Physical partitioning of mercury in till: an example from central British Columbia, Canada

Alain Plouffe *

Geological Survey of Canada, 601 Booth St., Ottawa ON, K1A 0E8, Canada

Received 25 February 1997; accepted 22 April 1997

Abstract

The physical partitioning of Hg into different grain size fractions of till is predominantly controlled by the primary bedrock mineralogy, the distance of glacial transport, and the relative stability of cinnabar (HgS) in the soil weathering environment. At sites located short distances down-ice from bedrock cinnabar mineralization, the highest Hg concentrations in unoxidized till were measured in the sand- and granule-sized fractions reflecting the abundance of cinnabar in those size ranges. Similar partitioning was measured in oxidized till as cinnabar was found to be relatively resistant to postglacial weathering. Discrete clay-sized cinnabar grains obtained from the unoxidized till were viewed under the scanning electron microscope and suggest that the terminal grade of cinnabar is in the clay-sized range. In till collected from areas barren of cinnabar mineralization, the highest Hg levels were found in the clay-sized fraction which is attributed to the high adsorption of Hg by clay minerals. © 1997 Elsevier Science B.V.

Keywords: mercury; till; physical partitioning; cinnabar

1. Introduction

Mercury has received a great amount of attention in the scientific literature because of: (1) its use as a pathfinder element in mineral exploration; (2) its well known toxicity to biota; (3) the environmental significance of its enrichment in the upper portion of some lacustrine sediment profiles; and, (4) to a lesser extent, its potential use to predict onset of earthquakes and detect major palaeoseismic periods. In spite of the abundance of publications on the topic of Hg, little has been written on the glacial transport and mode of occurrence of Hg in till. Part of this gap was filled by Plouffe (1997b) who presented evidence of the detrital glacial transport of Hg. The objective of this paper is to present new data on the mode of occurrence of Hg in till, at sites close to, and remote from cinnabar (HgS) mineralization in bedrock, and to compare the results with other partitioning studies. Furthermore, the terminal grade (optimum grain size to which a mineral can be reduced by glacial comminution; Dreimanis and Vagners, 1971) of cinnabar as well as the behaviour of cinnabar in the postglacial weathering environment are not well established. The physical partitioning study along with a comparative assessment of Hg in oxidized and unoxidized tills attempt to contribute to these issues. Results of this work will serve to improve the use of Hg as a pathfinder element for...
drift exploration and to characterize the natural signature of Hg in till for future environmental assessments.

Glacial sediments generally contain low concentrations of Hg (normal tills, glacial clay, sand, etc., have a range of 20–100 ppb; Jonasson and Boyle, 1971), close to the detection limit of Hg (ca. 10 ppb) for most common analytical methods. Such low concentrations in glacial sediments reflect in part the average Hg concentration of 80 ppb in the continental crust (Jonasson, 1970). To investigate the partitioning of Hg in different grain size fractions of till, a region enriched in Hg was selected to avoid the problem of having to measure Hg concentrations at or close to the analytical detection limit. Therefore, a segment of the Pinchi Fault in central British Columbia (Fig. 1) was chosen as a study area because of the known enrichment of Hg in till down-ice from cinnabar (HgS) occurrences in bedrock (Plouffe, 1995a,b, 1997b).

2. Setting

2.1. Bedrock geology

Large crustal fragments were accreted to North America in Mesozoic and Cenozoic time, following the easterly directed subduction of the Pacific Plate underneath the North American craton (Monger, 1984; Gabrielse et al., 1991). Following accretion, dextral strike slip motion took place along a system of transcurrent faults including the Pinchi Fault (fault zone) which extends over 450 km in central British

![Fig. 1. Study area location (shaded) and Pinchi Fault. CM = Cariboo Mountains; CP = Chilcotin Plateau; SM = Skeena Mountains.](image-url)
Cumulative displacement of as much as 300 km took place along these faults (Gabrielse, 1985).

Along the Pinchi Fault, deep circulation of meteoric waters during the faulting event introduced low-temperature mineralizing fluids which produced cinnabar (HgS) and gangue minerals, including stibnite, pyrite, marcasite, chalcopyrite, various carbonates, fine-grained quartz, and barite (Freeze, 1942; Armstrong, 1966; Nesbitt et al., 1987). Several cinnabar occurrences were mapped along the fault (Armstrong, 1944, 1946, 1948, 1949), two of which were developed into the Pinchi and Bralorne Takla mines (Fig. 2). Mining and ore processing took place at Pinchi Mine in the early 1940s and 1970s. At Pinchi Mine, cinnabar is the main ore mineral and occurs principally in brecciated fault zones in Cache Creek Group limestone (Armstrong, 1949).

3. Previous study: metal partitioning in different grain size fractions of till

The partitioning of metals in different grain size fractions of till has been investigated by many researchers including Shilts (1973, 1984, 1995) and Nikkarinen et al. (1984) for base metals, DiLabio (1982, 1988), Sopuck et al. (1986), Coker et al. (1988), Delaney and Fletcher (1993, 1995), and Sibbick and Fletcher (1993) for gold, and DiLabio (1985, 1995), Coker et al. (1990), and Cook and Fletcher (1994) for platinum group and lithophile elements. These studies have been focused on applications to mineral exploration designed to identify the optimal grain size range for detecting metal enrichment in till. Analysis of a specific size fraction allows a greater contrast between background and anomalous metal concentrations, facilitates the detection of mineralization, and eliminates the effects of textural variation on till geochemistry (Shilts, 1971). A general conclusion from these partitioning studies is that the physical distribution of metals in different size fractions of till reflects the grain size range of the bedrock mineralogy and can be affected by post-glacial weathering of the sediment. In the case of most base metals present in more labile mineral phases (e.g. pyrite), the enrichment is noted in the clay-sized material because of the primary enrichment of metals in phyllosilicates in the bedrock source and the adsorption of metals on clay particles following weathering of the less stable host minerals (Shilts, 1984, 1991, 1995). Phyllosilicates are known to be easily comminuted during glacial erosion and transport, and to have terminal grades in the clay-sized range (Dreimanis and Vagners, 1971; Shilts, 1984). On the other hand, metals present in mineral phases that are more resistant to weathering and oxidation, generally show enrichment in clay and in another coarser-size fraction. For instance, this is the case for tungsten which occurs in scheelite at Waverley, Nova Scotia (DiLabio, 1988), lithophile elements in pyrochlore and zircon at the Strange Lake alkalic complex, Labrador (DiLabio, 1995), and...
chromium in chromite near Thetford Mines (Shilts and Kettles, 1990). This second type of metal partitioning is thought to be related to a combination of the following factors: (1) the resistance to weathering of a primary mineral phase which is in the silt- and sand-sized ranges (i.e. 0.002–2 mm); (2) the primary enrichment of metals in phyllosilicates or other minerals within bedrock that easily get com-

Fig. 2. Simplified regional ice flow patterns; modified from Plouffe (1995b).
minuted to clay during glacial comminution; and, (3) probably to a lesser degree, the adsorption of metals on clay during postglacial weathering (Shilts, 1984, 1991, 1995; DiLabio, 1988).

4. Methods

Till samples were collected on road cuts, natural river bluffs, and hand-dug pits at a minimum depth of 1 m, well below the zone of most intense soil oxidation except at selected sections where the oxidized horizon was also sampled. Sampling was limited to areas where till is at the surface or overlain by less than 1 m of glaciolacustrine sediments.

Sediment preparation was completed by the author, in the laboratories of the Geological Survey of Canada. To separate till samples into different grain size fractions, approximately 300 g of till (bulk) was freeze-dried 24 h to remove moisture which facilitates grain size separation. Only stainless steel sieves were used in the separation process. The > 4 mm fraction was removed by dry sieving. The silt and clay-sized fraction (< 63 μm) was separated from the coarser particles by dry and wet sieving, using a defloculant solution of Na-hexametaphosphate (5 g/l). The > 63 μm material was then dried at room temperature under a fume hood and dry sieved to different grain size ranges: granules (4000–2000 μm); medium to coarse sand (2000–250 μm); fine sand (250–125 μm); and, very fine sand (125–63 μm). Each grain size fraction was weighed and then crushed using an electrical ceramic ball mill. The silt-sized fraction (2–63 μm) was separated from the clay-sized fraction (< 2 μm) using a centrifuge and following standard procedures of the Geological Survey of Canada sedimentology laboratory (Lindsay and Shilts, 1995) with the following modification: after the first centrifugation at 750 rpm, the complete supernatant was recovered to obtain all material < 2 μm. As it is practically impossible to perfectly separate the clay (< 2 μm) from the silt-sized fraction (2–63 μm), the amount of clay present in the silt-sized fraction or the presence of silt-sized particles in the clay separates was monitored using a Brinkmann particle size analyzer. Results indicate that a minor amount of clay particles (less than 10%) can still be present within the silt-sized fraction (2–63 μm). As stated by Shilts (1995), this could be a source of error in estimating the true metal content of the silt sized fraction. No silt was detected in the clay separates. To verify the reproducibility of the partitioning experiment, duplicates from three samples were independently carried through the separation procedures.

Heavy minerals (specific gravity > 3.3) were separated from the 63–250 μm grain size fraction with methylene iodide, for a selected number of till samples located near the Pinchi Mine area. Magnetic minerals were then removed with a hand magnet. Further references to the heavy mineral concentrates (HMC) in this paper relate to the nonmagnetic fraction of the heavy mineral concentrates. Cinnabar grains in the HMC, characterized by being bright red, were counted under a binocular microscope.

All Hg analyses were done by cold-vapour atomic absorption spectrometry (CV–AAS) in a commercial laboratory. The strong oxidizing power of aqua regia is known to destroy several sulphides including cinnabar (Saukov, 1946; Hall, 1991). This is important as all metals to be analyzed by CV–AAS have to be dissolved. The precision of the analytical method was calculated using randomly selected clay-sized fraction samples analyzed in duplicate. Following the methodology described by Thompson and Howarth (1978), at a 95% confidence level, the precision was found to be ± 17% for concentrations below 100 ppb and ± 16% above 100 ppb.

A scanning electron microscope (SEM) equipped for backscattered electron imaging and an energy-dispersive spectrometer was utilized to determine the mineral phase in which Hg is present in till and crushed mineralized bedrock.

5. Results and interpretation

5.1. Physical partitioning of Hg in till

A total of fourteen till samples were selected for the partitioning study of Hg in different grain size fractions. Four of these samples are from anomalous unoxidized till with high Hg concentrations in the clay-sized fraction located down-ice from known bedrock cinnabar occurrences (Fig. 3: samples 1 to 4). Eight unoxidized till samples are located in re-
Fig. 3. Regional till geochemistry: mercury content of the clay-sized fraction of till, modified from Plouffe (1997b). Location of samples utilized for the partitioning experiment (samples 1 to 14) depicted on the map.
regions without cinnabar occurrences in the proximal source area and have Hg concentrations less than 450 ppb in the clay-sized fraction (Fig. 3; samples 5 to 10; Plouffe, 1995a). Two of these eight samples were collected on the Chilcotin Plateau, 275 km south of the study area (Fig. 1). The last two samples were obtained from the oxidized horizon of till 100 m down-ice from the Pinchi Mine (Fig. 3; samples 11 and 12).

Analytical results for the various grain size fractions are summarized in Figs. 4 and 5. All samples collected near known cinnabar occurrences contain elevated Hg levels, i.e. > 500 ppb, in the clay-sized fraction, but the coarser grain size ranges, i.e. sand and granule (> 63 µm), yielded the highest Hg concentrations (Fig. 4). The high Hg levels in the sand-sized fraction are attributed to the presence of cinnabar grains. Viewing of the sand-sized fractions under the binocular microscope and the SEM allowed the identification of euhedral and anhedral cinnabar grains (Plouffe, 1997b). High Hg concentrations within the granule-sized fraction (2000–4000 µm) of some samples (Fig. 4) are related to the presence of mineralized rock fragments with cinnabar, similar to the one depicted on Fig. 6 but larger.
Till samples collected from regions without bedrock cinnabar mineralization clearly show a relative Hg enrichment in the clay-sized fraction (Fig. 5). The relative enrichment of Hg concentrations in the clay-sized fraction compared to coarser material can also be demonstrated by comparing the Hg content of the silt and clay- (<63 μm) and the clay-sized (<2 μm) fractions of 112 till samples. Results show that for 98% of the samples, a greater level of Hg is found in the clay-sized fraction (<2 μm) than in the silt and clay-sized fraction (<63 μm) (Fig. 7). The relative Hg enrichment in the clay-sized fraction is attributed to the high adsorption capacity of clay particles for Hg.

The analytical reproducibility of this partitioning experiment was found to be optimal for the finer grain size fractions (<63 μm) and in samples with extremely high Hg concentrations (Fig. 8A). This probably reflects the homogeneous distribution of Hg in those samples. Reproducibility deteriorates in sand-sized fractions especially in samples with less than 200 ppb Hg (Fig. 8B). This likely reflects the heterogeneous distribution of mineral(s) containing Hg in the sand-sized fraction of till, i.e. a phenomenon similar to the 'nugget effect' which characterizes the distribution of gold in various sediment types (Harris, 1982). It is not thought to be related to the laboratory analytical precision which was found to be equal to or better than ±17% within that concentration range (Plouffe, 1997b).

5.2. Glacial comminution

To test the potential link between the physical partitioning of Hg in till and glacial comminution, two fresh bedrock samples from a mineralized outcrop at Pinchi Mine were crushed, separated, and analyzed for Hg following the same procedures as for the till samples (Figs. 3 and 9; samples 13 and 14). Mercury values are much more elevated in the crushed bedrock than in the till since there is no

---

Fig. 8. Grain size vs mercury concentrations of duplicate samples collected from (A) oxidized till of the Pinchi Mine area and (B) areas of low mercury concentrations (<500 ppb). Sample locations are depicted in Fig. 3.

Fig. 9. Grain size vs mercury concentrations in unweathered bedrock samples from Pinchi Mine ore. Sample locations are depicted in Fig. 3.
dilution from non-mineralized bedrock lithologies as is the case for till. The partitioning of Hg, both in crushed bedrock (Fig. 9) and in unoxidized till collected near bedrock cinnabar occurrences (Fig. 4), show high Hg concentrations in the silt (2-63 μm) and very fine sand-sized (63-125 μm) fractions. As opposed to till, no high Hg concentrations were measured from any grain size fraction > 125 μm in the crushed bedrock (Figs. 4 and 9). This is likely related to: (1) the small number of bedrock samples analyzed which do not fully represent the complete physical characteristics of the cinnabar mineralization along the Pinchi Fault; and/or, (2) the stronger comminution effect of the bedrock crusher compared to the glacier. Based on this single experiment, the partitioning of Hg in unoxidized till is interpreted to reflect glacial comminution because unoxidized till and crushed bedrock show similar partitioning profiles.

5.3. Effects of postglacial weathering

To determine the effect of postglacial weathering on the partitioning of Hg in till, two till samples collected at a depth of 25 cm, in the most intensely oxidized horizon, were separated and analyzed following the same procedures as for the unoxidized till. The samples were obtained from sections located 100 m east (down-ice) from the Pinchi Mine, where Hg concentrations in the clay-sized fraction of the unoxidized till exceed 15,000 ppb. The partitioning profiles of the oxidized till are similar to the ones of unoxidized till collected close to cinnabar mineralization (Fig. 5) showing the highest Hg concentrations in the sand-sized fractions (Fig. 10). Higher Hg concentrations in the sand-sized fraction is attributed to the presence of cinnabar which was observed in the HMC of the oxidized till, under the binocular microscope. Cinnabar was found in association with goethite, some of which likely formed following the oxidation of other sulphides, as some goethite grains have cubic shapes indicating pyrite replacement. Therefore, it appears that some cinnabar grains have resisted oxidation since deglaciation while other sulphides such as pyrite, have been oxidized. This observation corroborates conclusions of other studies which suggest that cinnabar oxidizes more slowly than other sulphides (Engler and Patrick, 1975) and is relatively stable to chemical breakdown in the

weathering environment (Jonasson and Boyle, 1971, 1972; Rogers, 1979; Rose et al., 1979; Harsh and Doner, 1981).

Based on these observations, the partitioning of Hg in different grain size fractions of till is predominantly controlled by the glacial comminution of the bedrock ore and the remobilization of Hg was at least partly limited, because of the relative stability of cinnabar in the oxidized till.

5.4. Form of Hg in till matrix

As stated above, numerous cinnabar grains were observed in the sand-sized fraction of till. The strong
positive correlation ($r = 0.97$) between the number of cinnabar grains and Hg concentrations in the HMC (63-250 $\mu$m) of the Pinchi Mine area (Fig. 11) suggests that most of the Hg in the heavy minerals is bound within cinnabar. However, some samples devoid of visible cinnabar grains contain high concentrations of Hg (Fig. 11). Examination of these HMC under the SEM revealed the presence of cinnabar inclusions ($< 1$ $\mu$m to 48 $\mu$m) within goethite, hematite and quartz (Fig. 12) which reflects the mineralogy of the Hg ore from Pinchi Mine. No detailed study has been conducted on Hg concentrations in various minerals from Pinchi Mine bedrock, but in an unpublished mine closing report, Mason (1944) indicated that the ore is often surrounded by an iron oxide zone with high Hg levels which could be a source of goethite and hematite with cinnabar inclusions.

Abundant cinnabar grains smaller than 2 $\mu$m were detected under the SEM, in both the till samples collected close to cinnabar occurrences and in the crushed bedrock. Clay-sized particles of cinnabar in till most likely result from the glacial comminution of coarser cinnabar grains (cinnabar is a relatively soft mineral which would facilitate this process), and the release of fine-grained cinnabar inclusions following glacial comminution of other mineral phases (Fig. 12). Primary halo enrichment of Hg in phyllosilicates within the bedrock source such as reported by Ozerova (1971) near hydrothermal deposits, and the adsorption of Hg on clay particles following oxidative weathering of Hg-bearing minerals, may affect distribution of Hg in the clay-sized fraction of till, but would have to be quantified by more detailed testing such as sequential leaching analyses.

The strong correlation between the mineralogy of the till and that of the bedrock point to detrital transport rather than hydromorphic transport for the origin of Hg in till.

6. Discussion

An understanding of the residence sites of Hg in till has implications for studies on the use of this metal as a pathfinder element, and the distinction between anthropogenic and natural distribution of Hg in glacial sediments.

6.1. Other partitioning studies

Mercury was found to be enriched in the clay-sized fraction of other sediment types (Warren et al., 1966;
Jonasson, 1970; Dudas and Pawluk, 1976; Harsh and Doner, 1981) including till (Shilts, 1995), as was observed in this study in areas removed from cinnabar occurrences (Fig. 5). On the other hand, the enrichment of Hg in the sand-sized fraction of till (Fig. 4) is interpreted to be a characteristic specific to sites close to a bedrock source of cinnabar, i.e. a mineral relatively resistant to postglacial weathering. The physical partitioning profile for Hg near cinnabar occurrences (Fig. 4) is similar to the ones of other metals bound into stable mineral phases (see Section 3). High Hg concentrations in the silt- and sand-sized fractions of soils (Krömer et al., 1981) and fluvial sediments (Harsh and Doner, 1981; Gray et al., 1991; Eppinger, 1993; Sibbick and Laurus, 1995) in the vicinity of cinnabar mineralization, is most likely a manifestation of the extremely low solubility and relative resistance of cinnabar to oxidation.

6.2. Cinnabar terminal grade

Dreimanis and Vagners (1972) defined ‘terminal grade’ as the particle size range of a specific mineral which represents the final product of glacial comminution. Clay-sized cinnabar inclusions released following the postglacial weathering of hematite and quartz (Fig. 12) probably contributed only a small portion of the cinnabar in the clay-sized fraction of till, because of the relative stability of hematite and quartz in oxidizing soils (Krauskopf, 1979). Therefore, the presence of abundant cinnabar grains in the clay-sized fraction (< 2 μm) of unoxidized till strongly suggests that cinnabar can get comminuted to the clay-sized range by glacial grinding and that its terminal grade resides in the clay-sized range. The terminal grade of cinnabar in the clay-sized range corroborates findings of Dreimanis and Vagners (1969) who indicated that the terminal grade of soft minerals with Mohs’ hardness equal or smaller than 2 (Mohs’ hardness of cinnabar = 2–2.5; Berry et al., 1983) is usually < 2 μm. Therefore, the presence of cinnabar in the sand-sized fraction indicates that till collected close to the cinnabar occurrences, is immature from the cinnabar content point of view, and that cinnabar has not reached its terminal grade, because of the short distance of glacial transport.

6.3. Anthropogenic effect (?)

Anthropogenic deposition was noted by Henderson and McMartin (1995) and Henderson et al. (1997) at the Flin Flon smelter, Manitoba, Canada, where at less than 3 km from the source, airborne Hg can be detected in the clay-sized fraction of soils developed on till, to a maximum depth of ca. 45 cm, in areas of thin organic matter cover. With the available data, it is not possible to ascertain if any of the Hg present in the oxidized till of Pinchi Mine, collected at a depth of 25 cm, is derived from atmospheric fallout. On the other hand, the presence of sand-sized cinnabar grains clearly indicates detrital transport because cinnabar does not precipitate in normal soil-forming conditions (Azzaria and Habashi, 1976). However, metacinnabar, a meta-stable isomorph of cinnabar also known as black cinnabar (Saukov, 1946), can form in the low-temperature surface environment (Barnett et al., 1995) and evolve to cinnabar (Saukov, 1946). Nevertheless, no evidence of metacinnabar has been found in the sand-sized fraction of the till samples examined under both the binocular microscope and SEM. In addition, precipitation of metacinnabar from atmospheric Hg would have been limited by the availability of sulphur.

If cinnabar in till is the result of detrital glacial transport and if cinnabar did not precipitate in till one question remains: how to explain the presence of euhedral cinnabar grains in the sand-sized fraction as reported in Plouffe (1997b, fig. 5A), knowing that cinnabar is soft and has a terminal grade in the clay-sized range? It is possible that some grains might have sustained glacial abrasion and comminution, but a more likely scenario is that some cinnabar grains were transported in larger fragments of the mineralization host rock (limestone) (Fig. 6) and released following weathering of the clasts. A similar phenomenon has been described by Henderson and Roy (1995) who demonstrated the release of pristine gold grains in till following the postglacial weathering of sulphides.

6.4. Recommendations for future research

Conducting geochemical analyses on a limited grain size fraction of till restrains the effect of
texture on metal content as originally postulated by Shilts (1971, 1975, 1984) for base metal prospecting and DiLabio (1982, 1985) for gold exploration. From the results of this study, it was found that the clay-sized fraction of till was appropriate to demonstrate the natural distribution of Hg within the study area. Adequate results were obtained with the clay-sized fraction because: (1) it contains the highest concentrations of Hg in areas barren of cinnabar mineralization (Fig. 5), which allows more pronounced geochemical contrasts; (2) it seems to yield better reproducibility than the coarser fractions (Fig. 8); and, (3) the vast majority of samples collected close to cinnabar occurrences contain Hg concentrations above the regional threshold (600 ppb; Plouffe, 1997b; Fig. 3).

If more detailed work on the glacial transport of Hg was conducted in the vicinity of cinnabar occurrences, geochemical analysis of a coarser fraction, possibly within the sand-sized range, could yield better results as Hg concentrations were found to be the highest in that grain size range close to these sites (Fig. 4). Depending on project scale, scope, and available funding, heavy minerals could be separated and analyzed to increase the contrast and improve chances of detecting the 'tail' (as defined by Shilts, 1976) of a Hg dispersal train. Longer glacial transport of Hg has been detected at the Pinchi Mine in the HMC (Plouffe, 1997b). Analysis of large samples of a specific grain size range would be preferable, because of the likelihood of observing a heterogeneous distribution of cinnabar in the sediment.

Future till geochemical surveys conducted to demonstrate the natural distribution of Hg or to use Hg as a pathfinder element could make use of the data presented herein but, the physical partitioning experiment presented here could easily be repeated in other regions.

7. Conclusion

The partitioning of Hg into different grain size fractions of till follows two types of behaviour. At short distances down-ice from cinnabar occurrences, Hg is most abundant in the sand-sized (63–250 μm) of the till matrix and in a few cases shows extremely high concentrations in the granule-sized range (2–4 mm). These results are related to glacial comminution, short detrital glacial transport of the Hg bedrock mineralization, and relative stability of cinnabar in postglacial weathering environment. At sites removed from cinnabar mineralization, the clay-sized fraction of the till yielded the highest Hg concentration which is related to the high adsorption capacity of clay for Hg.

Cinnabar clay-sized grains were viewed under the SEM in the till collected close to the cinnabar bedrock source which suggests that cinnabar has a terminal grade in the clay sized range.

In future mineral exploration surveys or environmental assessment programs, the clay-sized fraction could yield the optimal analytical results for Hg, if cinnabar occurrences are not encountered. On the other hand, close to cinnabar occurrences, analysis of a coarser-sized fraction, within the sand-sized range, would probably be more appropriate to detect the Hg geochemical signature in till, derived from bedrock mineralization.

Acknowledgements

This paper is part of the author’s Ph.D. dissertation being completed at the University of Montréal under the supervision of M.A. Bouchard and W.W. Shilts. A. Tsai (SEM), D. Walker (SEM), P. Lindsay (supervision of geochemical analyses) and J. Boucher (interlibrary loans) provided valuable help to this project. Critical reviewing by M.A. Bouchard, S. Cook, P.J. Henderson, I.R. Jonasson, and W.W. Shilts, and both journal referees W.B. Coker and W.K. Fletcher greatly improved the manuscript. Cinnabar grain counts were completed by Consolminex, Gatineau, P.Q. The project was funded by the Canada–British Columbia Agreement on Mineral Development and the Nechako NATMAP Project.

References

metal smelter at Flin Flon, Manitoba, Canada. Env. Geol., in press.


Plouffe, A., 1997b. Detrital transport of metals by glaciers, an example from the Pinchi Mine site, central British Columbia. Environ. Geol. in press.


Warren, H.V., Delavault, R.E., Barakso, J., 1966. Some observations on the geochemistry of mercury as applied to prospecting. Econ. Geol. 61, 1010–1028.