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Glacial overburden profile sampling for porphyry copper exploration: Babine Lake area, British Columbia

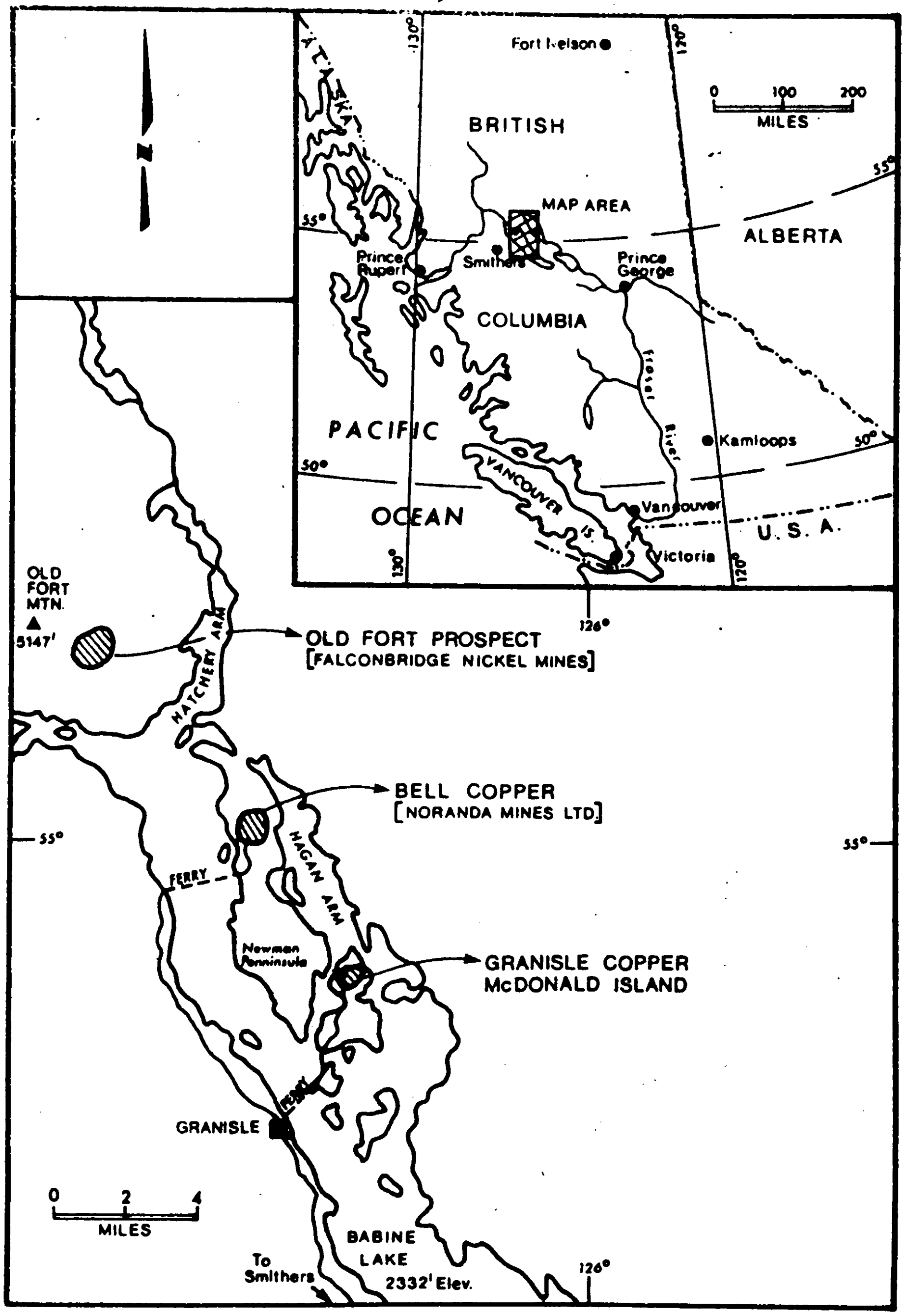


Figure 1. Location of Babine Lake area, with the Granisle Copper and Bell Copper mines, as well as the Old Fort prospect

ABSTRACT. Profile samples of glacial overburden, obtained from 14 locations in the Babine Lake area, British Columbia, were analyzed for base metals, and other geochemical and mineralogical parameters in order to determine the value of glacial till for exploration purposes. The results show great variability in the trace element content and other features within the profiles. Most of the dispersion is considered to be mechanical and a 'total extraction' procedure should be used.

Because of the complexity of the glacial deposits and dispersion in this area, the interpretation of geochemical data is difficult. Accordingly, possible areas of mineral potential in central British Columbia should not be eliminated from consideration solely on the basis of geochemical data obtained from glacial overburden.

INTRODUCTION. The use of geochemical techniques for exploration in glaciated areas is now an accepted method of exploration, and significant discoveries have been made in which geochemistry has played an important role. Numerous papers and symposia on the application of geochemical methods in glaciated terrain have been published (for example, see Jones 1973; Nichol and Bjorklund 1973; Jones 1975; Davis 1977), and the subject has been briefly reviewed by Levinson (1974 p451-467). However, in almost all cases emphasis has been placed on the description of methods and their results in areas of continental glaciation whereas very little has been published on geochemical studies in areas of alpine (or valley) glaciation. This is particularly true in British Columbia. Except for the work of Mehrtens et al (1973) and Bradshaw (1975), there have been few published studies on the use of glacial overburden for exploration purposes, although there are many publications dealing with the use of stream sediments, stream and lake waters, and rocks.

The purpose of this paper is to present

a summary of the significant fi gs obtained by Okon (1974) in his stud... of the applicability of geochemical methods in the vicinity of the Babine Lake porphyry copper area. This area is covered by up to 120 feet of glacial overburden which can be considered of alpine origin.

GEOLOGY

The location of the Babine Lake area is shown on Figure 1. This figure also shows the location of the Granisle and Bell Copper mines, as well as the Old Fort prospect from which samples were obtained for this study. The general geology of the area has been summarized by Carter (1972, 1973, 1976). Briefly, copper mineralization is closely related to small biotite-feldspar porphyry intrusions of granodiorite composition of Middle Eocene age (51.2±2 my) which intrude Jurassic and younger layered rocks. The intrusive porphyries are distributed in a manner that suggests a marked spatial relationship to major northwest-trending faults. The Granisle Copper mine contains 50-million tons of ore averaging 0.42 per cent copper and minor molybdenum, and the Bell Copper mine contains 50-million tons of about 0.5 per cent copper and minor molybdenum. The Old Fort prospect contains some mineralization grading 0.43 per cent copper. All deposits are zoned, and the principal ore minerals are chalcop rite, bornite, and molybdenite.

Extensive glacial deposits cover the Babine Lake area which is part of the Nechako Plateau, a physiographic subdivision of the Interior Plateau. Topography varies from relatively subdued (830-1000-metre average elevation) to mountainous in the Fawnie and Nechako Ranges where elevations reach 2000 metres. Stream drainage is well developed in the mountains compared to the plateau area proper.

GLACIAL HISTORY

Studies of the glacial history of north-central British Columbia by Armstrong and Tipper (1948) and Tipper (1971) are particularly applicable to this area. This part of British Columbia was extensively glaciated during the Pleistocene leaving such features as glacial till, drumlins, eskers, erratics, grooves, striae, and glacial lake sediments. The widespread occurrence of clay, silt, sand, and gravel are considered to represent deposition of irregularly shaped temporary glacial lake basins. The glacial history of the region, summarized in Figure 2A, is as follows:

(1) Ice movement was, in general, from west to east, but during the maximum development of Wisconsin glaciation, the ice moved in a generally easterly and northeasterly direction.

(2) Two general advances of the Cordilleran ice sheet have been recognized in the Nechako Plateau and Plain. The direction of movement of the last ice sheet was governed by topography and the ice flowed southwesterly down such valleys as now occupied by Babine Lake, Babine (Figure 2B), and Takla. At the south end of these valleys, the southerly moving ice coalesced with a stream of easterly and northeasterly flowing ice that moved along the Nechako Plateau (Figure 2A). This last advance of the ice was probably followed by stagnation and ice decay that led to the formation of compound eskers, kettles, and glacial lakes in the low-lying areas.

OVERBURDEN IN THE BABINE LAKE AREA

The study area contains glacial deposits of variable thickness (Figure 3) and character. In some parts of the area, particularly in topographic lows, thicknesses of up to 120 feet have been reported (Harington et al 1974) while elsewhere glacial deposits are absent and bedrock is exposed. Variations in the texture of the glacial deposits are extreme, ranging from gravels (Figure 4) to varved clays representative of glaciolacustrine sediments (Figure 5). In the Bell Copper mine pit a considerable thickness of these clays overlies a com-

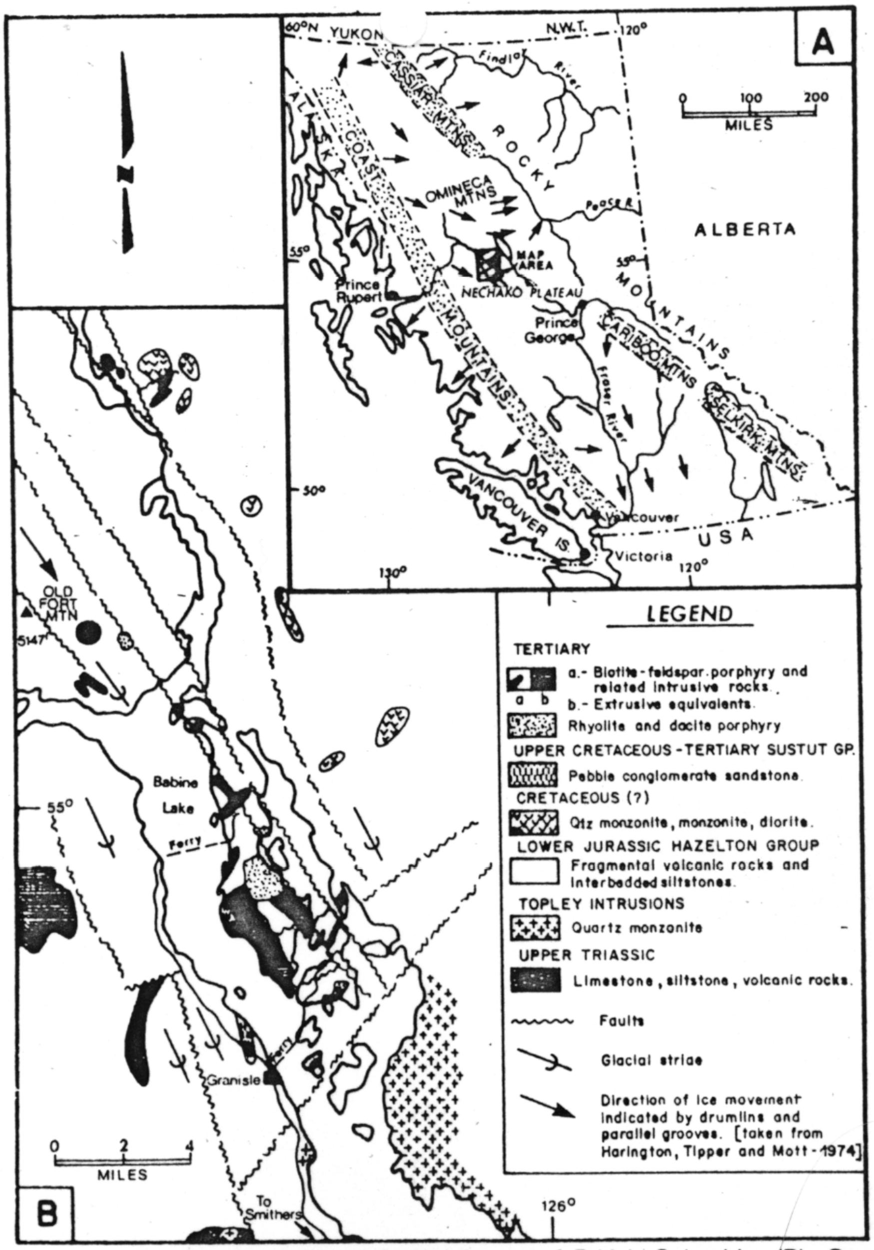


Figure 2. (A). Physiographic and glacial map of British Columbia. (B). General geology of the Babine Lake area, with superimposed indicators of the direction of ice movement. From Okon (1974) but based on data in Armstrong and Tipper (1948), Carter (1972), and Harington et al (1974)

Figure 3. North end of the Bell Copper mine pit area illustrating the variation in the thickness of gravelly and silty clay till (above the dashed line) which overlies intensely altered and bleached bedrock. The bench face is approximately 35 feet high

pact, unsorted basal till which, in turn, overlies a saprolitic zone of intensely altered bedrock. Thus it is clear that exploration geochemists attempting to use overburden material for exploration purposes in this area are faced with a great variety of glacial overburden which can vary in thickness from 0-120 feet.

GLACIAL OVERBURDEN IN MINERAL EXPLORATION

Glacial drift is the general term applied to all materials transported and deposited as a result of glaciation. Two general types of glacial drift are recognized: **till** (non-stratified) and **stratified drift**, but no sharp dividing line separates one from the other. Till is deposited directly from the ice without the direct aid of meltwater and, as water plays a minimum role in the deposition, it is dominantly unsorted with respect to grain size (Figure 4). Till is characterized by its lithological and physical heterogeneity and, in fact, is more variable than any other sediment.

Stratified drift, of which the pro-glacial varieties such as glacio-lacustrine (Figure 5) and outwash sediments are the most important, is composed of sediments deposited with the aid of glacial waters, and these sediments can travel a considerable distance from a glacier. Stratified drift, particularly glacio-lacustrine and outwash deposits, present serious problems in exploration because: (1) they represent distant material with no relation to any local mineralization; and (2) they generally mask any evidence of mineralization below them. Till, on the other hand, has been successfully used in mineral exploration (for example, see Nichol and Bjorklund 1973; Jones 1973; Levinson 1974; Jones 1975; Davis 1977). Because of the great diversity of glacial sediments, and the possible relationship of these products to local bedrock and mineralization, the sampling medium of glacial origin must be carefully chosen, and in most cases till is used.

Two principal types of glacial till (unstratified) are recognized:

Figure 4. Example of unsorted, unstratified till at the Granisle Copper mine. Subrounded to angular cobbles and pebbles are enclosed in a fine silty clay matrix. The width of the picture is approximately 1 metre

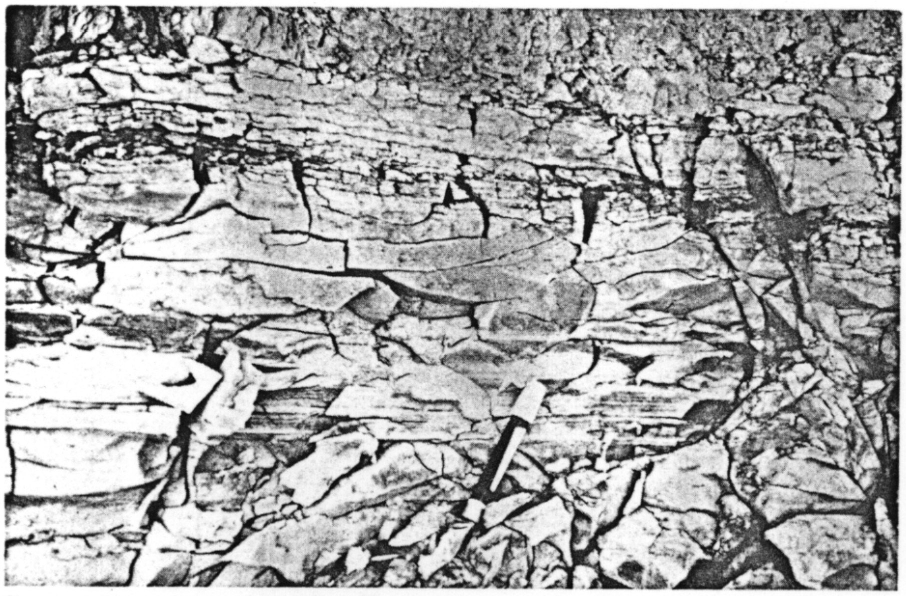


Figure 5. Varved clays in the Bell Copper mine pit area. Charred plant remains occur abundantly in the laminations indicated with an arrow

(1) **Lodgment till.** The particles in this type of till are 'lodged' in the accumulating drift under pressure on the subglacial floor. Crushing and abrasion of the particles is intense and the resulting till is compact. In general, lodgment till is composed of fragments of relatively local (perhaps less than 1 mile) origin and, therefore, it represents a favourable sampling medium for exploration purposes (Figure 6).

(2) **Ablation till.** This results from the release of supraglacial and englacial debris on the top or at the edge of a glacier by sliding, flowage, or dumping. This type of till bears no relation to underlying bedrock as the debris may have originated at a very distant source. Therefore, ablation till generally bears no relation to nearby underlying bedrock or mineralization and should be avoided for exploration purposes.

The most serious constraints on the use of glacial till as a prospecting medium are:

(a) the lack of understanding of the modes of till deposition in a particular area which manifests itself in the difficulty in distinguishing between lodgment and ablation facies, and

(b) the problems caused by the extreme variation in particle sizes within till; these problems appear during the sampling, preparation, and interpretational phases of a geochemical program.

In the Babine Lake area, many of the above-mentioned difficulties appear. For example, it is difficult to distinguish lodgment from ablation till, and glaciolacustrine and fluvioglacial deposits (stratified drift) are sometimes found within the till beds. Soil geochemical surveys conducted prior to this study were generally unsuccessful in delineating porphyry mineralization (Knauer 1975) and, therefore, an attempt to use the glacial till in the area is justified. Thus, this study was initiated because it offered the opportunity to contribute to basic geochemical information on problems associated with exploration in terrain covered by alpine glaciation. Throughout this study, concepts and terminology used for continental glaciation have been applied on the assumption that, at least as a first approximatic he differences between continental a... alpine glaciation are mainly those related to location and size.

PROCEDURES

In order to investigate the potential of till sampling within the study area, Okon (1974) attempted:

(1) to determine the distribution of copper, zinc, molybdenum, iron, and manganese vertically within the overburden overlying both mineralized and unmineralized bedrock (that is, profile sampling);

(2) to determine the various parameters, such as pH, type of clay mineral, mode of occurrence (hyrdomorphic or clastic) of the elements of interest, and the nature and composition of the glacial deposits;

(3) to relate the observed element distributions and other determined properties of the overburden materials and to bedrock mineralization.

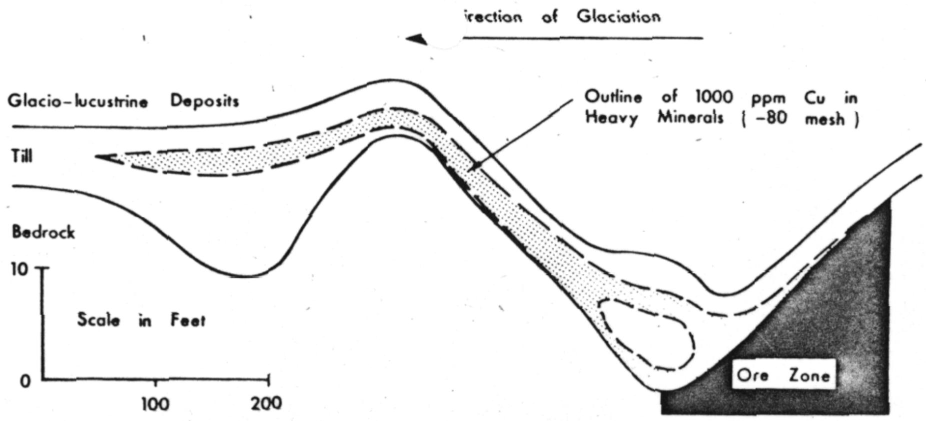


Figure 6. Idealized diagram showing a vertical profile for a copper dispersion train in till. The lateral dispersion of sulphide grains from this deposit in the lodgment (basal) till is about 600 feet. Note how topographic effects can result in the metal dispersion train being within the till. After Garrett (1971)

Toward these ends, profile samples were collected within the overburden from roadcuts, excavations, and test pits on the three deposits. Every attempt was made to keep the sample interval within each profile to 12 inches in order to maintain uniformity; however, this could not be achieved at some locations. In the Bell Copper mine pit a trench 7 feet deep was excavated over the mineralization on one of the benches specifically for this study (Figure 7). This particular profile, which is different from others in the area, intersected varved clay, lodgment till, and saprolite, in descending order, before encountering mineralized bedrock at a depth of about 78 inches. A detailed description of this profile is shown in Figure 8. At the Granisle Copper and Bell Copper mines, where there is active mining, only samples from freshly cut profiles were used to avoid contamination from dust and other sources. In total, seven complete profiles similar to that in Figure 8 were compiled, as were seven additional partial profiles of the trace elements and certain selected parameters.

Details of the analytical procedures may be found in Okon (1974). During the initial phases (orientation study) of the project seven different size fractions excluding the coarse material (-16, -32, -60, -80, -115, -200, and -325 mesh) were isolated and their trace element contents were determined by means of numerous different extractions in order to determine the optimum procedures. These preliminary studies indicated that no particular size fraction was preferred over another and, therefore, the most commonly used procedure involving the -80 mesh size fraction was used throughout the study.

Three extractions were used: (1) acetic acid, (2) ammonium oxalate at pH = 3.0, and (3) lithium metaborate fusion. The first two are partial extractions, whereas the third determines the total amount of an element in a sample.

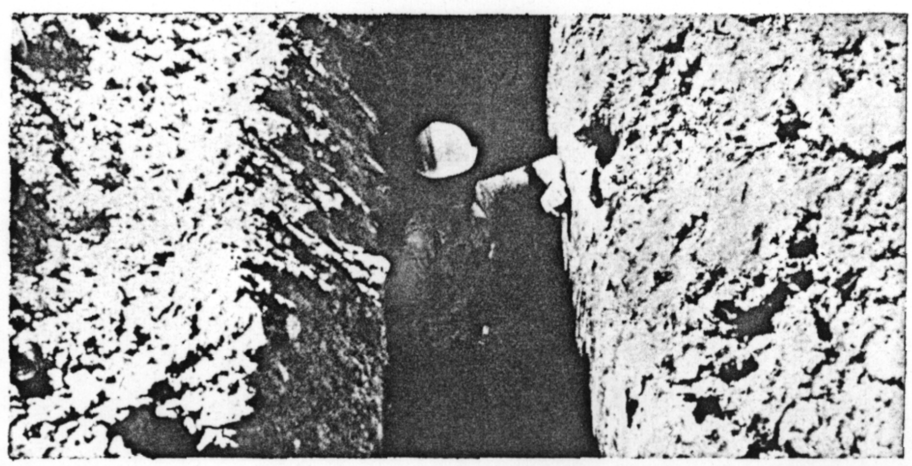
Brief comments on the analytical data follow:

(a) pH was determined on the less than 2-millimetre size fraction of the profile samples.

(b) The clay minerals were determined by X-ray diffraction techniques.

(c) Cation exchange capacity was determined by the procedure used at the Institute of Sedimentary and Petroleum

Figure 7. Sample pit excavated specifically for this study at the Bell Copper mine. A detailed description of the section is shown in Fig 8



Geology, Calgary (Dr A Foscolos personal communication).

(d) Copper, zinc, molybdenum, iron, and manganese were determined by atomic absorption following appropriate extraction or total digestion, but iron and manganese results are not shown on the diagrams.

(e) The amounts of loosely bonde copper, zinc, and molybdenum released by the ammonium oxalate extraction are given in per cent, and are indicated in the tables by such headings as (Cu oxalate ÷ Cu total) × 100.

RESULTS AND CONCLUSIONS

It is not possible in the scope of this paper to present all the profiles which form the basis of the conclusions, and therefore some selection is necessary. In addition to Figure 8 which is a profile over copper mineralization at the Bell

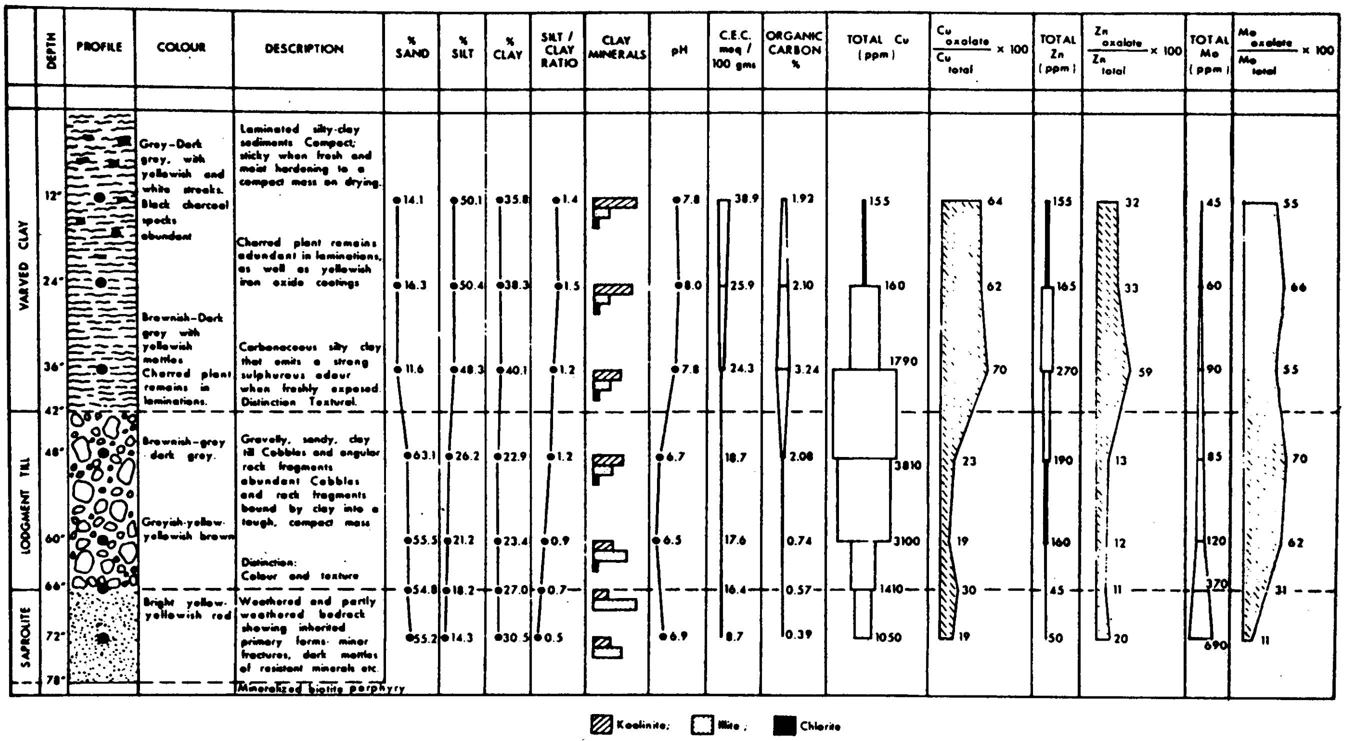
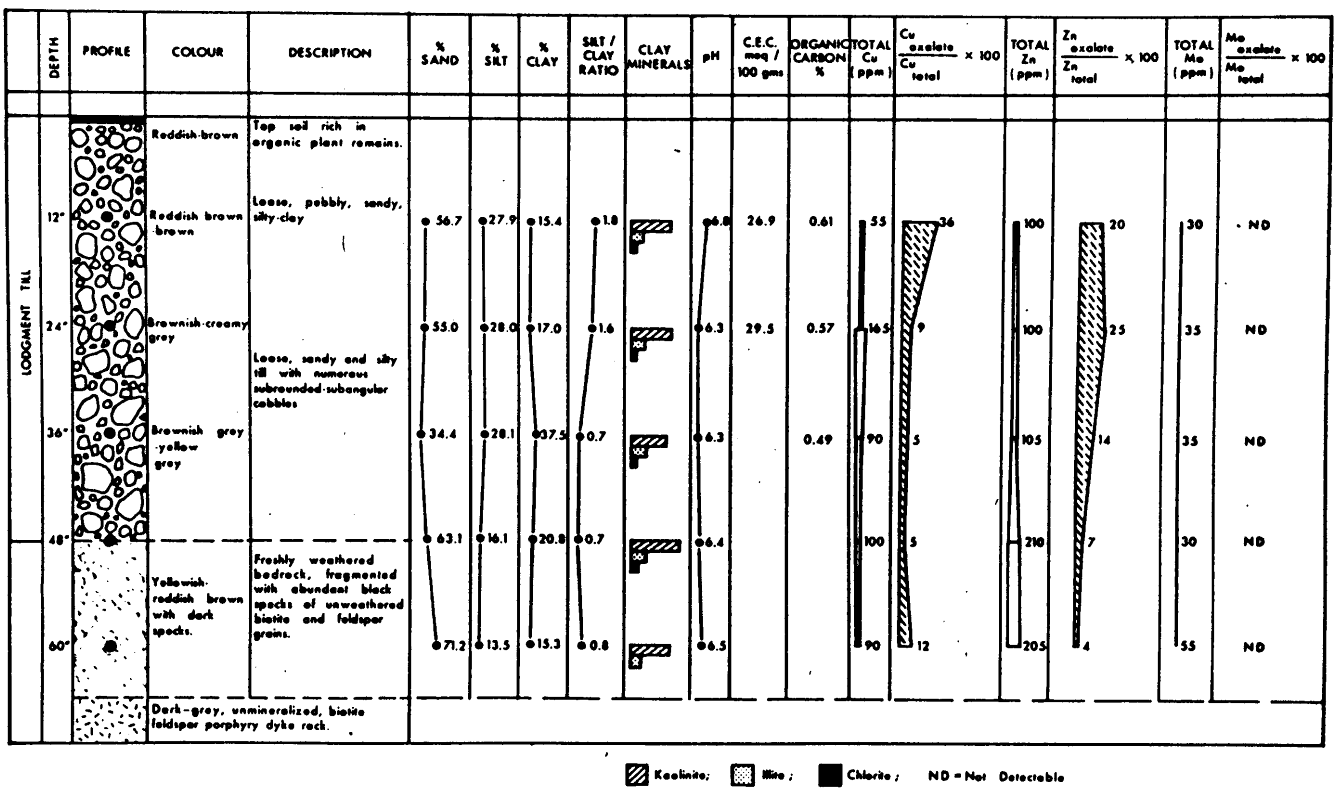


Figure 8. Lithology and analytical results obtained at intervals from profile sampling the test pit illustrated in Fig 7. This test pit is over mineralized bedrock

Figure 9. Lithology and analytical results obtained over unmineralized bedrock near the Bell Copper mine. This profile was taken approximately 0.8 mile south of the profile illustrated in Fig 8



Copper mine, Figure 9 illustrates typical results obtained over unmineralized bedrock about 0.8 mile away. Similarly, for the Granisle Copper mine, Figures 10 and 11 illustrate results obtained over mineralized and unmineralized bedrock, respectively.

Figures 8-11 clearly show the great variability in lithology and in almost all measured parameters. However, certain significant observations can be made.

(1) The total copper content of the till reflects the known presence or absence of copper mineralization in the underlying bedrock. However, over mineralization (Figures 8 and 10) the highest copper values are generally near the top of the till layers, possibly reflecting topographic control as illustrated in Figure 6.

(2) Molybdenum values in till overlying known mineralization are about twice as high as values over unmineralized bedrock.

(3) Zinc values are generally within a broad range of background values in tills overlying mineralized bedrock. However, in unmineralized areas, the zinc contents are significantly higher (this relationship is not well illustrated in the figures, especially in Figure 11 because of the intensely weathered nature of the saprolite zone from which zinc has probably been leached). This observation is consistent with the result of Carson and Jambor (1974) who showed that in the Babine Lake area high copper values in the bedrock are associated with low zinc values (less than 200 ppm), whereas in the peripheral areas (pyrite halo) low copper contents of the bedrock are associated with high zinc values. These observations are the result of the well-known zoning associated with porphyry copper deposits.

(4) The extractable (by ammonium oxalate treatment) copper, zinc, and molybdenum can be considered to represent the hydromorphically transported portion of these elements in the overburden material. The extractable copper ranges from 3-75 per cent, zinc 5-40 per cent, and molybdenum 0-70 per cent. The percentage of each element extracted by this treatment varies with the nature of the overburden material with the highest extractable values associated with the thick, massive, impermeable, silty clay glacial lake sediments. Iron and manganese (not shown in the figures) follow similar patterns to those of copper, zinc, and molybdenum suggesting association of all five elements. In addition, by statistical methods (correlation coefficients) the oxalate extractable copper and zinc (but not molybdenum) correlate significantly with extractable iron and manganese, as well as pH and the silt-clay content. In general, however, from interpretation of all the data, Okon (1974) concluded that copper, zinc, and molybdenum are only sparingly mobilized (ammonium oxalate extractable) in the overburden of the Babine Lake area; for example, in 80 per cent of all the samples analyzed, less than 30 ppm was oxalate extractable. From this it can be concluded that hydromorphic metal transport is less important than the mechanical mode. Further, the degree of mobilization is dependent upon, or correlated with, the pH of the fine fraction primarily, and to a lesser extent on the clay-silt content and the amount of extractable iron-manganese.

It is possible that the association of the ore elements with the clays is a result of weathering of mechanically transported sulphide grains within the till. As Shilts (1976) pointed out, in till that has been weathered, the clay-sized fraction should be separated and analyzed for elements of interest, as the clays are likely to have absorbed the mobilized cations (metals) in a manner analogous to the mechanisms operative in the B horizon of soils.

(5) In order to use the mechanically transported component of till for exploration purposes, a total extraction procedure (for example, a fusion or a nitric-perchloric acid digestion) is necessary to dissolve the sulphide minerals. Nevertheless, in certain situations partial extractions will be useful.

(6) Although we have not specifically investigated secondary dispersion trains other than in the glacial overburden in this area, we have enough information to concur with the conclusions of Mehrtens et al (1973) who found that ore elements are predominantly dispersed from their

bedrock source beneath glacia .l by shallow groundwaters, and to a lesser extent by mechanical (ice) transport and biochemical processes. Thus, the sampling of groundwater seepages, stream sediments, bogs, and organic-rich bottom sediments, where these are available, is recommended at least during the reconnaissance and early follow stages of exploration in central British Columbia.

(7) When glacial till is used for exploration purposes, probably during some detailed stage, a knowledge of the direction of glacial movement in the area (including the direction of each stage of glacial transport represented by a specific till sheet) must be known for maximum effectiveness. Even with this information available in the study area, the dispersion train might only be detected a relatively short distance (perhaps several hundred feet) from mineralization.

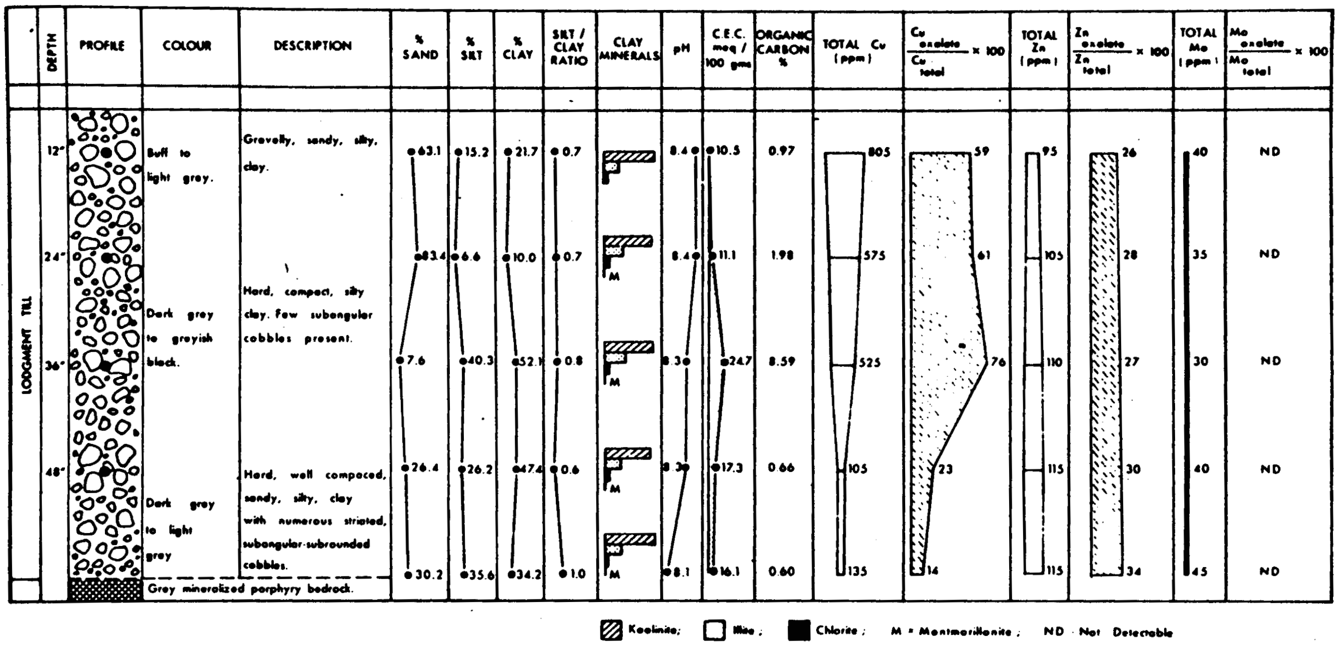
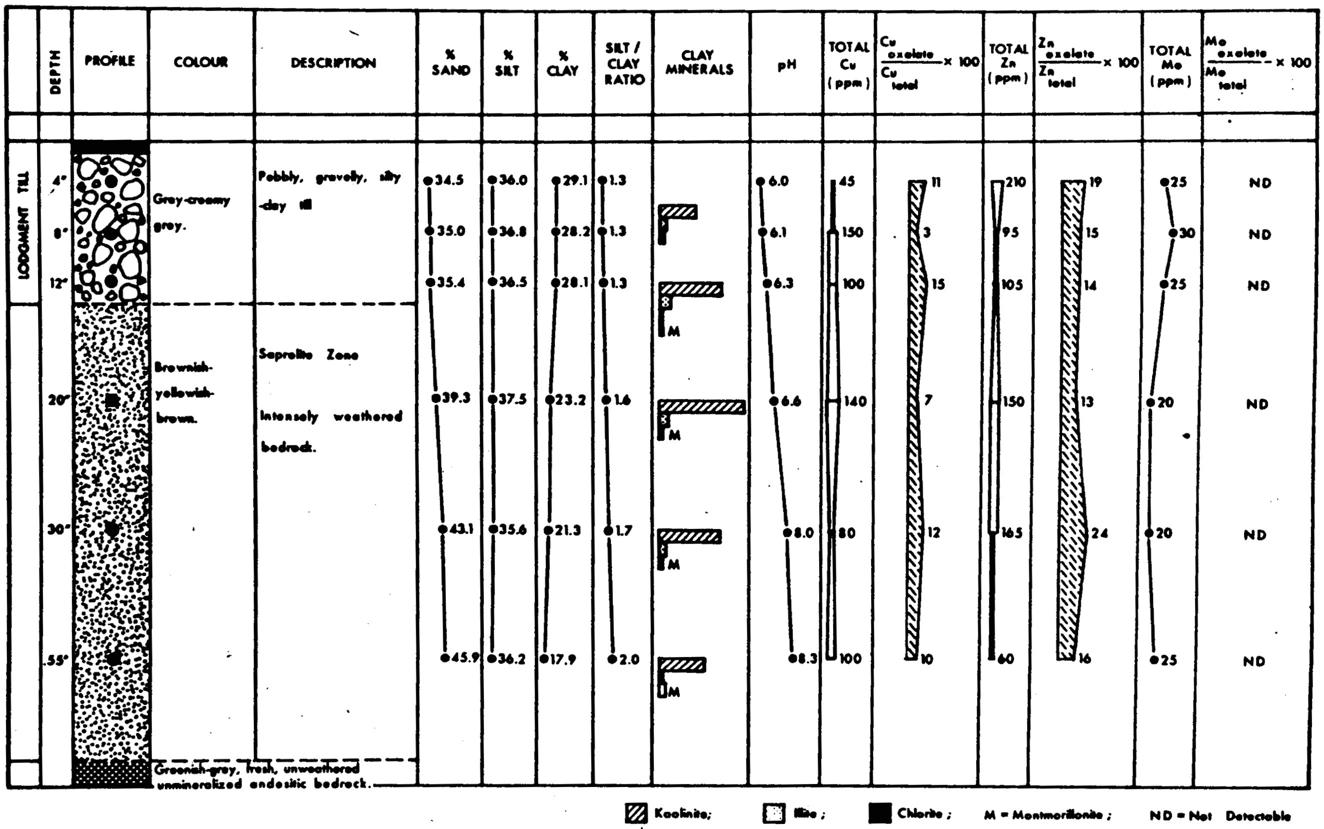


Figure 10. Lithology and analytical results obtained over mineralized bedrock at the Granisle Copper mine

Figure 11. Lithology and analytical results obtained over unmineralized bedrock near the Granisle Copper mine. This profile was taken approximately 0.5 mile southwest of the profile illustrated in Fig 10



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