The Quaternary history and till geochemistry of the Anvil District, east-central Yukon

Jeffrey D. Bond
Yukon Geology Program

ABSTRACT

Till geochemistry and glacial geology have rarely been integrated into Yukon mineral exploration. In the Anvil District, thick glacial deposits have consistently hampered exploration. From the initial (massive sulphide) discovery in Vangorda Creek, twenty years elapsed before the Grum deposit was discovered only two kilometres to the northwest. This work examines the utility of till geochemistry as a method to trace mineralized soil/till samples back to their source rocks in the Anvil District. The Anvil District was last glaciated during the McConnell glaciation, which had a significant impact on the local terrain. The relatively swift-flowing Cordilleran ice sheet deposited thick sequences of till in low-lying areas and eroded southeast-facing slopes and hill summits in the Swim Basin and Vangorda Plateau. This type of glacial history is conducive for till geochemical exploration. A 12 km^2 till grid was sampled northwest of the Faro deposit to map the glacial dispersion train. The till geochemistry on the –230 mesh fraction (silt and clay) indicated a broad dispersion plume for lead, zinc, and copper, extending more than 5 km west of the Faro Pb/Zn deposit. A section of the dispersion train may have a palimpsest origin. The soil geochemistry on the –80 mesh fraction, from 1964 data, indicated a much narrower dispersion plume extending directly from the Faro deposit. Till geochemistry, particularly on the fine fraction, has applications to similar drift-covered terrain, such as the Finlayson Lake massive sulphide district to the southeast.

RÉSUMÉ

La géochimie du till et la géologie des formations glaciaires ont été considérablement sous-utilisées en prospection minière au Yukon. Dans le district d'Anvil, d'épais dépôts glaciaires ont nui de manière persistante à l'exploration. Depuis l'époque de la découverte initiale au ruisseau Vangorda, il aura fallu 20 ans pour découvrir le gisement Grum pourtant situé à seulement deux kilomètres au nord-ouest. Dans cette étude, on examine l'utilité de la géochimie du till comme méthode pour retracer la source des échantillons de sol/till minéralisés jusqu'à la roche mère dont ils proviennent dans le district d'Anvil. La glaciation de McConnell est la dernière qui a touché le district d'Anvil et elle a eu une incidence importante dans ce secteur. L'inlandsis de la Cordillère, dont l'écoulement était relativement rapide, a déposé d'épaisses séquences de till dans les étendues basses et a érodé les versants face au sud-ouest ainsi que les sommets des collines du bassin Swim et du plateau Vangorda. Ce type d'histoire glaciaire se prête bien à la prospection basée sur la géochimie du till. Le till a été échantillonné sur un quadrillage s'étendant sur 12 km^2 au nord-ouest du gisement Faro dans le but de cartographier la dispersion par la glace des sédiments minéralisés. La géochimie de la fraction du till acceptée au tamis de 230 mesh (limon et argile) révèle pour le plomb, le zinc et le cuivre un large panache de dispersion s'étendant jusqu'à plus de 5 km à l'ouest du gisement Faro de Pb/Zn. Un segment de la traînée de dispersion peut avoir comme origine une structure résiduelle. La géochimie de la fraction du sol acceptée au tamis de 80 mesh révèle, d'après des données de 1964, un panache de dispersion beaucoup plus étroit directement derrière le gisement Faro. La géochimie du till, et particulièrement de la fraction fine, a des applications dans les terrains analogues recouverts de sédiments glaciaires comme le district à sulfures massifs de Finlayson au sud-est.

INTRODUCTION

Quaternary geology and till geochemistry research, in conjunction with bedrock mapping (see Pigage, this volume) and lithogeochemistry, has been initiated as part of an interdisciplinary research program in the Anvil District, east-central Yukon. Thick glacial deposits have consistently hampered exploration in the Anvil District. From the time of the initial Pb/Zn discovery made in Vangorda Creek in 1953, it took an additional twenty years before the Grum deposit was discovered only two kilometres to the northwest.

The study discussed in this paper examines the utility of till geochemistry as a method to trace dispersed mineralized sediment in the Anvil District. Research focussed on Quaternary history, surficial geological mapping, glacial dispersion mapping, stratigraphic and regional till geochemistry, as well as expanding on results of the drift exploration case study completed at the Faro Pb/Zn deposit.

BACKGROUND

The use of till geochemistry, or boulder tracing, as a method of prospecting in glaciated terrain has long been recognised. In Finland, as early as 1740, it had been noted that erratic blocks could be traced to their source and may have applications to

the location of ore deposits (Shilts, 1976). It was not until the early twentieth century however, that drift prospecting became recognized as a valuable method in the exploration industry. Canadian research into drift exploration has largely focussed in the Canadian Shield, and now more recently, to central British Columbia, Vancouver Island, and southern British Columbia by the British Columbia Geological Survey. Few studies have addressed the applicability of this technique in the Northern Cordillera where permafrost provides an additional hindrance to preliminary surveys.

A case study of this technique in the Anvil District aims to provide a background methodology for future reference by exploration programs in drift-covered terrain. This may prove particularly useful in the Finlayson Lake base metal district further to the southeast; this area has high mineral potential with a large portion of the area blanketed by glacial drift.

PHYSIOGRAPHY, DRAINAGE AND GEOLOGY

PHYSIOGRAPHY

The Anvil District is located in the east-central Yukon and is part of a northwest trending belt located between the northeastern flank of the Anvil Range and Tintina Trench (Figs. 1 and 2).
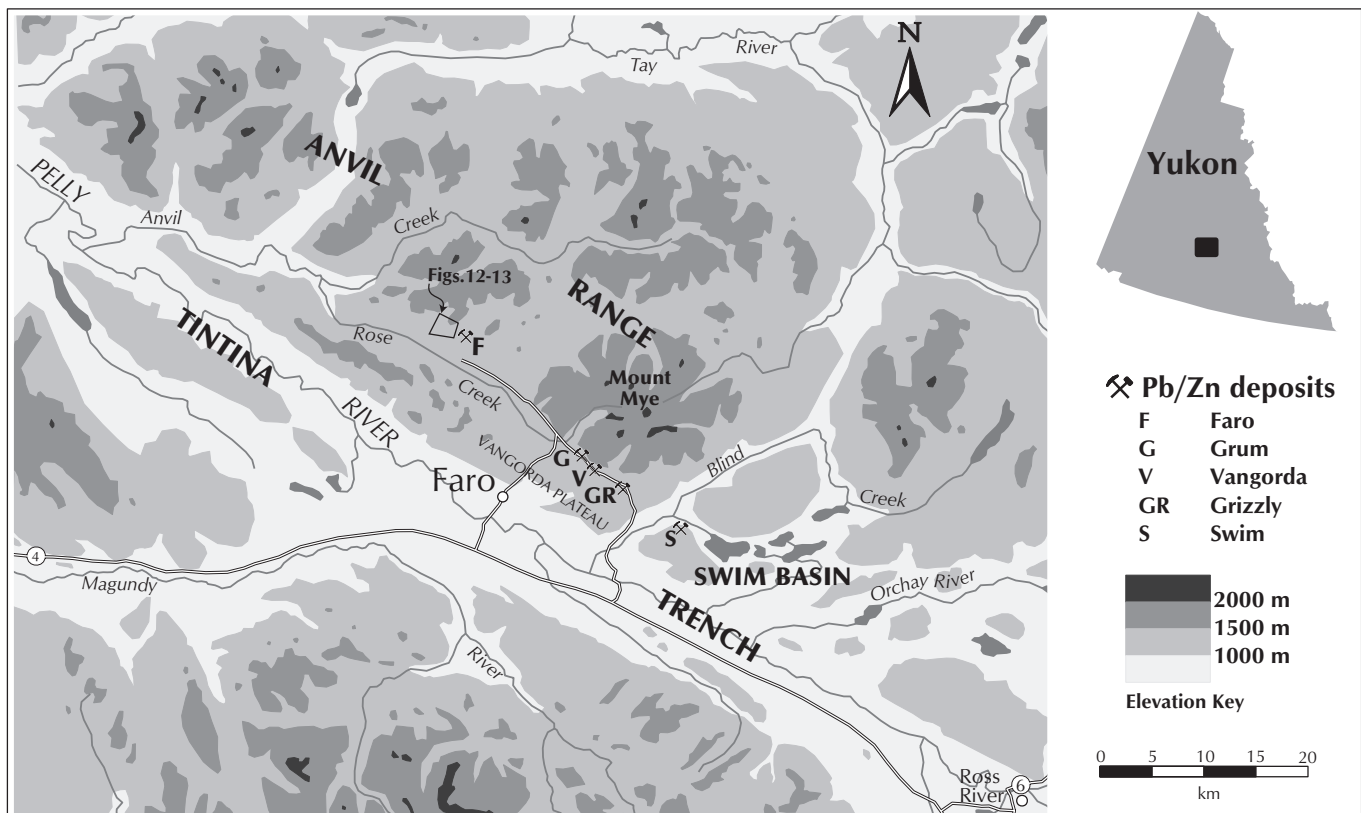

Figure 1. *Location and physiography of the Anvil District, east-central Yukon.*

Vangorda Plateau, a rolling upland averaging 1219 m (4000 ft), is bounded by the Blind Creek valley and Tie faults, and separates the Mount Mye upland from Tintina Trench. Swim Basin is the structural and physiographic continuation of Vangorda Plateau to the southeast. Anvil Range consists of a series of massifs reaching 1981 m (6500 ft) that are separated by glacial valleys averaging 1341 m (4400 ft). Cirque valleys radiate from all the uplands in the Anvil Range.

DRAINAGE

The regional drainage of the Anvil District is into the Pelly River (Fig. 1). Streams flowing north off the Anvil Range flow into the Tay River prior to entering the Pelly River and streams draining southeast and southwest feed into the Pelly River either directly, via Blind Creek, or via Anvil Creek.

GEOLOGY

The Anvil District is part of the Selwyn Basin, a deep-water sedimentary basin that formed along the ancient North American continental margin during the late Proterozoic and early Paleozoic (Gabrielse, 1967). The Anvil District is located on the outboard edge of the basin and is dominated by successions of basin-filling sediments. The stratigraphic sequence comprising the Anvil District extends from latest Precambrian to Ordovician and can be divided into three formations: Mount Mye (oldest), Vangorda, and Menzie Creek (youngest; Jennings and Jilson, 1986). Mount Mye formation is a deep marine sequence dominated by non-calcareous phyllite and schist with lesser marble and calc-silicate lenses, carbonaceous schist, minor psammitic schist and metabasite. Vangorda formation is also a deep marine sequence, dominated by calcareous phyllite and schist with lesser marble and calc-silicate lenses, carbonaceous schist, minor psammitic schist and

metabasite. Menzie Creek formation is a 1 km thick sequence of metavolcanic rocks deposited through episodic extensional tectonism on the continental margin and is gradational with the Vangorda formation. The Anvil District Zn/Pb/Ag stratiform pyritic massive sulphide deposits occur within a 150 m interval in the pre-Ordovician strata at the contact between Mount Mye and Vangorda formations. The Anvil District hosts five ore deposits along a northwest-southeast curvilinear trend: Faro, Grum, Vangorda, Grizzly, and Swim (Fig. 1).

The mid-Cretaceous Anvil Range plutonic suite intruded the Selwyn Basin stratigraphy in response to collision of Yukon-Tanana suspect terrane with ancient North America. Movement along the Tintina Fault began in the late Cretaceous and continued into the early Tertiary (Pigage, 1990).

METHODOLOGY

Surficial geological mapping was completed at 1:25 000 scale and provided the baseline information for the glacial history interpretation of the Anvil District. Quaternary sections were logged in the open pits on Vangorda Plateau and in Rose Creek valley, in addition to natural and road-cut sections in Blind Creek valley. The principal till geochemical case study for the 1998 season was completed northwest of Faro deposit in Rose Creek valley. In total, 140 samples were gathered from a 3 km by 4 km grid. Samples were spaced every 200 m and line spacing progressed from 200 m to 500 m over 13 lines total. Till samples were obtained by hand digging with a pick and shovel to a depth averaging 71 cm or sufficiently deep to penetrate post-glacial soil development and any possible air-born contamination in the soil from the nearby mining activity (Fig. 3). Where possible, compact basal till or colluviated till was sampled. On the lower slopes of the grid, alluvial organic silt
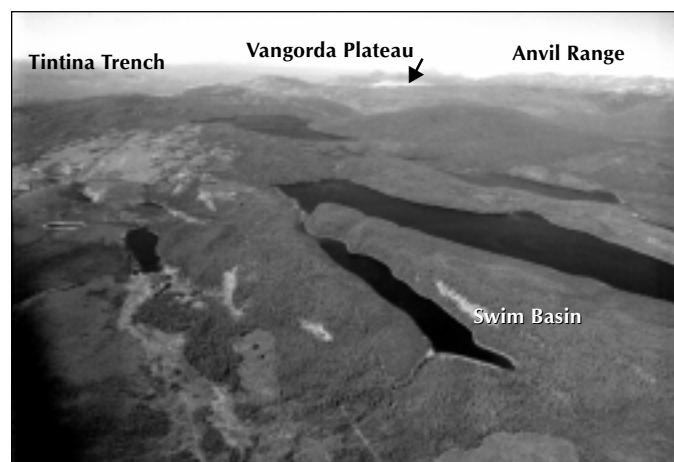

Figure 2. *An oblique air photograph of the Anvil Disrict physiography. View is to the west. Note the Grum and Vangorda mines in the middle background (see arrow).*

Figure 3. *Sample taken in a compact basal till on the Faro grid. The White River ash is visible at the surface next to the shovel. Soil development at locations such as this is limited to the upper 25 cm. Pit depth is 65 cm.*

containing sporadic permafrost was encountered; this often required digging more than one pit to reach depths sufficient to uncover at least a lens of colluviated till. This sampling method would be inhibited by widespread permafrost, especially where till is not part of the active layer. Samples averaging 10 kg were bagged, and later split and sieved to separate the silt/clay fraction (-230 mesh) for standard 32 element ICP-AES and a fire assay for gold at Chemex Labs in Vancouver, B.C. According to Shilts (1984), analysis of the –230 mesh fraction is advantageous for examining sulphide concentrations in till. Post-glacial weathering of sulphide minerals occurs readily and simultaneously causes metal enrichment in the clay-sized fraction. Clay minerals act as scavengers by retaining the metal fraction; thus the samples with a larger percentage of clay would give higher metal values, especially where mineralization occurs locally (Nikkarinen et al., 1983).

Till was sampled from Quaternary exposures in the Faro, Grum, and Vangorda open-pits to evaluate geochemical changes with depth. Regional till sampling was carried out on the southeastern end of the Vangorda Plateau, Blind Creek valley, and in the Swim Basin to assess the potential for a buried massive sulphide deposit and to better quantify the background geochemical values for the district. A small geochemical grid was sampled west of the Swim deposit. In total, 227 drift samples were obtained in the Anvil District in 1998.

Quality control was maintained by submitting field and analytical duplicates to check for problems in field sampling and analytical techniques. A field and analytical duplicate was submitted in every set of 20 samples. CANMET control standards were submitted in every 30 samples taken.

Field and analytical duplicates are presented for zinc, copper, and lead. The bivariate scatter plots show good reproducibility (r > 0.90) for both field and analytical duplicates (Fig. 4). Higher r-values were obtained for the analytical duplicates than the field duplicates for both copper and zinc. This suggests that field duplicates have higher geochemical variability than analytical duplicates for copper and zinc in this data set.

QUATERNARY HISTORY

The Yukon was last glaciated during the late Wisconsinan McConnell glaciation approximately 20,000 years ago (20 Ka). The McConnell glaciation represents the most recent glaciation in a glacial/ interglacial cycle that dates to the beginning of the Quaternary period approximately 2.5 million years ago (2.5 Ma). The earliest glaciations (pre-Reid), at the onset of the Quaternary period or early Pleistocene, were the most extensive and are largely responsible for the current regional drainage configuration in the Yukon (Fig. 5). More recent glaciations such as the Reid (middle Pleistocene) and McConnell (late Pleistocene) have well defined limits within the pre-Reid glacial limits (Bond, 1997). In the Anvil District,
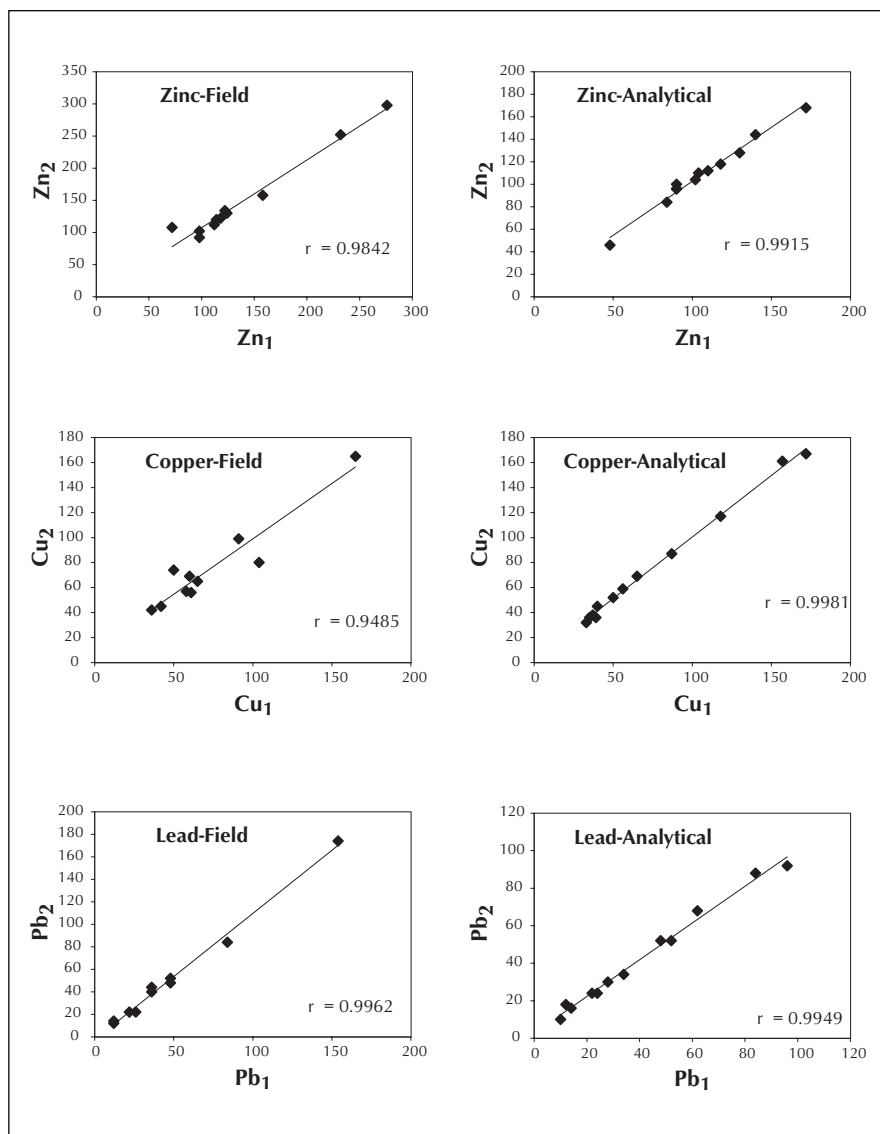

Figure 4. Bivariate scatter plots for field and analytical duplicates showing zinc, copper and lead in ppm's. The r-values (> 0.90) indicate a good correlation between the duplicate pairs and no major discrepancies for the field and analytical methods.
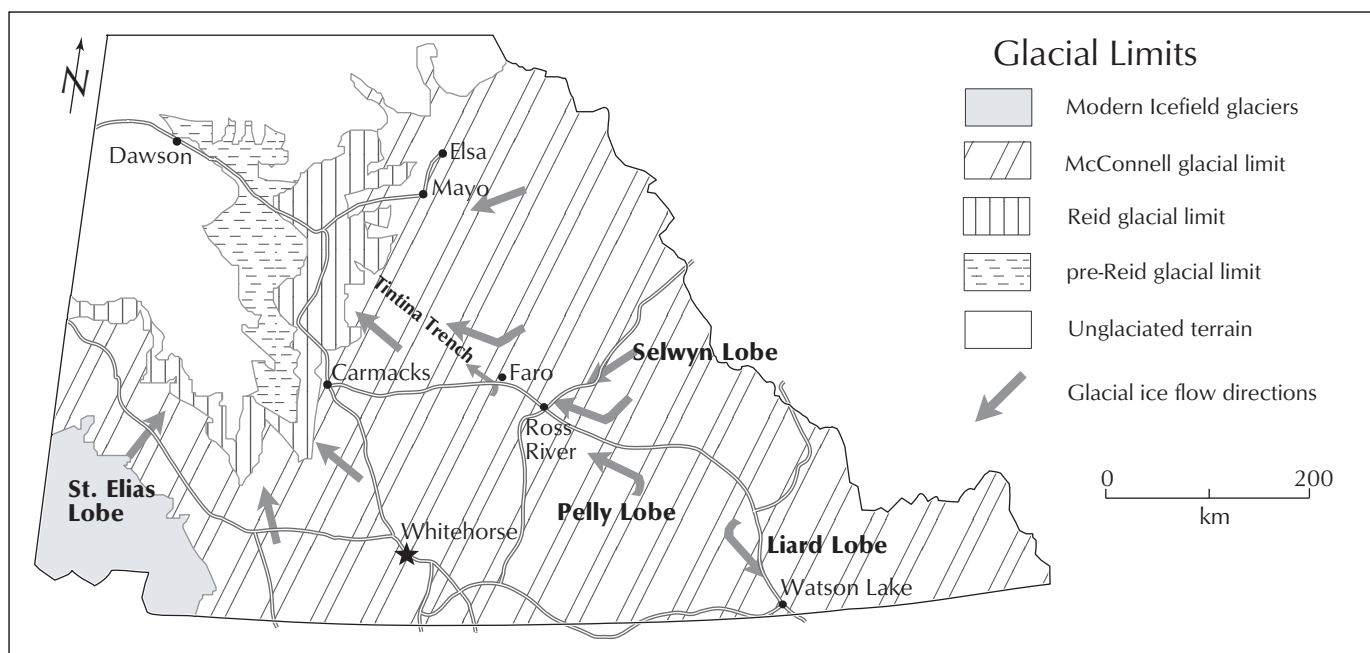
Figure 5. *Cordilleran glacial limits and flow lines in southern Yukon with position of regional ice lobes (Bostock, 1966; Jackson, 1994).*

record of the older glaciations was eroded or buried during the last glaciation.

McConnell ice originated from regional accumulation zones in the Selwyn, Pelly and St. Elias Mountains. The Anvil District was dominantly glaciated by ice from the Selwyn and Pelly Mountains, and by local glaciers from the Anvil Range. The Selwyn and Pelly lobes, in the vicinity of Ross River and Faro, were funneled into Tintina Trench and followed the topographic lineament northwest into central Yukon (Fig. 5). Streamlined landforms developed proximal to the Tintina Trench under the relatively rapid ice flow conditions (Fig. 6). Ice flow in the Swim Basin, according to aligned landforms, was largely from east to west, becoming more northwesterly upon intersecting Blind Creek valley and Vangorda Plateau. Till fabric data from exposures on Vangorda plateau show some ice-flow variability which likely reflects a directional change from Mount Mye alpine ice merging with the main Cordilleran ice sheet. Ice flow continued to the northwest into Rose Creek valley where it became valley-confined. Nunataks were present in the Anvil Range during the last glaciation (Jackson, 1994).

McConnell deglaciation, according to Jackson (1987; 1994), occurred rapidly when the equilibrium line rose significantly above the 1830 m elevation. This resulted in the wholesale starvation of the ice sheet. A subsequent re-advance by the Cordilleran ice sheet has been documented in many areas of central Yukon and appears to be consistent with the glacial history of the Anvil District. Lateral moraines and meltwater channels of the Cordilleran ice sheet extend into local alpine

valleys, and flights of kame terraces in the alpine valley bottoms indicate an invading ice front from outside the upland. A glacial lake formed in the Tintina Trench at the end of the glaciation and is informally termed Glacial Lake Pelly.

Figure 6. *Aerial photograph of streamlined terrain in the Swim Basin. The ice-flow direction, indicated by the arrow symbol, is to the west.*

The onset of the McConnell glaciation occurred after 26,350 ± 280 BP (Jackson, 1991; TO-393) according to a radiocarbon date on a bone fragment of *Bison priscus* along the Ketza River. According to Ward (1989), deglaciation of the Pelly River was complete by 12,590 ± 540 BP (TO-931).

SURFICIAL GEOLOGY

The surficial geology of the Anvil District is controlled by the three physiographic divisions: Anvil Range, Vangorda Plateau/
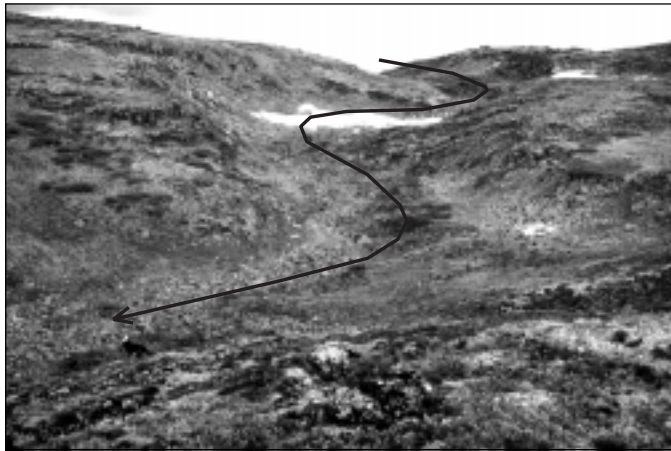

Figure 7. *A meltwater channel formed by outwash emitted off the Selwyn ice lobe. The channel cuts across a plateau at 1676 m (5500 ft) on Mount Mye. Landforms such as this are common on the flanks of the Anvil Range between the elevations of 1310 –1768 m (4300-5800 ft).*
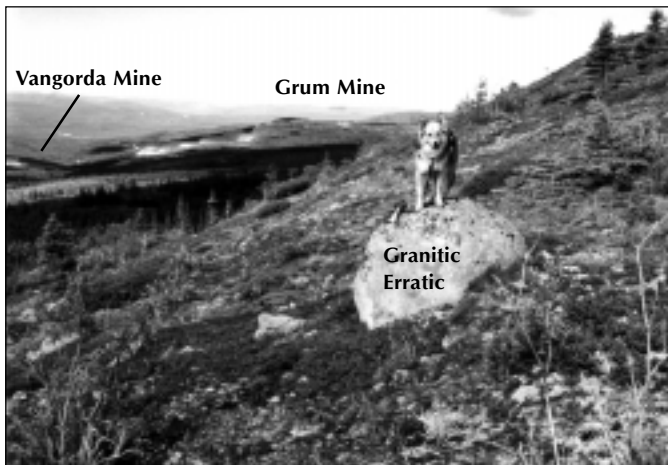

Figure 8. *Erratics are common in the Anvil District. Here a Cretaceous granitic boulder was found lying on rocks of the lower Cambrian Mount Mye formation at 1433 m (4700 ft). Vangorda Plateau and two of the Anvil District mines are visible in the background. View is to the west.*

Swim Basin, and Tintina Trench. Anvil Range is covered by colluvium, with exposed rock above 1768 m (5800 ft) and at lower elevations on north- and west-facing slopes where nivation processes are common. Erratics and meltwater channels were mapped to at least 1707 m (5600 ft), however no significant glacial deposits were noted at this elevation (Fig. 7). The flanks of the upland have increased glacial sediment cover below 1463 m (4800 ft; Fig. 8). Till and deltaic deposits were mapped in the Mount Mye alpine valleys to 1554 m (5100 ft). Glacial drift in the alpine valleys of Mount Mye, and possibly in other neighbouring alpine valleys, consists of combined sediment from alpine glaciers and the Cordilleran ice sheet which invaded the alpine uplands at the end of the McConnell glaciation. Sporadic rock glaciers were mapped in the Anvil Range on north-facing slopes.

Vangorda Plateau and Swim Basin are draped with till blankets and minor till veneers (Fig. 9). Glacial outwash deposits occupy low channels cutting the rolling upland surface. Till veneers and colluviated till veneers are common on south- and southeast-facing slopes which were exposed to glacial erosion by the northwesterly flowing ice sheet. Crag-and-tail landforms were also noted at the tops of southeast-facing slopes from subglacial erosion of relatively resistant bedrock (Fig. 10). These landforms develop when a glacier intersects a resistant bedrock "crag" and leaves a pressure void in the down-ice direction. In the pressure void, or "tail," sedimentation occurs and/or a ridge of less resistant bedrock is preserved. Crag-and-tails are useful indicators of ice-flow direction.

Thick glaciolacustrine beds were deposited in Tintina Trench at the end of the McConnell glaciation (Fig. 11). Holocene erosion of the glaciolacustrine deposits by the Pelly River has left remnant deposits lining the Tintina Trench/Pelly River valley. Complexes of hummocky glacial meltout surfaces, particularly common between Faro and Blind Creek valley, also line Tintina

Figure 9. *Vangorda mine looking to the southeast. A blanket of till is visible on the pit wall in the background. The till depth varies from 1 m to 50 m.*

Trench. Meltout deposits consist of mixed glaciofluvial gravel, resedimented till, and sporadic in-situ glacial ice lenses.

IMPLICATIONS OF GLACIAL HISTORY ON EXPLORATION IN THE ANVIL DISTRICT

Thick glacial sediment sequences across the Vangorda Plateau and Swim Basin has hampered exploration in the Anvil District. Excessive glacial deposition is likely a factor of the district's relatively low-rolling physiography. The rapid ice flow through the area had high erosional capabilities which increased the sediment being transported by the glacier and ultimately deposited by the glacier. Areas of thin drift (till veneers < 1 m) or exposed bedrock are found on or near the crest of southeast-

Figure 10. A crag-and-tail landform on the Vangorda Plateau. Direction of ice flow was from the lower left to the upper right or to the west northwest. This landform is approximately 175 m long.

Figure 11. Glaciolacustrine silt in the Pelly River valley/Tintina Trench. The silt exposure is more than 100 m high.

facing slopes and on hill summits in Swim Basin and on Vangorda Plateau. Thick glacial deposits, in contrast, accumulated on the lee-side of hill slopes, in localized basins and on the lower flanks of southeast-facing slopes. Surface samples from an area of thick till cover generally contain bedrock fragments which are further removed, as opposed to a shallow till which predominantly reflects local bedrock sources. With this in mind, soil assays can be relatively calibrated according to the topographic setting and the glacial sediments from which they were collected.

The late McConnell re-advance by the Cordilleran ice sheet could have implications regarding the origin of surface till in alpine valleys. Due to the absence of local alpine glaciers at the time of the readvance, alpine valleys were inundated by Cordilleran ice, therefore allowing for the deposition of foreign sediments. This late glacial history could play an important role in determining the origin of soil parent material and potential dispersion trends in alpine valleys in the Anvil District.

FARO DEPOSIT CASE STUDY

The underlying principal of till geochemistry is based on the probability of detecting a dispersion train which may have a surface area hundreds of times larger than its original bedrock source. The Faro deposit case study was completed to determine the size and magnitude of glacial dispersion from a known source, using a sampling technique designed to accentuate subtle enrichment related to sulphide deposits. This technique may be valuable in regional exploration for similar deposits in glaciated terrain to the southeast of the Anvil District. The sampling program was modeled after similar studies by the British Columbia Geological Survey in southern and central B.C. (Levson et al., 1994a, 1994b, and 1994c; Giles and Kerr, 1993; Bobrowsky et al., 1995, Bobrowsky et al., 1997a, 1997b; Bobrowsky et al., 1998). A 12 km^2 grid composed of 140 sample locations was surveyed and sampled northwest of the Faro deposits. Assay results for lead, zinc and copper were contoured and are presented in Figures 12 and 13 (see next page). The 1998 contoured geochemical maps are compared with equivalent geochemical results obtained from 1964 soil geochemistry. The presumed difference in the data sets is in the sampling and analytical procedures. The industry norm in 1964 was to collect B-horizon soils and assay the −80 mesh, whereas the technique employed in this study, as outlined earlier, focussed sampling below the soil horizons and assays on the −230 mesh fraction. The soil data obtained from the 1964 data set was interpolated to the 1998 sample locations from a more densely spaced soil grid in the same area.

RESULTS

Contoured results for lead, zinc, and copper are presented below for the 1998 and 1964 data.

The 1998 geochemical contours for lead data clearly show an increase towards the Faro deposit (Fig. 12a). The westward-oriented dispersion trend is consistent with ice-flow direction confined to Rose Creek valley and shows a slight drop in elevation with distance from the ore body. This reflects the progressive transport of subglacial debris into the valley bottom. In the vicinity of line 3 (L3), anomalous till values were mapped at higher elevations than the ore bodies.

Lead contours from the 1964 data show a narrow elongated plume to the west (Fig. 13a). Similarly, but more pronounced than the 1998 data, is a progressive reduction in elevation of the dispersion plume of 152 m (500 ft) over 4 km. In contrast to the 1998 data, the lead values from L3 at higher elevations are not anomalous.

The 1998 contoured geochemistry for zinc, like lead (1998), indicate a broad dispersion plume to the west extending beyond the sample grid (Fig. 12b). Contours show an extension of values that follow the topographic contours into Next Creek. Anomalies along the lower elevations of lines 3–7 are likely attributed to dispersal enrichment from the lower Faro deposit. An anomaly at the upper elevations of line 3 indicates proximal till enrichment 152 m (500 ft) above the source area.

The 1964 contoured geochemistry for zinc shows a well-defined dispersion plume almost 1.5 km wide by at least 4 km long with a narrow secondary anomalous ribbon near the top of the grid (Fig. 13b). The progressive

Figure 12. Contoured till geochemical values near the Faro ore deposits (1998 data). a) Lead: note the higher concentrations above the elevation of the upper Faro deposit. b) Zinc: note the broad ameboid-shaped dispersion plume from the Faro deposits. The contours also conform to Next Creek valley. c) Copper: note the broad dispersion plume to the northwest with a strong gradient of values decreasing down-ice.
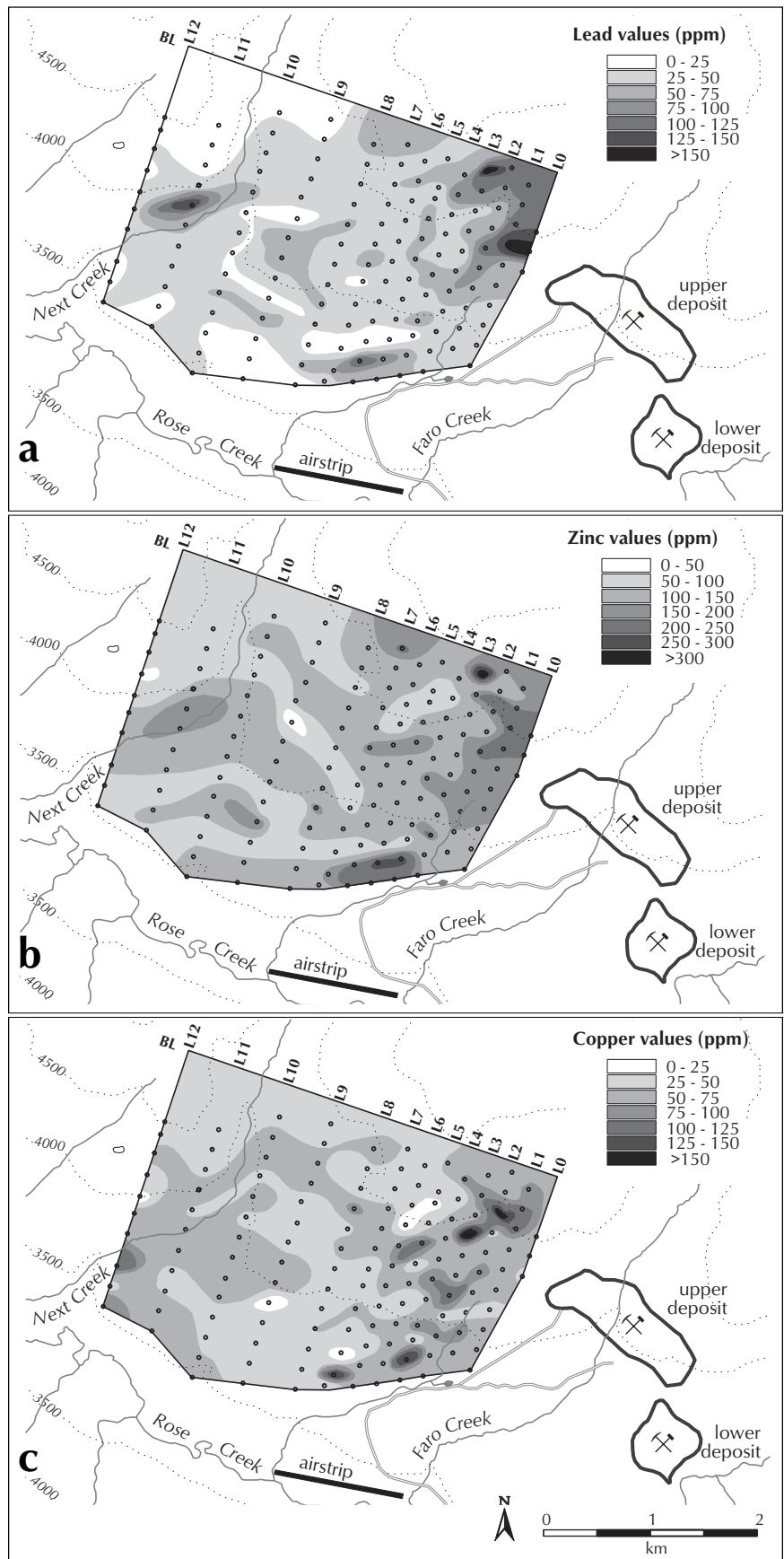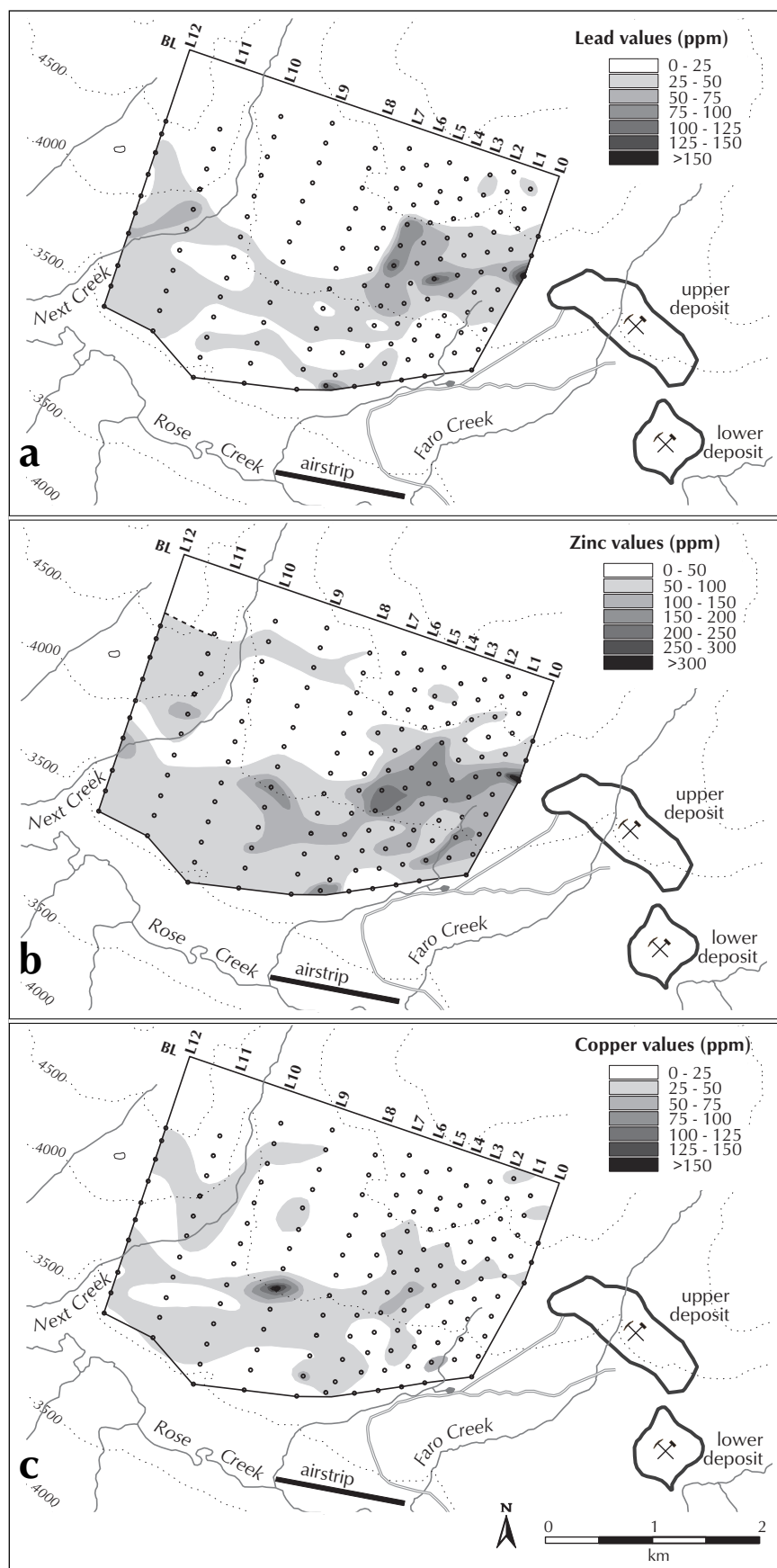
down-slope trend of the plume is also well pronounced, with a distinct anomalous core to the main dispersal body.

The 1998 contoured geochemistry for copper shows a clear dispersal plume with the highest values occurring in the first 1.5 km west of the upper ore deposit (Fig. 12c). Ribbon shaped plumes continue down-valley beyond the grid and appear to conform into Next Creek valley. The highest copper values in till were obtained from the upper elevations of lines 1-3.

The 1964 contoured geochemistry for copper shows a 600 m wide ribbon shaped dispersion plume from the Faro deposits (Fig. 13c). A second ribbon-shaped plume is visible near the end of the grid in Next Creek valley.

DISCUSSION

DRIFT EXPLORATION CASE STUDY

The 1998 Faro till geochemistry case study outlined distinct dispersion plumes for each of lead, zinc, and copper. The primary dispersion plume can be traced directly to the upper Faro deposit, and in some instances to an anomalous area above the main ore bodies. For copper (1964 and 1998 data) and zinc (1964 data), a secondary dispersion plume is visible at the upper elevations of the grid between lines 8 and 12 that appears to be directed towards the anomalous area near the upper elevations of line 3. This can be explained as either a dispersion plume from anomalous bedrock or as a palimpsest dispersal train. Palimpsest dispersal trains are residual trains that are produced from multiple ice-flow

*Figure 13. Contoured geochemical soil values near the Faro ore deposits (1964 data). **a)** Lead: note the well-defined dispersion plume from the upper Faro deposit to the west. **b)** Zinc: note the well-defined dispersion plume from the upper Faro deposit and a second ribbon at a slightly higher elevation. **c)** Copper: the dispersion plume is well defined, however lacks a decreasing concentration gradient away from the Faro deposits.*

directions, in which an earlier dispersal train is incompletely re-entrained by later glacial movement (Parent et al., 1996). In short, it requires dispersion of a dispersion plume. A neighbouring, but topographically isolated till anomaly could thus indicate an early dispersion (ice-flow direction) related to a differing ice-flow direction. The isolated anomaly near the upper elevations of line 3 could have formed when converging glaciers in Rose Creek valley forced ice to flow subparallel to the contours. This northwest-trending plume was then re-dispersed or elongated by a change in flow direction to the west. Evidence for a bedrock source that might otherwise explain this dispersion plume is currently unknown in this area (Pigage, pers. comm.).

The 1998 geochemical contours show a broad dispersion plume from the source area, whereas the 1964 geochemical contours show a narrow and more direct dispersion plume. The utility of glacial dispersion and till geochemistry is apparent from either of the two data sets. Typically, soil sampling is used as a method to trace anomalies at the property scale. Results from this study suggest it has wider applications to regional- and intermediate-scale massive sulphide exploration in drift-covered terrain. By contrast, the 1964 contoured data emphasizes the utility of this technique as a method in local-scale exploration for massive sulphides sub-cropping in drift covered terrain. In the case of the Faro deposit, the dispersion plumes for lead and zinc in the 1964 data set point directly back to the source rocks.

To compare the two data sets, the Pb and Zn values from the 1998 and 1964 Faro grid lines are compared to a background value and a 95th percentile threshold derived from Swim Basin regional samples. The background threshold is equal to the median value and the 95th percentile is considered to be a higher end anomalous threshold. Swim Basin is considered to be the most representative area to calculate a regional threshold because of its similar geology, physiography and glacial history to the Vangorda Plateau. It should be noted that the threshold values calculated for these data sets are based solely on relative significance. From the 1998 Faro grid line data, 94% of the zinc and 100% of the lead values fell above the background levels of 76 and 14 ppm, respectively. When plotted relative to the regional 95th percentile, 6.5% of the zinc values and 66% of the lead values were above the upper thresholds of 203 and 32 ppm, respectively. From the 1964 data, 51% of the zinc values and 70% of the lead values fell above background levels of 62 and 13 ppm, respectively. When the 1964 Faro grid line values were plotted relative to the regional 95th percentile, 16% of the zinc values and 53% of the lead values were above the thresholds of 128 and 23 ppm, respectively.

From these results, a comparison of the significance of the geochemical dispersion trains mapped from the 1998 and 1964 data can be drawn. The percentage values indicate that the sample and analytical technique employed during the 1998 study returned significantly more values above background levels. For the 1998 data, 30% more lead values and 43% more zinc values are above background in comparison to the 1964 data. The comparison of values above the 95th percentile differed less between the two data sets. For lead, 13% more values in the 1998 data lie above the 95th percentile and for zinc, 10% more values in the 1964 data lie above the 95th percentile. In short, these results show that both methods recognized values above the 95th percentile. Significantly more lead values than zinc values for both data sets appear above the 95th percentile. This suggests that lead anomalies that fall above the 95th percentile, from soil or till samples, may be a more reliable indicator of a nearby sulphide deposit. When considering regional exploration for more subtle sulphide dispersions, the method used during the 1998 study was a more effective identifier of above-background values for both lead and zinc.

Glacial sedimentation into Next Creek basin could have important implications to its stream sediment geochemistry. The dispersion plumes from the 1998 data appear to conform to Next Creek valley which suggests the ice behaved much like a fluid rather than staying rigidly confined to Rose Creek valley. Glacial sedimentation of possible Faro float into Next Creek from a conforming glacier could register anomalous stream sediment values for lead, zinc, and copper in that basin. This provides a good example of how, when in glaciated terrain, glacial history must be considered in the interpretation of alluvial geochemistry.

LIMITATIONS

The limitations of till geochemical sampling centre on sample collection and processing. Determining a sample medium may often require exposing up to 1 m of the soil profile which can be a time-consuming process. Sediment identification is especially valuable, for instance, in valley systems where colluviation has amassed organic beds and resedimented till together in a near-surface deposit. Sampling a lens of resedimented till is certainly more applicable to a till sampling study than would be an organic-rich alluvium. This deposit structure may not be readily identified from a soil auger or B-horizon sample. In short, a comparison of drift geochemical data requires homogeneity in the sample medium to best qualify the data set. Secondly, the –230 mesh fraction in a Cordilleran basal till is not always an abundant sediment fraction which means taking a large sample to obtain a sufficient amount for procedures such as gold fire assays. It is also beneficial to collect 50-100 pebbles for boulder tracing and as a lithological reference if anomalous geochemical values are obtained. Sample preparation costs may also be inflated because sieving to –230 mesh requires additional time.

Permafrost may provide the greatest hindrance for the application of this technique in the north. Permafrost limits the depth to which a sample can be taken and causes a mixing of

the soil through cryoturbation processes. At certain sample locations in the Anvil District, cryoturbation had essentially overturned the upper part of the soil column. For example, the White River ash, normally within 10 cm of the surface, was found in some areas at depths of 100 cm. Permafrost could also be variable within the soil column at a particular site. Unfrozen parent material was sometimes uncovered under a frozen pod of organic material. In the Anvil District, permafrost is most common where thick moss cover has accumulated on north-facing slopes and under mature forest cover.

SUMMARY

The Anvil District lies within the limits of the McConnell glaciation and is overlain by sediments originating from this glacial period. During the McConnell glaciation, ice from the Selwyn and Pelly mountains was funnelled into Tintina Trench and flowed north towards central Yukon. The location of the Anvil District adjacent to the Tintina Trench meant the Swim Basin and Vangorda Plateau were exposed to extreme glacial erosion and depositional processes. Till deposits on the Vangorda Plateau range in thickness from < 1 m to 200 m. During the late stages of glaciation, alpine ice retreated prior to the Cordilleran ice sheet which enabled Cordilleran ice to invade alpine valleys. Wholesale starvation of the ice sheet occurred shortly after, when the firn line dropped below 1830 m elevation for the Cordilleran ice sheet (Jackson, 1987).

Results of the 1998 till geochemistry case study, north of the Faro deposit, show a broad dispersion plume for lead, zinc, and copper, extending greater than 5 km west of the Faro deposits. Anomalous metal values in till proximal to the Faro deposit, but at a higher elevation, may indicate local anomalous bedrock or the presence of a palimpsest dispersal train.

The 1964 soil geochemistry data shows a well-defined, narrow dispersal train west of the Faro deposit. The core of the dispersion train can only be traced beyond the Faro deposit for 2.5 km for zinc and 1.5 km for lead.

Both methods recognized values above the 95th percentile, however significantly more lead values than zinc values appeared above the 95th percentile in both data sets. This suggests that lead anomalies that fall above the 95th percentile, from soil or till samples, may be more reliable indicators of nearby sulphide deposits than zinc. When considering regional exploration for more subtle sulphide dispersion the method used during this study was a more effective identifier of above-background values for both lead and zinc. This is consistent with findings by Shilts (1984) that show how weathering readily breaks down sulphide minerals and releases metals that are subsequently scavenged by the clay fraction. The geochemical signature of a weathered till is thus most strongly expressed in the clay fraction. The –80 mesh fraction seems best utilized in the mapping of dispersion trains at the property scale.

Finally, the dispersion plume also shows a movement of metals into a tributary valley oriented transverse to glacial ice flow. This suggests the ice behaved much like a fluid rather than a rigid mass confined to Rose Creek valley and exemplifies the process of stream sediment contamination by glacial dispersion.

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REFERENCES

Bobrowsky, P.T., Best, M., Dunn, C.E., Huntley, D.H., Lowe, C., Roberts, M., Seeman, D.A. and Sibbick, S.J.N., 1995. Integrated drift exploration studies on northern Vancouver Island (92L). *In:* Geological Fieldwork, 1994, B. Grant and J.M. Newell (eds.), B.C. Ministry of Energy, Mines, and Petroleum Resources, Paper 1995-1, p. 23-33.

Bobrowsky, P.T., Leboe, E.R., Dixon-Warren, A., Ledwon, A., MacDougall, D. and Sibbick, S.J., 1997b. Till geochemistry of the Adams Plateau-North Barriere Lake Area (82 M/4 and 5). British Columbia Ministry of Employment and Investment, Open File 1997-9. 1:50 000 scale map.

Bobrowsky, P.T., Paulen, R., Little, E., Prebble, A., Ledwon, A. and Lett, R., 1998. Till geochemistry of the Louis Creek-Chu Chua Creek area (NTS 92P/1E and 92P/8E). B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1998-6. 1:50 000 scale map.

Bond, J.D., 1997. Late Cenozoic history of McQuesten map area, Yukon Territory, with applications to placer gold research. Unpublished M.Sc. Thesis, University of Alberta, Edmonton, Alberta, 161 p.

Bostock, H.S., 1966. Notes on glaciation in central Yukon Territory; Geological Survey of Canada, Paper 65-36, 18 p.

Gabrielse, H., 1967. Tectonic evolution of the northern Canadian Cordillera. Canadian Journal of Earth Sciences, vol. 4, p. 271-298.

Giles, T.R. and Kerr, D.E., 1993. Surficial geology in the Chilanko Forks and Chezacut areas (93C/1, 8). *In:* Geologic Fieldwork 1992, B. Grant and J.M. Newell (eds.), British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1993-1, p. 483-490.

Jackson, L.E., 1987. Terrain inventory and Quaternary history of Nahanni map area, Yukon Territory and Northwest Territories. Geological Survey of Canada, Paper 86-18, 20 p.

Jackson, L.E., 1991. Pleistocene mammals, stratigraphy, and sedimentology at the Ketza River site, Yukon Territory. Geographie Physique et Quaternaire, vol. 49, p. 69-77.

Jackson, L.E., 1994. Terrain inventory and Quaternary history of the Pelly River area, Yukon Territory. Geological Survey of Canada, Memoir 437, 41 p.

Jennings, D.S. and Jilson, G.A., 1986. Geology and sulphide deposits of Anvil Range, Yukon. *In:* Mineral deposits of Northern Cordillera, J.A. Morin (ed.), Canadian Institute of Mining and Metallurgy, Special Vol. 37, p. 319-361.

Levson, V.M. and Giles, T.R., 1994a. Surficial geology and Quaternary stratigraphy of the Fawnie Creek area (NTS 93 F/3). British Columbia Ministry of Energy, Mines and Petroleum Resources, Open File 1994-9, 1:50 000 scale map.

Levson, V.M. and Giles, T.R., 1994b. Glacial dispersion patterns of mineralized bedrock with examples from the Nechako Plateau, central British Columbia. B.C. Ministry of Energy, Mines and Petroleum Resources, Drift Exploration in Glaciated and Mountainous Terrain, Short Course Notes, Cordilleran Roundup, Vancouver, B.C., 13 p.

Levson, V.M., Giles, T.R., Cook, S.J. and Jackaman, W., 1994c. Till geochemistry of the Fawnie Creek map area (NTS 93 F/3). British Columbia Ministry of Energy, Mines and Petroleum Resources, Open File 1994-18.

Nikkarinen, M., Kallio, E., Lestinen, P. and Ayras, M., 1983. Mode of occurrence of copper and zinc in till over mineralized bedrock (abstr.). *In:* X IGES-III SMGP, Finland 1983, Abstracts, A. Bjorklund and T. Kolijonen (eds.), Geological Survey of Finland, Espoo Finland, p. 54-55.

Parent, M., Paradis, S.J. and Doiron, A., 1996. Palimpsest glacial dispersal trains and their significance for drift prospecting. Journal of Geochemical Exploration, vol. 56, p.123-140.

Pigage, L.C., 1990. Field guide to the Anvil Pb-Zn-Ag District, Yukon Territory, Canada. *In:* Mineral Deposits of the Northern Canadian Cordillera, Yukon-Northeastern B.C, 8th IAGOD Symposium Field Trip Guide Book, J.G. Abbott and R.J.W. Turner (eds.), Geological Survey of Canada, Open File 2129; p. 283-308.

Pigage, L., 1999 (this volume). Preliminary geology of Rose Mountain, Anvil District, central Yukon (105K/05). *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 91-103.

Shilts, W.W., 1976. Glacial till and mineral exploration. *In:* Glacial Till, R.F. Legget (ed.), Royal Society of Canada, Special Publication 12, p. 205-223.

Shilts, W.W., 1984. Till geochemistry in Finland and Canada. Journal of Geochemical Exploration, vol. 21, p. 95-117

Ward, B.C., 1989. Quaternary stratigraphy along Pelly River in Glenlyon and Carmacks map areas, Yukon Territory. *In:* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 257-264.