Till composition and ice-flow history in the region of the Gibraltar Mine: developing indicators for the search of buried porphyry mineralization

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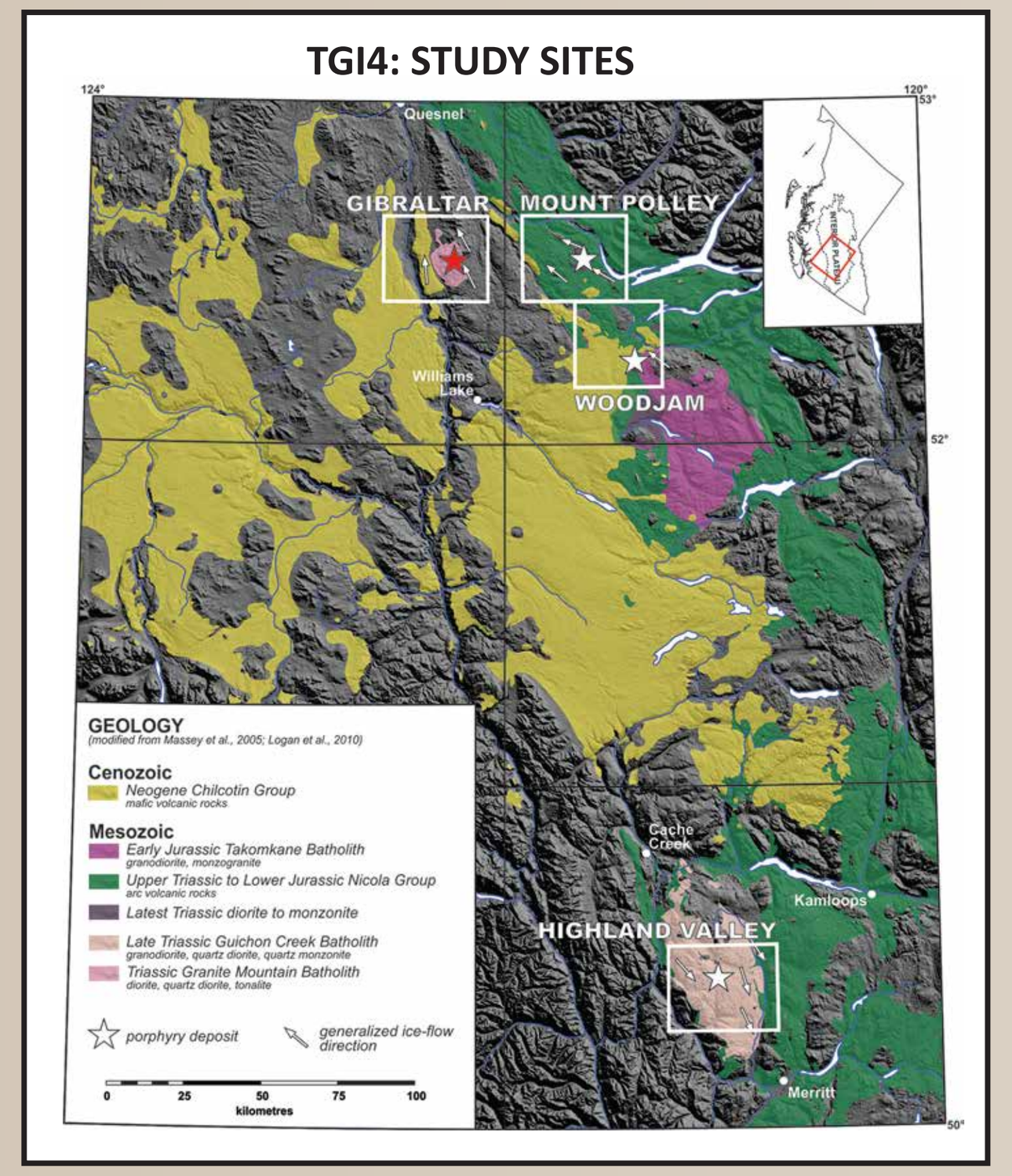
Geological Survey of Canada with Provincial Collaboration

TGI 4 Ore Systems

Intrusion - Related Ore System Project

Overview

Till samples were collected in the region of the Gibraltar Mine region (see location map below) as part of a TGI-4 project undertaken by the Geological Survey of Canada. The project aims at developing mineral exploration methods for the detection of buried porphyry mineralization. During field work, ice-flow indicators were measured to reconstruct ice movements and vectors of glacial transport. During the last glaciation, the Gibraltar Mine region was first covered by ice that was advancing southwestward from the Cariboo Mountains. This first movement was followed by northwestward ice flow as indicated by the orientation of flutings and drumlins. Striations measured near the mine indicate that a southeastward ice movement resulting from: 1) the migration of an ice-divide to the north of the mine or 2) the readjustment of the ice profile during deglaciation affected the mine region. Till composition analyses reveal copper, molybdenum, zinc and silver enrichments in the clay- (<0.002 mm) and silt plus clay- (<0.063 mm) sized fractions, and large number of chalcopyrite grains derived from the economic and sub-economic mineralized zones. Furthermore, till heavy mineral concentrates peripheral to the porphyry mineralization contain elevated perventage of epidote which is interpreted to be derived from the regional propylitic alteration. These indicators form amoeboid dispersal trains as a result of the complex ice-flow history (southwestward, northwestward and southeastward ice movements) and the large number of bedrock mineralized sources. These results demonstrate that regional indicators present in till can serve to detect buried subcropping porphyry mineralization that was exposed to glacial erosion.


TGI4: STUDY SITES
Quesnel
GIBRALTAR
MOUNT POLLEY
WOODJAM
HIGHLAND VALLEY
Merritt
Late Triassic Guichon Creek Batholith
granodiorite, quartz diorite, quartz monzonite
Triassic Granite Mountain Batholith
diorite, quartz diorite, tonalite
porphyry deposit
generalized ice-flow direction
0
25
50
75
100
kilometres

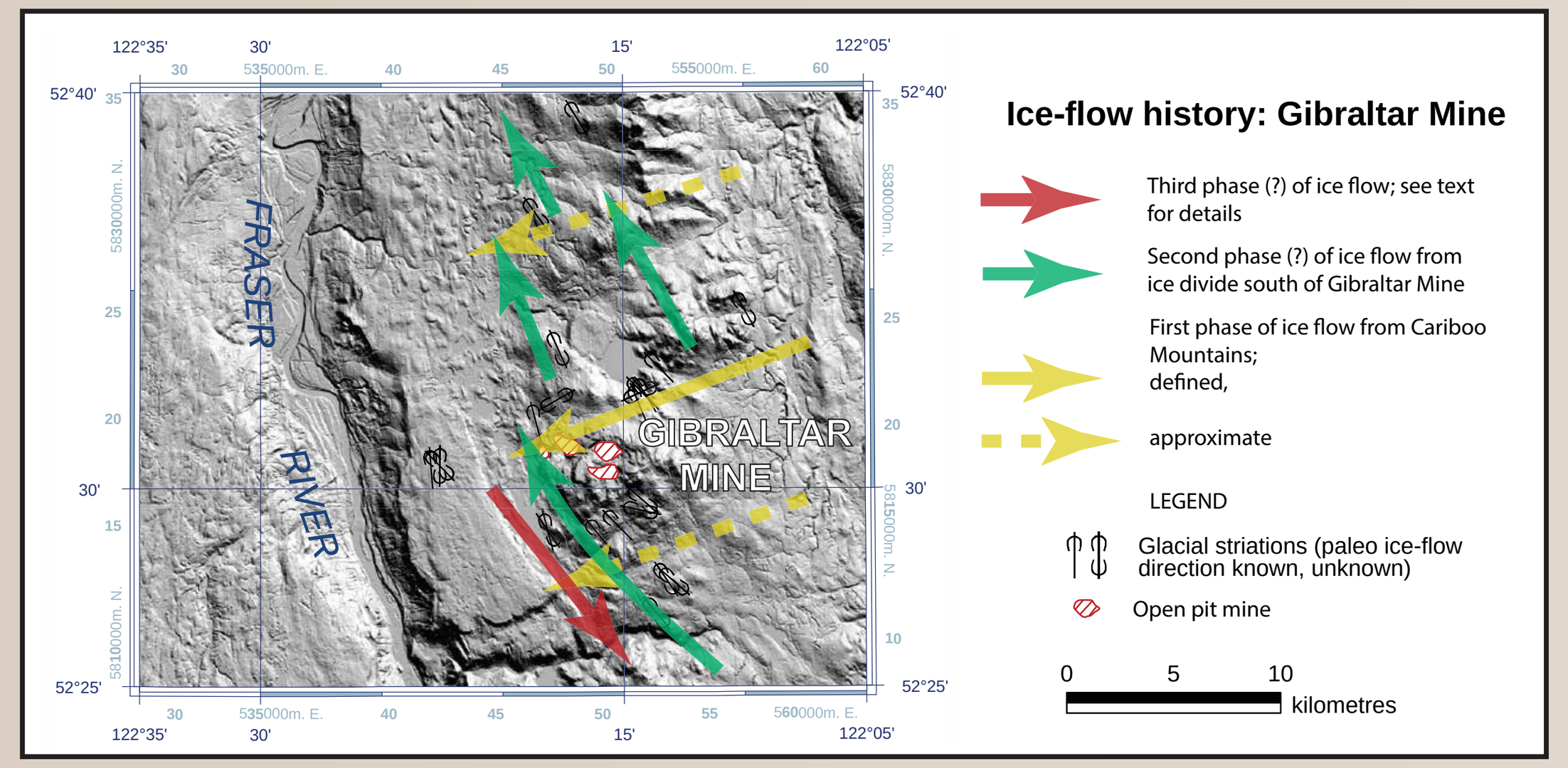
As part of this TGI-4 study, regional till sampling was completed at four study sites: Highland Valley Mine, Gibraltar Mine, Mount Polley Mine and the Woodjam district. This poster presents the results of the Gibraltar Mine: red star on the location map. Major bedrock units of south central British Columbia that are relevant to this study are depicted. Figure modified from Ferbey et al. (in press).

Geological Setting

Gibraltar Mine is a calc-alkaline Cu-Mo porphyry deposit hosted in the Late Triassic Granite Mountain Batholith located at the western limit of the Quesnel Terrane. The intrusion is divided into four units: the border phase (quartz diorite and tonalite) on the east side of the batholith, the mine phase (foliated tonalite) and the Granite Mountain phase (leucocratic tonalite and trondhjemite) which form the core of the intrusion, and a melanocratic quartz diorite at the western and northern margins of the intrusion (Drummond et al., 1973, 1976; Bysouth et al., 1995; Ash et al., 1999a, b; Ash and Riveros, 2001; P. Schiarizza, unpublished data, 2012). Economic mineralization occurs in three pits: Gibraltar (formerly Gibraltar West and Gibraltar), Pollyanna and Granite. Sulphide minerals include chalcopyrite, molybdenite, pyrite and minor sphalerite. Epidote and chlorite are present as alteration of the mafic minerals even distal to the mine (Anderson et al., 2012c). A number of sub-economic mineral occurrences are present in the Gibraltar Mine region (MINFILE, 2013) (see maps with bedrock geology in the third panel to the right).

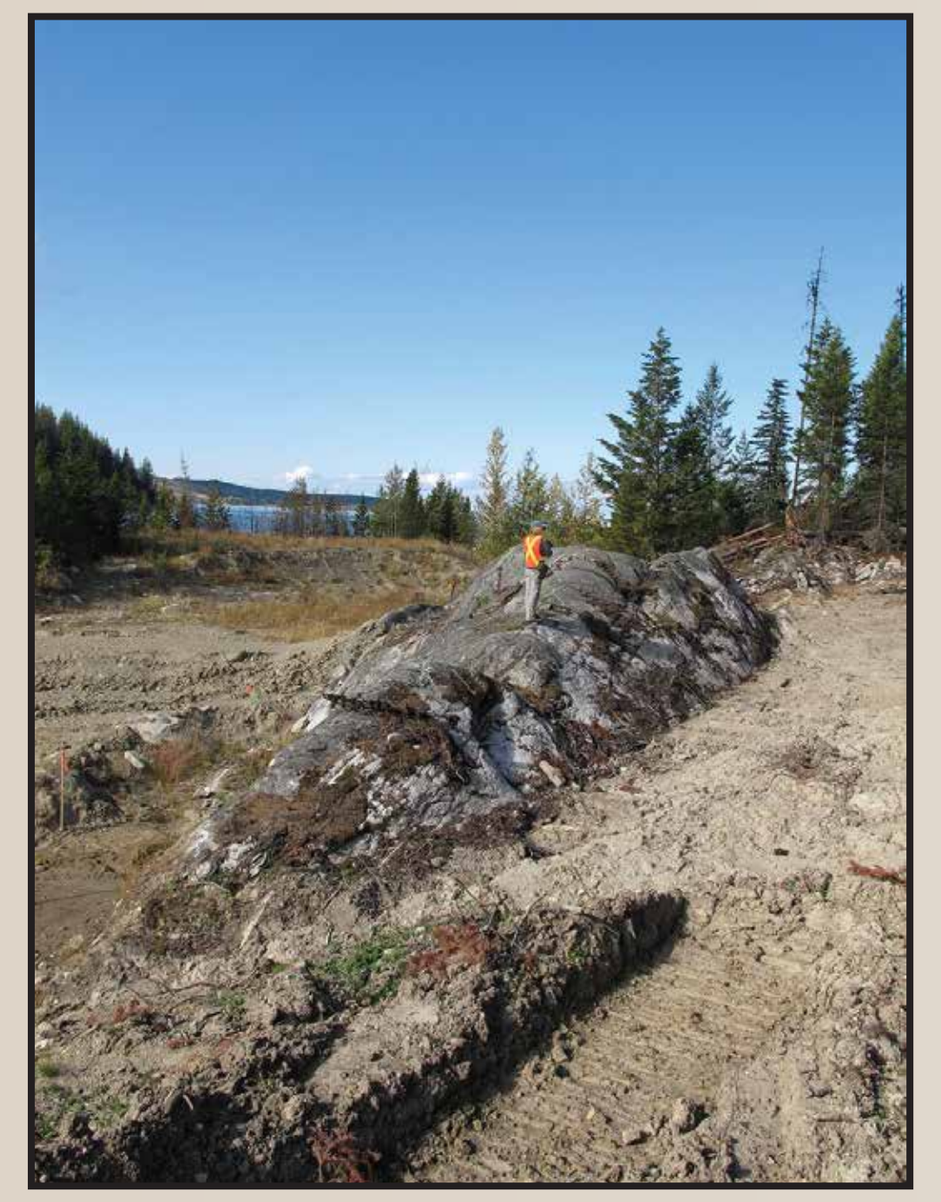
Ice-flow History

At the onset of the last glaciation, glaciers derived from the Cariboo Mountains were advancing generally to the southwest in the Gibraltar Mine region (see ice-flow map to the right). This first ice movement was identified in the glacial striation record measured on bedrock outcrops (two photographs below). As glaciation intensified, ice accumulated over the Interior Plateau of British Columbia resulting in the development of an ice divide around the 52° latitude from which ice was flowing to the northwest in the Gibraltar Mine area. Landforms such as flutings, crag-and-tails, and drumlins, roche moutonnées (see photograph below) and bedrock striations record this second phase of ice movement. A key outcrop was discovered during the 2012 field season on which mini crag-and-tails (rat tails) indicative of southeastward ice flow were measured (see photo below). The relative chronology of the southeastward flow with respect to the northwestward flow could not be established. The southeastward flow is tentatively interpreted to reflect the migration of an ice-divide to north of the mine or the readjustment of the ice profile during deglaciation. In summary, the Gibraltar Mine area was under the influence of three ice movements: to the southwest, northwest and southeast during the last glaciation.


Ice-flow history: Gibraltar Mine
Third phase (?) of ice flow; see text for details
Second phase (?) of ice flow from ice divide south of Gibraltar Mine
First phase of ice flow from Cariboo Mountains; defined,
approximate
LEGEND
Glacial striations (paleo ice-flow direction known, unknown)
Open pit mine
0
5
10
kilometres
122°35'
30'
15'
122°05'
52°40'
30'
52°25'
FRASER RIVER

View to the northeast at two rat-tails (black arrows) trending 145°. Site is located 3 km south of Gibraltar Mine. Knife is 20 cm long.

View to the northwest at striations trending 320°. Site is located 2.5 km northeast of Gibraltar Mine. Brunton compass is 20 cm long. From Anderson et al. (2012c).



View to the northwest at a roche moutonnée trending 315°. Site is located 5 km northeast of Gibraltar Mine. The person is 1.7 m tall. From Anderson et al. (2012c).

Methodology

Till samples were collected along forestry roads, dominantly from ditch sections at an average depth of 80 to 100 cm below the depth of most intense soil weathering (two photographs to the right). A large (10 kg) and small (2 kg) sample were collected at every site and processed following the flow chart below. The clay- (<0.002 mm) and silt plus clay-sized fractions (<0.063 mm) were submitted for geochemical analyses in a commercial laboratory (AcmeLabs, Vancouver, BC). Heavy mineral separation and identification were completed on the sand-sized fraction (0.250 – 2.0 mm) at Overburden Drilling Management Ltd., Ottawa, ON.

Bulk till sample

- ca. 10kg
  - Heavy mineral separation (0.25 - 2 mm; s.g. >3.2 and 3.2 - 2.8)
    - Identification of indicator minerals
- ca. 2kg
  - clay-sized fraction (<0.002 mm)
  - silt and clay-sized fraction (<0.063 mm)
    - Aqua regia ICP-MS (trace elements)
    - $LiBO_2$ / LiB_4O_7 HNO_3 fusion ICP-ES (major and trace elements)

s.g. - specific gravity
ICP-MS - inductively coupled plasma mass spectrometry
ICP-ES - inductively coupled plasma emission spectrometry
$LiBO_2$ / LiB_4O_7 HNO_3 - lithium borate/tetraborate, nitric acid

Typical sampling site along forestry road. Pick is 95 cm long.

Two samples collected at every site: ca. 2 kg and 10 kg samples. Shovel is 95 cm long.

Results

Cu content (aqua regia, ICP-MS) of the clay- and silt plus clay-sized fractions (Maps A and B): There is Cu enrichment in the clay-(>380 ppm) and silt plus clay-sized fractions (>183 ppm) of till in the region of the Gibraltar Mine. Both size fractions are depicting zones of enrichment extending 3 to 5 km north, west and south from the mine. However, the Cu levels are higher in the clay- (up to 5455 ppm) compared to the silt plus clay-sized fraction (up to 1803 ppm).

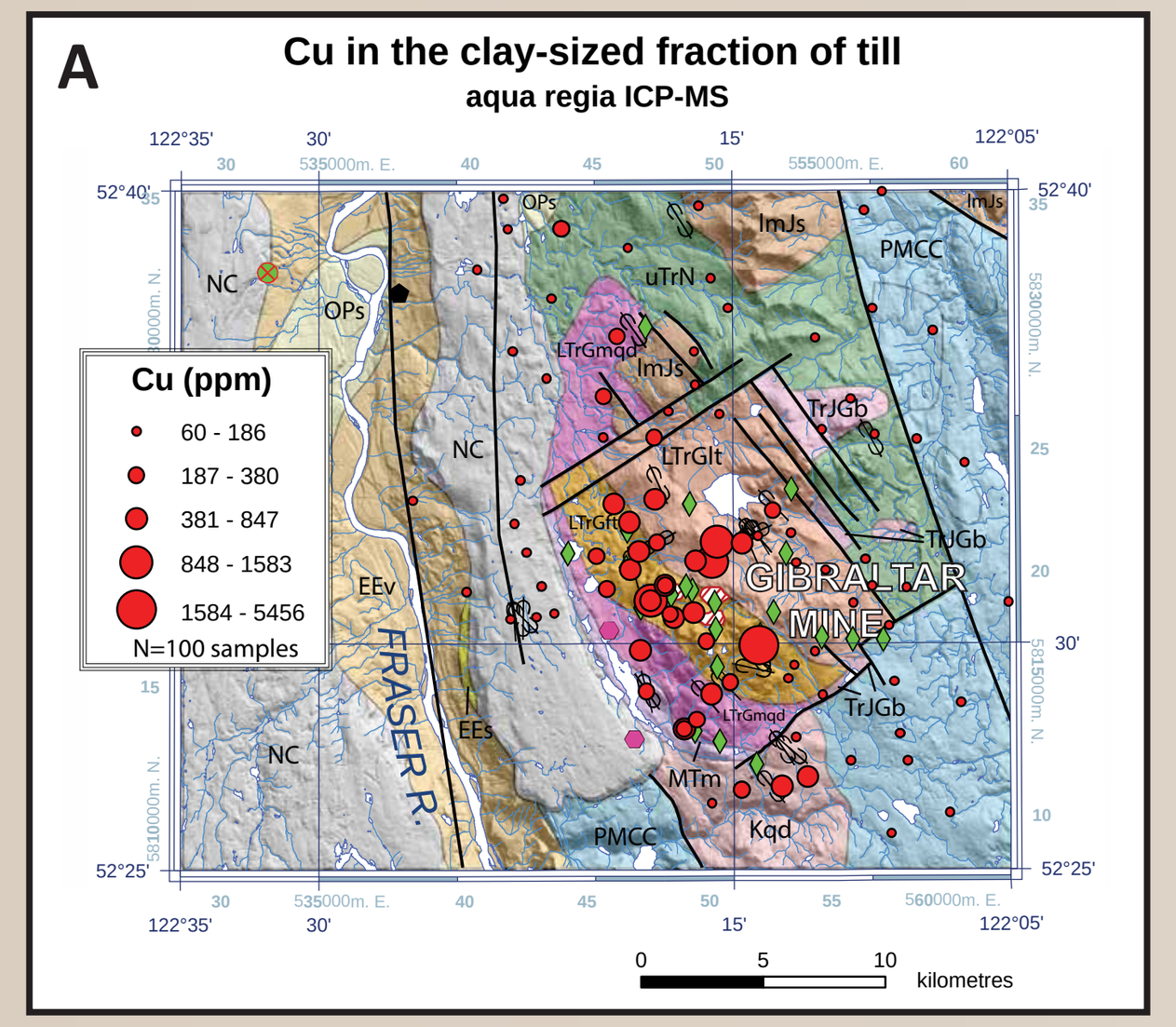
Mo content (aqua regia, ICP-MS) of the clay- and silt plus clay-sized fractions (Maps C and D): There is Mo enrichment in both sized fractions of till in the mine region (> 2 ppm in clay and the silt plus clay). However, the Mo zone of enrichment extending 2 to 3 km north, west and south from the mine is not as large as the one of Cu because the contrast between elevated and background is much lower for Mo than for Cu. The source of the elevated Mo content (6.7 ppm in clay and 5.11 ppm in silt plus clay) of a sample in the northeast sector of the study area is undetermined.

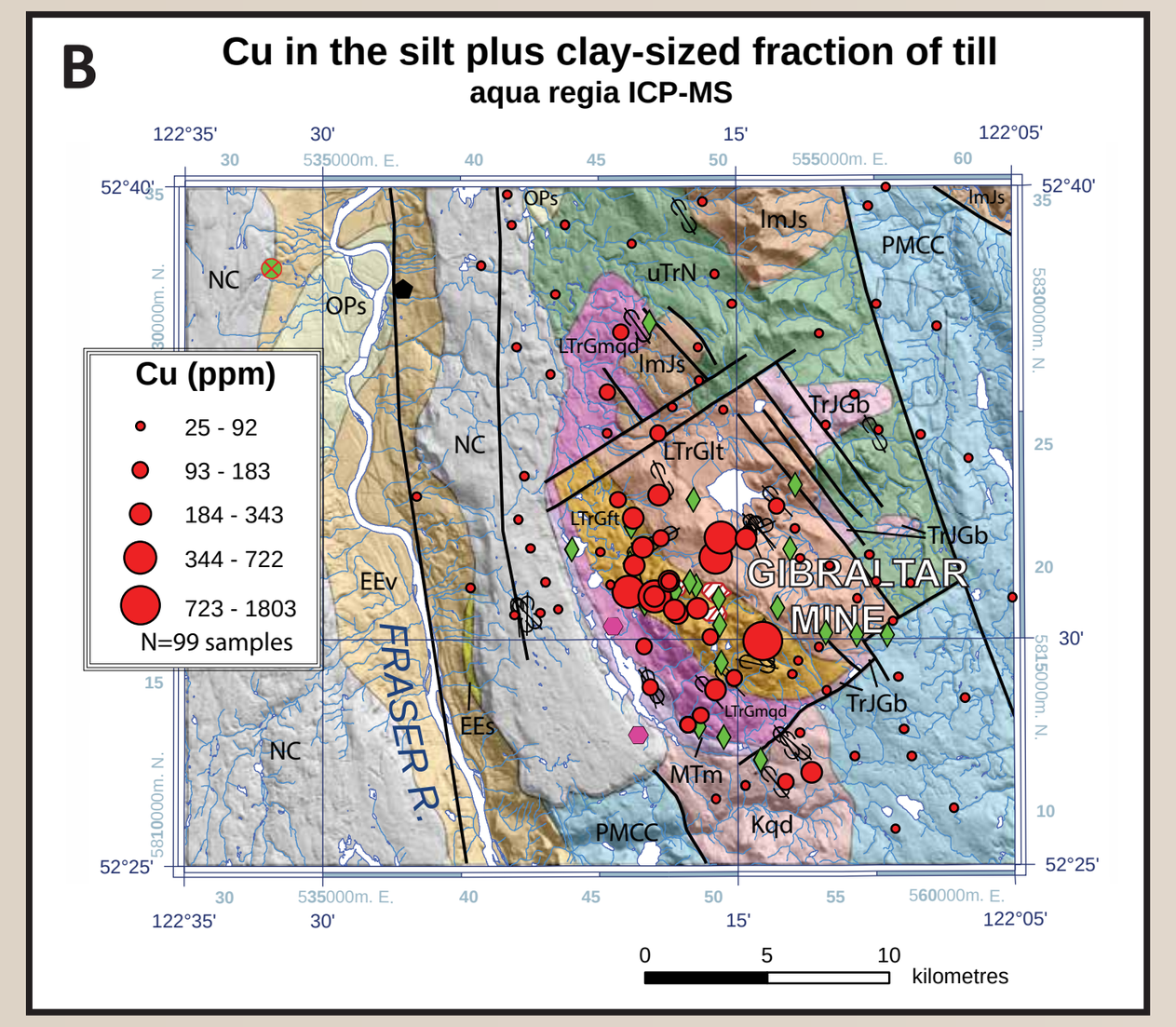
Zn and Ag (aqua regia, ICP-MS) content of the clay- and silt plus clay-sized fractions (Maps E, F, G, and H): Zn and Ag are enriched in both sized fractions of till in the mine region (Zn: >280 ppm in clay and >136 ppm in silt plus clay; Ag: >335 ppb in the clay and >283 ppb in silt plus clay). Bysouth et al. (1995) have defined sulphide zoning at Gibraltar Mine with a Cu-Mo core (chalcopyrite, molybdenite, ±bornite) changing outwards to a Cu zone (chalcopyrite ±molybdenite), a Cu-Zn-Ag zone (chalcopyrite, sphalerite) and a Zn zone (sphalerite ±chalcopyrite). The elevated Zn and Ag content of till is likely derived from the Zn and Ag zoning identified by Bysouth et al. (1995). Similarly, Plouffe et al. (2011) identified that the metal distribution in till follows the metal zoning observed by Bysouth et al. (1995). The sample with elevated Mo content in the northeast sector of the study area has an elevated Ag content (524 ppb in clay and 452 ppb in silt plus clay).

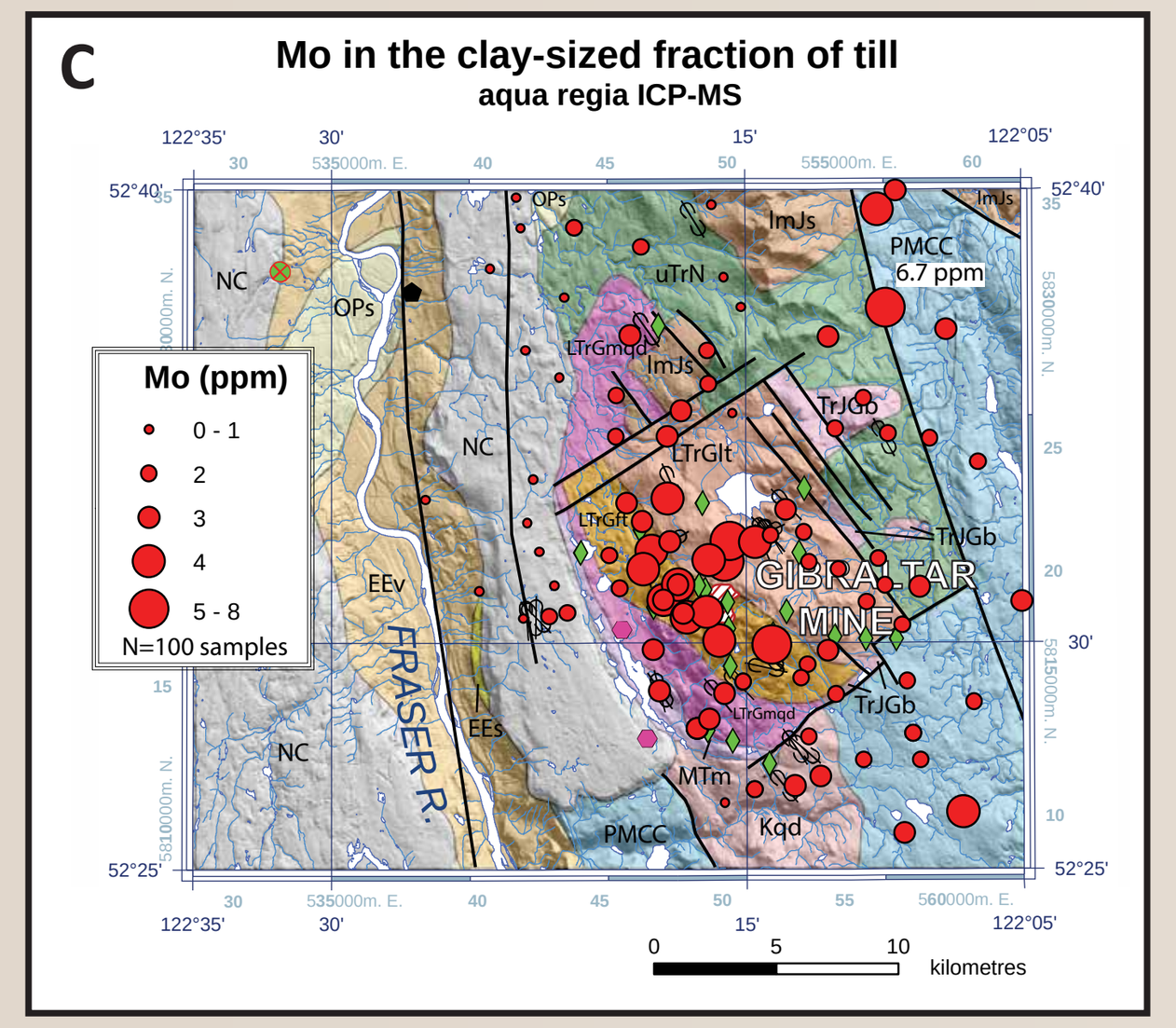
Chalcopyrite (Map I): The chalcopyrite grain counts (0.25 – 0.5 mm; s.g. >3.2) normalized to 10 kg of bulk till (<2 mm) are elevated (> 9 grains / 10 kg) in the mine region and extend 2 to 3 km north, west and south from the economic mineralization. The elevated chalcopyrite grain counts cover a region similar to the elevated Cu content of till.

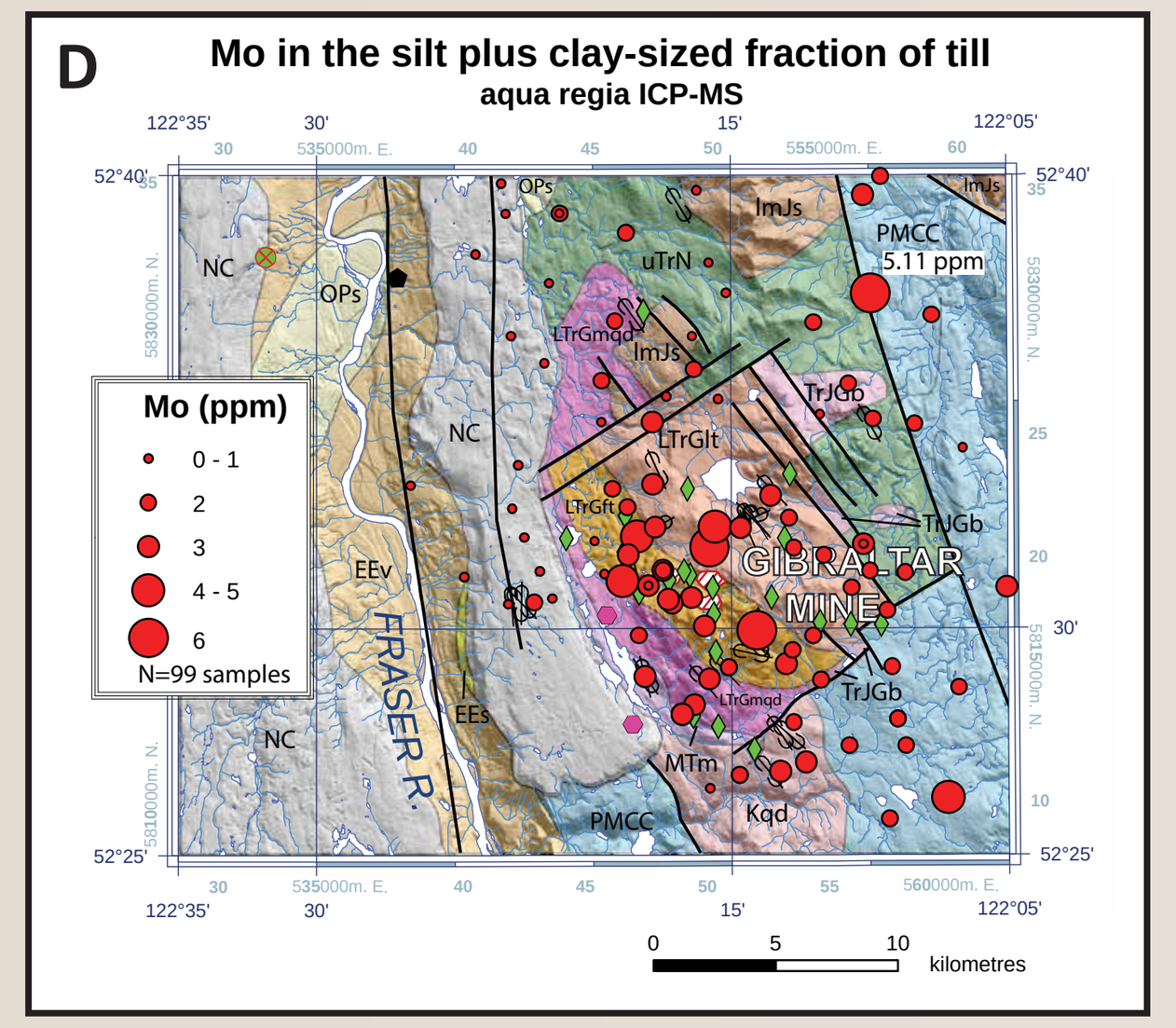
Green epidote (Map J): The elevated percentages of green epidote (0.25-0.5 mm; s.g. >3.2) in till (>70%) in the periphery of the mineralization are in contrast with the rest of the study area (<70%) and are interpreted to be reflecting the presence of propylitic alteration. Green epidote in till is not solely derived from propylitic alteration but from other sources such as the Nicola Group volcanic rocks. Therefore, the background epidote content of till in this region is not nil.

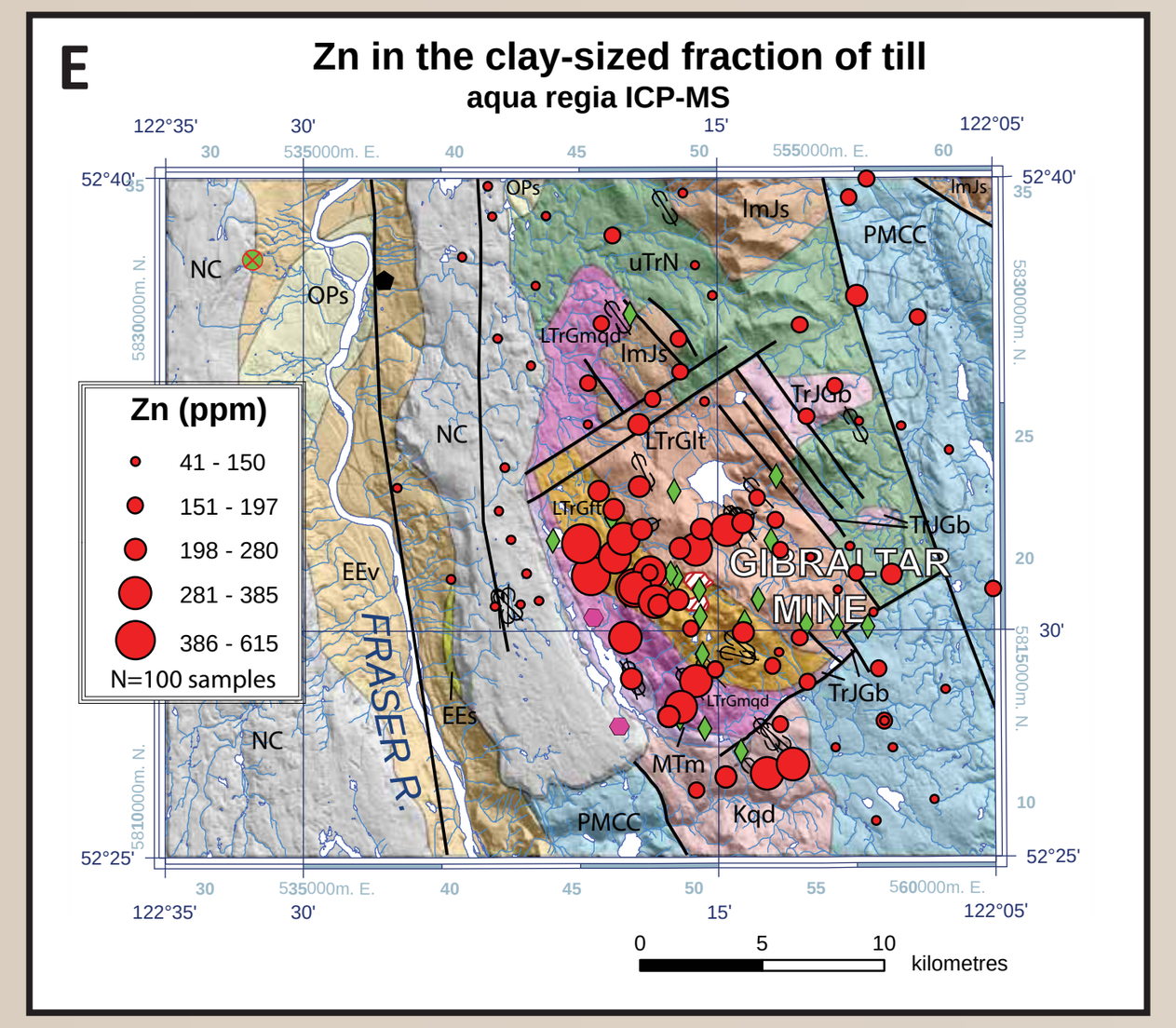
None of these indicators form dispersal trains extending in a single direction from the mine but rather form amoeboid dispersal trains that reflect irregular dispersal in multiple directions related to the complex ice-flow history and multiple bedrock sources (economic and sub-economic mineralized zones). Amoeboid dispersal was defined by Shilts (1993) to reflect dispersal pattern similar in shape to amoeba. Amoeboid dispersal has been described in other regions with shifting ice-flow directions similar to those observed in the Gibraltar Mine region.

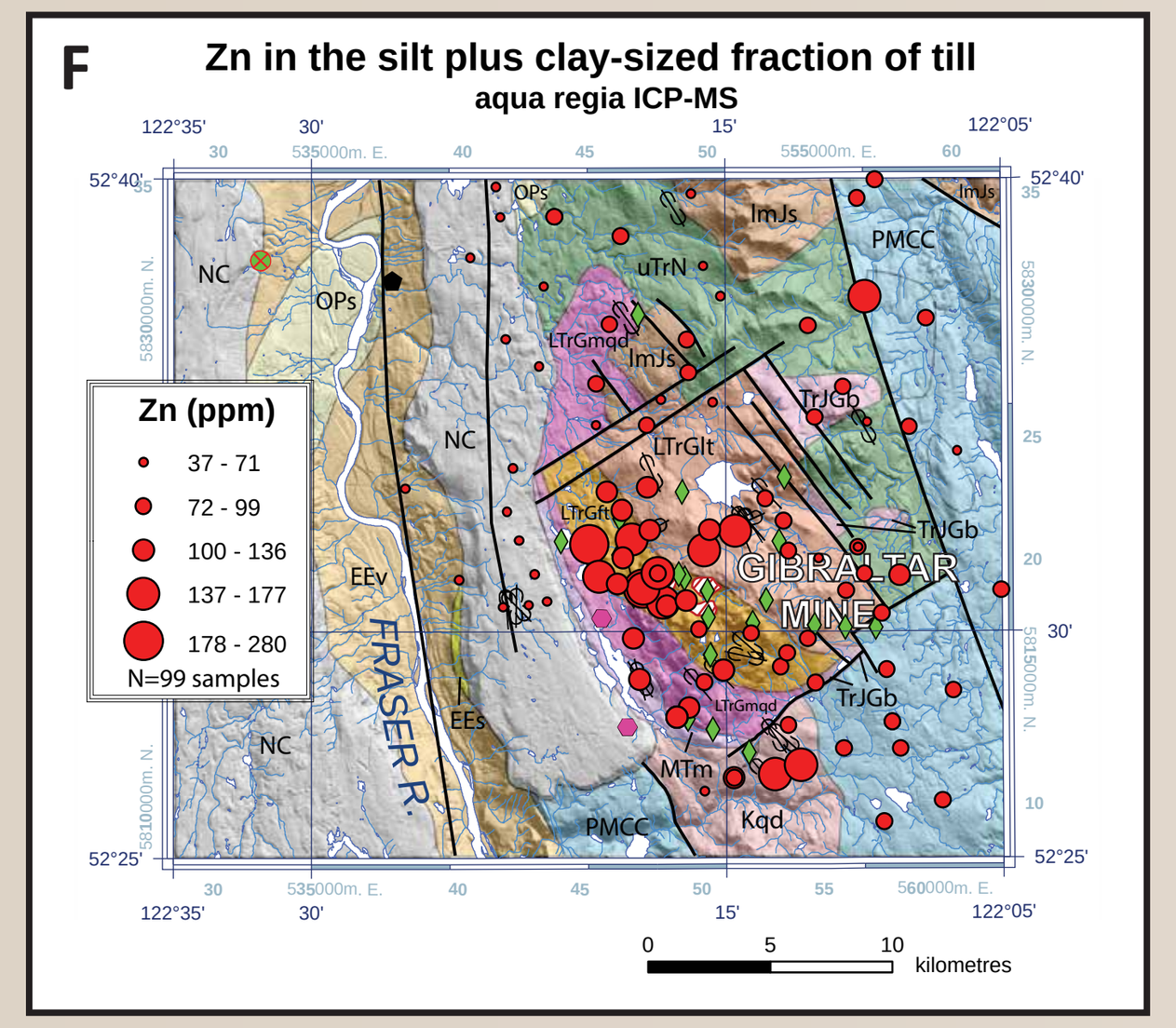


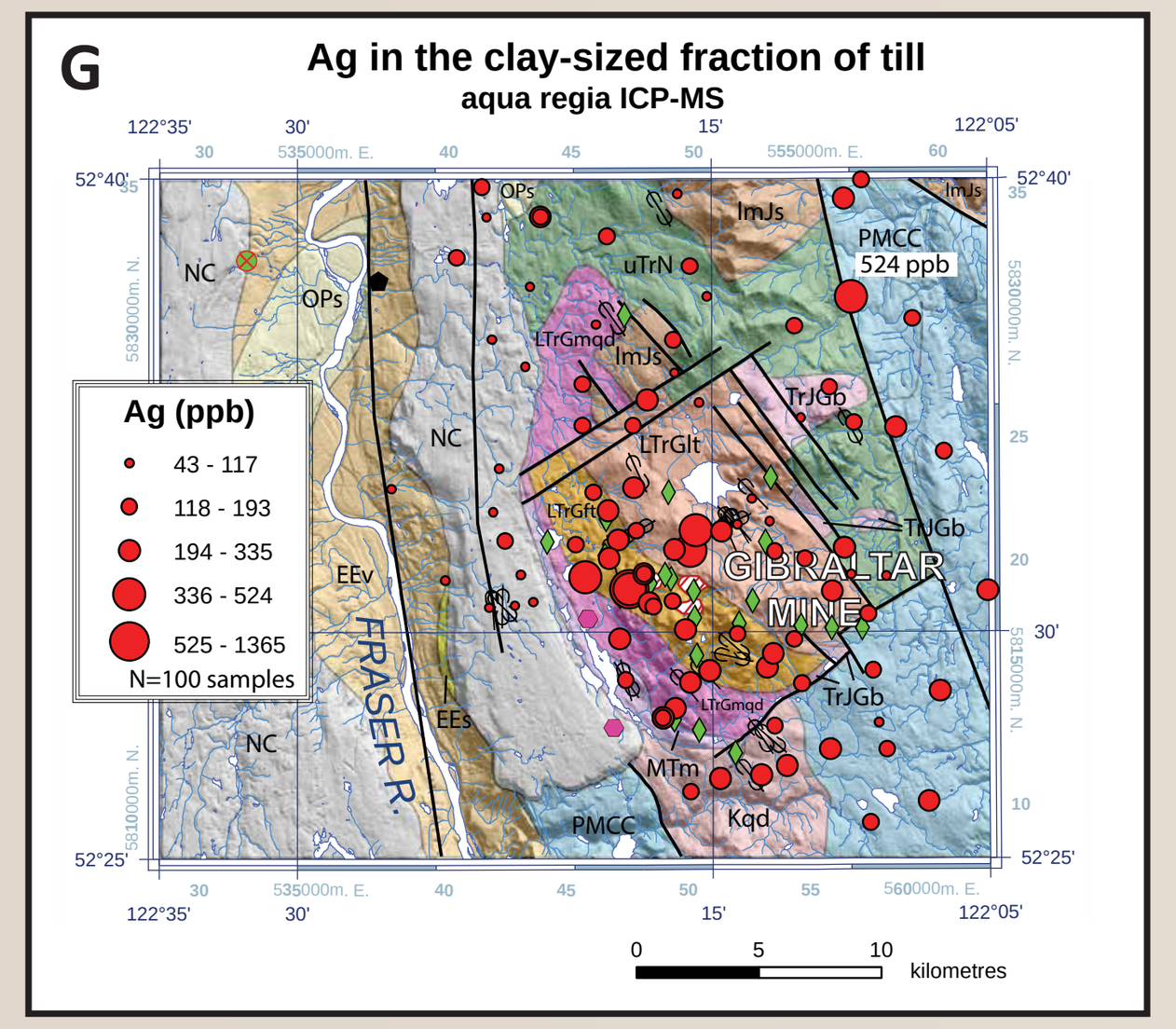


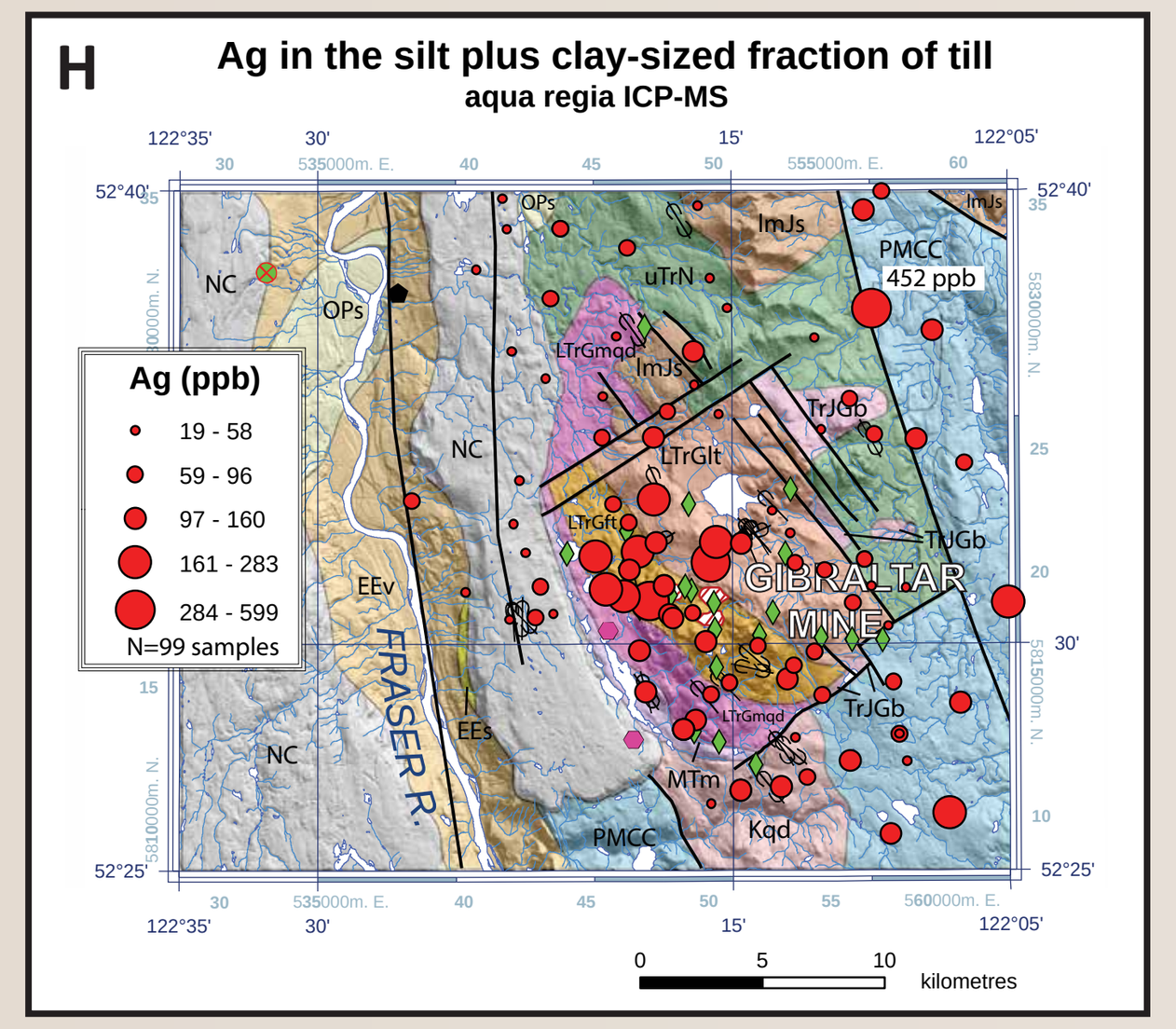


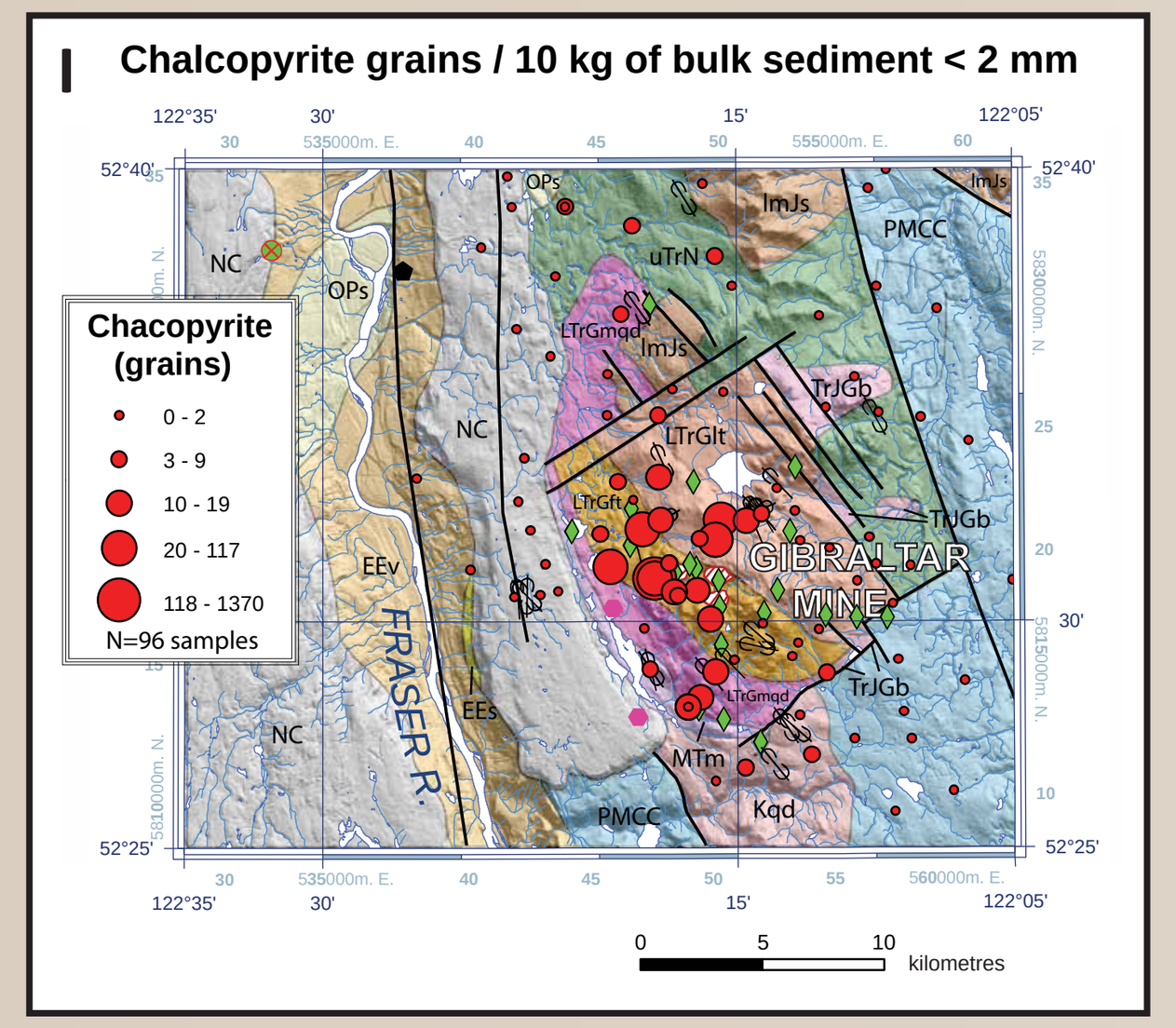


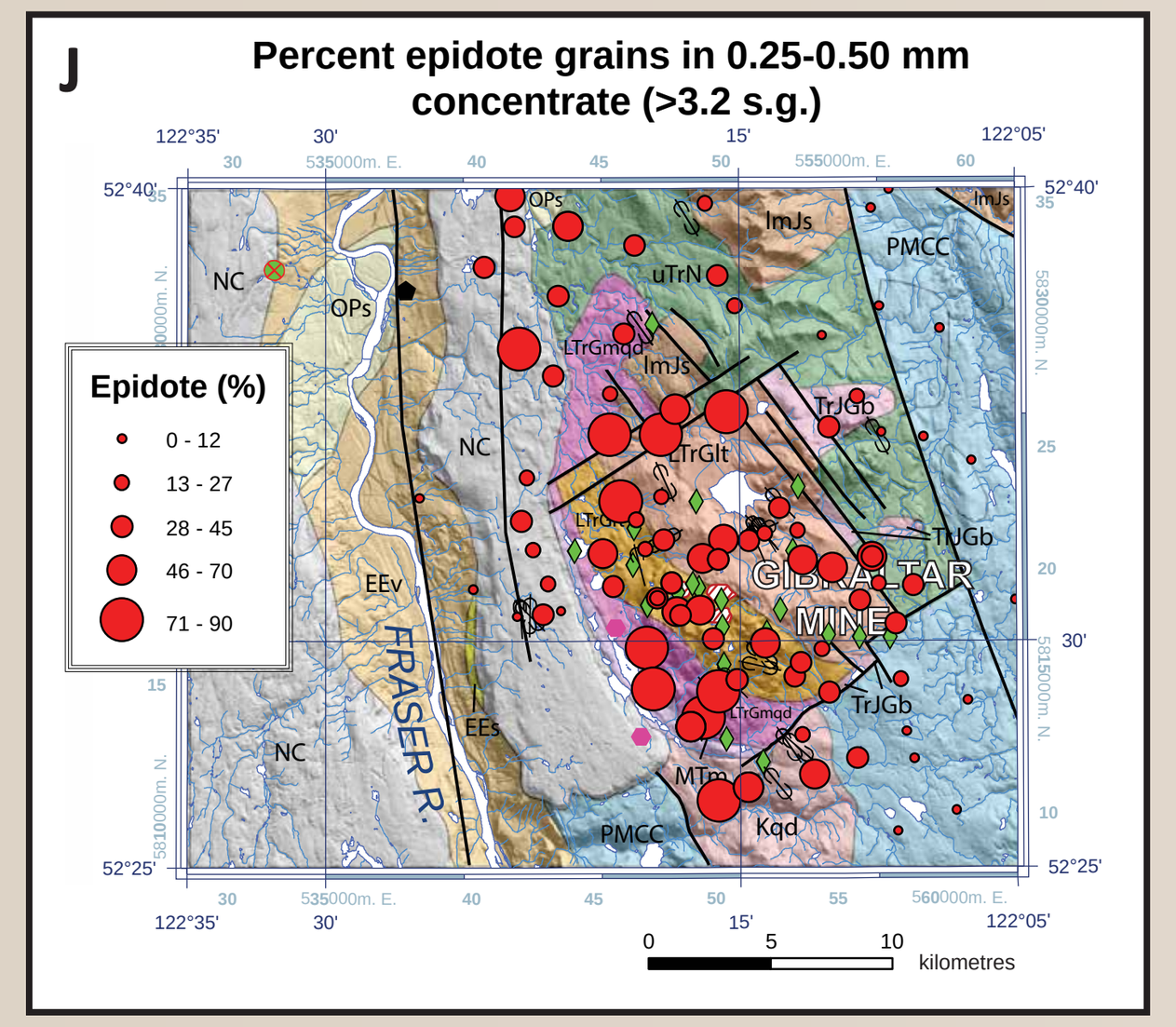


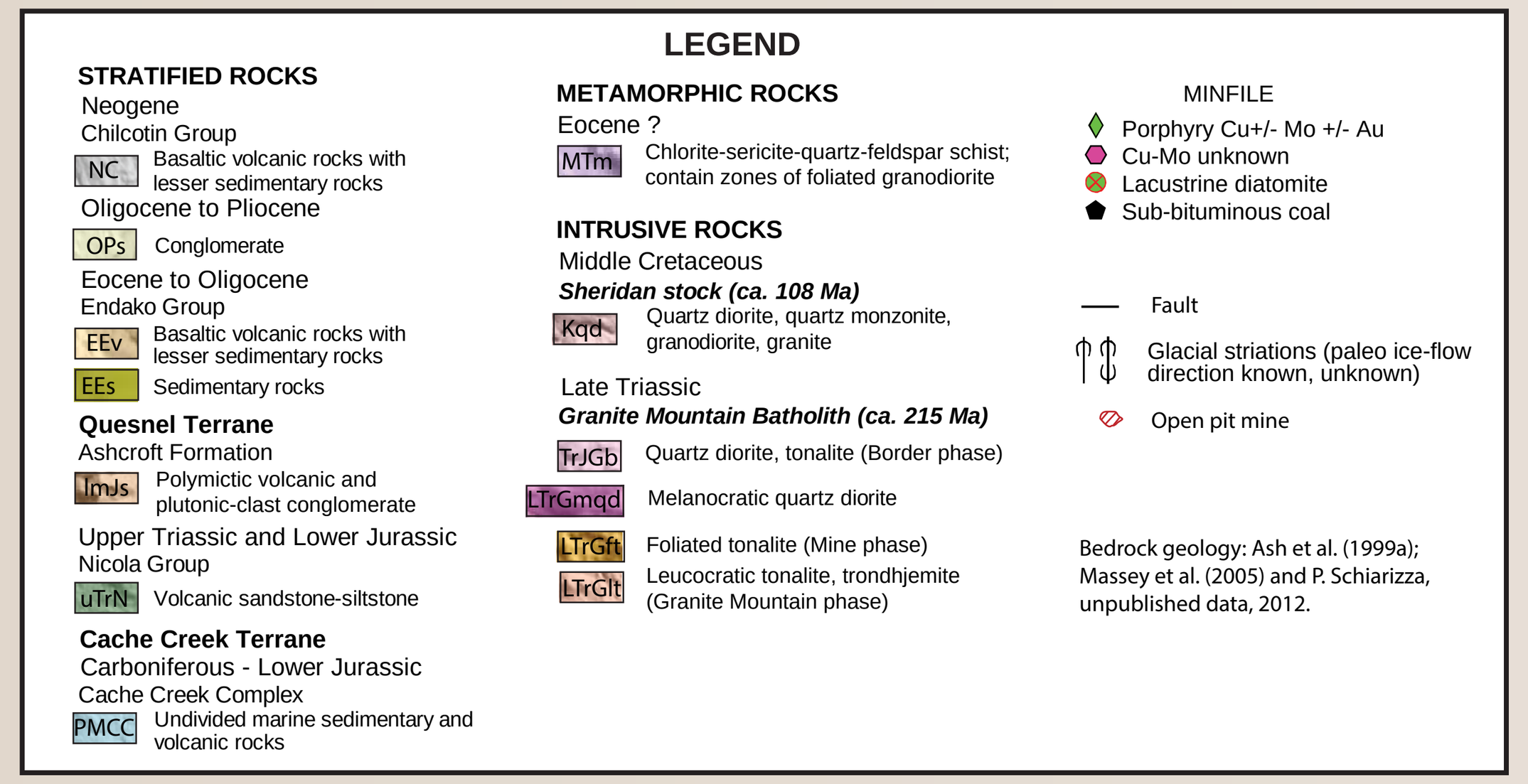












Conclusion

The porphyry mineralization at Gibraltar Mine is reflected in the geochemical composition of the clay- and silt plus clay-sized fractions (Cu, Mo, Zn, Ag) of till. Furthermore, chalcopyrite associated to the mineralization and green epidote associated to the propylitic alteration are enriched in till in the region of the mine. These results indicate that the geochemical and mineralogical indicators of porphyry mineralization identified in till as part of this study can be used for the search for buried porphyry mineralization in the Canadian Cordillera and in other glaciated landscapes.

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