TILL GEOCHEMISTRY OF THE HUCKLEBERRY MINE AREA, WEST-CENTRAL BRITISH COLUMBIA (NTS 093E/11)

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ABSTRACT

Basal till samples collected in the Huckleberry Mine area show that there is a good spatial relationship between the locations of elevated element concentrations and the locations of known mineralized bedrock. The maximum Cu and Mo values in the study (8924 and 216 ppm, respectively) occur in one sample at the northwest end of the Main Zone while maximum Au and Ag values (184 and 1721 ppb, respectively) occur over the western end of the Main Zone stock. The geochemical footprint of the orebodies at Huckleberry Mine is large with >95th percentile Cu values (>1515 ppm) occurring within 500 m of the Main and East zones. If put in to the context of a regional-scale till geochemical data set, and associated percentile class breaks, this footprint is substantially larger. Despite till thicknesses exceeding 30 m, subcropping mineralization at Huckleberry Mine can be detected in till samples right to surface. West dispersal can be preserved at surface in thick tills (tens of metres thick) and is associated with an ice flow reversal which occurred during the Late Wisconsinan glacial maximum. Sub- and near-surface till geochemical data sets suggest that samples elevated in commodity elements are offset 500 to 1000 m from their bedrock source.

INTRODUCTION

This report summarizes the results of a till geochemical study conducted in the vicinity of Huckleberry Mine (MINFILE 093E 037; Figure 1). The primary goal of this study is to document major, minor and trace element concentrations in tills adjacent to a known calcalkaline porphyry Cu±Mo±Au mineral deposit in west-central British Columbia. Initial results of this till geochemical survey are summarized by Ferbey and Levson (2007). Included here is a more detailed presentation of these data and of complementary studies into the area's stratigraphy and ice-flow history (Ferbey and Levson, 2001a, b; 2003; Ferbey, 2004).

The specific objectives of this study are to:

- model the horizontal and vertical dispersal of mineralization in till from known mineralized sources on Huckleberry Mine property using trace element geochemistry;
- characterise dominant or net detrital dispersal direction and transport distance of mineralization in till from these sources; and
- use till geochemistry to identify new geochemical exploration targets.

Figure 1. Location of study area.

The Huckleberry Mine area is within an area of west-central British Columbia that experienced an ice-flow reversal during the Late Wisconsinan glacial maximum and that has high potential for porphyry Cu±Mo±Au mineralization. The area is ideally suited to an investigation on the influence of ice-flow reversals on the dispersal of basal till for several reasons, including:

- proximity of the area to a shifting ice-divide that formed in west-central British Columbia during the Late Wisconsinan glacial maximum;
- dominance of basal tills in the area and numerous Quaternary exposures (from bedrock to surface and up to 20 m thick) on the Huckleberry Mine property that enable the detailed study of the local stratigraphy and the collection of basal till samples; and
- a unique set of sub-surface basal till samples that were collected prior to this study using a Becker hammer drill rig.

Geochemical data presented here will enable meaningful assessments of new regional-scale till geochemical data that have been collected in areas adjacent to the mine and provide a means of comparison for other explorationists working in the area who are using other geochemical sample types (e.g., stream sediments, till, etc.). As well, these results will help with the development of strategies for the design and implementation of till geochemistry programs in areas with similar physical and geological characteristics and complex glacial histories.

LOCATION AND PHYSIOGRAPHY

The study area is located in west-central British Columbia, approximately 120 km by road southwest of Houston, BC (Figure 1). In the Huckleberry Mine area, centred in the north-central part of NTS map area 093E/11, Quaternary sediments were studied in detail and basal till samples were collected for trace element geochemical analyses (Ferbey and Levson, 2001a; 2003; 2007 Ferbey, 2004). At a more regional scale, studies of streamlined and erosional landforms and features were conducted in NTS map areas 93E/10, 11, 14, 15, 16 to determine the Late Wisconsinan ice-flow history of the Tahtsa Lake – Ootsa Lake region (Ferbey and Levson, 2001b).

The study area was accessed by a moderately dense network of Forest Service and private mine roads. Abandoned mine roads and a private forestry barge were also utilized to access some of the more remote parts of the study area. Quaternary exposures along the shores of Ootsa Lake, Tahtsa Lake, and Tahtsa Reach were accessed by boat while remote mountain peaks in the study area were reached by helicopter.

The study area is situated within the Tahtsa Ranges, a belt of non-granitic mountains 15 to 25 km wide with a general northwest trend (Figure 2a). These ranges are within the Hazelton Mountains physiographic division (Holland, 1976), which is situated between the Coast Mountains to the west and the Nechako Plateau to the east (Figure 2b).

a)

b)

Figure 2. Physiography of Huckleberry Mine area. a) Looking northeast across Huckleberry Mine towards the Nechako Plateau; Tahtsa Reach and tailings pond in foreground and Huckleberry Mountain at centre (photo: D.J. Mate). b) Looking southwest from Huckleberry Mountain, over Huckleberry Mine, across Tahtsa Reach towards Mount Carl Borden. Main and East Zone pits, and mine buildings, can been seen in centre of photo, with the tailings pond in upper right.

The Tahtsa Ranges are dissected by major valleys trending east to northeast which are occupied by prominent lakes (e.g., Eutsuk, Ootsa, Tahtsa, Troitsa, and Whitesail lakes). Valley bottoms and mountain flanks are largely covered by thick sequences of Quaternary sediments with little bedrock exposure. Upper slopes and peaks extend into subalpine and alpine environments where bedrock outcrop is abundant.

Huckleberry Mine falls within the Tahtsa Lake Mining District and is located on the north side of Tahtsa Reach. It is a producing porphyry Cu-Mo open pit mine with minor recoverable amounts of Au and Ag. Ground preparation and pit development has produced easily accessible, clean and vertical Quaternary exposures that vary from approximately 1 to 20 m in height. The minesite itself is located in a poorly drained, arcuate, montane valley at the foot of Huckleberry Mountain, at approximately 1050 m asl. In this report this valley is referred to as Huckleberry valley. Drainage from this valley is directed to the southeast and to the west-southwest by a network of narrow, low-discharge streams which empty into Tahtsa Reach.

BEDROCK GEOLOGY

Regional Geology

The study area was included by Hedley (1935) in his 1:250 000-scale bedrock geology map of the Tahtsa-Morice area. Duffel (1952) also worked in the area and completed a regional-scale bedrock geology map of the Whitesail Lake map area (NTS 93E) while Woodsworth (1980) compiled this early mapping at 1:250 000-scale. More detailed 1:50 000-scale bedrock geology mapping was completed by Diakow and Mihalynuk (1987), which included the eastern half of NTS map area 93E/11.

Other geological work completed in the study area has focused on specific aspects of bedrock and mineral deposit geology (e.g., Carter, 1981). MacIntyre (1985) narrowed his study to described the geology and mineral deposits found in the Tahtsa Lake District.

The Tahtsa Lake District lies within the Intermontane Tectonic Belt, just east of the Coast Crystalline Belt (Monger et al., 1991). It is underlain mainly by Early to Middle Jurassic Hazelton Group volcanic and sedimentary rocks. These rocks are predominantly fragmental, red and green in colour, lapilli, lithic, and crystal tuffs, and tuff breccias (MacIntyre, 1985). Minor intercalations of porphyritic andesite, tuffaceous siliceous argillite, and pebble conglomerate also occur, and locally these rocks can include grey cherts and light-coloured felsic volcanics (e.g., ryholites). The Hazelton Group is unconformably overlain in areas by Middle to Late Jurassic Bowser Lake Group marine sedimentary rocks and Early Cretaceous Skeena Group turbidites and local basalt flows. These rocks are, in turn, unconformably overlain by felsic pyroclastics, felsic flows, and younger basaltic flows of Early to Late Cretaceous Kasalka Group volcanics. Many small to medium-sized, Late Cretaceous to Early Tertiary stocks have intruded these volcanic and sedimentary rocks (e.g., Bulkley Intrusions). Late Cretaceous to Early Tertiary rhyolitic to basaltic dike swarms occur in the region with general northwest trends (MacIntyre, 1985; Jackson and Illerbrun, 1995).

Huckleberry Mine Geology

The bedrock geology of Huckleberry Mine consists of two porphyritic hornblende-biotite-feldspar granodiorite stocks of the Late Cretaceous Bulkley Intrusions (Figure 3). These stocks intrude Early Jurassic Telkwa Formation pyroclastic andesites of the Hazelton Group (Figure 3; Blower, 2000) and may have been constrained by several east-west-trending faults and shear zones. Hazelton Group rocks that occur on the Huckleberry Mine property are biotite hornfelsed, which is thought to be associated with the emplacement of the Late Cretaceous intrusions.

Mineralization of the Main and East zone orebodies occurs within a stockwork system of fractures and veinlets in the hornfelsed, fragmental Telkwa Formation andesites. The deposit has been described as a classic calcalkaline Cu±Mo±Au porphyry (Panteleyev, 1995; Jackson and Illerbrun, 1995). Within the core of the mineralized areas, sulphide mineralization consists of chalcopyrite (l to 3%), molybdenite (<0.3%), and pyrite (l to 3%) (Blower, 2000). Mineralization grades outward from this to a pyrite rich halo (l to 5%) with minor chalcopyrite (0 to 0.3%). Supergene chalcocite and native Cu are only rarely observed near the bedrock/till contact. Minor malachite and tenorite can also occur on bedrock surfaces, in particular on hill-flanks outside of the Main and East zone pit limits (Blower, 2000).

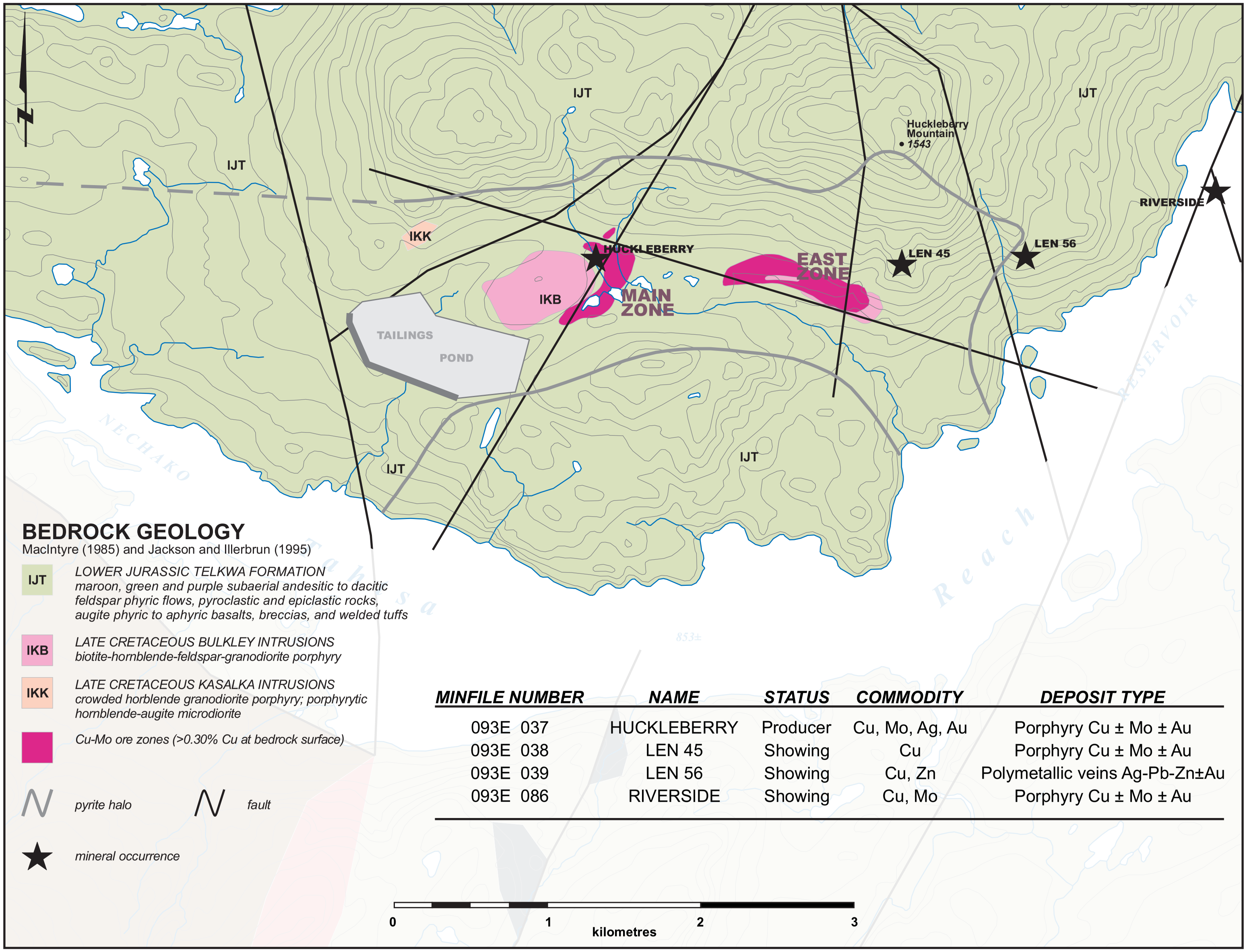
The dominant control on emplacement of mineralization is the stocks themselves. The orebodies occur as annular shells along the margins of, and adjacent to, the stocks. The grade of mineralization is dependent on the intensity of potassic alteration of the intrusive and host rocks, and the density of fractures in the host rocks (MacIntyre, 1985; Jackson and Illerbrun, 1995). Although there is Cu and Mo mineralization within both stocks, nearly all ore mined is from the adjacent volcanic rocks. Mineralization also appears to have been focused along a northeasterly-trending, steeply dipping shear zone that occurs along the east side of the Main zone stock (MacIntyre, 1985; Jackson and Illerbrun, 1995).

Cropping-out approximately 500 m northwest of the Main Zone stock is a small Late Cretaceous granodiorite stock that has intruded Telkwa Formation andesites (Figure 3). Belonging to the Kasalka Intrusions, this stock is approximately 250 m long and 150 m wide and trends northeast (MacIntyre, 1985). Mineralization has not been documented in the vicinity of this small stock. Elevated metal values in nearby till samples will be discussed later in this report.

Reserves in the Main and East zones have been exhausted and extraction is now taking place in the Main Zone extension pit, a north-trending continuation of the northern portion of the Main Zone orebody (Imperial Metals, 2011).

Geochemical Signature of Calcalkaline Porphyry Cu±Mo±Au Deposits

Calcalkaline Cu±Mo±Au porphyry deposits are zoned laterally outwards from: 1) a pyritic low-grade



MINFILE NUMBER	NAME	STATUS	COMMODITY	DEPOSIT TYPE
093E 037	HUCKLEBERRY	Producer	Cu, Mo, Ag, Au	Porphyry Cu ± Mo ± Au
093E 038	LEN 45	Showing	Cu	Porphyry Cu ± Mo ± Au
093E 039	LEN 56	Showing	Cu, Zn	Polymetallic veins Ag-Pb-Zn±Au
093E 086	RIVERSIDE	Showing	Cu, Mo	Porphyry Cu ± Mo ± Au

Figure 3. Bedrock geology, ore zones, and MINFILE occurrences of the Huckleberry Mine area.

potassic/propylitic altered core (see Late Cretaceous Bulkley intrusions, Figure 3); to 2) potassic or phyllic alteration zones with associated ore-grade Cu±Mo mineralization (see Main and East zone ore bodies, Figure 3); to 3) a barren propylitic pyritic halo (see pyrite halo, Figure 3; Jackson and Illerbrun, 1995; Panteleyev, 1995). In general, the geochemical signature of calcalkaline porphyry Cu±Mo±Au deposits is related to the lateral zoning of mineralization. Central zones containing Cu mineralization are commonly associated with Mo, Au, and Ag, and possibly Bi, W, Bo, and Se. Peripheral to this Cu zone, Pb, Zn, Mn, Va, Sb, As, Se, Te, Co, Ba, Ru, and possibly Hg enrichment can be observed (Panteleyev, 1995).

Mineral Occurrences

Four MINFILE occurrences are recorded in the study area and are summarized here.

Main and East Zones (MINFILE 093E 037)

The Main and East zone orebodies (Figure 3) have been previously discussed. The Huckleberry occurrence (MINFILE 093E 037) is located on the northwest end of the Main Zone orebody. The orebodies shown in Figure 3 are approximately delineated by economic mineralization (i.e., >0.30% Cu). Mineralization, although typically at lower concentrations, extends out from these orebodies (e.g., Main Zone extension pit).

Len 45 (MINFILE 093E 038)

The Len 45 Cu showing (MINFILE 093E 038) is located approximately 250 m northeast of the East Zone intrusion (Figure 3). Occurring as isolated stringers of chalcopyrite within hornfelsed Telkwa Formation rocks, this porphyry Cu showing appears to be related to a narrow northwest-trending, Tertiary-age, feldspar porphyry dyke (MacIntyre, 1985; Panteleyev, 1995). MacIntyre (1985) mapped another northwest-trending dyke, of similar composition <300 m east of this occurrence but there is no documented mineralization associated with it.

Len 56 (MINFILE 093E 039)

Located almost 1 km east of Len 45, is Len 56 (MINFILE 093E 039; Figure 3). This is a hydrothermal vein-type Cu-Zn showing in which quartz and calcite veinlets up to 10 cm wide are spaced erratically within an area approximately 250 m by 125 m. These veinlets contain arsenopyrite, chalcopyrite, pyrite, and sphalerite mineralization (Lefebure and Church, 1996).

Riverside (MINFILE 093E 036)

The most easterly known source of mineralization is the Riverside showing (MINFILE 093E 036; Figure 3). This is a replacement vein-type Au-Ag-Cu-Zn showing with veins and fractures up to approximately 36 cm wide, carrying arsenopyrite and minor amounts of pyrite, sphalerite, and chalcopyrite (Lefebure and Church, 1996; Alldrick, 1996). Riverside showing is now underwater following the flooding of Tahtsa River and the creation of Nechako Reservoir.

QUATERNARY GEOLOGY

The surficial geology of the study area was mapped by the British Columbia Ministry of Environment, Lands, and Parks (1976) at a scale of 1:50,000, while a more detailed 1:10,000 scale map of the Huckleberry Mine property was produced by New Canamin Resources (1993). In both cases, these maps are limited to the delineation and interpretation of landforms only; identification and interpretation of surficial sediments was not included.

The surficial geology of the Huckleberry Mine area has most recently been mapped by Ferbey and Levson (2003), while the ice-flow history for the Tahtsa-Ootsa lake area (which includes the Huckleberry Mine area) is described and summarized by Ferbey and Levson (2001b). Other Quaternary geological studies have been conducted by Tipper (1994), Levson et al. (1998, 1999), Mate and Levson (1999), and Stumpf et al. (2000), Ferbey (2010, 2011) but are limited to areas adjacent to the study area.

Surficial Geology

Late Wisconsinan Glacial Sediments

The dominant surficial unit found in the study area is a massive diamict, 2.5 to 19 m thick (Figure 4). Its character varies laterally and vertically, but it typically is a matrix-supported, sandy-silt, light brown to light gray, diamict. Locally it is dark grey and clay-rich. It has moderately well developed vertical jointing and exhibits good sub-horizontal fissility and high density. Modal clast size is medium to large pebble, but ranges from granule up to large cobble. Clast shape is generally sub-angular to sub-rounded, with locally higher concentrations of angular to sub-angular clasts. Matrix percent is typically 60 to 80%, and striated clasts are common. Lower contacts are typically clear to diffuse, and sub-horizontal to weakly undulating. This unit is interpreted as a basal till. Regional stratigraphic correlations suggest that this till was deposited during the Late Wisconsinan Fraser Glaciation.

Mineralized andesite and granodiorite clasts are common in tills immediately adjacent to, and west of, the Main and East zones; as are pyrite and chalcopyrite grains within the till matrix. Iron and Mn oxidation occurs mainly on joint planes, but near the surface (in the upper 1 to 2 m) the entire diamict matrix can be oxidized. Where the matrix is oxidized, extreme weathering of clasts (in particular intrusive lithologies) can occur. In most sections, this basal till overlies polished, grooved, and striated bedrock, but locally can overlie clast-supported, matrix-filled, rounded, small to large pebble gravels. These gravels commonly have cross-bedded, fine to coarse-grained sand lenses, ranging from a few centimetres to a few metres wide, and a few centimetres to tens of centimetres high. These gravel units are up to 3 m thick, and have sharp, trough-shaped lower contacts. They are interpreted as being glaciofluvial in origin.

Basal till also locally overlies laminated silts and clays, and thinly bedded, fine to medium-grained sands, that contain numerous, small to medium pebble dropstones and deformed sedimentary structures. These silts and clays are commonly interbedded with massive, matrix supported, sandy diamict lenses, 2 to 3 m in length, and up to 1 m high. Lenses have sharp, small scale (5 to 30 cm long, 0.5 to 1 cm high) undulatory to trough shaped lower contacts. Silt and clay units are up to 3 m thick, and have sharp, planar to sub-horizontal lower

Figure 4. A typical example of a dark grey, overconsolidated, clayey-silt basal till at Huckleberry Mine. The blocky appearance is due to well developed joint and fissility planes. In this photo, basal till is overlying mineralized andesite (pyrite±chalcopyrite) of the East Zone orebody.

contacts. They are interpreted as glaciolacustrine (possibly subglacial) sediments, with interbedded subaqueous debris flow deposits. They are only observed in exposures in the vicinity of the East Zone.

Multiple Till Units

At section TFE00-1, four till units have been identified and are labelled as 1, 2, 3a, 3b, and 4 in Figure 5. These basal till units are divided primarily on changes in matrix texture, colour, and percent clast content. For example, clast content in the upper portions of unit 4 is up to 50%. This is an increase over the typical 20 to 30% values observed in lower portions of this exposure. Also occurring in the upper portion of unit 4 is a change in matrix colour to a dark brown. All till units described below this are light to dark grey in colour. These differences likely represent a change in provenance.

Other primary features such as fissility, jointing, and density also change between units. For example, these features are more strongly developed in units 1 to 3 where the matrix has a higher component of silt/clay and lower clast content. Although most units are massive, units 1 and 4 can locally be crudely stratified (Figure 5). This stratification can take the form of sandy to gravelly lenses or discontinuous, sub-horizontal, silt/clay laminae found within the till matrix.

Clast lithologies occurring within these till units also vary. Of the clasts collected in units 2 and 3a, <5% are porphyritic granodiorites. In contrast, pebble counts conducted in unit 4, ~2.0 m below surface, yielded quite different results with approximately 10% of clasts being porphyritic granodiorite. Approximately 50 m west of section TFE00-1, the percentage of granodiorite clasts is even higher (27%) in till of unit 4. The enrichment of grandiorite clasts in this near-surface till unit, and changes in matrix colour and texture almost certainly reflects a change in provenance. The closest known source for granodiorite clasts is the Main Zone stock, <1 km to the east, which suggests that ice-flow direction, during deposition of this unit, was towards the west. This general lack of granodiorite clasts in the lower till units at section TFE00-1 suggests that an eastern provenance for these sediments is unlikely.

Holocene Sediments

Glacial units are often capped on steep valley slopes by angular to subangular, medium pebble to large cobble, colluvial deposits that are typically >1 m thick. In valley bottom settings they commonly grade upwards into organic soils and locally peats. The depth of Holocene soil development averages a few tens of centimetres.

Late Wisconsinan Ice-flow History

The Huckleberry Mine area, and surrounding region, has a complex Late Wisconsinan ice-flow history (Figure 6; Ferbey and Levson, 2001b). Orientations of small-scale (e.g., grooves, striae, rat-tails, and roches moutonnées) and intermediate to large-scale (e.g., drumlins, crag-and-tail ridges, roches moutonnées, and flutings) streamlined and erosional forms were measured as part of this study. Their orientations suggest there are two dominant ice-flow directions in the region: 050º to 090º (east/northeast) and

Figure 5. Section TFE00-1. a) Looking east into West Borrow Pit, location of section TFE00-1. b) Till units identified at this section are labelled in the stratigraphic column and in photographs.

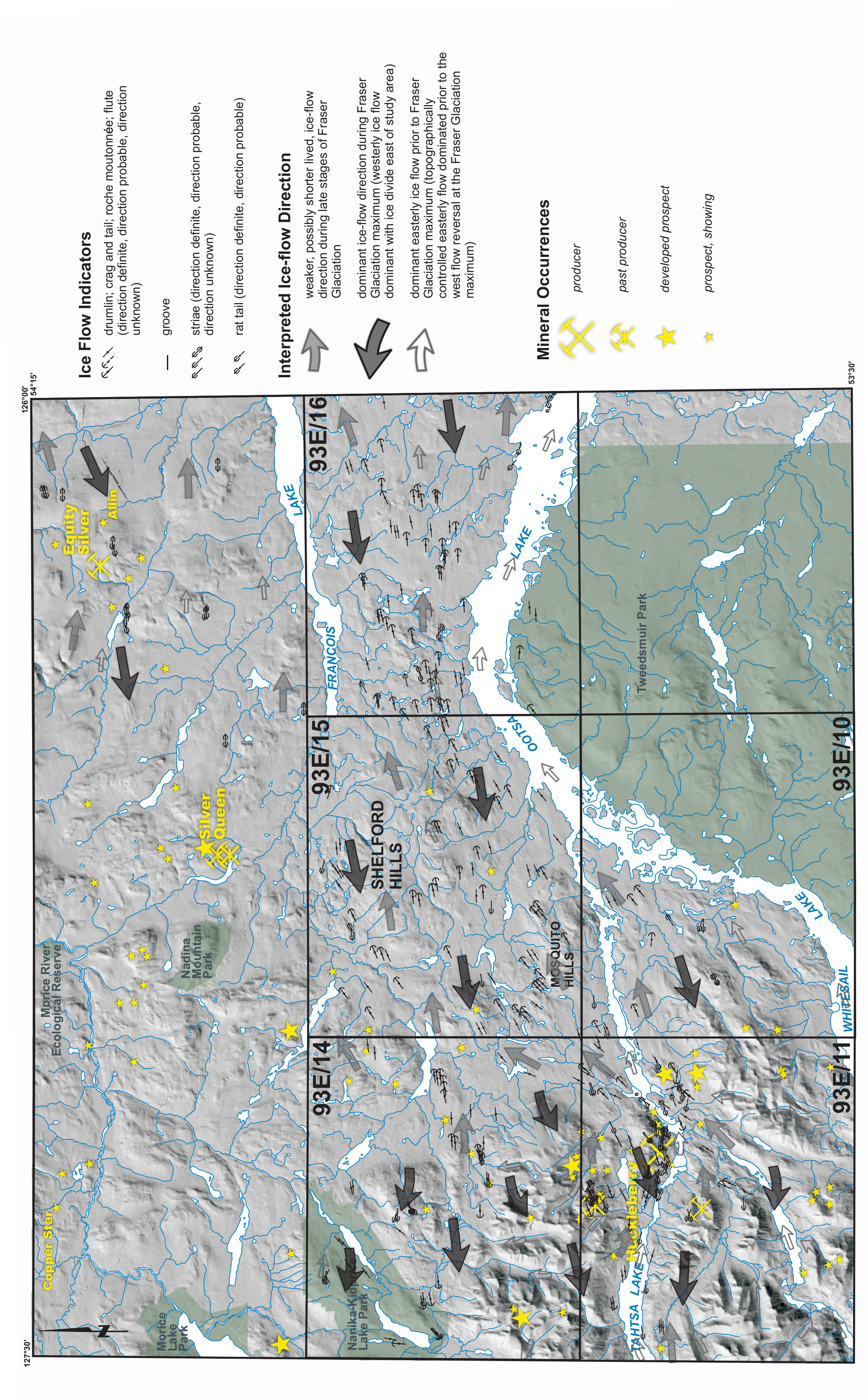


Figure 6. Ice-flow history of the study area and surrounding region (after Ferbey and Levson, 2001b; Ferbey, 2011).

240º to 270º (west/southwest). Field observations suggest that ice-flow direction and the preservation of ice-flow indicators have been effected by topography and (or) elevation and that, at least locally, glaciers flowed valley parallel, both up and down-valley at different times (Ferbey and Levson, 2001a, b).

During the onset of glaciation, ice flowed radially from accumulation centres such as the Coast Mountains towards central-BC and the coast (Davis and Mathews, 1944; Fulton, 1991). At sometime during the glacial maximum an ice-divide migrated from the Coast Mountains east into central BC. Ice then flowed from central BC resulting in a reversal of ice-flow over the study area. Glaciers that were first flowing east now flowed west across some parts of the western Nechako Plateau, over the Coast Mountains and towards the Pacific Ocean. Stumpf et al. (2000) suggested that this ice-divide was located east of the study area. Eastward ice-flow resumed within the study area after the ice divide migrated back over the axis of the Coast Mountains (in response to climate warming and a decline in ice volume) and continued until the close of the Late Wisconsinan glaciation.

In the Huckleberry Mine area, the westerly ice-flow event appears to be earlier and of a larger magnitude than the later east to northeast event. This interpretation is based on: 1) cross-cutting and superimposition relationships; 2) the presence of large-scale crag-and-tail ridge features in low elevation settings (<1500 m), that indicate ice-flow towards the west; and 3) the presence of well preserved roches moutonnées and rat-tails at high elevation sites (≥1500 m), that indicate ice-flow towards the west. In other words, in the Huckleberry Mine region, west to southwest flow dominated during the Fraser Glaciation maximum and was followed in some low elevation areas by a weaker, possibly shorter lived, east to northeast ice-flow event during the later stages of Fraser Glaciation. These two events were preceded by an eastward directed ice-flow event as ice moved downslope from the main accumulation centres to the west (e.g., Coast Mountains) during the onset, or advance phase, of glaciation. Evidence of this early eastward ice-flow at surface was likely erased in most areas by the later westward flow event.

These results are in general agreement with those discussed by Levson et al. (1998), Stumpf et al. (2000), Levson (2001a), Mate and Levson (2001), and indicate the presence of a migrating ice divide in central British Columbia during the Fraser Glaciation maximum. More recent work by Ferbey (2010, 2011) to the northeast of the study area also supports this interpretation. This ice-flow reversal undoubtedly influenced to some degree the detrital dispersal of bedrock mineralization in basal till of these areas.

TILL GEOCHEMICAL SURVEYS

Basal till, a first derivative of bedrock (Shilts, 1993), is transported in a relatively linear fashion parallel to ice-flow direction, down-ice from its bedrock source. The contrast between elevated and background geochemical values can be clear and the area represented by till samples with elevated values is almost always much more areally extensive than that of their bedrock source (Levson, 2001b). The transport history of basal till can be predictable making it an effective tool for tracing elevated geochemical values back to their bedrock source.

METHODOLOGY

While conducting a till geochemistry program, it is imperative that the sample medium is correctly identified. This ensures consistency between sample sites and understanding of the origin and mode of sediment transport and deposition (Levson, 2001b). To this end, sedimentological data, such as texture, colour, thickness, primary and secondary structures, density, matrix percentage, clast mode, shape and presence of striae, were collected at each sample site in order to ensure the proper discrimination of basal till from other sediment types such as colluvium and debris flows. As well, at each sample site, notes were made on the type of exposure sampled, surficial geology map unit, sample site geomorphology (e.g., topographic position, aspect, slope, drainage), stratigraphy, and type and thickness of soil horizons present. This information is useful when interpreting geochemical results.

Clasts in till were also examined. Data such as lithology, angularity, size, presence of striae, and occurrence of mineralization were recorded. From these data, inferences on clast provenance were made, providing additional insight into local, covered bedrock units.

Sample Collection

During the course of the field season 309 basal till samples, each 2 to 5 kg, were collected in the study area. Of these, 106 were collected from near-surface exposures (up to 4 m below surface; Figure 7), and 203 were collected from deeper units up to 30 m below surface (Figure 8). Sample sites were selected to obtain maximum spatial coverage of the study area while taking into account ice flow direction and location of mineralized sources. Although a spatially uniform sampling scheme is preferred, absence of appropriate sample media and human disturbance did limit sample site selection. No samples were taken in the area covered by the tailings pond or in areas disturbed by heavy machinery.

Near-surface samples were collected along road cuts (Figure 9), in hand-dug soil pits, and in naturally eroded sites such as gullies and wave-cut banks on lake shorelines. Samples were collected up to 4 km west of the Main Zone orebody, and up to 2 km east of the East Zone orebody, with sample depths ranging from <1 m up to 4 m.

Sub-surface samples were collected from Becker hammer boreholes. From 1998 to 2000, 75 Becker hammer boreholes were drilled by Huckleberry Mines Limited (HBL) and basal till samples were collected at 1 to 2 m intervals from the boreholes, to a maximum depth of 30 m. A Becker hammer drill rig hydraulically pounds a hollow drill stem into the substrate to be sampled (Figure 10). Compressed air then forces sediments back up the hollow drill stem to the surface where they are decelerated in a cyclone and collected in a sample pan.

Cohesive sediments, like basal till, come up the drill stem in clumps 10 to 15 cm in diameter. For this study, 203 till

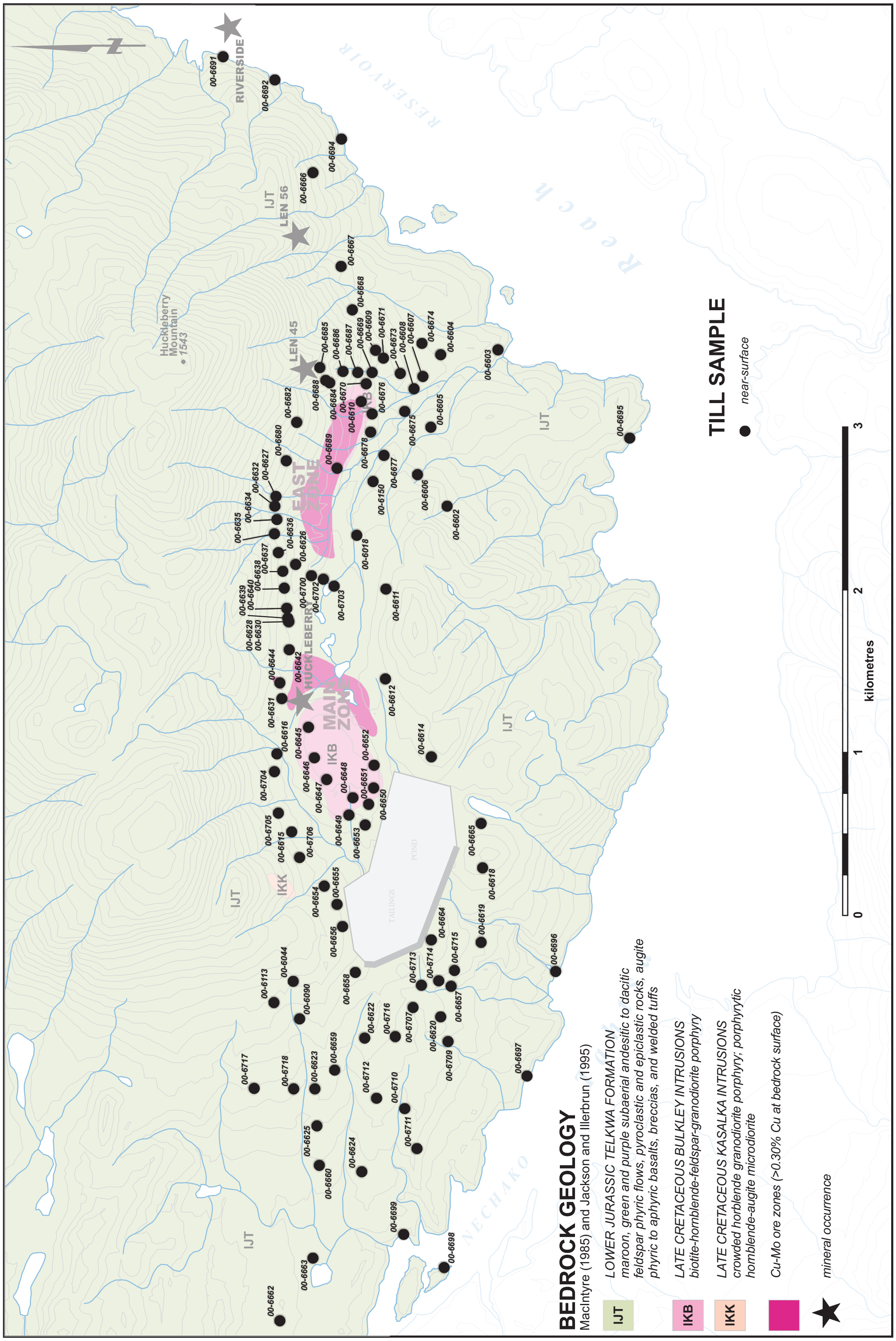


Figure 7. Location of near-surface till samples.

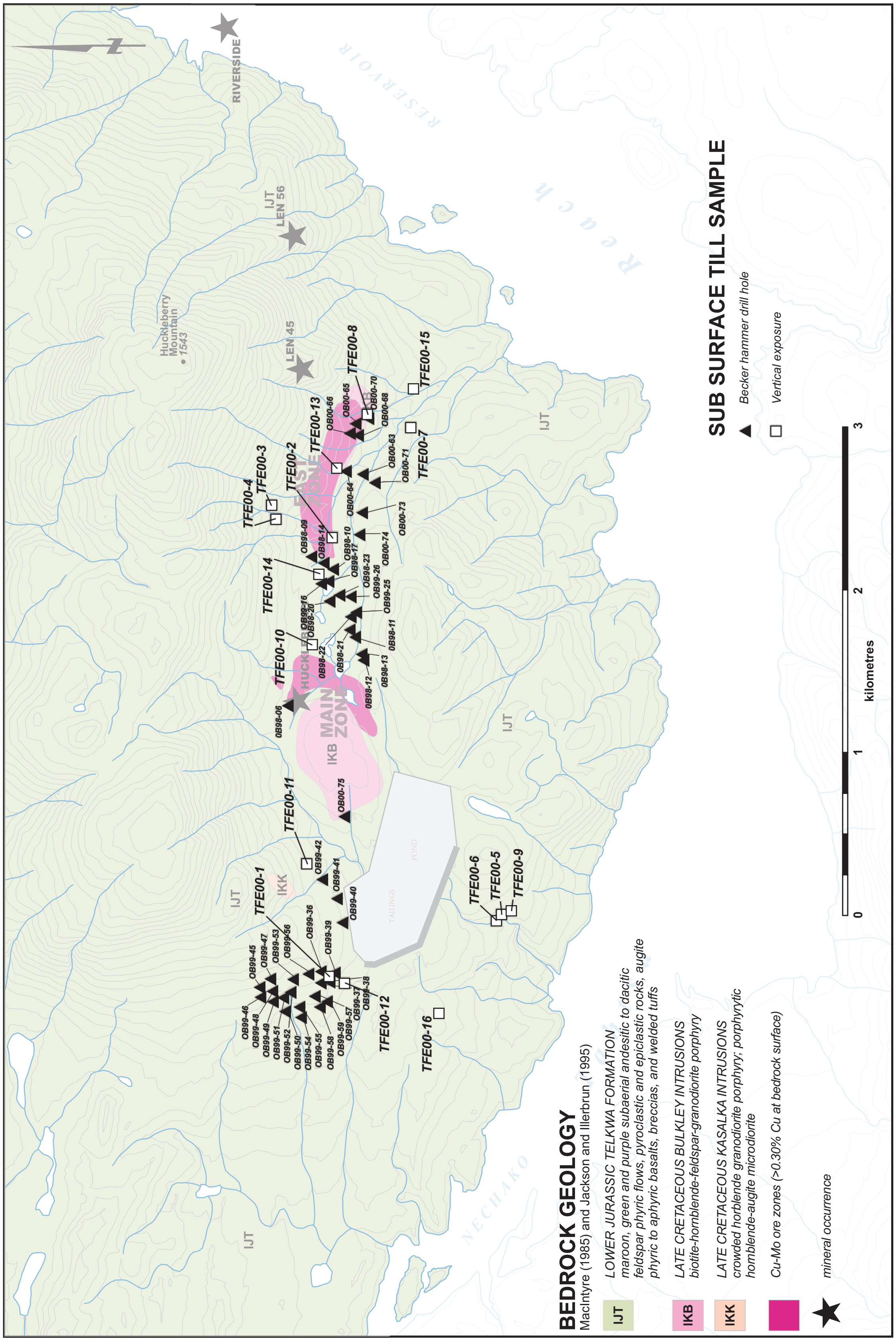


Figure 8. Location of sub-surface till samples.

a)

b)

Figure 9. Examples of near-surface till sample sites. Near-surface till samples were most commonly collected from a) roadcuts, but were also collected from b) hand-dug pits.

Figure 10. A Becker Hammer borehole rig, used to collect samples of basal till up to 30 m below surface.

samples from 47 Becker hammer boreholes were obtained. The outside surface of all samples was removed to avoid cross-sample contamination. Samples were examined for possible reconstitution that may have occurred as the original sample was brought up the drill stem. To supplement the drill samples, vertical profile sampling was conducted at 16 vertical sections on Huckleberry Mine property (Figure 8). Profile sampling was conducted in excavations ranging in depth from 2 to 20 m below surface (e.g., vertical walled borrow pits, and trenches). Detailed stratigraphic descriptions were completed at all sites and samples were collected from each till unit. Included in the discussion that follows are data from two key section: TFE00-1 and TFE00-16 (Figure 8).

To improve on the spatial coverage of near-surface samples, five shallow Becker hammer samples are included in the near-surface data set (00-6018, 6044, 6090, 6113, and 6150; Figure 7). The average depth of these samples is 2.5 m, with the maximum being 3.5 m.

Sample Preparation and Analysis

The 309 samples collected for this study were air dried, disaggregated, and sieved to <0.063 mm (or –230 mesh) at Bondar Clegg Canada Limited (Vancouver, BC). For each sample a 1.0 g split was analyzed for a total of 37 trace elements by inductively coupled plasma mass spectrometry (ICP-MS) following an aqua regia digestion. The elements determined for using this analytical method, and detection limits, are summarized in Table 1. A second split was used to determine major oxide concentrations using inductively coupled plasma emission spectrometry (ICP-ES) after a lithium metaborate fusion. These analyses were conducted at Acme Analytical Laboratories Limited (Vancouver, BC).

A 25 to 30 g sample-split was also analyzed for 35 elements by instrumental neutron activation analysis (INAA) at Activation Laboratories Limited (Ancaster, ON). The elements determined for using this analytical method, and detection limits, are summarized in Table 2.

Trace and major element analyses by aqua regia ICP-MS, INAA and lithium metaborate ICP-ES are presented in Appendix A through F for near- and sub-surface samples.

QUALITY CONTROL

Quality control measures were implemented in the field and laboratory. For each block of 20 samples submitted for analysis, one field duplicate (taken at a randomly selected sample site), one analytical duplicate (a sample split after sample preparation but before analysis), and one reference standard were included (in-house British Columbia Geological Survey (BCGS) standard). The analyses of field and analytical duplicate samples are used to estimate the precision of a geochemical data set, while reference standards can be used to measure the accuracy and (or) precision of an analytical method.

Analysis of Precision

Copper, Mo, Au, Ag, and Zn were selected for analysis of precision, as they are the main commodities in the Huckleberry Mine region. Although not mined for specifically at Huckleberry

Element	Detection Limit
Ag	2 ppb
Al	0.01%
As	0.1 ppm
Au	1 ppb
B	1 ppm
Ba	0.5 ppm
Bi	0.02 ppm
Ca	0.01%
Cd	0.01 ppm
Co	0.1 ppm
Cr	0.5 ppm
Cu	0.01 ppm
Fe	0.01%
Ga	0.02 ppm
Hg	5 ppb
K	0.01%
La	0.5 ppm
Mg	0.01%
Mn	1 ppm
Mo	0.01 ppm
Na	0.001%
Ni	0.1 ppm
P	0.001%
Pb	0.01 ppm
S	0.02%
Sb	0.02 ppm
Sc	0.1 ppm
Se	0.1 ppm
Sr	0.5 ppm
Te	0.02 ppm
Th	0.1 ppm
Ti	0.001%
Tl	0.02 ppm
U	0.1 ppm
V	2 ppm
W	0.2 ppm
Zn	0.1 ppm

Table 1. Elements analyzed for by aqua regia ICP-MS, on the silt plus clay-sized fraction (<0.063 mm) of till samples, and detection limits.

Element	Detection Limit
Ag	5 ppm
As	0.5 ppm
Au	2 ppb
Ba	50 ppm
Br	0.5 ppm
Ca	1%
Ce	3 ppm
Co	1 ppm
Cr	5 ppm
Cs	1 ppm
Eu	0.2 ppm
Fe	0.01%
Hf	1 ppm
Hg	1 ppm
Ir	5 ppb
La	0.5 ppm
Lu	0.05 ppm
Mo	1 ppm
Na	0.01%
Nd	5 ppm
Ni	20 ppm
Rb	15 ppm
Sb	0.1 ppm
Sc	0.1 ppm
Se	3 ppm
Sm	0.1 ppm
Sn	0.01%
Sr	0.05%
Ta	0.5 ppm
Tb	0.5 ppm
Th	0.2 ppm
U	0.5 ppm
W	1 ppm
Yb	0.2 ppm
Zn	50 ppm

Table 2. Elements analyzed for by INAA, on the silt plus clay-sized fraction (<0.063 mm) of till samples, and detection limits.

Mine, Zn is included, as it is a reported commodity at the Len 56 and Riverside mineral occurrences.

Figures 11 and 12 are scatter plots of trace elements measured in field and analytical duplicates, respectively. R-squared values approaching 1 (e.g., R^2 >0.9) for most elements indicate good reproducibility, and suggest a relatively high degree of both sampling and analytical precision. High positive correlation coefficients also indicate that there is a relatively homogenous distribution of those elements in till. Copper in field duplicates, however, produced an unusually weak correlation (R^2=0.342; Figure 11a). Stronger field duplicate correlations have been reported for Cu in till samples collected in the Babine porphyry Cu belt (R^2=0.933; Levson, 2002), the Tetachuck Lake and Marilla map areas (R^2=0.954; Levson and Mate, 2002), and in the Colleymount map area (R^2=0.9995; Ferbey, 2011). The outlier in the bottom right of this plot (Figure 11a; sample 00-6671; 1111 and 181 ppm Cu) is mainly responsible for the low R^2 value. This same sample is also an outlier in plots of Au values in field duplicates (Figure 11b). When this sample is not included, a stronger correlation results for Cu (R^2 = 0.881).

Sample 00-6671, and its field duplicate, were collected directly above hornfelsed pyritic andesite, approximately 300 m southeast of the East Zone orebody, in a dense, brown, sandy-silt diamicton. Given that visible sulphides (pyrite±chalcopyrite up to 3 mm in size) and mineralized clasts were observed in the till matrix of many samples, the nugget effect could explain the general poor reproducibility of Cu values in some field duplicates. Evidence of the nugget effect in Cu is unusual and has not been described before in detailed studies of Cu in tills in central British Columbia (c.f., Levson, 2001a; Levson and Mate, 2002).

Copper values in samples 00-6009 and 6118, and Mo values in sample 00-6118, also appear to be outliers (Figure 11a). These two samples were collected from approximately 2.5 m below surface in two adjacent Becker hammer boreholes (OB99-40 and 41). Although visible sulphides and mineralized clasts were not observed in these two samples specifically, they were in the lower sample collected from borehole OB99-41, to the west in samples collected from borehole OB00-75, and to the south in the upper portion of section TFE00-2 (Figure 8).

Figures 11b and 12b are scatter plots of Au values for field and analytical duplicates, respectively. As seen in these figures, scatterplots of ICP-MS Au values for field duplicates have an R^2 value of 0.003 while analytical duplicates have an R^2 value of 0.002. The correlation between field duplicate samples appears to be even weaker for Au values determined by INAA (R^2=0.001). The opposite is true in the case of analytical duplicate samples as the correlation between Au values in duplicate pairs, determined by INAA, improves (R^2=0.245). A re-run of the same field and analytical duplicate samples, using INAA, produced similarly poor results. It is interesting to note that in addition to being an outlier in Cu plots, sample 00-6671 is also an outlier in Au values of field duplicate samples. Overall poor reproducibility in Au values, using either method, is likely attributed to the nugget effect.

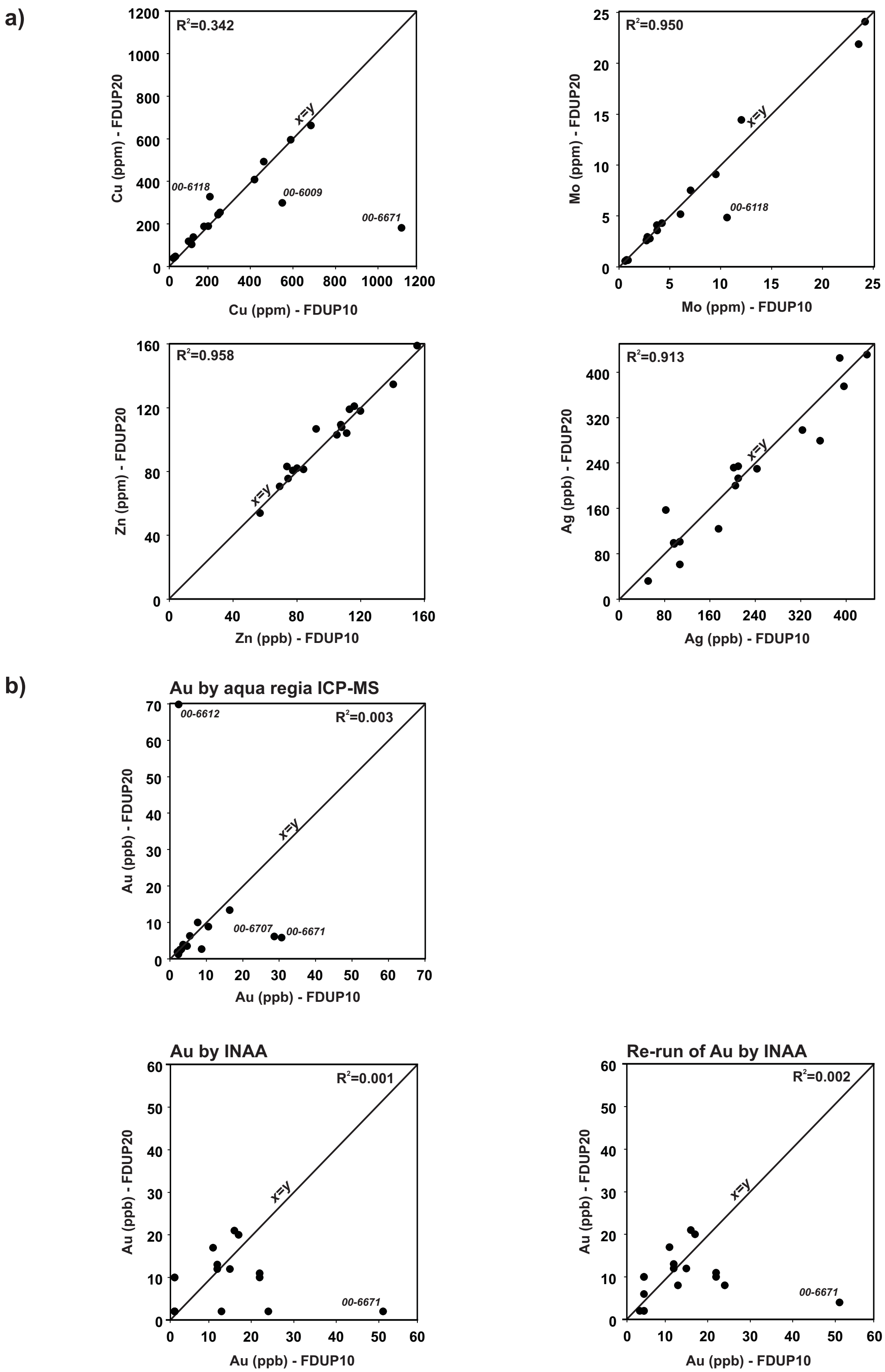


Figure 11. Field duplicate scatter plots of a) Cu, Mo, Ag, and Zn (n=17) and b) Au (n=17).

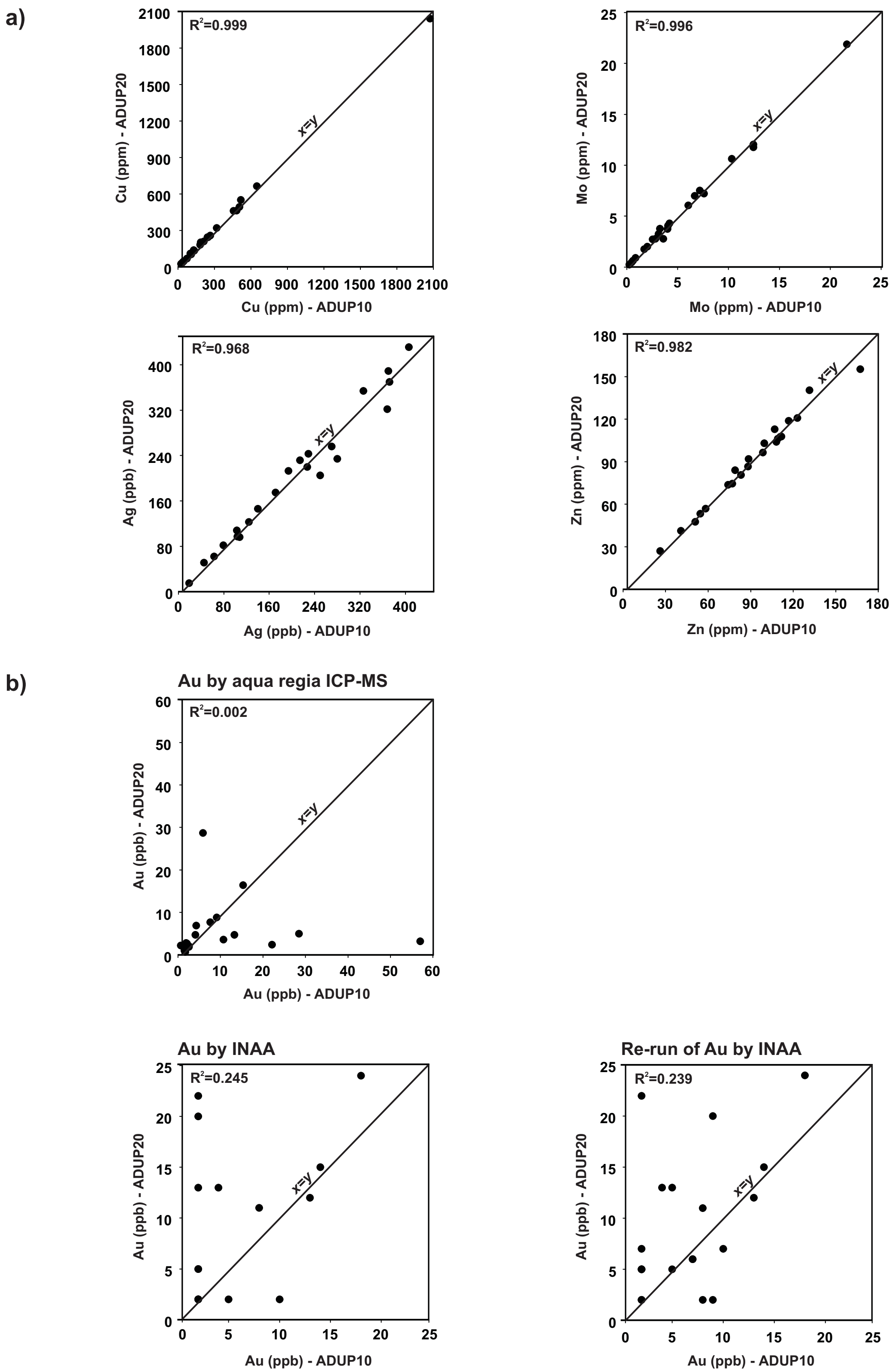


Figure 12. Analytical duplicate scatter plots of a) Cu, Mo, Ag, and Zn (n=21) and b) Au (n=21).

Differences in absolute values between methods could be related to the disparity between size of sample analyzed or potentially how Au was transported (e.g., free versus encapsulated). For all elements except Au, there is an increase in R^2 values for analytical duplicate plots (Figure 12). This suggests that there is more variability in sample material at a sample site than variability within a given sample, as one would expect.

Repeat determinations, conducted as part of this study, for two BCGS geochemical reference materials are presented in Table 3. Percent relative standard deviation values (%RSD; a measure of data dispersion around the mean) have been calculated for the five elements by dividing the standard deviation by the absolute value of the mean and multiplying by 100. As seen in Table 3, %RSD values vary from 1.8 to 7.6. Copper and Mo typically have lower %RSD values, while Au in both reference materials, has the highest. Percent relative standard deviation values presented here indicate that analytical precision for data used in this study is acceptable.

TILL GEOCHEMICAL DATA

Presented here are proportional symbol plots of near surface samples for Cu, Ag, Mo, and Zn by aqua regia ICP-MS (Figures 13 to 16) and for Au by INAA (Figure 17). Additional proportional symbol plots for Pb by aqua regia ICP-MS and As and Sb by INAA are presented in Appendix G. Percentile class breaks used in the proportional symbol plots that follow (<50, 50 to 70, 70 to 90, 90 to 95, 95 to 98, >98) are commonly used to categorize till geochemical data as they do not bias data classification (Plouffe and Ballantyne, 1993; Levson, 2001a; Levson, 2002; Levson and Mate, 2002; Lett et al., 2006; Plouffe et al., 2009; Ferbey, 2010). The second sample collected at a field duplicate sample site (i.e., FDUP 20; see Appendices A to F) has been removed from the data set. For the remainder of this report, presentations and discussions will therefore focus on samples with unique locations. Also presented here are vertical geochemical profiles of select sub-surface samples.

Summary statistics for aqua regia ICP-MS determinations for near surface and sub-surface samples are presented in Tables 4 and 5, respectively, while summary statistics for near surface and sub-surface INAA determinations are presented in Tables 6 and 7, respectively. Background concentrations are defined here as the median value for a given element while >95th percentile concentrations are considered elevated. The following is a discussion on background and elevated element values for the elements of interest and their spatial distribution.

Near-surface Samples

Elevated element concentrations in near-surface till samples are associated with mineralization in the Huckleberry Mine region (Figures 13 to 17). All samples with >95th percentile Cu values, occur within 500 m of the Main and East zone orebodies while maximum Au and Ag values (184 and 1721 ppb, respectively) occur over the western end of the Main Zone stock.

The highest Cu and Mo values in the study (8924 ppm and 216 ppm,

		Cu (ppm) ICP-MS	Mo (ppm) ICP-MS	Au (ppb) INAA	Ag (ppb) ICP-MS	Zn (ppm) ICP-MS
REFERENCE 1	n=	6	6	6	6	6
	Mean	165.96	0.86	21.6	1361	345.8
	Standard Deviation	4.01	0.04	1.6	41	6.3
	%RSD	***2.42***	***4.08***	***7.4***	***3***	***1.8***
REFERENCE 2	n=	8	8	8	8	8
	Mean	171.04	13.41	23.8	74	50.0
	Standard Deviation	5.42	0.38	1.8	4	3.1
	%RSD	***3.17***	***2.84***	***7.6***	***6***	***6.2***

Table 3. Percent relative standard deviation (%RSD) values for BCGS reference materials. Analytical data presented here were produced for this study. Six determinations were conducted on Standard 1 (n=6) while eight determinations were conducted on Standard 2 (n=8).

	Mo (ppm) ICP-MS	Cu (ppm) ICP-MS	Pb (ppm) ICP-MS	Zn (ppm) ICP-MS	Ag (ppb) ICP-MS	Hg (ppb) ICP-MS
Detection Limit	0.01	0.01	0.01	0.1	2	33
Maximum	216.13	8924.03	47.81	207.1	1721	145
Minimum	0.53	29.14	5.37	34.0	7	9
Mean	8.63	488.64	17.04	88.7	165	40
Median	3.10	216.31	16.16	85.6	105	35
Standard Deviation	23.17	1028.12	7.27	28.2	196	22
n=	106	106	106	106	106	105

Table 4. Summary statistics for aqua regia ICP-MS determinations (n=106) on the silt plus clay sized fraction (<0.063 mm) of near-surface samples.

	Mo (ppm) ICP-MS	Cu (ppm) ICP-MS	Pb (ppm) ICP-MS	Zn (ppm) ICP-MS	Ag (ppb) ICP-MS	Hg (ppb) ICP-MS
Detection Limit	0.01	0.01	0.01	0.1	2	33
Maximum	82.88	1005.42	109.72	207.1	723	132
Minimum	0.41	28.12	8.28	48.7	37	7
Mean	7.49	263.81	20.59	106.1	279	37
Median	3.73	178.74	17.34	108.7	285	33
Standard Deviation	10.01	229.04	12.55	24.7	143	20
n=	193	193	193	193	193	193

Table 5. Summary statistics for aqua regia ICP-MS determinations (n=193) on for the silt plus clay sized fraction (<0.063 mm) of sub-surface samples.

	Au (ppb) INAA	As (ppm) INAA	Sb (ppm) INAA
Detection Limit	2	0.5	0.1
Maximum	184	275.0	14.3
Minimum	2	5.3	0.8
Mean	14	35.9	2.6
Median	7	29.2	2.3
Standard Deviation	24	31.7	1.8
n=	106	106	106

Table 6. Summary statistics for INAA determinations (n=106) on the silt plus clay sized fraction (<0.063 mm) of near-surface samples.

	Au (ppb) INAA	As (ppm) INAA	Sb (ppm) INAA
Detection Limit	2	0.5	0.1
Maximum	40	84.0	7.6
Minimum	2	7.4	0.7
Mean	9	35.3	2.6
Median	5	36.7	2.5
Standard Deviation	9	20.2	1.4
n=	193	193	193

Table 7. Summary statistics for INAA determinations (n=193) on the silt plus clay sized fraction (<0.063 mm) of sub-surface samples.

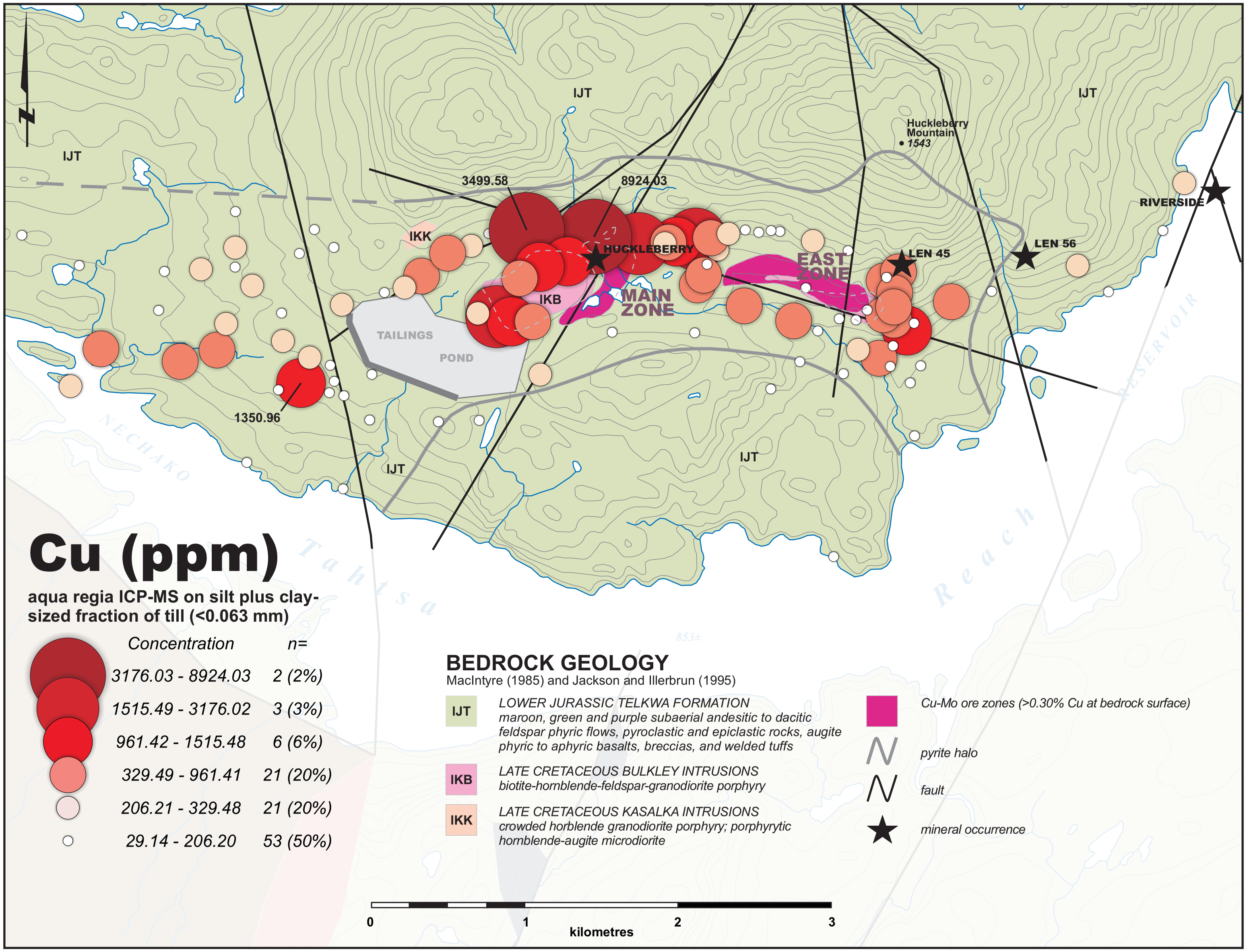


Figure 13. Proportional symbol plot for Cu values in the silt plus clay-sized fraction (<0.063 mm) of till samples collected in the study area.

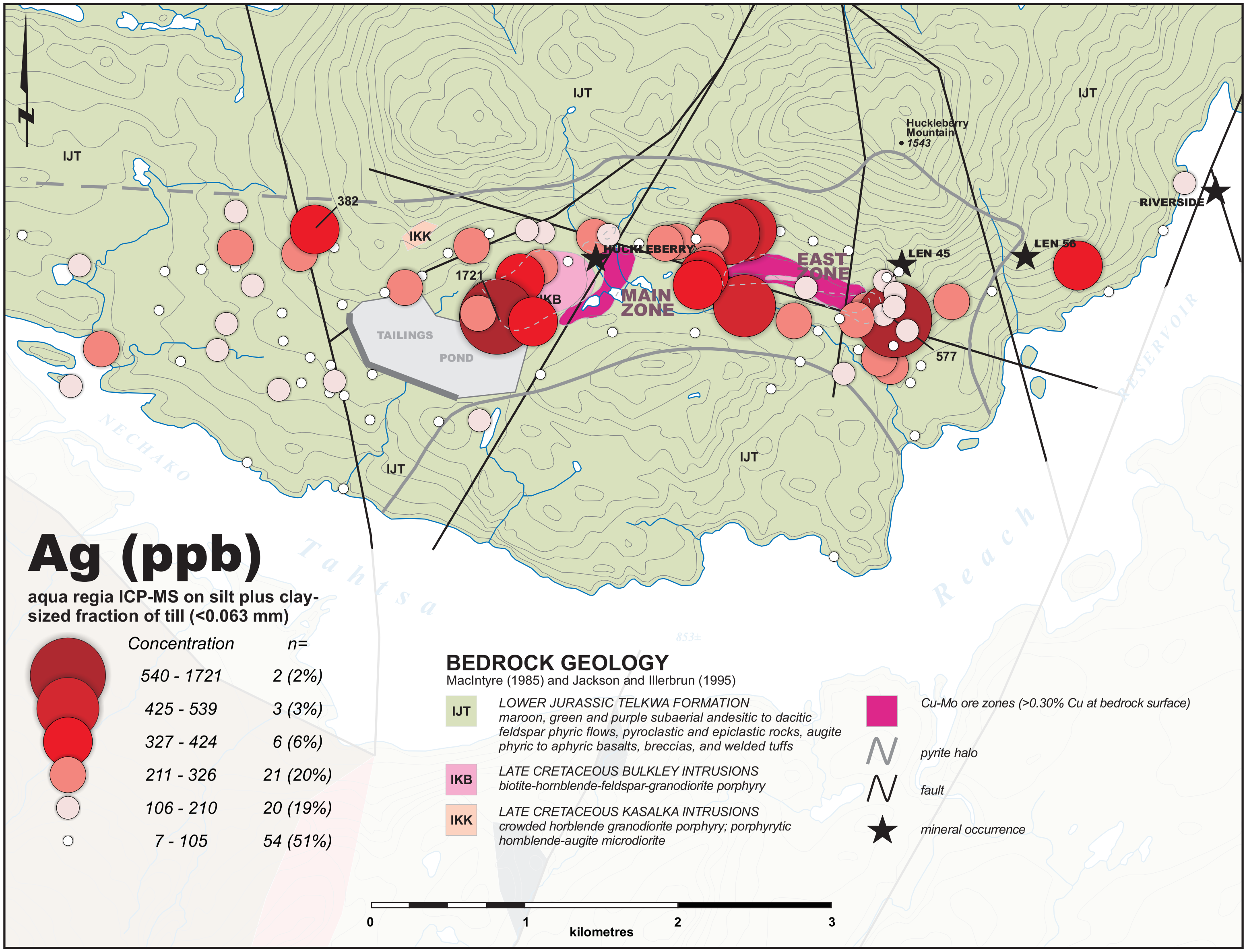


Figure 14. Proportional symbol plot for Ag values in the silt plus clay-sized fraction (<0.063 mm) of till samples collected in the study area.

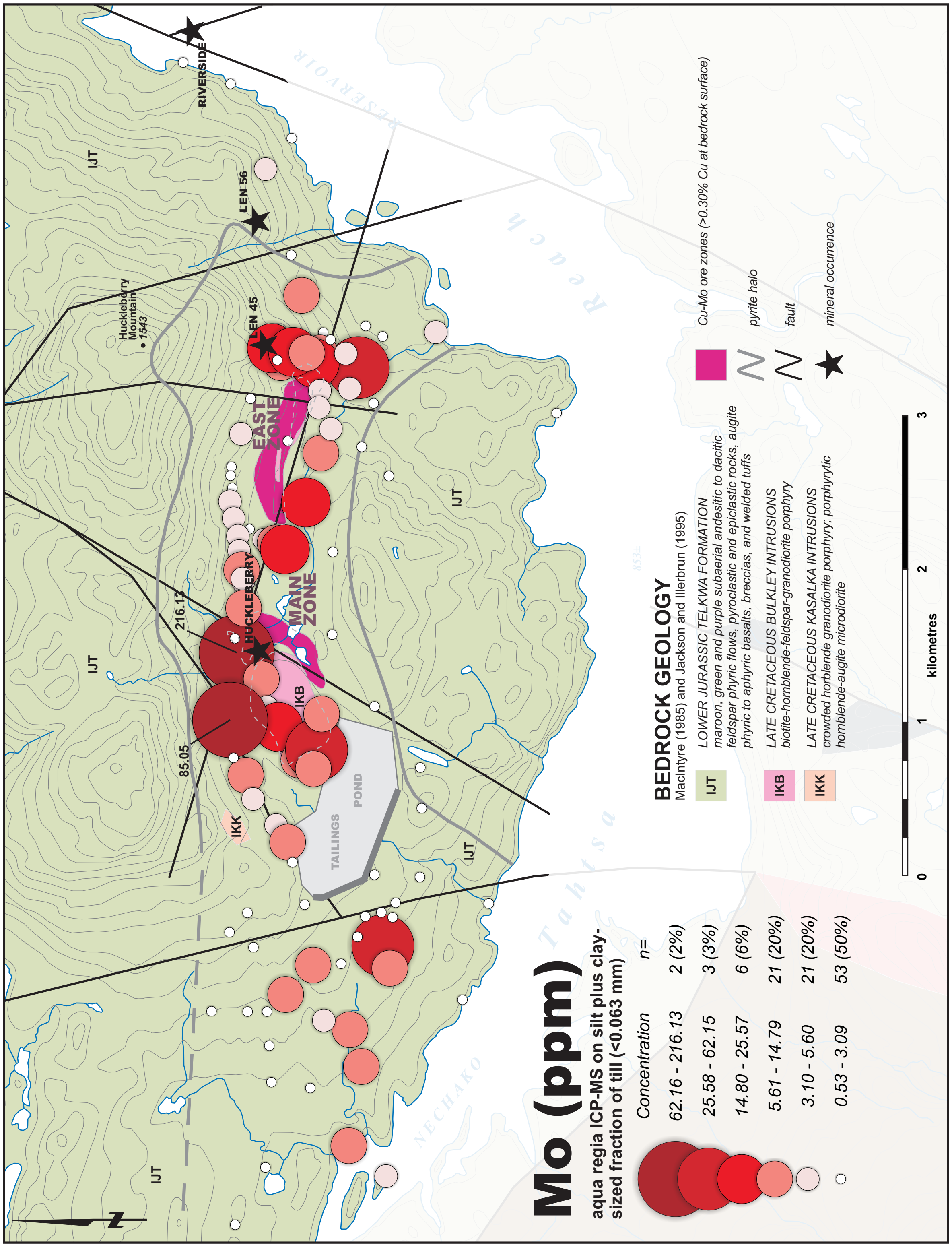


Figure 15. Proportional symbol plot for Mo values in the silt plus clay-sized fraction (<0.063 mm) of till samples collected in the study area.

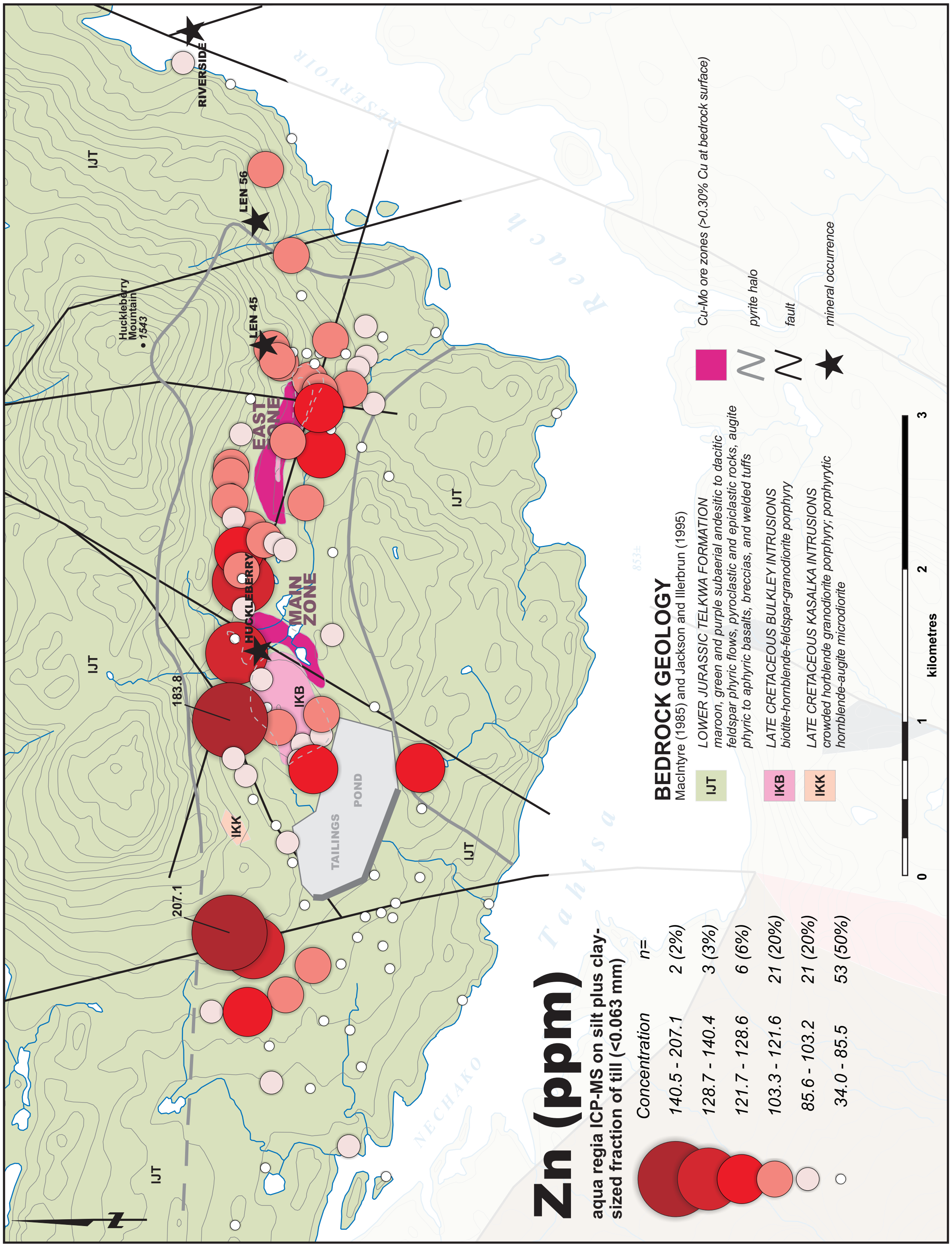


Figure 16. Proportional symbol plot for Zn values in the silt plus clay-sized fraction (<0.063 mm) of till samples collected in the study area.

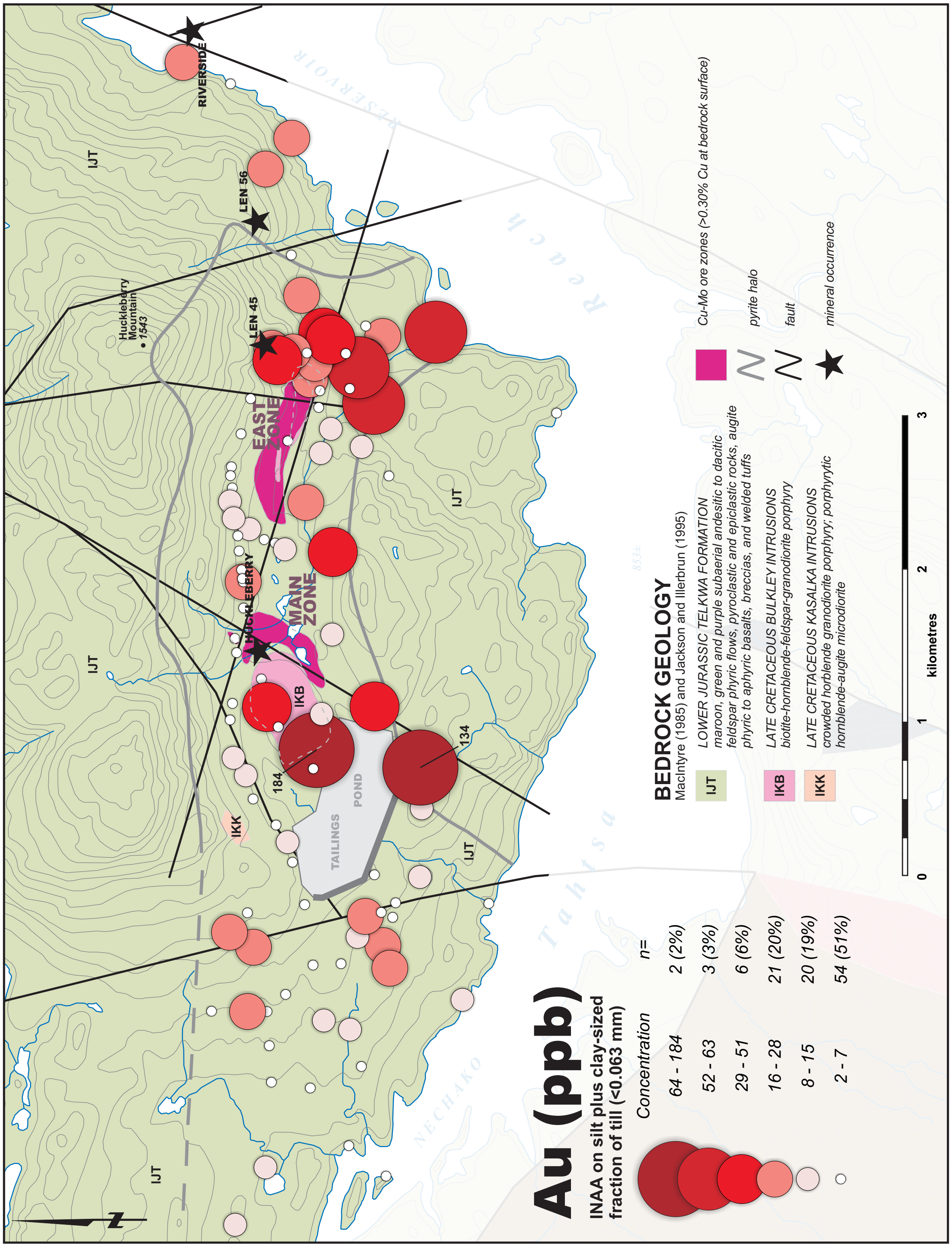


Figure 17. Proportional symbol plot for Au values in the silt plus clay-sized fraction (<0.063 mm) of till samples collected in the study area.

respectively) occur in one sample at the northwest end of the Main Zone. This sample was collected 30 cm above mineralized andesite of the Main Zone orebody.

Copper concentrations in the tills of the Huckleberry Mine region are higher than those found in nearby regional data sets (Table 8). For example, northeast of the Huckleberry Mine region, in NTS map areas 93E/15 and 93L/1, the median Cu value is reported to be 39 ppm and 31 ppm, respectively (Ferbey, 2010, 2011), compared to a median of 216 ppm reported in this study (Table 4). Copper concentrations in this study are also higher than values reported in other studies conducted on the Nechako Plateau (Table 8). For example, at the Nak porphyry Cu prospect, in the Babine porphyry copper belt, maximum and median Cu values in basal tills are 962 ppm and 66 ppm, respectively, compared to a maximum Cu concentration in this study of 8924 ppm. Maximum Cu concentrations in basal till samples collected in the Babine porphyry copper belt, around the Morrison deposit and now reclaimed Bell mine are 230 ppm and 1550 ppm, respectively. These case study data are part of a regional data set that has a median Cu value of 44 ppm (Levson, 2002).

A more realistic approximation of background Cu values for the Huckleberry Mine region might come from tills that have an unmineralized bedrock source. For example, Cu values of 29 ppm and 58 ppm come from two samples collected along the north shore of Tahtsa Reach (sample 00-6695 and sample 00-6696, respectively), directly south of the Huckleberry mine site. These values suggest that an appropriate approximation of median Cu values in the study area might be in the 30 to 60 ppm range, which is in-line with the above-mentioned regional data sets.

Although there is a good spatial relationship between element concentrations in till and mineralized bedrock, there is significant variability in the details of this relationship. For example, over 80% of the samples with >90th percentile concentrations for Cu, Mo and Ag occur within 500 m of the Main and East zone orebodies, but only about 50% of the samples with >90th percentile Au and Zn concentrations occur within the same area. Similarly, some samples located directly adjacent to or on top of the East Zone orebody, or located between the Main and East zones, have <50th percentile elemental concentrations. Samples with >90th percentile multi-element concentrations are not found north of the East Zone area. This variability is clearly illustrated in samples collected near bedrock (Table 9) and is likely a product of variability in bedrock and (or) the till unit being sampled.

Greater than 95th percentile Zn concentrations occur with >95th percentile Cu concentrations at two sites north of the Main Zone. This relationship with elevated Cu values, and the distribution of >90th percentile Zn values around the Main and East zone orebodies, suggests that Zn could be used as a pathfinder for mineralization occurring at Huckleberry Mine and perhaps other calcalkaline porphyries.

Survey	Cu (ppm) ICP-MS		Mo (ppm) ICP-MS		Ag (ppb) ICP-MS		Zn (ppm) ICP-MS		Au (ppb) INAA		Reference
	median	max	median	max	median	max	median	max	median	max	
93F/03	24	66	1	7	200	700	65	168	4	77	Levson et al. (1994)
93F/07	29	355	1	13	100	1200	68	250	4	79	Weary et al. (1997)
93L/09, 16, 93M/01, 02, 07, 08	44	1550	1	38	100	1400	97	5067	2	140	Levson (2002)
93F/05, 12	24	145	1	8	500	800	58	150	1	77	Levson and Mate (2002)
93E/15	39	107	0.85	3.24	50	526	96	203	4	37	Ferbey (2010)
Copper Star occurrence	51	686	0.81	4.98	41	101	77	99	2	90	Ferbey and Levson (2010)
93L/01	31	495	0.56	16.32	55	972	78	285	2	31	Ferbey (2011)
Huckleberry Mine	216	8924	3.09	216.13	105	1721	86	207	2	184	this paper

Table 8. A comparison of median and maximum values for select elements from this study to those of till geochemical surveys conducted in central British Columbia.

Sample	Height Above Bedrock (cm)	Cu (ppm)	Mo (ppm)	Au (ppb)	Ag (ppb)	Zn (ppm)	Comments on Bedrock
00-6609	100	186.98	2.58	13.5	36	80.7	oxidized, pyritic (~1%), jointed, andesite
00-6631	30	8924.03	216.13	4.6	220	139	ore-grade andesite; collected above Main Zone pit
00-6632	32	111.54	2.62	4.2	77	107.1	andesite
00-6634	12	93.15	1.96	5.9	78	82.1	andesite
00-6635	50	165.46	4.54	4.9	432	105.4	andesite
00-6636	5	282.47	3.53	8.3	539	101.9	andesite
00-6637	100	397.41	4.54	5.8	318	82.2	andesite
00-6638	15	3176.02	4.96	5.1	102	127.2	andesite
00-6639	35	1515.48	5.91	23	296	106.2	andesite
00-6640	15	452.57	5.21	4.8	79	72	andesite
00-6642	100	2691.91	8.04	3.9	58	87.7	andesite
00-6646	10	1065.85	3.73	54.6	258	67.2	collected above Main Zone stock
00-6647	20	539.44	15.36	7.6	361	106.3	collected above Main Zone stock
00-6658	50	267.93	2.62	5.6	42	77.8	oxidized and altered, heterolithic, volcanic conglomerate
00-6666	100	297.39	4.77	11.8	364	110.1	andesite
00-6667	63	86.42	1.63	3.3	59	108.9	pyrictic (<1%) andesite
00-6668	30	961.41	7.66	31.9	305	51.7	pyrictic (<1%) andesite
00-6671	0	1111.04	2.7	30.7	107	116	hornfelsed, pyrite-rich, andesite
00-6673	0	131.46	3.18	4.2	74	73.3	oxidized, pyritic (~1%), andesite
00-6689	63	124.1	3.03	2.6	210	111.2	mineralized, andesite; collected above East Zone pit

Table 9. Near-surface till samples collected within 100 cm of bedrock. Copper Mo, Ag, and Zn determinations are by aqua regia ICP-MS while Au determinations are by INAA.

Sub-surface Samples

As with near-surface samples, significant variability in the distribution of Cu occurs in sub-surface till samples (Figure 18). In areas of till cover >1 m thick, elevated Cu values can occur both near bedrock and close to surface. The range of Cu values in sub-surface samples can be quite high. For example, Cu ranges for boreholes OB98-12 and OB00-74 are 132 ppm to 606 ppm and 44 ppm to 944 ppm, respectively (Figure 18). All 10 boreholes shown in Figure 18 have at least one sample with a Cu value >100 ppm.

These results differ slightly from the only other similar study conducted in the region. Levson (2002) reports on Cu concentrations in sub-surface till samples from the Nak porphyry Cu prospect, collected from diamond drill holes at depths of up to 60 m. In the majority of these samples, Cu values are relatively uniform and overall concentrations are low compared to this study. For example, in one drill hole, 17 samples collected over a 30 m interval have a range of Cu concentrations of 53 to 83 ppm. Also, in the drill holes where more than one till sample was collected, only three had Cu concentrations >100 ppm. Levson suggests that this uniformity in Cu concentrations in many sub-surface samples is due to the size of the porphyry target that underlies the tills of this area. In one drill hole, however, >900 ppm Cu concentrations were maintained for an interval of 12 m, from 32 to 44 m below surface. He suggests that these values may represent a more concentrated dispersal plume within a larger area of less elevated Cu concentrations in till, possibly reflecting a higher grade zone within the overall deposit.

In boreholes located west of the Main Zone at Huckleberry Mine, there is a general increase in Cu values as the surface is approached; a trend most pronounced in boreholes OB99-39 and OB99-58 (Figure 18). In contrast to this the only two samples collected in borehole OB99-41 show an upward decrease in Cu. The limited number of samples in this borehole, however, makes it difficult to evaluate the significance of this. It is worth noting that Cu values in this borehole (550 and 678 ppm) are higher than in any of the other boreholes west of the Main Zone, and that these relatively high Cu values occur only 2 to 3 m below surface.

Similar trends were observed in till samples collected at vertical exposures west of the Main Zone (e.g., TFE00-1, and 16; Figure 8). Maximum Cu values (from 234 to 1457 ppm) at these sections occur between 1 and 2 m below surface (Figures 19 and 20). Maximum values for other elements such as Mo and Au also occur within this horizon. With increasing depth, Cu values decrease, but the range of Cu values at each section differs. For example, Cu values at TFE00-1 range from 18 to 234 ppm (Figure 19), while those at TFE00-16 vary from 594 to 1457 ppm (Figure 20).

At TFE00-1 the lower tills are interpreted to have a provenance to the west in unmineralized rocks, while the upper tills, and trend of increasing Cu concentrations close to surface, are thought to be a product of mineralized granodiorite glacially transported from the Main Zone. Attenuated Cu values near surface in boreholes OB99-39 and

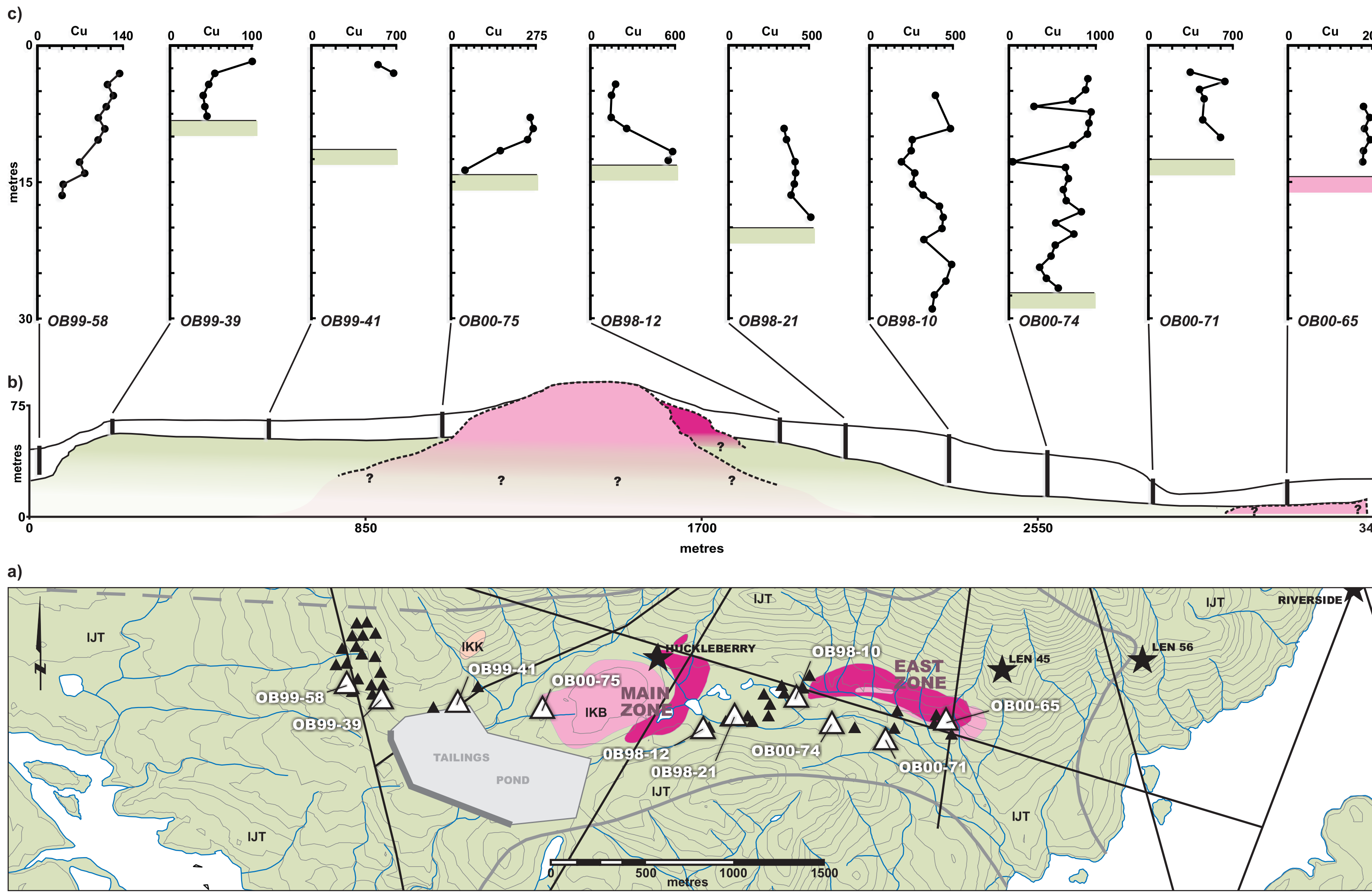


Figure 18. Cross-section through 10 Becker hammer boreholes. a) Small black triangles are locations of all boreholes sampled in this study, while large white triangles identify boreholes used to produce b) the east/west cross-section through the mine property. c) Copper concentrations with depth are shown for the same boreholes. In these plots, copper values are in ppm (note different scales for each borehole), while y-axis values are metres below surface. Depth of bedrock shown by coloured horizontal bars when recorded in borehole log. See Figure 3 for bedrock geology legend.

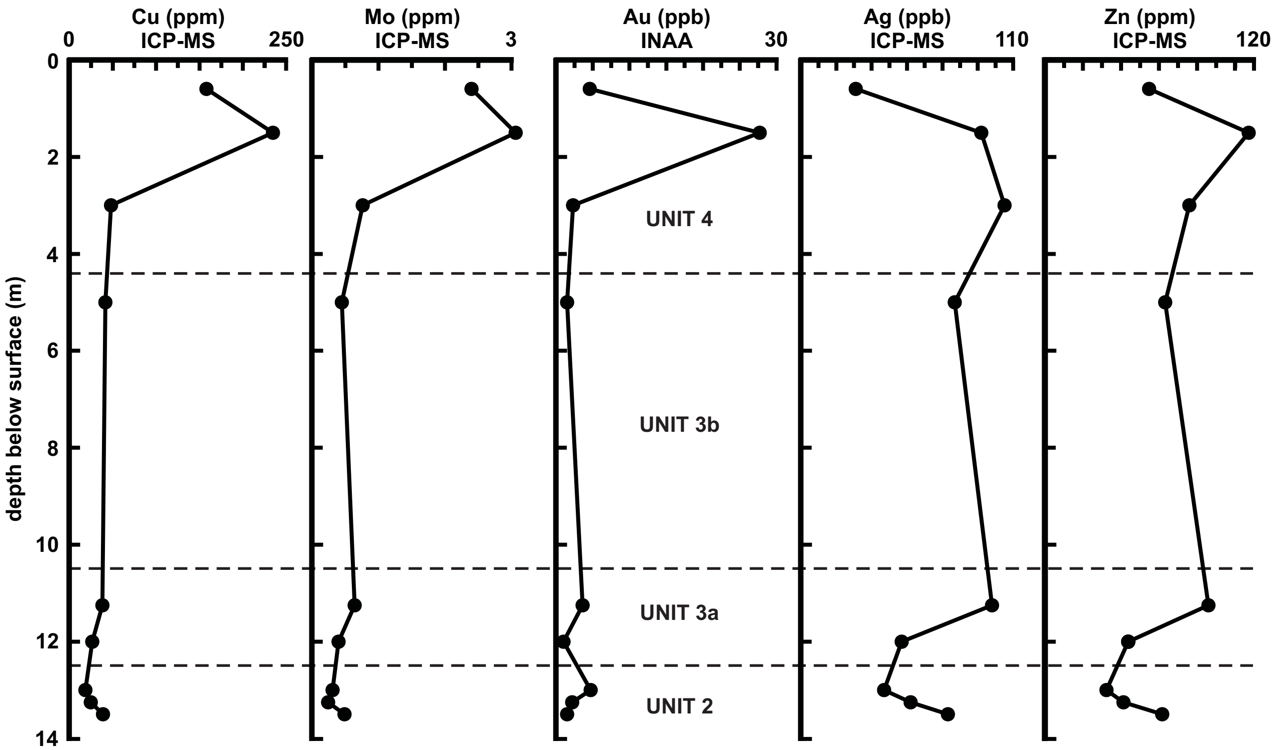


Figure 19. Select element concentrations in basal tills at section TFE00-1. Dashed lines separate basal till units.

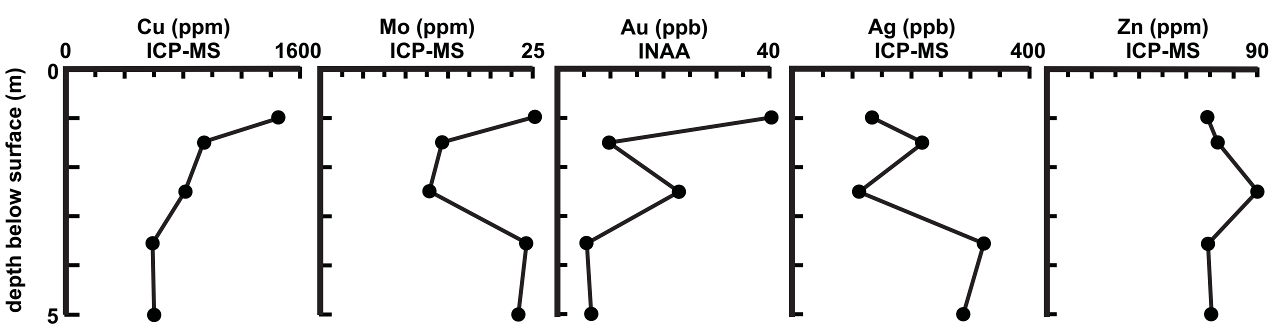


Figure 20. Select element concentrations in basal tills at section TFE00-16. The deepest four samples were collected in a 5.5 m deep trench, located approximately 10 m southwest of sample 00-6620.

58 (Figure 18), relative to those in samples close to surface in boreholes to the east, suggest that OB99-39 and 58 are located towards the distal end of a dispersal train (Figure 18). The head of this dispersal train is likely somewhere in between OB00-75 and OB99-41, suggesting that the net-offset distance from here to mineralized bedrock of the Main Zone is approximately 500 to 1000 m.

Copper values in boreholes OB98-10 and OB00-74 are more variable than those in any other borehole presented here (Figure 18). For example, maximum and minimum Cu values in OB98-10 are 492 and 192 ppm, respectively, and in OB00-74 they are 944 and 44 ppm, respectively. Borehole OB98-10 is located in the valley-centre between the two orebodies and is directly on trend with dispersal from both the Main and East zones.

DISPERSAL DIRECTION OF MINERALIZATION IN TILLS

The influence of a complex Late Wisconsinan ice-flow history in the Huckleberry Mine region can be observed in the lateral and vertical distribution of element concentrations in basal tills of the area. Westward ice-flow during the Late Wisconsinan glacial maximum, and both early and late eastward ice-flow from the Coast Mountains, has created complex dispersal patterns in Huckleberry Valley. Interpreting these dispersal patterns is further complicated by the existence of multiple known sources of mineralization in and adjacent to Huckleberry Valley (i.e., Huckleberry Mine's Main and East zone orebodies, and the Len 45, Len 56 and Riverside mineral occurrences). Nevertheless, evidence of both east and west dispersal of mineralization in till from these sources can be observed in the distribution of commodity element concentrations in specific areas.

The most convincing evidence of eastward dispersal is seen in the older till units exposed at section TFE00-1, a 19 m vertical exposure on Huckleberry Mine property (Figure 19), and the deeper sub-surface till samples collected in Becker hammer boreholes nearby (e.g., OB 99-58; Figure 18). These samples have below median Cu concentrations, with the lowest Cu value of all samples collected in this study (28 ppm) occurring 13 m below surface in borehole OB99-56, despite its close proximity to the Main Zone. Given these low Cu concentrations, these tills were most likely deposited during an early-eastward advance of ice from Coast Mountains and are thought to be a product of the erosion and transport of unmineralized bedrock located west of Huckleberry Mine.

Evidence of westward dispersal is apparent in most near-surface till samples west of the Main Zone orebody. In Becker hammer boreholes in this area till samples closest to surface have Cu values higher than those collected from deeper intervals (Figure 18). Over half of the samples with >90th percentile Cu values occur either on top, or to the west, of known mineralization. In addition, a general decrease in Cu values to the west of the Main Zone orebody is observed, further suggesting westward dispersal of mineralization.

Westward dispersal is well illustrated by the change in Cu values west of sample 00-6620 (1351 ppm Cu), located southwest of the tailings pond (Figure 13). Copper concentrations west of that site gradually decrease to 246 ppm, 1.5 km to the west at sample 00-6698. Till thickness is >5.5 m in a trench located approximately 10 m southwest of 00-6620. A similar trend occurs in near-surface samples north of TFE00-1 where >95th percentile Zn and >90th percentile Ag concentrations occur west of a small Late Cretaceous stock (00-6090 and 00-6113; Figures 16 and 14). Here again, element values gradually decrease to the west, with <70th percentile Zn and Ag concentrations occurring 1.6 km away (00-6662 and 00-6663; Figures 16 and 14). Becker hammer borehole logs indicate that till thickness in the vicinity of samples 00-6090 and 00-6113 varies from 15 to >28 m. Approximately 250 m east of these samples, tills vary from 6 to 14 m in thickness.

Examples of eastward dispersal of mineralization at surface, attributable to the latest eastward ice-flow event of the Late Wisconsinan glaciation, appear to be relatively uncommon. The clearest example is in a series of 12 near-surface samples, collected from thin till over bedrock, northeast of the Main Zone (Figure 21). Over a distance of approximately 1000 m there is a general decrease in Cu towards the east from 2692 to 144 ppm Cu. This eastward dispersal of mineralization is observed in tills up to 4 m thick.

Levson and Giles (1995), Paulen (2001), Levson (2002), and Ferbey and Levson (2010) suggest that there is a general relationship between till thickness and detrital transport distance, with an increase in till thickness resulting in an increase in transport distance. At Huckleberry Mine it also appears that till thickness is an important variable in determining the net transport direction of mineralization preserved at surface as there is west dispersal despite a late east ice-flow event. In areas with thick tills (tens of metres thick; e.g., west of the Main Zone) it appears that dispersal from an earlier ice-flow event is not completely erased but instead in part inherited and diluted by a subsequent event (cf. Parent et al., 1995; Stea and Finck, 2001). In areas with thinner tills (up to a few metres thick; e.g., northeast of Main Zone) adequate erosion and (or) reworking took place and dispersal from previous ice-flow events was essentially erased.

A simplified thick-till dispersal model (tills tens of metres thick) is presented in Figure 22 for the Huckleberry Mine area. In this model it is assumed that the mineralized bedrock source is only exposed to glacial erosion during the first, or early east, ice-flow event and that subsequent events inherit and dilute the mineralization's geochemical signature through the reworking of till. The change in colour of the dispersal plume from darker to lighter pink, as surface is reached, represents this reworking and dilution by subsequent ice-flow events. Till thickness, bedrock topography, and relative degree of erosion and (or) deposition during each subsequent ice-flow event can influence detrital transport direction observed at surface relative to the mineralized bedrock source. In Phase 1 and 2, the dispersal plume head (defined by high geochemical values) is offset from the bedrock source in the direction of ice-flow. In Phase 3, however, relatively

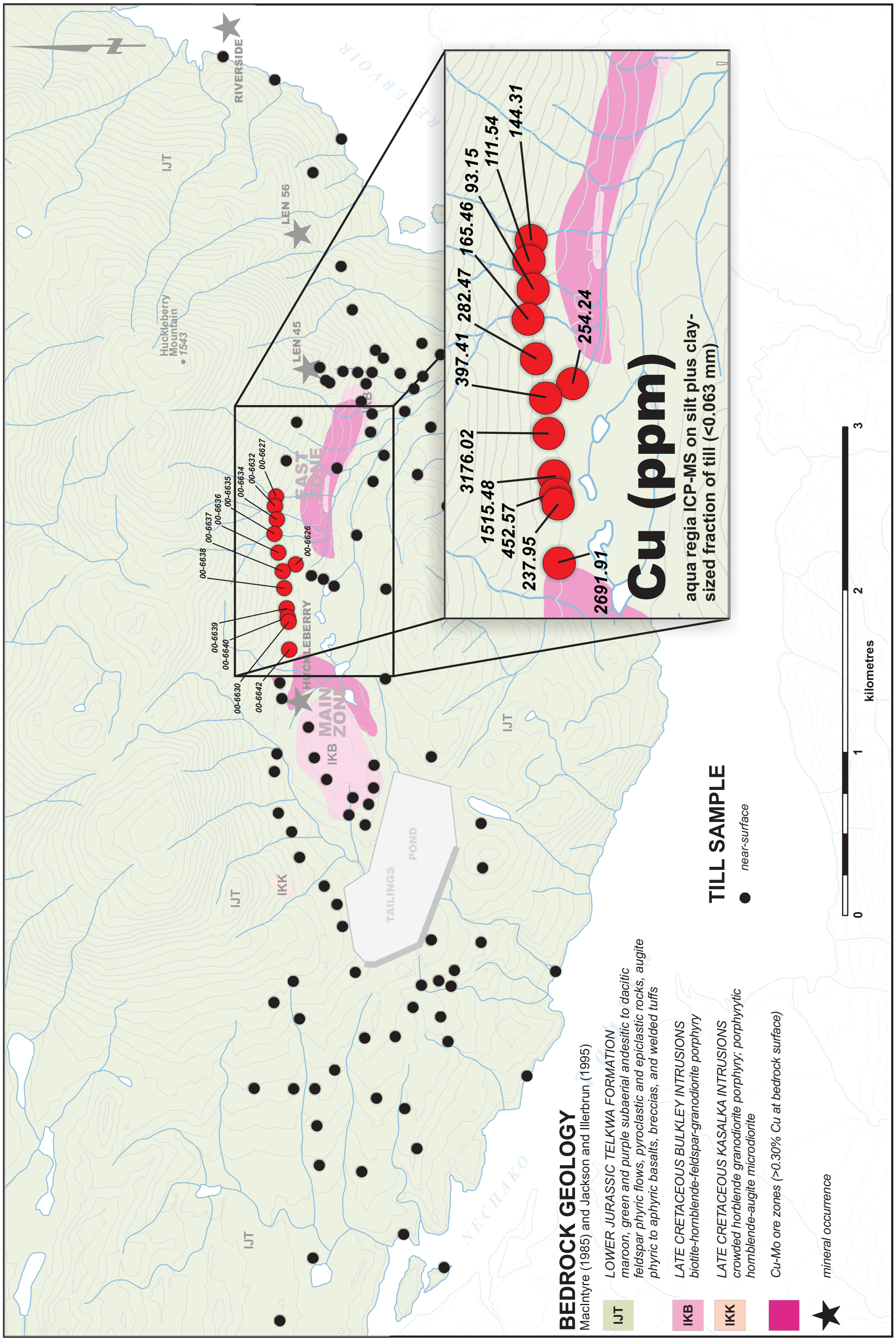


Figure 21. East dispersal in thin tills (< 4 m in thickness) associated with the late east ice-flow event.

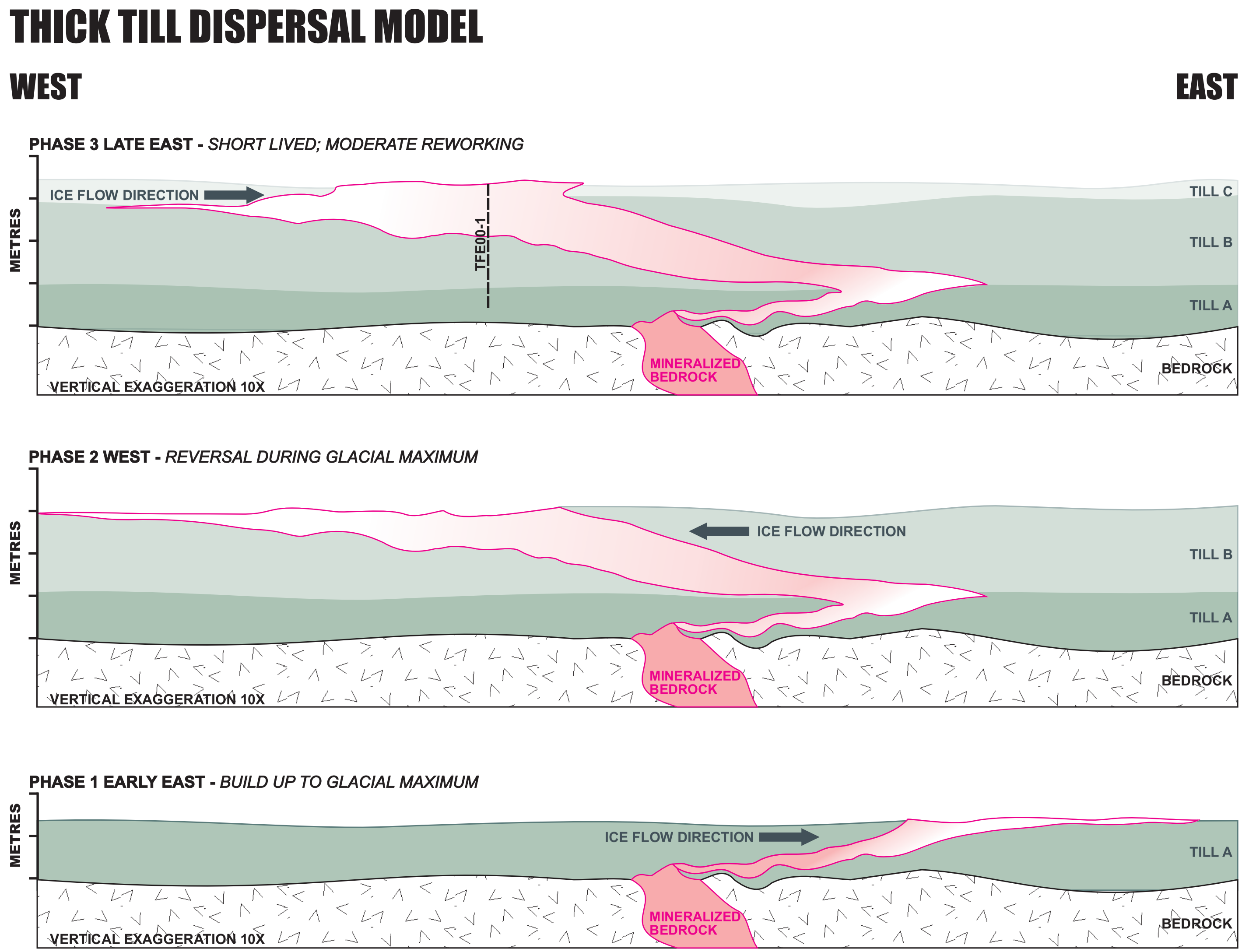


Figure 22. Dispersal model in thick tills of Huckleberry Mine area (tens of metres thick). In this simplified model of a dispersal train (in pink), the mineralized bedrock source is only exposed to glacial erosion during the early east ice-flow event. Till thickness, bedrock topography, and relative degree of erosion and (or) deposition during each subsequent ice-flow event can influence detrial transport direction observed at surface relative to the mineralized bedrock source. Phase 3 depicts net west transport of mineralization from a covered bedrock source. In Phase 3 the black dashed line approximates the theoretical location in this model of the vertical geochemical profile for TFE00-1.

little reworking has taken place and despite a late east ice-flow event net west transport is still preserved at surface. The vertical black dashed line approximates the location of section TFE00-1 in this model. The configuration of the dispersal plume at this position is thought to closely resemble the vertical geochemical profile for TFE00-1 (Figure 19). In general, this type of dispersal is more likely to be preserved where till units are thickest (e.g., valley bottoms or in the lee of topographic obstructions to ice-flow).

A simplified thin-till dispersal model (tills up to a few metres in thickness) is presented in Figure 23 for the Huckleberry Mine area. In this scenario, dispersal attributed to an earlier ice-flow event is more quickly modified (or perhaps erased altogether) and so the detrital transport direction preserved at surface is related to the last ice-flow event. In this model it is either assumed that the mineralized bedrock source is exposed to glacial erosion during each ice-flow event or that the pre-existing dispersal plume is completely reworked to reflect dispersal consistent with the most recent ice-flow event. Till thickness and bedrock topography can influence detrital transport direction observed at surface relative to the mineralized bedrock source. East dispersal observed at surface northeast of the Main Zone (Figure 21) is thought to be a product of events similar to those depicted in this model. In general, this type of dispersal is more likely to be preserved where till units are thinner (e.g., valley sides).

This idea of thick till units preserving westward dispersal at surface despite a late east ice-flow event seems to also hold true at the Equity Silver Ag-Cu-Au occurrence (MINFILE 093L 001), located approximately 80 km northeast of Huckleberry Mine, where westward dispersal in thick tills also occurs (Ney et al., 1972; Ferbey, 2011). Ferbey (2011) suggests a potentially similar scenario approximately 5 km east of Equity Silver in the vicinity of Allin Cu-Ag-Zn-Pb occurrence (MINFILE 093L 293). This is another area with thick till cover and prospecting and drilling have not yet identified a source for high-grade float found at surface. To date these exploration efforts have been based on a model of glacial transport towards the east. An exploration program for the Allin occurrence area that is based on following up west-transported mineralized float might produce different results.

Westward dispersal of mineralization in tills at Copper Star porphyry Cu-Mo-Au occurrence (MINFILE 093L 326) may represent the transition between Phase 2 and 3 of this thin-till dispersal model (Ferbey and Levson, 2010). Located 100 km north of Huckleberry Mine, still in the area affected by the Late Wisconsinan ice-flow reversal, westward dispersal on the order of 10's of metres from a buried bedrock source is preserved at surface in till <2 m thick (Ferbey and Levson, 2010). This dispersal likely represents an incomplete Phase 3 of the thin-till dispersal model. Phase 2 tills were partly reworked and (or) eroded but bedrock was not exposed to erosion during the relatively short-lived late east ice-flow event.

Observations on detrital dispersal of mineralization in till at Huckleberry, Equity Silver, Allin, and Copper Star

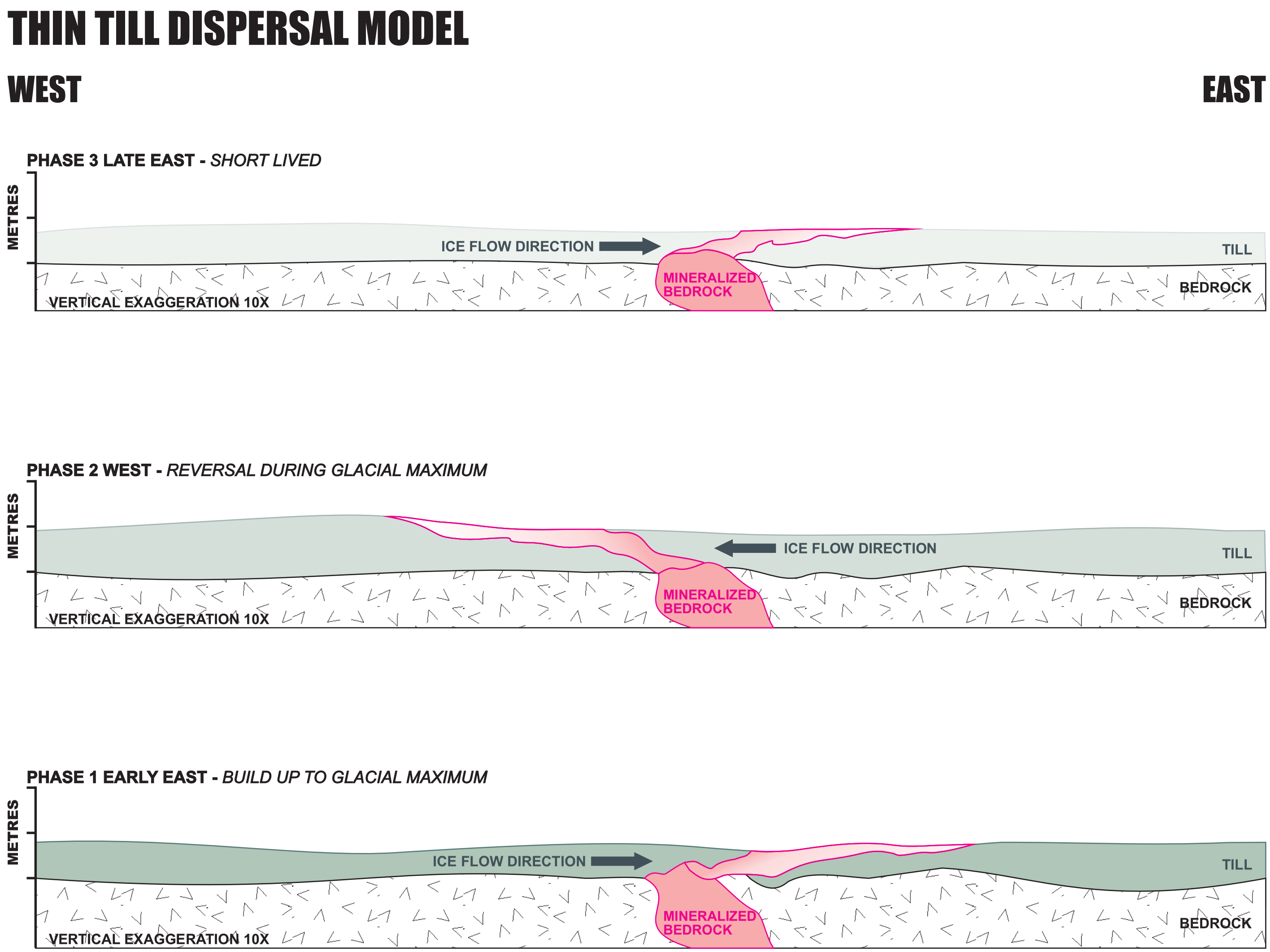


Figure 23. Dispersal model in thin tills of Huckleberry Mine area (up to a few metres thick). In this simplified model of a dispersal train (in pink), it is either assumed that the mineralized bedrock source is exposed to glacial erosion during each ice-flow event or that pre-existing dispersal plumes are completely reworked to reflect dispersal consistent with the most recent ice-flow event. Till thickness and bedrock topography can influence detrital transport direction observed at surface relative to the mineralized bedrock source. Phase 3 depicts net east transport of mineralization from a covered bedrock source.

have implications for mineral exploration programs being carried out in nearby areas. These observations from within an area with a complex ice-flow history suggest that till thickness has a strong affect on preservation of the geochemical record. Older west dispersal can be preserved in thicker tills while late east dispersal can be preserved in thinner tills. Understanding dispersal direction is required to successfully follow up elevated geochemical values in glacially transported sediments.

INDICATIONS OF UNDISCOVERED MINERALIZATION

Indications of undiscovered bedrock mineralization at Huckleberry Mine occur in two areas. The first is located approximately 2 km west-southwest of the Main Zone, where sample 00-6620 contains 1351 ppm Cu, 28 ppm Mo, 12 ppb Au, and 86 ppb Ag (Figures 13 to 15 and 17). This is the only >90th percentile Cu and Mo sample located >500 m from either the Main or East zone areas. These values were confirmed with a second sample collected at the same site (00-6460 containing 1457 ppm Cu, 25 ppm Mo, 40 ppb Au, 133 Ag). Approximately 10 m southwest of this sample a 5.5 m deep trench was excavated and five till samples were collected from 5 to 1.5 m below surface (Figure 20). Copper values in this vertical profile increase towards surface and range from 594 to 943 ppm. West of sample 00-6620 Cu, values at surface decrease from 372 to 246 ppm over a distance of 1.5 km. Several cobble and boulder-sized clasts with chalcopyrite and molybdenite mineralization were also observed at two sites west of sample 00-6620, at shallow depths; one yielded an assay of 0.62% Cu. To the east, Cu values abruptly drop from 180 to 66 ppm, over a distance of 250 m. These data suggest a west-trending dispersal plume with the head near sample 00-6020.

Although it is possible that these data could represent southwest dispersal from the Main Zone, a number of factors suggest that this dispersal train may be isolated or disconnected from dispersal from the Main Zone area and that there may be an undiscovered bedrock source for the mineralization near sample 00-6620. These factors include: the relatively long distance of the high Cu tills from the Main Zone (about 2 km); the very high concentration of Cu (1351 ppm) in till at 00-6620; the sharp decrease in Cu to the east of that site; and the presence of mineralized clasts in till west of sample 00-6620. Late in 2001, a diamond and rotary drill program conducted by HBL west of the tailings dam to follow up these results failed to identify a mineralized bedrock source west of the Main Zone orebody. However, this area still may have potential to host mineralized bedrock as drilling was not conducted directly up-ice (east) of sample 00-6620. It is possible that the source of the Cu in the tills could be mineralized volcanics located under the tailings pond (approximately 750 m to the east).

The second area that till geochemistry suggests the presence of undiscovered bedrock mineralization occurs 2 km west of the northern portion of the Main Zone orebody. Sample 00-6090 has 130 ppm Zn and 326 ppb Ag. Sample 00-6113, about 250 m to the northeast, has the highest Zn value on the property (207 ppm) and 382 ppb Ag (Figures 7, 14, 16). Copper values in these samples are 199 and 123 ppm, respectively. To the east of samples 00-6090 and 00-6113 there is a sharp decrease in Zn values, while to the west there is a more gradual decrease. For example, sample 00-6044, located about 200 m east of sample 00-6090, has Zn, Ag, and Cu values of 68 ppm, 65 ppb, and 46 ppm, respectively. Sample 00-6718, located about 500 m west of sample 00-6090, has 127 ppm Zn, 226 ppb Ag, and 291 ppm Cu. Another kilometre farther west at sample site 00-6663, Zn, Ag, and Cu concentrations are 50 ppm, 126 ppb, and 59 ppm, respectively.

As with the previous example, there is a gradual decrease in element values (in this case Zn and Ag) towards the west as would be expected with westerly dispersal. Although this trend is not as well defined with Cu values, there is a general decrease in Cu values west of sample 00-6718 to sample 00-6663. The decrease in Zn, Ag, and Cu values is thought to define a westward-directed dispersal train, with its head situated near samples 00-6113 and 00-6090. As with the first example, it is possible that these data could represent dispersal from the Main Zone, but several factors suggest that there may be an undiscovered bedrock source for the mineralization in this area. These factors include: the relatively long distance from the Main Zone (about 2 km); the sharp decrease in Ag and Zn values to the east of these sites; and the occurrence of <50th percentile concentrations of Zn and Ag due west of the southern portion of the Main Zone orebody. It is thought that the most likely source of mineralization is about 600 m east of the high Zn and Ag till sites, in the area around a small Late Cretaceous Kasalka Intrusions stock.

SUMMARY

Data presented here show that there is a good spatial relationship between elevated element concentrations in basal tills and the locations of known mineralized bedrock at Huckleberry Mine. All samples with >95th percentile Cu values (>1515 ppm), occur within 500 m of the Main and East zone orebodies. If put in the context of a regional-scale till geochemical data set, and associated percentile class breaks, the geochemical footprint of these orebodies is substantially larger. The mean and median Cu concentrations for near-surface basal tills of the Huckleberry Mine region are 489 and 216 ppm, respectively (n=106). The minimum concentration is 29 ppm while the maximum is 8924 ppm. Maximum Au and Ag values (184 and 1721 ppb, respectively) occur over the western end of the Main Zone stock. Despite till thicknesses exceeding 30 m, subcropping mineralization at Huckleberry Mine can be detected in strong till geochemical signatures that extend right to surface.

The association of high (>95th percentile) Cu and Zn concentrations in till at sites north of the Main Zone and the distribution of >90th percentile Zn values around the Main and East zone orebodies, suggests that Zn could be used as a pathfinder for mineralization occurring at Huckleberry and perhaps other calcalkaline porphyry deposits.

The Huckleberry Mine area has a complex ice-flow history, composed of three ice-flow events: I) an early eastward event attributed to the onset of the Fraser Glaciation and build-up of the Cordilleran ice sheet; II) an ice-flow reversal during the Fraser Glaciation maximum that resulted in a westward ice-flow event; and III) a return to eastward flow during latter stages of the Fraser Glaciation. Resultant patterns of detrital dispersal in till are, therefore, equally complex but evidence for all three is preserved.

At Huckleberry Mine it appears that till thickness is an important variable in the length of record preserved and generalizations can be made between it and net detrital transport direction. In areas with thick tills (tens of metres thick) it appears mineralized bedrock was only exposed to the early east ice-flow event. The net west dispersal direction preserved at surface in these thick sediments is thought to be a product of reworking of till during the subsequent west (glacial maximum) and late east ice-flow events. Conversely, in areas with thin tills (up to a few metres thick), it appears bedrock was either exposed to subglacial erosional processes during each of the three main ice-flow events or that pre-existing dispersal plumes were completely reworked to reflect dispersal consistent with the most recent east ice-flow event. This generalized pattern is more complicated where till thickness is unusually variable such as in areas of highly irregular bedrock topography.

Sub-surface samples (n=203), collected up to 30 m below surface using a Becker hammer drill rig, provide some insight into the offset distance of dispersal trains from their bedrock source. Sub-surface samples collected west of the Main Zone suggest that the head of a dispersal train located here is offset approximately 500 to 1000 m west (or down-ice) of its bedrock source. This is in agreement with Zn and Ag values in near-surface samples collected northwest of the Main Zone that suggest a similar 600 m net offset distance.

Till geochemical data from the Huckleberry Mine area indicate that the dispersal direction preserved at surface in areas with thick tills may differ from the direction of the last ice-flow event through an area. The potential for multiple ice-flow events should be considered when conducting geochemical surveys in areas where thick tills generally occur (e.g. valley bottoms). In these areas, the dispersal direction encountered at the surface may be the product of an older ice-flow event, in contrast to areas where relatively thin tills occur.

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