Natural Resources Canada / Ressources naturelles Canada

The use of till geochemistry and mineralogy to explore for buried porphyry deposits in the Cordillera -- preliminary results from a TGI-4 Intrusion-related Ore Systems Project

by: A. Plouffe[1], T. Ferbey[2], R.G. Anderson[3], S. Hashmi[4], B.C. Ward[4], and D.A. Sacco[4]

1. Geological Survey of Canada, 601 Booth Steet, Ottawa, Ontario. K1A 0E8; email: aplouffe@nrcan.gc.ca
2. British Columbia Geological Survey Branch, 5th Floor, 1810 Blanshard Street, Victoria, B.C. V8W 9N3; email: Travis.Ferbey@gov.bc.ca
3. Geological Survey of Canada-Pacific, 1500 - 605 Robson Street, Vancouver, B.C. V6B 5J3; email: boanders@nrcan.gc.ca
4. Simon Fraser University, 8888 University Drive, Burnaby, British Columbia V5A 1S6; email: shashmi@sfu.ca, bcward@sfu.ca, dsacco@sfu.ca

Geological Survey of Canada with Provincial and Territorial Collaboration

TGI 4 Ore Systems

SETTING

The Targeted Geoscience Initiative 4 is a 5-year federal program to provide public geoscience knowledge to improve deep mineral exploration effectiveness. Intrusion-related ore systems are one of the mineral deposit settings being studied and this poster provides a summary of current results of till geochemistry and porphyry indicator mineral studies on four porphyry deposits in south central British Columbia.

The project objective is to improve mineral exploration effectiveness for porphyry mineralization in regions covered with glacial sediments and Tertiary volcanic rocks. Two types of sampling media are being tested: 1) plant tissue including tree bark from pine and spruce, and twigs from cedar, and 2) till. Previous studies in the Cordillera by the Geological Survey of Canada and the British Columbia Geological Survey have demonstrated that the geochemical compositions of trees and glacial sediments are influenced by underlying or nearby mineral deposits (e. g. Plouffe, 1995; Levson, 2001; Plouffe et al., 2001, 2011a, b; Dunn, 2007; Dunn and Thompson, 2007; Ferbey and Levson, 2009; Ferbey et al., 2009; Ferbey, 2010; Dunn and Anderson, 2011). However, the elements and components in tree bark and twigs, and surficial sediments indicative of the buried fertile porphyry systems need to be identified and modelled to test if their distribution can be used to vector towards concealed mineralization.

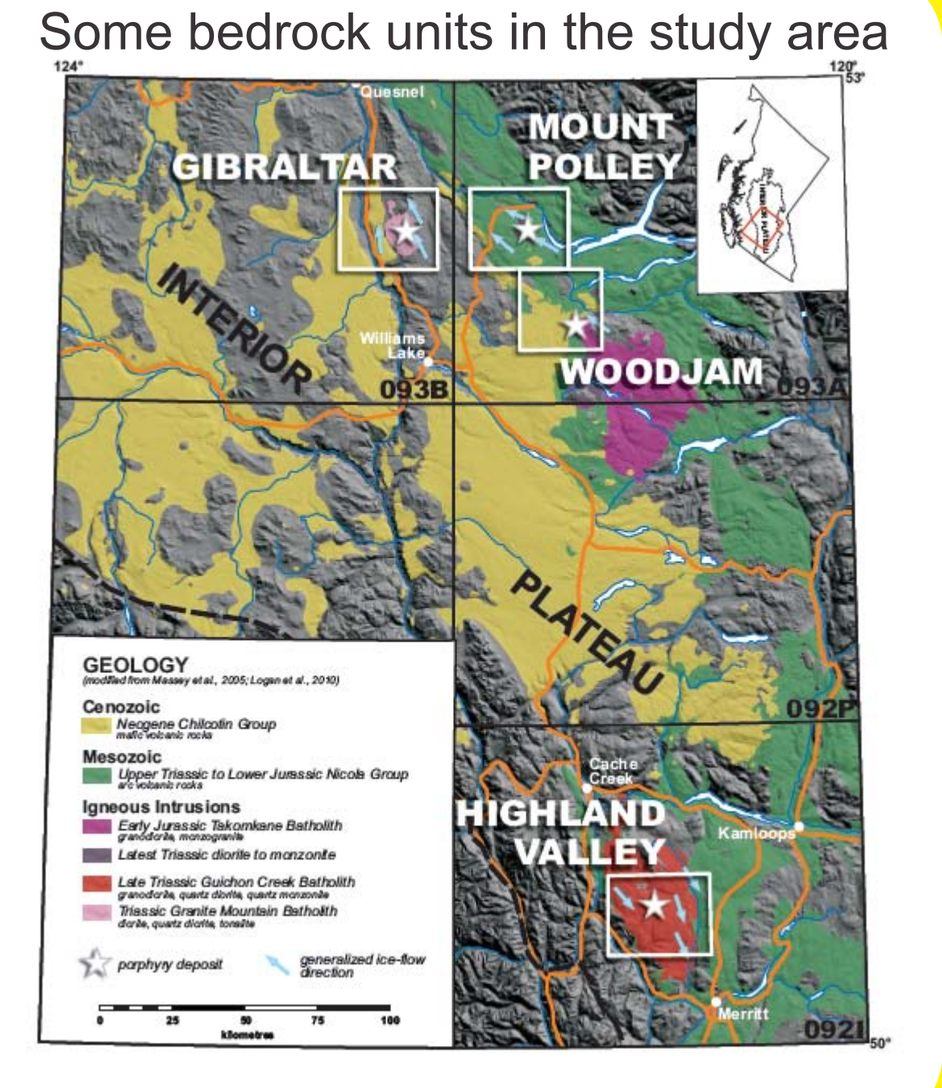
The first stage of this project consisted of reconnaissance field work completed in the fall of 2011 at three study sites: Woodjam district and Gibraltar and Highland Valley mines. It was reported in Anderson et al. (2012a b, c).

Information in this poster is a summary of some results from the past and continued regional sampling in 2012 at the three previous sites and at Mt. Polley Mine and are shown on adjacent panels. Samples included 282 till samples, 487 samples of pine and spruce bark and cedar foliage, and 65 bedrock samples collected for geochemical and mineralogical studies that will link the bedrock source to compositional and mineralogical enrichments identified in the till.

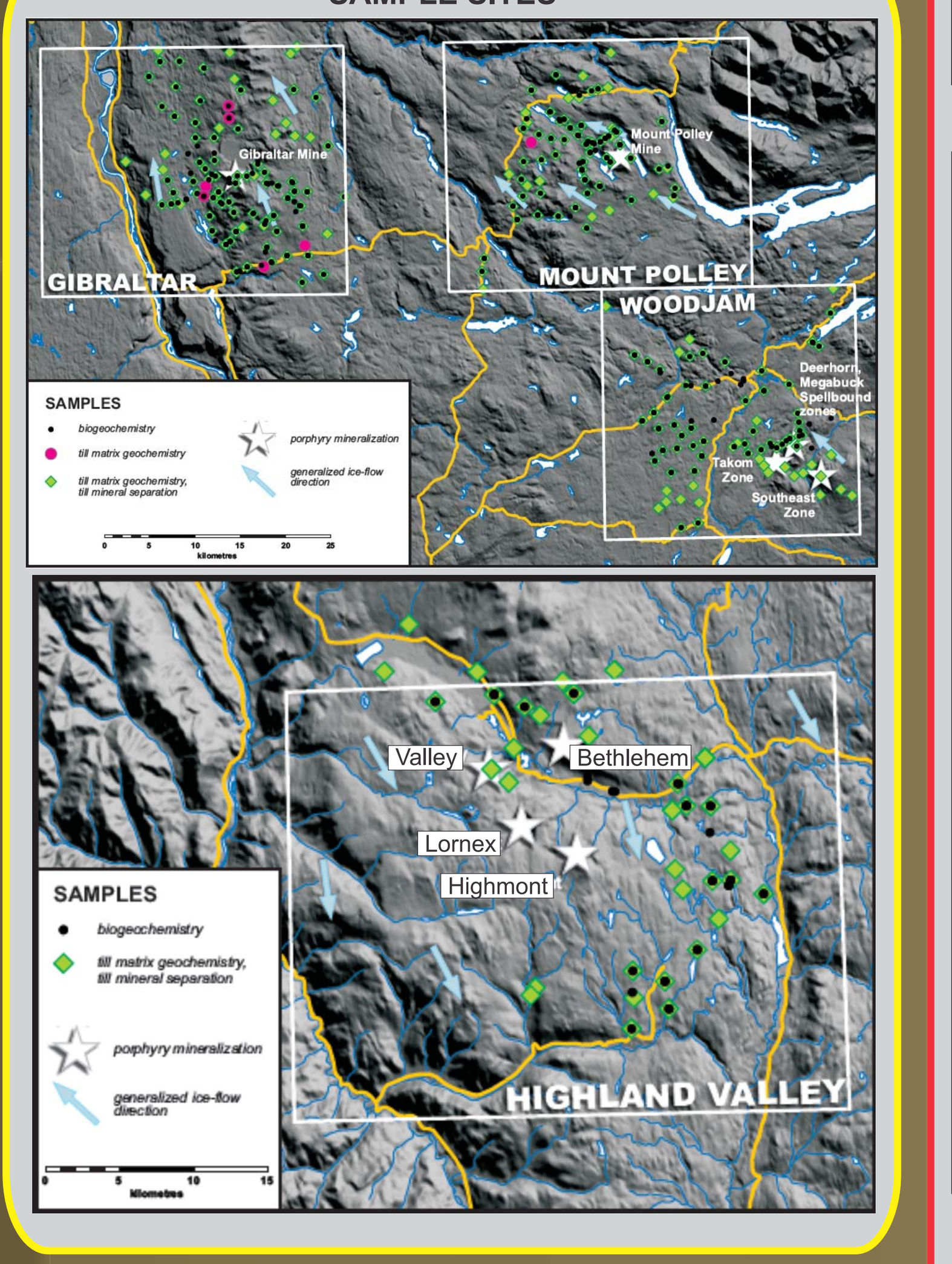
In addition to sampling, field work includes the mapping of surficial sediments and ice-flow indicators at map- (e.g. drumlins) and outcrop- (e.g. glacial striations) scales. Reconstruction of the ice-flow history based on these indicators is key to tracing the geochemical and mineralogical anomalies back to their source(s) in glaciated terrains particularly where the ice-flow history is complex.

The preliminary geochemical and mineralogical results for the till samples, shown in relations to bedrock geology, known MINFILE deposit locations and types and iceflow history, indicate that Cu and porphyry indicator mineral enrichments help identify the large known mineral deposits and other areas were mineral occurrences are not known but may be prospective.

Some bedrock units in the study area



SAMPLE SITES



REFERENCES

PROJECT SPECIFIC:

Anderson, R. G., Plouffe, A., Ferbey, T., and Dunn, C. E., 2012a. The search for surficial expressions of buried Cordilleran porphyry deposits; a new TGI4 activity in the southern Canadian Cordillera; Geological Survey of Canada, Open File 7081, poster.

Anderson, R. G., Plouffe, A., Ferbey, T., and Dunn, C. E., 2012b. The search for surficial expressions of buried Cordilleran porphyry deposits; preliminary findings in a new TGI4 activity in the southern Canadian Cordillera; Geological Survey of Canada, Open File 7266, 82 p.

Anderson, R. G., Plouffe, A., Ferbey, T. F., and Dunn, C. E., 2012c. The search for surficial expressions of buried Cordilleran porphyry deposits; background and progress in a new TGI-4 activity in the southern Canadian Cordillera; Geological Survey of Canada, Current Research 2012-7, 15 p.

CITED:

Ash, C. H., Panteleyev, A., MacLellan, K. L., Payne, C. W., and Rydman, M. O., 1999. Geology of the Gibraltar Mine area (93B/6&9); British Columbia Ministry of Energy and Mines, Open File 1999-7, scale 1:50 000.

Dunn, C. E., 2007. Biogeochemistry in Mineral Exploration; Elsevier, Handbook of exploration and environmental geochemistry, Amsterdam, Volume 9, 462 p.

Dunn, C. E. and Anderson, R. G., 2011. Biogeochemical surveys in the Bonaparte Lake area, south-central British Columbia (NTS 92P09 and 10); Geological Survey of Canada, Open File 6726, 1 CD-ROM.

Dunn, C. E. and Thompson, R. I., 2007. Biogeochemical exploration using douglas-fir tree tops in the Mabel Lake area, Southern British Columbia (NTS 82L09 and 10); Geological Survey of Canada, Open File 5538, 65 p.

Ferbey, T., 2010. Till geochemistry of the Nadina River map area (093E/15), west-central British Columbia; British Columbia Geological Survey, Victoria, B.C., Open File 2010-7 and Geoscience BC Report 2010-10, 52 p.

Ferbey, T. (2011): Till Geochemistry of the Colleymount map area (093L/01), west-central British Columbia; British Columbia Ministry of Energy, Mines, and Petroleum Resources, Open File 2011-6, Geoscience BC, Report 2011-9, 51 p.

Ferbey, T. and Levson, V. M., 2009. The influence of ice-flow reversals on the vertical and horizontal distribution of trace element values in tills, Huckleberry Mine area, west-central British Columbia; *in* Application of till and stream sediment heavy mineral and geochemical methods to mineral exploration in western and northern Canada, (ed.) R. C. Paulen and I. McMartin; Geological Association of Canada, Short Course Notes 18, p. 177-183.

Ferbey, T., Levson, V. M., and Lett, R. E., 2009. Till geochemical exploration targets, Babine porphyry copper belt, central British Columbia; British Columbia Ministry of Energy, Mines and Petroleum Resources, Victoria, Open File 2009-4, Geoscience BC Report 2009-10, 34 p.

Lett, R.E., Cook, S.J. and Levson, V.M. (2006): Till geochemistry of the Chilanko Forks, Chezacut, Clusko, and Toil Mountain map areas, British Columbia (NTS 93C/1, 8, 9, and 16); British Columbia Ministry of Energy, Mines, and Petroleum Resources, GeoFile 2006-1, 272 p.

Levson, V. M., 2001. Regional till geochemical surveys in the Canadian Cordillera: sample media, methods and anomaly evaluation; *in* Drift Exploration in Glaciated Terrain, (ed.) M. B. McClenaghan, P. T. Bobrowsky, G. E. M. Hall, and S. J. Cook; Geological Society, Special Publication 185, London, p. 45-68.

McMillan, W. J., Anderson, R. G., Chan, R., and Chow, W., 2009. Geology and Mineral Occurrences (minfile), Guichon Creek Batholith and Highland Valley porphyry copper district, British Columbia; Geological Survey of Canada, scale 1:100 000 and 1:150 000, 2 sheets.

Massey, N. W. D., MacIntyre, D. G., Desjardins, P. J., and Cooney, R. T., 2005. Geology of British Columbia; British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey, scale 1:1 000 000.

Plouffe, A., 1995. Geochemistry, lithology, mineralogy and visible gold grain content of till in the Manson River and Fort Fraser map areas, central British Columbia (NTS 93K and N); Geological Survey of Canada, Open File 3194, 119 p.

Plouffe, A., Anderson, R. G., and Dunn, C. E., 2011a. Till composition and biogeochemistry near a porphyry Cu-Mo deposit: Gibraltar Mine, British Columbia; Geological Survey of Canada, Open File 6755, 25 p.

Plouffe, A., Anderson, R. G., Gruenwald, W., Davis, W. J., Bednarski, J. M., and Paulen, R. C., 2011b. Integrating ice-flow history, geochronology, geology, and geophysics to trace mineralized glacial erratics to their bedrock source, an example from south central British Columbia; Canadian Journal of Earth Sciences, v. 48, p. 1113-1130.

Plouffe, A., Bednarski, J. M., Huscroft, C. A., Anderson, R. G., and McCuaig, S. J., 2011c. Late Wisconsinan glacial history in the Bonaparte Lake map area, south central British Columbia: implications for glacial transport and mineral exploration; Canadian Journal of Earth Sciences, v. 48, p. 1091-1111.

Plouffe, A., Levson, V. M., and Mate, D. J., 2001. Till geochemistry of the Nechako River map area (NTS 93F), central British Columbia; Geological Survey of Canada, Open File 4166.

ACKNOWLEDGMENTS

This study could not have been undertaken without the support of GSC TGI4 project personnel and extraordinary mineral and mining company support. Mike Villeneuve, Neil Rogers, Christine Hutton and Cathryn Bjerkelund from the Geological Survey of Canada provided the Program and Project support to enable the fieldwork to be undertaken.

The cooperation, support and assistance of: John Fleming (Gibraltar Mines Ltd); Tom Schroeter, Ross Sherlock, John Hertel, Jacqueline Blackwell, and Amelia Rainbow (Consolidated Woodjam Copper); Gerald Grubisa, Chris LeClair, Mathieu Veillette, and Ron Grayden (Teck Highland Valley Copper Partnership); and, Amber Marko (Imperial Metals Corporation) facilitated the success of our scoping studies at Gibraltar Mine, the Woodjam District, the Highland Valley District, and Mount Polley Mine. Field assistance by Nicole Evanoff and Kerry-Lynn Robillard was invaluable.

The geology depicted on the figures of this poster was kindly provided in digital format by William Chow, Jim Logan, and Paul Schiarizza.

METHODOLOGY

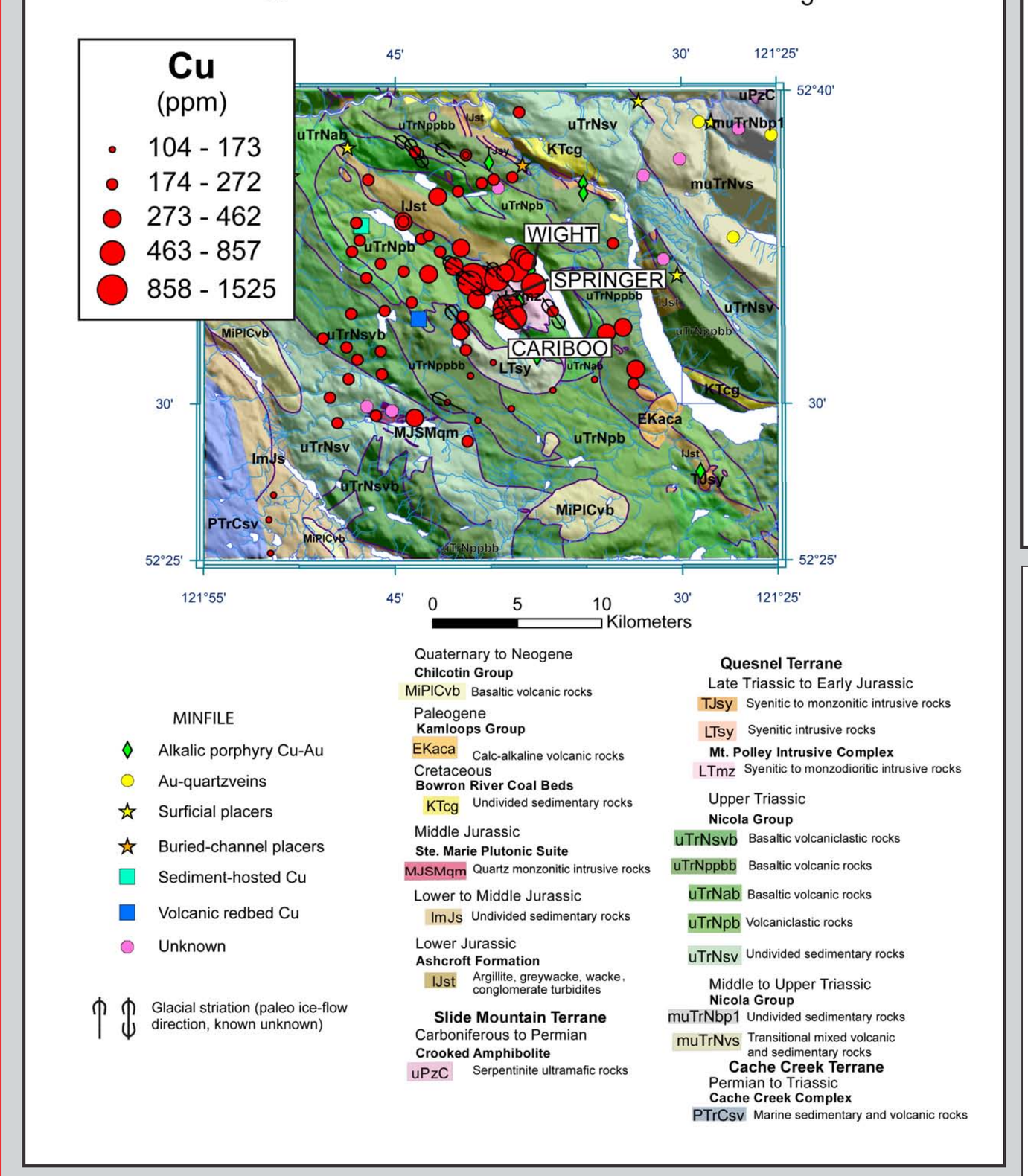
The silt and clay- (<0.063 mm; -230 mesh) and the clay-sized (<0.002 mm) fractions of the till samples were submitted for the following analytical procedures at ACME Analytical Laboratories (Vancouver, BC): 1) 0.2 g aliquots were digested with lithium metaborate/tetraborate, fused at 980°C, dissolved in 5% HNO_3 and then analyzed by inductively coupled plasma-emission spectrometry (ICP-ES) analysis (package 4A-4B at ACME) and 2) 0.5 of clay and 30 g of silt and clay aliquots were diluted in a hydrochloric and nitric acid solution (ratio 1:1, modified aqua regia) and analyzed by ICP mass spectrometry (ICP-MS) (package 1F at ACME).

Till samples were submitted to Overburden Drilling Management Ltd. (ODM, Ottawa, ON) for indicator mineral separation and identification. Heavy mineral concentrates were produced using a two step procedure including a shaking table and heavy liquids with specific gravities of 2.8 and 3.2. A variety of heavy minerals were identified in the 0.25 – 2 mm sized fraction under a binocular microscope using minerals optical and physical properties (e.g. color, lustre, crystal form, etc.). The identification of a number of mineral grains was verified with a scanning electron microscope (SEM). To date, 183 till samples have been processed for indicator minerals. The remaining 96 samples will be processed within the next month.

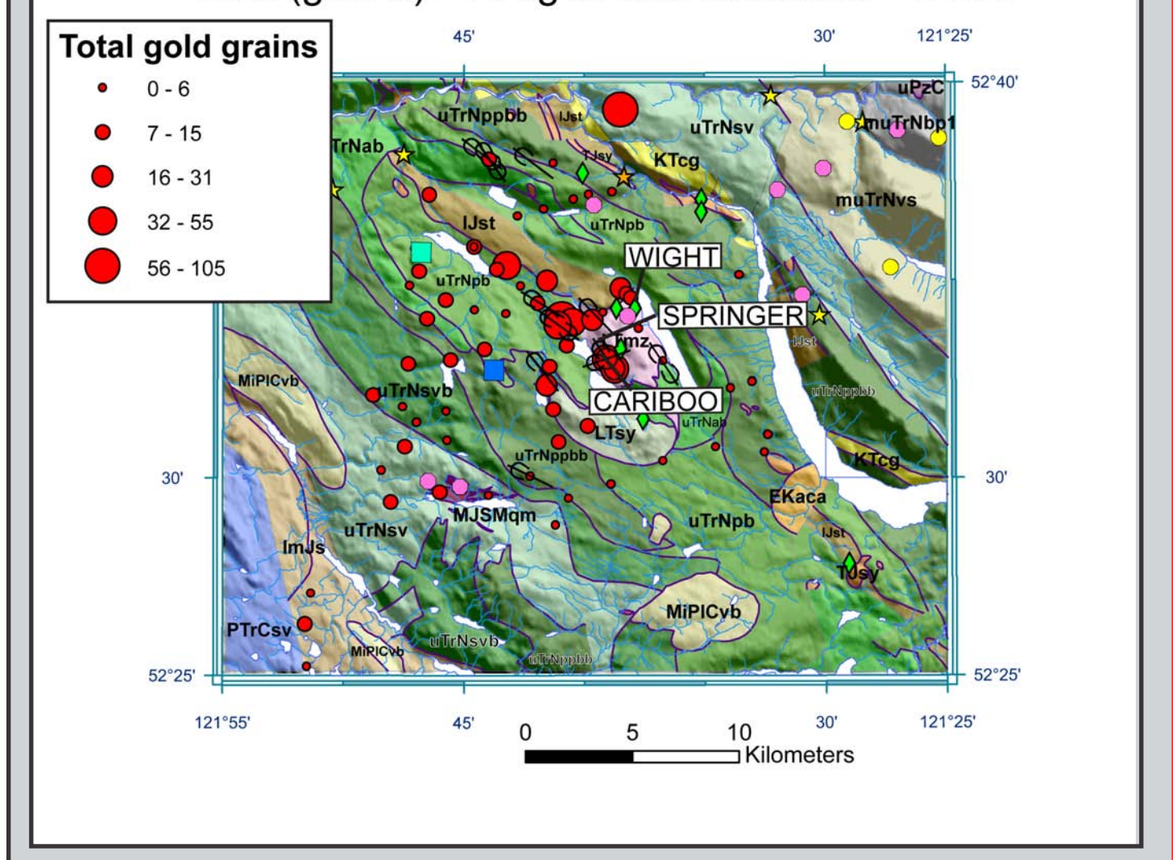
Mount Polley Mine

Panoramic view to the north in Springer Pit at Mount Polley Mine (May 2012)

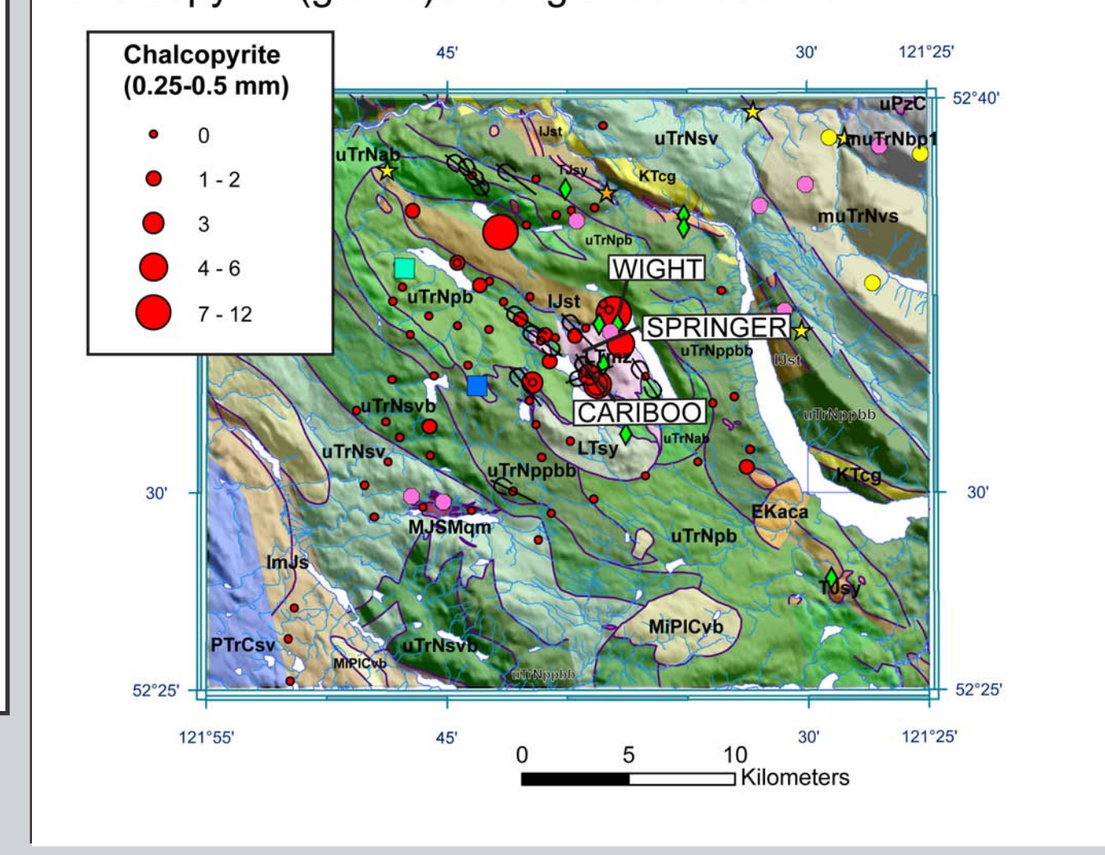
Cu in the clay-sized fraction of till
Methodology: Lithium metaborate/tetraborate, HNO_3 ICP-ES



Gold (grains) / 10 kg of bulk sediment < 2 mm



Chalcopyrite (grains) / 10 kg of bulk sediment < 2 mm



The Mount Polley Mine region was first covered by glaciers originating from the Cariboo Mountains to the east of the Fraser Plateau with ice flow initially towards the west to southwest. As the glaciation intensified, ice was moving to the north and northwest following the development of an ice-divide around the 52° parallel (Anderson et al., 2012; Plouffe et al. 2011). These two dominant ice-flow directions are interpreted from the glacial striation record measured in the mine region during the May 2012 field work. Most striated sites reveal a northwest flow except for one measurement near the Springer Pit indicating an earlier southwestward flow.

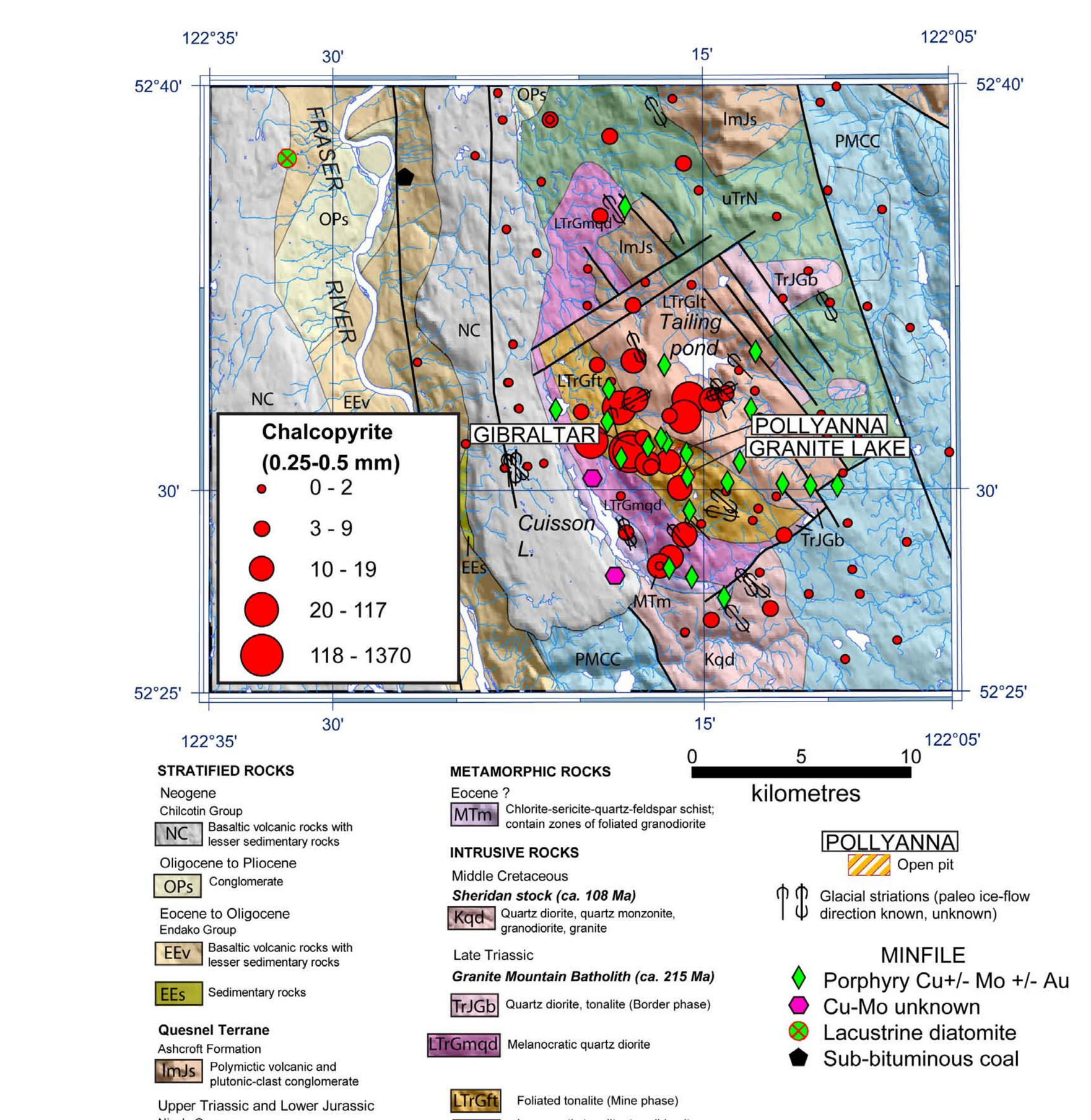
The gold grain content of till is elevated (>32 grains / 10 kg bulk sediment) near the mine and northwest from it. At Mount Polley, gold grains might be a good indicator of the mineralization. Copper concentrations in the clay-sized fraction of till changed from elevated values (>463 ppm) near the mine to lesser values (174-272 ppm) to the west and northwest which is likely related to glacial dispersion in those directions. Few samples located close to mineralization contain small amount (7 to 12 grains) of chalcopyrite in the 0.25-0.5 mm fraction (s.g. > 3.2). Chalcopyrite might be a local indicator of buried mineralization at Mount Polley.

Bedrock geology is from Massey et al. (2005) and Logan et al. (2010).

Gibraltar Mine

View south to panorama of Gibraltar pit (July 2011).

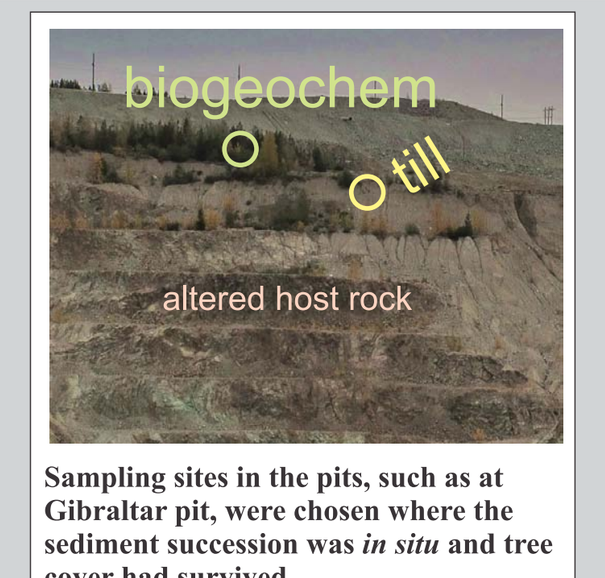
Chalcopyrite (grains) / 10 kg of bulk sediment < 2 mm



During the last glaciation, the Gibraltar Mine region was first covered by ice flowing to the west-southwest derived from the Cariboo Mountains (Plouffe et al., 2011c; Anderson et al., 2012c). As glaciation intensified, an ice-divide formed to the south around the 52° latitude from which ice was flowing to the north-northwest in the mine region (Plouffe et al., 2011c). During the 2012 field investigation, one outcrop with both north-northwest and south-southeast ice-flow indicators (rat-tails) (see photograph) was discovered. It indicates that in addition to the west-southwest and the north-northwest ice movement, Gibraltar Mine area was under the influence of south flowing ice possibly when the ice divide migrated north of the mine at some point during the last glaciation.

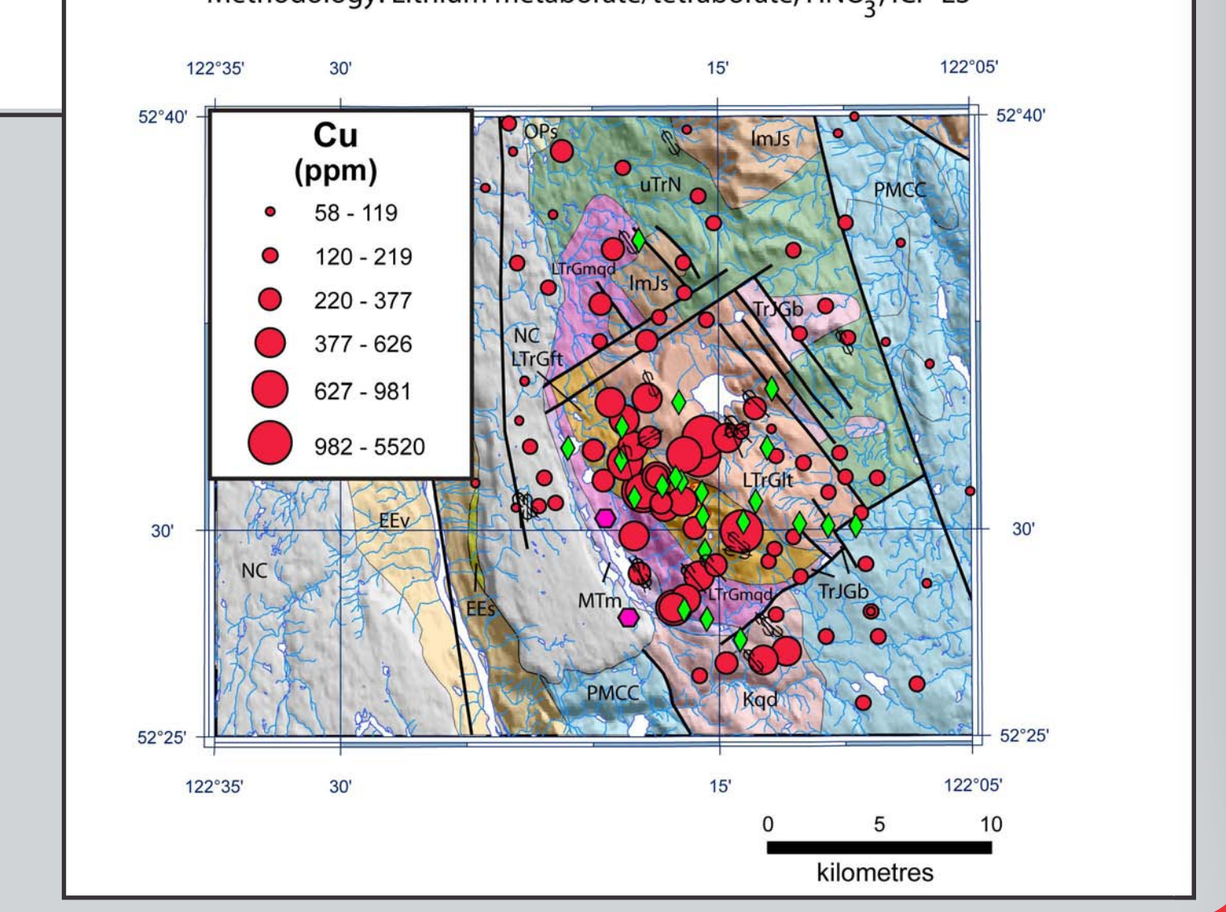
Copper concentrations in the clay-sized fraction of till are more elevated (>388 ppm) in the region of the Granite Mountain Batholith compared to surrounding regions. The same region is also characterized by elevated chalcopyrite grains in the 0.25 to 0.5 mm size fraction (s.g. >3.2) compared to surrounding regions. Some elevated copper concentrations and chalcopyrite grain counts are not associated to known mineralization. No clear dispersal pattern has been identified. This could be related to the complex ice-flow history of the region which might have formed amoeboid dispersal.

Bedrock geology depicted on the maps is from Ash et al. (1999), Massey et al. (2005), and P. Schiarizza, (unpublished data, 2012).



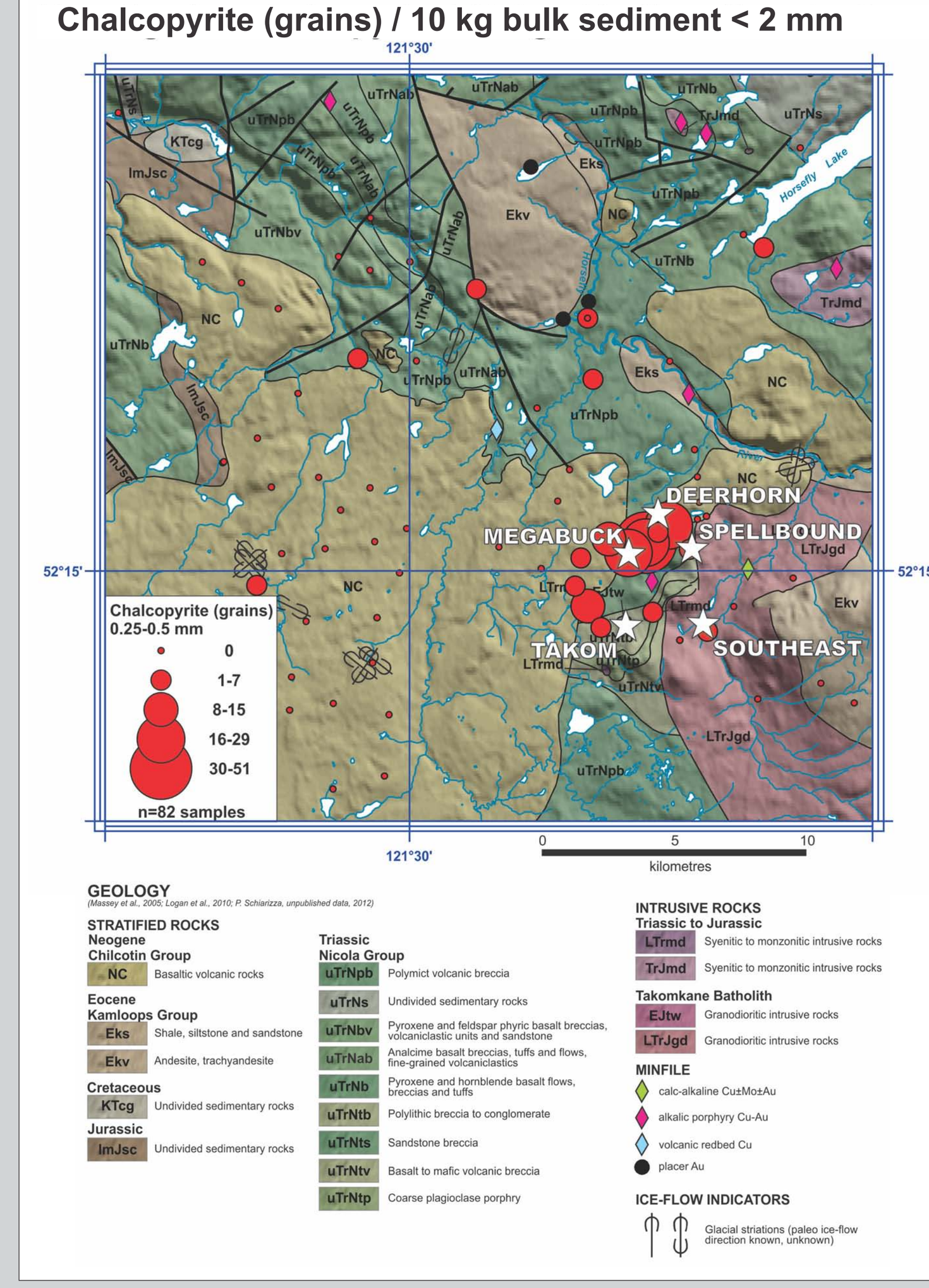
Rat-tail (black arrow) showing southward ice flow in the Gibraltar Mine region

Cu in the clay-sized fraction of till
Methodology: Lithium metaborate/tetraborate, HNO_3 ICP-ES

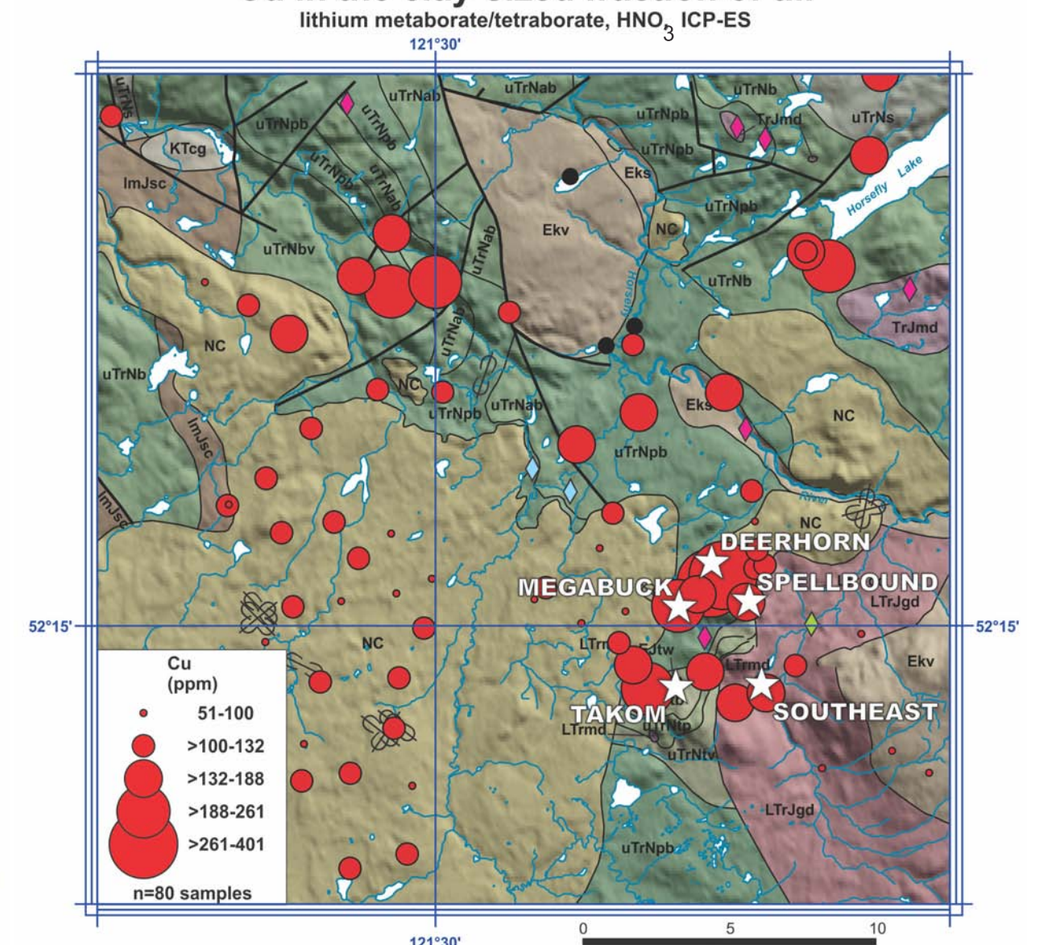


Woodjam District

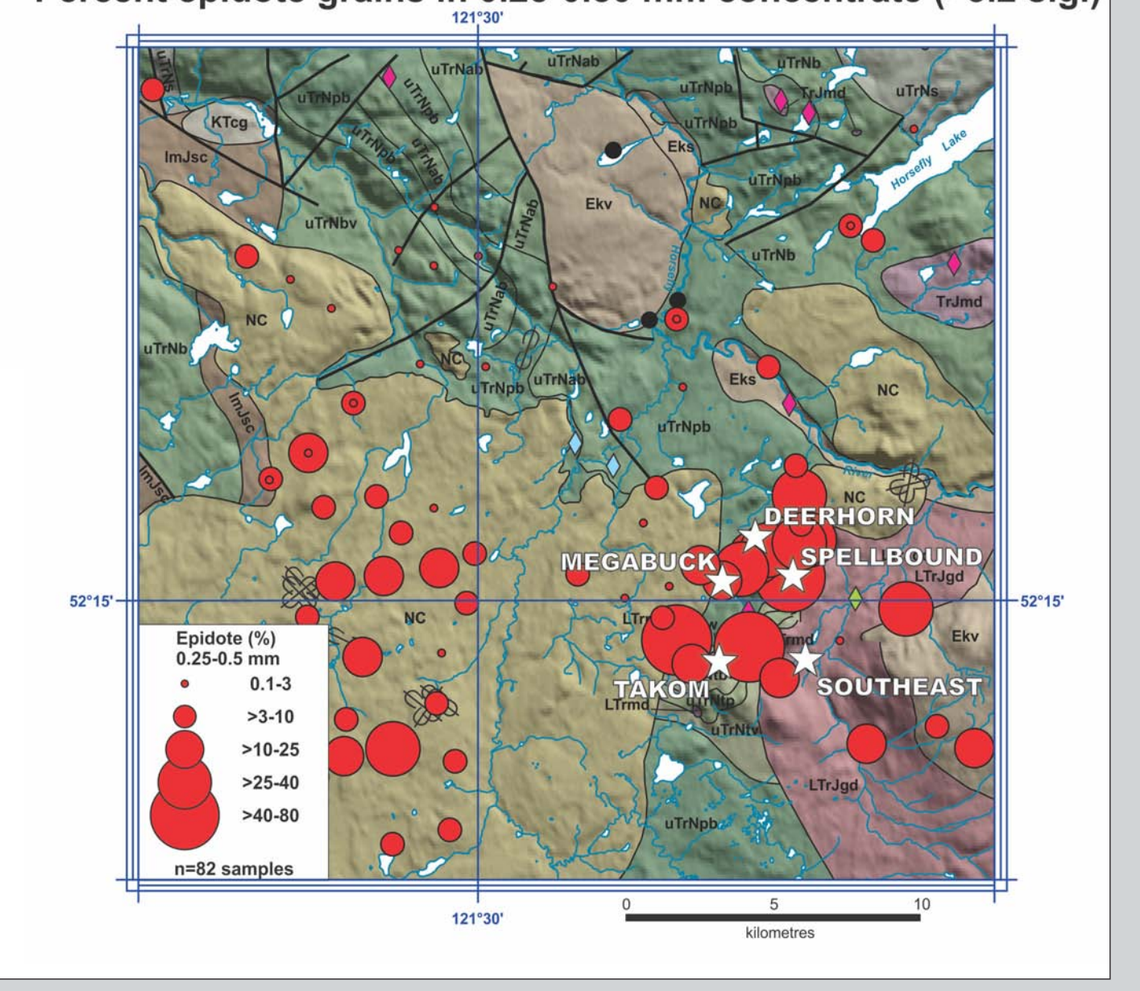
Chalcopyrite (grains) / 10 kg bulk sediment < 2 mm



Cu in the clay-sized fraction of till



Percent epidote grains in 0.25-0.50 mm concentrate (>3.2 s.g.)

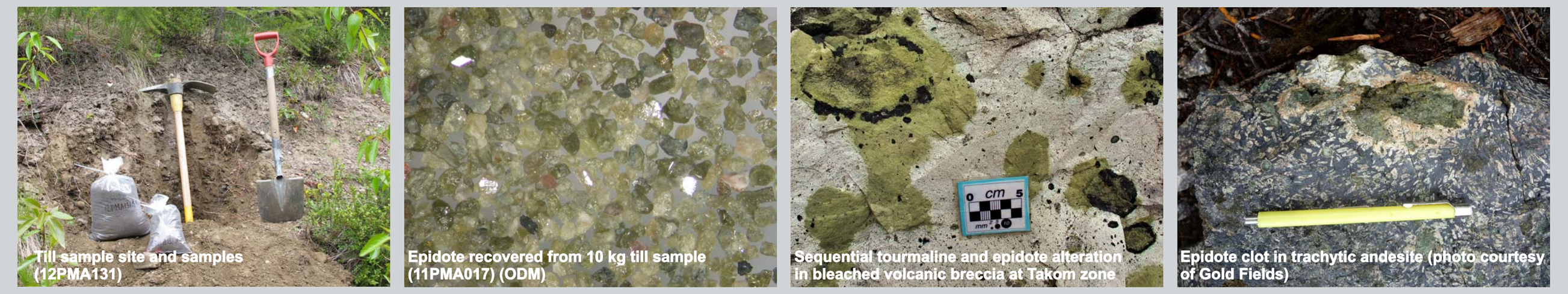


During Late Wisconsinan glaciation, the Woodjam district was covered by ice flowing from the Cariboo Mountains. Ice-flow direction through the district appears to have been variable and striations measured at one site suggest that flow towards 235° was followed by flow towards 305°. Summer 2013 field work (outcrop-scale) and air photograph interpretation (landform-scale) will focus on more detailed summary of the district's ice-flow history. The details of this ice-flow history will be integral to characterising dispersal of commodity elements and porphyry indicator minerals in till from the mineralized zones at Woodjam.

The maximum Cu value in the clay-sized fraction of till (<0.002 mm) is 411 ppm and occurs midway between Megabuck, Deerhorn, and Spellbound zones. This maximum value, and the background or median value for this dataset (111 ppm Cu), are elevated when compared to other regional-scale till geochemical surveys conducted in the Cordillera (e.g., Lett et al., 2006; Ferbey 2010; Ferbey, 2011). Localities with elevated Cu values (220 to 235 ppm) also occur to the northwest and northeast of the Woodjam district where there are no known mineral occurrences.

Sulphides such as chalcopyrite have survived erosion and deposition in the subglacial environment and weathering in the oxidizing surficial environment. There is a significant positive correlation between elevated Cu in <0.002 mm size-fraction of tills and elevated concentrations of chalcopyrite grains in till derived from mineralized zones at Woodjam.

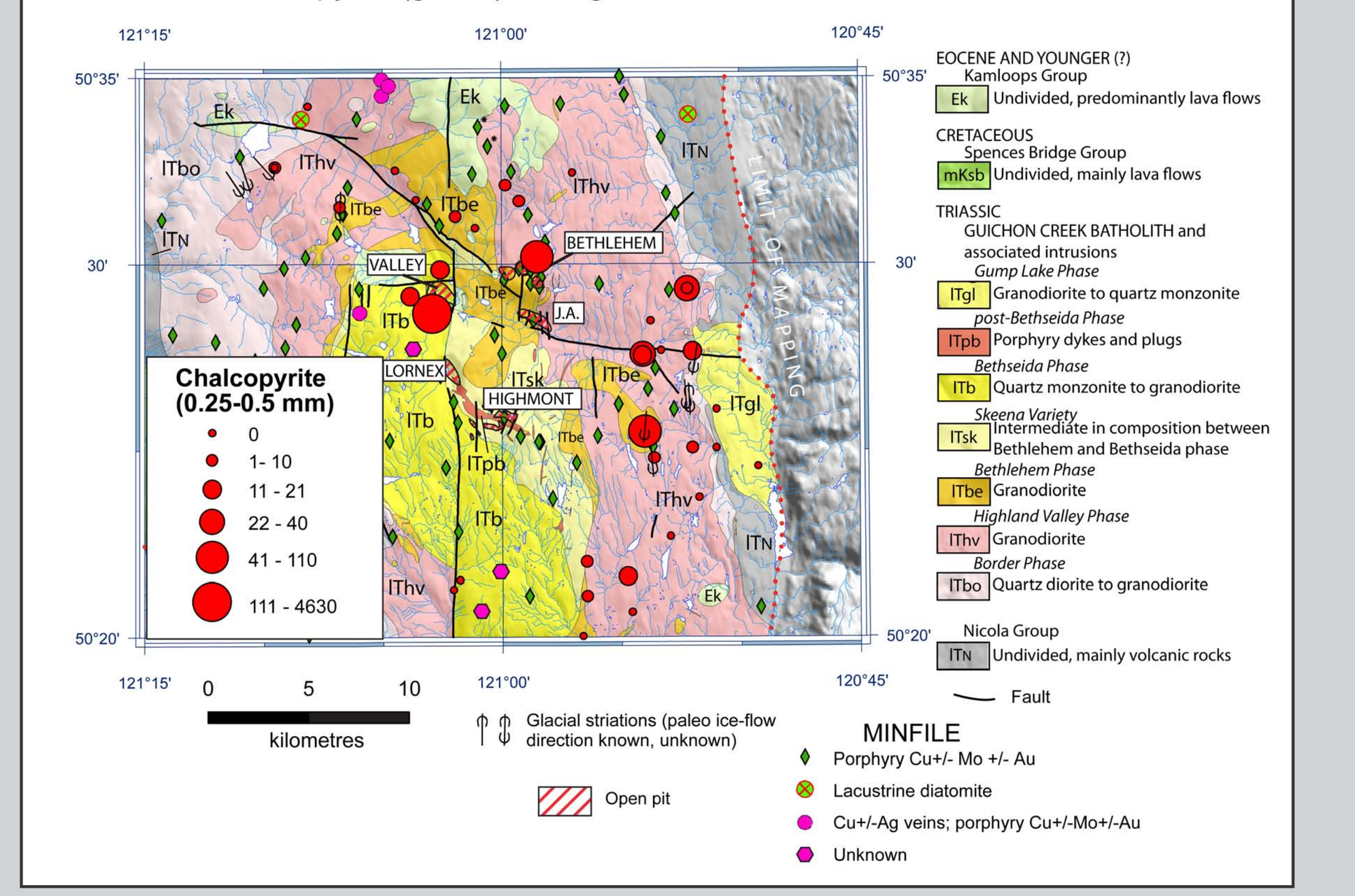
Epidote grains are most numerous near mineralized zones at Woodjam. Samples from the Spellbound and Deerhorn areas yielded the highest epidote counts, whereas the third highest count was from northwest of Takum. Because epidote can originate from both hydrothermal alteration and contact metamorphism of the Nicola Group volcanic rocks at the margin of the Takomkane Batholith, more work is required to test if epidote grains recovered from till samples are related to the mineralization process.



Highland Valley District

View west to panorama of Valley Pit (July 2011). Pre-glacial sediment succession (in brown) visible on right hand side of pit.

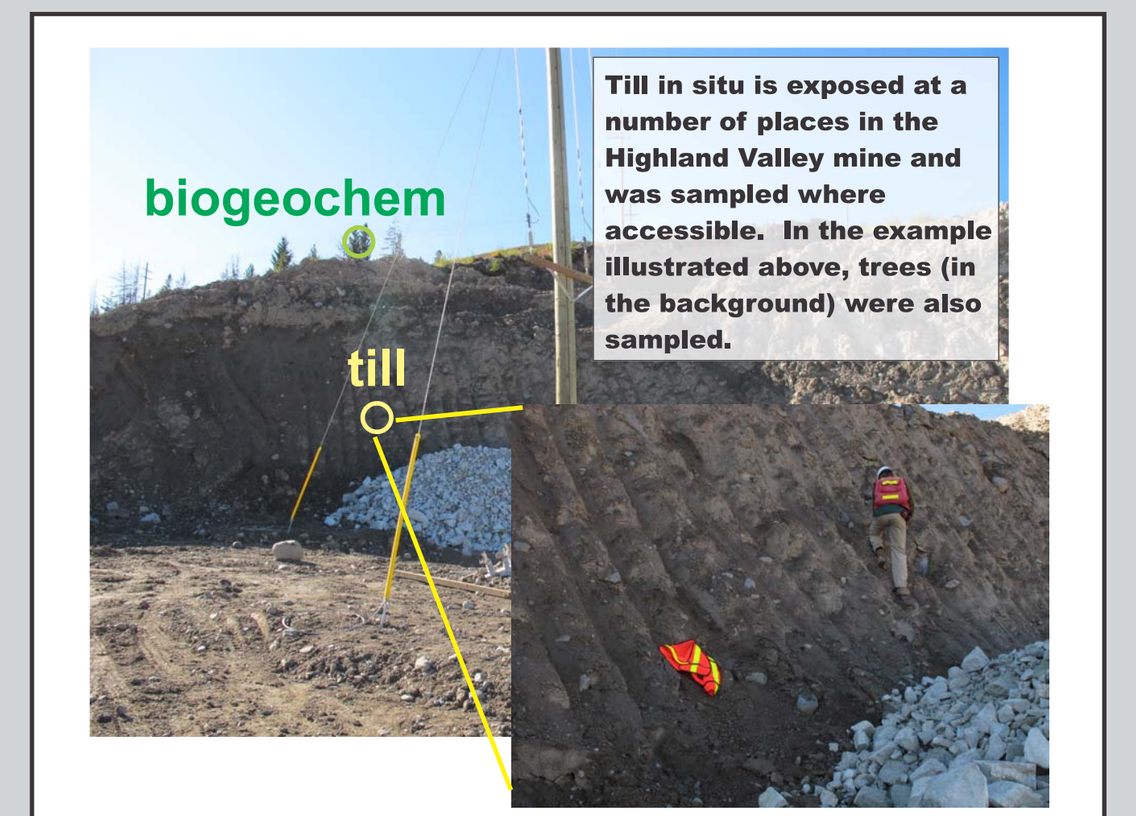
Chalcopyrite (grains) / 10 kg of bulk sediment < 2 mm



The Highland Valley mine region was affected by a single ice movement fluctuating from south to southeast during the last glaciation. Ice was derived from the ice divide located farther north around the 52° latitude.

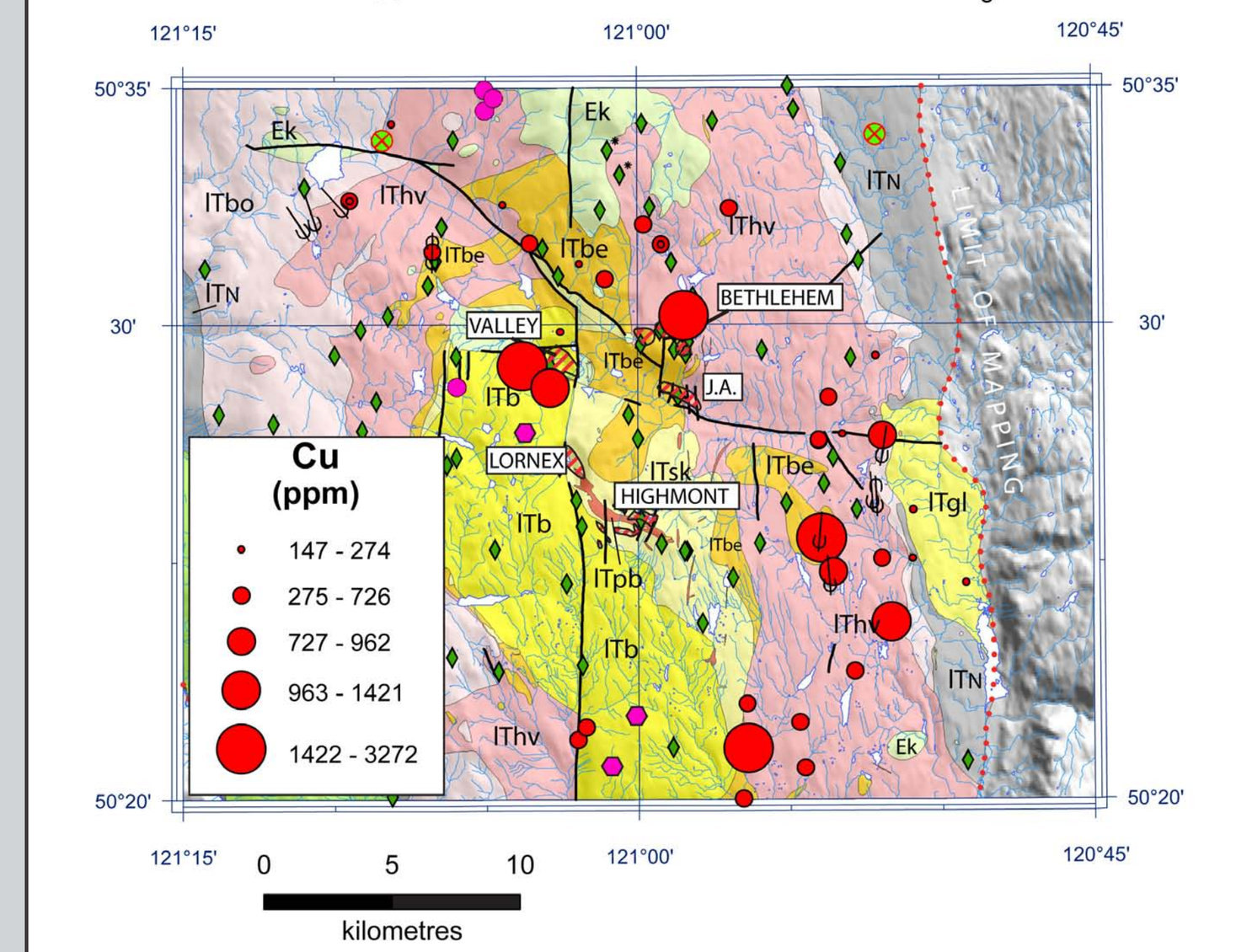
Limited sampling was completed in May 2012 down-ice from Highland Valley Mine because of snow cover which limited access. Preliminary till composition results reveal the presence of elevated copper concentrations in the clay-sized fraction near the Valley Pit but also in the southeastern sector of the Guichon Creek Batholith (GCB) where no MinFile occurrences have been reported. Similarly, chalcopyrite grain content of the 0.25-0.5 mm sized fraction (s.g. >0.32) is highest near the Valley and Bethlehem pits but also elevated in the eastern and southeastern sector of the GCB. No clear dispersal pattern has been identified to date because of the limited sampling.

Bedrock geology depicted on the maps is simplified from McMillan et al. (2009).



Sampling of till in two different units in the Highland Valley Mine area

Cu in the clay-sized fraction of till
Methodology: Lithium metaborate/tetraborate, HNO_3, ICP-ES



Canada