DRIFT PROSPECTING ACTIVITIES IN BRITISH COLUMBIA: AN OVERVIEW WITH EMPHASIS ON THE INTERIOR PLATEAU

By Daniel E. Kerr
Geological Survey of Canada
and Victor M. Levson
British Columbia Geological Survey

Geological Survey of Canada Contribution No. 1996601)

KEYWORDS: Surficial geology, Quaternary stratigraphy, drift prospecting, till geochemistry, clast provenance, soil geochemistry, biogeochemistry

INTRODUCTION

Drift prospecting is playing an increasingly greater role in the search for mineral resources in British Columbia, as exploration progresses into areas with extensive surficial sediments and complex glacial histories. Yet, relatively few detailed studies, in the province, have been published that integrate geochemical and geophysical surveys with surficial geology and glacial history data. Drift prospecting, used here in its most general sense, includes all types of exploration activities for mineral deposits covered by surficial, especially glacial, deposits (drift). This paper provides an overview of drift prospecting studies in British Columbia (Figure 1) for the purpose of planning and assessing the usefulness and application of different techniques. Several different types of drift prospecting methods are discussed, focusing mainly on geological and geochemical techniques. For more detailed information on specific methods and case studies in British Columbia, reference should be made to an annotated bibliography on drift prospecting recently compiled as a research tool for mineral exploration in drift-covered areas (Kerr and Levson, 1995).

Emphasis in this paper is placed on drift prospecting activities in the British Columbia Interior physiographic system (Holland, 1976) where the greatest number of published drift-prospecting investigations have been carried out in the province (Figure 1). The highest concentrations of research are in the central and southern Interior; relatively little has been published on research in the Coast Mountains or Rocky Mountains.

The Interior System is the largest and most diversified physiographic subdivision in British Columbia and includes the Interior Plateau (including the Nechako, Fraser and Thompson plateaus, the Quesnel, Shuswap and Okanagan highlands and the Fraser Basin), the Cassiar, Omineca and Skeena mountains, the Yukon and Stikine plateaus, and the Columbia Mountains (Holland, 1976). The region is largely underlain by flat-lying or gently dipping Cenozoic lava flows, folded and faulted sedimentary and volcanic rocks of Mesozoic age, as well as intrusive and metamorphic rocks. The area has a complex history of ice flow due to multiple ice sources and varied topography, although within any one area, the ice-flow history may be relatively simple. More information on the Quaternary geology of central British Columbia can be found in Clague (1987, 1989, 1991), Ryder and Clague (1989) and Levson *et al.* (1995).

Drift exploration methods commonly used in British Columbia are numerous and diverse. They include geochemical, geological and geophysical exploration techniques. Geological methods include terrain mapping, Quaternary stratigraphic studies and boulder tracing. Geochemical techniques involve the sampling and chemical analysis of a wide variety of materials including soils (A or B soil horizon samples), tills or other surficial deposits (C-horizon samples), stream sediments, lake sediments, plants and soil gas (Hg, He, Ra). Geophysical techniques, not discussed in detail here, include both airborne and ground geophysical methods such as electromagnetic (Klein and Lajoie, 1981) and electrical (resistivity and induced polarization) surveys (Seigel, 1989; Best, 1995), gamma-ray spectrometry (Hansen, 1981), seismic (reflection and refraction) surveys (Pullan *et al.*, 1987; Pullan, 1995), ground-penetrating radar studies, aeromagnetic surveys and remote sensing techniques (Schreier, 1976; Goetz *et al.*, 1983; Watson and Raines, 1989). Regional lake sediment and stream sediment geochemical surveys are included for completeness, but also are not discussed at length.

A brief review of drift exploration methods is presented, together with their potential applications and associated problems and limitations, in the context of the Quaternary geology. Emphasis is placed mainly on British Columbia research and does not make substantial reference to the extensive literature dealing with studies in shield areas. For more information on drift prospecting and glacial indicator tracing in areas covered by continental glaciers, the reader is referred to articles in three excellent reference volumes compiled by DiLabio and Coker (1989), Kujansuu and Saarnisto (1990) and Kauranne *et al.* (1992).

GEOLOGICAL EXPLORATION METHODS

In glaciated terrain, mineral exploration is often hindered by the thickness and complexity of surficial deposits which may show little direct relationship with the underlying bedrock. If drift exploration programs are to be successful, it is essential to know the type and origin of the surficial sediments in the study area, their stratigraphic relationships and the local ice-flow history (Hoffman, 1986; Brummer *et al.*, 1987; Levson and Giles, 1995). This information can be

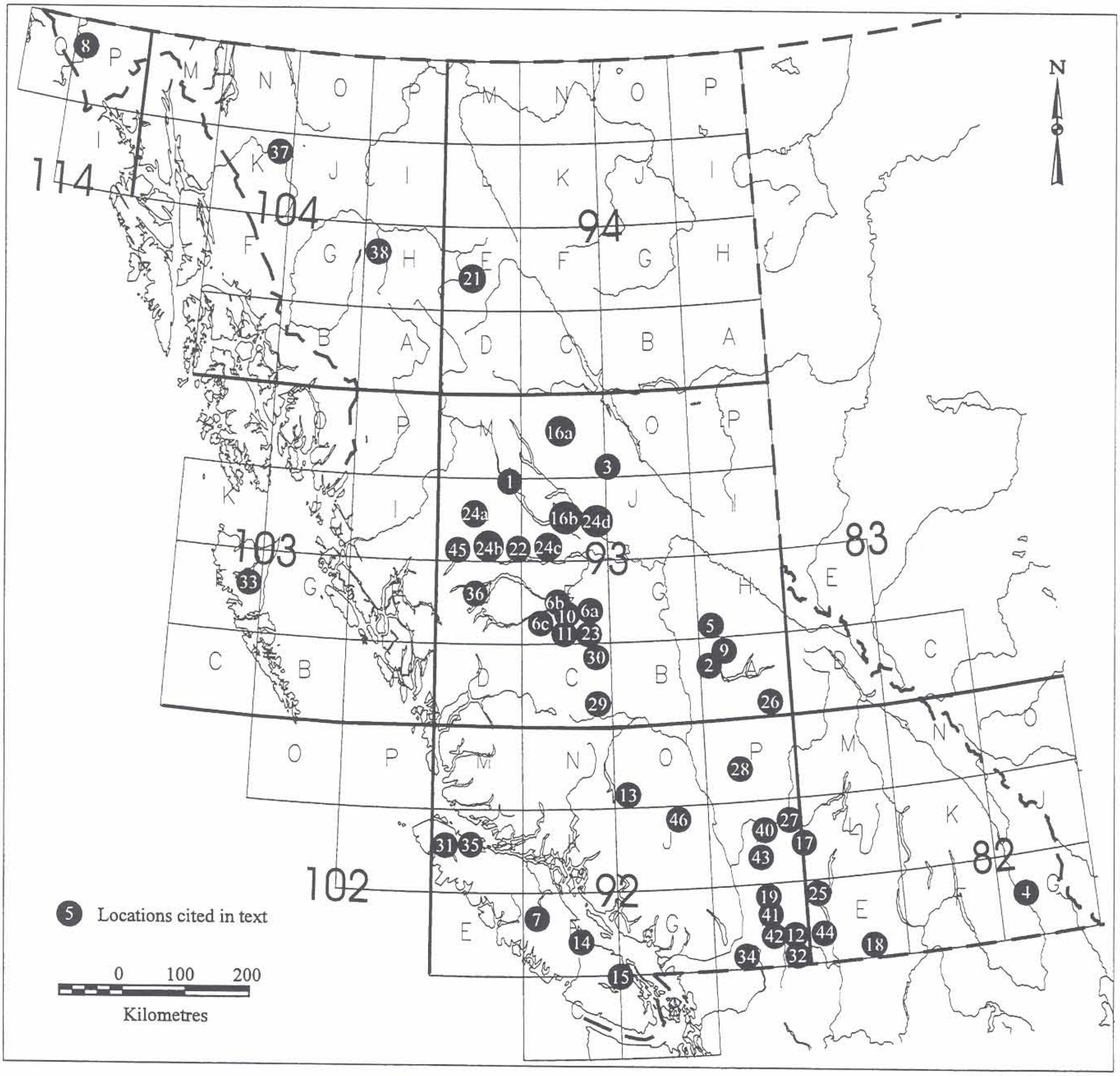

Figure 1. Location of published drift prospecting studies conducted in British Columbia. Note the concentration of research in the interior parts of the province where thick drift is a common obstacle to exploration

obtained by mapping the surficial deposits, studying landforms, stratigraphic investigations (requiring drilling if natural exposures are not available) and clast provenance studies. These geological methods also provide information required for the interpretation of various types of geophysical and geochemical data.

SURFICIAL GEOLOGY MAPPING

The mapping of surficial deposits and landforms and the identification of lithostratigraphic units should be the first stage in drift prospecting investigations. Terrain mapping conventions in the province are outlined in the British Columbia terrain classification system (Howes and Kenk, 1988), subsequently updated by the Resource Inventory Committee (1995). Surficial mapping generally involves air photo interpretation to determine the distribution and extent of surficial sediments, depositional and erosional landforms and structures, and regional ice-movement indicators such as drumlins and flutings. Follow-up ground inspections are also required to verify interpreted surficial map units and to compile sedimentologic, stratigraphic and local ice-flow data. An example of a simplified surficial geology map compiled as part of a drift exploration program in the Interior Plateau is provided in Figure 2. Although unconsolidated surficial sediments in British Columbia are extremely variable and have complex distributions controlled largely by physiography and glacial history, most types of surficial deposits can readily be identified by conventional mapping techniques.

Figure 2. Surficial geology map of the Fawnie Creek map area (NTS 93 F/3). Simplified from Levson and Giles (1994). Note the dominance of morainal deposits throughout the region.

The origin and mode of deposition of surficial deposits often has a direct influence on their degree of usefulness as sampling media in the search for mineralization. For instance, mineralized materials, discovered in residual soils or basal tills, can be more easily traced to their source than glaciolacustrine or glaciofluvial deposits (Levson *et al.*, 1994). These latter sediments contain relatively distal material that may have little relation to any local mineralization. A progressive ranking of surficial materials, in terms of their utility for tracing geochemical anomalies to source, from least to most useful, is as follows: marine, glaciomarine, glaciolacustrine, glaciofluvial, lacustrine, fluvial, morainal, colluvial and residual soils. The importance of differentiating surficial sediments in geochemical surveys has been illustrated by numerous authors in British Columbia including Levinson and Carter (1979) in the Babine Lake area (location 1, Figure 1), Fox *et al.* (1987) at the Quesnel River gold deposit (location 2, Figure 1), Kerr and Bobrowsky (1991) at Mount Milligan (location 3, Figure 1) and Levson *et al.* (1994) in the Fawnie Ranges (location 11, Figure 1).

Terrain maps, showing the distribution of surficial deposits, landforms and ice-flow patterns, are available for many parts of British Columbia. A list of terrain and surficial geology maps in the province, with information on the scale and type of maps (*i.e.*, detailed, inventory or reconnaissance maps) was compiled by Bobrowsky *et al.* (1992). Surficial geology map coverage exists for most areas in the interior of the province and for most coastal regions.

GLACIAL DEPOSITS

Till is probably the most common surficial material in the province and typically consists of massive, matrix-supported diamicton. There are many different varieties of till, reflecting different depositional environments (*e.g.*, Figure 2). Till characteristics also change regionally as a result of differences in source materials. For example, tills derived from volcanic rocks, carbonates, mudstone and shale typically have a fine-grained (silt and clay) matrix, whereas a sandy matrix is often derived from the erosion of granite, gneiss, quartzite or sandstone. In the Interior Plateau region, extensive till-blankets cover most of the plateaus and lowlands, as well as the floors of many valleys and adjacent slopes. Unconsolidated deposits locally attain thicknesses of 200 metres or more. Drumlins and other streamlined landforms cover large parts of the area and indicate an eastward to northeastward ice flow in the region north and west of Prince George and northward flow near Quesnel. A thick mantle of drift also covers much of the bedrock in the Kamloops-Okanagan area, with flutings oriented toward the south and southeast. The divide between northward and southward-flowing ice was south of Williams Lake.

During the Late Wisconsinan, widespread valley glaciation in high-elevation areas in the Coast Mountains and Rocky Mountains preceded the development of the Cordilleran ice sheet over the Interior Plateau. Alpine valley glaciers also persisted in these high areas after retreat of the main ice sheet. Evidence of these glaciers includes numerous cirques and hanging valleys as well as extensive ice fields. Holocene glacial advances occurred in the northern and southern Coast Mountains and Rocky Mountains as recently as 100 years ago (Ryder, 1989). Till in these areas is common in most valley bottoms and sides, but generally forms a veneer or is absent at higher elevations and on steeper slopes. Colluviated drift, landslide deposits and aprons are found on steep to moderate slopes.

GLACIOFLUVIAL AND GLACIOLACUSTRINE DEPOSITS

Glaciofluvial sands and gravels, including ice-contact deposits in kames and eskers and more distal deposits in terraces and outwash plains, are as readily mapped as glacial deposits (Figure 2). Esker and kame complexes are common in the Interior Plateau (Armstrong and Tipper, 1948; Tipper, 1971a, b) and thick accumulations of postglacial fluvial deposits, in the form of terraces, fans and deltas, are also widespread.

Glaciolacustrine deposits, consisting mainly of well stratified sand, silt and clay, may be difficult to recognize in regional mapping programs, but they usually can be identified by ground surveys. Glaciolacustrine sediments are common in large valleys, as well as in some plateau areas, where they may completely mask the morphology of underlying deposits. In the central Interior Plateau, for example, widespread glaciolacustrine clays were deposited in a series of ice-dammed lakes in basins around Prince George, Fort St. James, Vanderhoof and Williams Lake. These may attain 30 metres or more in thickness, often overlying drumlins and locally obscuring the underlying topography. Thick and extensive deposits of glaciolacustrine origin are also common in the southern Interior (Mathews, 1944; Fulton, 1969). Many of the larger valleys are partially infilled with these sediments, including the Fraser, Thompson and North Thompson River valleys; unconsolidated surficial deposits are 230 metres thick in the lower Okanagan Lake region and over 400 metres in thickness near Enderby (Holland, 1976).

STRATIGRAPHIC STUDIES

Exposures of Quaternary sediments are commonly less than 10 metres thick and typically reveal only one or two major stratigraphic units. Consequently, in order to reconstruct the Quaternary history of an area, it is generally necessary to compile composite stratigraphic sections by correlating units between several sections (*e.g.,* Figure 3).

Much Quaternary stratigraphic data can be obtained from natural exposures but, because of limited exposure in many areas, it is often necessary to use overburden drilling techniques such as augering, reverse circulation and rotasonic drilling (Coker and DiLabio, 1989; Plouffe, 1995a). Only rotasonic drilling provides a continuous solid core, but other drilling methods have been used effectively for Quaternary stratigraphic studies in British Columbia. For example, Levson *et al.* (1993) demonstrated the utility of reverse circulation drilling for stratigraphic investigations of Quaternary deposits in the Cariboo region (location 5, Figure 1). In regions of thin overburden, stratigraphic data and samples may also be obtained by trenching.

Although the majority of the surficial sediments in British Columbia were deposited during the last (Fraser) glaciation and during postglacial time, older materials underlie these Late Wisconsinan glacial deposits in many valleys and lowlands and it is not uncommon to find sequences of till underlain and overlain by glaciofluvial, glaciolacustrine and nonglacial sediments. However, some valleys are filled by a complex succession of sediments representing several glacial cycles (more than one till with intervening glaciofluvial,

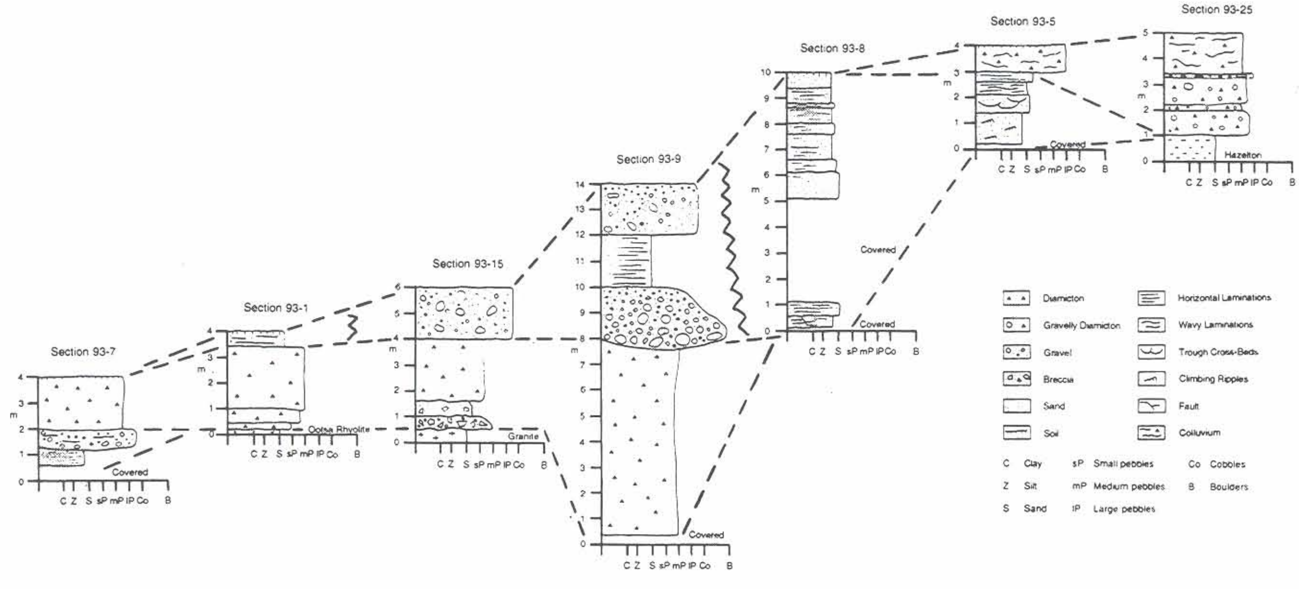

Figure 3. Representative stratigraphic columns of Quaternary deposits exposed in the Fawnie Creek map area (Figure 2) and interpretive correlation of main units (from Giles and Levson, 1994).

glaciolacustrine, fluvial, lacustrine and/or deltaic deposits; Ryder and Clague, 1989; Levson *et al.*, 1995; Plouffe *et al.*, 1996). Pre-Wisconsinan nonglacial deposits are known from only a few sites in the central Interior of British Columbia, including one at Babine Lake (location 1, Figure 1) and two sites in the Cariboo region (Clague *et al.*, 1990; Levson *et al.*, 1995; area 5, Figure 1). Fulton (1975) reported 180 metres of interglacial fluvial and lacustrine sediments in the Nicola-Vernon area. Three tills have been identified stratigraphically in the Lillooet area and Fulton and Smith (1978) recorded the presence of at least two tills and three interglacial periods in south-central British Columbia (location 17, Figure 1).

The presence of multiple tills in an area may result in complex, but traceable, patterns of mechanical and hydromorphic dispersion (Maurice and Meyer, 1975; Plouffe *et al.*, 1996). Ice-flow history data, fundamental to tracing dispersal trains to source, may be obtained from different stratigraphic units by measuring till fabrics, paleocurrent directions and orientations of glaciotectonic structures and striae in sediments or rock underlying tills. Broster *et al.* (1979) for example, identified two glacial-flow directions in the Cranbrook area (location 4, Figure 1) by studying glacially induced fracturing and faulting.

CLAST PROVENANCE INVESTIGATIONS

Tracing of mineralized clasts in glacially-derived deposits in an up-ice direction to their bedrock source has been a successful method of drift exploration in many glaciated areas (Evenson *et al.*, 1979; Hyvarinen *et al.*, 1973; Stobel and Faure, 1987; Shilts, 1993; Levson and Giles, 1995; Bobrowsky, 1995). Linear to fan-shaped erratics trains may extend for many kilometres down-ice of their bedrock sources. Erratics trains occur at a variety of scales: continental, regional, local and small-scale (Shilts, 1984a). Many examples of trains up to several kilometres long are known (Rose *et al.*, 1979; Levson and Giles, 1995; locations 6a, b, c, Figure 1). Maximum concentrations of mineralized boulders, occurring 6 kilometres, and as much as 9 to 18 kilometres, down-ice from bedrock sources, have been documented in shield areas (Shilts, 1973; Steele, 1988). Examples of the application of this technique in British Columbia were provided by Hicock (1986, 1995), who documented ore dispersal from a known mineral deposit in the Buttle Valley on Vancouver Island (location 7, Figure 1), and by Clague (1975) who used till provenance investigations to determine glacier flow patterns in the southern Rocky Mountain Trench. Another example of tracing mineralized erratics is reported from the St. Elias Mountains (Day, 1985; Day *et al.*, 1987; location 8, Figure 1). Distinctive properties of indicator clasts in erratics trains include: unique lithologies, the presence of metallic minerals, radioactivity, alteration and structural features such as quartz veinlets (*e.g.*, Stephens *et al.*, 1990).

GEOCHEMICAL EXPLORATION METHODS

The purpose of geochemical surveys is to identify anomalous concentrations of economic or pathfinder elements which may assist directly or indirectly in locating mineral occurrences. Till geochemistry programs are usually conducted at regional scales (commonly 1:50 000) and are designed to identify areas with potential for more detailed follow-up studies, whereas soil and biogeochemical surveys are often used in property-scale investigations. Till geochemical sampling programs are discussed in detail by Levson *et al.* (1994) and Levson and Giles (1996, this volume). Stream and lake sediment geochemical surveys are also mainly used in regional exploration programs. In all types of surveys, multi-element approaches using statistically adequate sampling densities are recommended, and detailed records of sample site and medium characteristics should be maintained. Geochemical analytical methods commonly used in drift exploration programs are discussed by Lett (1995).

SOIL GEOCHEMICAL SURVEYS

This method, in general terms, involves: sampling of soil horizons or parent materials of surficial deposits; analyzing for anomalous concentrations of elements; and tracing anomalies along dispersal paths to their bedrock sources. Soil geochemical programs conducted at property scales in British Columbia generally sample illuvial or enriched (B) soil horizons or, less commonly, eluvial or leached (A) horizons, whereas more regional drift or till sampling programs focus on parent material (C-horizon) samples. Advantages and disadvantages of these two different types of sampling programs are discussed by Bradshaw *et al.* (1974; location 9, Figure 1), Boyle and Troup (1975; location 10, Figure 1), Giles and Levson (1994), Levson *et al.* (1994; location 11, Figure 1) and Levson and Giles (1994, 1995, 1996, this volume; locations 1, 11 and 6a to 6c, Figure 1). Sampling media, sample density, preparation procedures and analytical methods should be selected to optimize anomaly to background contrasts. This information may be obtained from the literature or by conducting orientation surveys to determine patterns of mechanical dispersal in the region. Preferred methods will generally vary with the type of deposit and surficial geology setting. Geochemical soil anomalies may result from dispersal of mineralized bedrock by glacial, glaciofluvial, colluvial, fluvial or other processes as well as by hydromorphic dispersion. Reconnaissance stages of soil geochemistry sampling programs, like regional till sampling programs, are typically carried out with sample densities on the order of one sample per 1 to 10 square kilometres. Once elevated element concentrations have been identified in an area, detailed sampling on the order one sample per 0.02 to 0.1 square kilometre is usually then required to outline the size and shape of the anomaly and to determine the source area.

Most soil geochemical surveys in British Columbia recover and analyze the -80 mesh (<180µm), clay to fine sand fraction, although some evidence suggests preferential enrichment of trace metals in specific grain sizes in some sediment types (Lett, 1995). Shilts (1984a, 1995), for example, has shown that anomalous concentrations of copper, uranium and arsenic can best be observed in till samples when the fine fraction (<50µm) is analyzed, and that the clay (<2µm) fraction may be the most enriched in metals. However, high separation costs generally make exclusive use of the clay fraction economically unviable (Coker and DiLabio, 1989). Another important factor in the sampling, analysis and interpretation stages of soil geochemical surveys is the influence of post-depositional hydromorphic remobilization of certain soluble elements. Groundwater and surface water percolation may alter the original clastic dispersal train by spreading it down slope, partially obscuring its initial shape and outline. Surface weathering processes may also alter original dispersal patterns in till (Sibbick and Fletcher, 1993). Shilts (1984a) and Coker and DiLabio (1989) noted that very low concentrations of copper, lead, zinc, cobalt and nickel occurred in heavy mineral samples from surface horizons 1 to 2 metres deep due to oxidation and weathering of detrital sulphides; the less than 2 micron fraction provided a better representation of the original distribution of certain elements such as nickel and chromium throughout the studied profiles.

TILL GEOCHEMICAL SURVEYS

Due to the extensive cover of till in British Columbia, the most common type of dispersal trains in the province are formed by mechanical dispersal by glacial ice (Levson and Giles, 1995). Idealized models illustrating characteristic features of glacial dispersal trains have been described by Miller (1984), Shilts (1984a) and DiLabio (1990). Three-dimensional aspects of dispersal trains were studied using drilling results from areas of thick glacial overburden in various parts of Canada (Coker and DiLabio, 1989). Dispersal trains may vary in length from tens of metres to hundreds of kilometres (Shilts *et al.*, 1979) and they are commonly ribbon or fan shaped with sharp lateral boundaries. They generally broaden and become more diluted with distance from source, in the down-ice direction, due to lateral and vertical mixing with surrounding barren material. The size, shape and strength of a glacial dispersal train are controlled in part by the size, erodability and orientation, relative to ice flow, of the bedrock source. Local topography can also play an important role as, for example, transported mineralization may be trapped in low areas. The broad tail regions of dispersal trains are often detected first during regional till geochemical surveys.

Most till geochemical sampling programs analyze the -230 mesh (<62.5µm) fraction. The clay and silt (<62.5µm) fraction of tills is geochemically the most active due to surface electrostatic charges and adsorption capacities of surface (Fe, Mn) coatings (DiLabio, 1979). Work by Shelp and Nichol (1987) illustrated that anomalous gold concentrations in glacial dispersal trains can occur in both heavy mineral concentrates and the clay/silt fraction. By contrast, at Hemlo, gold within heavy mineral concentrates from drift is restricted to the zone overlying mineralization and only the clay/silt fraction shows significant down-ice dispersal, suggesting that these two material types, when used in conjunction with one another, can provide complimentary data (Coker and DiLabio, 1989). Gold grain-shape analyses may also be used with other methods to provide relative indications of source proximity (Sauerbrei *et al.*, 1987) but estimates of transport distances made on the basis of clast shape may be misleading if the glacial setting is not well understood. For example, angular gold grains, incorporated by ice-thrusting or other mechanisms into the englacial zone of an ice sheet, may be transported over long distances without being significantly rounded or abraded.

Although morainal deposits are the principal sampling media of drift sampling programs (Levson *et al.*, 1994; Levson and Giles, 1996, this volume), colluvial deposits may also be used effectively as shown, for example, at Mount Milligan by Gravel *et al.* (1991; location 3, Figure 1) and at the Pellaire prospect by Sibbick and Gravel (1991; location 13, Figure 1). Dispersal patterns in colluvial deposits are generally smaller than in tills but they better reflect local bedrock conditions. In spite of typical dilution problems, glaciofluvial sediments may also be utilized if they include significant amounts of local material (Gravel and Sibbick, 1991). Other investigations of glaciofluvial deposits for drift prospecting purposes include studies by Baker (1982), Shilts (1984b), Martin and Eng (1985), Perttunen (1989) and Lilliesköld (1990).

As noted by Coker and DiLabio (1989) and Levson and Giles (1995), correct identification of sediment type sampled in a geochemical survey is key to tracing anomalies back to bedrock sources. For example, up-ice tracing of anomaly patterns will lead to discovery of mineralization only if glacial transport was the principal dispersal mechanism and the sampled media was basal till. Exotic debris in supraglacial tills can mask the lithology and geochemistry of mineralized debris in locally derived basal tills (Geddes and Kristjansson, 1986; Gleeson and Sheehan, 1987). In addition, due to the effects of multiple glaciation in many areas, the stratigraphic position and origin of each stratigraphic unit should be determined, especially in overburden sampling or drilling programs in areas of complex stratigraphy. In all geochemical surveys, the glacial and ice-flow history and stratigraphy of the area must be determined as part of the program.

BIOGEOCHEMICAL SURVEYS

Biogeochemical exploration methods can provide useful complimentary data in the search for mineralization in drift-covered areas (Dunn, 1989, 1995). For example, Warren and Horsky (1986) noted a close relationship between gold and thallium in plants growing above a zone of gold mineralization. Similarly, a down-ice dispersal train of gold at the QR deposit (location 2, Figure 1) was detected by tree-top sampling (Dunn and Scagel, 1989). Living plant tissues, as well as peat, forest litter and plant sap have served as sampling media for biogeochemical exploration for uranium and precious and base metals (Dunn, 1989). Plants not only extract and concentrate elements from soils, bedrock and groundwater but some plant root systems may penetrate thin exotic overburden (*e.g.*, lacustrine clays). Element concentrations in these plants may be more representative of underlying bedrock than concentrations in the surface sediments. Cohen *et al.* (1987) concluded from several case studies that plant anomalies over gold mineralization were often more extensive than those in soils, suggesting that exploration targets may be identified by collecting a smaller number of plant samples than soil samples. DiLabio *et al.* (1982) identified a metalliferous glacial dispersal train which was reflected in zinc concentrations found in local conifers and grasses.

In spite of some advantages over other methods, plant geochemistry does not always reflect local soil or rock geochemistry. Dunn (1983), for example, noted that plant chemistry in glaciated areas may be more heavily influenced by groundwater than the soil composition itself. Furthermore, preferred indicator plants may not be available or ubiquitous in potentially mineralized areas. The interpretation of biogeochemical data must also take into consideration seasonal and annual chemical variations observed in different plant parts.

OTHER GEOCHEMICAL METHODS

Other exploration methods applicable to drift prospecting studies in British Columbia include regional stream sediment, lake sediment, moss-mat sediment, stream water and lake water geochemical surveys. Regional geochemical surveys undertaken by the British Columbia Geological Survey in cooperation with the Geological Survey of Canada, cover many areas of the province. They provide data on the distribution and concentration of a number of elements for each of the different media sampled.

Stream sediments represent a mixture of mineral debris derived from bedrock and/or overburden found within a drainage basin. It is therefore possible to detect a source of mineralization if downstream mechanical and/or chemical transport produces stream sediments enriched in commodity or pathfinder elements. Anomaly length within the stream is a function of the means of transport (mechanical and/or chemical), size of the drainage system, size of the mineral occurrence, physiography, abundance of barren material also in transit and several other local and regional environmental factors. A recent discussion of stream sediment sampling procedures was provided by Fletcher (1990) and an example of a regional stream sediment sampling program is provided Matysek *et al.* (1990) for central Vancouver Island (location 14, Figure 1). The ability of moss mats growing within active stream channels to trap both fine-grained light sediment and heavy minerals was demonstrated by Gravel *et al.* (1990) on southern Vancouver Island (location 15, Figure 1) where fine-grained stream sediments are otherwise lacking. Moss mats grow on top of, or on the downstream side of boulders and logs; they require a cool, moist climate and seasonal stream flooding, as is the case on Vancouver Island and in some mountain ranges of western and eastern British Columbia (Plant *et al.*, 1989). In comparison to routine fine-grained stream sediments, moss mats contain similar concentrations of elements associated with fine sediment (either as hydroxide coatings or adsorbed/absorbed ions) and enhanced concentrations of elements transported as discrete heavy mineral grains.

Stream sediment sampling is of limited use in large drainage basins (Plant *et al.*, 1989) and in areas where fine-grained stream sediments are lacking, making the search for representative samples a time consuming process. Contamination from transported (non-local) deposits such as streambank and floodplain sediments may give erratic results in the case of semi-mobile metals (Rose *et al.*, 1979). Another problem is encountered in glacially deranged drainage systems where short stream sections are interrupted by small lakes, ponds and swamps. Under such conditions, it is difficult to obtain representative samples of the drainage basin. In addition, low-gradient streams in these areas often do not penetrate the glacial drift; this results in stream sediments which reflect the nature of the drift and not that of the underlying bedrock. However, stream sediments can still be used to detect mineralization if the nature and origin of the drift is understood.

Lake sediment geochemistry involves the analysis of lake sediments for trace elements as a mineral exploration tool. Like streams, lakes represent the catchment point for a basin. Sampling of lake sediment/water, therefore, may reveal hidden mineral occurrences within the catchment basin. The interaction of chemical, physical and biological processes in lacustrine environments leads to the fixation of elements on sediments (Coker *et al.*, 1979). Lake sediment sampling has been used for base metal and uranium exploration and, more recently, for gold, tin, tungsten, platinum group and rare earth elements (Hornbrook, 1989). It is particularly useful in areas with abundant lakes, where streams are difficult to access. Regional lake sediment geochemical sampling programs have recently been conducted in the Nechako Plateau region in central British Columbia (Cook and Jackaman, 1994). Lake sediment geochemical sampling programs have proven to be particularly effective when conducted in conjunction with till geochemical surveys and geological mapping programs (Cook *et al.*, 1995).

A knowledge of sediment provenance and hydromorphic dispersion in lake basins is necessary to identify factors that could affect the interpretation of geochemical data, notably complications due to adsorption capacities and rates of sedimentation (Rose *et al.*, 1979). However, these effects may be accounted for by using selective extraction (Hoffman and Fletcher, 1981a, b), and by selective sampling of the basin, that is near stream inlets and along the breaking slope of the lake basin. Sub-bottom acoustic profiling can be used to map the distribution of lacustrine sedimentary facies and aid in the geochemical interpretation. Care must also be taken that the surrounding landscape has not been geochemically contaminated (Hornbrook, 1989). The effectiveness and specific problems of gold data for lake sediment exploration are discussed by Coker *et al.*, (1982), Schmitt and Friske (1987) and McConnell (1987).

In the northern part of British Columbia, 1:250 000-scale regional geochemical sampling programs mainly have focused on stream sediments and stream waters (NTS sheets

104B, F, G, I, K, M, N, O and P; 114O and P), but lake sediment and lake water samples were also collected in 104N and O. Regional geochemical sampling programs in central parts of the province (93A, B, E, G, H, J, L, M and N; 103I, J, O and P) and in the southern interior (82E, F, L, M and 92H, I, J, O, P) have focused principally on stream sediments and water. The 93E and L map areas and parts of 93F and K were also sampled for lake sediments and lake water. In the southwest part of the province, stream sediment and stream water surveys have been conducted in 92F, G, K, L, N and 102I. Moss-sediment data were also collected in several map areas on Vancouver Island (92B, C, E, F, K and L and 102I). In the southern Rocky Mountain Trench and Rocky Mountain areas (82G, J and K), as in most central regions, regional geochemical sampling programs involved the sampling of stream sediments and water.

DRIFT PROSPECTING ACTIVITIES IN BRITISH COLUMBIA

A brief review of drift exploration studies in British Columbia is presented here to provide sources of information which may be of assistance in the interpretation stages of geochemical surveys.

Early drift prospecting surveys, such as those by White and Allen (1954) in the southern Okanagan area (location 18, Figure 1) and Warren *et al.* (1957) in the Ashcroft-Kamloops region (locations 19 and 20, Figure 1) demonstrated the usefulness of geochemical sampling for mineral exploration in the Interior physiographic system. However, despite these early successes in geochemical applications, relatively few results of systematic exploration surveys have since been published, even though several thousand exist in the form of assessment reports and private industry internal reports. The south-central and central interior of British Columbia have received the greatest attention in the published literature in recent years, but these investigations remain isolated, few in number and generally of a preliminary nature.

The importance of a multidisciplinary approach, involving soil and stream geochemistry, geophysics, mapping and drilling programs, in this largely drift-covered region, is particularly well illustrated by studies on the Shasta (Downing and Hoffman, 1987) and Chapelle (Barr, 1978) deposits (area 21, Figure 1). Work on the Sam Goosly (Equity Silver) deposit (location 22, Figure 1) by Ney *et al.* (1972) and Sutherland Brown (1975a) and the QR deposit (location 2, Figure 1; Fox *et al.*, 1987) demonstrate the usefulness of incorporating local ice-flow history into the interpretation of geochemical data. Other studies in the region deal with mechanical and hydromorphic dispersion, such as at the Chutanli deposit (location 6a, Figure 1; Mehrtens, 1975), and mercury dispersion halos in soils at several sites in the Nechako region (locations 24a, b, c, d, Figure 1; Sutherland Brown, 1967). In the southern interior, soil and stream geochemical surveys contributed to the discovery of the Brenda and Boss Mountain deposits (locations 25 and 26, Figure 1; Soregaroli, 1975a, b) and a recent study of glacial dispersal processes was conducted on the Galaxy property near Kamloops (location 27, Figure 1; Kerr *et al.*, 1993). Published accounts of boulder tracing of mineralized clasts are reported from the southern Okanagan (location 18, Figure 1; White and Allen, 1954) and southern Cariboo (location 28, Figure 1; Hoffman, 1972) regions. Recognition of the importance of surficial geology mapping and regional (1:50 000 scale) till geochemistry surveys in areas with thick drift cover in the Interior Plateau region, has resulted in several recent regional surficial mapping and till geochemistry programs there [Giles and Kerr, 1993 (location 29, Figure 1); Proudfoot, 1993 (location 30); Levson and Giles, 1994, Levson *et al.*, 1994 and Cook *et al.*, 1995 (location 11); Giles and Levson, 1994 (location 23)]. The results of a regional till geochemistry survey in the Quatsino map area (92L/12) on Vancouver Island (location 31, Figure 1) were also recently presented by Kerr *et al.* (1992). Additional reconnaissance (1:250 000 scale) till geochemistry survey data are also available in certain areas, such as the Manson River (NTS 93N; location 16a, Figure 1) and Fort Fraser (NTS 93K; location 16b, Figure 1) map regions (Plouffe and Ballantyne, 1993; Plouffe, 1995b).

Multidisciplinary studies using several different drift exploration techniques have been conducted at the Ashnola deposit (location 32, Figure 1; Montgomery *et al.*, 1975) and in the Deadwood camp in the Boundary district (location 18, Figure 1; White and Allen, 1954). Combined soil and stream sediment geochemical surveys produced successful results at the Cinola gold deposit on the Queen Charlotte Islands (location 33, Figure 1; Champigny and Sinclair, 1982) and Giant Copper east of Hope (location 34, Figure 1; Wilton and Pfuetzenreuter, 1990). An integrated approach using geochemistry and magnetic and induced polarization surveys, was instrumental in the discovery of the Island Copper orebody (location 35, Figure 1; Young and Rugg, 1971; Sutherland Brown, 1975b; Witherly, 1979).

More detailed geochemical studies of soil profiles were carried out in central British Columbia at Babine Lake (location 1, Figure 1; Levinson and Carter, 1979), at the Huckleberry deposit (location 36, Figure 1; Sutherland Brown, 1975c) and in the Capoose Lake area (location 10, Figure 1, Boyle and Troup, 1975). Similar detailed studies were conducted in the southern interior near the Pellaire deposit (location 13, Figure 1; Sibbick and Gravel, 1991) and in the Tulameen region (location 41, Figure 1; Cook and Fletcher, 1993), as well as in northwestern British Columbia at the Sheslay (location 37, Figure 1; Coope, 1975) and Red-Chris prospects (location 38, Figure 1; Peatfield and Armstrong, 1980). Similar investigations in the southern Interior discuss the behavior of gold in soils and soil profiles over strong, medium and weak copper mineralization [*e.g.*, Carr *et al.*, 1975 (location 40); Fletcher, 1989 (location 41); Sibbick, 1990; Sibbick and Fletcher, 1993 (Nickel Plate Mine, location 12, Figure 1)]. A number of relevant studies emerged from industry interest in porphyry copper deposits in the Cordillera including the Afton, Morrison, Cariboo-Bell, Endako, Catface, O.K., Maggie, Highmont, Poison Mountain, Mount Milligan and Kemess deposits [see papers in Sutherland Brown (1976) and Schroeter (1995); also Gravel and Sibbick (1991), Sibbick *et al.* (1992) and Sibbick and Kerr (1995)].

Other published studies in the region have dealt with hydromorphic metal dispersion and remobilization of elements [Nichol and Bjorklund, 1973; Gunton and Nichol, 1974 (location 42, Figure 1); Horsnail, 1975 (location 43, Figure 1); Levinson *et al.*, 1984; (location 44, Figure 1)]. Biogeochemical methods have focused on the sampling of bark, twigs and needles in various regions of the central Interior [Hornbrook, 1970a, b (location 45, Figure 1); Boyle and Troup, 1975 (location 10, Figure 1); Dunn and Scagel, 1989 (location 2, Figure 1)] and the southern Interior [Warren *et al.*, 1957; Montgomery *et al.*, 1975 (location 32, Figure 1); Cooke and Barakso, 1987 (location 46, Figure 1)].

CONCLUSIONS

The integration of surficial geology studies, together with several geochemical and geophysical techniques, provides the best means of locating buried mineral deposits throughout British Columbia in areas where bedrock is partially or totally obscured by overburden. In areas of thick overburden such as the Interior Plateau, till geochemical sampling programs and surficial geology mapping programs can be carried out at relatively low cost and are best in early stages of investigations. In conjunction with other methods such as seismic surveys, these techniques can assist in guiding exploratory drilling by providing an approximation of bedrock topography and overburden thickness. In areas where bedrock is totally or partially obscured by overburden, it may also be beneficial to undertake till provenance studies and determine the effects of exotic drift on local soil geochemistry. Stratigraphic investigations of surficial deposits and ice-flow patterns assist in the correlation of tills and in developing a better understanding of glacial dispersal in areas of complex stratigraphy. Regional reconnaissance stream, lake, soil and biological geochemical sampling programs are also often beneficial in the early stages of mineral exploration, depending on the geologic setting. Post-depositional remobilization of elements in soils should be considered, and orientation surveys performed to determine the physical characteristics of dispersal of ore minerals (*e.g.*, such as appropriate grain sizes for analytical procedures).

ACKNOWLEDGMENTS

This paper was reviewed by A. Plouffe, R.N.W. DiLabio and J.M. Newell and was greatly improved by their comments.

REFERENCES

Armstrong, J. and Tipper, H. (1948): Glaciation in North Central British Columbia; *American Journal of Science*, Volume 246, pages 283-310.

Baker, C. (1982): Report on the Sedimentology and Provenance of Sediments in Eskers in the Kirkland Lake Area, and on Finding of Kimberlite Float in Gauthier Township; *in* Summary of Field Work 1982, Wood, J., White, O., Barlow, R. and Colvine, A. Editors, *Ontario Geological Survey*, Miscellaneous Paper 106, pages 125-127.

Barr, D.A. (1978): Chappelle Gold-Silver Deposit, British Columbia; *Canadian Institute of Mining and Metallurgy*, Bulletin, Volume 71, pages 66-79.

Best, M.E. (1995): Resistivity Mapping Using Electromagnetic Techniques; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 251-264.

Bobrowsky, P.T. (1995): Lithological Analysis in Drift Prospecting Studies; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 113-120.

Bobrowsky, P. T. , Giles, T. and Jackaman, W. (1992): Surficial Geology Map Index of British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1992-13.

Boyle, D.R. and Troup, A.G. (1975): Copper-Molybdenum Porphyry Mineralization in Central British Columbia, Canada: An Assessment of Geochemical Sampling Media Useful in Areas of Glaciated Terrain; *in* Prospecting in Areas of Glaciated Terrain, Jones, M.J., Editor, *The Institution of Mining and Metallurgy*, London, pages 6-15.

Bradshaw, P.M.D., Thomson, I., Smee, B.W. and Larsson, J. (1974): The Application of Different Analytical Extractions and Soil Profile Sampling in Exploration Geochemistry; *Journal of Geochemical Exploration*, Volume 3, pages 209-225.

Broster, B., Dreimanis, A. and White, J. (1979): A Sequence of Glacial Deformation, Erosion and Deposition at the Ice-Rock Interface During the Last Glaciation: Cranbrook, British Columbia, Canada; *Journal of Glaciology*, Volume 23, pages 283-295.

Brummer, J.J., Gleeson, C.F., and Hansuld, J.A. (1987): A Historical Perspective of Exploration Geochemistry in Canada - The First 30 Years; *Journal of Geochemical Exploration*, Volume 28, pages 1-39.

Carr, J.M., Bradshaw, P.M.D. and Smee, B.W. (1975): Afton Cu Deposit, British Columbia; *in* Conceptual Models in Exploration Geochemistry, *Journal of Geochemical Exploration*, Volume 4, No. 1, pages 47-49.

Champigny, N. and Sinclair, A.J. (1982): Cinola Gold Deposit, Queen Charlotte Islands, B.C. - A Geochemical Case History; *in* Precious Metals in the Northern Cordillera, Levinson, A., Editor, *The Association of Exploration Geochemists*, pages 121-137.

Clague, J.J. (1975): Glacier Flow Patterns and the Origin of Late Wisconsinan Till in the Southern Rocky Mountain Trench, British Columbia; *Geological Society of America*, Bulletin, Volume 86, pages 721-731.

Clague, J.J. (1987): Bibliography of Quaternary Geoscience Information, British Columbia; *Geological Survey of Canada*, Open File 1448.

Clague, J.J., compiler, (1989): Quaternary Geology of the Canadian Cordillera; *in* Quaternary Geology of Canada and Greenland, Fulton, R.J., Editor, *Geological Survey of Canada*, Geology of Canada, Number 1, pages 17 - 96.

Clague, J.J. (1991): Quaternary Glaciation and Sedimentation; *in* Geology of the Cordilleran Orogen in Canada, Gabrielse, H. and Yorath, C.J., Editors, *Geological Survey of Canada*, Geology of Canada, Number 4, pages 419 - 434.

Clague, J.J., Hebda, R.J. and Mathewes, R.W. (1990): Stratigraphy and Paleoecology of Pleistocene Interstadial Sediments, Central British Columbia; *Quaternary Research*, Volume 34, pages 208-226.

Cohen, D., Hoffman, E. and Nichol, I. (1987): Biogeochemistry: A Geochemical Method for Gold Exploration in the Canadian Shield; *Journal of Geochemical Exploration*, Volume 29, pages 49-73.

Coker, W. and DiLabio, R. (1989): Geochemical Exploration in Glaciated Terrain: Geochemical Responses; Proceedings of Exploration '87, *Ontario Geological Survey*, Special Volume 3, pages 336-383.

Coker, W., Fox, J. and Sopuck, V. (1982): Organic Centre-lake Sediments - Application in the Geochemical Exploration for Gold in the Canadian Shield of Saskatchewan; *in* Geology of Canadian Gold Deposits, Hodder, R. and Betruck, W., Editors, *Canadian Institute of Mining and Metallurgy*, Special Volume 24, pages 267-280.

Coker, W., Hornbrook, H. and Cameron, E. (1979): Lake Sediment Geochemistry Applied to Mineral Exploration; *in* Geophysics and Geochemistry in the Search for Metallic Ores, Hood, P., Editor, *Geological Survey of Canada*, Economic Geology Report 31, pages 435-477.

Cook, S.J. and Fletcher, W.K. (1993): Distribution and Behaviour of Platinum in Soils, Sediments and Waters of the Tulameen Ultramafic Complex, Southern British Columbia, Canada; *Journal of Geochemical Exploration*, Volume 46, pages 279-308.

Cook, S.J. and Jackaman, W. (1994): Regional Lake-sediment and Water Geochemistry Surveys in the Northern Interior Plateau, B.C. (NTS 93 F/2,3,6,11,12,13,14); *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1994-1, pages 39-44.

Cook, S.J., Levson, V.M., Giles, T.R. and Jackaman, W. (1995). A Comparison of Regional Lake Sediment and Till Geochemistry Surveys: A Case Study from the Fawnie Creek Area, Central British Columbia; *Exploration and Mining Geology*, Volume 4, No. 2, pages 93-110.

Cooke, B.J. and Barakso, J.J. (1987): Soil and Plant Geochemical Orientation Surveys on the Congress Property, Bridge River District, B.C; *in* Geoexpo /86, Elliott, I.L. and Smee, B.W., Editors, *Association of Exploration Geochemists*, pages 77-82.

Coope, J.A. (1975): Sheslay Cu-Mo Prospect, British Columbia; in Conceptual Models in Exploration Geochemistry, *Journal of Geochemical Exploration*, Volume 4, No. 1, pages 97-99.

Day, S. (1985): A Petrographic and Geochemical Comparison of Massive Sulphide Boulders in East Arm Glacier, St. Elias Mountains, British Columbia with the Windy Craggy Deposit; unpublished B.Sc. thesis, *The University of British Columbia*.

Day, S., Broster, B.E. and Sinclair, A.J. (1987): Sulphide Erratics Applied to Subglacial Exploration: St. Elias Mountains, British Columbia; *Canadian Journal of Earth Sciences*, Volume 24, pages 723-730.

DiLabio, R.N.W. (1979): Drift Prospecting in Uranium and Base Metal Mineralization Sites, District of Keewatin, Northwest Territories; *in* Prospecting in Areas of Glaciated Terrain, *The Institution of Mining and Metallurgy*, London, pages 91 - 100.

DiLabio, R.N.W. (1990): Glacial Dispersal Trains; *in* Glacial Indicator Tracing, Kujansuu, R. and Saarnisto, M., Editors, *A.A. Balkema*, Rotterdam, 109-122.

DiLabio, R.N.W. and Coker, W.B., Editors, (1989): Drift Prospecting; *Geological Survey of Canada*, Paper 89-20, 169 pages.

DiLabio, R., Rencz, A. and Eggington, P. (1982): Biogeochemical Expression of a Classic Dispersal Train of Metalliferous Till Near Hopetown, Ontario; *Canadian Journal of Earth Sciences,* Volume 19, pages 2297-2305.

Downing, B.W. and Hoffman, S.J. (1987): A Multidisciplinary Exploration Case History of the Shasta Epithermal Gold-Silver Deposit, British Columbia, Canada; *in* Geoexpo /86, Elliott, I.L. and Smee, B.W., Editors, *Association of Exploration Geochemists*, pages 72-76.

Dunn, C.E. (1983): Detailed Biogeochemical Studies for Uranium in the NEA/IAEA Athabasca Tent Area; *in* Uranium Exploration in the Athabasca Basin, Saskatchewan, Canada, Cameron, E., Editor, *Geological Survey of Canada*, Paper 82-11, pages 259-272.

Dunn, C.E. (1989): Developments in Biogeochemical Exploration; in Proceedings of Exploration '87, *Ontario Geological Survey*, Special Volume 3, pages 417-438.

Dunn, C.E. (1995): Biogeochemical Prospecting in Drift-covered Terrain of British Columbia; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 229-238.

Dunn, C.E. and Scagel, R.K. (1989): Tree-top Sampling from a Helicopter - A New Approach to Gold Exploration; *Journal of Geochemical Exploration*, Volume 34, pages 255-270.

Evenson, E., Pasquini, T., Stewart, R. and Stephens, G. (1979): Systematic Provenance Investigations in Areas of Alpine Glaciation; Applications to Glacial Geology and Mineral Exploration; *in* Moraines and Varves, Schluchter, C., Editor, *Balkema Publishers*, Rotterdam, pages 25-42.

Fletcher, W.K. (1989): Preliminary Investigations of Platinum Content of Soils and Sediments, Southern British Columbia (82E/9, 92H/7, 10, 92I/14); *in* Geological Fieldwork 1988, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1989-1, pages 607-610.

Fletcher, W.K. (1990): Dispersion and Behavior of Gold in Stream Sediments; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1990-28.

Fox, P., Cameron, R. and Hoffman, S. (1987): Geology and Soil Geochemistry of the Quesnel River Gold Deposit, British Columbia; *in* Geoexpo '86, Elliott, I.L. and Smee, B.W., Editors, *The Association of Exploration Geochemists*, pages 61-67.

Fulton, R. (1969): Glacial Lake History, Southern Interior Plateau, British Columbia; *Geological Survey of Canada*, Paper 69-37, 14 pages.

Fulton, R. (1975): Quaternary Geology and Geomorphology, Nicola-Vernon Area, British Columbia (82L West Half and 92I, East Half); *Geological Survey of Canada*, Memoir 380, 50 pages.

Fulton, R. and Smith, G. (1978): Late Pleistocene Stratigraphy of South-central British Columbia; *Canadian Journal of Earth Sciences*, Volume 15, pages 971-980.

Geddes, R. and Kristjansson, F. (1986): Quaternary Geology of the Hemlo Area: Constraints on Mineral Exploration; *Canadian*

Geology Journal of the Canadian Institute of Mining and Metallurgy, Volume 1, pages 5-8.

Giles, T.G. and Kerr, D.E. (1993): Surficial Geology in the Chilanko Forks and Chezacut Areas (93 C/1,8); *in* Geological Fieldwork 1992, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1993-1, pages 483 - 490.

Giles, T.G. and Levson, V.M. (1994): Surficial Geology and Drift Exploration Studies in the Fawnie Creek Region (93 F/3); *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1994-1, pages 27-37.

Gleeson, C. and Sheehan, D. (1987): Humus and Till Geochemistry over the Doyon, Bousquet and Williams Gold Deposits; *Canadian Institute of Mining and Metallurgy*, Bulletin, Volume 80, pages 58-66.

Goetz, A., Rock, B. and Rowan, L. (1983): Remote Sensing for Exploration: An Overview; *Economic Geology*, Volume 78, pages 573-590.

Gravel, J.L. and Sibbick, S.J. (1991): Geochemical Dispersion in Complex Glacial Drift at the Mount Milligan Copper-Gold Porphyry Deposit (93N/1E, 93O/4W); *in* Exploration in British Columbia 1990, *B.C. Ministry of Energy, Mines and Petroleum Resources*, pages 117-134.

Gravel, J., Jackaman, W. and Matysek, P. (1990): 1989 Regional Geochemical Survey, Southern Vancouver Island and Lower Mainland (92B, 92C, 92F and 92G); *in* Geological Fieldwork 1989, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1990-1, pages 503-510.

Gravel, J.L., Sibbick, S. and Kerr, D. (1991): Geochemical Research, 1990: Coast Range - Chilcotin Orientation and Mount Milligan Drift Prospecting Studies (92O, 92N, 93N); *in* Geological Fieldwork 1990, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1991-1, pages 323-330.

Gunton, J.E. and Nichol, I. (1974): Delineation and Interpretation of Metal Dispersion Patterns Related to Mineralization in the Whipsaw Creek Area; *in* Exploration Geochemistry, *Canadian Institute of Mining and Metallurgy*, Volume 67, pages 66-74.

Hansen, D. (1981): Geological Applications for Portable Gamma-ray Spectrometers; *in* Practical Geophysics for the Exploration Geologist, Van Blaricom, R., Compiler, pages 1-38.

Hicock, S. (1986): Pleistocene Glacial Dispersal and History in Buttle Valley, Vancouver Island, British Columbia: A Feasibility Study for Alpine Drift Prospecting; *Canadian Journal of Earth Sciences*, Volume 23, pages 1867-1879.

Hicock, S. (1995): Glacial Geology Applied to Drift Prospecting in Buttle Valley, Vancouver Island; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 33-42.

Hoffman, S.J. (1972): Geochemical Dispersion in Bedrock and Glacial Overburden Around a Copper Property in South-central British Columbia; unpublished M.Sc. thesis, *The University of British Columbia.*

Hoffman, S.J. (1986): Case History and Problem 5: A Copper Property; *in* Exploration Geochemistry: Design and Interpretation of Soil Surveys, Fletcher, W.K., Hoffman, S.J., Mehrtens, M.B., Sinclair, A.J. and Thomson, I., Editors, *Reviews in Economic Geology*, Volume 3, pages 155-180.

Hoffman, S. and Fletcher, W.K. (1981a): Detailed Lake Sediment Geochemistry of Anomalous Lakes on the Nechako Plateau, Central British Columbia - Comparison of Trace Metal Distribution in Capoose and Fish Lakes; *Journal of Geochemical Exploration*, 14, pages 221-244.

Hoffman, S. and Fletcher, W.K. (1981b): Organic Matter Scavenging of Copper, Zinc, Molybdenum, Iron and Manganese, Estimated by Sodium Hypochloride Extraction (pH 9.5); *International Geochemical Exploration Symposium*, Hanover, pages 549-562.

Holland, S. (1976): Landforms of British Columbia; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 48, 138 pages.

Hornbrook, E.H.W. (1970a): Biogeochemical Prospecting for Molybdenum in West-central British Columbia; *Geological Survey of Canada*, Paper 68-56, 34 pages.

Hornbrook, E.H.W. (1970b): Biogeochemical Prospecting for Copper in West-central British Columbia; *Geological Survey of Canada*, Paper 69-49, 39 pages.

Hornbrook, E. (1989): Lake Sediment Geochemistry: Canadian Applications in the Eighties; *in* Proceedings of Exploration '87, *Ontario Geological Survey*, Special Volume 3, pages 405-416.

Horsnail, R.F. (1975): Highmont Cu-Mo Deposits, British Columbia; *in* Conceptual Models in Exploration Geochemistry, *Journal of Geochemical Exploration*, Volume 4, No. 1, pages 67-72.

Howes, D. and Kenk, E. (1988): Terrain Classification System for British Columbia; Ministry of Environment Manual 10, *B.C. Ministry of Environment, Lands and Parks*, 90 pages.

Hyvarinen, L., Kauranne, K. and Yletyinen, V. (1973): Modern Boulder Tracing in Prospecting; *in* Prospecting in Areas of Glaciated Terrain 1973, Jones, M., Editor, *The Institution of Mining and Metallurgy*, London, *pages 87-95.*

Kerr, D.E. and Bobrowsky, P.T. (1991): Quaternary Geology and Drift Exploration at Mount Milligan (93N/1E, 93O/4W) and Johnny Mountain (104B/6E, 7W, 10W, 11E), British Columbia; *in* Exploration in British Columbia 1990, Part B, *B.C. Ministry of Energy, Mines and Petroleum Resources*, pages 135-152.

Kerr, D.K. and Levson, V.M. (1995): Annotated Bibliography of Drift Prospecting Activities in British Columbia; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 277-303.

Kerr, D.E., Sibbick, S.J. and Belik, G.D. (1993): Preliminary Results of Glacial Dispersion Studies on the Galaxy Property, Kamloops, B.C. (92I/9); *in* Geological Fieldwork 1992, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1993-1, pages 439-443.

Kerr, D.E., Sibbick, S.J. and Jackaman, W. (1992): Till Geochemistry of the Quatsino Map Area (92L/12); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1992-21.

Klein, J. and Lajoie, J. (1981): Electromagnetic Prospecting for Minerals; *in* Practical Geophysics for the Exploration Geologist, Van Blaricom, R., Compiler, pages 239-293.

Kuaranne, K. Salminen, R. and Eriksson, K. (1992): Handbook of Exploration Geochemistry, Volume 5, *Regolith Exploration*

Geochemistry in Arctic and Temperate Terrains; *Elsevier Science Publishers*, 443 pages.

Kujansuu, R. and Saarnisto, M., Editors, (1990): Glacial Indicator Tracing; *A.A. Balkema*, Rotterdam, 252 pages.

Lett, R.E. (1995): Analytical Methods for Drift; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 215-228.

Levinson, A. and Carter, N. (1979): Glacial Overburden Profile Sampling for Porphyry Copper Exploration: Babine Lake Area, British Columbia; *Western Miner*, May, pages 19-32.

Levinson, A.A., Bland, C.J. and Dean, J.R. (1984): Uranium Series Disequilibrium in Young Surficial Uranium Deposits in Southern British Columbia; *Canadian Journal of Earth Sciences*, Volume 21, pages 559-566.

Levson, V.M. and Giles, T.R. (1994): Surficial Geology and Quaternary Stratigraphy of the Fawnie Creek Area (NTS 93F/3); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1994-9 (1:50 000 map).

Levson, V.M. and Giles, T.R. (1995): Glacial Dispersal Patterns of Mineralized Bedrock with Examples from the Nechako Plateau, Central British Columbia; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 67-76.

Levson, V.M. and Giles, T.R. (1996): Quaternary Geology and Till Geochemistry Studies in the Nechako and Fraser Plateaus, Central British Columbia (NTS 93 C/1, 8, 9, 10; F/2, 3, 7; L/16, M/1); *in* Interior Plateau Geoscience Project: Summary of Geological, Geochemical and Geophysical Studies, Newell, J.M. and Diakow, L.J., Editors, *B.C. Ministry of Employment and Investment,* Paper 1997-2, this volume.

Levson, V.M., Clarkson, R. and Douma, M. (1993): Evaluating Buried Placer Deposits in the Cariboo Region of Central British Columbia (93A, B, G, H); *in* Geological Fieldwork 1992, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1993-1, pages 463-474.

Levson, V.M., Clague, J.J. and Fulton, R.J. (1995): Quaternary Geology and Placer Gold Deposits of Central British Columbia; *Geological Association of Canada and Mineralogical Association of Canada*, Annual Meeting Field Trip Guidebook A4, 87 pages.

Levson, V.M., Giles, T.R., Cook, S.J. and Jackaman, W. (1994): Till Geochemistry of the Fawnie Creek Area (93F/03); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1994-18, 34 pages with appendices.

Lilliesköld, M. (1990): Lithology and Transport Distance of Glaciofluvial Material; *in* Glacial Indicator Tracing, Kujansuu R. and Saarnisto, M., Editors, *Balkema*, Rotterdam, pages 151 - 164.

Martin, D. and Eng, M. (1985): Esker Prospecting Over the Duluth Complex in Northeastern Minnesota; *Minnesota Department of Natural Resources*, Division of Minerals Report 246, 27 pages.

Mathews, W. (1944): Glacial Lake and Ice Retreat in South-central British Columbia; *Royal Society of Canada*, Transactions, Series 3, Volume 38, Section 4, pages 39-57.

Matysek, P., Gravel, J., Jackaman, W. and Feulgen, S. (1990): British Columbia Regional Geochemical Survey, Stream Sediment and Water Geochemical Data, Alberni - NTS 92F; *B.C. Ministry of Energy, Mines and Petroleum Resources*, RGS 25.

Maurice, Y. and Meyer, W. (1975): Influence of Preglacial Dispersion on Geochemical Exploration in County Offaly, Central Ireland; *Journal of Geochemical Exploration*, 4, pages 315-330.

McConnell J. (1987): Gold and Associated Trace Elements in Newfoundland Lake Sediments from Four Areas of Gold Mineralization; *Newfoundland Department of Mines and Energy*, Open File, Newfoundland 1509, 38 pages.

Mehrtens, M.B. (1975): Chutanli Mo Deposit, British Columbia; *in* Conceptual Models in Exploration Geochemistry, *Journal of Geochemical Exploration*, Volume 4, Number 1, pages 63-65.

Miller, J. (1984): Model for Clastic Indicator Trains in Till; *in* Prospecting in Areas of Glaciated Terrain 1984, *The Institution of Mining and Metallurgy*, London, pages 69-77.

Montgomery, J.H., Cochrane, D.R. and Sinclair, A.J. (1975): Discovery and Exploration of Ashnola Porphyry Copper Deposit near Keremeos, B.C.; A Geochemical Case History; *in* Geochemical Exploration 1974, Fletcher, W.K. and Elliott, I.L., Editors, *Elsevier*, Amsterdam, pages 85-100.

Ney, C.S., Anderson, J.M. and Panteleyev, A. (1972): Discovery, Geologic Setting and Style of Mineralization, Sam Goosly Deposit, B.C.; *Canadian Institute of Mining and Metallurgy*, Bulletin, Volume 65, pages 53-64.

Nichol, I. and Bjorklund, A. (1973): Glacial Geology as a Key to Geochemical Exploration in Areas of Glacial Overburden with Particular Reference to Canada; *Journal of Geochemical Exploration*, Volume 2, Number 2, pages 133-170.

Peatfield, G.R. and Armstrong, A.T. (1980): The Red-Chris Porphyry Copper-Gold Deposit, Northwestern British Columbia; A Geochemical Case History; *in* Seventh International Geochemical Exploration Symposium, *Geochemical Exploration Symposium*, Watterson, J. and Theobald, P.K., Editors, Proceedings 7, pages 479-485.

Perttunen, M. (1989): Transportation of Garnets in Glaciofluvial Deposits in Southeastern Finland; *in* Drift Prospecting, DiLabio, R.N.W. and Coker, W.B., Editors, *Geological Survey of Canada*, Paper 89-20, pages 13 - 20.

Plant, J., Hale, M. and Ridgway, J. (1989): Regional Geochemistry Based on Stream Sediment Sampling; *in* Proceedings of Exploration '87, *Ontario Geological Survey*, Special Volume 3, pages 384-404.

Plouffe (1995a): Drift Prospecting Sampling Methods; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 167-180.

Plouffe, A. (1995b): Geochemistry, Lithology, Mineralogy and Visible Gold Grain Content of Till in the Manson River and Fort Fraser Map Areas, Central British Columbia (NTS 93K, N); *Geological Survey of Canada*, Open File 3194, 119 pages.

Plouffe, A. and Ballantyne, S.B. (1993): Regional Till Geochemistry, Manson River and Fort Fraser Area, British Columbia (93K, 93N), Silt Plus Clay and Clay Size Fractions; *Geological Survey of Canada*, Open File 2593, 270 pages.

Plouffe, A. , Levson, V.M. and Giles, T.R. (1996): Quaternary Stratigraphy of Taseko Valley, South Central British Columbia; *in* Current Research, Part-A, *Geological Survey of Canada*, Paper 1996-A, pages 129-134.

Proudfoot, D.N. (1993): Drift Exploration and Surficial Geology of the Clusko River and Toil Mountain Map Sheets (93C/9, 16); *in* Geological Fieldwork 1992, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, pages 491-498.

Pullan, S.E. (1995): Shallow Seismic Methods: Application to Drift Prospecting; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 239-245.

Pullan, S.E., Hunter, J., Gagne, R. and Good, R. (1987): Delineation of Bedrock Topography at Val Gagne, Ontario, Using Seismic Reflection Techniques; *in* Current Research, Part A, *Geological Survey of Canada*, Paper 87-1A, pages 905-912.

Resource Inventory Committee (1995): Guidelines and Standards for Terrain Mapping in British Columbia; *B.C. Resource Inventory Committee*, unpublished report, 123 pages.

Rose, A., Hawkes, H. and Webb, J. (1979): Geochemistry in Mineral Exploration; *Academic Press*, Second Edition, 657 pages.

Ryder, J. (1989): Holocene Glacier Fluctuations (Canadian Cordillera); in Chapter 1 of Quaternary Geology of Canada and Greenland, Fulton, R., Editor, *Geological Survey of Canada*, Geology of Canada, No. 1, pages 74-76

Ryder, J. and Clague, J. (1989): British Columbia (Quaternary Stratigraphy and History, Cordilleran Ice Sheet); *in* Chapter 1 of Quaternary Geology of Canada and Greenland, R. Fulton, Editor, *Geological Survey of Canada*, Geology of Canada, No. 1, pages 48-58.

Sauerbrei, J., Pattison, E. and Averill, S. (1987): Till Sampling in the Casa Berardi Gold Area, Quebec: A Case History in Orientation and Discovery; *Journal of Geochemical Exploration*, Volume 28, pages 297-314.

Schmitt, M. and Friske, P. (1987): Regional Geochemical Surveys and Gold in Lake Sediment Investigations in Saskatchewan; *in* Special Publication Number 8, Gilboy, C. and Vigrass, I., Editors, *Saskatchewan Geological Society*, pages 66-77.

Schreier, H. (1976): Chemical Terrain Variability: A Geomorphological Approach Using Numerical and Remote Sensing Techniques; unpublished Ph.D. thesis, *The University of British Columbia.*

Schroeter, T.G., Editor, (1995): Porphyry Deposits of the Northwestern Cordillera of North America; *Canadian Institute of Mining, Metallurgy and Petroleum*, Special Volume 46, 888 pages.

Seigel, H. (1989): New Horizons in Mining Geophysics; *in* Proceedings of Exploration '87, *Ontario Geological Survey*, Special Volume 3, pages 93-104.

Shelp, G. and Nichol, I. (1987): Distribution and Dispersion of Gold in Glacial Till Associated with Gold Mineralization in the Canadian Shield; *in* Geochemical Exploration 1985, Garrett, R., Editor, *Journal of Geochemical Exploration*, Volume 28, pages 315-336.

Shilts, W. (1973): Glacial Dispersion of Rocks, Minerals and Trace Elements in Wisconsin Till, Southeastern Quebec, Canada; *Geological Society of America*, Memoir 136, pages 189-219.

Shilts, W. (1984a): Till Geochemistry in Finland and Canada; *Journal of Exploration Geochemistry*, Volume 21, pages 95-117.

Shilts, W. (1984b): Esker Sedimentation Models, Deep Rose Lake Map Area, District of Keewatin; *in* Current Research, Part B, *Geological Survey of Canada*, Paper 84-1B, pages 217-222.

Shilts, W. (1993): Geological Survey of Canada's Contributions to Understanding the Composition of Glacial Sediments; *Canadian Journal of Earth Sciences*, Volume 30, pages 333 - 353.

Shilts, W. (1995): Geochemical Partitioning in Till; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 149-164.

Shilts, W., Cunningham, C. and Kaszycki, C. (1979): Keewatin Ice Sheet - Re-evaluation of the Traditional Concept of the Laurentide Ice Sheet; *Geology*, Volume 7, pages 537-541.

Sibbick, S.J. (1990): The Distribution and Behaviour of Gold in Soils in the Vicinity of Gold Mineralization, Nickel Plate Mine, Hedley, Southern British Columbia; unpublished M.Sc. thesis, *The University of British Columbia.*

Sibbick, S.J. and Fletcher, W.K. (1993): Distribution and Behavior of Gold in Soils and Tills at the Nickel Plate Mine, Southern British Columbia, Canada; *Journal of Geochemical Exploration 1991*, Volume 47, pages 183-200.

Sibbick, S.J. and Gravel, J.L. (1991): Talus-Fines Geochemistry of the Pellaire Mesothermal Au Vein Prospect (92O/4E); in Geological Fieldwork 1990, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1991-1, pages 101-108.

Sibbick, S.J. and Kerr, D.E. (1995): Till Geochemistry of the Mount Milligan Area, North-central British Columbia; Recommendations for Drift Exploration for Porphyry Cu-Au Mineralization; *in* Drift Exploration in the Canadian Cordillera, Bobrowsky, P.T., Sibbick, S.J., Newell, J.M. and Matysek, P.F., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-2, pages 167-180.

Sibbick, S.J., Rebagliati, C.M., Copeland, D.J. and Lett, R.E. (1992): Soil Geochemistry of the Kemess South Porphyry Gold-Copper Deposit; *in* Geological Fieldwork 1991, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1992-1, pages 349-361.

Soregaroli, A.E. (1975a): Brenda Cu-Mo Deposit, British Columbia; *in* Conceptual Models in Exploration Geochemistry, *Journal of Geochemical Exploration*, Volume 4, No. 1, pages 58-60.

Soregaroli, A.E. (1975b): Boss Mountain Mo Deposit, British Columbia; *in* Conceptual Models in Exploration Geochemistry, *Journal of Geochemical Exploration*, Volume 4, No. 1, pages 56-58.

Steele, K. (1988): Utilizing Glacial Geology in Uranium Exploration; Dismal Lakes, Northwest Territories, Canada; *Boreas*, Volume 17, pages 183-194.

Stephens, G., Evenson, E. and Detra, D. (1990): A Geochemical Sampling Technique for Use in Areas of Active Alpine Glaciations: An Application from the Central Alaska Range; *Journal of Geochemical Exploration*, 37, pages 301-321.

Stobel, M. and Faure, G. (1987): Transport of Indicator Clasts by Ice Sheets and Transport Half Distances: A Contribution to Prospecting for Ore Deposits; *Journal of Geology*, Volume 95, pages 687-697.

Sutherland Brown, A. (1967): Investigation of Mercury Dispersion Haloes Around Mineral Deposits in Central British Columbia; *in* Proceedings, Symposium on Geochemical Prospecting, *Geological Survey of Canada*, Paper 66-54, pages 72-83.

Sutherland Brown, A. (1975a): Sam Goosly Cu Deposit, British Columbia; *in* Conceptual Models in Exploration Geochemistry, *Journal of Geochemical Exploration*, Volume 4, No. 1, pages 94-97.

Sutherland Brown, A. (1975b): Island Copper Deposit, British Columbia; *in* Conceptual Models in Exploration Geochemistry, *Journal of Geochemical Exploration*, Volume 4, No. 1, pages 76-78.

Sutherland Brown, A. (1975c): Huckleberry Cu-Mo Deposit, British Columbia; *in* Conceptual Models in Exploration Geochemistry, *Journal of Geochemical Exploration*, Volume 4, No. 1, pages 72-75.

Sutherland Brown, A., Editor, (1976): Porphyry Deposits of the Canadian Cordillera; *Canadian Institute of Mining and Metallurgy*, Special Volume 15, 510 pages.

Tipper, H. (1971a): Glacial Geomorphology and Pleistocene History of Central British Columbia; *Geological Survey of Canada*, Bulletin 196, 89 pages.

Tipper, H. (1971b): Multiple Glaciation in Central British Columbia, *Canadian Journal of Earth Sciences*, Volume 8, pages 743-752.

Warren, H. and Horsky, S. (1986): Thallium, a Biogeochemical Prospecting Tool for Gold; *Journal of Geochemical Exploration*, Volume 26, pages 215-221.

Warren, H.V., Delavault, R.E. and Cross, C.H. (1957): Geochemical Anomalies Related to some British Columbia Copper Mineralization; *in* Methods and Case Histories in Mining Geophysics, *Sixth Commonwealth Mining and Metallurgical Congress*, pages 277-282.

Watson, K. and Raines, G. (1989): Exploration Remote Sensing - A Look to the Future; *in* Proceedings of Exploration '87, *Ontario Geological Survey*, Special Volume 3, pages 78-87.

White, W.H. and Allen, T. M. (1954): Copper Soil Anomalies in the Boundary District of British Columbia; *American Institute of Mining Engineers*, Transactions, Volume 199, pages 49-52.

Wilton, H.P. and Pfuetzenreuter, S. (1990): Giant Copper (092H/SW 001, 002); *in* Exploration in British Columbia 1989, *B.C. Ministry of Energy, Mines and Petroleum Resources*, pages 91-93.

Witherly, K.E. (1979): Geophysical and Geochemical Methods Used in the Discovery of the Island Copper Deposit, Vancouver Island, British Columbia; *in* Geophysics and Geochemistry in the Search for Metallic Ores; Hood, P.J., Editor, *Geological Survey of Canada*, Economic Geology Report 31, pages 685-696.

Young, M.J. and Rugg, E.S. (1971): Geology and Mineralization of the Island Copper Deposit; *Western Miner*, Volume 44, pages 31-40.