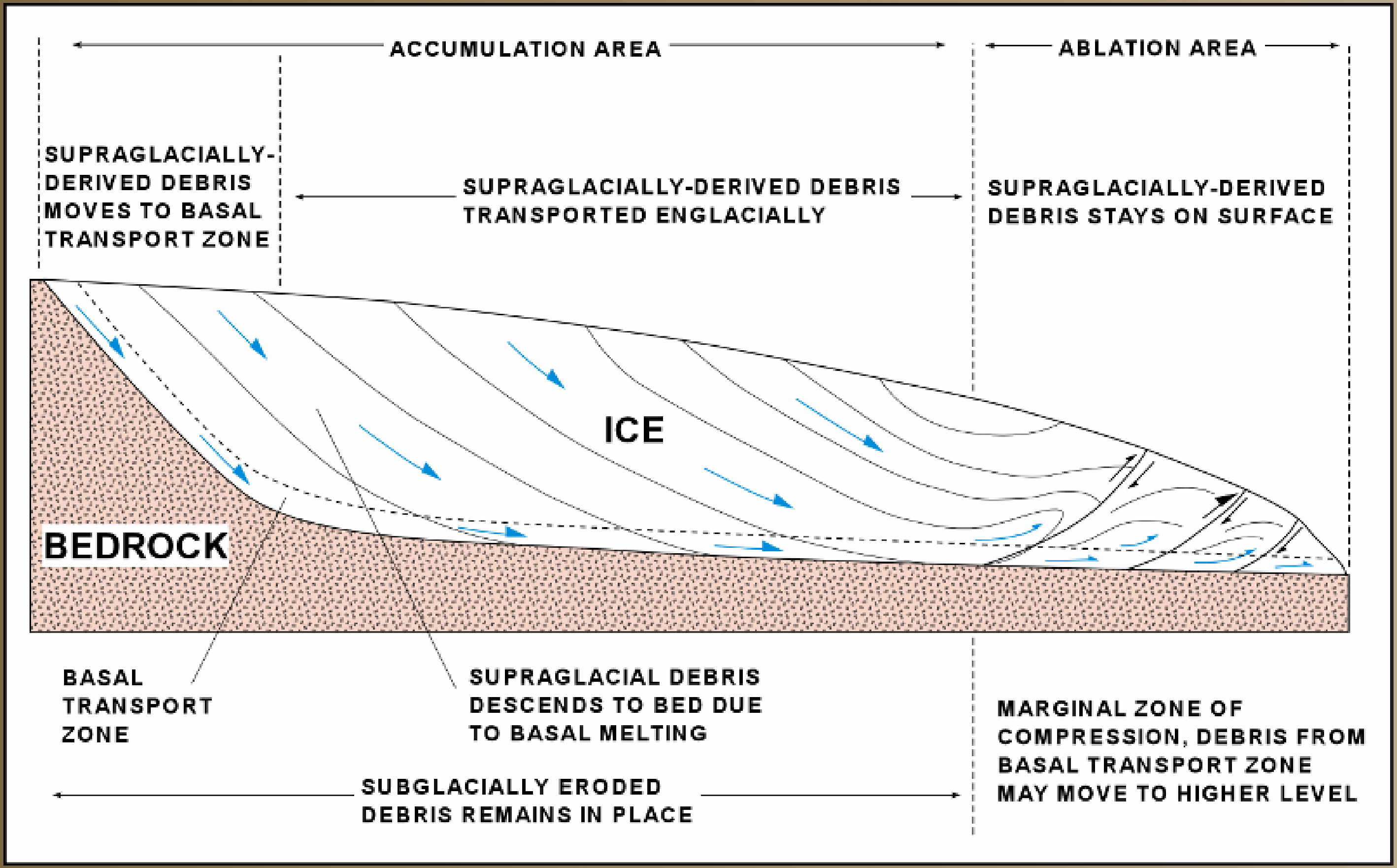
Canada



Spatial Climate Analysis Service, Oregon State University Copyright 2000

Most of Canada covered by glaciers during the last glaciation except for west central and northern Yukon because of the lack of precipitation: regions in yellow and red above

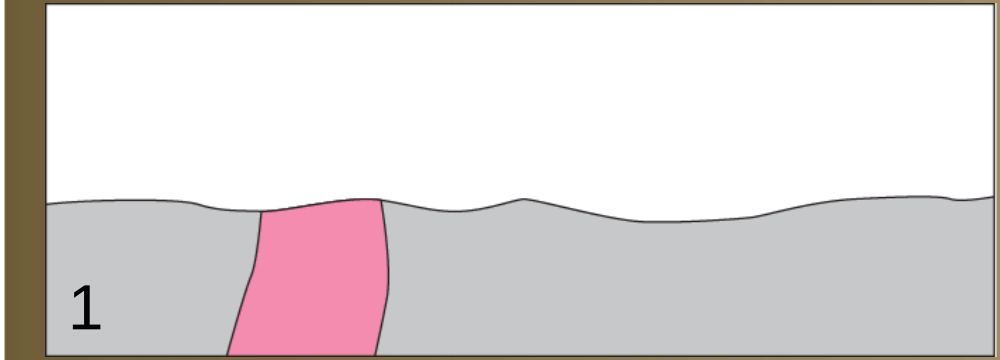
Profile of a glacier



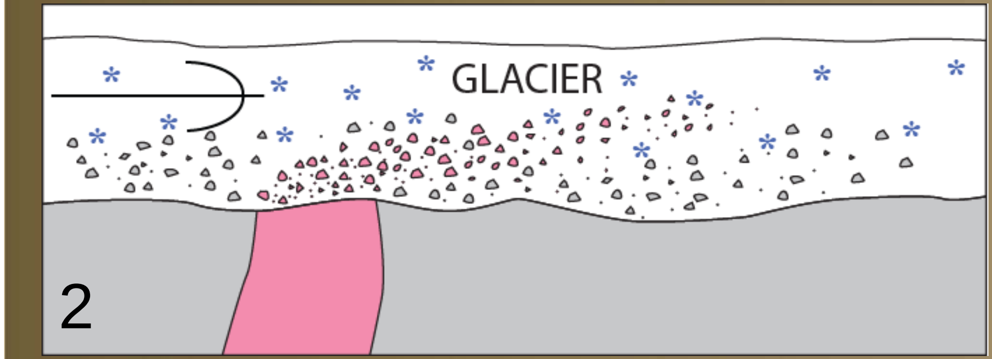
Boulton (1996)

Basic components of a valley glacier: ice is moving forward even during glacier retreat creating the “conveyor belt effect” of debris transport in a down-ice direction.

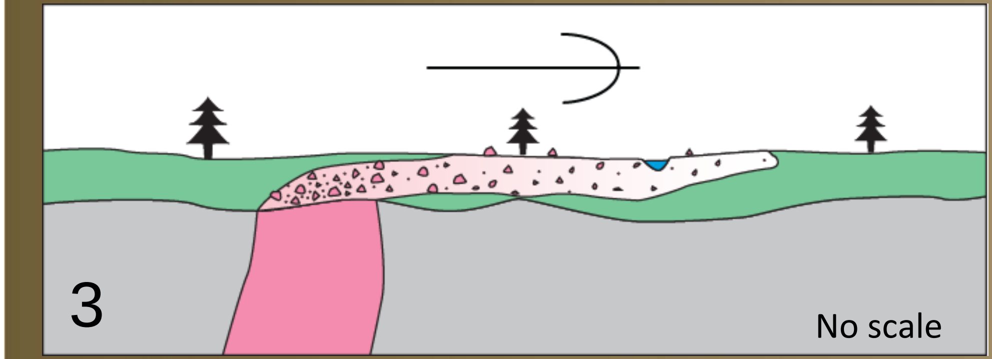
Glacial transport: dispersal train



Mineralized zone (in pink) exposed at surface prior to a glaciation



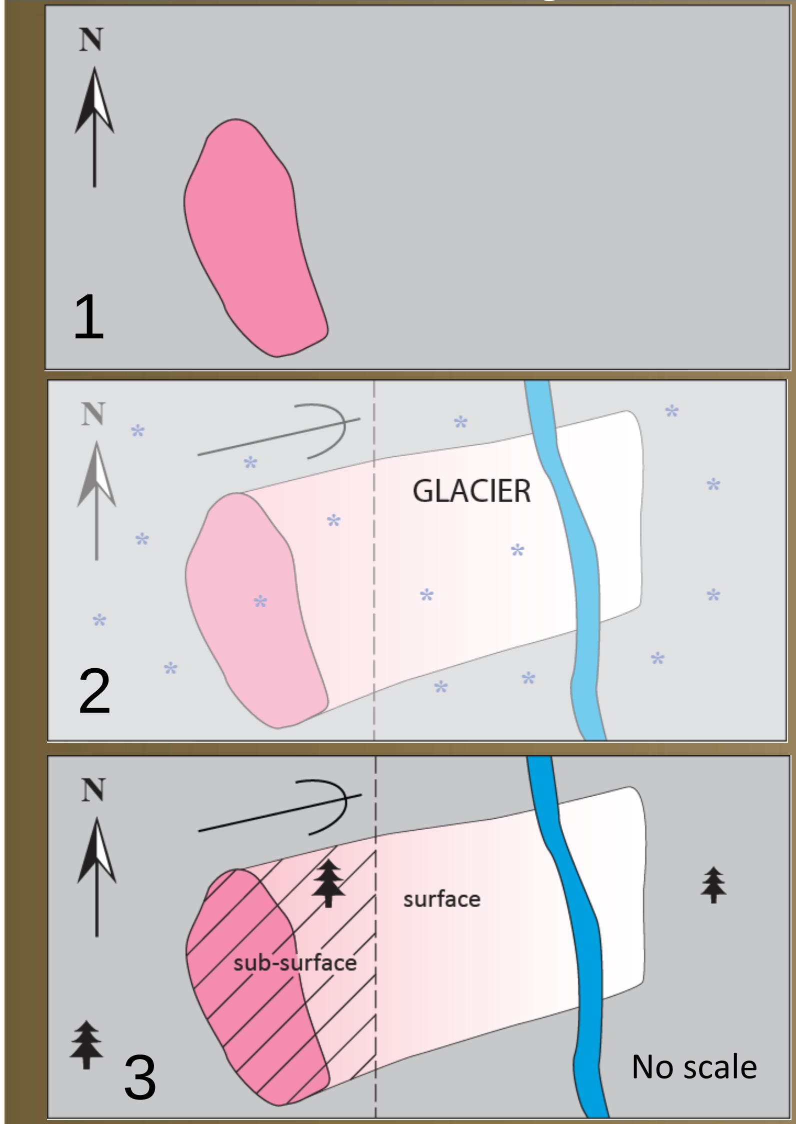
Mineralized zone eroded by a glacier during a glaciation and mineralized debris transported in the direction of glacier flow (down-ice direction)



After glaciation, resulting glacial dispersal train (pink zone) in till (green); no scale on this diagram; scale of dispersal train depends on numerous factors: size of mineralized zone, contrast between mineralized zone and host rock, till thickness, topography and position of source rock, etc.

Modified from Drake (1983), Miller (1984), McClenaghan and Kjarsgaard (2007)

Glacial transport: dispersal train



Same as previous figure but in plan view; mineralized zone exposed at surface prior to a glaciation

Mineralized zone eroded by a glacier during a glaciation and mineralized debris transported in the direction of glacier flow (down-ice direction)

After glaciation, resulting glacial dispersal train (pink zone) is in the sub-surface close to the source and at surface at some distance; as previous diagram, no scale; debris from the dispersal train can be reworked by streams affecting stream sediment composition

Modified from Drake (1983), Miller (1984), McClenaghan and Kjarsgaard (2007)

Mineral discoveries

Mineral discoveries were made at the following example sites with the help of drift prospecting or soil geochemistry derived from till:

YUKON

- Spice Claims (Bond and Plouffe 2002; YEG)
- East Detour Gold anomaly (Bond and Plouffe 2003; YEG)
- Big Salmon Fault gold anomaly (Bond and Plouffe 2003; YEG)

BRITISH COLUMBIA:

- Equity Silver (Sam Goosly) (Ney et al. 1972, CIM Bulletin)
- Potential Cu mineralization north of known mineralization at Huckleberry Mine (Ferbey and Levson 2009; GAC Short Course Notes 18)

Mineral discoveries (cont’d):

BRITISH COLUMBIA:

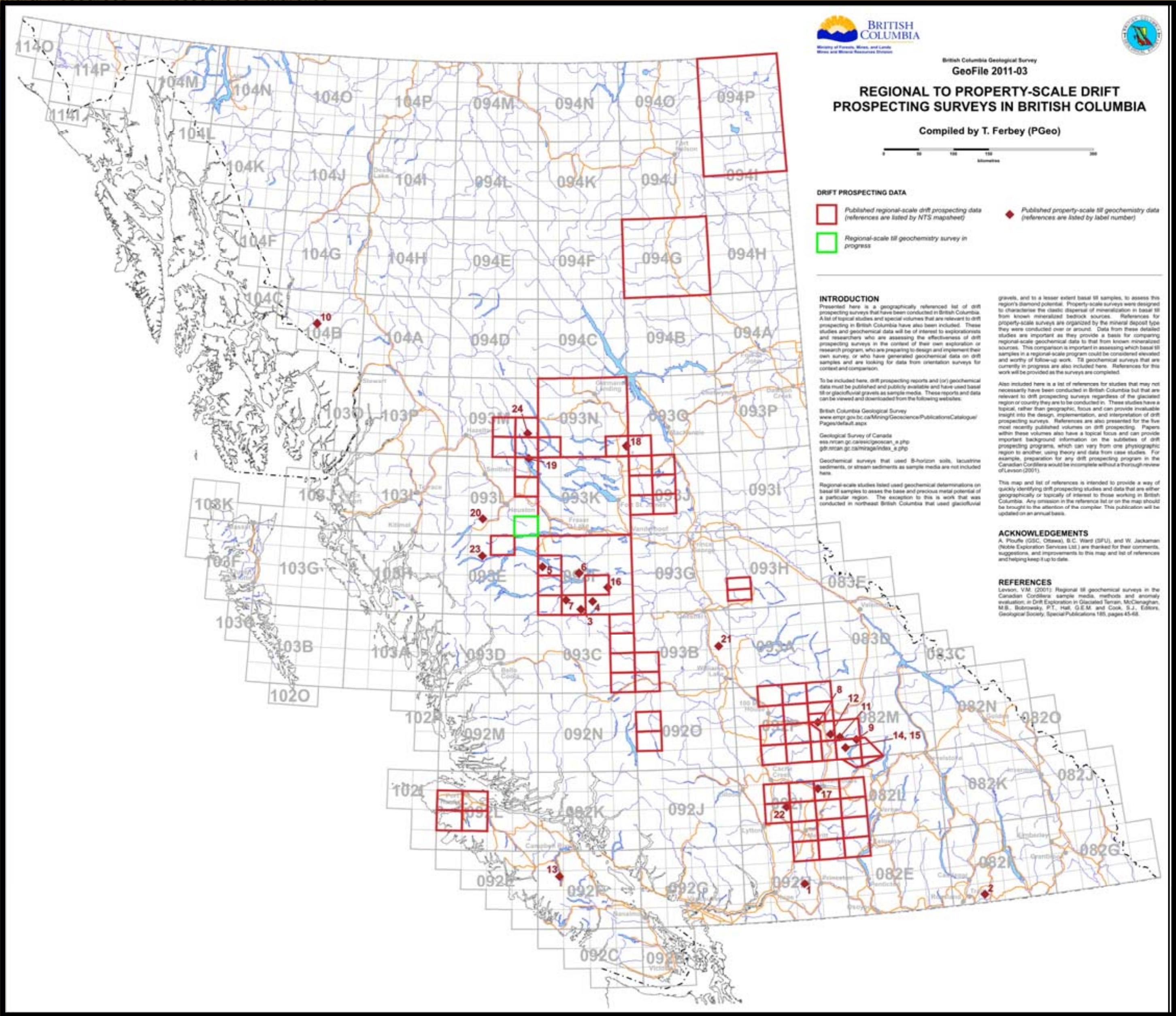
- Boulder tracing of gold mineralization (Plouffe et al. 2011; CJES)
- Evidence of subglacial mineralization in the region of Windy Craggy (Day et al. 1987; CJES)
- Chappell Gold Silver deposit (Barr 1978; CIMM Bulletin)
- Sullivan Mine (Burchett 1944; Western Miner)
- Island Copper Deposit, Vancouver Island (Witherly 1979)
- 3Ts and Cigar anomalies (Levson et al. 1994; Levson, 2001; Cook et al., 1995)
- Red Sky property (Ferbey, 2010)

Natural Resources Canada Ressources naturelles Canada

Regional and property scale surveys: Yukon

Sites where regional and property scale drift prospecting surveys have been conducted in the Yukon

Canada



British Columbia Geological Survey
GeoFile 2011-03

REGIONAL TO PROPERTY-SCALE DRIFT PROSPECTING SURVEYS IN BRITISH COLUMBIA

Compiled by T. Ferbey (PGeo)

DRIFT PROSPECTING DATA

- 🟥 *Published regional-scale drift prospecting data (references are listed by NTS mapsheet)*
- ◆ *Published property-scale till geochemistry data (references are listed by label number)*
- 🟩 *Regional-scale till geochemistry survey in progress*

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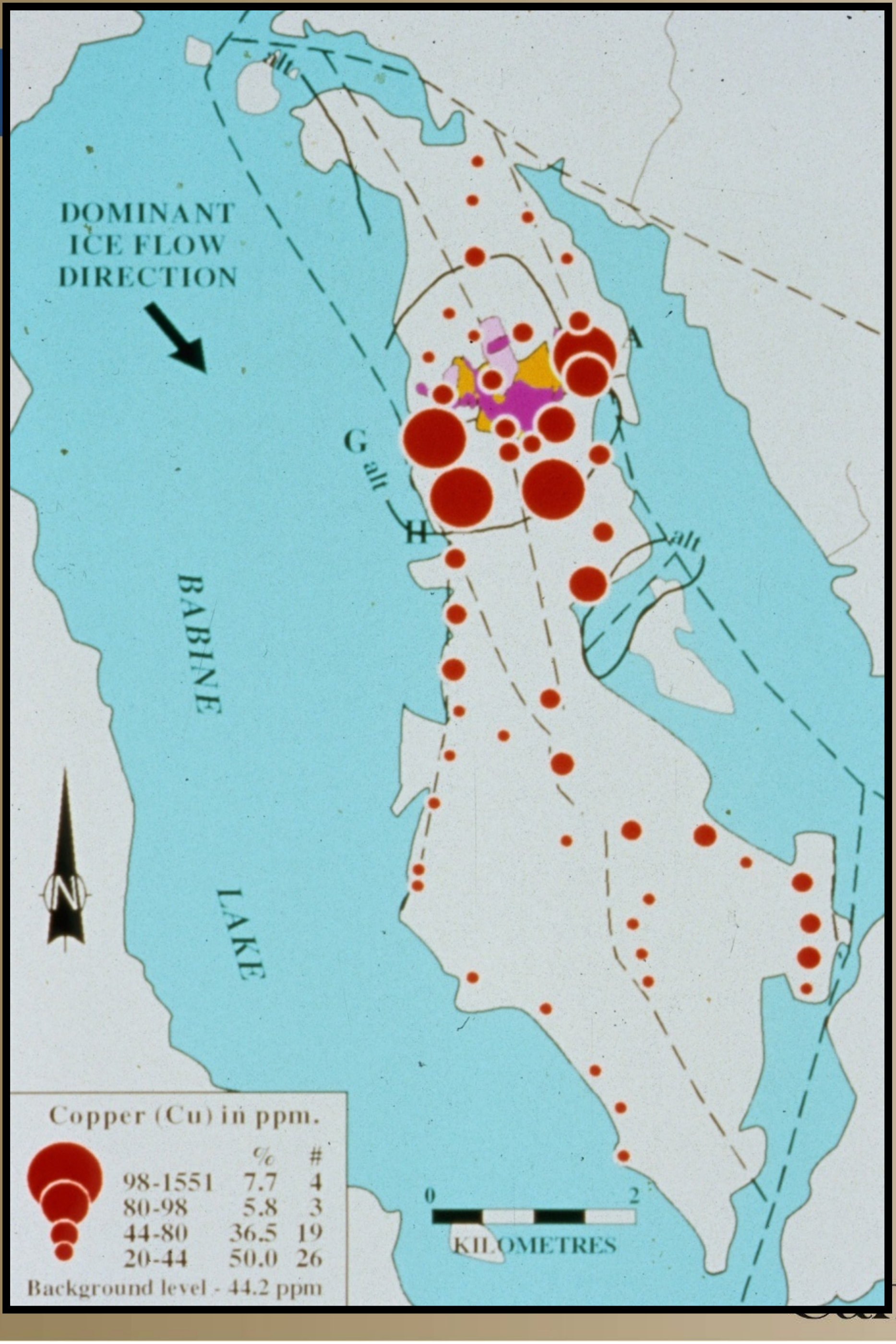
Ferbey (2011)

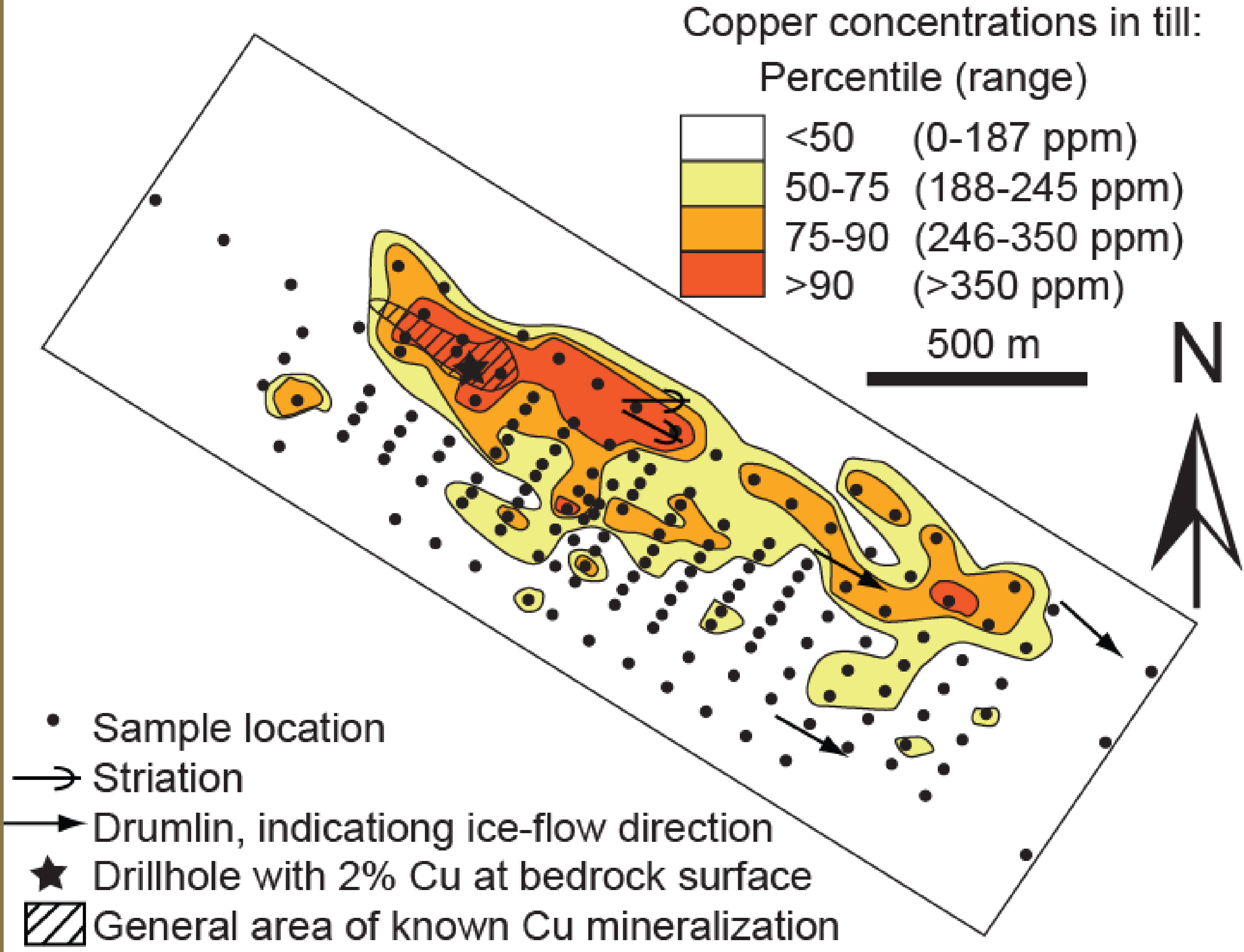
Canada

Bell Mine: Babine Lake



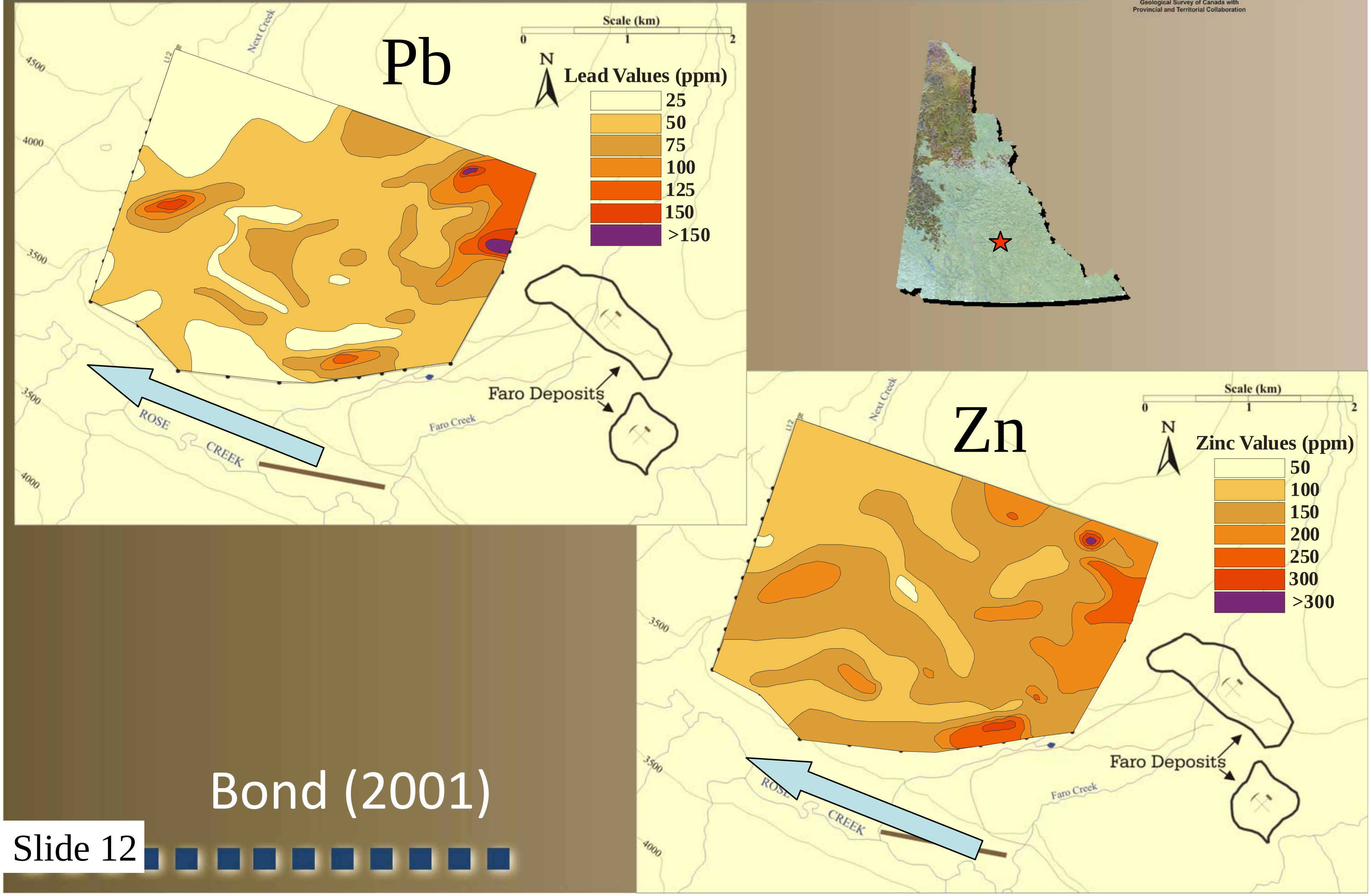
Levson (2002)

Galaxy: porphyry Cu-Au



Kerr et al. 1993; Levson, 2001; Lett, 2011

Anvil SEDEX deposit



Bond (2001)

Clear Lake: SEDEX

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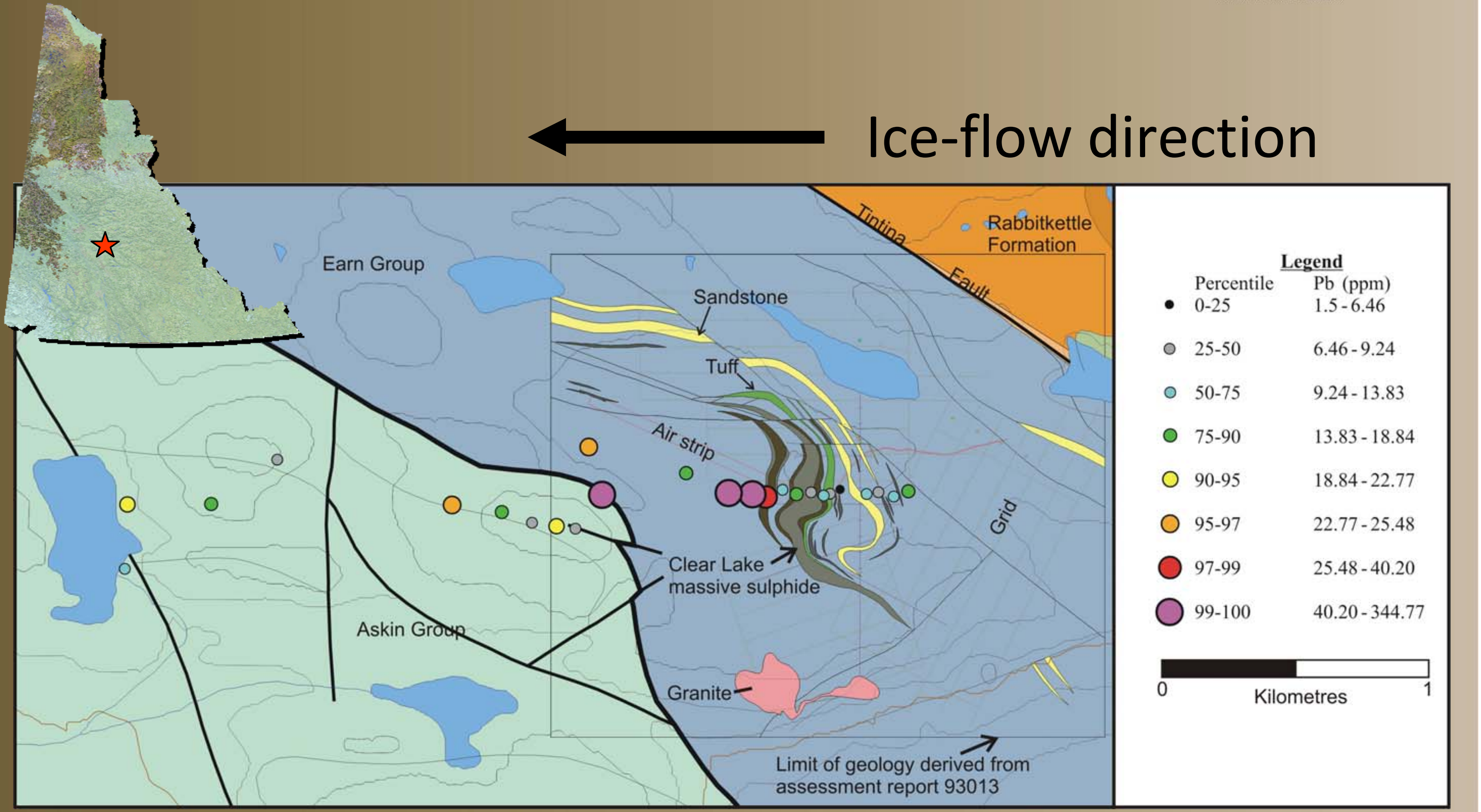
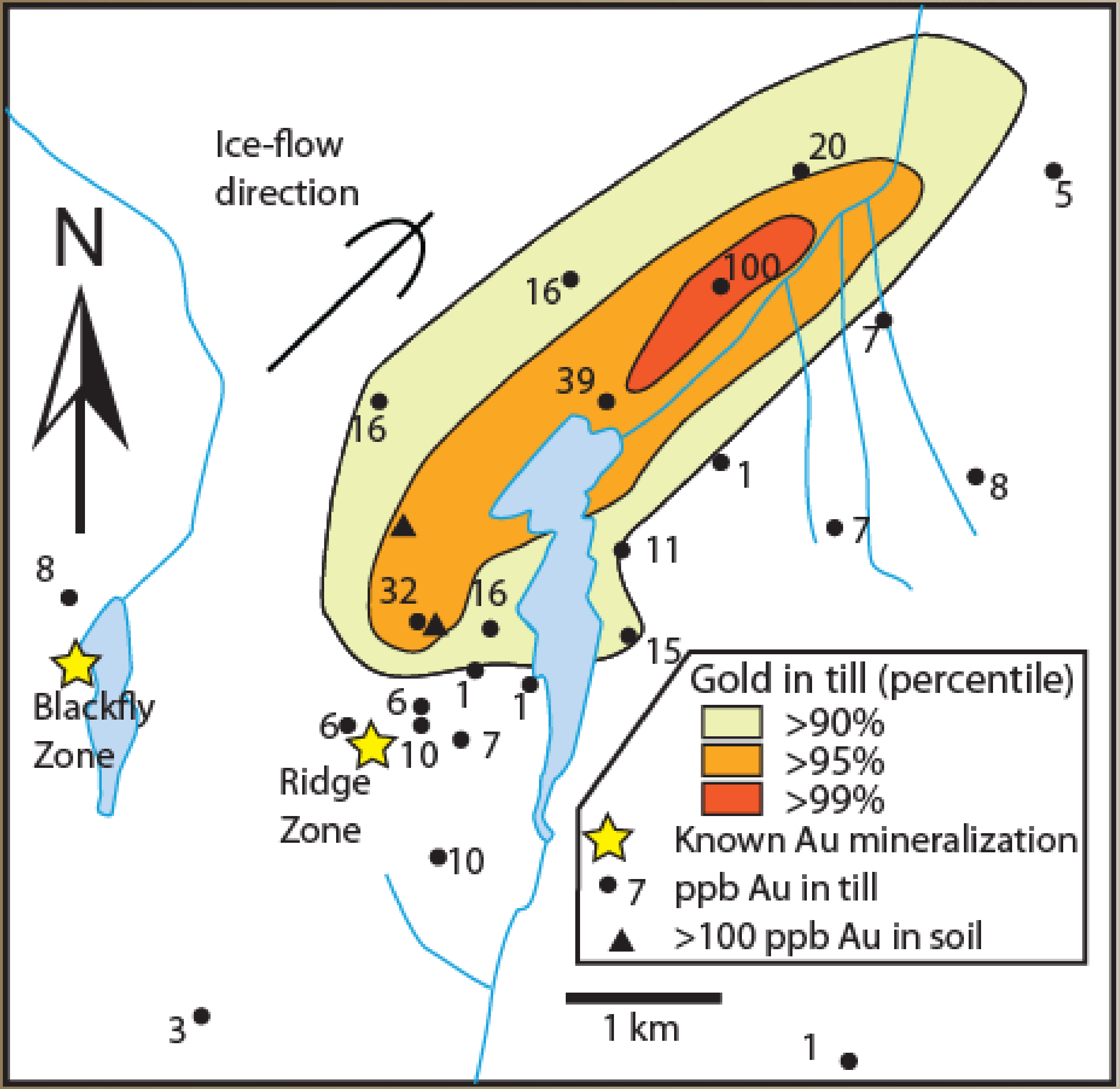
TGI 4 Ore Systems

Ice-flow direction



Bond and Plouffe (2003)

Wolf: epithermal Au-Ag



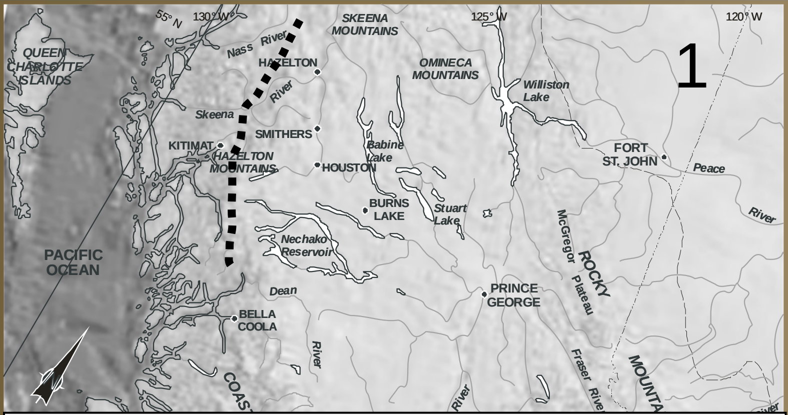
Levson, 2001

Recent developments

Migration of an ice-divide

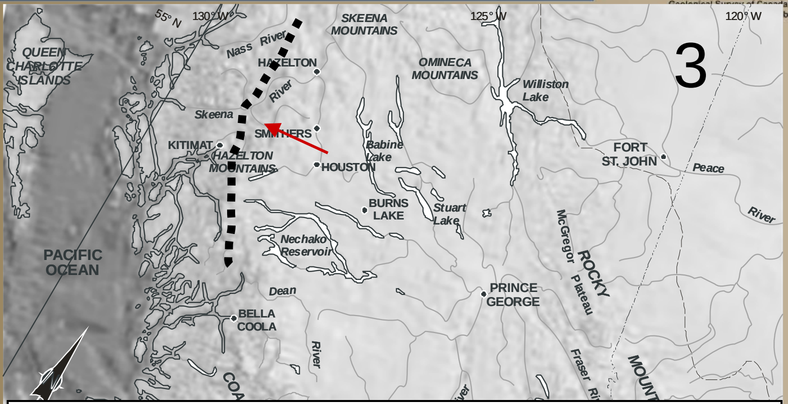
Migration of ice source regions

Glacial transport: the effect of ice divides

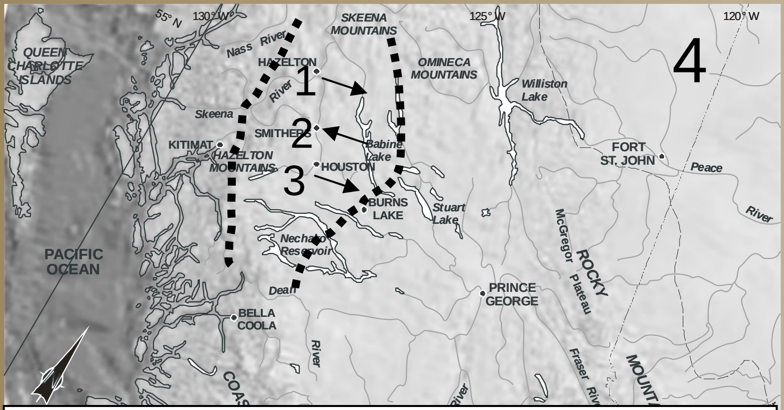


Ice divide (dotted line) above the Coast Mountains at the onset of the last glaciation

Migration of ice divide (dotted line) easterly (red arrow) above the Interior Plateau at glacial maximum



Ice divide (dotted line) migrated westerly (red arrow) during deglaciation.

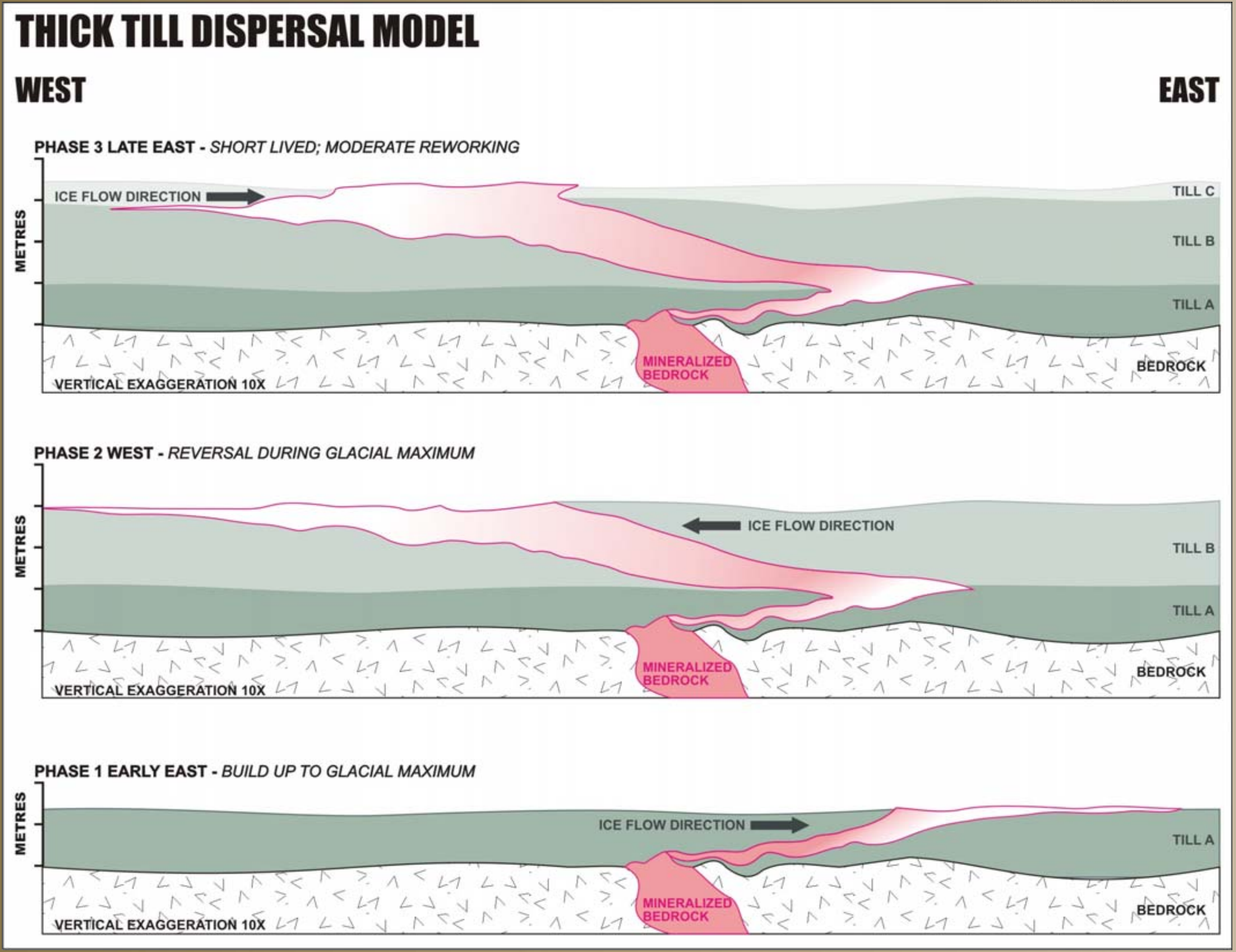


Major changes in ice-flow direction within the zone of ice divide migration

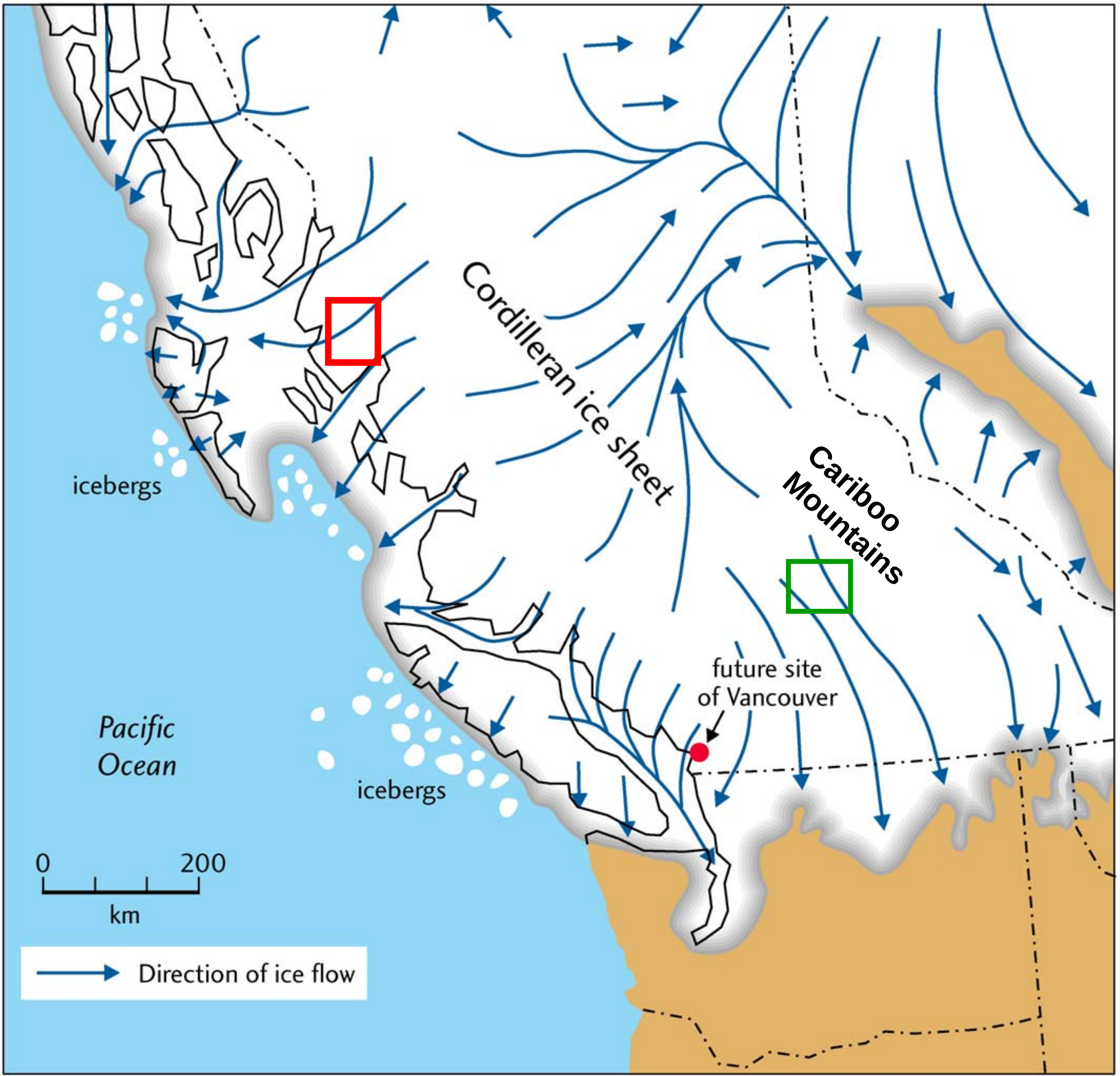
Stumpf et al. (2000)

Migration of ice-divide: impact on glacial dispersal

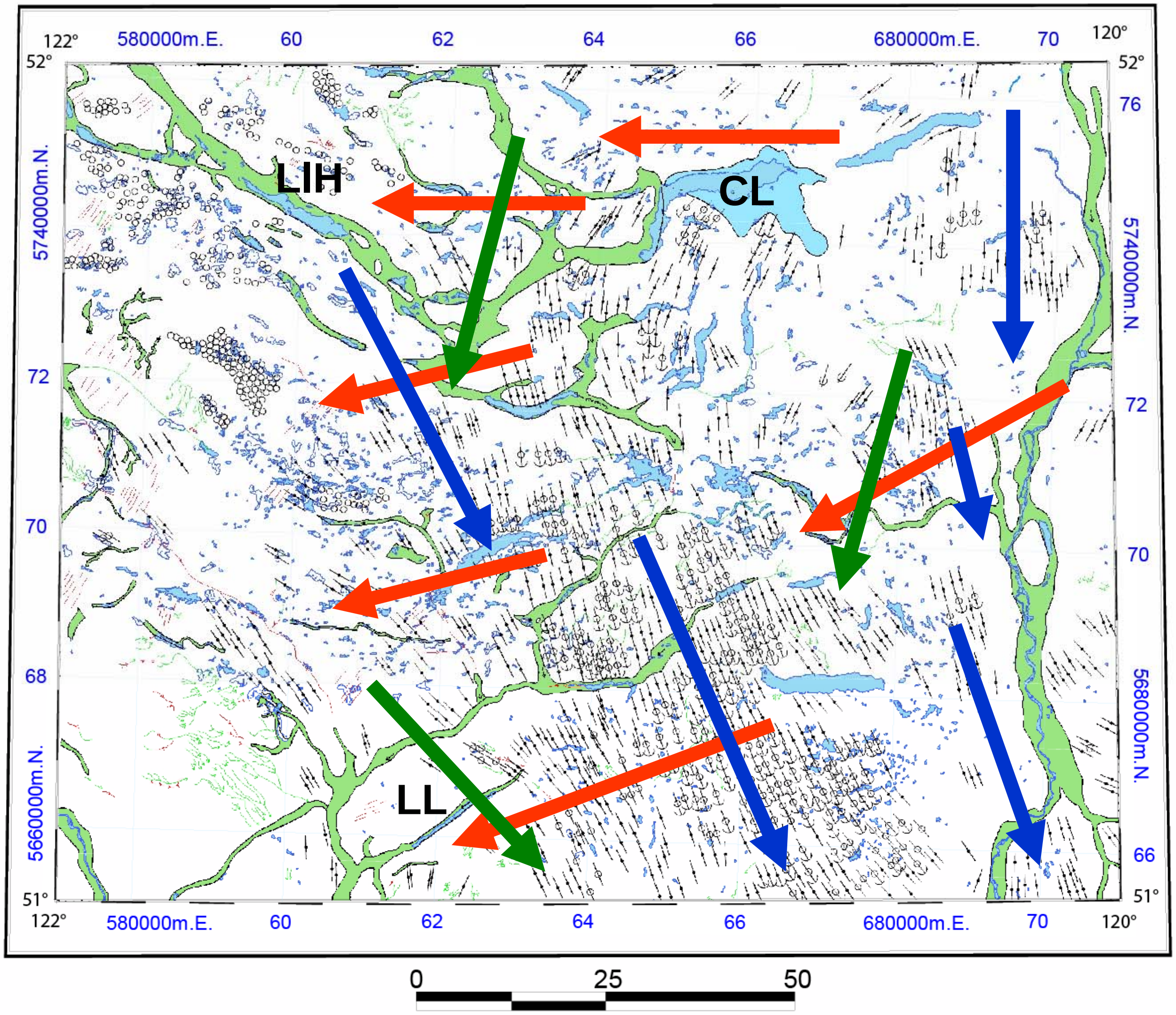
Based on dispersal at Huckleberry Mine



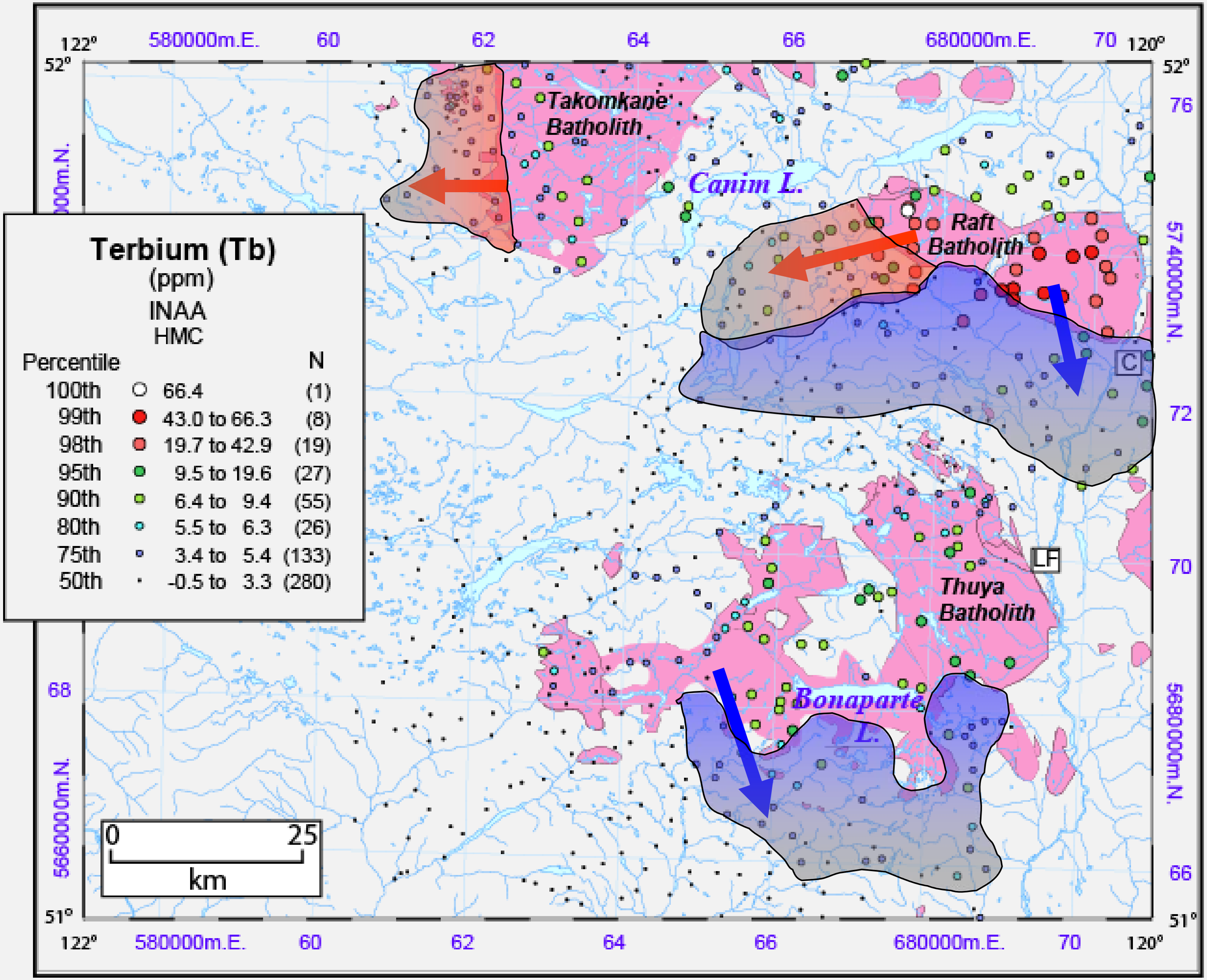
Ferbey et al. (2012; BCGS Open File 2012-02)


Cordilleran ice sheet
Cariboo Mountains
future site of Vancouver
icebergs
icebergs
Pacific Ocean
0
200
km
Direction of ice flow

Ice-flow history: south central British Columbia



(Plouffe et al., 2011, CJES)

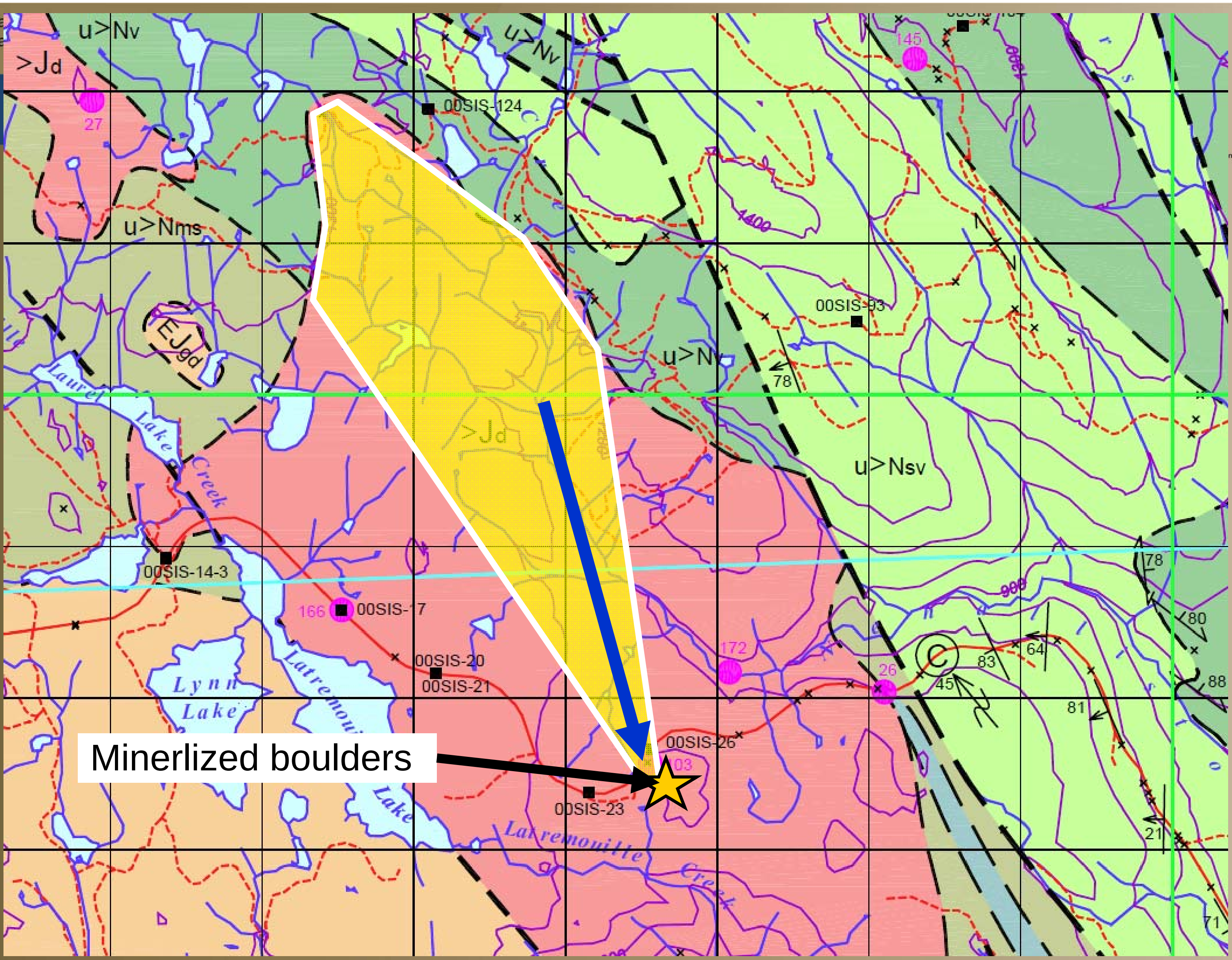


Terbium (Tb)
(ppm)
INAA
HMC

Percentile			N
100th	○	66.4	(1)
99th	🔴	43.0 to 66.3	(8)
98th	●	19.7 to 42.9	(19)
95th	🟢	9.5 to 19.6	(27)
90th	●	6.4 to 9.4	(55)
80th	●	5.5 to 6.3	(26)
75th	•	3.4 to 5.4	(133)
50th	·	-0.5 to 3.3	(280)

(Plouffe et al., 2011, CJES)

TGI 4
Ore Systems



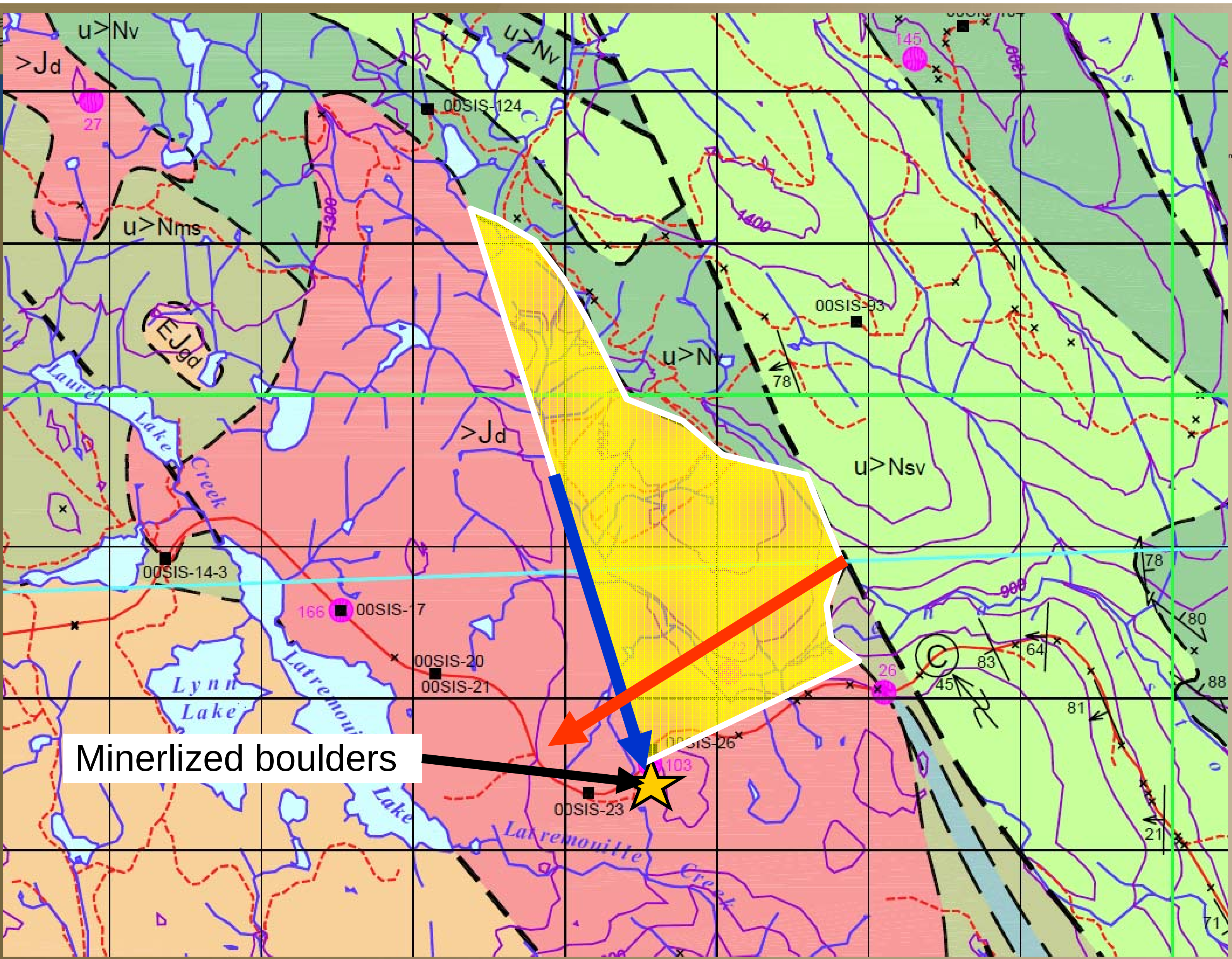
Minerlized boulders

(Schiarizza et al. 2002; Plouffe et al. 2011a)

SCALE 1:50 000

0 1 2 3 4 5

Kilometres



Minerlized boulders

(Schiarizza et al. 2002; Plouffe et al. 2011a)

SCALE 1:50 000

0 1 2 3 4 5

Kilometres

Unglaciated terrain: Yukon

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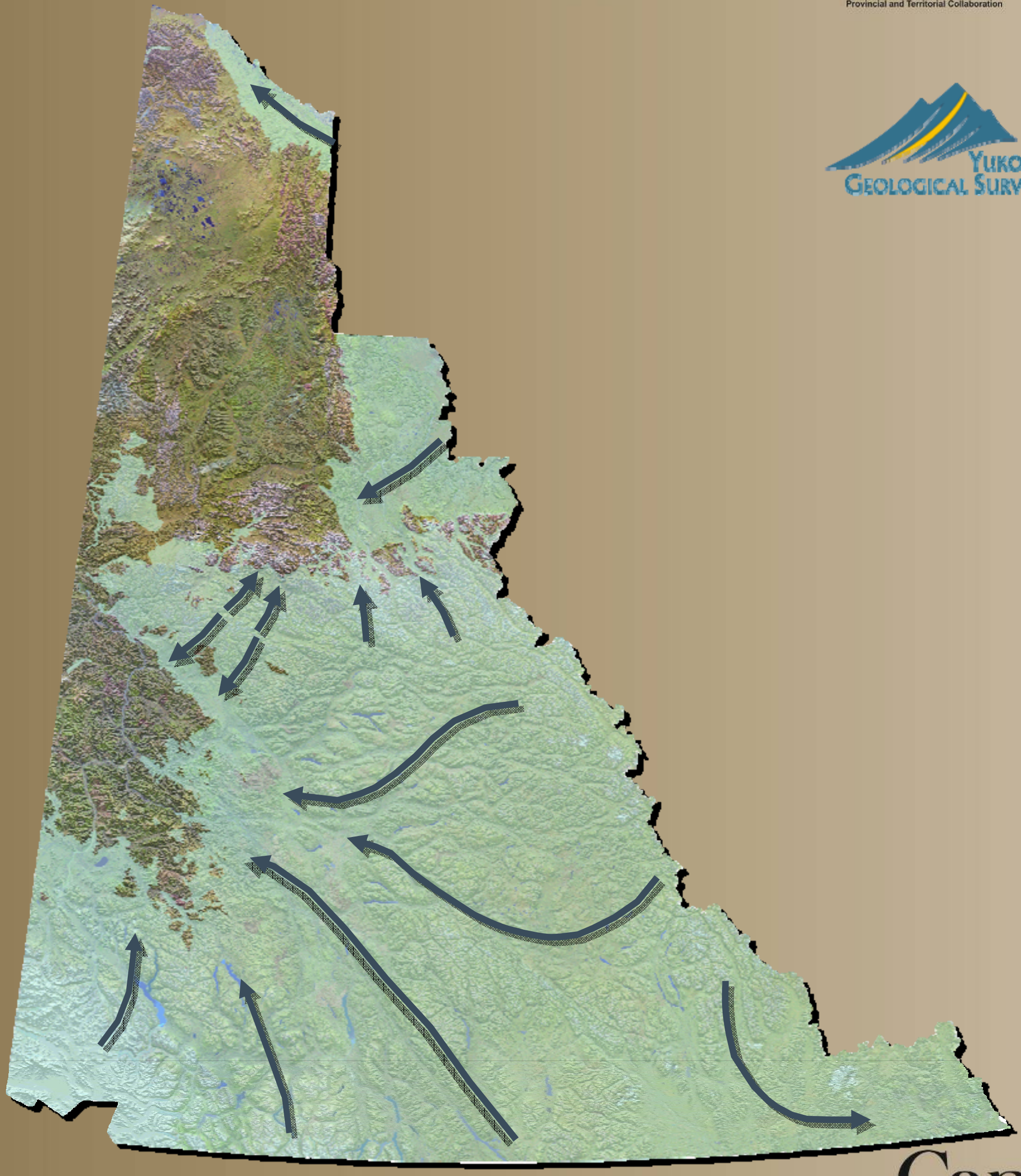
TGI 4 Ore Systems

Yukon Geological Survey

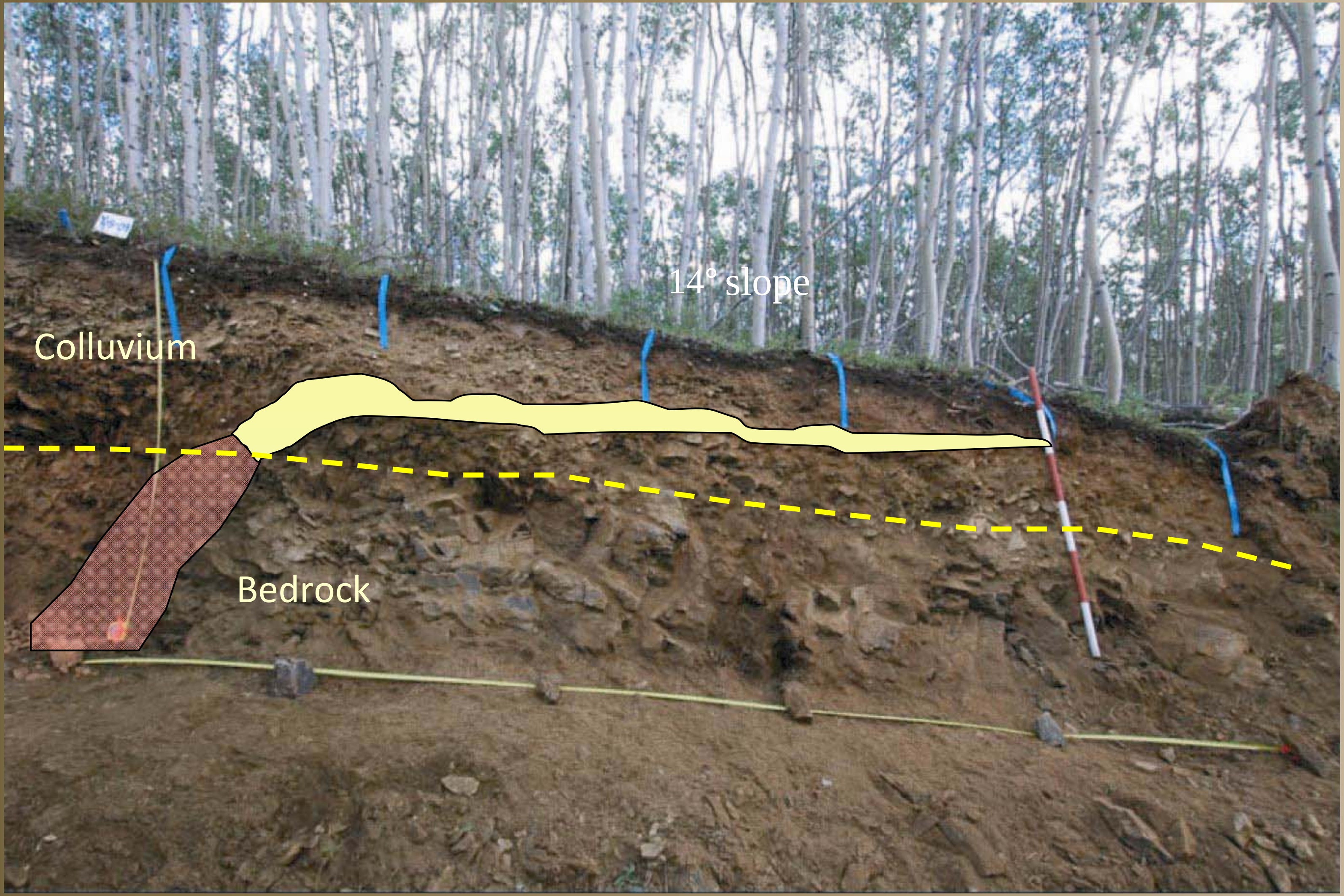
J.D. Bond

Yukon Geological

Survey

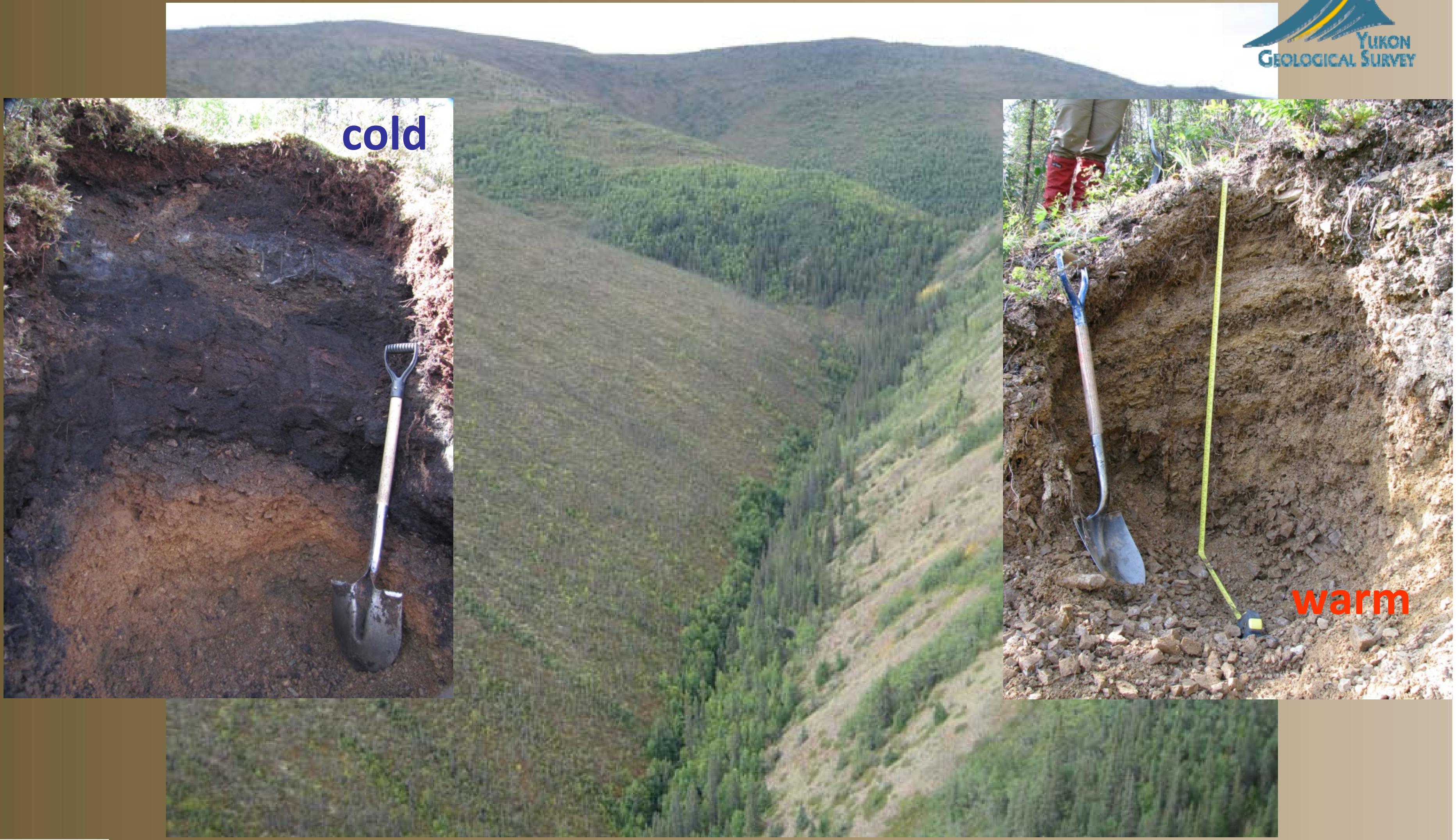


Colluvial process on warm aspect slopes



(J.D. Bond, YGS)

Slope aspect soil contrasts



(J.D. Bond, YGS)

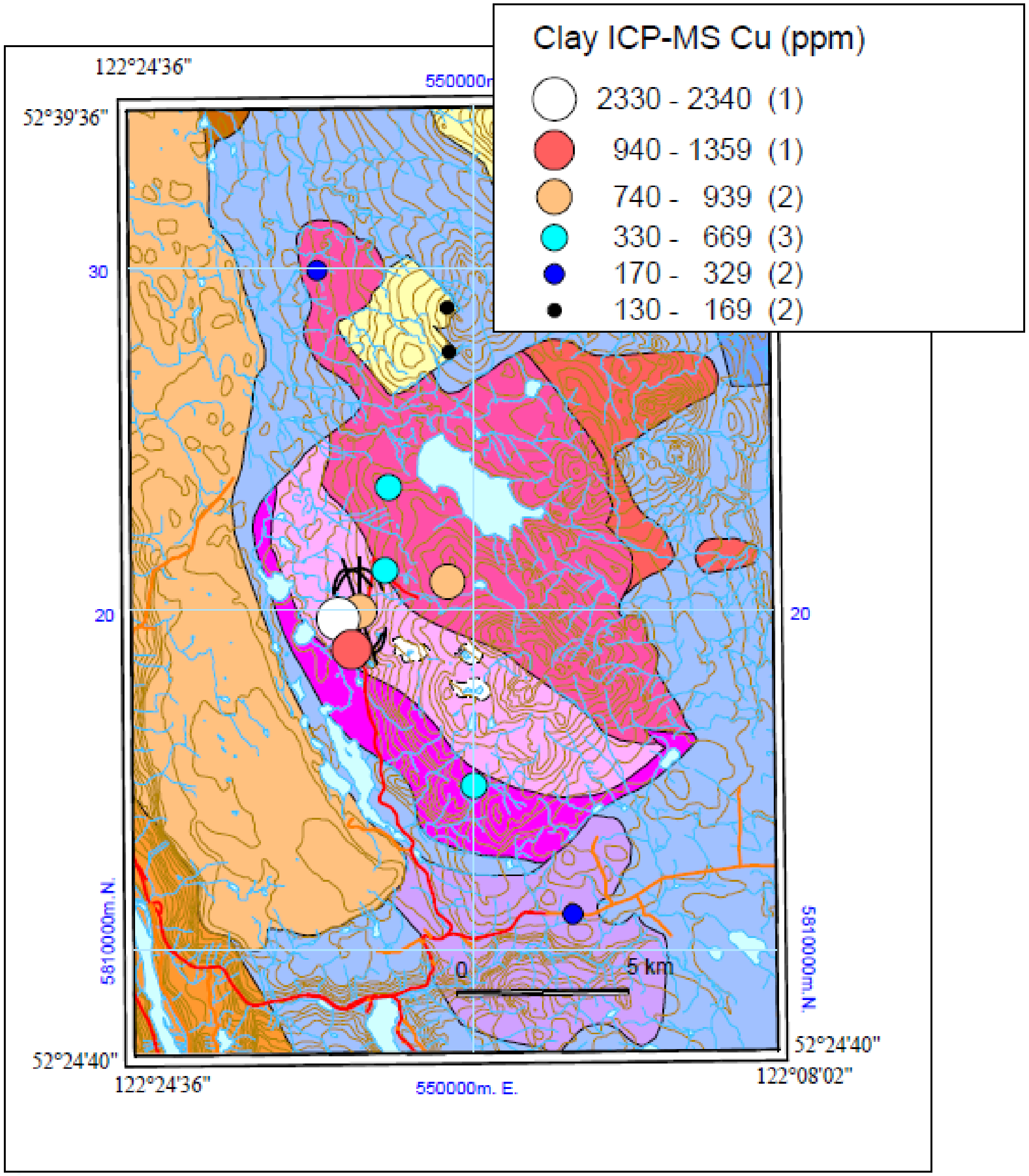
Photo by Robin McKillop

Work in progress: TGI-4

- Till composition near porphyry mineralization: geochemistry and mineralogy
- What geochemical signal is present in trees
- Objective: detect buried mineralization

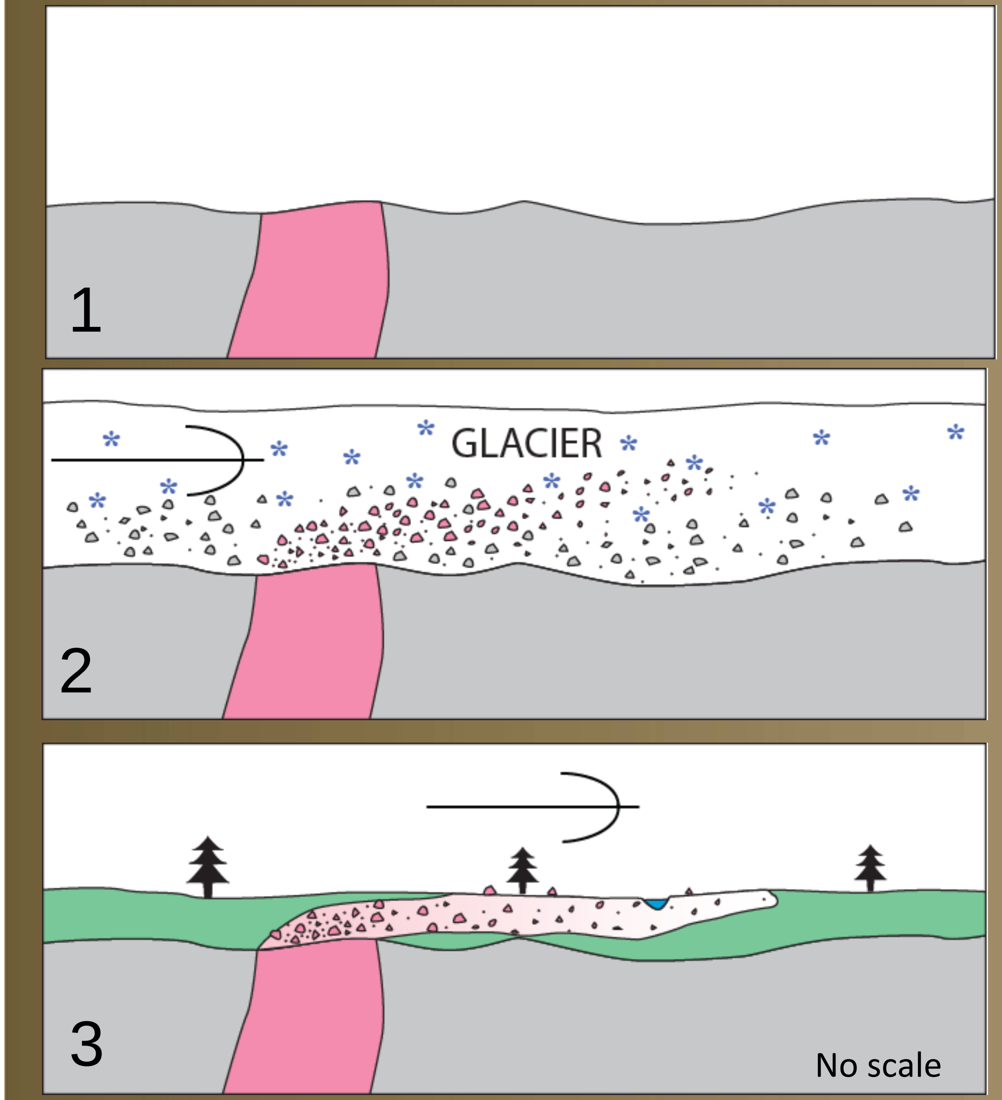
Gibraltar Mine

Preliminary results



Plouffe et al (2011)

Glacial transport: dispersal train



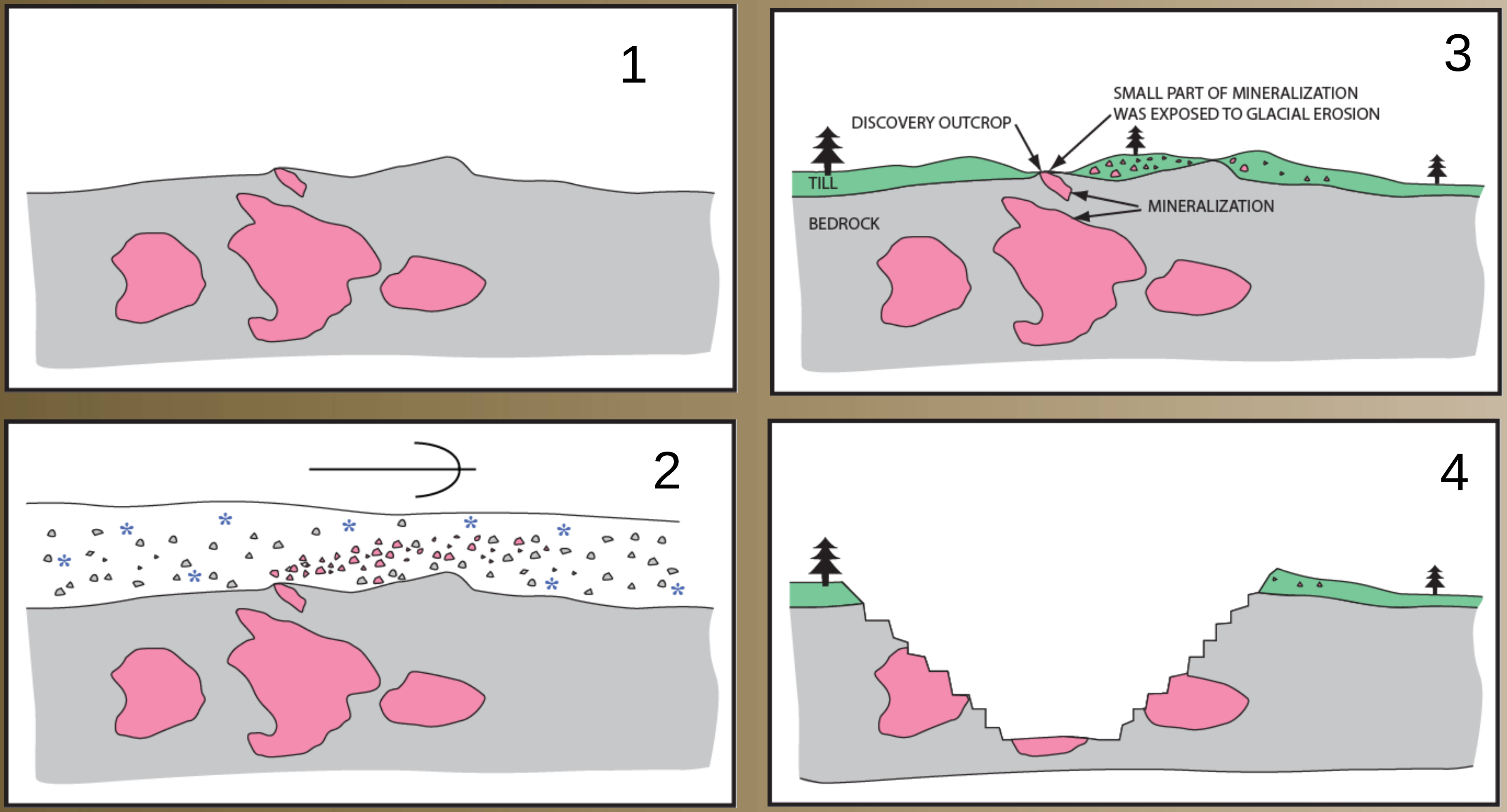
Mineralized zone (in pink) exposed at surface prior to a glaciation

Mineralized zone eroded by a glacier during a glaciation and mineralized debris transported in the direction of glacier flow (down-ice direction)

After glaciation, resulting glacial dispersal train (pink zone) in till (green); no scale on this diagram; scale of dispersal train depends on numerous factors: size of mineralized zone, contrast between mineralized zone and host rock, till thickness, topography and position of source rock, etc.

Modified from Drake (1983), Miller (1984), McClenaghan and Kjarsgaard (2007)

Glacial Processes – Source area and dispersal; present *NOT* the key to the past?

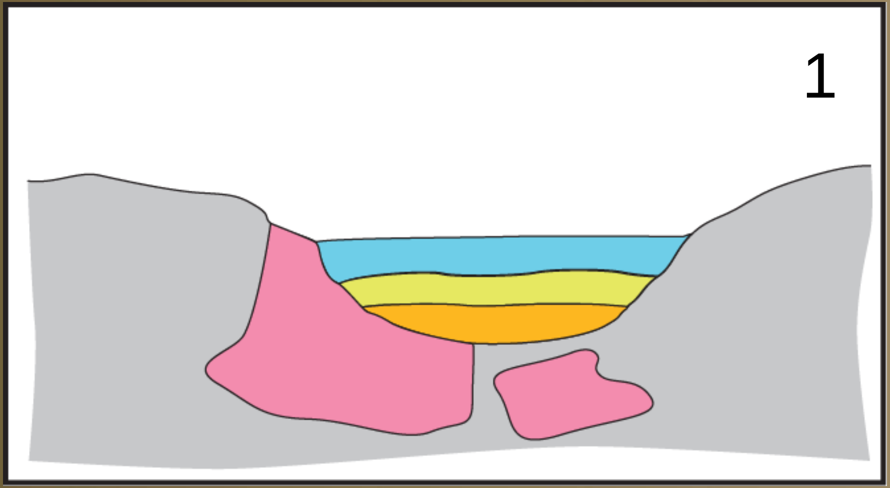


e.g. Gibraltar Mine

Gibraltar Pit: Gibraltar Mine

Glacial Processes – Source area and dispersal; present *NOT* the key to the past?

1



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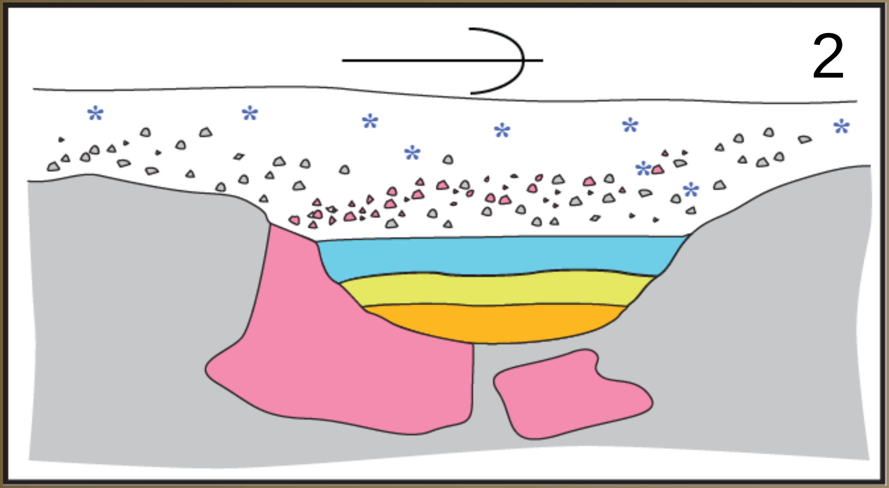

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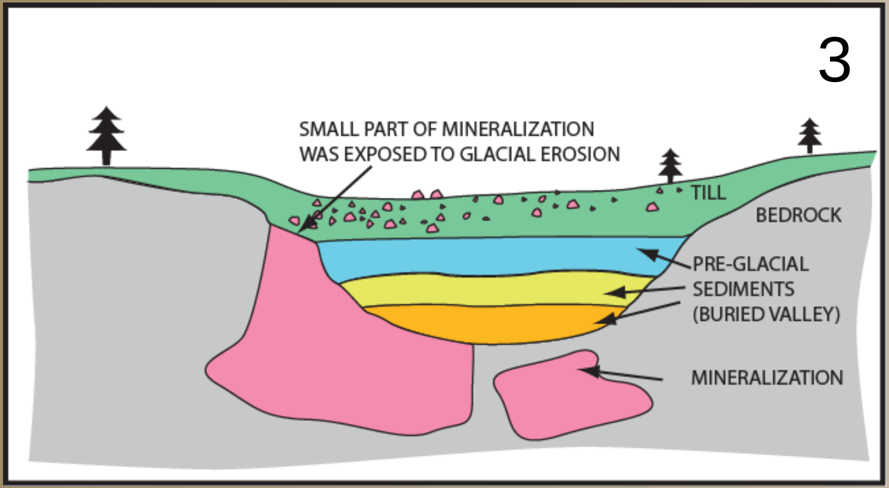

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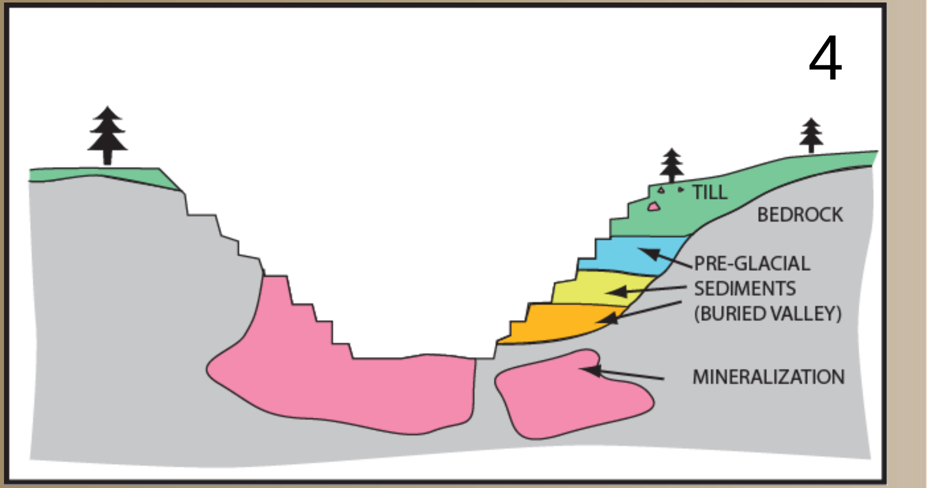
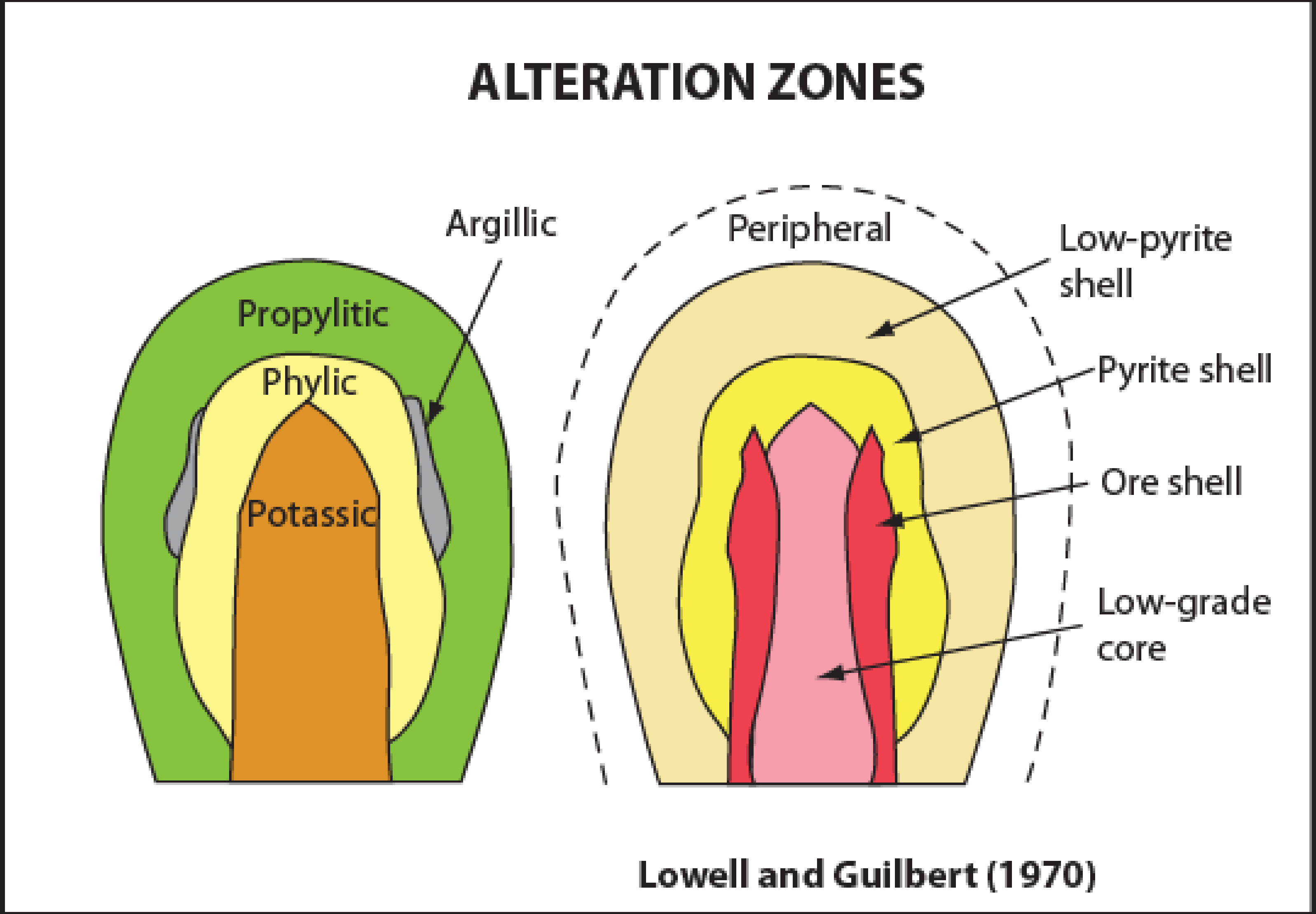


e.g. Highland Valley Mine

Valley Pit: Highland Valley Mine; July 2011

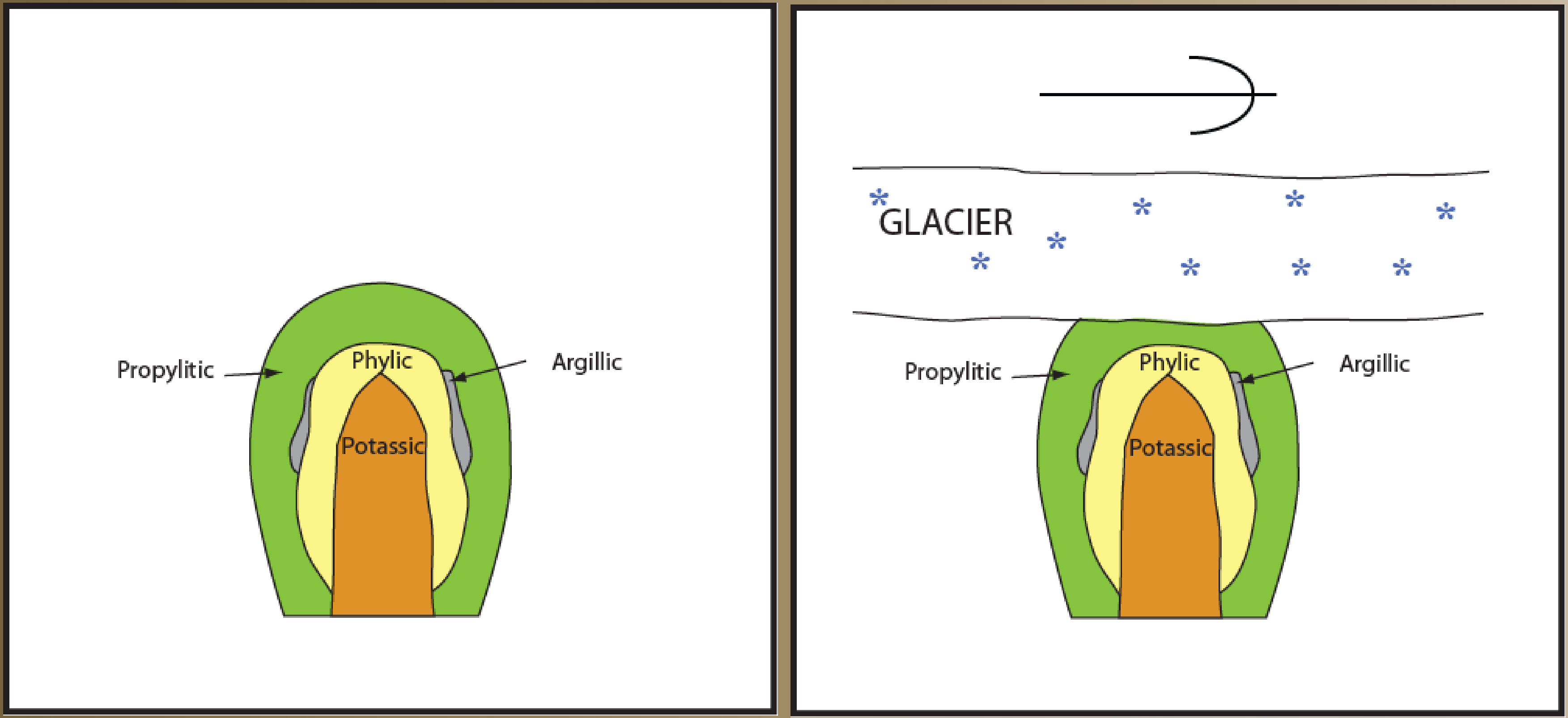
Photograph: R.G. Anderson

Alteration zones



Lowell and Guilbert (1970)

Glacial erosion of alteration zones



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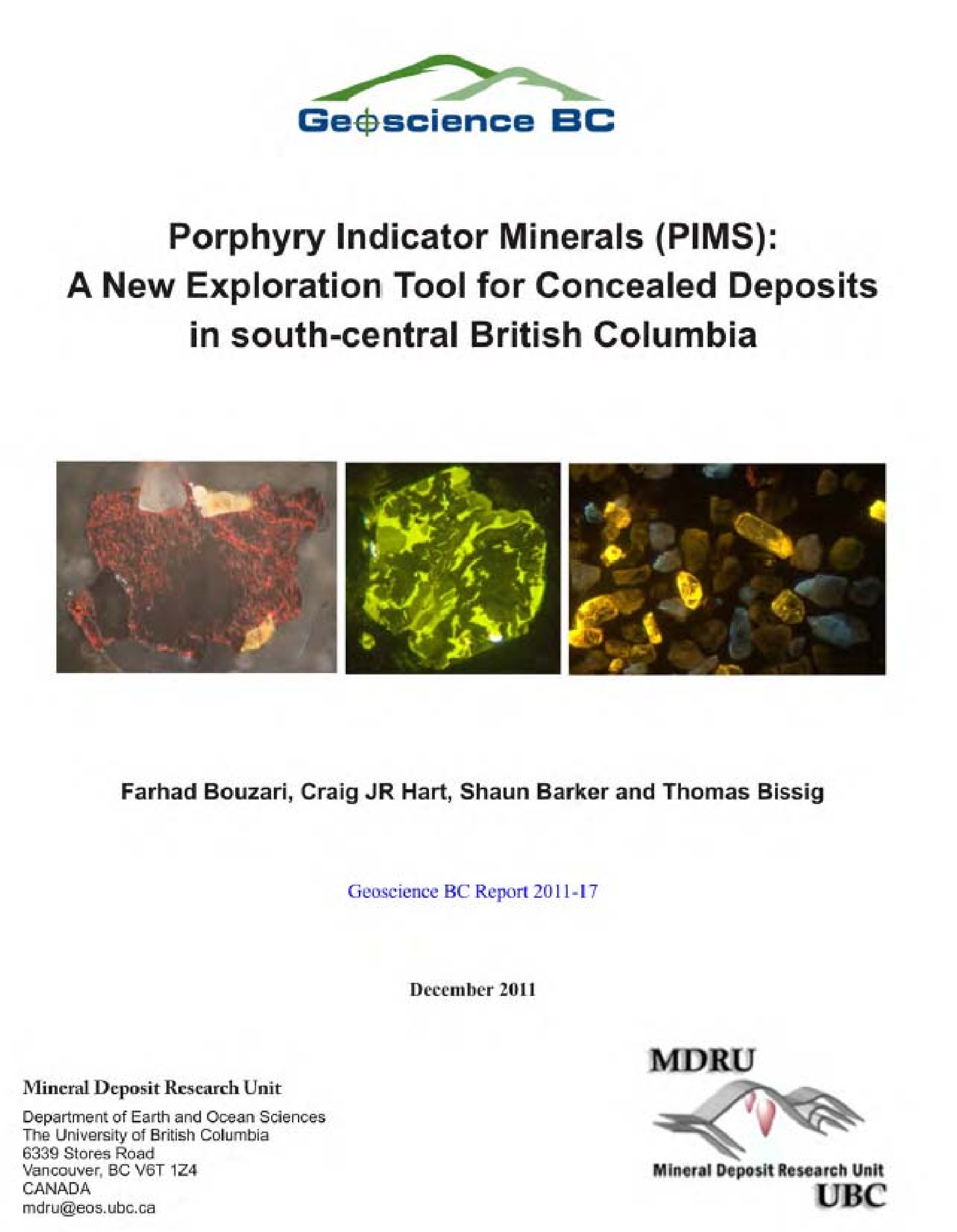
TGI 4 Ore Systems



Geoscience BC

Porphyry Indicator Minerals (PIMS): A New Exploration Tool for Concealed Deposits in south-central British Columbia

Farhad Bouzari, Craig JR Hart, Shaun Barker and Thomas Bissig

Geoscience BC Report 2011-17

December 2011

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UBC

Canada

Conclusion

Geological Survey of Canada with Provincial and Territorial Collaboration

TGI 4 Ore Systems

- Drift prospecting is well applicable in the Cordillera
- Need to know the environment: glaciated vs unglaciated
- Relies on the reconstruction of the ice-flow directions
- Identifying the best tracers: geochemistry, mineralogy