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DRIFT COMPOSITION AND GLACIAL DISPERSAL TRAINS, BAKER LAKE AREA, DISTRICT OF KEEWATIN, NORTHWEST TERRITORIES

R.A. Klassen

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Cover description

Meltwater channel in bedrock of the Dubawnt Group. Indicator erratics derived from that Group, including Pitz and Thelon formations, define glacial dispersal trains extending tens to hundreds of kilometres southeast of their source areas. (Photo by R.A. Klassen, 1975; GSC 1995-090)

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Preface

Through regional surveys of glacial deposits and lithological and geochemical analyses of till, the Geological Survey of Canada develops models of ice flow and glacial dispersal trains that characterize large parts of Canada. The models serve as a framework for understanding the geological and glaciological controls on drift composition, both areally in the near-surface and vertically in stratigraphic sections.

The results of this work are valuable in any mineral exploration that uses drift prospecting techniques. The mineralized sources can be identified, as well as the distances and directions of glacial transport within till. Site specific exploration methods can also be determined. The natural geochemical baseline and its variations can be understood using the geochemical maps and data files and can also assist in environmental studies and risk assessment.

This Quaternary geology report describes glacial dispersal trains at scales of metres to hundreds of kilometres in the Baker Lake area and illustrates the effects of different bedrock sources on till geochemistry.

Elkanah A. Babcock
Assistant Deputy Minister
Geological Survey of Canada

Préface

En s'appuyant sur des levés régionaux des dépôts glaciaires et sur des analyses lithologiques et géochimiques du till, la Commission géologique du Canada élabore des modèles d'écoulement glaciaire et des traînées de dispersion glaciaire caractérisant de grandes régions du Canada. Les modèles servent de cadre à la compréhension des facteurs géologiques et glaciologiques qui contrôlent la composition des sédiments glaciaires, que ce soit horizontalement dans la zone quasi superficielle ou verticalement dans les coupes stratigraphiques.

Ces données sont utiles pour l'exploration minérale basée sur la prospection des sédiments glaciaires. En effet, on peut localiser les sources minéralisées et déterminer les distances et les directions du transport glaciaire dans le till. On peut aussi choisir les méthodes d'exploration en fonction du site. On peut établir la ligne de base géochimique naturelle et ses variations en utilisant les cartes géochimiques et les fichiers de données; cette ligne peut également faciliter la réalisation des études environnementales et l'évaluation des dangers.

Le présent rapport sur la géologie quaternaire contient une description des traînées de dispersion glaciaire à des échelles métriques à kilométriques dans la région du lac Baker et illustre les effets des différents substratums rocheux sur la géochimie des tills.

Elkanah A. Babcock
Sous-ministre adjoint
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Abstract

In the District of Keewatin, glacial dispersal trains defined by lithology and geochemistry are mapped at regional (hundreds of kilometres), local (tens of kilometres), and detailed (kilometres) scales. The trains reflect glacial dynamics and the bedrock composition. Despite complex ice flow near the Keewatin Ice Divide, they have a prominent southeastward trend, although there is evidence for older regional southward and eastward flows, and for later flow northward and westward from the divide. In till, trace element concentrations are low, reflecting glacial erosion of metal-poor sedimentary and volcanic bedrock of the Dubawnt Group, Thelon Formation sandstone in particular. Glacial dispersal trains impoverished in trace elements extend into crystalline terrain masking the geochemical expression of underlying bedrock. In sections and drill cores, vertical compositional variations record differences in provenance related to either change in ice flow, or glacial erosion, or both. The models of glacial dispersal trains provide a context for mineral exploration based on drift prospecting.

Résumé

Dans le district de Keewatin, les traînées de dispersion glaciaire définies par la lithologie et la géochimie sont cartographiées à différentes échelles, soit régionale (centaines de kilomètres), locale (dizaines de kilomètres) et détaillée (kilomètres). Les traînées reflètent la dynamique glaciaire et la composition du substratum rocheux. Malgré un écoulement glaciaire complexe près de la ligne de partage glaciaire du Keewatin, elles affichent une nette direction vers le sud-est; on note, cependant, des indices d'écoulement régional antérieur vers le sud et l'est et d'écoulement ultérieur vers le nord et l'ouest à partir de la ligne de partage glaciaire. Dans le till, les concentrations en éléments traces sont faibles, ce qui témoigne de l'érosion glaciaire d'un substratum sédimentaire et volcanique à faible teneur en métaux du Groupe de Dubawnt, du grès de la Formation de Thelon en particulier. Les traînées de dispersion glaciaire appauvries en éléments traces se prolongent vers un terrain cristallin masquant l'expression géochimique du substratum rocheux. Dans les coupes et les carottes de sondage, les variations verticales de la composition révèlent des différences de provenance liées à un changement de l'écoulement glaciaire ou de l'érosion glaciaire ou des deux. Les modèles des traînées de dispersion glaciaire fournissent un contexte pour l'exploration minérale basée sur la prospection des sédiments glaciaires.

SUMMARY

During the early seventies, the Geological Survey of Canada undertook a major study of surficial deposits in the District of Keewatin to examine the geochemical properties of till within perennially frozen, glaciated terrain, and to establish a Quaternary geological basis for mineral exploration by drift prospecting (Shilts, 1971, 1973 1977, 1984; Ridler and Shilts, 1974). To define drift composition and to model glacial dispersal trains thousands of till samples were collected and analyzed geochemically and lithologically. The compositional analyses are interpreted in terms of bedrock geology, ice flow history, and glacial dispersal trains (Shilts, 1994). The work defines a geological framework both for mineral exploration and for environmental studies that require knowledge of the natural geochemical landscape and the effects of glaciation on it.

Near Baker Lake in 1975, 200 km north of Kaminak Lake, detailed study of drift composition and glacial dispersal was carried out in the context of distinctive geological terrain and complex ice flow associated with a major ice divide of the Laurentide Ice Sheet (Fig. 1). The Baker Lake area is underlain by sedimentary and volcanic bedrock of the Dubawnt Group (Donaldson, 1965) comprising the Baker Lake Basin. It also straddles the axis of the Keewatin Ice Divide, which was a major late glacial feature of the ice sheet and an area of complex ice flow (Lee et al., 1957; Shilts, 1980a). This report describes the ice flow patterns and glacial dispersal trains defined by the till sampling program in the Baker Lake area.

The Baker Lake study area lies within a rectangular area 60 km wide and 130 km long south of Baker Lake (Fig. 1). It occupies parts of MacQuoid Lake (55 M) and Thirty Mile Lake (65 P) map areas. Within the area, nearly 2000 till samples were collected and analyzed for lithology and geochemistry to define glacial dispersal trains originating with diverse bedrock sources, including mineralized occurrences. The lithological analyses define provenance of glacial debris, and provide a geological basis for interpretation of till geochemistry. Models of glacial dispersal are described in terms of bedrock geology, glacial history, and ice flow directions, and are mapped at regional (tens to hundreds of kilometres), local (kilometres to tens of kilometres), and detailed (metres to kilometres) scales (e.g. Shilts, 1984).

Within the study area, till samples were collected at density of 1 sample per 3 to 4 km^2 to define local to regional scale glacial dispersal trains. The samples were collected from mudboils which are distinctive periglacial features common throughout much of the region (Shilts, 1978). At detailed scales, glacial dispersal from mineralized bedrock was investigated at two sites where samples were collected tens to hundreds of metres apart. Outside the study area,

SOMMAIRE

Au début des années soixante-dix, la Commission géologique du Canada a entrepris une importante étude des dépôts superficiels dans le district de Keewatin afin d'analyser les propriétés géochimiques du till dans les pergélisols englacés et d'établir une base de données sur la géologie quaternaire aux fins de l'exploration minérale basée sur la prospection des sédiments glaciaires (Shilts, 1971, 1973, 1977, 1984; Ridler et Shilts, 1974). Pour déterminer la composition des sédiments glaciaires et pour modéliser les traînées de dispersion glaciaire, on a recueilli des milliers d'échantillons de till dont on a analysé la composition géochimique et lithologique. Les analyses de la composition sont interprétées en fonction de la géologie du substratum rocheux, de l'évolution de l'écoulement glaciaire et des traînées de dispersion glaciaire (Shilts, 1994). Ces travaux permettent de définir un cadre géologique tant pour l'exploration minérale que pour des études environnementales nécessitant une connaissance du profil géochimique naturel et des effets de la glaciation sur celui-ci.

En 1975, près du lac Baker, à 200 km au nord du lac Kaminak, on a mené une étude détaillée de la composition des sédiments glaciaires et de la dispersion glaciaire dans le contexte d'un terrane de géologie distinctive et d'un écoulement glaciaire complexe associés à une importante ligne de partage glaciaire de l'Inlandsis laurentidien (fig. 1). La région du lac Baker repose sur un substratum sédimentaire et volcanique du Groupe de Dubawnt (Donaldson, 1965) incluant le bassin du lac Baker. Elle chevauche en outre l'axe de la ligne de partage glaciaire du Keewatin qui constituait un élément tardiglaciaire important de la nappe glaciaire et une région d'écoulement glaciaire complexe (Lee et al., 1957; Shilts, 1980a). Le présent rapport donne une description des écoulements glaciaires et des traînées de dispersion glaciaire tels que déterminés par le programme d'échantillonnage du till dans la région du lac Baker.

La région du lac Baker qui est à l'étude s'étend sur une superficie rectangulaire de 60 km de largeur sur 130 km de longueur au sud du lac Baker (fig. 1). Elle occupe des parties de deux régions cartographiques : celles du lac MacQuoid (55 M) et du lac Thirty Mile (65 P). Dans cette région, on a prélevé et analysé la lithologie et la géochimie de près de 2 000 échantillons de till afin de définir les traînées de dispersion glaciaire prenant leur source dans divers substratums, dont des occurrences minéralisées. Les analyses lithologiques permettent de déterminer la provenance des débris glaciaires et d'établir la base géologique nécessaire à l'interprétation de la géochimie du till. Les modèles de dispersion glaciaire sont décrits en fonction de la géologie du substratum rocheux, de l'histoire glaciaire et des directions de l'écoulement glaciaire; ils sont cartographiés à différentes échelles, soit régionale (des dizaines à des centaines de kilomètres), locale (des kilomètres à des dizaines de kilomètres) et détaillée (métrique à kilométrique) (p. ex. Shilts, 1984).

Dans la région à l'étude, on a recueilli des échantillons de till selon une densité de 1 échantillon par 3 à 4 km^2 afin de déterminer les traînées de dispersion glaciaire à une échelle locale à régionale. Les échantillons provenaient d'ostioles qui sont des formes périglaciaires particulières répandues dans la majeure partie de la région (Shilts, 1978). À l'échelle détaillée, on a analysé la dispersion glaciaire à partir d'un substratum minéralisé à deux sites en recueillant des échantillons à des intervalles

till samples collected at a density of 1 per 100 to 200 km^2 and determinations of ice flow directions made as part of the investigations of Shilts are used to define a regional geological context. Sections exposed along streams, and overburden drill core collected along a proposed pipeline corridor across the District of Keewatin (Shilts, 1980b) were examined to determine till stratigraphy and thickness, and sampled to compare the composition of surface and sub-surface sediments (see Fig. 5).

To characterize till geochemistry, the clay-sized fraction (<0.002 mm) was routinely separated. The clay was geochemically analyzed for copper, lead, zinc, nickel, manganese, and iron by atomic absorption spectrometry (AAS) following a hot aqua regia digestion. Within the study area uranium was determined by delayed neutron activation methods. Drift provenance is based on lithological analyses of pebbles (see Appendices 1, 3). In the study area, pebbles are 4-5.6 mm, whereas for the surrounding region they are 2-5.6 mm. Fewer samples have been analyzed for lithology than for geochemistry (~200 vs. 2000). Lithological categories include: 1) Dubawnt Group (undifferentiated), 2) Thelon Sandstone, 3) Sedimentary and Volcanic Rocks (undifferentiated), 4) porphyritic volcanic rock of Pitz Formation, referred to as 'Pitz Volcanic Rocks', 5) Volcanic Rock (undifferentiated), and 6) Crystalline Rock. The subdivisions permit mapping glacial dispersal trains originating with several sources in Baker Lake Basin.

The principal dispersal trends are northwest-southeast, parallel with the regional direction of ice flow (see Fig. 10). Dubawnt Group pebbles are either absent or rare in till in crystalline terrain north and east of Baker Lake, and the eastern margin of their glacial dispersal train trends southeast along the Thelon River and east across Baker Lake. Along the Thelon River, the compositional break between till containing more than 40 wt. % Dubawnt Group pebbles and to 0 wt. % is well defined and abrupt. The zone is less than 10 km wide, and is coincident with the boundary between red and grey till mapped by Cunningham and Shilts (1977) (see Fig. 5).

Regional geochemical patterns in till defined by copper, zinc, nickel, uranium, iron, and manganese (see Fig. 11) correspond closely with those defined by pebble lithology. Till containing more than 60 wt. % Dubawnt Group pebbles has low trace metal concentrations (<20 ppm Cu, <50 ppm Zn, and <2 ppm U), whereas till containing less than 40 wt. % has relatively high trace element levels (>40 ppm Cu, >75 ppm Zn and >2 ppm U). Isopleths for copper (20 ppm) and zinc (50 ppm) define glacial dispersal trains characterized by low trace metal concentrations that extend more than 100 km southeast of Pitz Lake. The copper and zinc trains correspond with the 60 wt. % Dubawnt Group isopleth. Glacial dispersal trains defined by nickel and uranium are not as well defined, although their geochemical contours generally display a southeast elongation.

variant de dizaines à des centaines de mètres. À l'extérieur de la région à l'étude, la densité d'échantillonnage a été de 1 par 100 à 200 km^2, et les directions de l'écoulement glaciaire déterminées dans le cadre des travaux de Shilts servent à définir un contexte géologique régional. Les coupes exposées le long des cours d'eau et les carottes prélevées dans les terrains de couverture le long d'un corridor proposé pour un pipeline traversant le district de Keewatin (Shilts, 1980b) ont été examinées pour déterminer la stratigraphie et l'épaisseur du till; on a utilisé des échantillons pour comparer la composition des sédiments de surface et des sédiments souterrains (fig. 5).

Pour caractériser la géochimie du till, la fraction argileuse (<0,002 mm) a été systématiquement séparée. L'argile a fait l'objet d'une analyse géochimique pour établir la teneur en cuivre, en plomb, en zinc, en nickel, en manganèse et en fer par spectrométrie d'absorption atomique (SAA) suivant une digestion d'eau régale chaude. La teneur en uranium dans la région à l'étude a été déterminée par activation neutronique retardée. La provenance des sédiments glaciaires est basée sur des analyses lithologiques des cailloux (annexes 1, 3). Dans la région à l'étude, les cailloux mesurent entre 4 et 5,6 mm tandis que dans la région environnante, leur taille varie de 2 à 5,6 mm. Les échantillons analysés pour leur lithologie sont moins nombreux que ceux analysés pour leur géochimie (~200 vs 2 000). Les catégories lithologiques incluent : 1) le Groupe de Dubawnt (non différencié), 2) le Grès de Thelon, 3) les roches sédimentaires et volcaniques (non différenciées), 4) les roches volcaniques porphyriques de la Formation de Pitz, désignées «Volcanites de Pitz», 5) la roche volcanique (non différenciée) et 6) la roche cristalline. Les subdivisions permettent de cartographier les traînées de dispersion glaciaire issues de plusieurs sources différentes dans le bassin du lac Baker.

Les principales directions de dispersion sont nord-ouest-sud-est, parallèlement à la direction régionale de l'écoulement glaciaire (fig. 10). Les cailloux du Groupe de Dubawnt sont soit absents ou rares dans le till du terrain cristallin situé au nord et à l'est du lac Baker; la bordure est de leur traînée de dispersion glaciaire est orientée vers le sud-est le long de la rivière Thelon et vers l'est à travers le lac Baker. Le long de la rivière Thelon, la rupture de composition entre le till contenant plus de 40 % en poids de cailloux du Groupe de Dubawnt et le till renfermant jusqu'à 0 % en poids est bien définie et abrupte. La zone ne dépasse pas 10 km de largeur et coïncide avec la limite entre le till rouge et gris cartographié par Cunningham et Shilts (1977) (fig. 5).

Les configurations géochimiques régionales observées dans le till et basées sur le cuivre, le zinc, le nickel, l'uranium, le fer et le manganèse (fig. 11) correspondent assez bien à celles définies par la lithologie des cailloux. Le till contenant plus de 60 % en poids de cailloux du Groupe de Dubawnt a des concentrations faibles en métaux traces (<20 ppm Cu, <50 ppm Zn et <2 ppm U), tandis que le till contenant moins de 40 % en poids a des concentrations relativement élevées en éléments traces (>40 ppm Cu, >75 ppm Zn et >2 ppm U). Les isoplèthes du cuivre (20 ppm) et du zinc (50 ppm) dessinent des traînées de dispersion glaciaire caractérisées par des concentrations faibles en métaux traces qui s'étendent sur plus de 100 km au sud-est du lac Pitz. Les traînées de cuivre et de zinc correspondent à l'isoplèthe de 60 % en poids du Groupe de Dubawnt. Les traînées de dispersion glaciaire définies par le nickel et l'uranium ne sont pas aussi bien définies, même si leurs isolignes géochimiques s'allongent généralement vers le sud-est.

At local scales within the study area, glacial dispersal trains can be defined by pebbles (4-5.6 mm) of Dubawnt Group, Thelon Sandstone, and Pitz Volcanic Rocks (see Fig. 12). The 75 wt. % Dubawnt Group isopleth outlines bedrock of Thelon Formation within Pitz Lake basin, and it extends southeastward from there to the southern margin of the study area as a narrow (5-10 km wide), ribbon-shaped glacial dispersal train. Its regional extension farther southeast is outlined by the 60 wt. % Dubawnt Group isopleth. Glacial transport in directions other than southeastward is a few kilometres to tens of kilometres. It is evident near the eastern end of Baker Lake where the southward trend of salients in the 40 wt. % Dubawnt Group isopleth and streamlined landforms indicate local southward glacial transport of crystalline debris.

Thelon Sandstone pebbles are widespread, varying from less than 10 wt. % to more than 50 wt. %. The 20 wt. % isopleth defines a prominent glacial dispersal train originating in Pitz Lake basin (see Fig. 12b). The train is 20 km wide and extends more than 70 km southeast from its bedrock source, coincident with the regional train defined by the 60 wt. % Dubawnt Group isopleth (see Fig. 10a). The southwestern margin of the sandstone train is linear and well defined, marked by an abrupt change in the concentration of indicator debris from more than 20 wt. % to less than 10 wt. %. It trails southeastward from the western limit of Thelon Sandstone within the study area. The eastern margin of the sandstone train is irregular, and there is a zone 20-50 km wide in which sandstone varies between 10 and 20 wt. %.

Pitz Volcanic Rocks are widespread across the central and western part of the study area. In till overlying their bedrock source west of Pitz Lake, and 20 km southeast of it, they comprise more than 15 wt. % (Fig. 12c). The 0 wt. % isopleth trends southeast across the central study area from the easternmost bedrock source. Scattered, rare erratics of Pitz Volcanic Rocks east of that isopleth are either the result of ice flow and glacial transport in a direction more easterly than southeast, or were derived from unknown sources within Baker Lake, or both. Limited evidence for eastward ice flow is also provided by east-trending striations of uncertain relative. Northwest of Pitz Lake, Pitz Volcanic Rocks outside Baker Lake Basin indicate limited glacial transport from the western side of the Keewatin Ice Divide, most likely during late glacial time.

In the study area, geochemical patterns defined by copper, lead, zinc, and nickel are similar; elevated metal concentrations to the northeast (Cu, Pb, Zn) and southwest (Cu, Pb, Zn, Ni) flank a central core of low metal concentrations (< 15 ppm Cu; < 20 ppm Pb; < 50 ppm Zn; <25 ppm Ni) that trends southeast across the central study area (see Fig. 13). The low trace metal concentrations define a glacial dispersal train 20 km wide and more than 70 km long extending southeast from Pitz Lake into crystalline

Aux échelles locales dans la région à l'étude, les traînées de dispersion glaciaire peuvent être définies par des cailloux (4-5,6 mm) du Groupe de Dubawnt, du Grès de Thelon et des Volcanites de Pitz (fig. 12). L'isoplèthe de 75 % en poids du Groupe de Dubawnt délimite le socle de la Formation de Thelon dans le bassin du lac Pitz; elle s'étend vers le sud-est jusqu'à la bordure méridionale de la région à l'étude en une étroite (5-10 km de largeur) traînée de dispersion glaciaire formant un ruban. Son étendue régionale plus loin vers le sud-est est délimitée par l'isoplèthe de 60 % en poids du Groupe de Dubawnt. Le transport glaciaire dans des directions autres que vers le sud-est varie de quelques kilomètres à des dizaines de kilomètres. Il est manifeste près de l'extrémité est du lac Baker où la direction vers le sud de promontoires dans l'isoplèthe de 40 % en poids du Groupe de Dubawnt et les formes de relief fuselées indiquent un transport glaciaire local vers le sud de débris cristallins.

Les cailloux du Grès de Thelon sont abondants, variant de moins de 10 % en poids à plus de 50 % en poids. L'isoplèthe de 20 % en poids définit une traînée de dispersion glaciaire proéminente prenant sa source dans le bassin du lac Pitz (fig. 12b). La traînée mesure 20 km de largeur et s'étend sur plus de 70 km vers le sud-est à partir du substratum d'origine, ce qui coïncide avec la traînée régionale définie par l'isoplèthe de 60 % en poids du Groupe de Dubawnt (fig. 10a). La bordure sud-ouest de l'alignement de cailloux de grès est linéaire et bien définie, marquée par un changement sans transition de la concentration des débris indicateurs allant de plus de 20 % à moins de 10 % en poids. Elle s'étire vers le sud-est à partir de la limite ouest du Grès de Thelon dans la région à l'étude. La bordure orientale de l'alignement de cailloux de grès est irrégulière, et il existe une zone de 20 à 50 km de largeur dans laquelle le grès varie entre 10 et 20 % en poids.

Les Volcanites de Pitz sont abondantes dans toutes les parties centrale et occidentale de la région à l'étude. Dans le till reposant sur leur substratum source, à l'ouest du lac Pitz, et à 20 km au sud-est de celui-ci, elles constituent plus de 15 % en poids (fig. 12c). L'isoplèthe de 0 % en poids est orientée vers le sud-est à travers le centre de la région à l'étude depuis le substratum source le plus à l'est. Les rares blocs erratiques disséminés des Volcanites de Pitz à l'est de cette isoplèthe sont soit le résultat d'un écoulement glaciaire et d'un transport glaciaire dans une direction plus à l'est qu'au sud-est, soit originaires de sources inconnues dans le lac Baker, ou les deux. Des stries à orientation est, d'origine incertaine, fournissent également des indices limités d'un écoulement glaciaire vers l'est. Au nord-ouest du lac Pitz, les Volcanites de Pitz à l'extérieur du bassin du lac Baker indiquent un transport glaciaire restreint à partir du côté ouest de la ligne de partage glaciaire du Keewatin, surtout au tardiglaciaire.

Dans la région à l'étude, les configurations géochimiques définies par les teneurs en cuivre, plomb, zinc et nickel sont semblables; les concentrations métalliques élevées au nord-est (Cu, Pb, Zn) et au sud-ouest (Cu, Pb, Zn, Ni) flanquent un noyau central de concentrations métalliques faibles (<15 ppm Cu; <20 ppm Pb; <50 ppm Zn; <25 ppm Ni) à orientation sud-est à travers le centre de la région à l'étude (fig. 13). Les faibles concentrations en métaux traces définissent une traînée de dispersion glaciaire de 20 km de largeur et plus de 70 km de longueur qui s'étend au sud-est du lac Pitz vers un terrane cristallin au sud du terrain south of Baker Lake Basin. The train is coincident with the dispersal train outlined by the 20 wt. % isopleth of Thelon Sandstone pebbles (see Fig. 12b).

Near sites of uranium and copper mineralization, glacial dispersal trains can be geochemically defined up to 2 km down-ice, typically several hundreds of metres (see Fig. 14, 15). The trains are poorly defined, in part because they occur within local dispersal trains of metal-poor debris that mask the compositional expression of underlying bedrock. Glacial dispersal trains defined by samples enriched in both copper and uranium are better defined, although more limited in their down-ice extent. At a sample density of one per 5 km^2, glacial dispersal trains originating with mineralized sources in the study area are too small to be reliably encountered.

At the most detailed scale of investigation, no significant geochemical variation was noted in mudboils, and the clay-sized fractions of carapace and of thawed mud substrate are comparable. Although vertical differences are evident within some mudboils (e.g. Fig. 9), trace element concentrations are low and the slight geochemical differences are difficult to interpret in terms of provenance, weathering, and analytical variation. The greatest contrasts are evident between till and other sediments incorporated within till and sediment characterized by iron and manganese staining, which is indicative of secondary weathering.

Linear correlations between till geochemistry and lithology reflect mixing of a bipartite 'end member' system comprising crystalline debris enriched in trace elements and Dubawnt Group debris depleted in trace elements. Trace element concentrations are positively correlated with concentrations of Crystalline Rock pebbles, most strongly so for copper (0.630) and for zinc (0.639). Correlations of Crystalline Rock with manganese (0.570), iron (0.496), and lead (0.446) are weaker. In contrast, geochemical correlations with Dubawnt Group detritus are negative and weak (<0.500). The strongest correlations are between Thelon Sandstone pebbles and copper (-0.476), iron (-0.537), and manganese (-0.561).

In addition to quartz and feldspar, clay-sized material of the Dubawnt Group includes kaolin and hematite as metal-poor diluents, especially in the Thelon Sandstone (Dean, 1967). The diluents lead to the negative correlations between Dubawnt Group pebbles and trace element concentrations (see Fig. 24). The relative abundance of clay-sized debris and its geochemical contrast with minerals derived from crystalline terrain, which are geochemically enriched, lead to 'negative' geochemical dispersal trains originating with bedrock of the Dubawnt Group, and Thelon Sandstone in particular.

For the nearly 2000 till samples representing the Baker Lake study area, copper, lead, and zinc are strongly and positively inter-correlated, as well as individually with iron and manganese (Table 2). Correlations are strongest between zinc and copper (0.812), zinc and lead (0.613),

bassin du lac Baker. Cette traînée coïncide avec la traînée de dispersion délimitée par l'isoplèthe de 20 % en poids de cailloux du Grès de Thelon (fig. 12b).

Près des sites de minéralisation en uranium et en cuivre, on peut définir la composition géochimique des traînées de dispersion glaciaire jusqu'à 2 km en aval, en général plusieurs centaines de mètres (fig. 14, 15). Les traînées sont mal définies du fait en partie qu'elles se trouvent au sein de traînées de dispersion locales de débris faiblement métalliques qui masquent l'expression de la composition du substratum rocheux. Les traînées de dispersion glaciaire définies par des échantillons enrichis en cuivre et en uranium sont mieux définies, bien que plus limitées dans leur extension en aval-glaciaire. À la densité d'échantillonnage de 1 par 5 km^2, les traînées de dispersion glaciaire prenant naissance dans des sources minéralisées de la région à l'étude sont trop petites pour être prises en compte de façon fiable.

À l'échelle d'analyse la plus détaillée, on n'observe pas de variations géochimiques significatives dans les ostioles, et les fractions argileuses de la carapace et du substrat de boue dégelé sont comparables. Bien qu'il existe des différences évidentes dans le profil vertical de certaines ostioles (p. ex. fig. 9), les concentrations en éléments traces sont faibles et les légères différences géochimiques sont difficiles à interpréter en ce qui concerne la provenance, l'altération et la variation analytique. Les contrastes les plus frappants s'observent entre, d'une part, le till et d'autres sédiments incorporés dans le till et, d'autre part, les sédiments caractérisés par des imprégnations de fer et de manganèse révélant une altération secondaire.

Les corrélations linéaires entre la géochimie et la lithologie du till reflètent le mélange d'un système bipartite à «termes extrêmes» contenant des débris cristallins enrichis en éléments traces et des débris du Groupe de Dubawnt appauvris en éléments traces. Les concentrations en éléments traces sont positivement corrélées aux concentrations des cailloux de roche cristalline, surtout en ce qui a trait au cuivre (0,630) et au zinc (0,639). Les corrélations de la roche cristalline avec le manganèse (0,570), le fer (0,496) et le plomb (0,446) sont plus faibles. En revanche, les corrélations géochimiques avec les débris du Groupe de Dubawnt sont négatifs et faibles (<0,500). C'est entre les cailloux du Grès de Thelon et le cuivre (-0,476), le fer (-0,537) et le manganèse (-0,561) que les corrélations sont les plus fortes.

La fraction argileuse du Groupe de Dubawnt contient, en plus du quartz et du feldspath, du kaolin et de l'hématite comme diluants faiblement métalliques, en particulier dans le Grès de Thelon (Dean, 1967). Les diluants conduisent aux corrélations négatives observées entre les cailloux du Groupe de Dubawnt et les concentrations en éléments traces (fig. 24). L'abondance relative des débris de granulométrie argileuse et leur contraste géochimique avec les minéraux dérivés du terrain cristallin, qui sont géochimiquement enrichis, donnent des traînées de dispersion géochimiquement négatives provenant du substratum rocheux du Groupe de Dubawnt, et du Grès de Thelon en particulier.

Pour pratiquement 2 000 échantillons de till représentant la région du lac Baker, le cuivre, le plomb et le zinc sont fortement et positivement intercorrélés, et ils le sont individuellement avec le fer et le manganèse (tableau 2). Les corrélations les plus fortes existent entre le zinc et le cuivre (0,812), le zinc et le plomb (0,613) et le cuivre et le plomb (0,585). Les concentrations en and copper and lead (0.585). Iron and manganese concentrations are correlated with copper (0.747 Fe, 0.595 Mn), zinc (0. 842 Fe; 0.689 Mn), and lead (0.639 Fe; 0.609 Mn) (see Fig. 25). Correlations are either weak or not evident for nickel and uranium. The linear correlations indicate that trace element ratios are largely independent of till lithology, something that is unexpected in view of the lithological diversity of the samples and the geologically distinct terrains represented.

In surficial deposits, Ni:Cu ratios greater than two are associated with bedrock of Christopher Island Formation near Pitz Lake, and ratios greater than one-and-a-half define a glacial dispersal train extending southward and southeastward from there. The contours are similar to trains defined by pebbles of Thelon Sandstone and of Pitz Volcanic Rocks, extending across distinct geological terranes and thus reflecting glacial transport. North of that bedrock source, ratios greater than two in till over Pitz Formation could either reflect westward ice flow recorded by striations, or change in bedrock composition, or both. Zn:Cu ratios also reflect bedrock lithology, defining glacial dispersal from Thelon Formation north of Pitz Lake. Thus trace element ratios can define glacial dispersal trains not evident in single element geochemical maps.

Sub-surface compositional variations indicate the need for geological observations of texture, structure, and lithology of till, as well as stratigraphic controls on sample collection. The Kazan River sections (see Fig. 5) define a transect perpendicular to the southeast trend of regional ice flow, and comprise three tills distinguished by lithology and geochemistry. The composition of correlated units depends on context in glacial dispersal trains. In the Upper till, for example, Pitz Volcanic Rocks were found only in sections KA and KB, consistent with their glacial dispersal train in surficial deposits. They also occur in the Lower till in section KC, recording earlier, more eastward ice flow. In drill core and in stratigraphic sections trace element ratios also reflect that change in provenance and ice flow direction. Ni:Cu ratios in the Upper till are greater in section KB than in section KC, consistent with their location in southeast-trending glacial dispersal trains defined by those ratios (see Fig. 27). The Lower till in section KC has high Ni:Cu ratios related to a provenance in Christopher Island Formation near Pitz Lake. In drill core south of Pitz Lake, slight geochemical variation with depth, and differences in Ni:Cu ratios in particular, indicate earlier southward flow, consistent with the observations of Lee (1959) and Shilts (1973) for an older phase of regional southward flow across the District of Keewatin. The changes in ice flow relate change in the location and orientation of either the Keewatin Ice Divide, or precursors of it.

fer et en manganèse sont corrélées avec le cuivre (0,747 Fe, 0,595 Mn), le zinc (0,842 Fe; 0,689 Mn) et le plomb (0,639 Fe; 0,609 Mn) (fig. 25). Les corrélations sont faibles ou non évidentes en ce qui concerne le nickel et l'uranium. Les corrélations linéaires indiquent que les rapports des éléments traces sont largement indépendants de la lithologie du till, ce qui est inattendu compte tenu de la diversité lithologique des échantillons et de la géologie différente des terrains représentés.

Dans les dépôts de surface, les rapports Ni/Cu supérieurs à deux sont associés à un substratum de la Formation de Christopher Island près du lac Pitz tandis que les rapports plus élevés que un et demi correspondent à une traînée de dispersion glaciaire s'allongeant vers le sud et vers le sud-est à partir de là. Les isolignes sont semblables aux traînées définies par les cailloux du Grès de Thelon et des Volcanites de Pitz, qui s'étendent sur des terranes géologiques distincts et reflètent ainsi le transport glaciaire. Au nord du substratum source, les rapports plus élevés que deux dans le till reposant sur la Formation de Pitz pourraient indiquer soit un écoulement glaciaire vers l'ouest enregistré par des stries, soit un changement de la composition du substratum rocheux, ou les deux. Les rapports Zn/Cu reflètent aussi la lithologie du substratum rocheux, définissant la dispersion glaciaire à partir de la Formation de Thelon au nord du lac Pitz. C'est pourquoi les rapports des éléments traces peuvent définir des traînées de dispersion glaciaire qui ne seraient pas mises en valeur par les cartes géochimiques d'un seul élément.

Les variations de composition des roches subsuperficielles révèlent la nécessité d'effectuer des observations géologiques de la texture, de la structure et de la lithologie du till ainsi que des contrôles stratigraphiques sur les échantillons. Les coupes de la rivière Kazan (fig. 5) définissent un transect perpendiculaire à la direction sud-est de l'écoulement glaciaire régional; elles comprennent trois tills différenciés par la lithologie et la géochimie. La composition des unités corrélées dépend du contexte des traînées de dispersion glaciaire. Dans le till supérieur, par exemple, les Volcanites de Pitz n'étaient présentes que dans les coupes KA et KB, ce qui est cohérent avec leur traînée de dispersion glaciaire dans les sédiments superficiels. Elles sont également présentes dans le till inférieur de la coupe KC, relatant un écoulement glaciaire plus précoce et orienté plus à l'est. Dans les carottes de sondage et les coupes stratigraphiques, les rapports des éléments traces reflètent également ce changement de provenance et de direction de l'écoulement glaciaire. Les rapports Ni/Cu dans le till supérieur sont plus élevés dans la coupe KB que dans la coupe KC, ce qui est en accord avec leur emplacement dans les traînées de dispersion glaciaire à orientation sud-est tel que défini par ces rapports (fig. 27). Le till inférieur de la coupe KC donne des rapports Ni/Cu élevés liés à leur origine dans la Formation de Christopher Island près du lac Pitz. Dans la carotte de sondage du sud du lac Pitz, une légère variation géochimique en fonction de la profondeur et des différences notées dans les rapports de Ni/Cu en particulier indiquent un écoulement antérieur vers le sud, ce qui est compatible avec les observations de Lee (1959) et de Shilts (1973) relativement à une phase plus ancienne d'écoulement régional vers le sud à travers le district de Keewatin. Les changements d'écoulement glaciaire correspondent à un changement de l'emplacement et de l'orientation de la ligne de partage glaciaire du Keewatin ou de ses précurseurs.

INTRODUCTION

Purpose and overview

During the early seventies, the Geological Survey of Canada undertook a major study of surficial deposits in the District of Keewatin to examine the geochemical properties of till within perennially frozen, glaciated terrain, and to establish a Quaternary geological basis for mineral exploration by drift prospecting (Shilts, 1971, 1973 1977, 1984; Ridler and Shilts, 1974). To define drift composition and to model glacial dispersal trains thousands of till samples were collected and analyzed geochemically and lithologically. The compositional analyses have been interpreted in terms of bedrock geology, ice flow history, and glacial dispersal trains (Shilts, 1994). The work has defined a geological framework for both mineral exploration and environmental studies that require knowledge of the natural geochemical landscape and the effects of glaciation on it.

Initially the work was focused on the Kaminak Lake area, including the Rankin-Ennadai greenstone belt of exploration interest, and it was later broadened to include much of the eastern District of Keewatin between the Manitoba border and latitude 66°N, north of Baker Lake (Shilts, 1977, 1984)

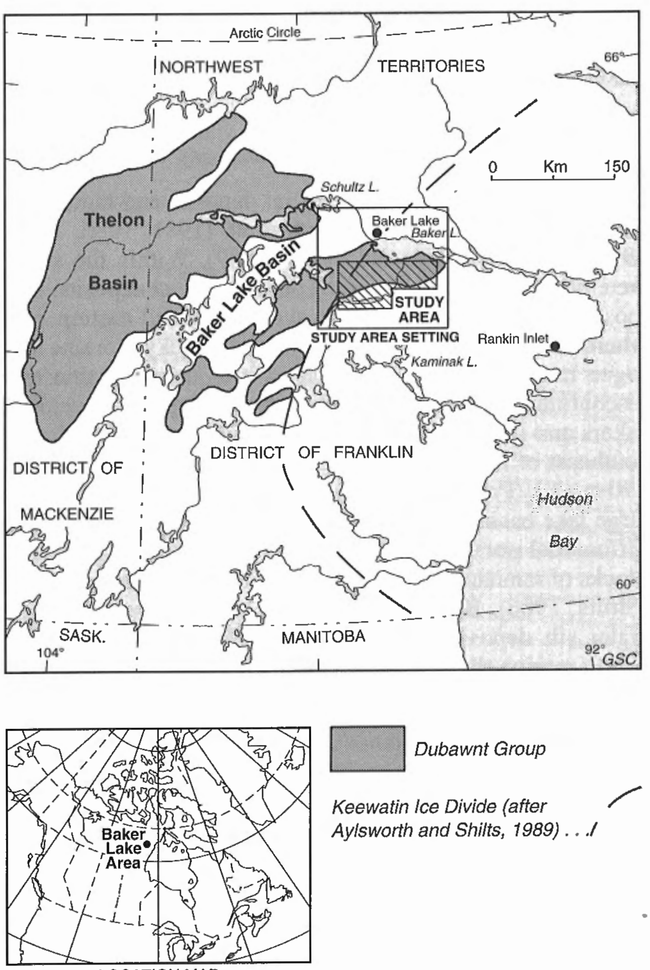


Figure 1. *Location map of study area and study area region.*

(Fig. 1). Near Baker Lake, 200 km north of Kaminak Lake, a second, detailed study was initiated in 1975 to examine drift composition and glacial dispersal in the context of distinctive geological terrain and complex ice flow associated with a major ice divide of the Laurentide Ice Sheet (Fig. 1). The Baker Lake area is underlain by sedimentary and volcanic bedrock of the Dubawnt Group (Donaldson, 1965) comprising the Baker Lake Basin. Lithological contrasts between bedrock of the Canadian Shield and relatively unmetamorphosed bedrock of Baker Lake Basin allow the use of till lithology to map glacial dispersal trains. The study area also straddles the axis of the Keewatin Ice Divide, which was a major late glacial feature of the Laurentide Ice Sheet and an area of complex ice flow (Lee et al., 1957; Shilts, 1980a). Quaternary geological mapping and study of the ice divide was also carried out as part of the study (Shilts et al., 1979, Shilts, 1980a; Gilchrist, 1982). This report describes the ice flow patterns and glacial dispersal trains defined by the till sampling program in the Baker Lake area.

The Baker Lake study area lies within a rectangular area 60 km wide and 130 km long south of Baker Lake. It occupies parts of MacQuoid Lake (55 M) and Thirty Mile Lake (65 P) NTS map areas. Within the study area, more than 2000 till samples were collected and analyzed for lithology and geochemistry. The compositional analyses define glacial dispersal trains originating with diverse bedrock sources, including mineralized occurrences. The lithological analyses, which define the provenance of glacial debris, provide a geological basis for the interpretation of till geochemistry and modeling glacial dispersal trains. Dispersal trains are described in terms of geology, glacial history, and ice flow directions, and at regional (tens to hundreds of kilometres), local (kilometres to tens of kilometres), and detailed (metres to kilometres) scales (e.g. Shilts, 1984). They demonstrate that drift prospecting requires knowledge of geological, geographic, and glaciological context within an ice sheet to resolve glacial transport directions and to determine the origins of glacial dispersal trains.

Fieldwork was carried out during the summers of 1975 and 1976, and analytical work completed by 1977. Data of Shilts and co-workers from the surrounding region are also included in this report (Appendix 1). Those regional studies have defined regional glacial dispersal trains extending tens to hundreds of kilometres across the Baker Lake area at least to the western coast of Hudson Bay (Shilts, 1977, 1984; Kaszycki and Shilts, 1979, 1980). In combination with ice flow indicators, such as striations and glacially streamlined landforms, the dispersal trains and drift provenance represent constraints on the ice flow history of the Laurentide Ice Sheet, and the Keewatin Ice Divide in particular (Shilts, 1980a).

Since completion of the project there have been significant changes in our understanding of the bedrock geology in the Baker Lake area (i.e. metallogenic studies of uranium mineralization (Miller, 1980) and a recognition of the potential for diamonds), and of the Quaternary geology as well, including major revisions to models of the Laurentide Ice Sheet (e.g. Shilts, 1980a; Dyke et al., 1982; Dyke and Prest, 1987; Dyke and Dredge, 1989; Boulton and Clark, 1990a,b). Had that information been available, it would undoubtedly have had significant influence on the Baker Lake project, affecting the location and size of the study area relative to the Keewatin Ice Divide, sampling design and striation observations.

Physiography and vegetation

Described as 'rather expressionless terrain', the area south of Baker Lake lies within the Kazan Upland, which is part of the Kazan Physiographic Region (Bostock, 1970). It is characterized by broad rolling hills having a relief of about 75 to 100 m, and elevations are generally less than 180 m a.s.l. The greatest elevations of about 290 m a.s.l. occur along a bedrock ridge west of Pitz Lake. The landscape is characterized by rolling till plains, which can be locally fluted or drumlinized, relatively minor areas of hummocky till, and flights of raised strandlines. Within till plains, lakes commonly are elongated northwest-southeast, a trend parallel to the last dominant direction of regional ice flow. Below marine limit, in areas of relatively fine grained marine sediments, lakes are not elongate, and their shape may be controlled by meltout of buried ground ice.

The area lies north of the treeline within the zone of tundra vegetation, well within the zone of deep, continuous permafrost. Thickness of the active layer varies between 0.15 and 2 m, depending on the type of sediment, local drainage conditions, and surface vegetation.

Bedrock geology

Bedrock includes a supracrustal sequence of sedimentary and volcanic rocks, and underlying crystalline basement rocks (Fig. 2). The basement complex consists of Archean and Aphebian metasedimentary and metavolcanic rocks, gneisses and migmatitic rocks derived in part from them, granulite, gneissic to massive granitic intrusive rock, gabbro, anorthosite and diabase dykes (LeCheminant et al., 1977, 1979; Blake, 1980). The supracrustal Dubawnt Group is a relatively flat-lying, little metamorphosed sequence comprising sedimentary and volcanic rocks and their intrusive equivalents. It overlies and is separated from the basement rocks by a major unconformity. Within the study area, the Dubawnt Group forms part of the Baker Lake Basin (Miller and LeCheminant, 1985), which extends several hundred kilometres farther west and southwest.

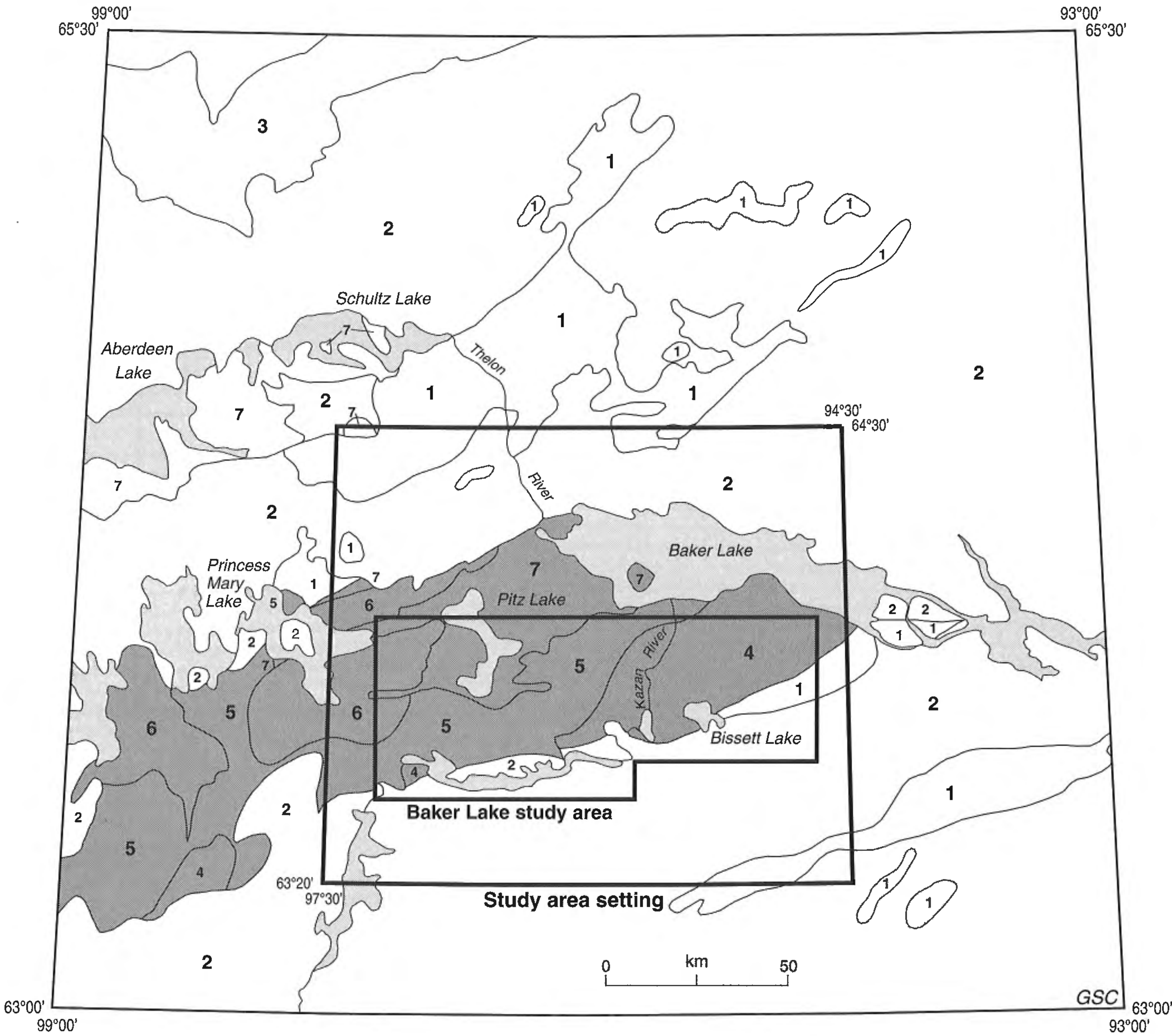
The Dubawnt Group is subdivided into six formations that include, in ascending stratigraphic sequence: the South Channel, Kazan, Christopher Island, Martell Syenite, Pitz, and Thelon formations (Donaldson, 1965). South Channel and Kazan formations form a basal sequence of redbeds, with pebble-supported conglomerates and sandstone in their lower part, and arkose with interbedded mudstone and siltstone in their upper part. They are overlain conformably to unconformably by Christopher Island Formation comprising alkaline volcanic rocks and pyroclastic rocks, and volcaniclastic sediments derived from them. The Martell Syenite includes syenite and monzonite intrusive rock, and is locally porphyritic. Pitz Formation consists of red to purple felsic volcanic rocks containing large feldspar phenocrysts and smaller phenocrysts of quartz. Near Pitz Lake, Pitz Formation is distinctive because feldspar phenocrysts within it are chalky white as the result of weathering. Thelon Formation is the uppermost stratigraphic unit and comprises friable sandstone and conglomerate. The sandstone is compositionally mature and composed largely of quartz and kaolinized feldspar grains (Dean, 1967; Cecile, 1973). Thelon Formation also occurs as part of the Thelon Basin northwest of the study area, near Schultz Lake (Fig. 1). Arkose, mudstone, and orthoquartzite of the Amer or Hurwitz groups occurs farther northwest, outside the study area region.

The volcanic and sedimentary rocks of the Dubawnt Group host uranium mineralization, and minor base and precious metal mineralization associated with it (Miller, 1980; Miller and LeCheminant, 1985; Miller et al., 1986). According to Miller (1980), three types of uranium mineralization are present including: 1) fracture controlled mineralization in the Dubawnt Group and basement gneisses (U-Cu-Ag-Au-Se or U-Cu-Pb-Mo-Zn), 2) diatreme breccia mineralization in basement gneisses (U-Cu-Zn), and 3) impregnation and microfracture mineralization in altered arkose peripheral to lamprophyre dykes. Within and adjacent to the study area, mineralized occurrences have been mapped at 20 locations (Miller, 1980). Uranium mineralization also occurs within Aphebian metasedimentary rocks in crystalline terrain south and east of Bissett Lake (Miller and LeCheminant, 1985; Miller et al., 1986). Recently there has been exploration interest for diamonds in the Christopher Island Formation of Baker Lake Basin (Northern Miner, 1994).

Quaternary geology and glacial history

In the District of Keewatin, glacial deposits and landforms have been mapped by Aylsworth et al. (1981; 1986, 1989, 1990), and Aylsworth and Shilts (1989). Within the study area, till is the most widespread of the surficial deposits. It is most extensive and thickest in the central and eastern part where it includes extensive areas of hummocky moraine and rogen moraine (Fig. 3). Elsewhere it is generally thin and discontinuous over bedrock. Glaciofluvial deposits, including eskers and kames preferentially occur in the east, south and southeast of Bissett Lake. Regionally, the marine limit is at 170 m a.s.l. (Prest et al., 1968), although it can be lower within large lake basins, varying between 100 and 150 m a.s.l. The differential isotatic uplift could reflect the distribution of large blocks of remnant ice within lake basins that excluded the sea (Shilts, 1986). Below marine limit, both fine grained deep water silt deposits and coarse grained, nearshore deposits occur; marine shorelines are most extensive within Pitz Lake basin.

Regional ice flow trends are southeastward, with indication of southward flow in the northeastern part of the study area, and of both northwestward and westward flow in its western part (Wright, 1967; Prest et al., 1968). The same general flow trends are also given by Cunningham and Shilts (1977), Aylsworth et al. (1981), Gilchrist (1982), and Aylsworth et al. (1986, 1989). Striations (Lee, 1953; Shilts, 1973) and the regional distribution of orthoquartzite pebbles (Cunningham and Shilts, 1977) provide evidence for older, southward ice flow across the District of Keewatin. Striations,



EARLY PROTEROZOIC
DUBAWNT GROUP*

7	*Thelon Formation (sandstone)*
6	*Pitz Formation (rhyolite)*
5	*Christopher Island and Kunwak formations (volcanic and volcaniclastic rock)*
4	*South Channel and Kazan formations (conglomerate, arkose)*

AMER and HURWITZ GROUPS

3	*Arkose, mudstone, quartzarenite, quartzite*

ARCHEAN AND APHEBIAN

2	*Foliated granite, orthogneiss, paragneiss*
1	*Metavolcanic and metasedimentary rocks*

* Martell Syenite not shown

Baker Lake Basin

Modified after Dudas et al. (1991), Miller et al. (1986), and Miller and LeCheminant (1985)

***Figure 2.** Geological outline map.*

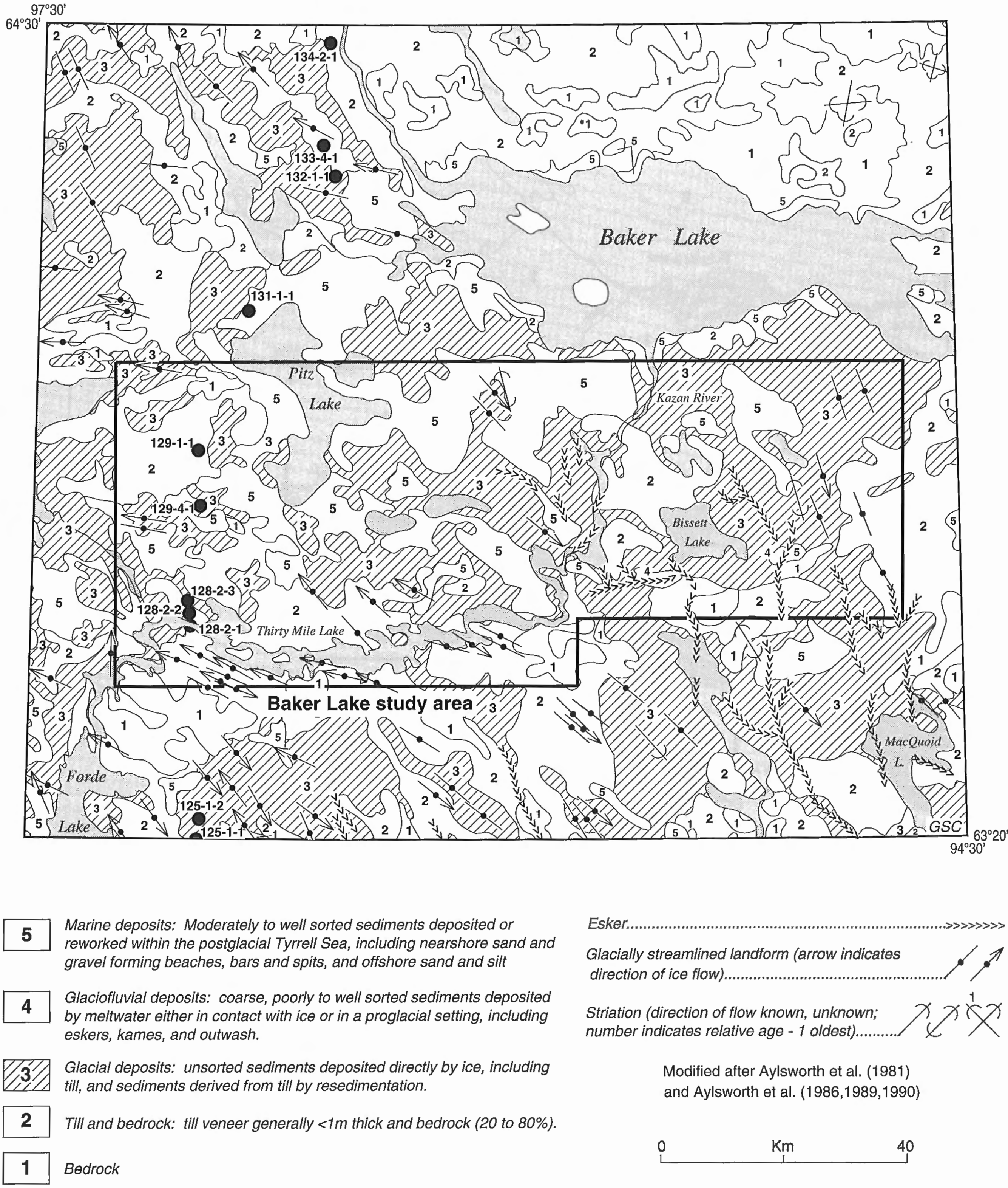


***Figure 3.** Surficial geology of the study area region. Till is the most widespread surficial sediment, and its colour and texture reflect lithology and provenance. Till derived from crystalline terrain is sandy and brown, whereas that derived from the Baker Lake Basin is silty and red. Streamlined landforms reflect a prominent phase of southeastward ice flow.*

glacially streamlined landforms, and eskers are radially distributed about a zone characterized by low hummocky moraine, featureless till plains, and an absence of eskers (Lee, 1953; Aylsworth and Shilts, 1989). The zone was associated with an ice divide (Fyles, 1955) named by Lee et al. (1957) as the Keewatin Ice Divide. It was interpreted as a zone occupied by the last glacial remnants rather than a centre of ice dispersal, and it is outlined by the features of late glacial flow and of late glacial recession (Lee, 1959). The Keewatin Ice Divide last occupied a curvilinear zone extending northward across much of the District of Keewatin (Lee et al., 1957). In the western part of the study area, the demarcation between opposing ice flow trends locates the final position of the ice divide within Pitz Lake basin (Cunningham and Shilts, 1977; Aylsworth et al., 1989).

Deglaciation of the District of Keewatin occurred between 6000 and 5000 BP, although there are few radiocarbon dates available to map change in the location of the ice margin (Shilts, 1973; 1986). As the ice front retreated westward across the Baker Lake area, it faced directly in deep marine water (tens of metres to more than 100 m) of the postglacial Tyrrell Sea.

METHODS

Till sampling

To characterize drift composition within the Baker Lake study area, approximately 2000 samples were collected at density of 1 sample per 3 to 4 km^2. The sample density was chosen to define glacial dispersal trains at local (tens of kilometres) and regional (tens to hundreds of kilometres) scales, and to intersect the 'tails' (Shilts, 1976) of smaller trains that could originate from mineralized bedrock sources at detailed scales (hundreds of metres to kilometres). At detailed scales, glacial dispersal from mineralized bedrock was investigated at two sites where samples were collected tens to hundreds of metres apart along traverses oriented at right angles to ice flow directions. Most samples were collected down ice of the mineralized occurrence. Till samples collected at a density of 1 per 100 to 200 km^2 and observations on ice flow directions made by A.N. Boydell and by C.M. Cunningham as part of the investigations of Shilts are used to define a regional geological context for glacial dispersal trains at local scales.

Most till samples were collected from mudboils that are distinctive periglacial features occurring throughout the study area. They appear as circular to elongate bare patches in areas of tundra vegetation (Fig. 4a), and their origins and characteristics are described by James (1972), Shilts (1973, 1978), and Egginton (1979). They are composed of a central core, derived from 'thawed mud substrate' overlying the permafrost table, that can intrude, as a diapir, a comparatively rigid surface 'carapace' (Fig. 4b) (Shilts, 1973, 1978). The carapace materials are derived from the underlying sediments and are characteristically coarser grained, likely through the removal of fines by the washing of rain and spring runoff. Within mudboils, circulation of sediment is indicated by diapiric structures, by the incorporation of carapace materials and organic matter at the outer margins of mudboils, and by lenses and pockets other sediment types within thawed mud substrate (Fig. 4b). As the result of circulation they can also include other, younger sediments, especially in areas of marine or glaciolacustrine inundation.

Mudboils developed in till are typically 1 m or more in diameter with a stony rim. Where they are developed in fine grained marine sediment, they tend to be smaller, without a stony rim, reflecting the finer texture and better sorting of those sediments. Because they are preferentially developed in till and are readily apparent from aircraft, mudboils were used as a convenient guide for locating and sampling till in areas of other glacial and non-glacial sediments. Till samples (2 to 3 kg) were routinely collected from the central core of mudboils at depths of 10 to 40 cm. Where the core of thawed mud substrate could not be located, as was common in the case of inactive mudboils having a thick carapace, samples were collected from the carapace itself. Sediment containing either organic material or iron and manganese staining indicative of postglacial weathering was not sampled. The exposure and concentration of washed clasts at the margins of mudboils provide an opportunity for determination of lithology and provenance of till. At nine locations (Fig. 5) mudboils were sectioned by trenching to frozen ground and sampled to characterize internal structural and compositional variation, as well as the effects of postglacial weathering on till geochemistry. Some of the mudboils are located within glacial dispersal trains originating with uranium-copper mineralization.

Sections and drill core

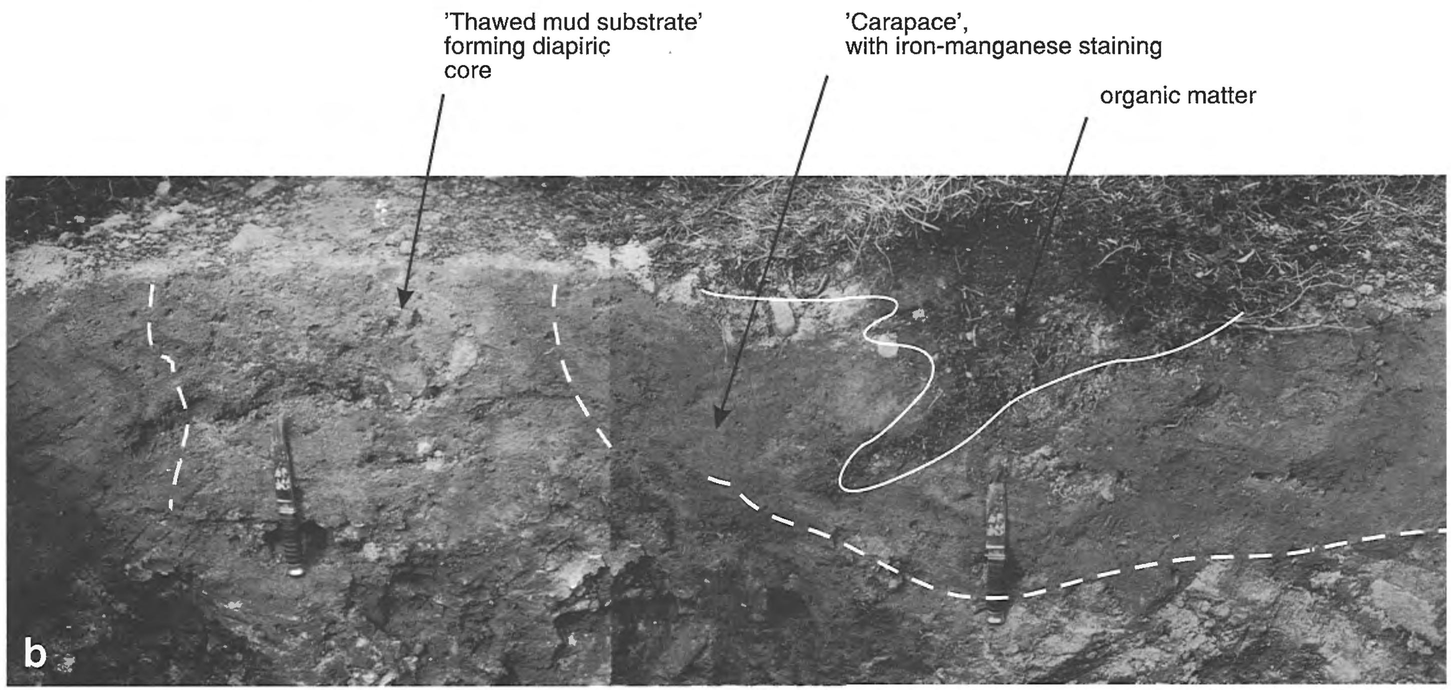
Sections exposed along streams, and overburden drill core collected along a proposed pipeline corridor across the District of Keewatin (Shilts, 1980b) were examined to determine till stratigraphy and thickness, and sampled to compare the composition of surface and sub-surface sediments (Fig. 5). Drilling records and overburden drill core were obtained from the Polargas Corporation and EBA Engineering Consultants Ltd. (Shilts, 1980b). Because they were obtained for purposes of geotechnical investigation, drill core are continuous and are well suited for stratigraphic studies and geochemical analysis.

Geochemical analysis

For routine geochemical analysis the clay-sized fraction of till (<0.002 mm) was separated by centrifuge methods described by Jackson (1969) and modified within the Sedimentology Laboratory of the Geological Survey of Canada. The clay was geochemically analyzed for copper, lead, zinc, nickel, manganese, and iron by atomic absorption spectrometry (AAS) following a hot aqua regia (LeForte: 1 part HCl : 3 parts HNO_3) digestion. Within the study area uranium was analyzed by delayed neutron activation (DNA) methods. Outside the study area, uranium was analyzed by fluorimetric methods. Geochemical analyses were by Bondar-Clegg Co. Ltd. (Ottawa) (AAS), and by Atomic Energy Ltd. of Canada (DNA). Estimates of analytic reproducibility and detection

Figure 4.

*Mudboils are widespread and preferentially developed in till, and were used as a guide to sampling. They appear as circular to elongate bare patches **(a)** Structural elements of mudboils include a diapiric core and carapace. Near the margins, organic material, and iron and manganese stained sediment can be incorporated, illustrating sediment circulation **(b)** (Mudboil site 75-02-2821 (21-24), see Fig. 5). (GSC 1992-026A; GSC 1992-026 E, F)*



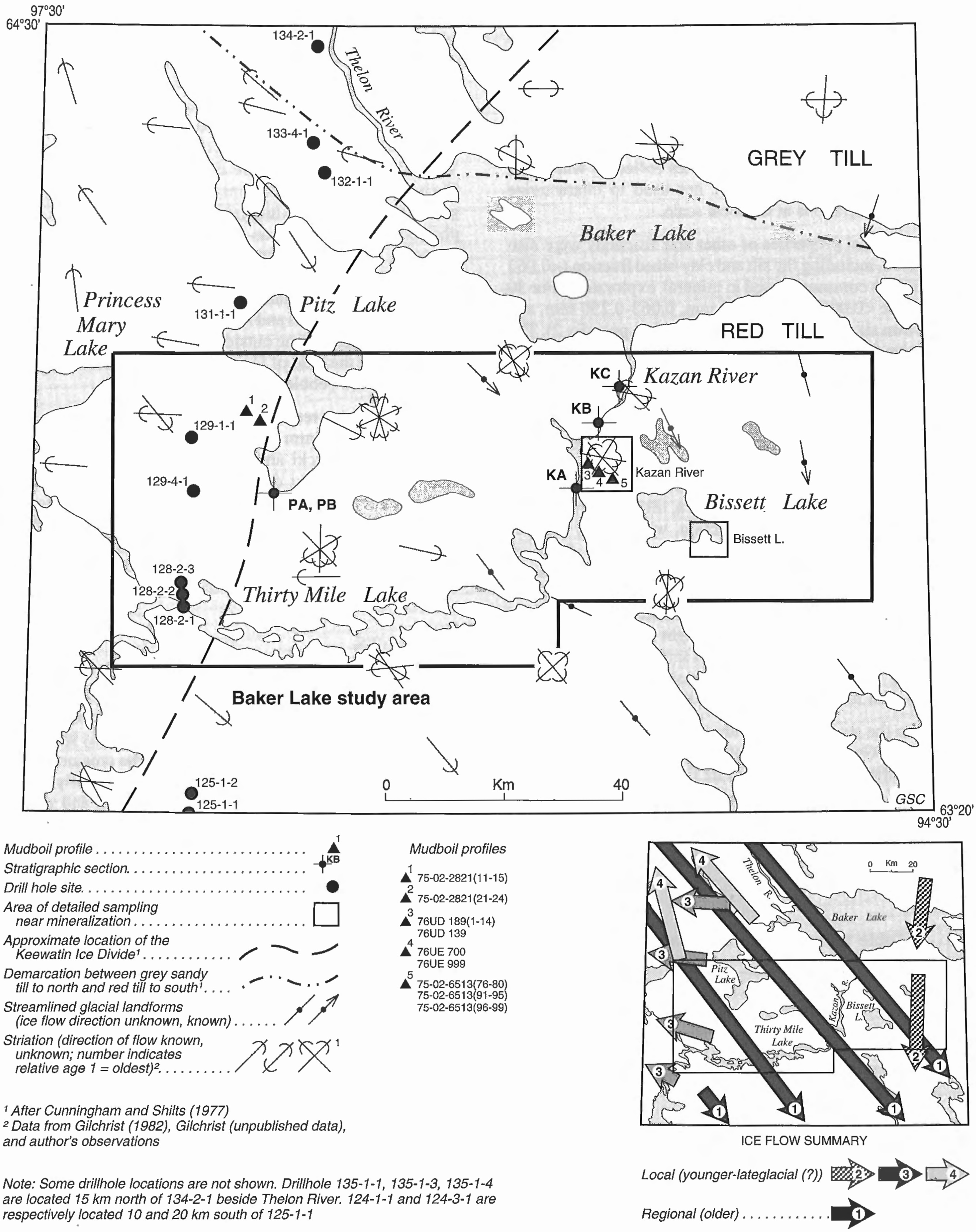


Figure 5. Locations of stratigraphic sections, mudboil profiles, boreholes, and detailed sampling grids within the Baker Lake study area and surrounding region. The location of the Keewatin Ice Divide, striations, and the regional boundary between red and grey till are indicated. Drillhole numbers are from EBA drilling records.

limits are from Bondar-Clegg (Table 1). At low trace element concentrations, within two to three times the detection limit, replicate analysis indicates analytical reproducibility can be as much as ± 100%. Geochemical data are reported in Open Files for the study area (Klassen and Burns, 1986), and in Appendix 1 for the study area region. Manganese and iron analyses are available only for samples collected within the study area during 1975, and are not used to characterize geochemical variations at the local scale.

Geochemical properties of other size fractions were also investigated, including the silt and clay-sized fraction (<0.063 mm) which is commonly used in mineral exploration. For 30 samples, the <0.002 mm, <0.063 mm, 0.063-0.250 mm, and 0.250-2 mm sized fractions were analyzed (Appendix 2). The coarser size fractions were separated by dry sieving.

Lithological analyses

Drift provenance and models of glacial dispersal trains are based on lithological analyses of pebbles obtained by sieving the washed residual of the clay separation process (Appendices 1, 3). For the Baker Lake study area, till lithology is based on analyses of the 4-5.6 mm fraction, whereas for the surrounding region it is based on the 2-5.6 mm fraction. Lithological subdivisions of the two pebble size fractions (4-5.6 and 2-5.6 mm) cannot be directly compared because they represent different size fractions. The relative abundance of rock types was estimated as weight per cent: the total weight of pebbles counted from each sample varied from 5 to more than 15 g. Fewer samples have been analyzed for lithology than for geochemistry (~200 vs. 2000).

Within the study area, the lithological categories include: 1) Dubawnt Group (undifferentiated), 2) Thelon Sandstone, 3) porphyritic volcanic rock of Pitz Formation, referred to in this report as 'Pitz Volcanic Rocks', 4) Volcanic Rock, 5) Sedimentary and Volcanic Rock (undifferentiated), and 6) Crystalline Rock. The subdivisions permit mapping glacial dispersal trains at local scales that originate with several bedrock sources. Thelon Sandstone is a distinctive, light coloured, kaolinized quartz sandstone derived from the Thelon Formation. Pitz Volcanics are characterized by chalky white feldspar phenocrysts in a red to purple, fine grained groundmass, and they are derived from volcanic bedrock of the Pitz Formation. All other volcanic rocks are classed as Volcanic Rock, and they are derived chiefly from Pitz and Christopher Island formations, the latter of which has the greatest areal extent. Although volcanic rock of the Christopher Island Formation can also contain white feldspar phenocrysts, it can be distinguished from volcanic rock of Pitz Formation by the presence of mica and an absence of quartz eyes (A.N. LeCheminant, pers. comm.; 1987). Crystalline Rock includes igneous and metamorphic rock fragments from Canadian Shield terrane outside the Baker Lake Basin. In this classification the total of Dubawnt and Crystalline rock comprises all of the pebble fraction.

For the study area region, till lithology is based on analyses of the 2-5.6 mm fraction by C.A. Kaszycki (Shilts et al.,1979; Kaszycki and Shilts, 1980) (Appendix 1). The analyses of Kaszycki differ from those applied within the study area because they are based on a broader size range. Her categories (Dubawnt Group (undifferentiated), Volcanic Rock, and Crystalline Rock) serve principally to distinguish between sedimentary and volcanic bedrock of the Dubawnt Group and crystalline bedrock of the Canadian Shield.

RESULTS

Striations and streamlined landforms

To characterize ice flow history, the trends and relative ages of striations and glacially streamlined landforms were measured throughout the study area (Fig. 3). The erosional record of ice flow on Dubawnt Group bedrock is poorly defined because outcrop is extensively drift covered and exposed bedrock surfaces weather easily. Most flow indicators indicate southeastward regional ice flow. Near Pitz Lake, striations clearly indicate that the last direction of ice flow was

Table 1. Summary of univariate statistics for geochemical analysis of till (<0.002 mm).

	Copper (ppm)	Lead (ppm)	Zinc (ppm)	Manganese (ppm)	Iron (wt.%)	Uranium (fl) (ppm)	U (dna) (ppm)
Number of Samples	1994	1994	1994	1050	1050	1988	1871
Average Concentration	23.2	26.5	56.7	353.7	2.51	2	3.8
Median	20	26	55	335	2.52	1.7	3.5
Mode	16	28	36	240	2.8	1.7	3.2
Geometric Mean	20.2	25.6	51.7	318.7	2.39		3.63
Variance	150.2	50.9	522.5	29058.9	0.587	1.2	
Standard Deviation	12.3	7.1	22.9	170.5	0.766	1.1	1.2
Minimum	2	8	8	20	0.24	0	1.2
Maximum	107	77	207	1785	8.64	13.5	12.8
Range	105	69	199	1765	8.4	13.5	11.6
Lower Quartile	14	22	38	235	1.98	1.3	3.1
Upper Quartile	30	30	74	440	3.04	2.3	4.1
Detection Limit	2	5	2	2	0.1	0.1*	0.1*
Analytical (*+/-100% <2 ppm)	(+/-20%)	(+/-20%)	(+/-20%)	(+/-20%)	(+/-20%)	(+/-20%)	(+/-20%)

westward to northwestward, and the eastern extent of those striations defines the axis of the Keewatin Ice Divide. Crossing striations indicate diverse ice flow trends, although their relative ages have not been clearly established and their significance to regional ice flow history remains unclear. South-trending striations could record an older regional phase of southward ice flow described by Lee (1953) and Shilts (1973). North of Baker Lake ice flow was generally eastward. Across the eastern end of the lake, south to southwest flow recorded by glacial landforms and striations represents a local deviation in regional ice flow patterns.

Drift thickness and colour

Generally, till thicknesses are greatest in Baker Lake Basin, where they range from 1 to 3 m across highland areas, to more than 20 m in lowlands and valleys. Surficial cover, however, is not uniform, and areas of outcrop and thin (<1m thick) till are common. South of the basin, over crystalline bedrock of the Canadian Shield, till is typically thin and discontinuous, although the drilling records of EBA Consultants Ltd. indicate thicknesses of up to 10 m locally in low-lying areas. Near the Keewatin Ice Divide, north and west of Pitz Lake, till can be more than 30 m thick. Texture, colour, and thickness of till vary. In the eastern part of the study area, till is sandy and brown, reflecting its provenance in crystalline rock north of Baker Lake. In contrast, to the west till is a sandy silt and red due to the incorporation of red sedimentary and volcanic rocks of the Dubawnt Group. Hematite from bedrock of the Dubawnt Group imparts the distinctive red colouration.

Till geochemistry

For geochemical analyses results from the study area, frequency histograms and descriptive statistics, including mean, standard deviation, minimum, and maximum, are given in Figure 6 and Table 1. The statistics are derived from StatView (Abacus Concepts, Inc., Berkeley, CA, 1992), and are used to characterize and compare relations among elements. For the most part, trace element concentrations are low compared with elsewhere in the District of Keewatin (e.g. Klassen and Shilts, 1977; Shilts, 1984).

The greatest concentrations of trace elements are within the clay-sized (<0.002 mm) fraction, and they are nearly twice those of the silt and clay-sized (<0.063 mm) fraction (Fig. 7). With the possible exceptions of zinc and nickel, geochemical relations between the two size fractions are not linear. Although trace element concentrations generally decrease with increase in the size fraction (Fig. 8), there are exceptions, especially so within the sand-sized (0.063-0.250 mm) fraction for nickel and manganese which can contain greater concentrations than the clay-sized fraction.

Within the clay-sized fraction, there is little or no geochemical difference between samples of carapace and thawed mud substrate from mudboils (Fig. 9). For samples having either iron or manganese staining or containing organic material, or both, trace element levels are marginally greater, with the greatest difference in uranium. Within mudboils no evidence for vertical change in provenance was seen and the deposits are monolithic. Slight geochemical differences are evident between till and other sediments incorporated in till, and between samples of frozen and non-frozen till. Although the differences are not great, base metal concentrations are greater within non-frozen till, whereas uranium concentrations are lower. The frozen and non-frozen till samples were collected near mineralized bedrock, and could contain uranium- and copper-bearing minerals.

Regional patterns of glacial dispersal

Till composition and glacial dispersal trains are described separately for the region surrounding the study area and for the study area itself, reflecting differences in sampling density and in the basis for lithological analysis in those two areas.

Till pebble lithology (2-5.6 mm)

Dubawnt Group pebbles are either derived from bedrock of the Baker Lake Basin within the study area, or Proterozoic bedrock to the northwest, or both. They define prominent glacial dispersal patterns that trend northwest-southeast across the region, parallel with the principal direction of regional ice flow (Fig. 10a, b). Dubawnt Group pebbles are either absent or rare on crystalline terrain north and east of Baker Lake. Elsewhere they are greater than 20 wt. %, typically greater than 40 wt. %, even within crystalline terrain south of the study area. The 40 wt. % isopleth outlines the central and western part of Baker Lake Basin, and the tongue of a regional glacial dispersal train extending southeast from there. The margin of the train trends southeast along Thelon River where it is coincident with the change from red to grey till mapped by Cunningham and Shilts (1977) (Fig. 5). Across it, Dubawnt Group pebbles decrease from more than 40 wt. % to none in 10 km. Near the eastern end of Baker Lake, a salient in the 40 wt. % isopleth trends south to southwest, aligned with striations and glacially streamlined landforms that are a local exception to the regional southeast trends. The salient reflects southward transport of crystalline debris into Baker Lake Basin.

Dubawnt Group pebbles are most abundant (>80 wt. %) in areas underlain by Thelon and Pitz formations, indicating they were preferentially subject to glacial erosion compared to other formations of the Dubawnt Group (Fig. 10a). The 60 wt. % isopleth lies generally inside the Baker Lake Basin, within 20 km of its margin. It also defines the core of a prominent, southeast-trending glacial dispersal train 50 km wide and 100 km long that extends into crystalline terrain south of the basin.

The principal bedrock source of Volcanic Rock pebbles is Pitz Formation west of Pitz Lake where concentrations of Volcanic Rock are greater than 50 wt. % (Fig. 10b), and a glacial dispersal train outlined by the 30 wt. % isopleth extends more than 100 km southeast from there. Near Princess Mary and Pitz lakes, Volcanic Rock pebbles decrease northward from 50 wt. % to less than 20 wt. %. There, Volcanic Rock could be derived from metavolcanic bedrock north of the basin. The uniform northward decrease in lithological abundance and the orientation of isopleths subparallel to the basin margin, however, indicates that the bedrock source most likely lies within the basin and that glacial transport was to the west and north. Along the topographic ridge west of Pitz Lake, striations indicate the last direction of ice flow was west and northwest (Gilchrist, 1982). Together, striations and drift composition are evidence for limited northwestward glacial transport, likely during late glacial time when the Keewatin Ice Divide lay within Pitz Lake (e.g. Fig. 1).

Till geochemistry

Regional geochemical patterns defined by copper, zinc, nickel, uranium, manganese, and iron (Fig. 11a-f) correspond with lithological patterns (Fig. 10a, b), reflecting large scale glacial transport and bedrock composition. Till containing more than 60 wt. % Dubawnt Group pebbles is impoverished in trace metals (<20 ppm Cu, <50 ppm Zn, and <2 ppm U), whereas till containing less than 40 wt. % is enriched (>40

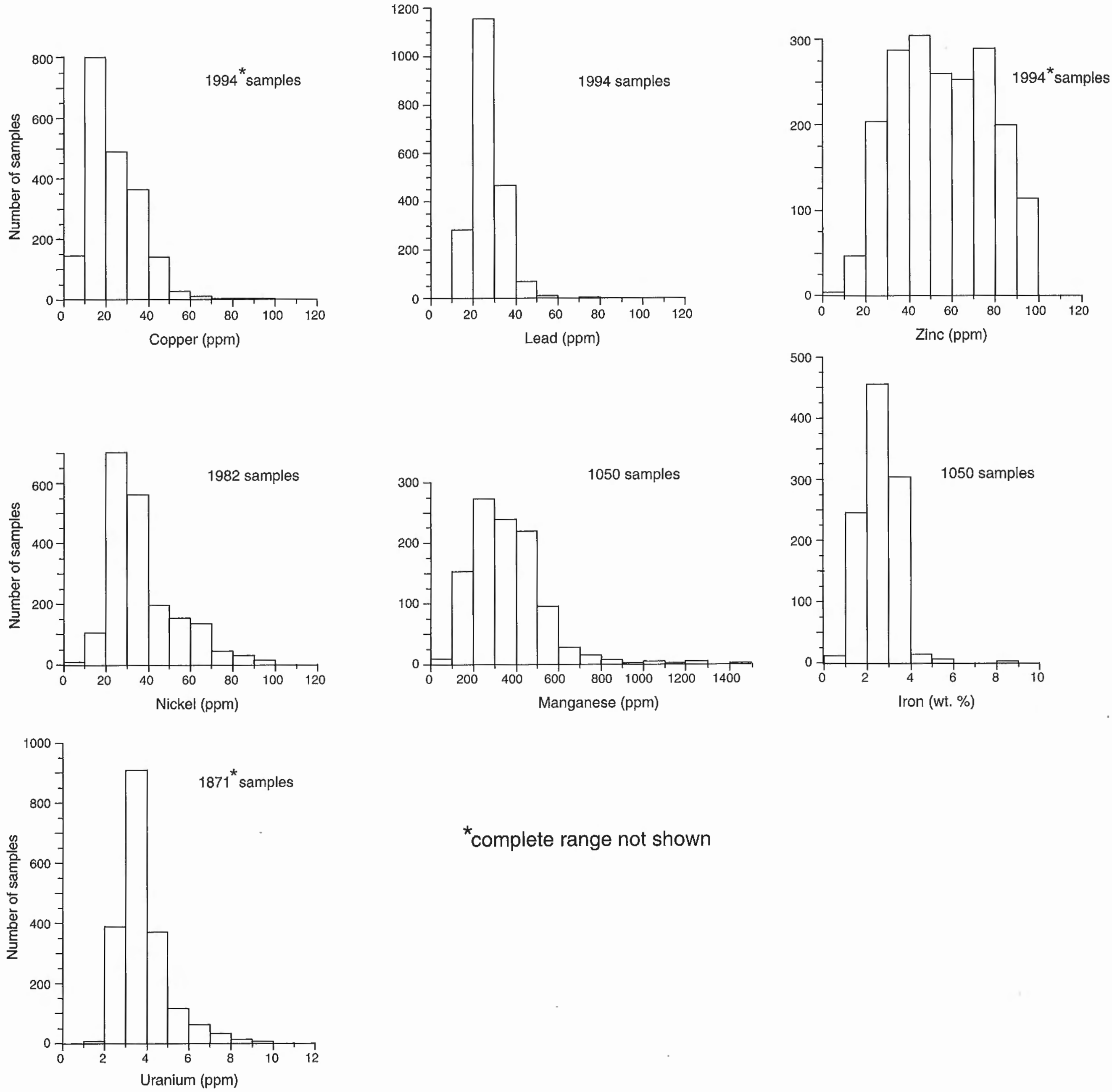


Figure 6. *Frequency distributions for copper, lead, zinc, nickel, uranium, manganese, and iron for the clay-sized fraction of till, Baker Lake study area. Samples containing anomalous concentrations of copper, zinc, nickel, and uranium are few and are omitted.*

ppm Cu, >75 ppm Zn, and >2 ppm U). Till depleted in copper (<20 ppm) and zinc (<50 ppm) (Fig. 11a, b) defines a glacial dispersal train that extends more than 100 km southeast of Pitz Lake, coincident with the 60 wt. % isopleth of Dubawnt Group pebbles (Fig. 10a). The glacial origins of the geochemical patterns are evident in both their southeast elongation and their extension across distinct geological terrains. Glacial dispersal trains defined by nickel and uranium are not as well defined, although their geochemical contours also trend southeast and concentrations are least (<25 ppm Ni) in the central part of the Dubawnt Group dispersal train (Fig. 11c, d). The 25 ppm nickel isopleth is centred on bedrock of Thelon Formation, indicating dilution of till by that source. Nickel concentrations are more than 50 ppm in till overlying mafic crystalline bedrock northwest of Pitz Lake, and Christopher Island Formation southeast of the lake. For till collected outside the study area, lead analysis is incomplete and no maps for lead are available.

Till dominated by Dubawnt Group detritus is also impoverished in manganese (<300 vs. >500 ppm) and in iron (>5 vs. < 3 wt. %) (Fig. 11e, f). The low iron concentrations are surprising because till dominated by Dubawnt Group rock is red, reflecting hematite from bedrock of the Baker Lake Basin, and thus it could be expected to contain greater iron concentrations than grey till. For till of the study area matrix colour is not a reliable indication of manganese and iron concentrations.

Local patterns of glacial dispersal

Till pebble lithology (4-5.6 mm)

In the study area, glacial dispersal trains are clearly defined by Dubawnt Group pebbles, and by formations of the Dubawnt Group, especially Thelon and Pitz (Fig. 12a-e). Dubawnt Group pebbles are typically more than 50 wt. %,

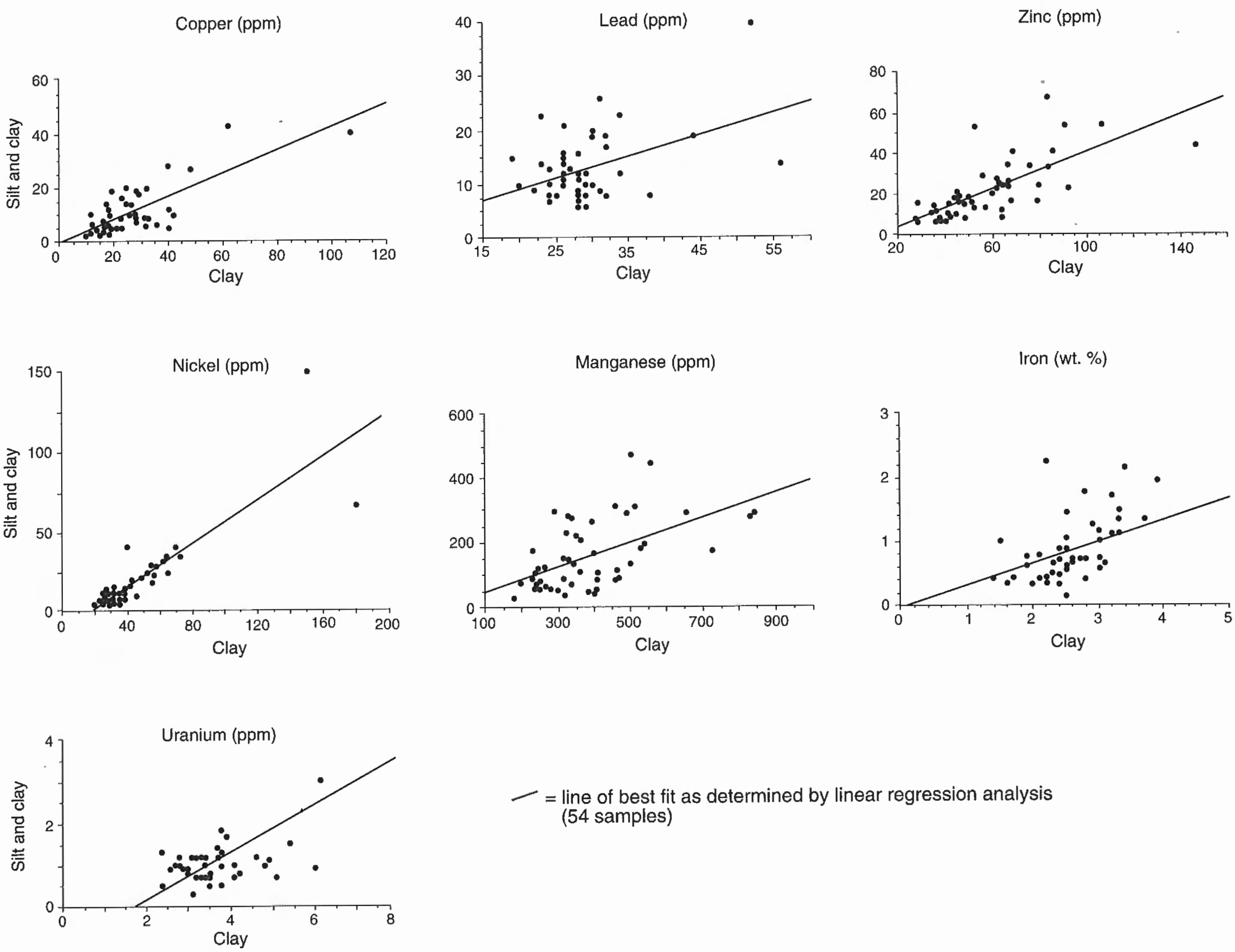


***Figure 7.** Geochemical relations between clay-sized and silt and clay-sized fractions. The clay-sized fraction (<0.002 mm) contains greater concentrations of trace and minor elements than the silt and clay-sized fraction (<0.063 mm), and relations between size fractions are not linear. Silt and clay-sized material contains greater concentrations of quartz and feldspar which act as geochemical diluents, lowering trace and minor element concentrations.*

even within crystalline terrain south of Baker Lake Basin. Their greatest concentrations (>75 wt. %) occur within till over bedrock of Thelon Formation, and within a narrow, ribbon-shaped glacial dispersal train extending southeast from Pitz Lake to the southern margin of the study area (Fig. 12a). The train is 5 to 10 km wide and 40 to 50 km long; its regional extension farther southeast is outlined by the 60 wt. % isopleth in Figure 10a.

In Baker Lake Basin, Crystalline Rock pebbles are more than 30 wt. % of till and they are the product of ice flow into the basin from either the north or west based on the widespread evidence for regional southeast ice flow. Northeast of Bissett Lake, the shape and orientation of the 50 wt. % Dubawnt Group isopleth reflect local south to southwest glacial transport of Crystalline Rock into the basin (Fig. 12a), directions of ice flow which are also defined by striations and glacially streamlined landforms at the eastern end of Baker

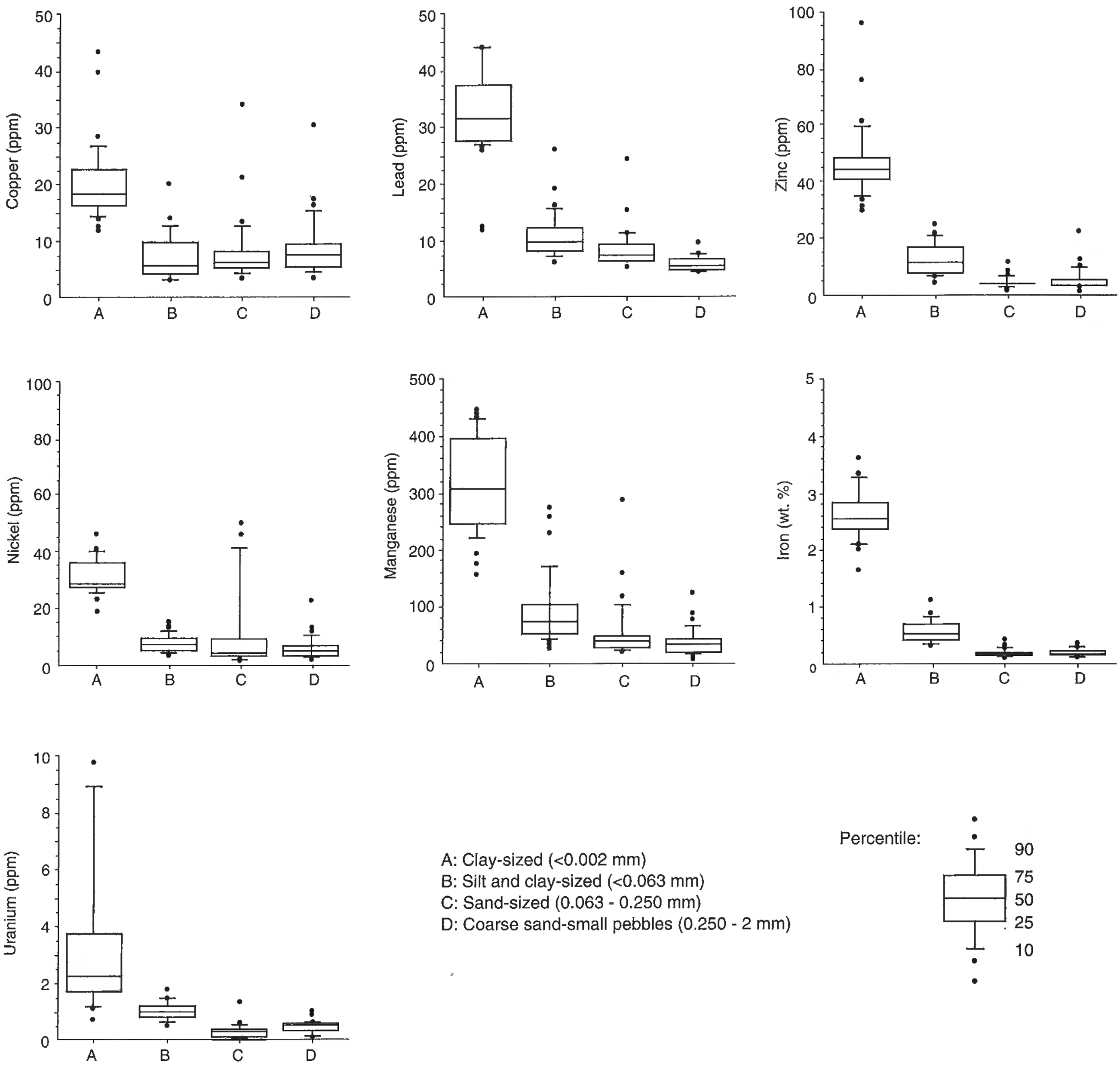


Figure 8. *Box and whisker plots illustrating geochemical relations among different size fractions, including clay-, silt and clay-, sand-, and coarse sand-sized material. Generally, trace and minor element concentrations increase with decrease in grain size, reflecting mineralogical and lithological differences among size fractions. The percentiles are indicated by horizontal lines (see legend), and outliers by symbols.*

Lake (Fig. 3). Although not separated as a subdivision of Crystalline Rock, micaceous schist and phyllite pebbles occur in till throughout the study area in low concentrations, and are most abundant in the western part. They are presumed to be derived from metasedimentary and metavolcanic bedrock north and northwest of Baker Lake (Fig. 2).

Thelon Sandstone pebbles are widespread and vary from less than 10 to more than 50 wt. %. The 20 wt. % isopleth defines a prominent glacial dispersal train originating in Pitz Lake basin that is 20 km wide and extends more than 70 km southeast (Fig. 12b). The southwestern margin of the train is linear and well defined, trailing southeastward from the western limit of Thelon Formation within the study area. In contrast, the eastern margin of the train is diffuse, with a zone 20 to 50 km wide where sandstone varies between 10 and 20 wt. %. The diffuse character of the margin reflects either glacial erosion of Thelon Formation outliers within Baker Lake, or change in ice flow direction, or both. Two small areas of till characterized by more than 20 wt. % sandstone near the mouth of the Kazan River and the eastern end of Baker Lake were likely derived from bedrock sources within the lake.

Pitz Volcanic Rocks are widespread across the central and western part of the study area. Over their bedrock source west of Pitz Lake, and up to 20 km southeast, they are more than 15 wt. % (Fig. 12c). The 0 wt. % isopleth trends southeast across the central study area from the easternmost bedrock source. Scattered, rare erratics of Pitz Volcanic Rocks east of that isopleth are either the result of ice flow and glacial transport in a direction more eastward than southeast, or are derived from unknown sources within Baker Lake, or both. From the regional geological setting, it is not likely that porphyritic volcanic rock outcrops beneath Baker Lake (A.N. LeCheminant, pers. comm., 1987), and thus the scattered erratics are evidence for more eastward glacial transport. Limited evidence for eastward ice flow is also provided by east-trending striations of uncertain relative age that occur throughout the study area.

In areas that are either underlain by, or are down-ice (south or southeast) of, Christopher Island and Pitz formations, Volcanic Rock pebbles vary between 10 and more than 20 wt. % (Fig. 12d). The 10 wt. % isopleth trends southeast from the easternmost bedrock source, similar to the dispersal train of

Figure 9 Legend

Surface vegetation

Organic matter

Iron oxide staining

Clasts

Sand to sandy gravel

Sand to silty sand diamicton ('Carapace')
(Note: can contain inclusions of underlying till)

Red, red brown, and brown sandy silt diamicton (thawed mud substrate)
(Note: may be gradational with overlying materials)

Contact (well defined, poorly defined)

Permafrost table

Sample (till; other sediment)

•+▲ (102) Geochemical analysis (reported value greater than indicated scale)

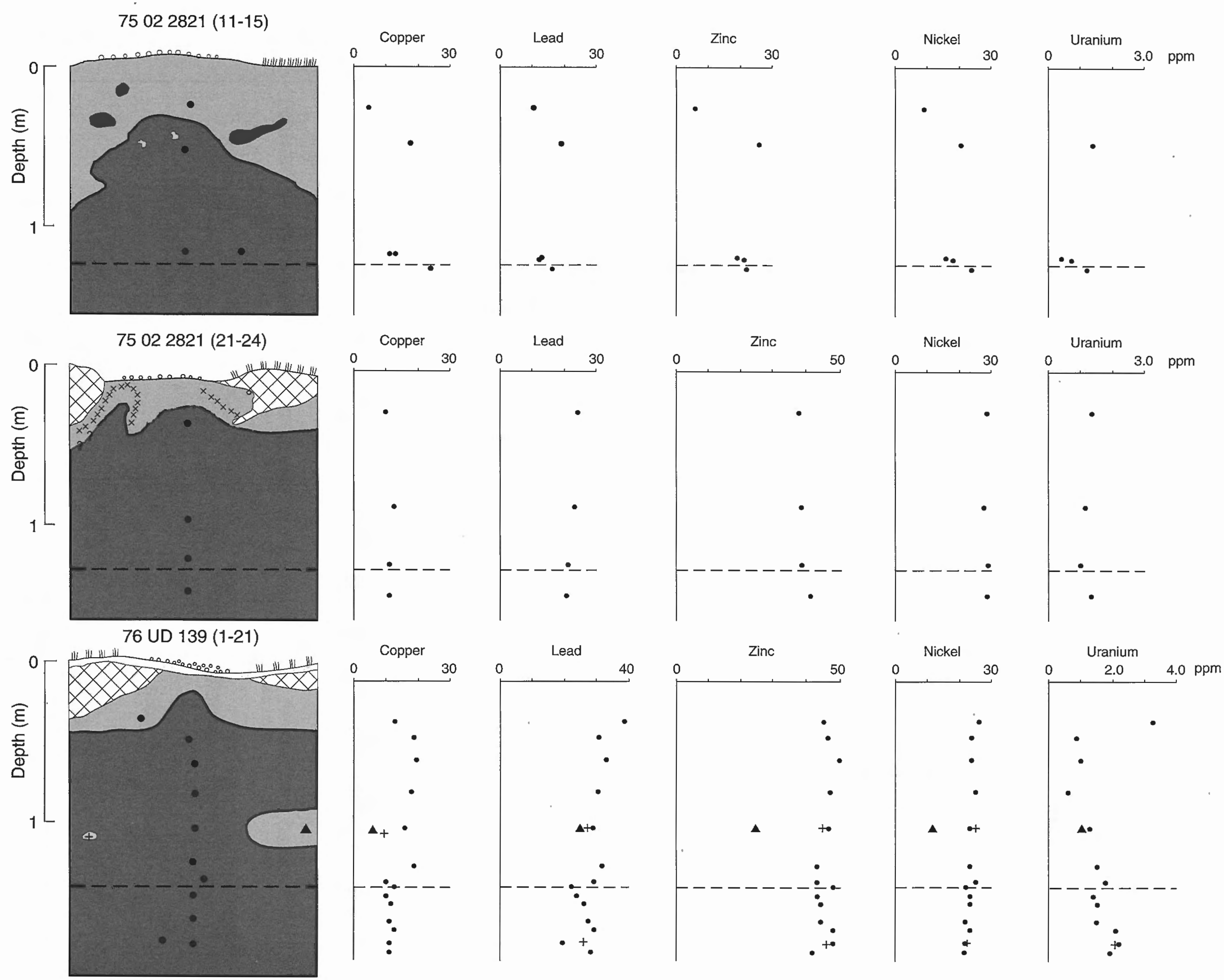


Figure 9. *Mudboil profiles illustrating internal structure and geochemistry of till and of non-till sediment. Within the clay-sized fraction, geochemical variation within mudboils is minimal. Differences are greatest within mudboils located in drift derived from mineralized sites, between frozen and non-frozen till, and between till and non-till sediments.*

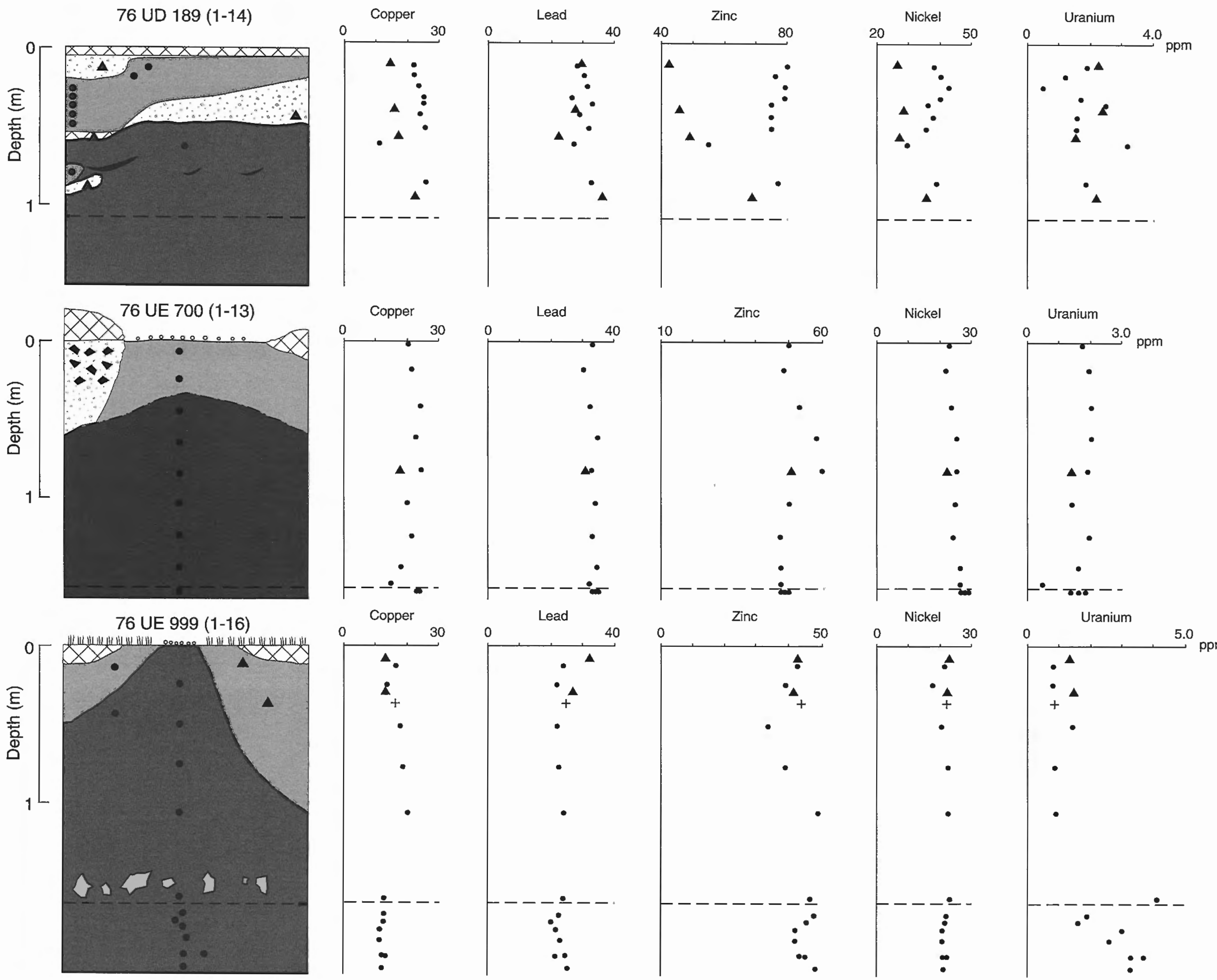


Figure 9. *(cont.)*

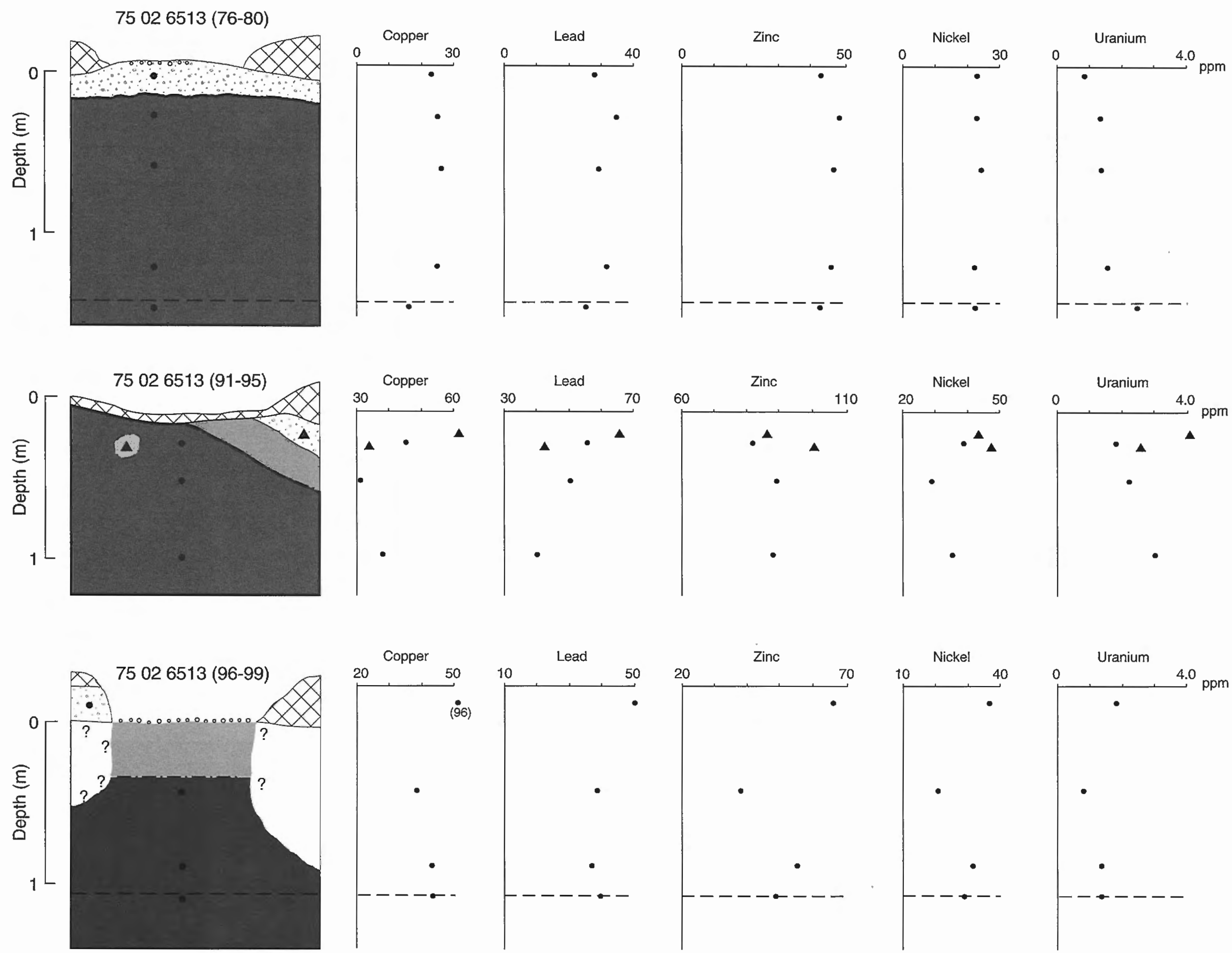


Figure 9. (cont.)

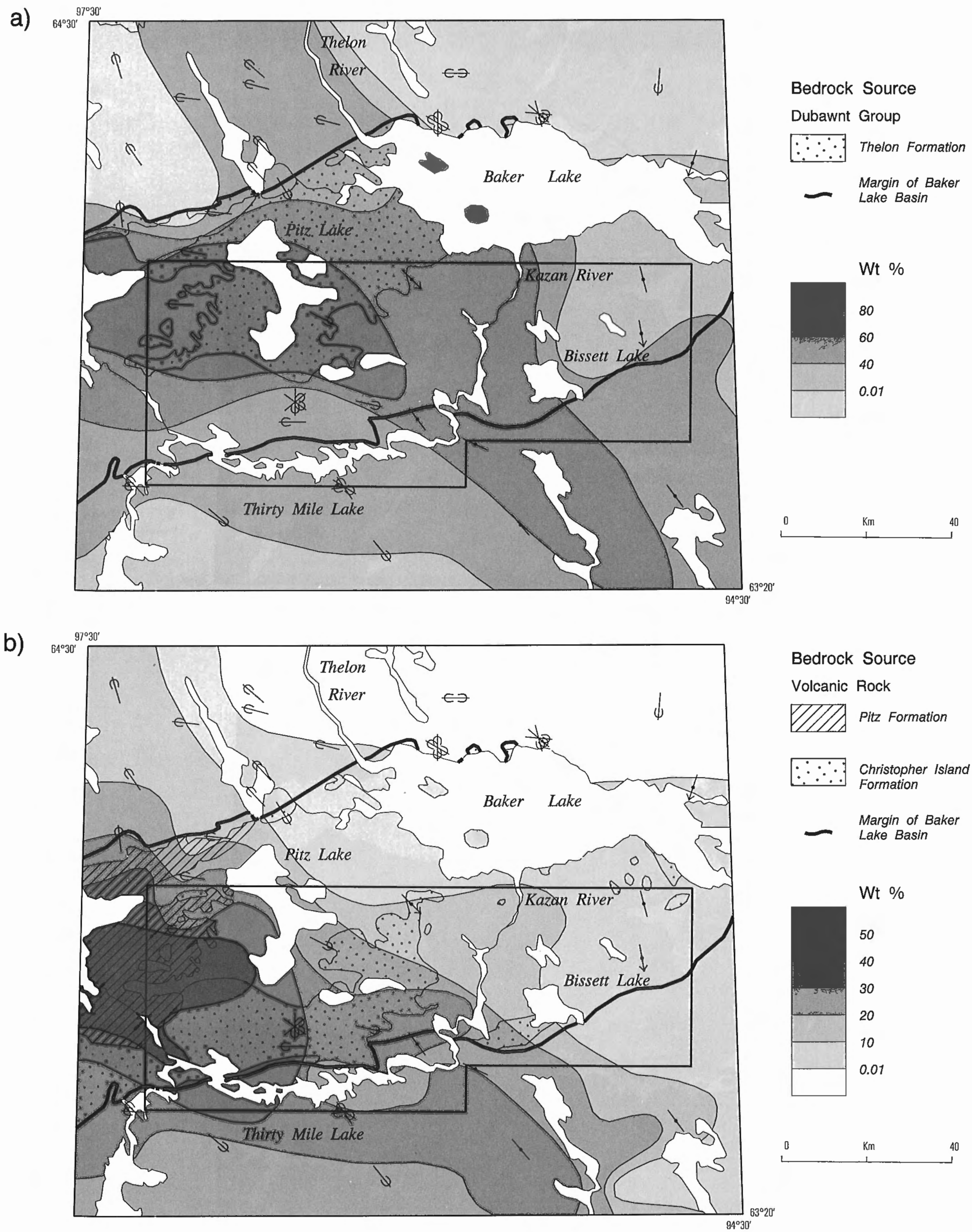
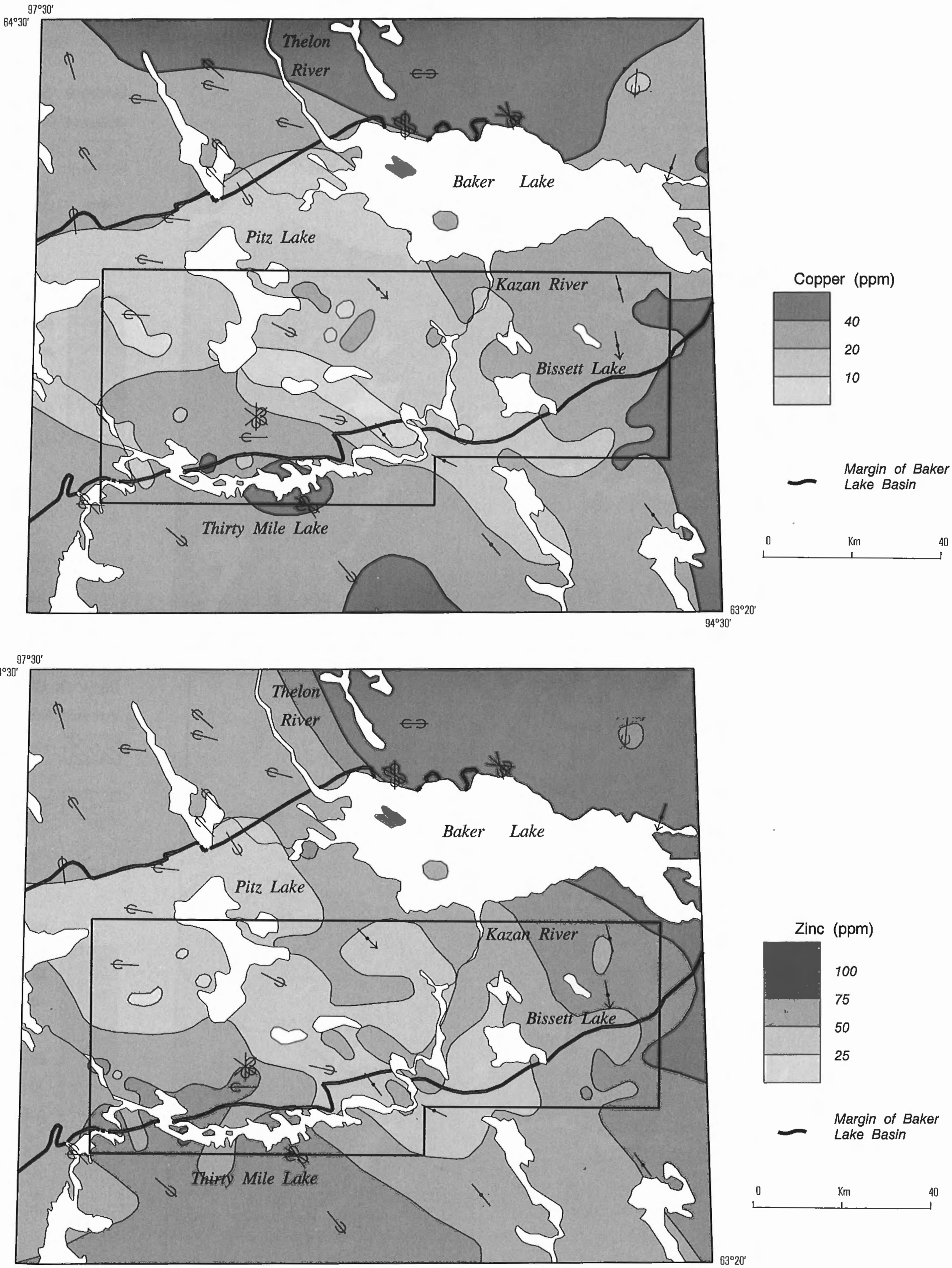


Figure 10. *Regional lithological variations in till. Till lithology is defined by pebbles (2-5.6 mm) of Dubawnt Group (**a**) and Volcanic Rock (**b**). Isopleths outline regional scale glacial dispersal trains reflecting southeastward glacial transport. Locally there is indication of westward and northwestward, and of southward glacial transport.*

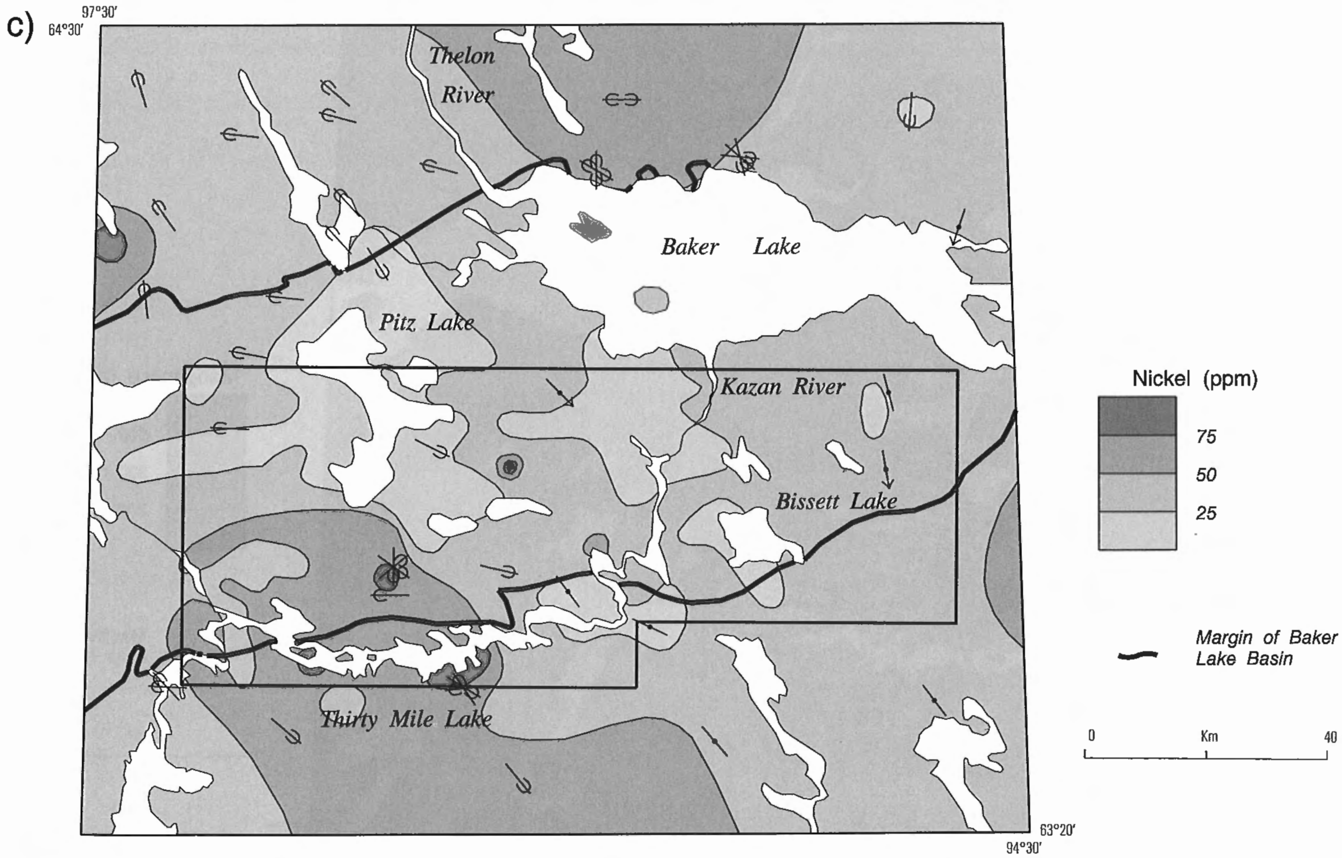
a)



b)

Figure 11. *Regional till geochemistry. Geochemical maps for copper (**a**), zinc (**b**), nickel (**c**), uranium (**d**), manganese (**e**) and iron (**f**) are based on analysis of the clay-sized fraction. Low trace and minor element concentrations reflect the distribution of Dubawnt Group detritus in till (Fig. 10a). Sample density is approximately 1 per 100 km^2.*

c)



d)

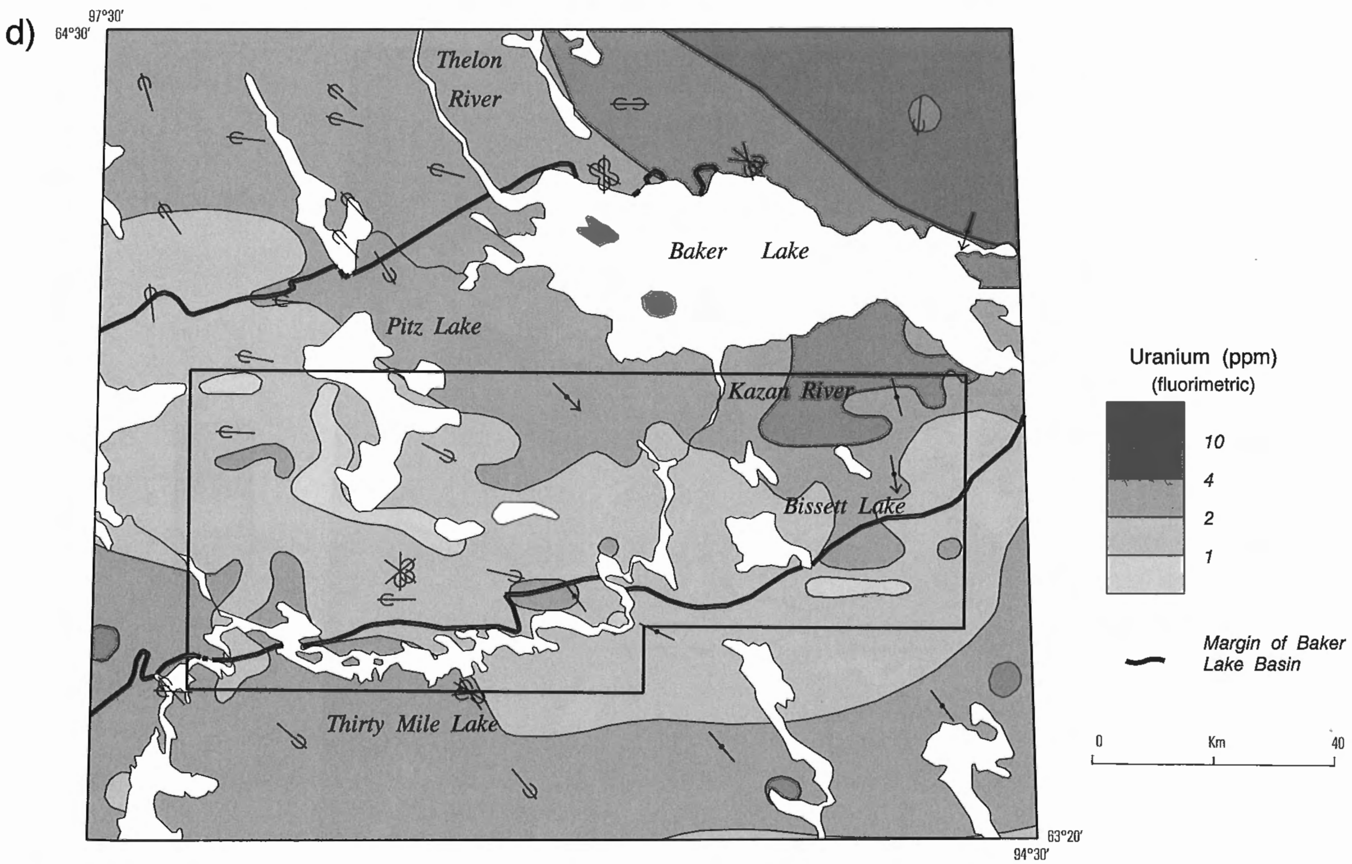
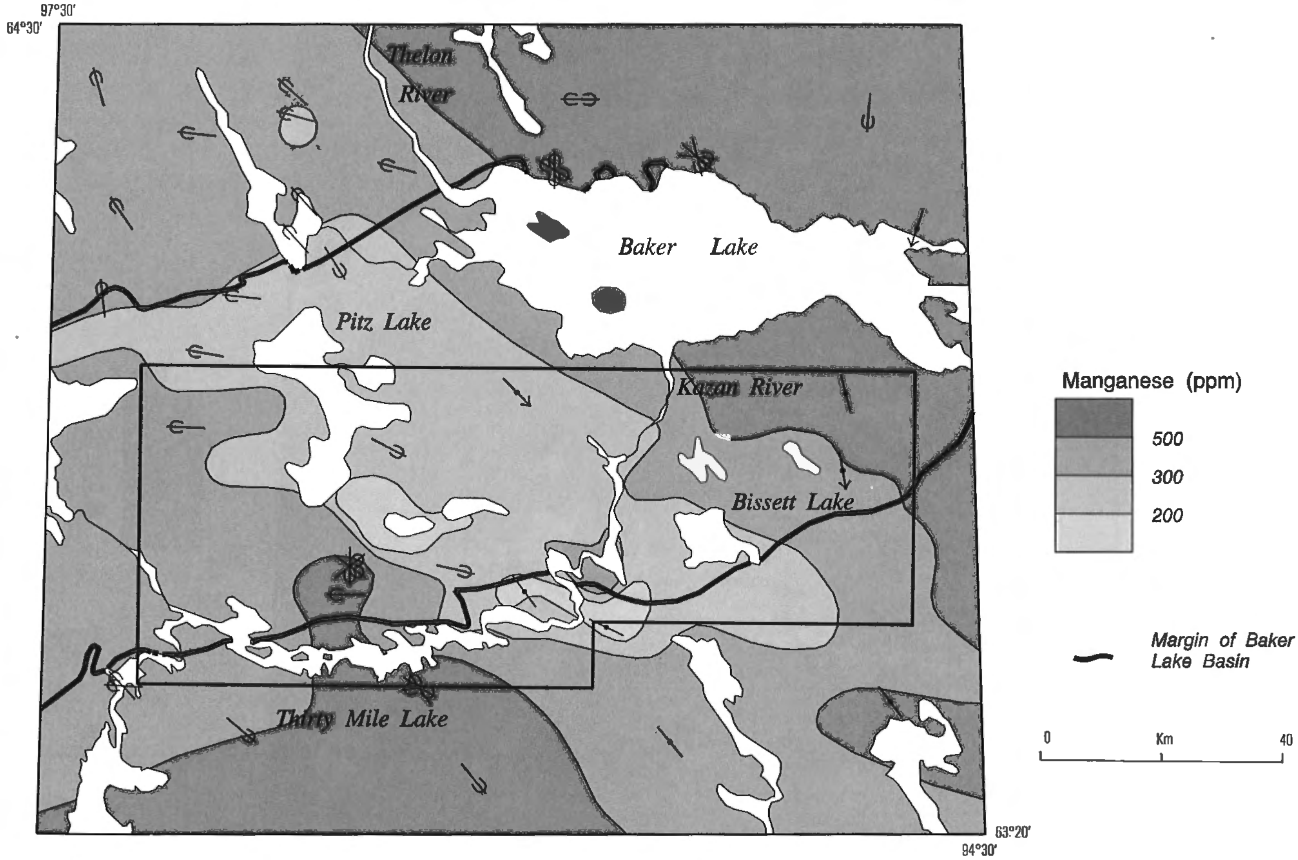


Figure 11. *(cont.)*

e)



f)

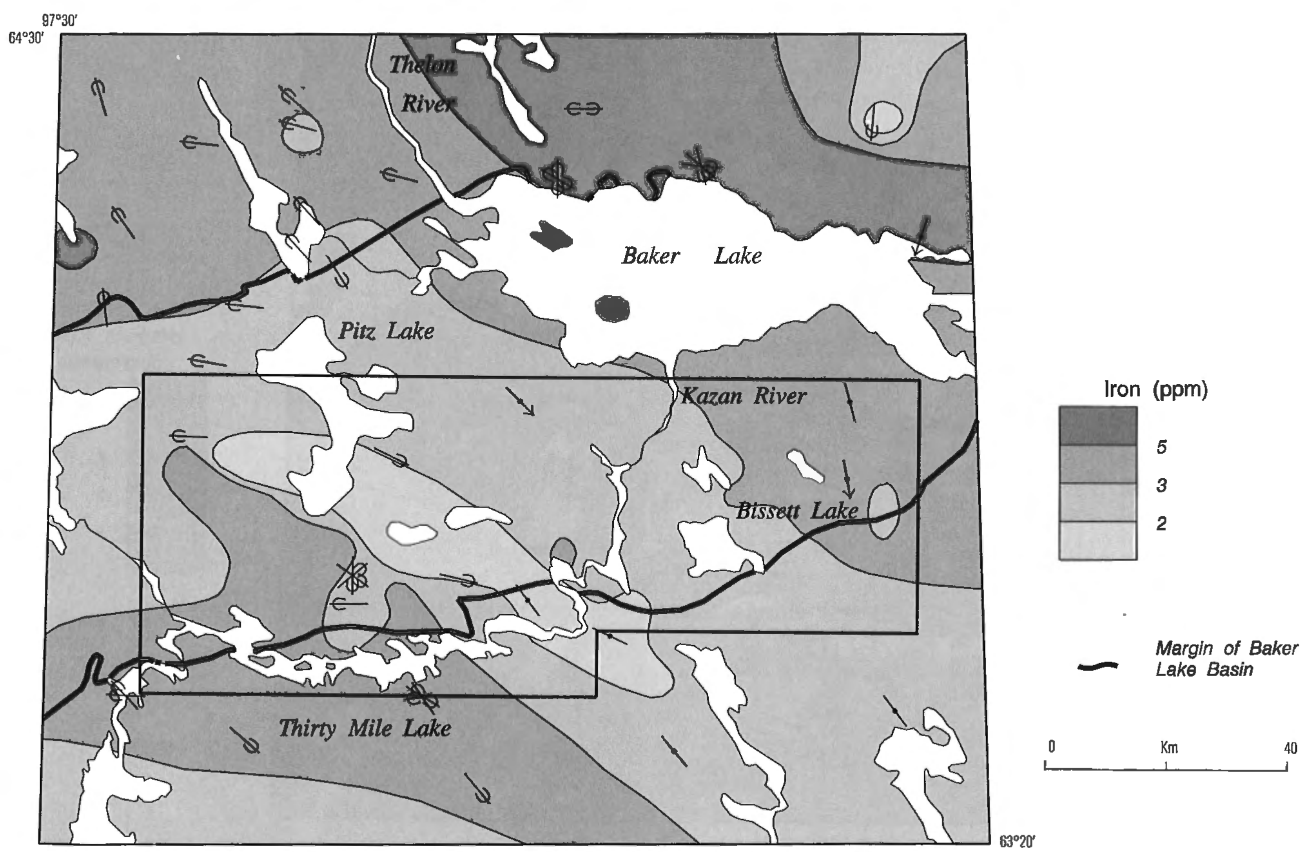


Figure 11. (cont.).

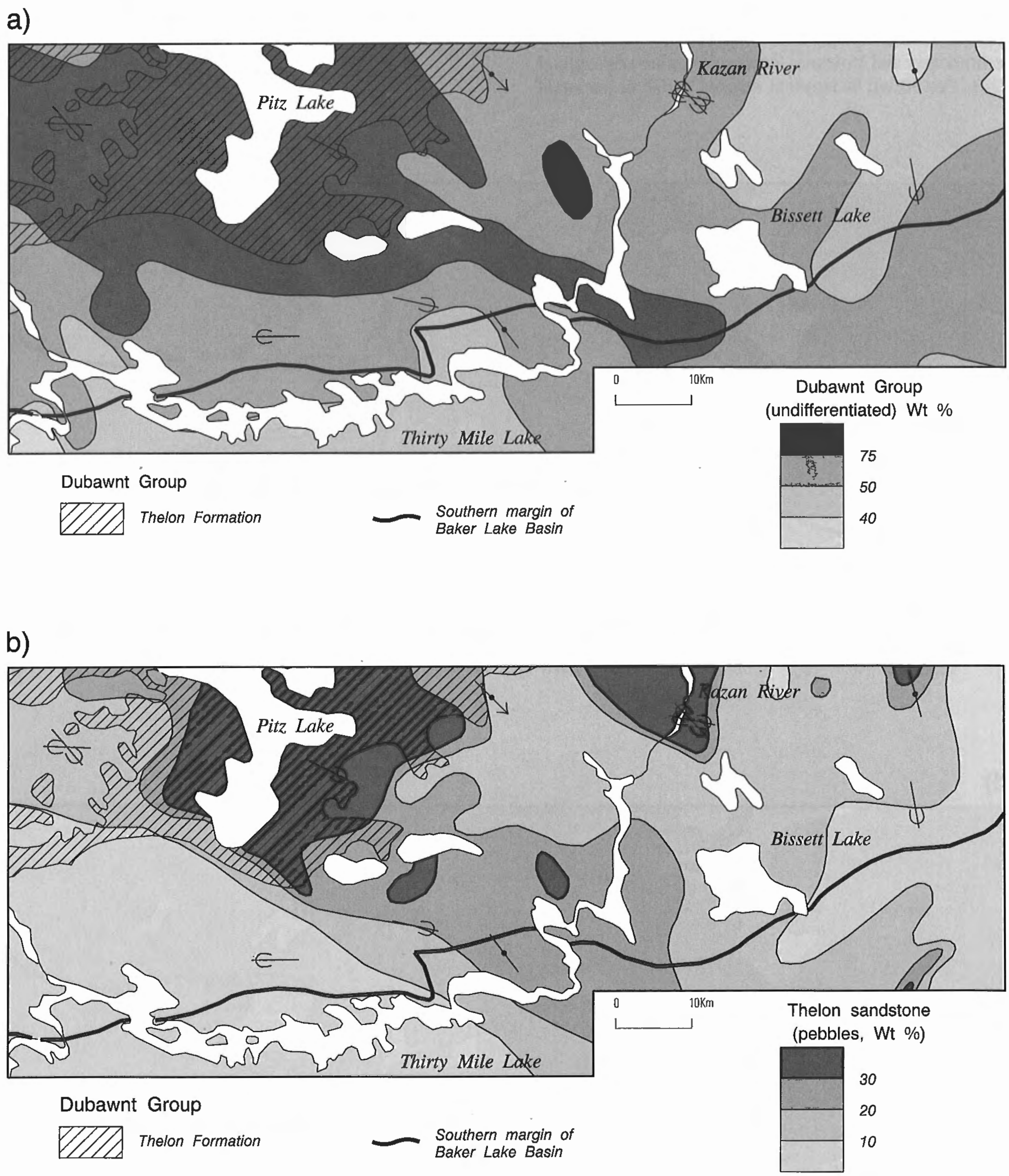
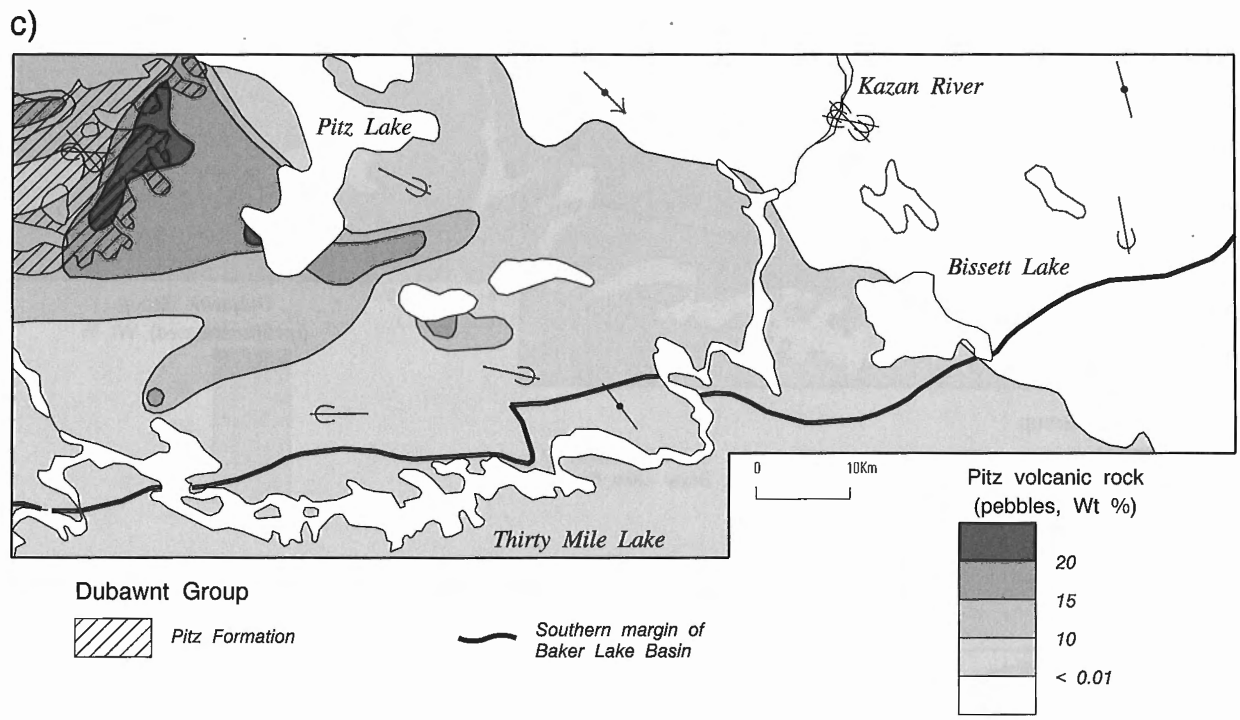


Figure 12. *Till lithology is defined by pebbles (4-5.6 mm) of Dubawnt Group (**a**), Thelon Sandstone (**b**), Pitz Volcanic Rocks (**c**), Volcanic Rock (excluding Pitz Volcanic Rocks) (**d**), and Sedimentary and Volcanic Rock (excluding Thelon Sandstone and Pitz Volcanic Rocks) (**e**). Glacial dispersal trains reflect the predominant southeastward direction of glacial transport. Thelon Sandstone has been preferentially eroded by the ice sheet and for its area of exposure has contributed greater amounts of debris to till than other rock types.*

Pitz Volcanic Rocks. The poor definition of Volcanic Rock dispersal patterns is in part because its identification is based on textures that may not be evident in pebbles.

Although most abundant in the western part of the study area, Sedimentary and Volcanic Rock pebbles are widespread (Fig. 12e). The 30 wt. % isopleth defines a glacial dispersal train that extends at least 20 km southeast of Pitz Formation, reflecting the relative abundance of non-porphyritic fragments of that formation within till. In the northeast, till contains less than 10 wt. % of Sedimentary and Volcanic Rock pebbles, reflecting the relative abundance of crystalline rock in that part of Baker Lake Basin (e.g. Fig. 12a).



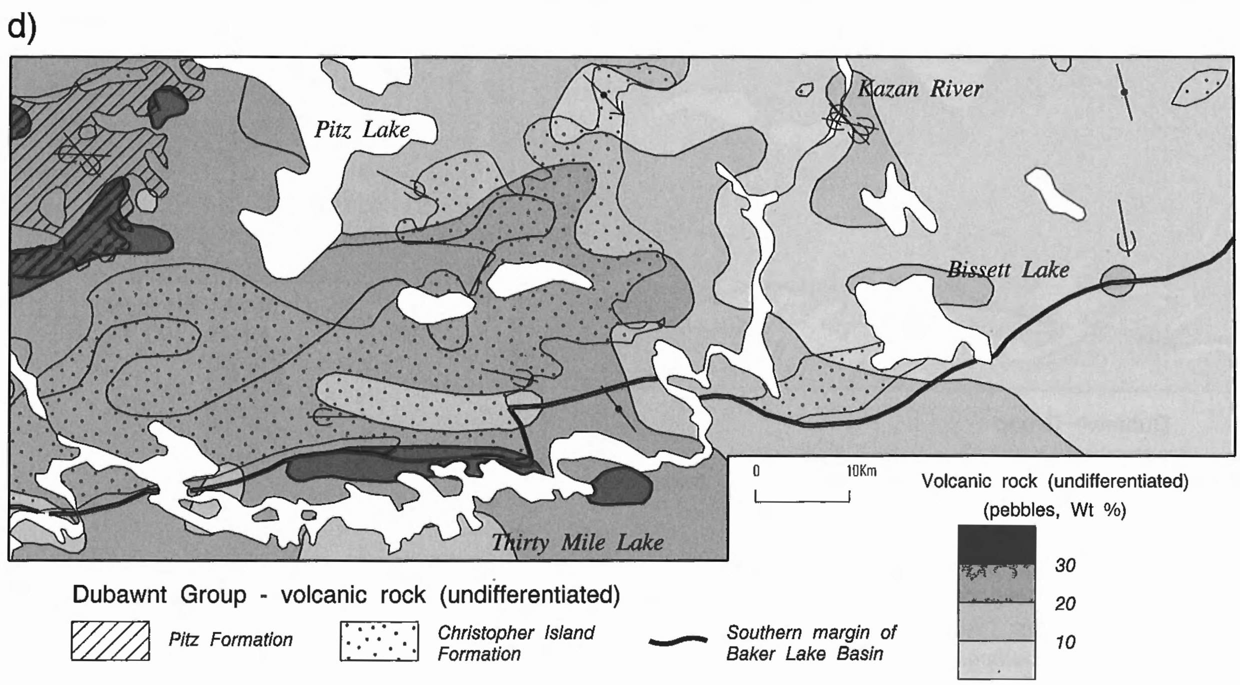


***Figure 12.** (cont.)*

Till geochemistry

Within the study area, geochemical patterns defined by copper, lead, zinc, and nickel are similar (Fig. 13 a, b, c, d): elevated metal levels in the northeast (Cu, Pb, Zn) and southwest (Cu, Pb, Zn, Ni) flank a central core of low metal concentrations (<15 ppm Cu; <20 ppm Pb; <50 ppm Zn; <25 ppm Ni). The low trace metal concentrations define a glacial dispersal train 20 km wide and more than 70 km long trending southeastward from Pitz Lake into crystalline terrain. The southwestern margin of the dispersal train is better defined than the northeastern, where contours are irregular and the geochemical contrast is poor. The geochemically defined train is also outlined by the 20 wt. % isopleth of Thelon Sandstone pebbles (Fig. 12b).

In the northeastern part of the study area, zinc concentrations greater than 75 ppm define a small part of a regional glacial dispersal train that originates in crystalline terrain north of Baker Lake and extends across the District of Keewatin to the Hudson Bay coast (Shilts, 1984; Fig. 5). To the southwest, higher trace metal concentrations reflect the distribution of either volcanic rock of Christopher Island Formation or crystalline bedrock, or both (e.g. Fig. 12d). There, zinc concentrations greater than 75 ppm (Fig. 13c) are coincident with the southeast dispersal trend of Sedimentary and Volcanic Rock pebbles derived from bedrock west of Pitz Lake (Fig. 12e). The eastern margin of the train is coincident with the western margin of the Thelon Sandstone train which is characterized by low trace element concentrations (Fig. 12b).

The distribution of uranium in till (Fig. 13e) differs from base metal elements. Although concentrations are generally less than 3 ppm, and they are greater than 5 ppm in the northeast where Crystalline Rock is most abundant (e.g. Fig. 10a). The low uranium concentrations and analytical imprecision mean that geochemical patterns are difficult to define and to interpret in terms of glacial dispersal and variation in bedrock type. Throughout the study area, however, there are single or small clusters of samples that are 'anomalous', although their significance to bedrock mineralization is unknown. None is associated with the mineralized showings mapped by Miller (1980) and Blake (1980). The term 'anomalous' means samples that are characterized by metal concentrations significantly greater than adjacent samples, and it is used here in a relative sense. Southeast Bissett Lake samples containing more than 3 ppm U could relate to local mineralization (see discussion of Bissett Lake (site 8), below).

Detailed patterns of glacial dispersal

At scales of hundreds of metres to kilometres, glacial dispersal was studied at mineralized sites near Kazan River and Bissett Lake (Fig. 5). Site numbers and descriptions of mineralization are from Miller (1980; Fig. 1). The Kazan River site was chosen because mineralized occurrences there were under active exploration and considered to have economic potential when the sampling was done. The Bissett Lake site was chosen because mineralized boulders had been identified there (A. Miller, pers. comm., 1976), and the regional sampling grid was modified to determine whether additional

e)

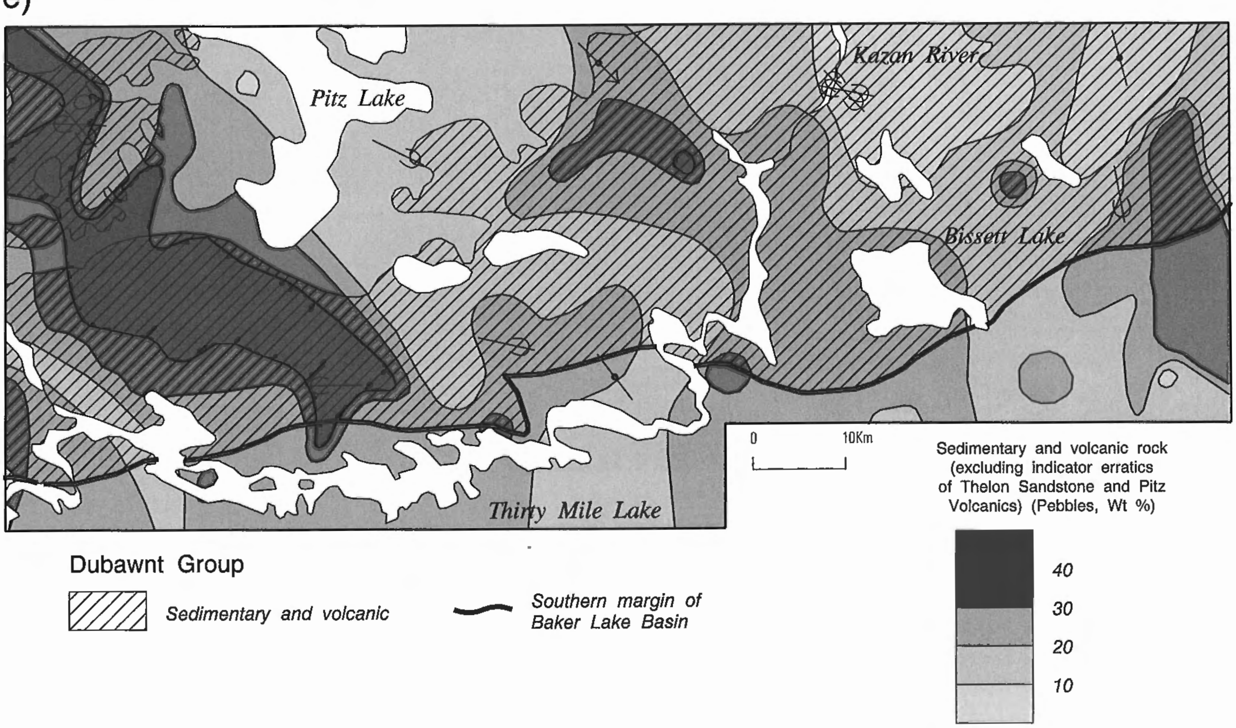
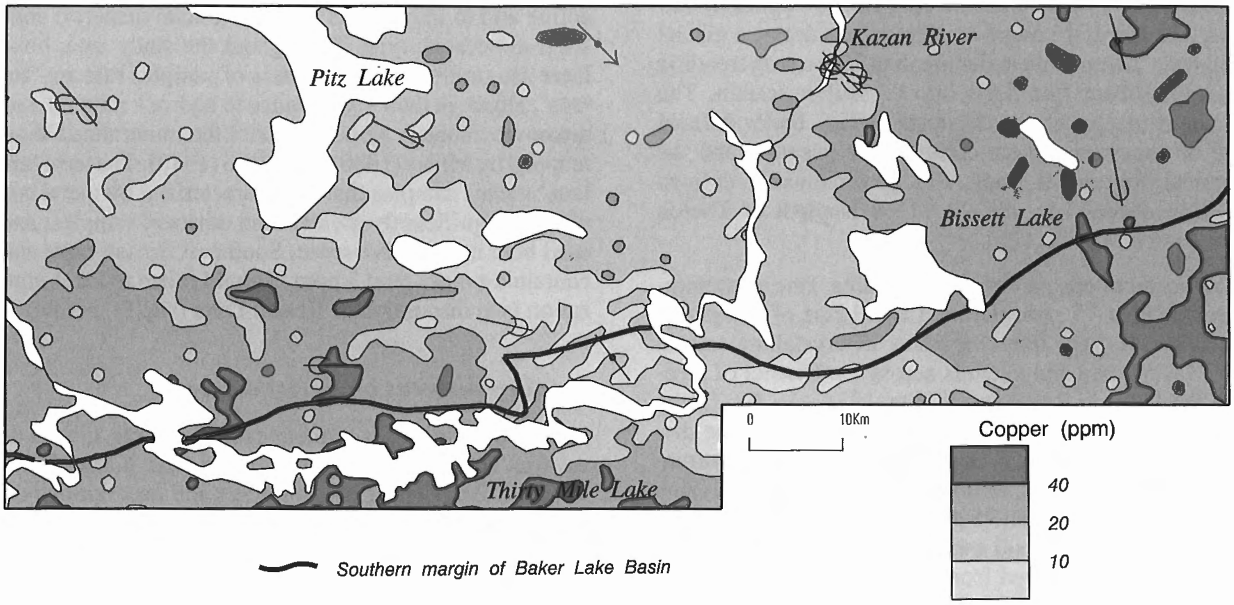


***Figure 12.** (cont.)*

a)



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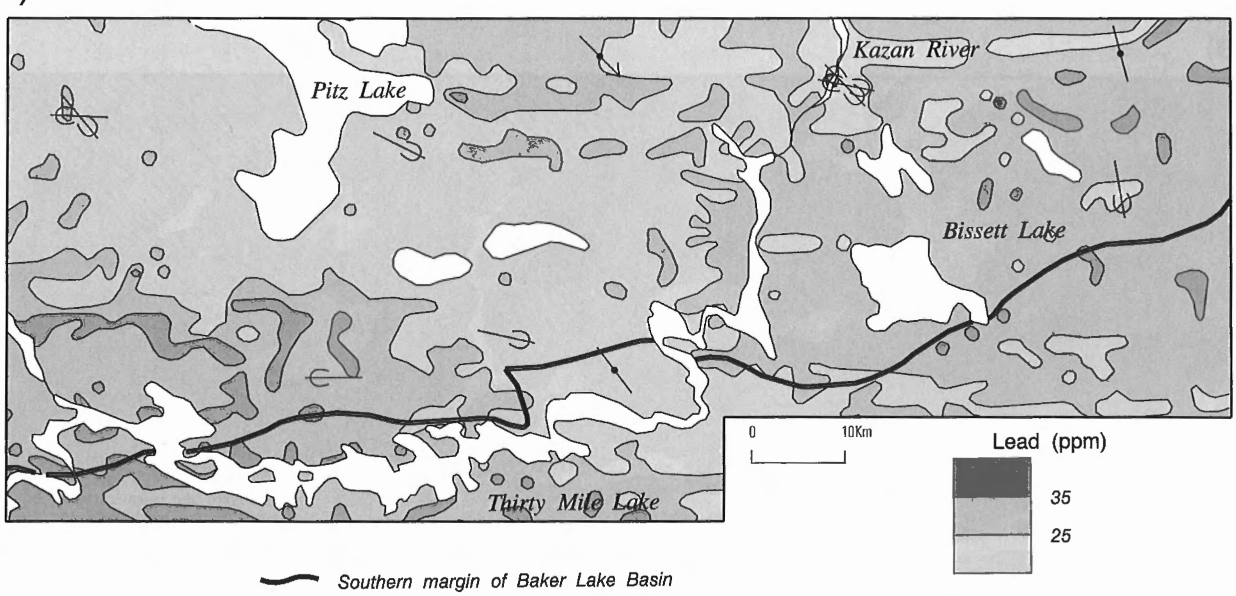


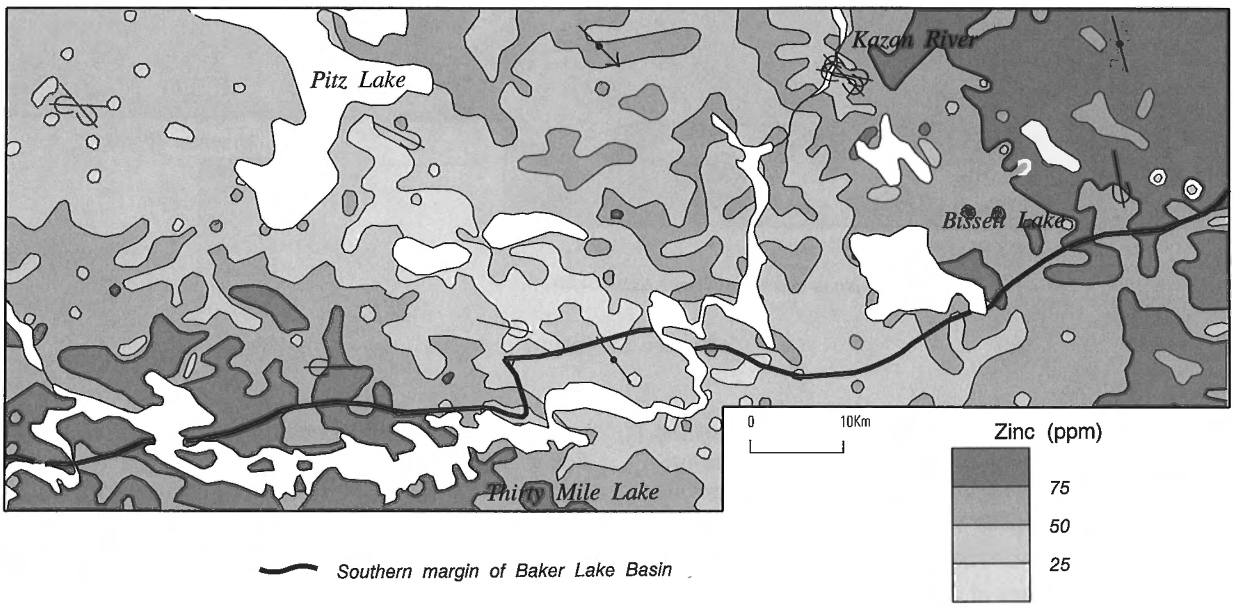
Figure 13. *Local till geochemistry. Geochemical maps for copper* ***(a)****, lead* ***(b)****, zinc* ***(c)****, nickel* ***(d)****, and uranium* ***(e)*** *are based on analysis of nearly 2000 till samples collected at an approximate sample density of 1 per 3-4 km2. Geochemical patterns closely reflect till lithology and the distribution of Thelon Sandstone (Fig. 12b) in particular.*

information concerning their source could be determined from geochemical analyses of till. Both sites lie below the limits of marine submergence, and surficial deposits comprise not only till but marine sediments, including coarse grained, nearshore sediments forming beaches and lag deposits, and fine grained mud. The surficial cover of marine sediments made collection of till at regular intervals difficult at the detailed scale of investigation.

Kazan River (sites 9,10,11)

The Kazan River grid is 6 km west-northwest of Bissett Lake, where uranium, copper, and silver mineralization occurs at three sites as impregnations and as fracture fillings in association with lamprophyre dykes within Kazan arkose (Miller, 1980). Near the dykes, the approximate differences in metal levels between 'background' and mineralized bedrock are 17 vs. 500-15 000 ppm for Cu, 2.0 vs. 12-2500 ppm for U, and

c)



d)

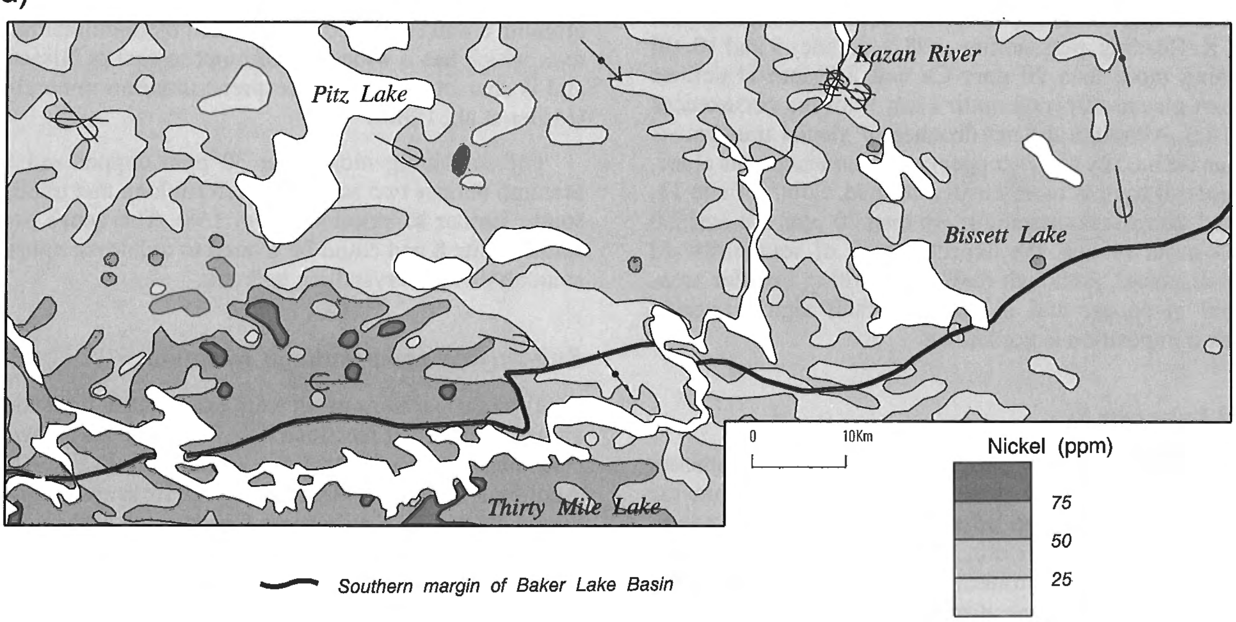


***Figure 13.** (cont.)*

e)

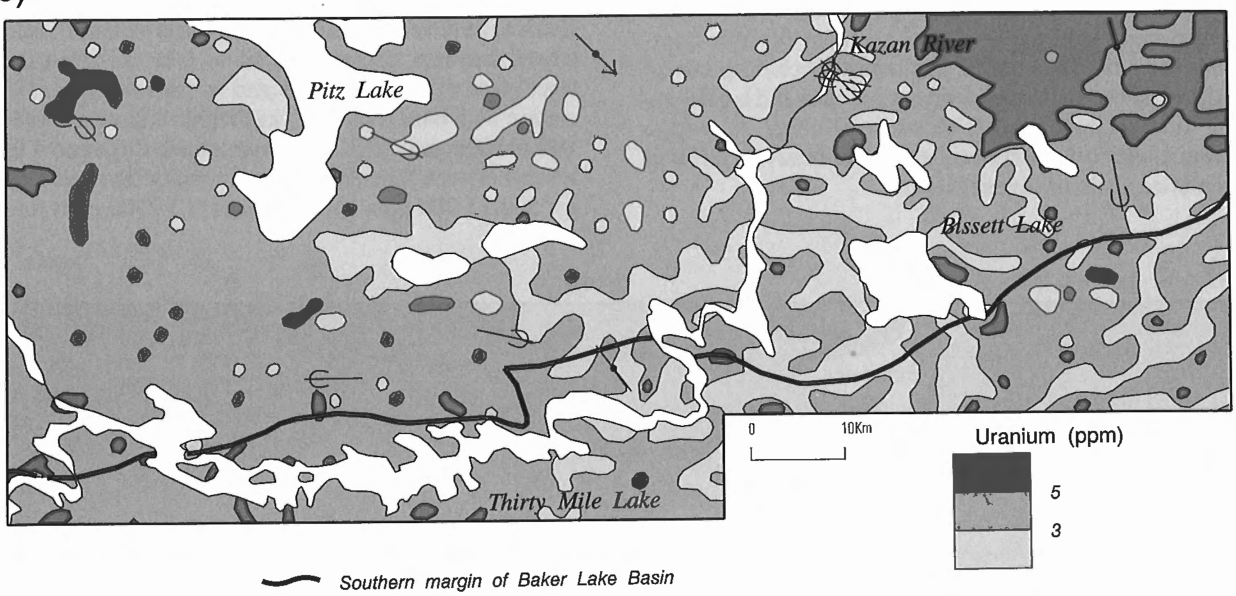


Figure 13. *(cont.)*

20 vs. 35 ppm for Zn (Miller, 1980). Samples were collected 100 m intervals along traverses about 500 m apart and oriented perpendicular to the regional direction of southeast ice flow (Fig. 14). Sample density was greater near known mineralization.

Within a hundred metres of the showings, till contains 30 to more than 200 ppm Cu, and 3.0 to more than 9.0 ppm U. Throughout most of the train, however, concentrations are only slightly greater than local background values of 10 to 20 ppm Cu, and 1.0 to 2.0 ppm U. Southeast of site 9, a broader area of elevated uranium occurs where mineralized erratics of unknown origin were found subsequent to the sampling program (K. Reading, pers. comm., 1982). At sites 9 and 10, till containing more than 20 ppm Cu and 2.0 ppm U defines southeast glacial dispersal up to 1 km from the occurrences (Fig. 14c). Although the net distance of glacial transport is less than defined by either copper or uranium isopleths alone, the dispersal train is more clearly defined. South of site 11, scattered samples containing more than 20 ppm Cu and 2.0 ppm U occur outside the expected path of southeastward glacial dispersal. Although they occur within broader areas enriched in copper and in uranium, their significance to bedrock composition is not known.

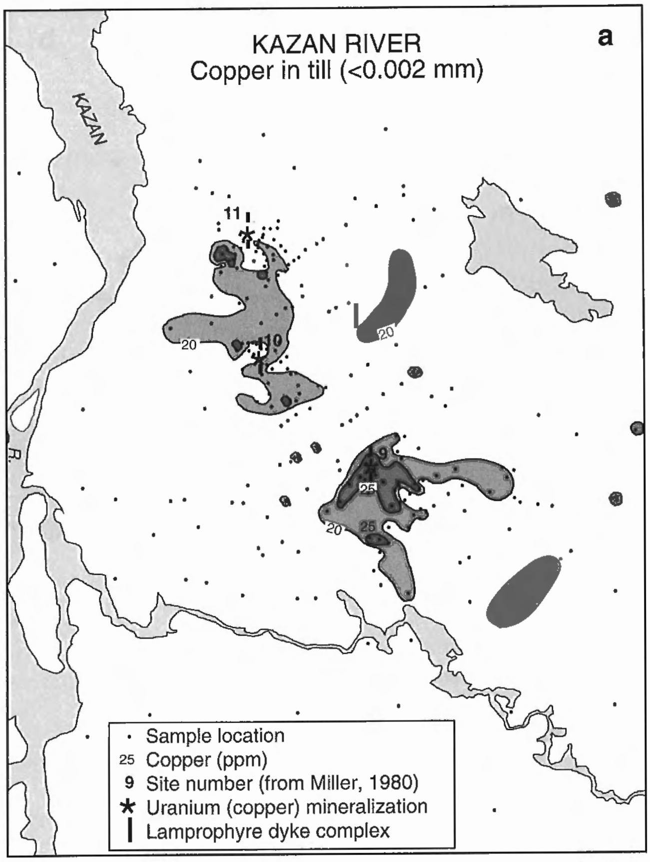
Bissett Lake (site 8)

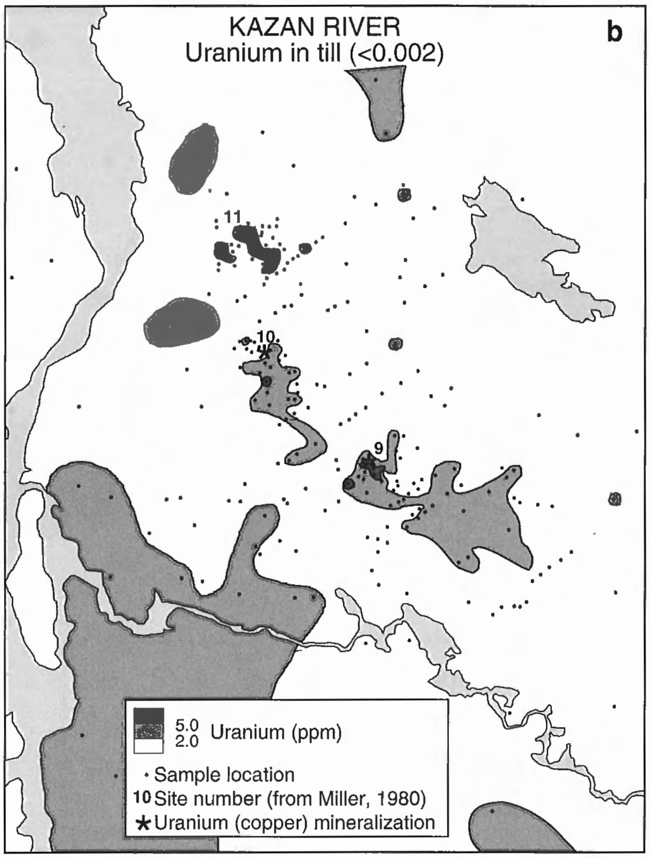
At the southeast end of Bissett Lake, uranium, selenium, copper, silver, and gold mineralization occurs within the South Channel Formation, adjacent to narrow north- south-trending dykes (Miller, 1980, site 8). In crystalline terrain south and east of there, mineralized occurrences also occur within Aphebian metasedimentary rocks (Miller and LeCheminant, 1985; Miller et al., 1986). Elevated concentrations of copper and uranium occur in till within an area that is larger than could be expected by glacial erosion and dispersal of the known mineralized occurrence (Fig. 15a, b). Copper concentrations greater than 30 ppm characterize a 5 km^2 area south and east of the mineralized showing, where copper concentrations are 40-80 ppm. Uranium concentrations are less than 3.0 ppm near the mineralization, although till containing more than 3 ppm U occurs at two sites north of Bissett Lake, up ice of the showing, and is widespread in crystalline bedrock south and east of the showing. No clear pattern of glacial dispersal can be interpreted from the uranium isopleths. South and east of site 8, the enrichment in uranium could be related to Aphebian metasedimentary bedrock which has a wide area of outcrop east of Bissett Lake and is characterized by widespread uranium mineralization (Miller et al., 1986).

Till containing more than 30 ppm copper and 3 ppm uranium defines two zones 1 to 1.5 km long that trend north-south, similar to striations (Fig. 15c). The zones originate south of site 8 and could be related to unknown mineralized source(s) within crystalline bedrock.

Sub-surface compositional variation

Stratigraphic sections of till were examined at three locations along Kazan River (sections KA, KB, KC) and at two adjacent sites south of Pitz Lake (sections PA, PB) (Fig. 5). Additional subsurface data are derived from overburden drill core collected by the Polargas Corporation along a segment of their north-south transect across the study region. The drill core samples were analyzed geochemically, and the heavy minerals of selected samples were examined (Shilts, 1980b; Paré, 1982).





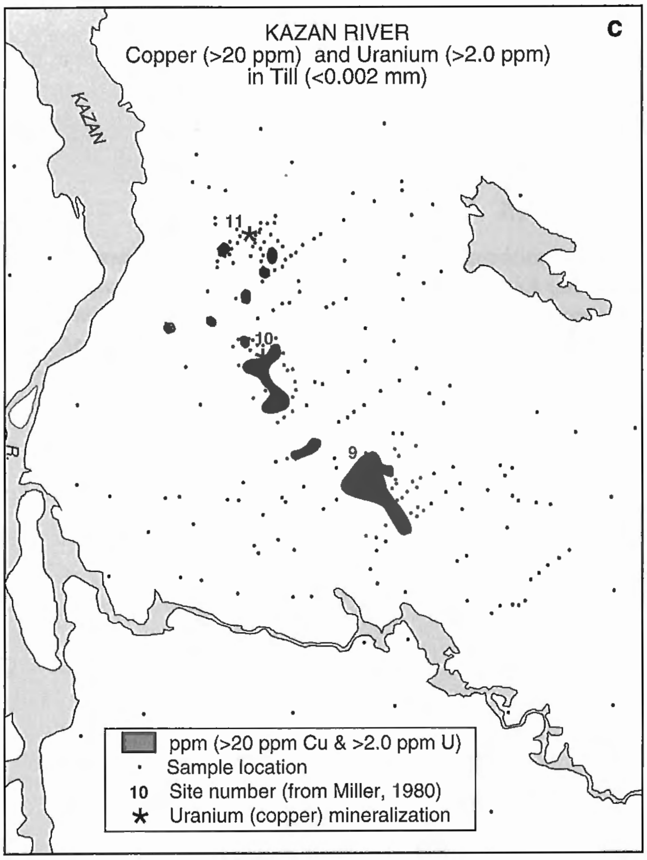
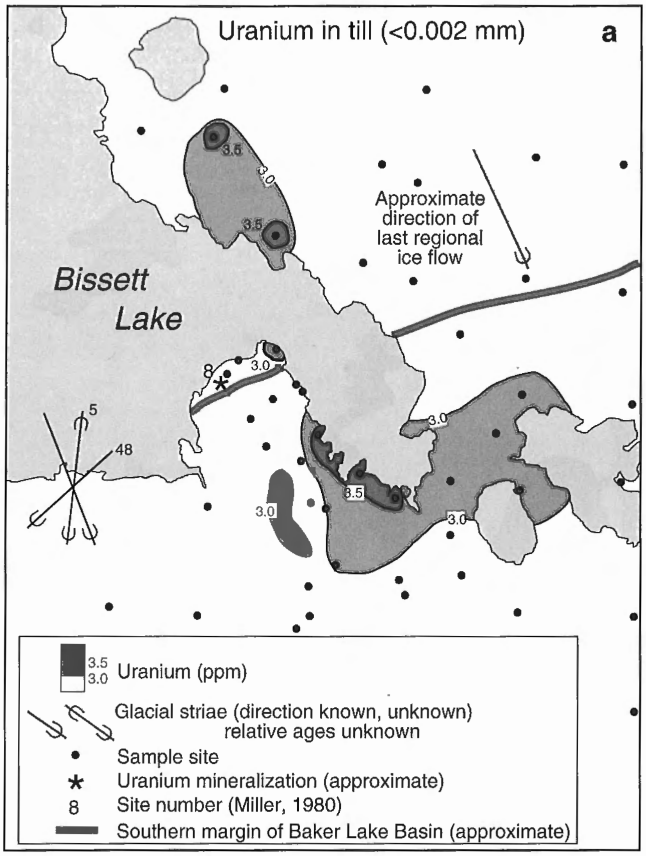
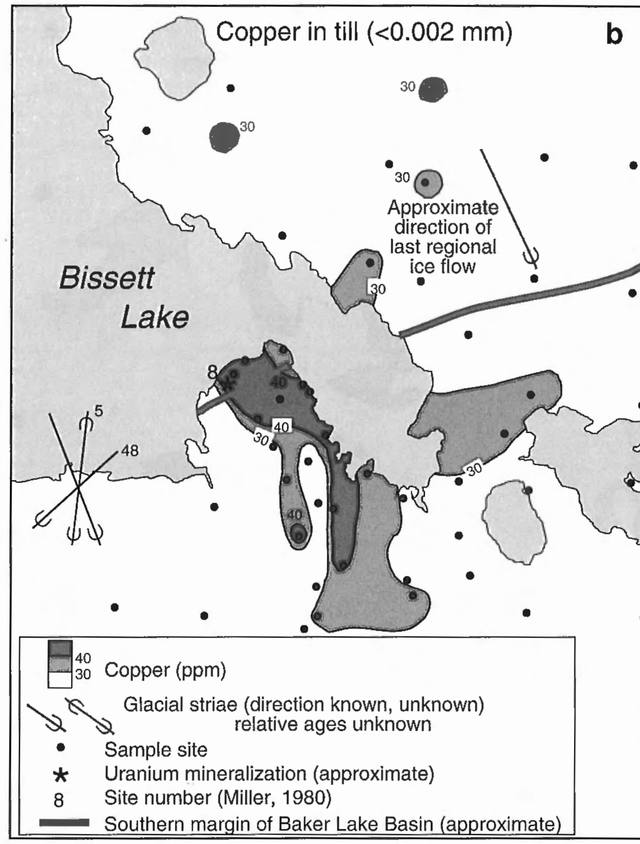


Figure 14.

*Till geochemistry at detailed scales near mineralization within the Kazan River sampling grid (Fig. 5). Uranium (**a**), copper (**b**), and copper (>20 ppm) and uranium (>2.0 ppm) (**c**) analyses define glacial dispersal trains trending southeast from three sites (sites 9, 10, 11: Miller, 1980).*





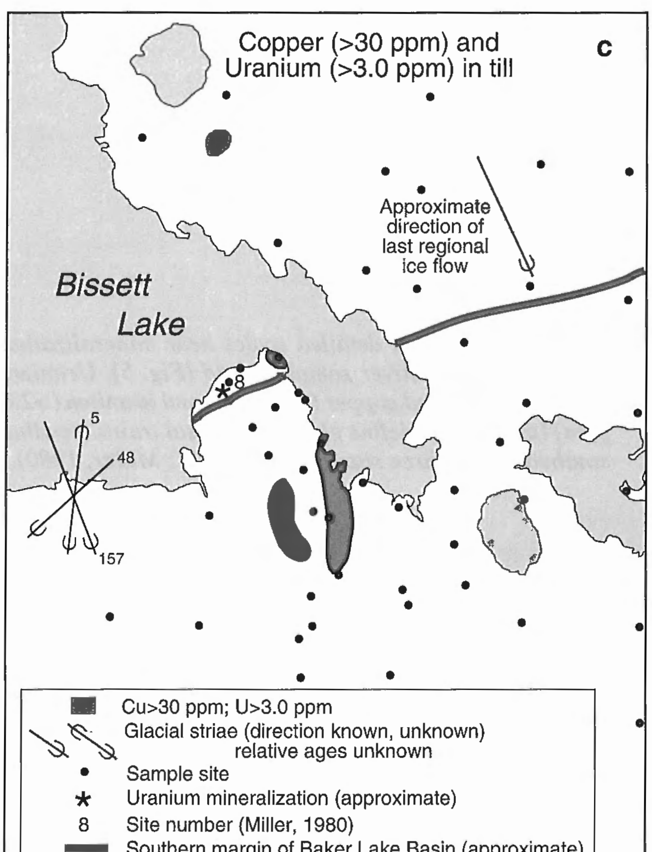


Figure 15.

*Till geochemistry at detailed scales near mineralization in the Bissett Lake sampling grid (Fig. 5). Uranium **(a)**, copper **(b)**, and copper (>30 ppm) and uranium (>3.0 ppm) **(c)** analyses define glacial dispersal patterns from an area where mineralized boulders occur within till, and indicate areas where bedrock could be generally enriched in those elements (site 8: Miller, 1980).*

Kazan River sections

Along Kazan River, three compositionally distinct tills are distinguished on the basis of lithology, referred to as Upper, Middle, and Lower. Correlations based on geochemistry appear contradictory; trace element concentrations generally increase with depth in section KB whereas they decrease in section KC. The Upper till is characterized by a relative abundance of Thelon Formation pebbles compared to Dubawnt Group. In sections KA and KB (Fig. 16, 17, 18) it is a red silty diamicton, characterized geochemically by low trace element concentrations (10-15 ppm Cu, 20-25 ppm Pb, 40-55 ppm Zn, and 20-30 ppm Ni) with little internal variation. In section KC (Fig. 19, 20), it is a sandy red-brown diamicton with greater trace element concentrations and variation, most notably for copper (20-30 ppm) and zinc (60-80 ppm). There, sandstone is less (30-40 wt. % in section KC compared with 40-50 wt. % in section KB), although it remains relatively abundant compared to Dubawnt Group pebbles in both sections. Compared with underlying units the Upper till contains greater amounts of micaceous, quartzose schists and phyllites that are presumed to have been derived from bedrock northwest of Baker Lake.

The Middle till occurs only in sections KB and KC. It is a red-brown sandy diamicton characterized similar proportions of Thelon Formation and Dubawnt Group pebbles. Within it, vertical geochemical trends and concentrations differ between sections. Trace element concentrations of the Middle till are generally greater in section KB, most notably for copper and nickel (20-30 ppm Cu and 30-80 ppm Ni in section KB compared with 10-20 ppm Cu and 20-30 ppm Ni in section KC). In section KC concentrations are less variable and tend to decrease with increasing depth. Compared with the Upper till, trace metal concentrations of the Middle till are either similar or less in KC, and are greater in section KB, notably so for nickel (>50 ppm versus 20 ppm) and zinc (>60 ppm versus 40 ppm).

The Lower till was found only in section KC. It is a red sandy silt diamicton similar in colour, texture, and geochemistry to the Upper till in sections KB and KA. Unlike Upper till in those sections, however, the proportions of Thelon Formation and Dubawnt Group (undifferentiated) pebbles are similar. In section KC, pebbles of Pitz Volcanic Rocks occur only in the Lower till.

Pitz Lake sections

Sections PA and PB are located 200 m apart along a stream flowing into southern Pitz Lake. They comprise red sandy silt till and are characterized by low trace element concentrations that increase slightly with depth (Fig. 21). Concentrations of copper, zinc, nickel, and uranium are slightly greater in till of section PB.

Overburden drill cores

Stratigraphic descriptions of overburden cores obtained along a north-south drilling transect across the western study area are from Shilts (1980b), from unpublished summaries prepared by W.W. Shilts, and from observations made by the author (Fig. 5, 22). Grey till in drill cores is derived largely from crystalline terrain, whereas red till includes a significant component of red sedimentary rock of the Dubawnt Group. The regional boundary between surficial deposits of red and grey tills lies north of Pitz Lake, along Thelon River (Cunningham and Shilts, 1977) (Fig. 5). Trace element concentrations in red till are much less than in grey till. Geochemical fence diagrams of the borehole transect show a decrease in trace element concentration with depth in red till. In contrast, the lower parts of grey till are enriched in copper, zinc, and nickel compared with the upper parts (Fig. 23a, b, c).

Near Thelon River, drill core (hole 135-1-4) presents a complex stratigraphy, including grey and grey-brown till, pink till, and an inter-till waterlain unit of either interstadial or interglacial rank (Fig. 22) (Shilts, 1980b). Variations in grey likely reflect change in the amount of schistose debris which occurs in bedrock near the boreholes. No clasts derived from Proterozoic sources to the west-northwest and to the southeast were found in the grey and grey-brown tills, and they are geochemically similar to till in crystalline terrain to

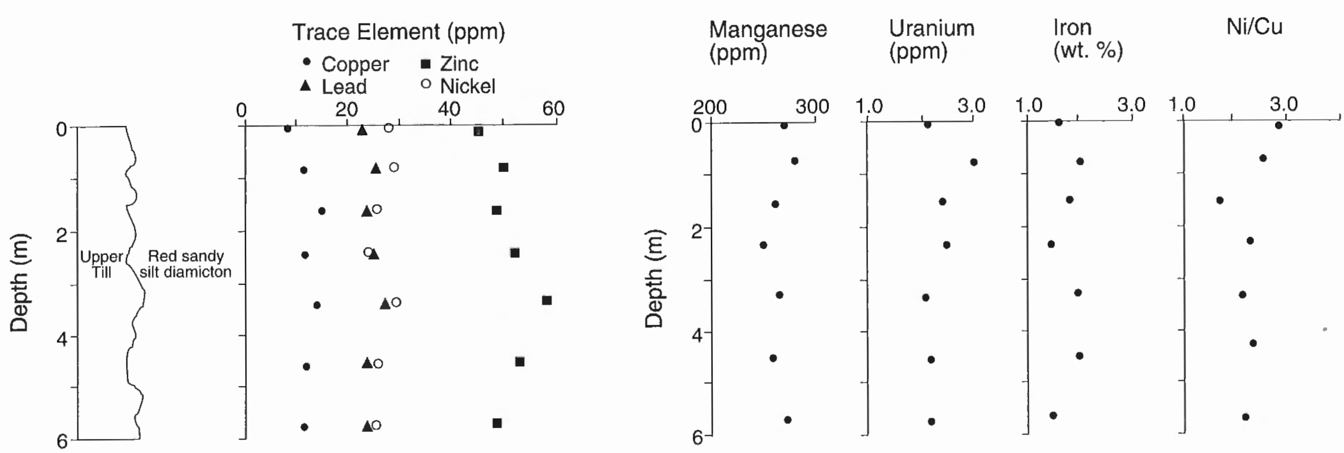


Figure 16. Geochemical profiles of section KA: red, sandy silt diamicton (Upper till). See Figure 5 for section location.

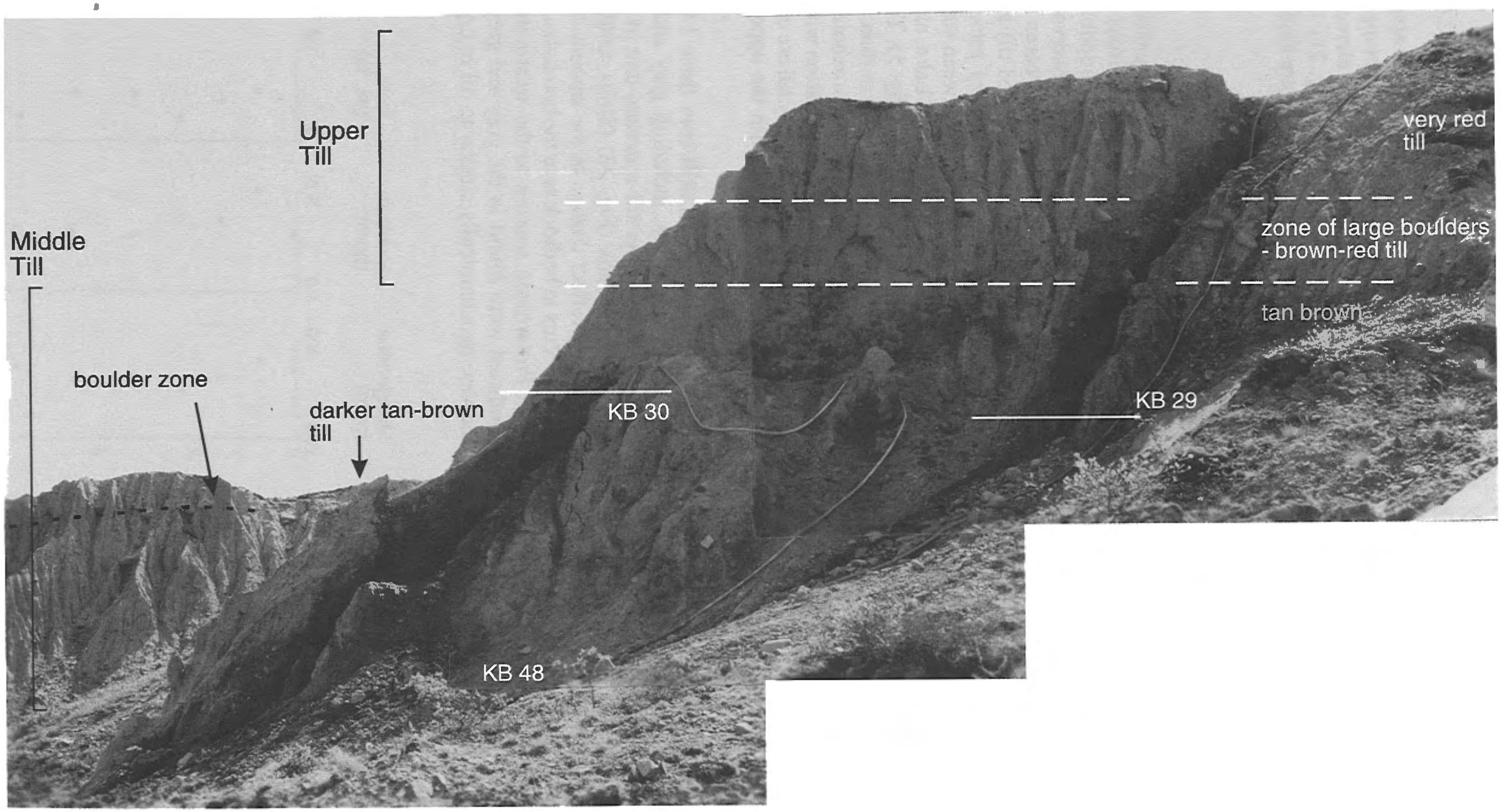


Figure 17. *Photograph of section KB along Kazan River. Thickness and poorly sorted character of Upper and Middle tills are evident. Sampling trenches appear dark; firehose provides scale. See Figure 5 for section location (right to left: GSC 203095, 203095 A, B).*

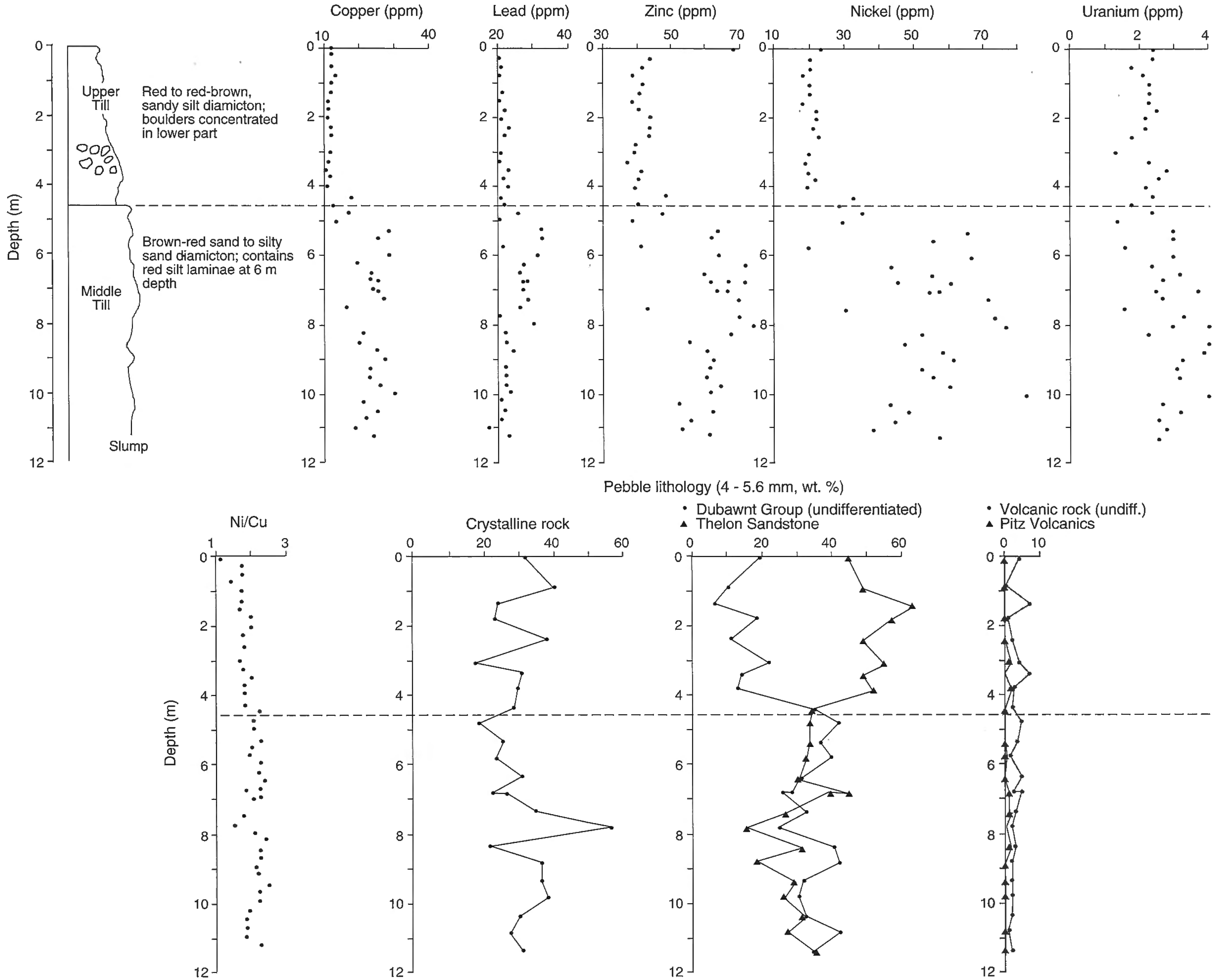


Figure 18. *Geochemical and lithological profiles of section KB. The Upper till is distinguished by a relative abundance of Thelon Sandstone pebbles and low concentrations of trace and minor elements. The underlying Middle till contains equivalent proportions of Thelon Sandstone and Dubawnt Group pebbles, and greater concentrations of trace and minor elements. Pitz Volcanic Rocks are more common in the Middle till.*

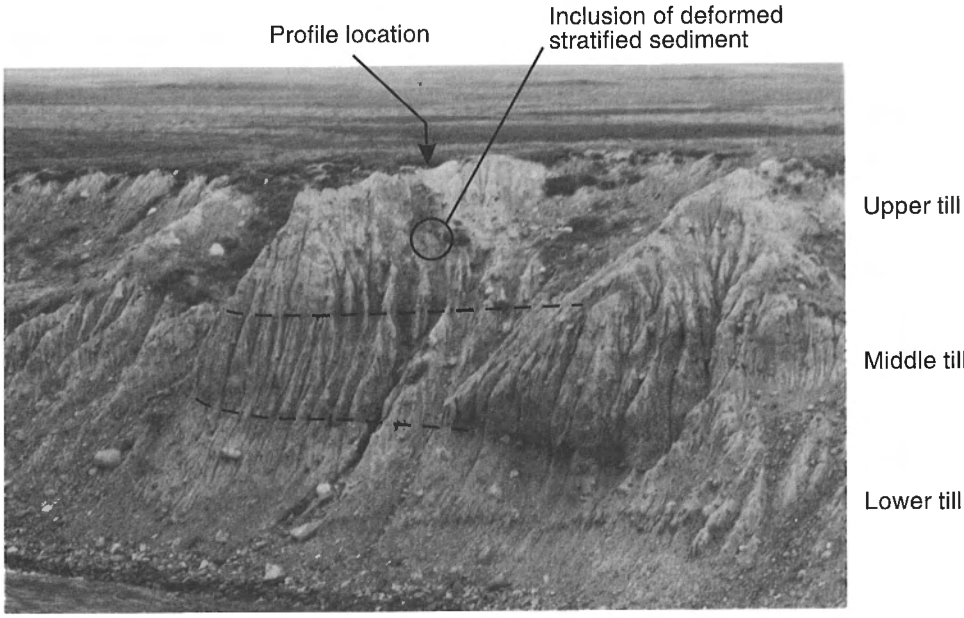


Figure 19. Section KC along Kazan River. The section includes Upper, Middle and Lower tills. (GSC 1992-026C). The Lower till contains pebbles of Pitz Volcanic Rocks which do not occur in overlying surficial deposits. For scale, section is approximately 16 m high above Kazan River. See Figure 5 for section location.

the north and northeast. Those observations are consistent with the interpretation of Shilts (1980b) that the grey tills are the product of southwestward ice flow. Within the pink till, a fragment of porphyritic volcanic rock was found that serves as an indicator erratic of net glacial transport direction. The clotted texture of the white feldspar crystals within the fragment, along with the presence of mica and absence of quartz eyes, indicates it was derived from bedrock of Christopher Island Formation (A.N. LeCheminant, pers. comm., 1987). The nearest and most extensive outcrop of Christopher Island Formation is south of the borehole between Princess Mary and Pitz lakes, and it is the most likely bedrock source. Christopher Island Formation that occurs more than 100 km west of the borehole site is not considered likely to have been the source due to its limited areal extent.

In hole 135-1-3 near Thelon River, a grey silty till overlies a grey sandy till containing significantly greater amounts of copper (Fig. 23a) and lead (not shown). "The magnitude of the maximum trace element concentrations [within the lowermost grey sandy till] ... suggests that one or more significant zones of mineralization lie in close proximity to this site." (Shilts, 1980b).

DISCUSSION AND CONCLUSIONS

Controls on till geochemistry

In till, enrichment of trace elements in the clay-sized fraction, compared to coarser fractions (Fig. 7, 8), has been observed elsewhere (e.g. Shilts, 1973, 1984, 1993; DiLabio, 1979; Peuraniemi, 1982). It reflects mineralogical differences among size fractions that result from differential glacial comminution of rock-forming minerals during glacial transport. Minerals released from rock fragments are ground preferentially to different size fractions according to physical properties, such as size, hardness, and cleavage (Dreimanis and Vagners, 1971; Ridler and Shilts, 1974; Nevalainen, 1989). Soft cleavable minerals, such as phyllosilicates, and amphiboles tend to concentrate in the clay-sized fraction, whereas quartz, feldspar, and resistate minerals characterize silt-sized and coarser fractions (Soveri and Hyppa, 1966). Quartz and feldspar, which can be considered as metal-poor diluents, dominate the silt-and sand-sized fractions and lower trace element concentrations. Likewise, physical differences among rock types comprising the pebble and coarser fractions can be reflected by lithological partitioning. Crystalline rocks, for example, are more likely to remain as coarser fragments than Thelon Sandstone which is much softer and more easily disaggregated.

Due to the linkages among grain size, mineralogy, and trace element geochemistry, postglacial, physical processes can lead to geochemical variation in surficial sediments (Shilts, 1973, 1977). Where clay-sized material is preferentially removed from surficial sediments by washing, the remaining coarser lag tends to be enriched in quartz and feldspar and thus geochemically depleted. In contrast, differences in either grain shape or density do not lead to differential winnowing of clay-sized minerals, and the geochemical properties of that fraction are less likely to be affected by postglacial physical processes. Within mudboils no significant geochemical differences are evident among the clay-sized fractions of carapace, thawed mud substrate, and frozen ground.

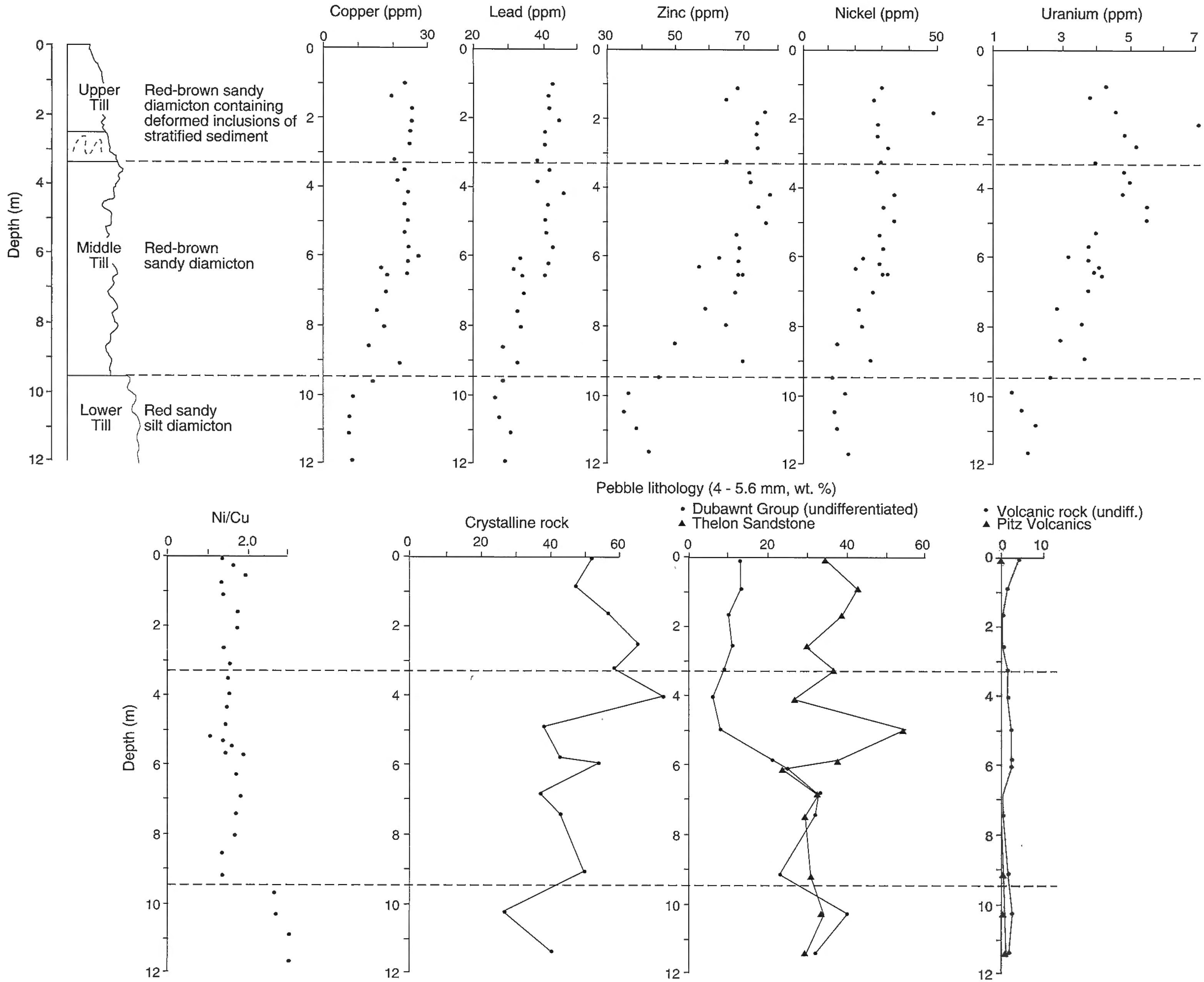


Figure 20. *Geochemical and lithological profiles of section KC. The Lower till is similar in geochemistry and lithology to the Upper till in sections KA and KB. The compositional differences relate to the section's location within the context of glacial dispersal trains and glacial transport direction. Pebbles of Pitz Volcanic Rocks in the Lower till define earlier eastward ice flow.*

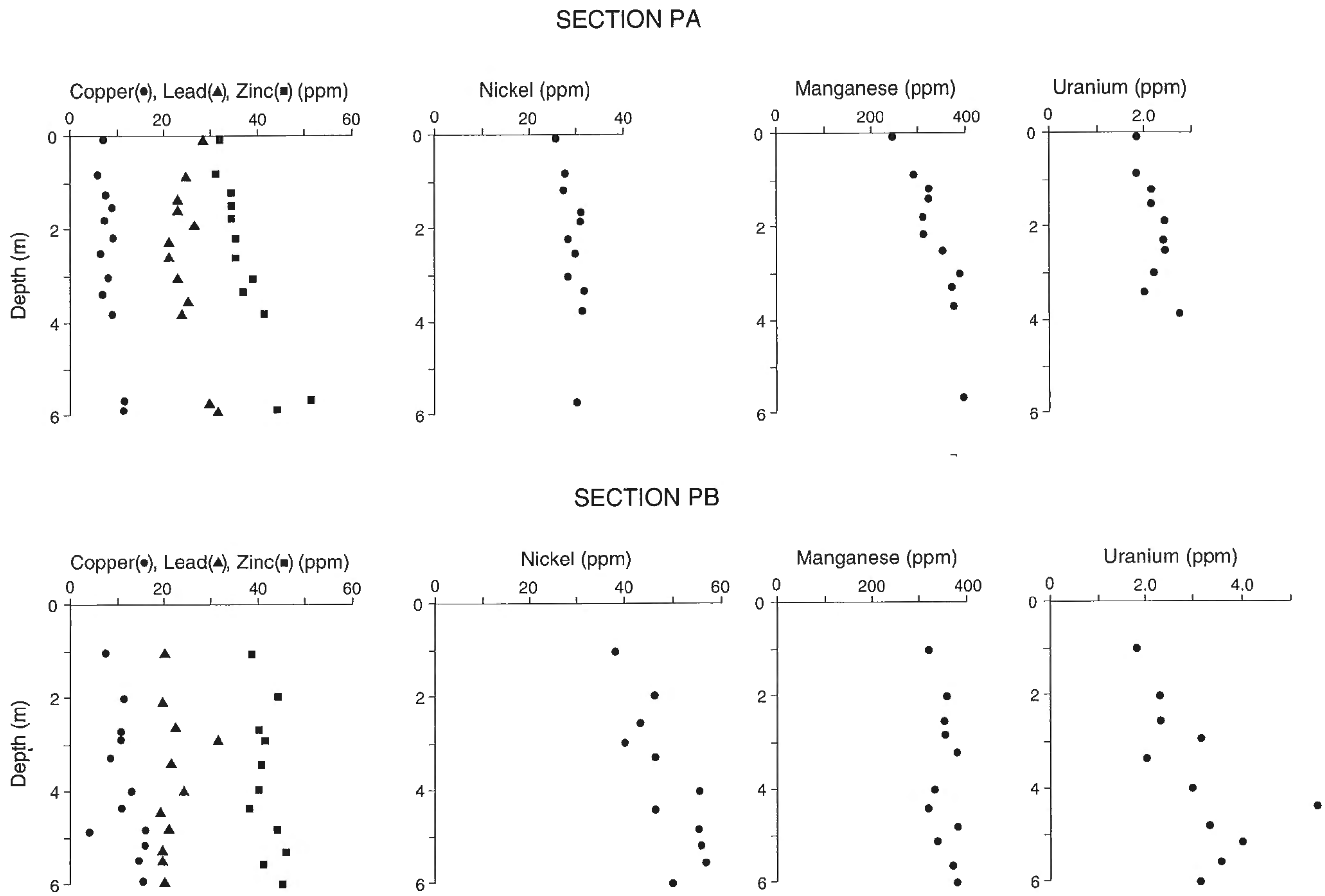


Figure 21. *Geochemical profiles of sections PA and PB (Fig. 5).*

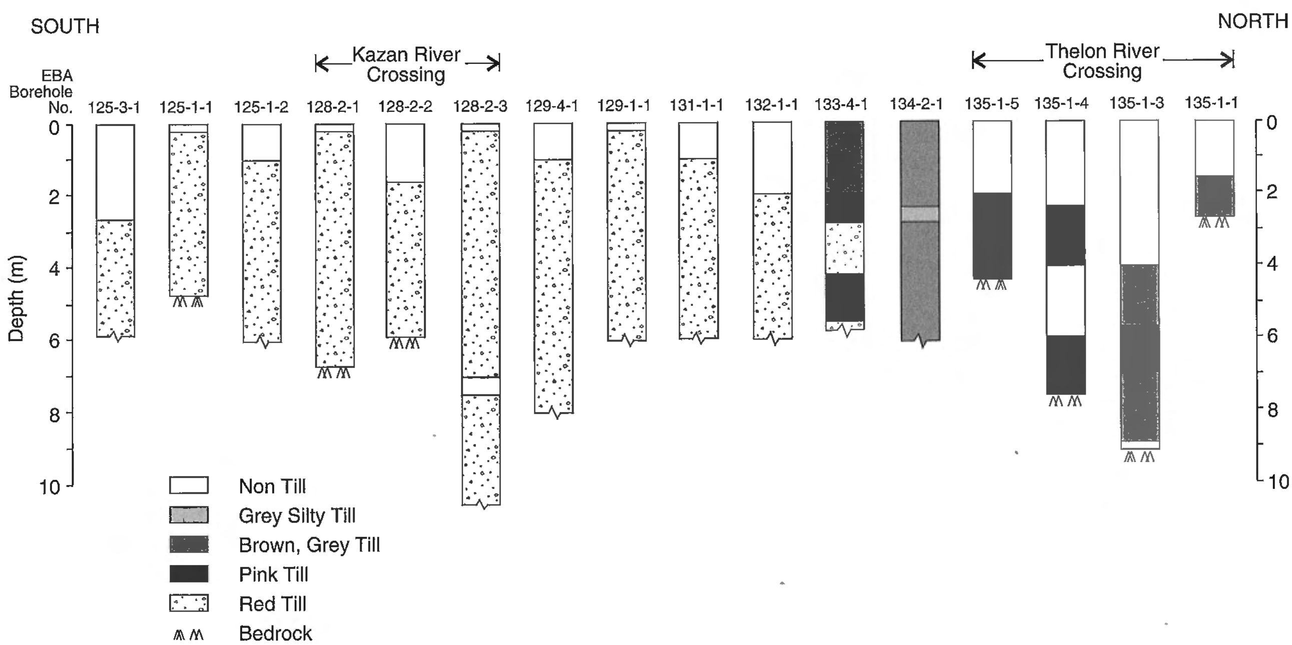
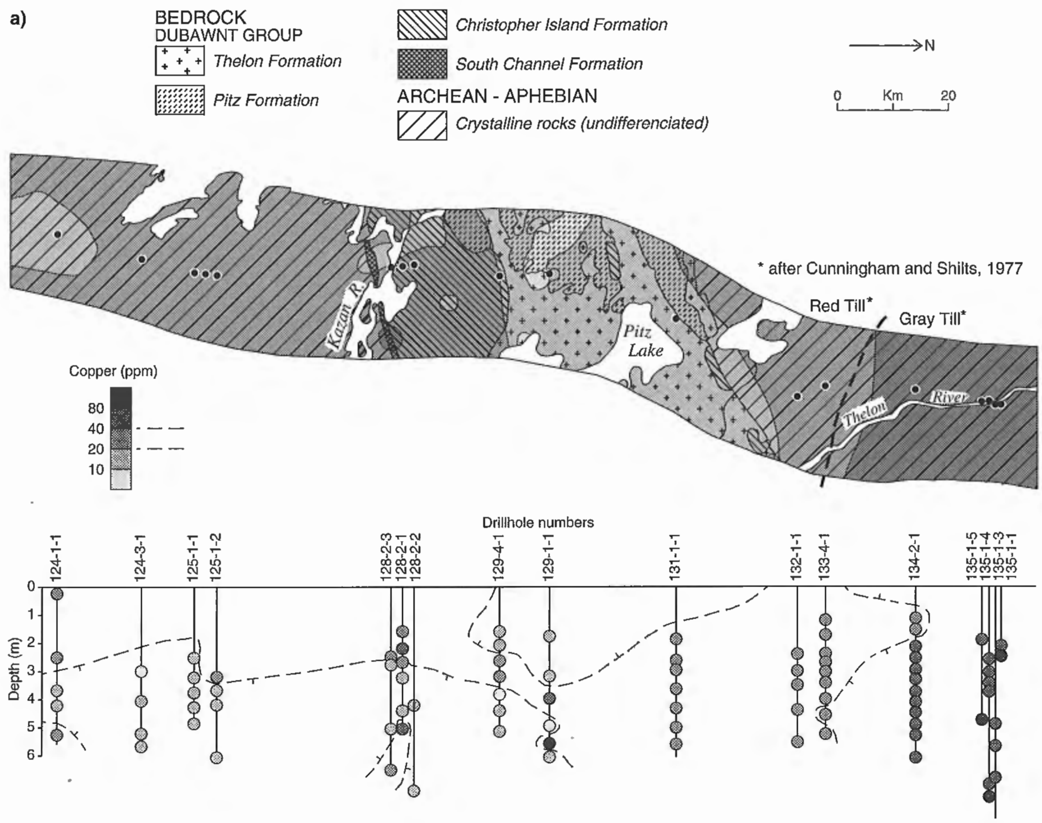


Figure 22. *Stratigraphic summaries of drill core collected along the Polargas Pipeline transect (see Fig. 5, modified after W.W. Shilts, pers. comm., and Shilts, 1980b).*


a)
BEDROCK
DUBAWNT GROUP
Thelon Formation
Pitz Formation
Christopher Island Formation
South Channel Formation
ARCHEAN - APHEBIAN
Crystalline rocks (undifferenciated)
N
0 Km 20
* after Cunningham and Shilts, 1977
Red Till*
Gray Till*
Kazan R.
Pitz Lake
Thelon River
Copper (ppm)
80
40
20
10
Drillhole numbers
124-1-1
124-3-1
125-1-1
125-1-2
128-2-3
128-2-1
128-2-2
129-4-1
129-1-1
131-1-1
132-1-1
133-4-1
134-2-1
135-1-5
135-1-4
135-1-3
135-1-1
Depth (m)
0
1
2
3
4
5
6

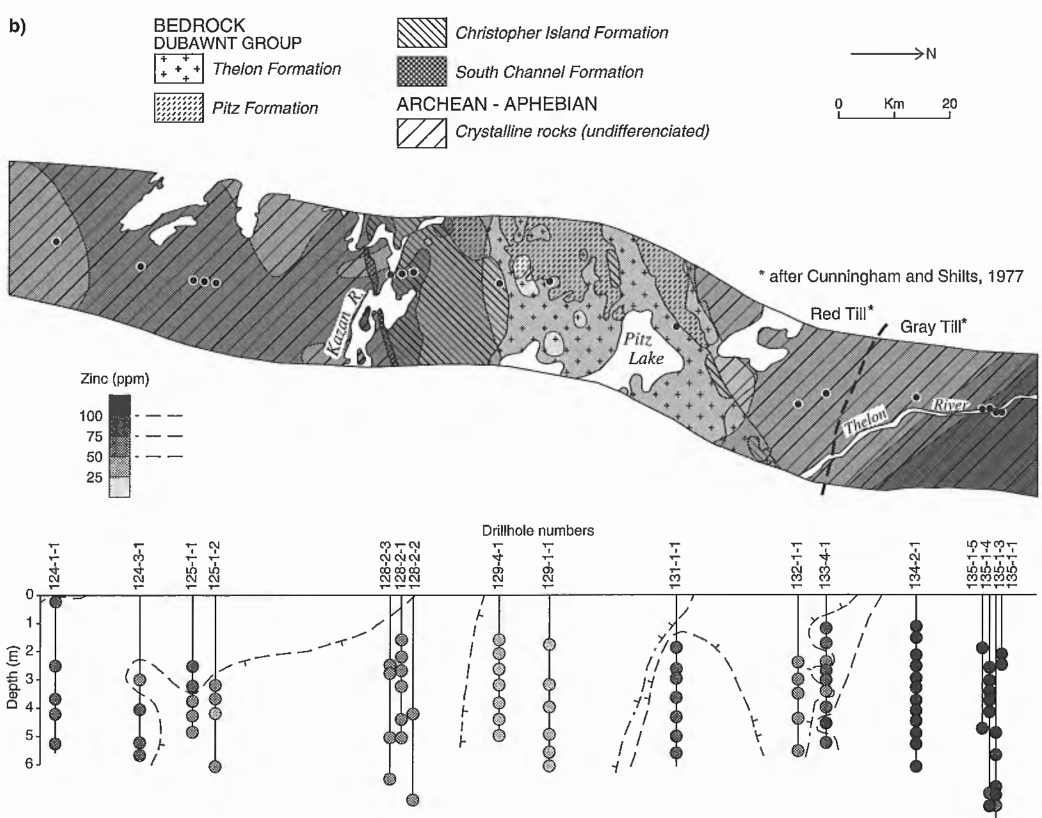

b)
BEDROCK
DUBAWNT GROUP
Thelon Formation
Pitz Formation
Christopher Island Formation
South Channel Formation
ARCHEAN - APHEBIAN
Crystalline rocks (undifferenciated)
N
0 Km 20
* after Cunningham and Shilts, 1977
Red Till*
Gray Till*
Kazan R.
Pitz Lake
Thelon River
Zinc (ppm)
100
75
50
25
Drillhole numbers
124-1-1
124-3-1
125-1-1
125-1-2
128-2-3
128-2-1
128-2-2
129-4-1
129-1-1
131-1-1
132-1-1
133-4-1
134-2-1
135-1-5
135-1-4
135-1-3
135-1-1
Depth (m)
0
1
2
3
4
5
6

Figure 23.

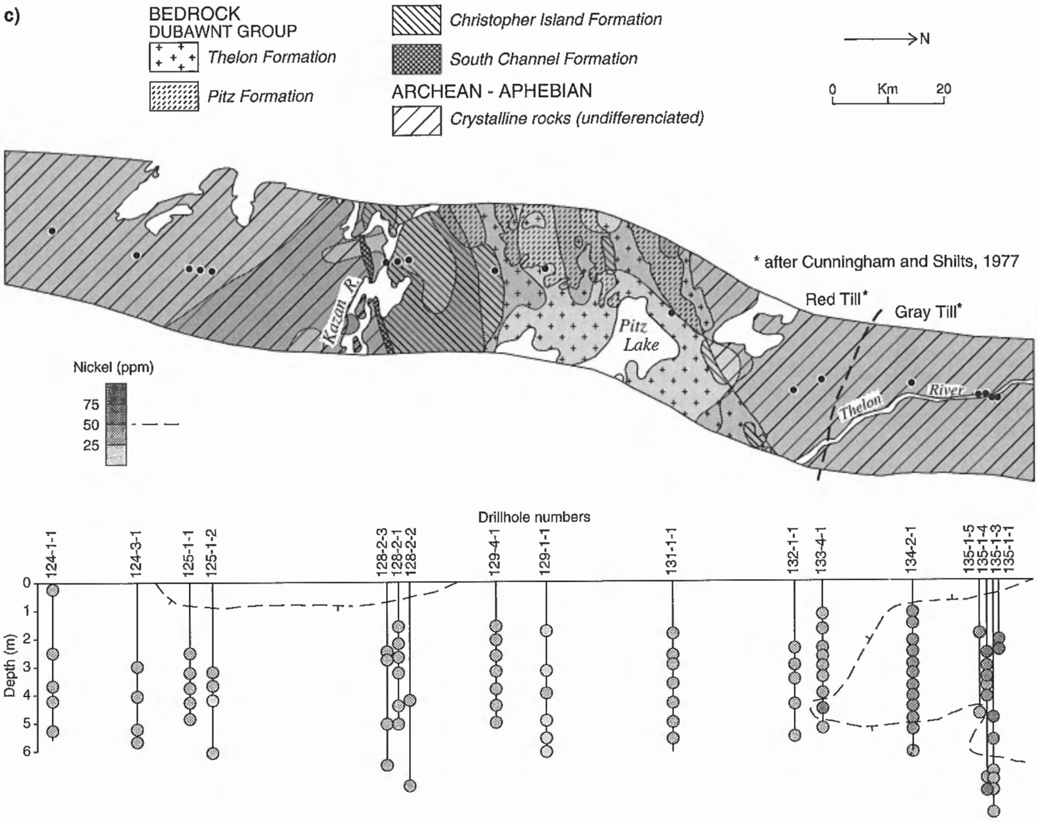


***Figure 23.** Bedrock geology and till geochemistry for copper (**a**), zinc (**b**), and nickel (**c**) in surface and subsurface samples along the Polargas Pipeline transect (see Fig. 5). Regional geochemical variations in surficial sediments are based on Figure 11.*

Geochemical differences within mudboils are slight and difficult to resolve in terms of provenance, weathering, and analytical variation. The clay-sized fraction does not reflect differential washing of carapace and thawed mud substrate, and the greatest geochemical contrasts are between till and non-till sediments, and sediment with iron and manganese staining indicative of weathering. Within active layer samples, labile minerals such as sulphides are likely oxidized. Trace elements released by their weathering are 'fixed' or otherwise scavenged by clay-sized minerals, leading to geochemical enrichment in that size fraction (e.g. Shilts, 1977, 1984, 1993). Compared with active layer samples, frozen till near uranium and copper mineralization at Kazan River is enriched in uranium and depleted in copper. The samples were collected near the base of the active layer and, although frozen at the time of collection, they may not have remained frozen and unweathered since glaciation. The geochemical differences between frozen and non-frozen till could result from either: 1) weathering differences between frozen and thawed sediment as reported by Shilts (1977) or, 2) primary, vertical variation in till composition, with sediment at and below the freeze-thaw boundary more closely related to nearby bedrock mineralization. Near uranium mineralization at Kazan Falls, much greater geochemical variation has been observed within mudboils (DiLabio, 1979; Fig. 3, p. 93).

Till pebble lithology and geochemistry

Lithological analysis defines provenance, and distance and direction of glacial transport, and it serves as a context for interpretation of till geochemistry. Geochemical analysis reflects the proportions and the mineralogical and geochemical properties of the diverse bedrock types comprising till, and thus has a close linkage with lithology (Fig. 18, 20). Geochemical correlations with Crystalline Rock pebbles are positive, most strongly for copper (0.630) and zinc (0.639), and less so for manganese (0.570), iron (0.496), and lead (0.446) (Table 2). In contrast, correlations with Dubawnt Group pebbles are negative and weak (<0.500); they are strongest between Thelon Formation and copper (-0.476), iron (-0.537), and manganese (-0.561). Pitz Volcanic Rocks are negatively correlated with zinc (-0.474). No clear lithological control is evident for either nickel or uranium. Due to their small size, unless a diagnostic property is evident provenance cannot be reliably determined, and indicator pebbles reflect some unknown fraction of all the detritus originating from a source. Correlations between till geochemistry and specific sources (e.g. Pitz Volcanic Rocks) are likely weaker than if a basis for precise pebble classification were available.

Table 2. Correlation coefficients for till geochemistry **(a)** and number of samples correlated **(b)**.

(a)	Cu	Fe	Mn	Ni	Pb	U(f)	U(d)	Zn	Dub. (Und.)	Thel. (Sed)	Pit Vol.	Other Vol.	Crys. (Undif.)
Cu	1.000	.747	.595	.188	.585	.192	.252	.812	-.044	-.476	-.382	-.159	.630
Fe	.747	1.000	.626	.045	.639	.360	.386	.842	.196	-.537	-.280	-.265	.496
Mn	.595	.626	1.000	.158	.609	.214	.349	.689	.063	-.561	-.265	-.175	.570
Ni	.188	.045	.158	1.000	.189	.039	.053	.169	.177	-.334	-.058	.226	.236
Pb	.585	.639	.609	.189	1.000	.243	.345	.613	-.006	-.304	-.346	-.039	.446
U(f)	.192	.360	.214	.039	.243	1.000	.798	.285	-.208	-.059	-.207	-.137	.306
U(d)	.252	.386	.349	.053	.345	.798	1.000	.349	-.102	-.180	-.093	-.002	.326
Zn	.812	.842	.689	.169	.613	.285	.349	1.000	-.111	-.413	-.474	-.132	.639
Dub (Und.)	-.044	.196	.063	.177	-.006	-.208	-.102	-.111	1.000	-.398	.307	.207	-.348
Thel. (Sed)	-.476	-.537	-.561	-.334	-.304	-.059	-.180	-.413	-.398	1.000	.004	-.173	-.507
Pit. Vol.	-.382	-.280	-.265	-.058	-.346	-.207	-.093	3-.474	.307	.004	1.000	.308	-.521
Other vol.	-.159	-.265	-.175	.226	-.039	-.137	-.002	-.132	.207	-.173	.308	1.000	-.405
Crys. (Undif.)	.630	496	.570	.236	.446	.306	.326	.639	-.348	-.507	-.521	-.405	1.000

(b)	Cu	Fe	Mn	Ni	Pb	U(f)	U(d)	Zn	Dub. (Und.)	Thel. (Sed)	Pit Vol.	Other Vol.	Crys. (Undif.)
Cu	1994	1050	1050	1982	1994	1988	1868	1994	190	190	190	190	190
Fe	1050	1050	1050	1038	1050	1044	945	1050	83	83	83	83	83
Mn	1050	1050	1050	1038	1050	1044	945	1050	83	83	83	83	83
Ni	1982	1038	1038	1982	1982	1976	1868	1982	190	190	190	190	190
Pb	1994	1050	1050	1982	1994	1988	1868	1994	190	190	190	190	190
U(f)	1988	1044	1044	1976	1988	1988	1868	1988	190	190	190	190	190
U(d)	1868	945	945	1868	1868	1868	1871	1868	183	183	183	183	183
Zn	1994	1050	1050	1982	1994	1988	1868	1994	190	190	190	190	190
Dub (Und.)	190	83	83	190	190	190	183	190	190	190	190	190	190
Thel. (Sed)	190	83	83	190	190	190	183	190	190	190	190	190	190
Pit. Vol.	190	83	83	190	190	190	183	190	190	190	190	190	190
Other vol.	190	83	83	190	190	190	183	190	190	190	190	190	190
Crys. (Undif.)	190	83	83	190	190	190	183	190	190	190	190	190	190

The strong linear correlations between lithology and geochemistry reflect mixing of a bipartite 'end-member' system comprising Crystalline Rock enriched in trace elements and Dubawnt Group debris, Thelon Sandstone in particular, depleted in trace elements. Graphs of copper plotted against Crystalline Rock and Thelon Sandstone illustrate the linear relations between lithology and geochemistry (Fig. 24). Samples containing more than 25 wt. % Thelon Sandstone generally contain less than 20 ppm copper, and copper concentrations increase directly with the concentration of Crystalline Rock. For other elements, such as Pb, Mn, and Fe, concentrations increase directly with the concentration of Crystalline Rock although no relation with Thelon Sandstone is evident.

Rocks that either are preferentially eroded or comminuted to the clay-sized fraction, or both, can have a disproportionate influence on till geochemistry, particularly if the detritus is geochemically distinctive. Dubawnt Group bedrock is little metamorphosed and relatively soft, and it has contributed proportionally greater amounts of debris for its area of exposure than crystalline rock. It is also more readily ground to the finer size fractions subject to geochemical analyses. Thelon and Pitz formations are preferentially susceptible to glacial erosion because of deep preglacial weathering (Blake, 1980), and they define prominent local trains. Although Thelon Sandstone is easily broken and disaggregated, it can be readily traced within surficial deposits as rounded quartz pebbles which are resistant to glacial comminution. Kaolin and hematite derived from the sandstone, and sedimentary bedrock of the Dubawnt Group in general (Dean, 1967), are metal-poor and lead to negative correlations between that bedrock type and till geochemistry (Table 2; Fig. 24). Thus the glacial dispersal train of Thelon Sandstone is geochemically defined by an absence of trace metals. It can be traced tens to hundreds of kilometres from its source, masking the compositional expression of other bedrock types down-ice. The large extent of the train reflects: 1) the abundance of metal-poor detritus, including kaolin and kaolinized feldspar, and their geochemical contrasts with Crystalline Rock minerals; 2) preferential glacial erosion of the source; 3) the comparative resistance of minerals within crystalline rocks to glacial comminution to the clay-sized fraction; and 4) the large geochemical contrasts between clay-sized materials of those two geological terrains.

Geochemical contour intervals used here are arithmetic and do not emphasize variation at the higher range of concentration, unlike intervals commonly applied in geochemical exploration (e.g. Rose et al., 1979). The contours define glacial dispersal trains impoverished in trace metals, 'negative' dispersal trains, and enriched in them, 'positive' trains (Klassen and Shilts, 1977). Within the study area, geochemical dispersal trains are more limited in their down-ice extent than those defined by lithology, a feature also observed elsewhere (e.g. Lehmuspelto, 1987; Klassen and Thompson, 1993). The dispersal train of Thelon Sandstone pebbles (>20 wt. %) is more extensive than defined by either low copper (<10 ppm) or zinc (<20 ppm) concentrations, reflecting the abrasion resistance of quartz pebbles and dilution of the finer fraction during glacial transport. The fine fraction subject to geochemical analysis represents glacial debris from a much wider area than that of coarser fractions (Nevalainen, 1989, p. 65). It is the result of comminution of coarse debris

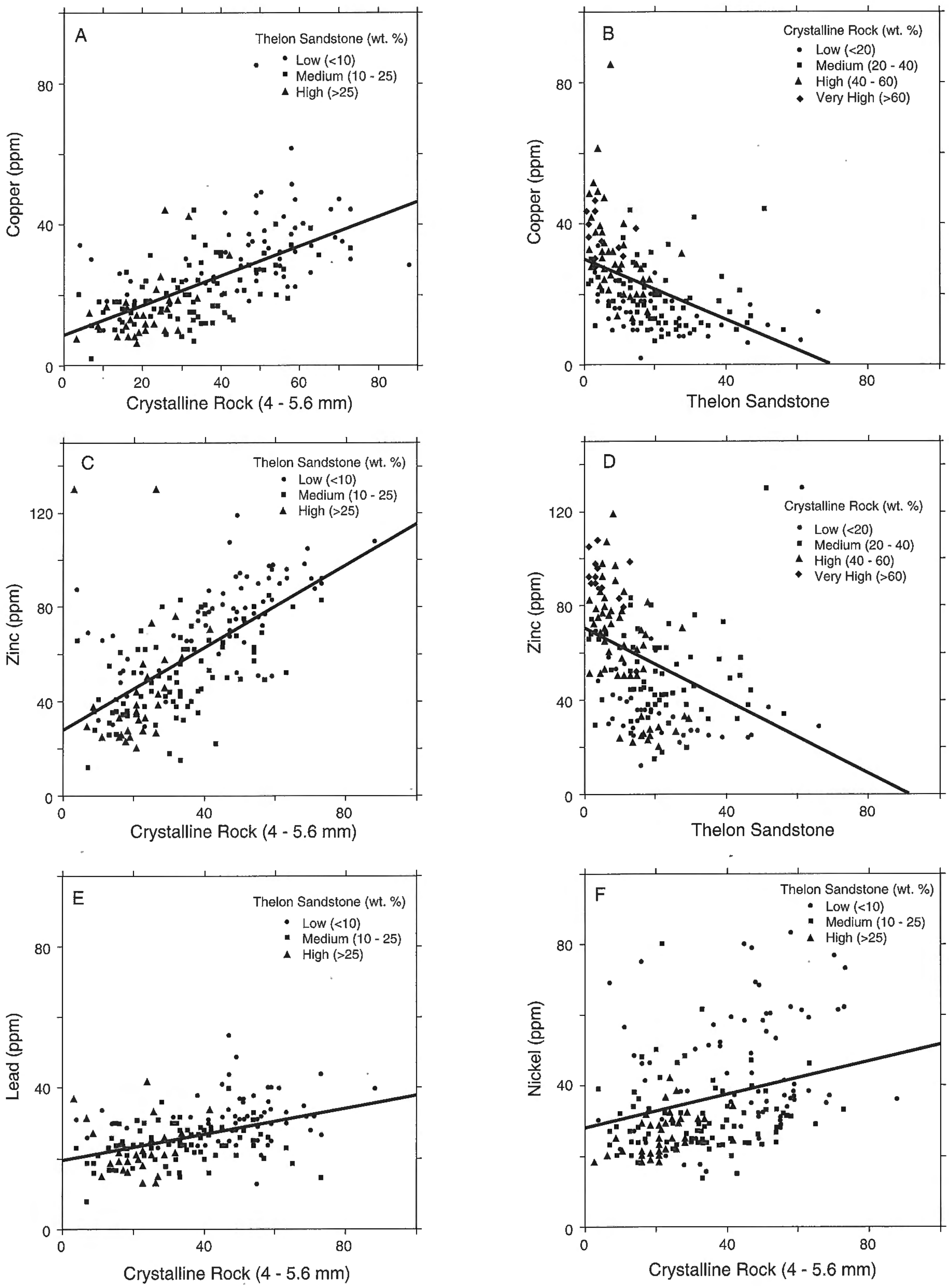

A
Thelon Sandstone (wt. %)
Low (<10)
Medium (10 - 25)
High (>25)
Copper (ppm)
0
40
80
0
20
40
60
80
Crystalline Rock (4 - 5.6 mm)
B
Crystalline Rock (wt. %)
Low (<20)
Medium (20 - 40)
High (40 - 60)
Very High (>60)
Copper (ppm)
0
40
80
0
40
80
Thelon Sandstone
C
Thelon Sandstone (wt. %)
Low (<10)
Medium (10 - 25)
High (>25)
Zinc (ppm)
0
40
80
120
0
40
80
Crystalline Rock (4 - 5.6 mm)
D
Crystalline Rock (wt. %)
Low (<20)
Medium (20 - 40)
High (40 - 60)
Very High (>60)
Zinc (ppm)
0
40
80
120
0
40
80
Thelon Sandstone
E
Thelon Sandstone (wt. %)
Low (<10)
Medium (10 - 25)
High (>25)
Lead (ppm)
0
40
80
0
40
80
Crystalline Rock (4 - 5.6 mm)
F
Thelon Sandstone (wt. %)
Low (<10)
Medium (10 - 25)
High (>25)
Nickel (ppm)
0
40
80
0
40
80
Crystalline Rock (4 - 5.6 mm)

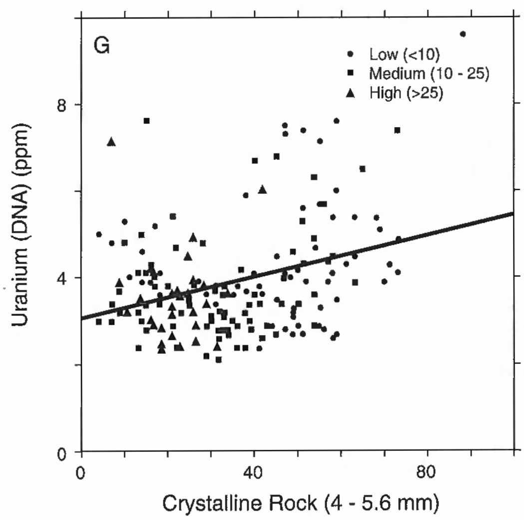
Figure 24.

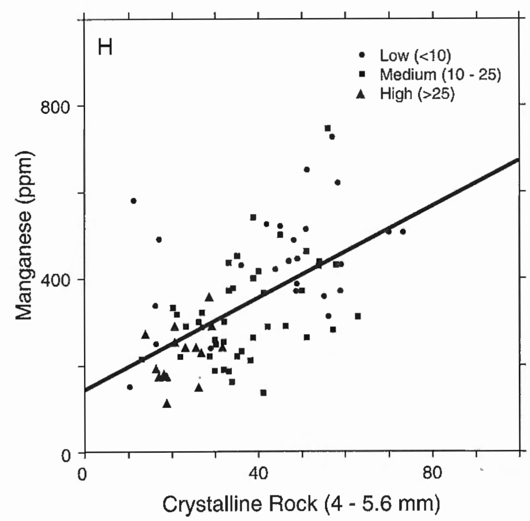
transported near the base of the ice sheet and bedrock erosion, and its composition changes more rapidly with distance of glacial transport. Englacially transported clasts are not subject to continued comminution through intraclast contact and to deposition during transport. They are either transported farther or remain as identifiable fragments in glacial deposits, or both, leading to larger mappable areas of glacial dispersal.

In the northeastern study area zinc concentrations are elevated (>100 ppm) (Fig. 13c). They define part of a regional glacial dispersal train that originates at least 200 km northwest of Baker Lake and extends southeast 300 km to the coast of Hudson Bay (Shilts, 1984). Although the bedrock source of zinc is not known, where the dispersal train crosses the study area till geochemistry likely reflects the regional glacial transport from north of Baker Lake more strongly than local bedrock. Locally, striations (e.g. Fig. 5) and isopleths of Dubawnt Group pebbles (e.g. Fig. 10, 12) indicate that geochemical patterns are modified by southward ice flow across eastern Baker Lake. Northwest of Pitz Lake, geochemical isopleths lie along the margin of Baker Lake Basin, whereas lithological isopleths of Volcanic Rock are displaced 5-10 km northward of it. The differences between geochemical and lithological isopleths indicate volcanic rock was not glacially comminuted to the finer size fractions by ice flowing northwestward from the Keewatin Ice Divide. The glacial dispersal trains could reflect either limited duration of glacial transport, or englacial transport of Volcanic Rock, or both.

Trace element correlations and ratios

For the nearly 2000 till samples from the Baker lake study area, copper, lead and zinc are strongly and positively intercorrelated, as well as individually with iron and manganese (Table 2). Correlations are strongest between zinc and copper (0.812), zinc and lead (0.613), and copper and lead (0.585). Iron and manganese concentrations are correlated





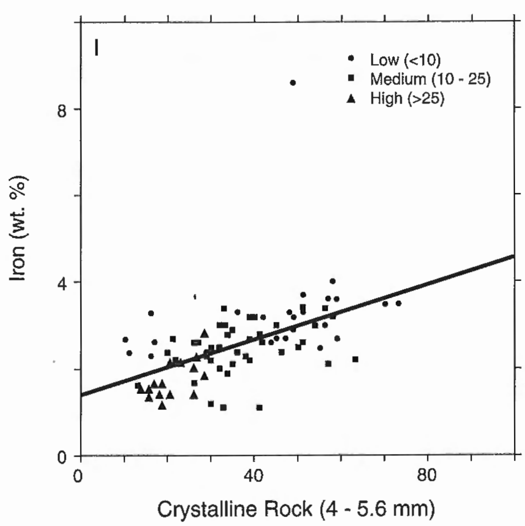


Figure 24.

Bivariate plots of trace, minor and major elements with Crystalline Rock and with Thelon Sandstone pebbles (4-5.6 mm). Best fit line was determined by regression analysis. Graphs are coded to reflect the proportions of either Sandstone or Crystalline Rock. Generally, trace element concentrations increase with Crystalline Rock. Copper and zinc are negatively correlated with Thelon Sandstone.

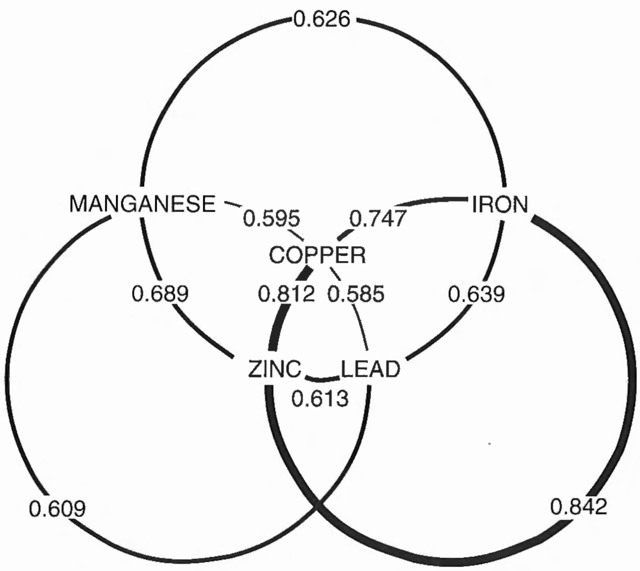


Figure 25. Schematic summary of correlations greater than 0.500 among elements. Correlations are based on comparison of approximately 1994 (Cu, Pb, Zn) and 1050 (Mn, Fe) samples.

with copper (0.747 Fe, 0.595 Mn), zinc (0. 842 Fe; 0.689 Mn) and lead (0.639 Fe; 0.609 Mn) (Fig. 25, 26). Correlations are either weak or not evident for nickel and for uranium. The linear correlations indicate that trace element ratios are largely independant of till lithology, something that is unexpected in view of the lithological diversity of the samples and the geologically distinct terranes represented.

Linear relations could result either if trace element ratios in common rock-forming minerals of the clay-sized fraction are similar, or if secondary weathering is a major geochemical control, or both. Although correlations with iron and manganese can reflect weathering and scavenging of trace elements (e.g. Coker and Nichol, 1975; Levinson, 1980, p. 657), the latter interpretation is not consistent with studies of metal partitioning in till (Shilts, 1977, 1984). In weathered till 'The scavenging portions of till, present primarily in the clay sizes, adsorb cations such as copper, zinc, uranium, nickel, etc., in approximate proportion to the concentrations of these elements in primary particles in the original, unweathered, undisturbed till. Thus, given similar clay mineral composition, soil chemistry, and exchange capacity, the trace element concentrations of the clay-sized portions of till can reflect the configuration of primary glacial dispersal train of sulphide (or other labile) particles.' (Shilts,1977, p. 205-206). From partitioning studies based on partial and total extractions, trace metals in Canadian Shield till are largely held in the structure of the clay-sized minerals and are not adsorbed or incorporated into secondary mineral phases (Shilts, 1984, p. 101). His work indicates iron and manganese in secondary oxide-hydroxide phases are not associated with trace elements, and thus either they are not efficient scavengers or little metal is released during weathering.

In till, there is a close spatial relationship between Ni:Cu ratios greater than 2 and volcanic bedrock of Christopher Island Formation near Pitz Lake, and from there a glacial dispersal train defined by ratios greater than 1.5 extends southeast across distinct geological terranes (Fig. 27). The train defined by the ratios is comparable to those defined by pebbles of Thelon Sandstone and of Pitz Volcanics, and the high Ni:Cu ratios clearly reflect a provenance within Christopher Island Formation south of Pitz Lake. Although the formation extends farther west (e.g. Miller and LeCheminant, 1985), it becomes more felsic in that direction and the compositional change could be why high Ni:Cu ratios in till are areally restricted. North of the Christopher Island source, ratios greater than 2 in till over Pitz Formation could reflect either northwestward ice flow recorded by striations, or the composition of Pitz Formation, or both. In bedrock of Christopher Island Formation a direct relationship between nickel and chromium is attributed to magmatic history and to chemical substitution within phyllosilicates and mafic minerals (A.N. LeCheminant, pers. comm., 1988). Chromium analysis of till was not done, and the spatial association of Ni:Cr ratios in till and bedrock cannot be checked, although it is inferred here that the Ni:Cu ratios have similar derivation.

One of the strongest linear correlations is between zinc and copper (0.812; 1994 samples). Although the correlation is based on analysis of samples having a broad range of lithological compositions, a map of Zn:Cu ratios reflects regional bedrock geology and glacial dispersal (Fig. 28). In crystalline terrain north of Baker Lake, Zn:Cu ratios are generally low (<1) to the west and are high (>4) to the east. Ratios greater than two characterize till in Baker Lake Basin and the regional dispersal train of Dubawnt Group detritus southeast of it. In the study area, ratios greater than three are associated with Thelon Formation northeast of Pitz Lake, and they define a glacial dispersal train trending southeast from there. In the northeastern study area, ratios greater than three reflect either glacial erosion of Thelon Sandstone within Baker Lake or crystalline bedrock north of the lake where ratios of Zn:Cu are typically greater than four (e.g. Shilts, 1984; Fig. 5).

The Ni:Cu and Zn:Cu ratio maps reflect aspects of bedrock geology and glacial dispersal that are not evident in single element geochemical maps. They indicate that despite strong inter-element correlations there are consistent geochemical differences among bedrock types. Their significance to bedrock geochemistry is uncertain, although in the case of Christopher Island Formation they could reflect gross aspects of magmatic history, as inferred by LeCheminant from Ni:Cr ratios.

Stratigraphy and stratigraphic correlations

Compositional changes with depth occur in drill cores and stratigraphic sections, even within till that appears monolithic. Their interpretation requires geological observations of texture, structure lithology, and stratigraphy, because they can reflect change in: 1) provenance, as the result of change in ice flow direction or in sediment source or in distance of glacial transport; 2) conditions of ice flow affecting glacial entrainment, transport, and deposition; and 3) postglacial weathering.

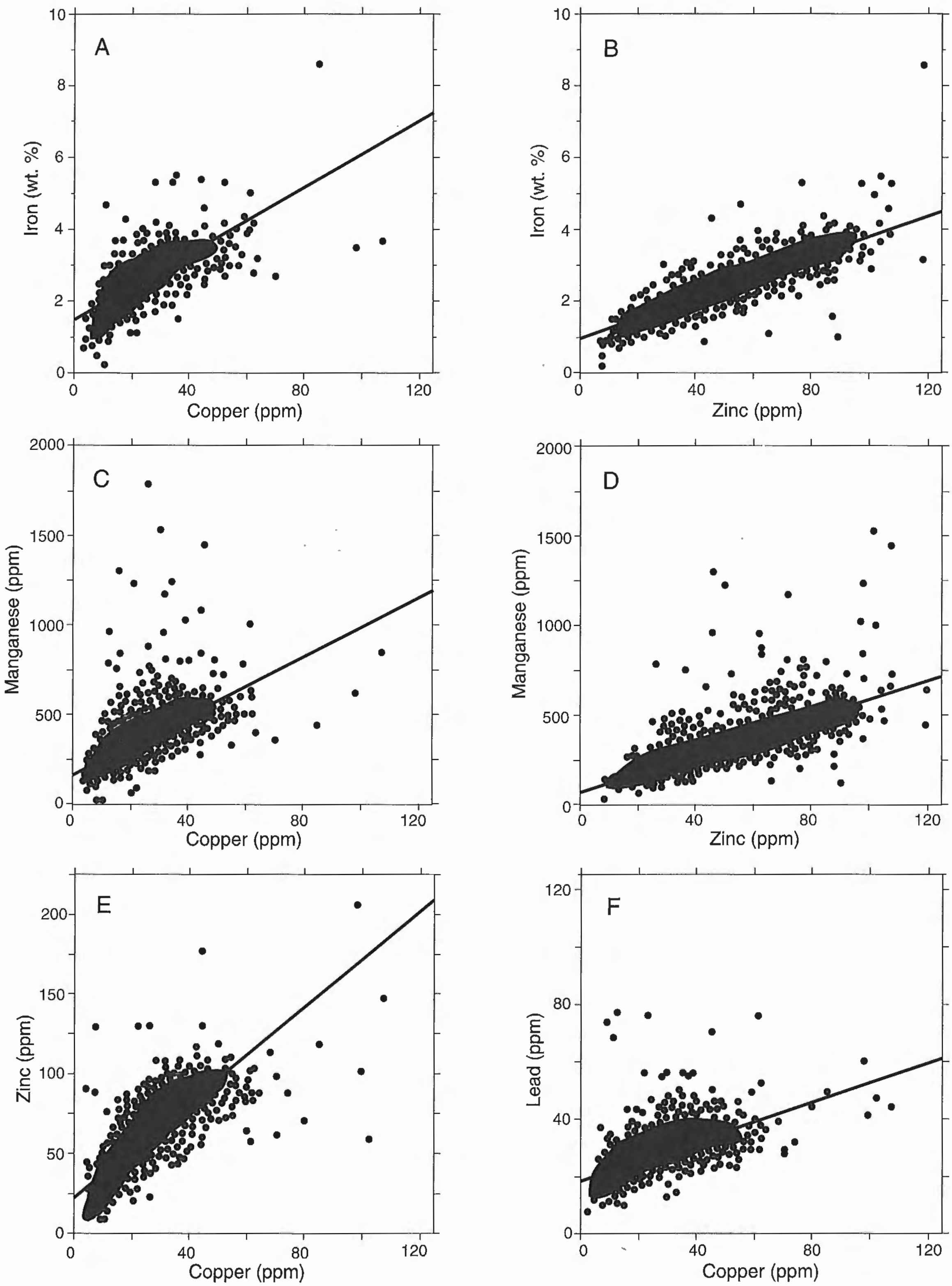


***Figure 26.** Bivariate plots of trace, minor and major elements. Geochemical relations are linear.*

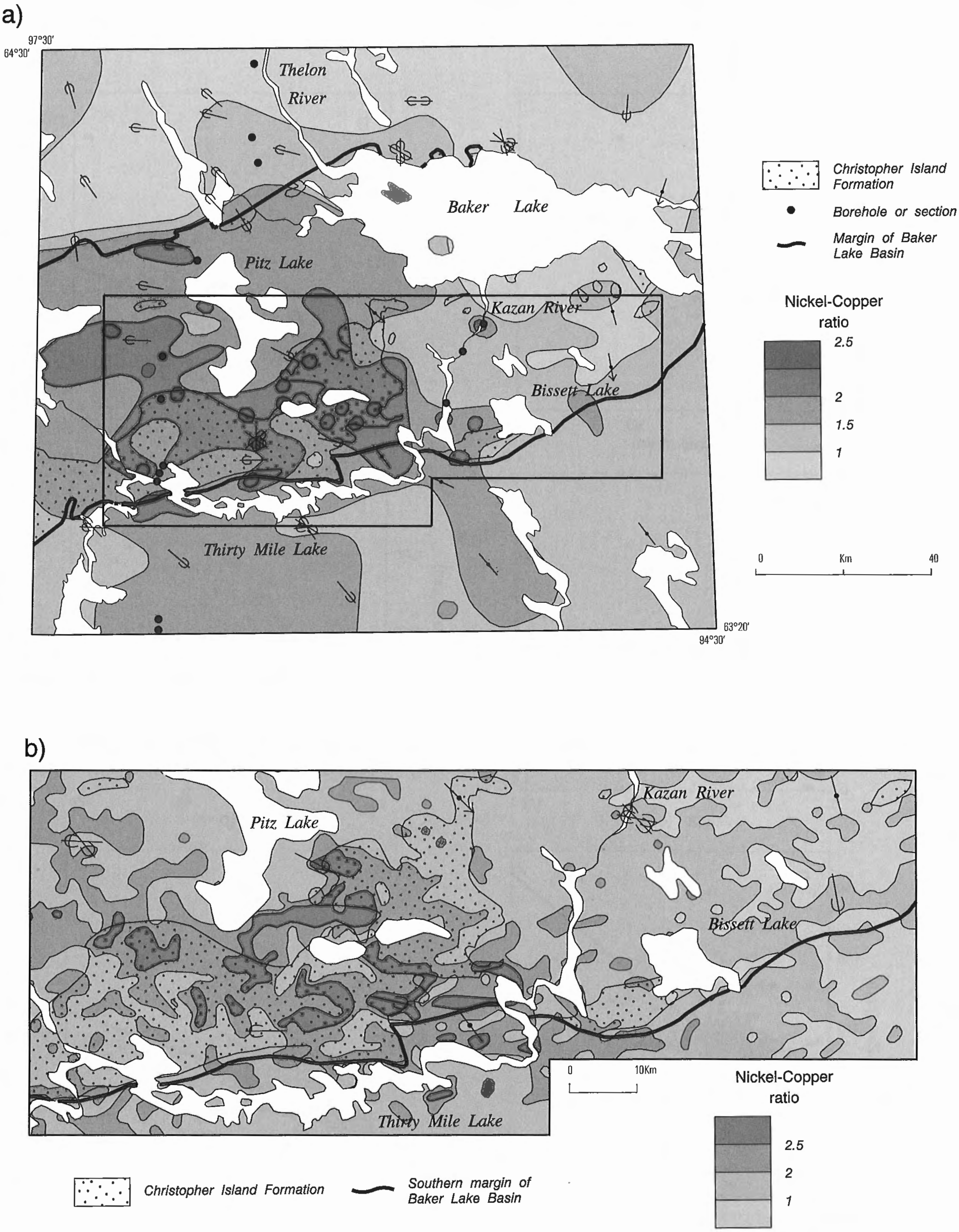
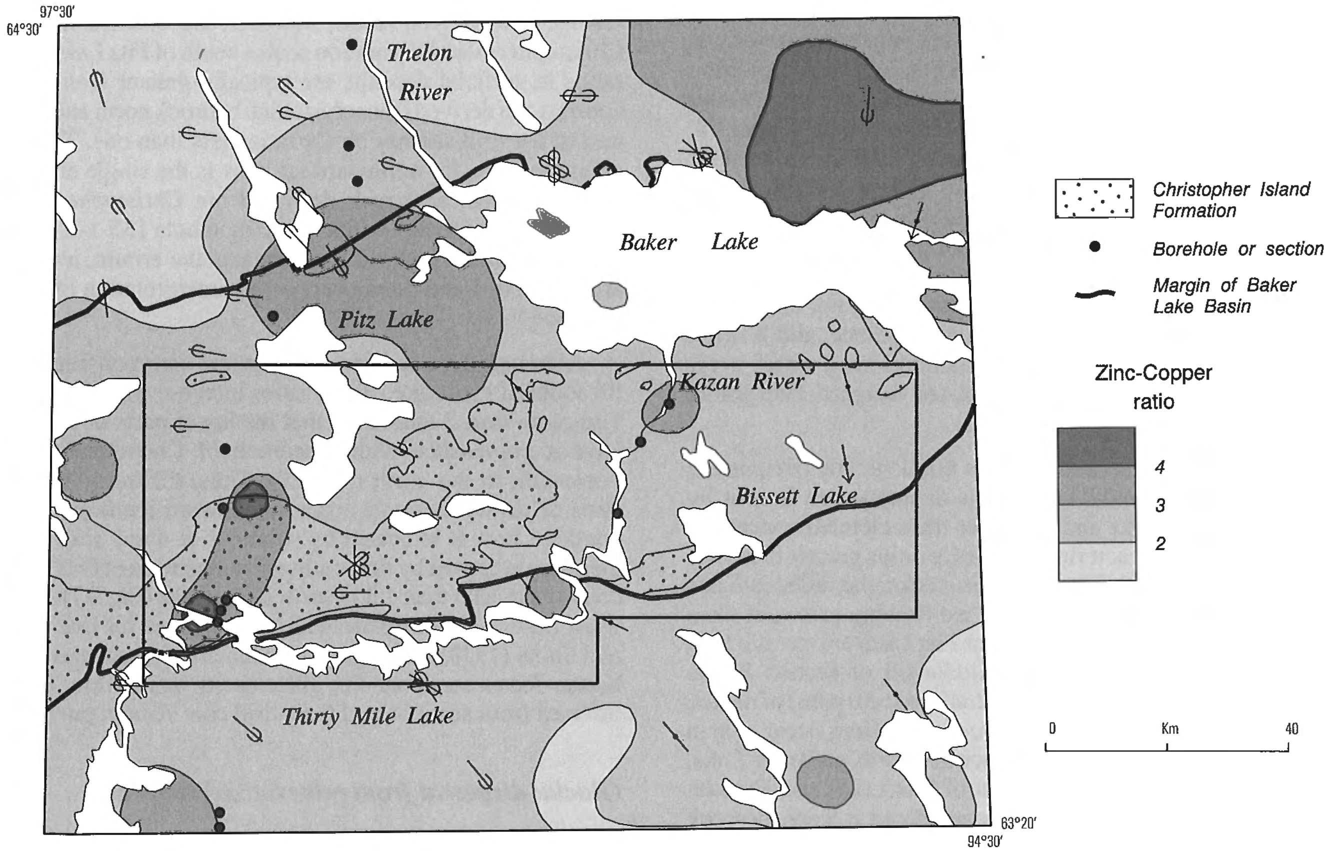


Figure 27. *Regional (**a**) and local (**b**) variations in Ni:Cu ratios. Ratios greater than 2 are spatially related to volcanic rock of Christopher Island Formation in the area of Pitz Lake and likely reflect trace element ratios in phyllosilicates of that bedrock unit.*

a)



b)

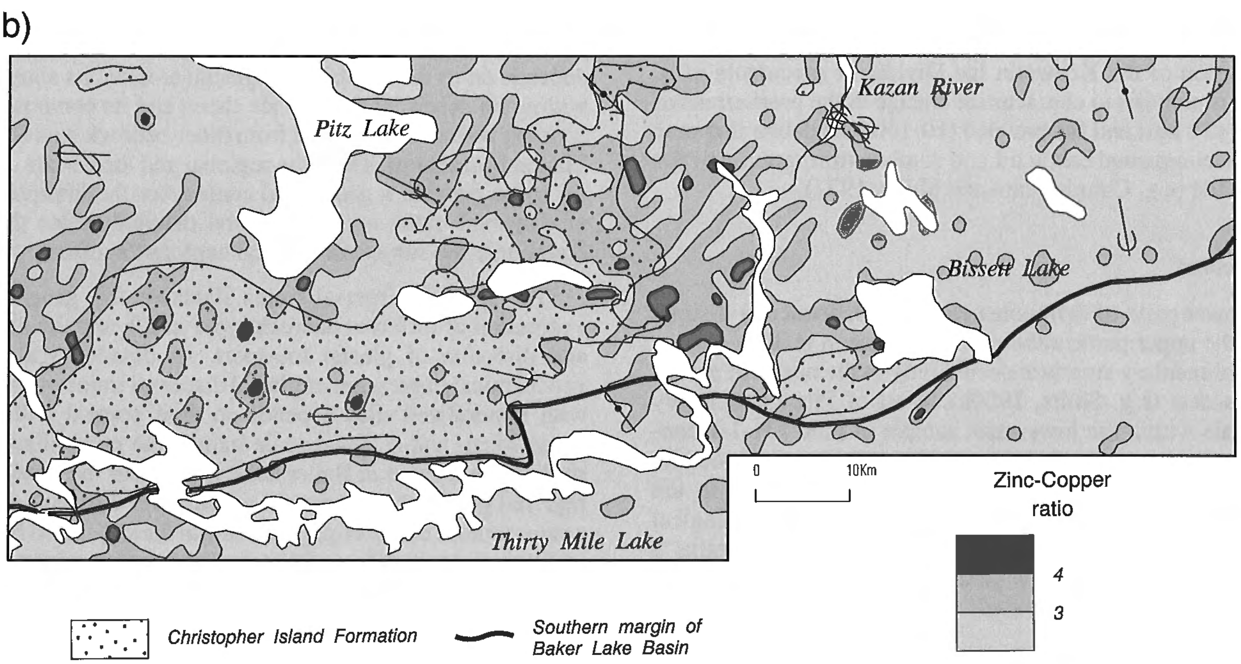


Figure 28. *Regional* ***(a)*** *and local* ***(b)*** *variations in Zn:Cu ratios. Ratios greater than 3 reflect a Thelon Formation provenance north and east of Pitz Lake.*

Stratigraphic Sections

The Kazan River sections define a transect across southeast-trending glacial dispersal trains that are prominent in surficial deposits. Thus, the geochemical and lithological composition of the uppermost till in the sections varies according to their location within the glacial dispersal trains. In the Upper till, for example, Pitz Volcanic Rocks were found only in sections KA and KB and they are absent in section KC which lies outside their southeast-trending dispersal train (Fig. 12c, 18, 20). Stratified sediment within the Upper till in section KC is poorly sorted, deformed and discontinuous, and it could have formed by debris flow resedimentation. It is not interpreted to have interglacial or interstadial significance, and it is not correlated with waterlain sediments intersected within boreholes along the Thelon River that are assigned interglacial status (Shilts, 1980b).

The Lower till in section KC is lithologically comparable to the overlying Middle till,and is distinguished from it by Pitz Volcanic Rocks and by lower trace element concentrations. It is also characterized by Ni:Cu ratios greater than two. In combination with Pitz Volcanic Rocks, the ratios indicate the Lower till was deposited by ice flowing eastward from Christopher Island Formation near Pitz Lake prior to the later southeastward ice flow. The Middle till of section KB is characterized by elevated concentrations (>50 ppm) of nickel. In surficial deposits, comparable concentrations occur only in three areas: 1) over crystalline terrain north of Baker Lake, 2) over mafic bedrock northwest of Pitz Lake, and 3) south of Pitz Lake in an area of Christopher Island volcanic bedrock (Fig. 11c). Nickel geochemistry and the absence of Pitz Volcanic Rocks indicate that its most likely provenance is northwest, north of Pitz Lake.

The compositional profiles of the sections indicate change in provenance and ice flow direction from eastward to southeastward that are likely related to change in the location and orientation of the Keewatin Ice Divide, or precursors of it. There is no basis to characterize change in the proportions of local (<10 km) and far traveled (10-100 km) debris that may have accompanied eastward and southward migration of the ice divide (e.g. Cunningham and Shilts, 1977).

Drill cores

The lower parts of drill cores can be geochemically distinct from the upper parts, although difference in texture, colour, and sedimentary structure occurs only in the northern part of the transect (e.g. Shilts, 1980b). West of Pitz Lake, heavy minerals within the lowermost sample of hole 131-1-1 contain greater amounts of titanite and lesser amounts of goethite and barite, as compared with two samples higher in the section (Paré, 1982). According to Paré, the mineralogical differences indicate that the lowermost sample contains a greater proportion of crystalline debris from terrain north of Baker Lake Basin, where till contains greater amounts of titanite.

In drill core north of Pitz Lake, Ni:Cu ratios are 1 to 2, although they are typically less than one within the upper metre of surficial deposits in crystalline terrain (Fig. 29). The higher ratios occur within grey brown till interpreted to have been derived from crystalline bedrock to the north or northeast (Shilts, 1980b). The ratios, however, are consistent with a Christopher Island Formation source south of Pitz Lake where ratios in surficial deposits are typically greater than 1.5. In contrast, till derived from crystalline bedrock north and northeast of the drill site has Ni:Cu ratios less than one. The only other evidence for northward ice flow is the single erratic of porphyritic volcanic rock derived from Christopher Island Formation that occurs within pink till in hole 135-1-4 . Ni:Cu ratios within the pink till that contains the erratic, however, are less than 1 and do not support an interpretation of northward ice flow.

Although there is little geochemical variation within red till south of Pitz Lake, Ni:Cu ratios increase with depth from 1 to more than 2 indicating that the lower parts of drill core have a provenance within bedrock of Christopher Island Formation to the north (Fig. 29). Thus, till from the lower parts of drillholes could record southward ice flow. Southward ice flow is indicated by striations at a few sites within the study area, and by the southward elongation of Ni:Cu ratio contours greater than 1.5 in surficial deposits (Fig. 27). Southward flow could correlate with that reported by Lee (1959) and Shilts (1973), although no evidence for it was seen in the Kazan River sections. The differences in ice flow history inferred from sections and from drill core remain puzzling.

Glacial dispersal from mineralized sources

For the Baker Lake region of the Keewatin Ice Divide, drift composition and glacial dispersal trains described in this report serve as a geological framework for mineral exploration by drift prospecting. The results illustrate that till is a complex of glacial dispersal trains of varied sizes, shapes, and orientations that incorporate both far traveled and local debris. The expression of a specific bedrock source within till depends on its susceptibility to glacial erosion, its abundance within the debris load of the ice sheet, and its compositional contrast with debris derived from other bedrock sources (e.g. Thelon Formation). Thus, the regional and local scale dispersal trains provide a geological context for the interpretation of dispersal trains at the local and detailed scales that are commonly the subject of mineral exploration effort.

The glacial dispersal trains illustrate the geochemical expression of different bedrock types in till, and the distance and direction of glacial transport. At detailed scales, the geochemical expression of glacial dispersal trains originating with mineralized sites depends on their context within the larger local- and regional-scale trains. The mineralized sites studied are located in Baker Lake Basin near the head of the regional glacial dispersal train of Dubawnt Group rock. The predominance of metal-poor detritus in the clay-sized fraction of till there masks the geochemical expression of the mineralized sources, and the difference between 'anomalous' and 'background' is slight. At the detailed scales common in mineral exploration, till geochemistry must be interpreted in terms of context within local and regional scale trains and their geochemical properties as 'background', and not in terms of either overall trace element concentrations or in underlying bedrock type. Although glacial sediments are undoubtedly oxidized and weathered, the effects of post-glacial weathering and of hydromorophic transport are not evident in the results of this work.

Glacial dispersal trains commonly have an exponential decrease in the concentration of indicator debris with distance down-ice from their bedrock source (Shilts, 1976; Puranen, 1988). The 'head' is that part of the train overlying or directly down-ice of the bedrock source where indicator concentrations are greatest (Shilts, 1976). The 'tail' is that part of the dispersal train where the rate of decrease in concentration with distance along the path of ice flow is least and the concentration of indicator debris approaches 'background'. The tail represents the greater part of the train and is most likely to be encountered.

Glacial dispersal trains originating with mineralized sources in the study area are too small to be reliably encountered at a sample density of one sample per 5 km^2, a conclusion arrived at by DiLabio (1979). From the two mineralized sites, glacial dispersal trains defined by uranium and copper trend southeastward hundreds of metres to nearly 2 km (Fig. 14, 15). The trains are irregular in outline, and at Kazan River they can be more extensive than the known extent of mineralized bedrock. That could be the result of: 1) glacial transport in directions other than southeast, 2) local redistribution of trace elements due to either weathering, or local mass movement, or both, 3) mineralization being more extensive in subcrop than mapped, or 4) some combination of all those factors. Below marine limit, indicator minerals derived from till can be further transported as the result of marine processes, leading to more widespread dispersal (DiLabio, 1979). The estimates of glacial transport distance are compatible with glacial dispersal trains in Finland defined by geochemical analyses (e.g. Peuraneimi, 1982; Lehmuspelto, 1987).

The choice of 'anomaly thresholds' requires knowledge of glacial geology, including the relative volumes of rock within the till and their trace element characteristics, and how the proportions of different rock types change with distance of glacial transport (Salminen and Hartikainen, 1985, p. 44; Puranen, 1988). As an example, glacial dispersal trains derived from uranium mineralization in Kazan Formation (e.g. Fig. 14) are defined by uranium concentrations in till of greater than 2 ppm. In comparison, in the northeastern part of the study area, till contains more than 5 ppm uranium reflecting a provenance in crystalline bedrock north of Baker Lake. The geochemical contrasts near the margins of both regional and local scale trains could overwhelm geochemical patterns at the detailed scales of investigation typically used in mineral exploration.

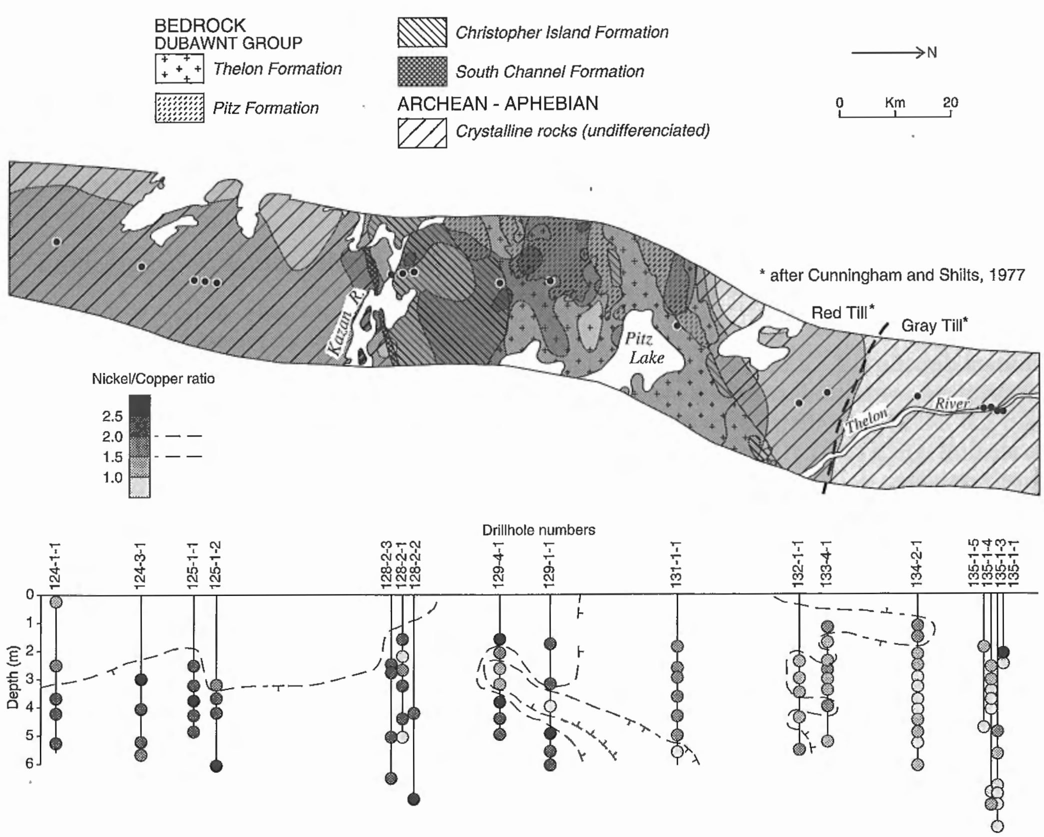


Figure 29. Nickel:copper ratios in drill core along the Polargas Pipeline corridor; variations in ratios indicate change in vertical provenance within drill core samples.

Samples characterized by several elements above a selected threshold can define glacial dispersal trains and discrimination of analytical and geological 'noise' from the input of mineralized sources. Salminen and Hartikainen (1985) have indicated that metal ratios are useful where till has been transported a short distance. From mineralized sources, glacial dispersal defined by the combination of copper and uranium is more clearly outlined than by the individual elements (Fig. 12a, b, c). From mineralized occurrences at sites 9 and 10, southeast-trending glacial dispersal trains are defined by till that contains both more than 20 ppm copper and more than 2.0 ppm uranium (Fig. 14c). Although the net distance of glacial transport (<1 km) is less than defined either by either copper or uranium isopleths, geochemical patterns defined by a combination of those trace elements present less 'noise' and the bedrock source is more clearly outlined. South of site 11, scattered samples containing both more than 20 ppm copper and more than 2.0 ppm uranium occur outside the expected path of southeastward glacial dispersal, although their significance to bedrock composition is not known. South of site 8, till containing more than 30 ppm copper and 3 ppm uranium occurs within two elongate zones that are 1 to 1.5 km long and trend north-south (Fig. 13c), similar to local striations. The zones do not originate at site 8, and they could be related to unknown mineralized source(s) within crystalline bedrock. This study also indicates that trace element ratios (e.g. Ni:Cu and Zn:Cu) can be used to map glacial dispersal at local scales.

Implications for mineral exploration

The glacial dispersal trains and the relations between till lithology and geochemistry described here represent a geological framework for mineral exploration by drift prospecting. Some of the implications for exploration are:

1. At detailed scales characteristic of exploration, sampling programs require knowledge of ice flow direction and context within local and regional glacial dispersal trains to establish the most effective orientation and spacing of samples.

   The predominant direction of ice flow and glacial transport is southeastward, with local variations evident near the Keewatin Ice Divide and the eastern end of Baker Lake where ice flow was westward to northwestward and southward, respectively.

2. Glacial dispersal from mineralized sources is less than 2 km, typically a few hundred metres, and geochemical contrasts with background concentrations can be limited depending on the properties of the local scale dispersal trains that they occur within.

   From the examples in this report, along transects oriented perpendicular to main ice flow directions samples can be spaced at 100 m intervals, and the transects can be spaced up to 500 m apart. To more clearly define glacial dispersal, combinations of trace elements above selected threshold levels can be useful in mapping geochemical analyses results.

3. Geochemical analysis of the clay-sized fraction provides the greatest trace element concentrations and contrasts with 'background' populations. Lithological analysis of the pebble fraction provides an important basis for the interpretation of geochemical results and context within glacial dispersal trains.

   Till lithology and geochemistry are closely linked. Some rock types such as Thelon Sandstone can depress trace element levels whereas others such as Crystalline Rock can elevate them. Glacially transported debris can mask underlying bedrock where the bulk of it is far-traveled, and where it is either volumetrically predominant or compositionally distinct, or both. Depending on the origin and orientation of local and regional scale trains, detailed scale investigations can include till having distinctive geochemical properties unrelated to underlying bedrock and masking the source.

4. Where glacial deposits are thick (>2 m), vertical compositional variations can be related to change in ice flow direction, in provenance, or in processes of glacial erosion, transport, and deposition.

5. Linear correlations among trace elements indicate that they occur in similar proportions within the common minerals comprising the clay-sized fraction. The proportions do not vary greatly among different geological terranes, indicating that trace element concentrations reflect the mineralogy of glacial sediments and mechanical processes of glacial erosion, transport, and deposition.

   Ratios of trace elements can define dispersal from specific sources and aid provenance determination. They could be useful to identify sources that are either enriched in uncommon minerals, such as sulphides, or that are otherwise geochemically distinct.

Ice flow history and drift composition

Ice divides are zones of outflow within an ice sheet. They are dynamic features, changing in size, shape, and location during glaciation. The Keewatin Ice Divide was one of several centres of outflow within the Laurentide Ice Sheet that dominated large scale ice flow across the Canadian Shield (Andrews, 1982). Glacial dynamics can change in time and space, particularly near ice divides, as the result of change in basal flow conditions within the ice sheet as well as change in ice flow direction. Theoretical ice sheet models indicate that ice divides are characterized by low basal ice velocities, and thus by limited glacial erosion and debris transport (Boulton, 1984; Boulton and Clark, 1990b). Basal ice flow velocity, which relates directly to the erosive character of the ice sheet, increases exponentially towards glacier margins, and near ice divides it is greatest only during the buildup and decay stages. Slight change in either the configuration or location of an ice divide, or both, can be accompanied by marked changes in ice flow direction (e.g. Boulton and Clark, 1990a, b). Thus, near ice divides, glacial history can be difficult to resolve because of the complex ice flow record, and mineral exploration by drift prospecting can be complicated by multiple ice flow directions, by varied distances and directions of glacial transport, and by thick glacial and nonglacial deposits (e.g. Boulton, 1984; Puranen, 1988).

Major ice divides within the District of Keewatin were defined by the pioneering work of Tyrrell (1897), who identified three positions successively occupied by the centre of the 'Keewatin Glacier', which he considered to have been active "...during a part, or perhaps during the whole, of the glacial period." (Tyrrell, 1897; p.175f;178f). The history of the Keewatin Ice Divide, however, is not well known due to the complexity of the geological record and to its geographically remote setting: it remains a subject of debate (e.g. Shilts, 1980a; Dyke et al., 1982; Boulton et al., 1985; Dyke and Prest, 1987; Boulton and Clark, 1990a, b). Glacial dispersal trains originating with the Dubawnt Group extend hundreds of kilometres southeast from Baker Lake Basin to the coast of Hudson Bay, and farther east within glaciomarine sediments of the bay (Kaszycki and Shilts, 1979; Shilts et al., 1979; Shilts, 1980a, 1984; Henderson, 1983). The large distance and direction of glacial transport that they define have been used to infer stability in the location of a major ice divide within the District of Keewatin, and to identify it as a long-lived feature of the Laurentide Ice Sheet (Cunningham and Shilts, 1977; Shilts et al., 1979; Shilts, 1980a; 1982). According to Aylsworth and Shilts (1989, p. 3), although the Keewatin Ice Divide may have migrated as much as a hundred kilometres east and south towards the western end of Baker Lake, "... its final location is a reasonable approximation of its general position throughout the last glaciation.". That interpretation is generally consistent with portrayals of Ancestral Keewatin and Keewatin ice divides by Dyke and Prest (1987). In contrast, large scale lineations evident on satellite images have lead to the proposal that there could have been one or more highly mobile ice divides in the District of Keewatin and that the regional dispersal patterns reflect changing rather than stable patterns of flow (Boulton and Clark, 1990a, b).

The predominant direction of glacial transport within the study area is southeastward. The regional glacial dispersal train defined by the 40 wt. % isopleth of the Dubawnt Group (undifferentiated) could originate 1) with Proterozoic bedrock northwest of the study area as the product of regional southeastward ice flow, 2) with bedrock of the study area as the product of northwestward and southeastward flow outwards from the Keewatin Ice Divide, or 3) be the net product of ice flow associated with migration of an ice divide from the northwest. Glacial transport in directions other than southeastward is a few kilometres to tens of kilometres. It is evident near the eastern end of Baker Lake where the shape of lithological isopleths and streamlined landforms both indicate southward glacial transport of crystalline debris. Northwest of Pitz Lake, Pitz Volcanic Rocks outside Baker Lake Basin indicate limited northward glacial transport from the western side of the Keewatin Ice Divide, most likely during late glacial time.

The significant length of glacial transport (>100 km) southeast of the Keewatin Ice Divide and strong southeast orientation of glacial dispersal trains that extend across it are not compatible with ice divides as zones of minimal basal ice flow and glacial erosion, and varied flow directions (Boulton, 1984; Boulton and Clark, 1990b). Ice flow from the final location of the divide across across the western part of the study area has had minimal effect on drift composition at regional and local scales. Within the study area, the dominant compositional character of surficial deposits relates to southeastward ice flow from a divide located north and west of the last position of the Keewatin Ice Divide. The interpretations are consistent with conclusions of Boulton and Clark (1990b). An early position of the ice divide could have been near Schultz Lake northwest of the study area (e.g. Kaszycki and Shilts, 1980: Fig. 6, position 4, p. 34; Boulton and Clark, 1990b: Fig. 18b, p. 342). Its location, however, is speculative, in part because no geological information is available to define the western and northern limits of glacial erosion associated with southeastward transport. The northeastern margin of the regional dispersal train shown by Kaszycki and Shilts trails southeastward from the eastern limits of sedimentary bedrock near Schultz Lake, and it is consistent with the location and trends of dispersal train margins defined as part of this study.

Within the drill core and sections, change in provenance and ice flow direction is indicated. In the Kazan River sections, the change is from eastward to southeastward, and no evidence for southward flow was recognized. In contrast, in drill core slight geochemical variation with depth, and differences in Ni:Cu ratios in particular, indicate earlier southward flow, consistent with the observations of Lee (1959) and Shilts (1973) for older regional southward flow across the District of Keewatin. Although rare, quartzite derived from crystalline bedrock either north or west of Baker Lake is widespread in and south of the study area; its distribution is cited as evidence for southward or southeastward glacial transport from the Schultz Lake region (Cunningham and Shilts, 1977).

ACKNOWLEDGMENTS

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APPENDIX 1

Geochemical and lithological analyses for the study area region

										Dubawnt Group Pebbles (2-4.6 mm)			
Sample No.	UTM	EAST	NORTH	Copper	Iron	Manganese	Nickel	Uranium (fl)	Zinc	Crystalline	Volcanic	Sedimentary	Rounded
	Zone	metres	metres	ppm	wt. %	ppm	ppm	ppm	ppm	Rock	Rock	Rock	Quartz
7501 1614	14	590131	7078004	17	2.3	285	38	2.4	53				
7501 2014	14	596300	7078387	10	2.7	150	22	2.3	32				
7501 2414	14	602818	7078441	24	2.6	490	41	3.4	53				
7501 2814	14	609167	7078090	20	2.3	250	46	1.3	48				
7501 3002	14	612894	7058724	44	3.4	435	61	1.9	83				
7501 3206	14	616395	7065422	38	3.7	650	60	1.9	74				
7501 3214	14	615300	7078400	22	2.4	330	50	1	52				
7501 3352	14	618466	7051386	35	3.3	515	55	3.6	65				
7501 3402	14	620487	7059721	18	2.4	580	56	2	66				
7501 3411	14	619844	7074142	16	3.3	335	75	2	52				
7501 3607	14	622254	7067975	28	2.7	520	80	1.7	81				
7501 3614	14	621603	7078998	9	1.6	170	19	1	27				
7501 3650	14	622808	7054189	44	3.5	505	73	2.5	92				
7501 3803	14	625979	7060893	20	2.6	300	46	1.1	63				
7501 3811	14	625872	7073924	11	1.3	190	20	0.9	24				
7501 3913	14	628573	7077407	9	1.7	150	23	1	30				
7501 4006	14	629087	7066266	23	3.3	430	57	2	66				
7501 4016	14	628517	7082151	8	1.4	175	31	1.9	22				
7501 4152	14	631232	7051684	61	4	620	83	2.6	85				
7501 4202	14	632639	7060217	35	3.3	490	69	1.1	79				
7501 4211	14	632149	7074011	18	1.5	185	29	1	33				
7501 4406	14	635363	7066397	39	2.2	310	46	1.4	52				
7501 4414	14	634882	7079072	10	1.6	215	20	1.3	26				
7501 4450	14	636298	7055118	47	3.5	505	77	1.6	92				
7501 4602	14	638762	7060981	21	2.4	240	38	1.2	40				
7501 4611	14	638177	7074398	8	1.5	270	150	1.9	25				
7501 4806	14	641710	7066752	19	2.1	280	31	2.4	49				
7501 4813	14	640561	7077232	6	1.1	110	28	1.4	24				
7501 5002	14	644989	7060361	22	2.7	370	38	1.3	51				
7501 5011	14	644418	7074382	8	1.2	250	106	1.3	18				
7501 5206	15	351916	7066488	10	1.4	150	22	2.3	26				
7501 5213	15	352526	7077984	12	2.1	235	36	2.5	55				
7501 5402	15	354413	7059915	15	2	190	24	1.1	33				
7501 5411	15	355288	7074648	12	2.2	290	32	1.4	62				
7501 5606	15	357932	7066315	7	1.1	185	14	1.6	15				
7501 5713	15	360167	7077463	10	1.8	285	32	2.1	46				
7501 5803	15	360171	7061777	11	1.4	250	18	1	20				
7501 5811	15	361853	7074472	14	2.1	285	25	1.2	44				
7501 6007	15	364301	7067233	24	2.7	316	42	3.7	62				
7501 6014	15	364900	7078755	16	2	240	29	1.8	44				
7501 6019	15	365515	7087499	24	2.2	185	24	1.1	44				

										Dubawnt Group Pebbles (2-4.6 mm)			
Sample No.	UTM	EAST	NORTH	Copper	Iron	Manganese	Nickel	Uranium (fl)	Zinc	Crystalline	Volcanic	Sedimentary	Rounded
	Zone	metres	metres	ppm	wt. %	ppm	ppm	ppm	ppm	Rock	Rock	Rock	Quartz
7501 6202	15	367979	7059647	14	1.9	160	23	1.1	32				
7501 6211	15	368157	7074666	14	2.6	320	32	1.7	51				
7501 6406	15	371126	7065761	8	1.6	170	18	1.2	25				
7501 6414	15	371341	7078643	14	2.2	220	24	2	42				
7501 6416	15	371680	7082079	20	3	300	27	1.7	52				
7501 6602	15	373753	7059462	16	2.2	225	30	1.3	43				
7501 6611	15	374532	7073830	12	2.4	230	25	1.5	40				
7501 6619	15	375299	7086555	20	2.8	365	25	1.6	53				
7501 6807	15	376878	7067285	28	2.5	252	29	1.6	48				
7501 6814	15	378108	7078449	22	2.3	220	24	0.9	47				
7501 6816	15	378140	7081851	24	2.8	375	28	1.8	62				
7501 7002	15	380301	7058974	32	2.5	355	30	1.6	51				
7501 7011	15	380856	7073680	12	2.1	220	22	1.7	38				
7501 7019	15	381125	7086871	20	2.5	370	23	2.2	49				
7501 7206	15	383841	7065768	17	2.3	210	23	1.1	35				
7501 7214	15	384365	7078723	23	2.7	400	28	1.1	57				
7501 7216	15	384899	7081753	20	3	435	28	1.7	57				
7501 7402	15	386709	7059214	14	2.6	285	28	1.5	50				
7501 7419	15	388534	7086521	28	3	430	27	3.2	63				
7501 7606	15	390217	7066347	21	2.6	420	28	1	60				
7501 7614	15	390704	7077908	29	2.9	450	29	1.6	62				
7501 7623	15	367226	7091810	17	2.2	260	23	1.3	45				
7501 7716	15	392369	7081585	24	3	500	32	1.7	65				
7501 7810	15	393616	7071925	27	2.6	260	38	2.9	75				
7501 7818	15	394700	7084300	31	3.2	415	34	2.4	77				
7501 7923	15	372227	7091457	23	2.5	255	25	2.2	50				
7501 8006	15	396640	7065439	21	2.4	290	24	0.9	50				
7501 8014	15	396917	7077827	22	3.6	725	34	2.7	77				
7501 8016	15	397442	7081177	47	3.6	430	36	5	83				
7501 8210	15	400374	7071560	25	3	310	41	3.6	72				
7501 8219	15	400331	7086279	34	3.2	430	31	2.6	85				
7501 8406	15	403097	7065154	15	1.1	135	20	0.7	66				
7501 8414	15	403647	7077884	24	3.2	385	25	1.6	52				
7501 8416	15	403935	7081087	32	3.4	460	33	3.4	75				
7501 8423	15	379728	7091638	18	2.8	355	25	2.7	57				
7501 8610	15	406273	7071579	36	3	370	32	1.4	67				
7501 8618	15	407200	7084200	32	3.2	540	38	1.9	80				
7501 8723	15	385058	7091732	27	3.4	745	32	4.4	69				
7501 8813	15	409952	7075994	34	2.7	440	35	0.4	70				
7501 8816	15	409774	7080459	26	2.9	370	32	1.3	75				
7501 9010	15	413200	7071500	85	8.6	445	68	7.9	119				

Appendix 1 (cont.)

										Dubawnt Group Pebbles (2-4.6 mm)			
Sample No.	UTM	EAST	NORTH	Copper	Iron	Manganese	Nickel	Uranium (fl)	Zinc	Crystalline	Volcanic	Sedimentary	Rounded
	Zone	metres	metres	ppm	wt. %	ppm	ppm	ppm	ppm	Rock	Rock	Rock	Quartz
7501 9118	15	414907	7083967	37	3.2	525	37	1.4	79				
76PL 1519	14	587340	7085395	11			23	1.4	29				
76PL 1550	14	589722	7053784	25			52	3.1	78				
76PL 1606	14	590245	7064486	20			43	2.9	72				
76PL 1608	14	590327	7068279	34			59	1.8	92				
76PL 1623	14	589628	7092237	10			27	1.4	31				
76PL 1726	14	590790	7096091	11			20	0.7	29				
76PL 1750	14	592454	7054100	35			61	2.4	88				
76PL 1802	14	594197	7059104	30			58	1.8	86				
76PL 1808	14	592524	7067765	24			48	1.7	80				
76PL 1810	14	593462	7071310	24			51	1.7	74				
76PL 1816	14	592391	7081401	17			26	1.3	42				
76PL 1824	14	592719	7094012	18			34	1.1	35				
76PL 1920	14	594309	7087402	10			20	1.2	28				
76PL 1953	14	596174	7048912	40			61	1.9	90				
76PL 2006	14	597375	7065118	33			60	1.6	93				
76PL 2008	14	596425	7068169	28			49	4.2	68				
76PL 2023	14	596242	7092473	13			27	2.2	30				
76PL 2052	14	597557	7050827	30			62	1.5	90				
76PL 2117	14	597620	7083132	2			27	1.4	12				
76PL 2126	14	596972	7097143	18			29	0.8	38				
76PL 2150	14	599437	7054405	18			43	1.6	70				
76PL 2152	14	599647	7050617	28			47	2	74				
76PL 2153	14	598935	7048936	27			58	2	88				
76PL 2202	14	600570	7059356	37			62	2.2	92				
76PL 2207	14	599962	7066618	18			30	1.9	52				
76PL 2210	14	600264	7071753	30			50	1.6	68				
76PL 2219	14	599238	7086337	12			24	2.1	25				
76PL 2224	14	598737	7094130	18			38	3.1	36				
76PL 2406	14	604828	7065514	30			69	2.2	69				
76PL 2408	14	602451	7068619	26			48	2	68				
76PL 2418	14	602875	7084902	15			32	2.9	41				
76PL 2524	14	603718	7093844	18			36	5.9	36				
76PL 2525	14	603802	7095782	18			28	1.6	36				
76PL 2526	14	603456	7097606	13			21	1.3	26				
76PL 2550	14	605631	7053857	26			53	4	77				
76PL 2608	14	606317	7068781	18			46	2.1	58				
76PL 2610	14	607145	7072082	26			51	1.5	66				
76PL 2616	14	605803	7081582	16			28	0.9	41				
76PL 2619	14	605320	7086450	12			26	1.6	34				
76PL 2621	14	605085	7089321	15			24	1.4	39				

										Dubawnt Group Pebbles (2-4.6 mm)			
Sample No.	UTM	EAST	NORTH	Copper	Iron	Manganese	Nickel	Uranium (fl)	Zinc	Crystalline	Volcanic	Sedimentary	Rounded
	Zone	metres	metres	ppm	wt. %	ppm	ppm	ppm	ppm	Rock	Rock	Rock	Quartz
76PL 2624	14	604853	7094479	17			25	2.1	34				
76PL 2625	14	605028	7095521	17			33	1.3	36				
76PL 2806	14	611338	7065073	32			59	1.3	87				
76PL 2807	14	609735	7066698	24			50	1.5	68				
76PL 2818	14	608795	7084802	17			21	1	25				
76PL 2823	14	608263	7092104	16			24	1	38				
76PL 2850	14	610398	7054224	37			79	4	107				
76PL 2926	14	609879	7097915	11			23	1	27				
76PL 3024	14	611735	7094738	14			20	1.4	27				
76PL 3116	14	613650	7081939	10			18	1.2	26				
76PL 3618	14	621700	7085300	15			20	4.6	29				
76PL 4119	14	638000	7086700	10			27	2.3	32				
76PL 4125	14	628764	7096403	20			39	2.2	66				
76PL 4223	14	631453	7092844	12			23	1.7	38				
76PL 4319	14	633300	7087300	11			29	1.7	32				
76PL 4325	14	632449	7096798	21			39	4.6	62				
76PL 4327	14	632529	7100255	15			30	3	49				
76PL 4418	14	634800	7085700	12			24	2.6	36				
76PL 4423	14	634304	7093729	21			32	1.5	50				
76PL 4525	14	635936	7096833	11			25	3	37				
76PL 4619	14	637824	7087411	10			25	1.8	38				
76PL 4818	14	641252	7086336	31			80	2.6	70				
76PL 4823	14	640644	7093617	7			18	2.1	130				
76PL 4927	14	642608	7100359	19			30	2.5	58				
76PL 5020	14	643728	7089178	26			48	2.3	61				
76PL 5024	14	643326	7095488	18			27	2	42				
76PL 5116	14	646046	7082490	13			31	1.7	44				
76PL 5223	14	647000	7093800	20			25	2.4	40				
76PL 5326	15	354920	7099458	16			29	2.8	48				
76PL 5419	15	356691	7087329	15			32	1.7	56				
76PL 5424	15	355739	7095880	16			22	2.1	44				
76PL 5516	15	356862	7082577	13			26	1.7	42				
76PL 5727	15	361579	7100336	12			23	1.7	44				
76PL 5819	15	362790	7088034	18			24	2.3	55				
76PL 5916	15	364003	7081508	18			23	1.2	44				
76PL 6226	15	369112	7098055	21			24	2.6	58				
76PL 6624	15	376037	7095054	10			28	2	34				
76PL 6726	15	377358	7097849	25			25	1.8	73				
76PL 7126	15	384013	7097733	27			26	2.5	68				
76PL 7526	15	390126	7097498	33			33	5.9	83				
76PL 7627	15	392225	7099522	27			35	4.3	79				

Appendix 1 (cont.)

Sample No.	UTM Zone	EAST metres	NORTH metres	Copper ppm	Iron wt. %	Manganese ppm	Nickel ppm	Uranium (fl) ppm	Zinc ppm	Dubawnt Group Pebbles (2-4.6 mm) Crystalline Rock	Volcanic Rock	Sedimentary Rock	Rounded Quartz
76PL 7726	15	393706	7097375	32			30	4.3	81				
76PL 7826	15	394914	7097300	31			29	4.9	80				
76PL 7827	15	395113	7098824	24			24	5.1	63				
76PL 8022	15	397726	7090857	32			40	4.7	96				
76PL 8025	15	398633	7095706	34			30	3.1	87				
76PL 8026	15	398676	7097494	30			31	5.4	76				
76PL 8205	15	399895	7063767	13			15	1.3	22				
76PL 8422	15	404233	7090588	28			24	4	61				
76PL 8425	15	404688	7095832	31			24	3.4	70				
76PL 8503	15	404310	7060130	42			30	1.5	76				
76PL 8602	15	406027	7058570	40			33	1.8	80				
76PL 8603	15	406162	7060161	42			37	1.1	82				
76PL 8607	15	405904	7066401	43			31	1	78				
76PL 8627	15	407979	7098529	44			38	2.8	130				
76PL 8702	15	407465	7058502	32			28	1.6	76				
76PL 8703	15	407397	7060346	51			36	1.7	97				
76PL 8806	15	409332	7064362	34			41	1	72				
76PL 8822	15	410634	7090492	49			32	1.2	94				
76PL 8907	15	411380	7066417	43			35	1	78				
76PL 8925	15	412370	7095093	28			29	4.2	90				
76PL 9025	15	414200	7094704	44			35	2.8	98				
76PL 9026	15	414633	7096625	39			37	3.3	97				
76PL 9027	15	414680	7098010	36			37	2.5	105				
76PL 9106	15	414169	7064622	48			38	1.3	93				
76PL 9125	15	415820	7094447	26			38	3.2	96				
76PL 9127	15	416399	7097933	28			36	5.6	108				
73BD 0159	15	377500	7094500	11	1.8	330	26	5.1	43	31	14	30	25
73BD 0172	15	415400	7079500	40	3.1	530	39	1.4	93	50	23	22	6
73BD 0175	15	359100	7058800	21	1.9	300	30	1.4	44	25	38	27	10
73BD 0178	15	425300	7072700	48	3.8	680	50	3.8	130	81	9	10	
73BD 0179	15	403300	7071300	32	3	660	38	3.3	82	45	2	31	23
73BD 0180	15	359400	7073600	30	3.5	325	62	17.1	77	52	37	8	3
73BD 0181	15	364700	7042500	39	2.4	460	55	3.3	73	55	35	8	3
73BD 0186	15	420800	7050300	47	2.9	440	37	13.6	86	58	10	17	15
73BD 0187	15	394300	7052000	29	2.4	425	32	1.2	58	28	11	34	27
73BD 0188	15	353100	7057900	38	2.8	590	38	1.7	82	59	28	11	1
73BD 0189	15	358000	7033700	72	3.6	560	82	2.2	100	68	23	8	2
73BD 0190	15	366500	7032400	33	3.2	450	67	3.3	84	56	34	5	5
73BD 0191	15	384700	7034400	22	2.3	320	36	4.1	60	28	35	24	12
73BD 0192	15	398700	7032700	21	2.4	405	30	2.7	64	42	5	19	34
73BD 0193	15	447900	7030500	74	3.5	565	53	1.2	108	71	5	15	9

										Dubawnt Group Pebbles (2-4.6 mm)			
Sample No.	UTM	EAST	NORTH	Copper	Iron	Manganese	Nickel	Uranium (fl)	Zinc	Crystalline	Volcanic	Sedimentary	Rounded
	Zone	metres	metres	ppm	wt. %	ppm	ppm	ppm	ppm	Rock	Rock	Rock	Quartz
73BD 0194	15	433100	7022400	62	2.8	380	40	1.9	86	48	10	24	18
73BD 0195	15	412800	7023300	31	2.6	350	32	2	69	46	11	24	19
73BD 0197	15	384400	7023700	33	2.2	460	36	1.1	54	51	30	12	8
73BD 0198	15	365200	7025400	51	3.2	600	70	1.7	100	65	26	8	2
73BD 0199	15	361600	7016400	28	2.4	350	45	1.7	58	37	44	14	4
73BD 0200	15	385900	7081500	33	2.7	460	28	2.4	72				
73BD 0201	15	402700	7065600	31	2.8	420	30	1.9	77	59	6	16	20
73BD 0202	15	421300	7062000	36	2.8	555	54	2	94	57	7	21	15
73BD 0203	15	403400	7045700	27	2.6	560	30	3.3	62	41	22	22	15
73BD 0204	15	351200	7010800	50	2.8	460	51	1.7	95	70	21	4	2
73BD 0205	15	358500	7001300	36	2.9	540	57	3.1	98	79	16	4	1
73BD 0206	15	378800	7002300	52	2.9	520	63	2.4	99	80	14	5	1
73BD 0207	15	385800	7010700	61	3.2	690	63	1.3	94	67	27	4	2
73BD 0208	15	395400	7004100	148	4.2	680	90	2.2	140	73	19	4	5
73BD 0210	15	430700	7003000	75	2.9	440	48	2.7	95	71	14	11	4
73BD 0211	15	446100	7002400	93	3.9	675	70	2.3	148	70	9	16	5
73BD 0212	15	445100	7012400	56	2.7	390	40	1.4	81	58	10	24	8
73BD 0213	15	422600	7012900	43	2.3	350	35	1.7	59	60	12	16	12
76CC 0001	14	612400	7087900	11	1.7	340	16	2.1	24				
76CC 0003	14	612400	7087900	7	1.4	206	14	1.6	17				
76CC 0005	14	596800	7101300	15	2.5	264	27	3.5	32	9	30	33	28
76CC 0006	14	591300	7099100	12	2	203	24	1.8	28	12	32	33	21
76CC 0007	14	586200	7100100	18	2.6	372	33	1.7	39	22	49	17	12
76CC 0009	14	576400	7103600	15	2.2	267	27	2.2	38	15	31	46	8
76CC 0010	14	562600	7104500	33	3	435	53	1.5	42	44	30	13	13
76CC 0014	14	557400	7117000	36	3.3	453	43	1.4	63				
76CC 0015	14	557400	7117000	46	3.9	324	49	3.5	72	64	19	12	5
76CC 0016	14	564400	7115600	70	4.9	439	67	1.4	58	62	26	6	6
76CC 0017	14	596400	7110500	29	3	308	65	2	50	73	9	16	2
76CC 0019	14	620900	7104200	13	2.2	267	21	2.6	38				
76CC 0021	14	617100	7121100	11	2.2	187	20	2.1	36	47	3	17	33
76CC 0023	14	611100	7138600	27	2.6	206	31	4.4	54	53		47	
76CC 0024	14	605200	7113400	14	2.5	276	27	2.1	47	44	16	24	12
76CC 0025	14	633600	7103200	12	2.5	218	24	2.3	44	28	6	32	34
76CC 0027	15	363600	7138800	50	6.2	720	52	5.4	141				
76CC 0033	14	575000	7118700	129	5.6	680	106	1.4	77	71	22	5	3
76CC 0034	14	552800	7135000	24	2.8	270	34	3	54	66	16	10	8
76CC 0046	14	573500	7140500	33	3.5	411	44	2.3	66	66	14	14	6
76CC 0047	14	631900	7133300	26	3.4	460	32	2.7	68	58	2	16	25
76CC 0057	14	592000	7145300	42	3.6	407	39	2.1	76	59	9	16	16
76CC 0058	14	600300	7117200	40	3	414	29	1.4	90	60	13	20	8

Appendix 1 (cont.)

Sample No.	UTM	EAST	NORTH	Copper	Iron	Manganese	Nickel	Uranium (fl)	Zinc	Dubawnt Group Pebbles (2-4.6 mm) Crystalline	Volcanic	Sedimentary	Rounded
	Zone	metres	metres	ppm	wt. %	ppm	ppm	ppm	ppm	Rock	Rock	Rock	Quartz
76CC 0059	14	603100	7108600	13	2.2	231	27	1.8	38	24	28	32	15
76CC 0065	14	613200	7157900	84	5.6	700	56	3.6	139				
76CC 0066	14	644100	7140400	78	5.9	700	64	1.7	129	100			
76CC 0085	14	607800	7093500	15	2.5	630	22		24	22	48	22	8
76CC 0086	14	565700	7092100	78	2.8	491	149	1.8	72	24	49	11	17
76CC 0087	14	559000	7091400	6	1.6	380	9	1.4	16	18	44	21	18
76CC 0088	14	553300	7087600	8	1.4	227	14	1.3	24	18	70	7	15
76CC 0089	14	553100	7073700	30	2.8	593	28	4.2	69	39	52	6	3
76CC 0090	14	562500	7054800	29	2.8	340	26	3	58	46	43	6	4
76CC 0091	14	553400	7046600	26	2.8	425	34	2.2	84	56	41	1	2
76CC 0092	14	564300	7037000	12	1.4	187	14	0.9	25	54	39	6	1
76CC 0094	14	575000	7055800	25	3.4	356	48	5.5	74	44	37	15	5
76CC 0095	14	605600	7079200	10	3.5	348	40	2.3	45	16	68	13	3
76CC 0096	14	587600	7070300	20	2.4	380	34	1.5	58	23	63	6	8
76CC 0097	14	595100	7066600	16	2.8	449	27	2.4	40	47	36	10	7
76CC 0098	14	597300	7060500	14	3.1	298	38	2	60	43	50	4	3
76CC 0100	14	580300	7032100	24	2.3	404	28	1.7	70	64	29	5	1
76CC 0101	14	560200	7038000	33	3.5	526	39	4	89	63	27	7	2
76CC 0103	14	563800	7011900	46	3.2	625	49	4.4	104	73	23	3	1
76CC 0104	14	565400	6996800	36	2.8	445	48	2.9	84	78	18	2	2
76CC 0107	15	410000	7104100	39	3.4	570	31	2.5	104	63	8	20	8
76CC 0108	15	425300	7106200	36	5	800		2.7	123	73	11	12	4
76CC 0109	15	435700	7099700	38	3.4	725	39	6.6	109	87	14		
76CC 0110	15	445300	7111100	40	3.7	745	39	9.9	103	97	3		
76CC 0111	15	427100	7122900	43	5.1	1000		13.2	168	98	2		
76CC 0113	15	429400	7123400	38	4.1	890	40	2.5	150	99	1		
76CC 0114	15	443900	7129400	32	3.8	765	41	13.2	134	100			
76CC 0115	15	409300	7129900	39	5.8	900	38	11.6	198				
76CC 0116	15	384800	7134400	53	6.2	809	48		138	100	tr		
76CC 0117	15	389800	7144000	61	7	800	50	18.9	214	100	tr		
76CC 0118	15	400400	7145400	40	5.6	900	40	16.8	175	100	tr		
76CC 0128	15	438600	7152100	17	1	165	12	10.2	32	100	tr		
76CC 0129	15	420800	7144100	38	3.5	860	30	35.2	145	100			
76CC 0130	15	412400	7140300	12	1.8	580	16	8.5	82	100			
76CC 0132	15	394100	7128400	56	7.2	1150		5.7	265				
76CC 0133	14	591600	7030500	20	2.2	630	32	3.2	84	63	29	6	1
76CC 0134	14	612100	7031200	29	2.5	540	56	3	80	64	23	3	10
76CC 0135	14	629400	7030700	29	2.8	605	55	13.2	83	69	24	5	2
76CC 0136	14	601100	7085100	7	1.2	280	13	1.8	18	15	69	13	4
76CC 0140	14	593900	7084500	10	3.2	491	24	3.2	28	16	65	12	6
76CC 0141	14	578700	7082900	12	2.2	320	25	2.2	40	20	62	11	7

										Dubawnt Group Pebbles (2-4.6 mm)			
Sample No.	UTM	EAST	NORTH	Copper	Iron	Manganese	Nickel	Uranium (fl)	Zinc	Crystalline	Volcanic	Sedimentary	Rounded
	Zone	metres	metres	ppm	wt. %	ppm	ppm	ppm	ppm	Rock	Rock	Rock	Quartz
76CC 0142	14	593300	7041500	30	3.2	421	36	3	68	62	27	3	2
76CC 0143	14	615600	7047800	22	3	332	38	2.2	56	48	40	9	4
76CC 0144	14	627300	7059300	41	3.4	442	58	1.7	82	59	28	13	
76CC 0145	14	640400	7047800	19	3.5	917	36		36	53	40	4	5
76CC 0146	14	640800	7048200	38	3.5	530	72	1.3	80	45	46	3	6
76CC 0147	15	355200	6994400	50	3	484	43	5.4	62				
76CC 0148	14	638800	6995100	29	3.1	414	46	2.8	87	74	24		2
76CC 0149	14	629100	6991100	16	1.4	348	18	1.6	24	66	29	4	1
76CC 0150	14	612400	6993500	22	2.7	396	30	2.8	72	59	30	5	5
76CC 0151	14	612400	6993500	14	2	264	21	2.5	48				
76CC 0152	14	591800	6994700	16	3.5	352	28	2.1	68	61	26	10	3
76CC 0153	14	582600	6990100	40	3.5	376	44	4.2	74	63	29	6	2
76CC 0154	14	579500	7007200	34	3	435	47	1.9	84	73	20	6	tr
76CC 0155	14	599300	7004400	16	1.8	410	27	2.9	74	50	40	5	5
76CC 0158	14	637100	7013700	28	2.4	585	44	3.6	78	69	26	3	2
76CC 0160	14	620400	7065100	34	2.6	545	54	1.6	78	51	42	4	3
76CC 0164	15	356200	7065200	8	1.2	270	20	1.1	26				
76CC 0167	14	633800	7118100	29	4	550	47	5.8	132				
76CC 0168	14	633800	7118100	40	4.2	585	56	6.1	146	59	9	33	3

APPENDIX 2

Geochemical analyses of clay-, silt and clay-, sand-, and coarse sand and pebble-sized fractions

Sample No.	Copper Clay	Copper Silt and Clay	Copper Sand	Copper Pebbles
75 01 6007	24	20	34	8
75 01 6107	16	6	4	8
75 01 6207	19	5	6	3
75 01 6307	16	8	12	11
75 01 6407	44	10	7	6
75 01 6507	19	6	21	9
75 01 6607	18	8	5	4
75 01 6607 01	14	6		
75 01 6707	18	14	11	17
75 01 6807	29	10	6	5
75 01 6907	25	10	5	8
75 02 6907 01	19	4	5	8
75 01 7007	20	5	6	8
75 01 7107	17	8	6	5
75 01 7207	19	12	9	7
75 01 7207 01	17	4	6	30
75 01 7307	26	14	5	5
75 01 7407	25	9	5	
75 01 7507	26	5	4	
75 01 6009	16	5	5	13
75 01 6109	13	3	13	4
75 01 6209	19	3	7	5
75 01 6309	20	4	3	5
75 01 6409	18	4	8	5
75 01 6509	18	10	5	5
75 02 6509 02	12	3	5	9
75 01 6609	18	8	6	8
75 01 6709	15	3	5	16
75 01 6809	17	3	3	11
75 01 6909	15	3	6	3
75 01 7009	21	4	6	6
75 01 7509	40	5	8	6

Sample No.	Lead Clay	Lead Silt and Clay	Lead Sand	Lead Pebbles
75 01 6007	31	26	15	5
75 01 6107	40	12	7	5
75 01 6207	28	6	7	4
75 01 6307	14	13	9	6
75 01 6407	32	9	8	7
75 01 6507	28	8	24	5
75 01 6607	28	12	6	4
75 01 6607 01	28	10		
75 01 6707	30	16	6	6
75 01 6807	31	10	6	5
75 01 6907	30	11	6	4
75 02 6907 01	36	7	7	6
75 01 7007	28	10	7	4
75 01 7107	26	12	6	4
75 01 7207	27	15	7	5
75 01 7207 01	38	7	5	6
75 01 7307	38	19	7	5
75 01 7407	58	14	7	9
75 01 7507	39	8	6	6
75 01 6009	28	9	6	5
75 01 6109	32	8	7	5
75 01 6209	44	8	7	7
75 01 6309	44	7	5	4
75 01 6409	36	8	6	5
75 01 6509	27	14	7	6
75 02 6509 02	36	10	6	6
75 01 6609	27	11	11	7
75 01 6709	56	8	11	4
75 01 6809	32	8	11	7
75 01 6909	37	8	10	5
75 01 7009	34	8	7	4
75 01 7509	30	6	10	5

Sample No.	Zinc Clay	Zinc Silt and Clay	Zinc Sand	Zinc Pebbles
75 01 6007	62	22	7	6
75 01 6107	42	8	4	6
75 01 6207	42	9	4	4
75 01 6307	32	25	4	7
75 01 6407	96	22	9	11
75 01 6507	44	14	12	4
75 01 6607	46	16	3	2
75 01 6607 01	41	11		
75 01 6707	42	15	4	6
75 01 6807	48	15	4	8
75 01 6907	51	16	4	4
75 02 6907 01	41	8	4	4
75 01 7007	44	8	4	4
75 01 7107	44	18	6	4
75 01 7207	47	19	4	5
75 01 7207 01	38	8	2	10
75 01 7307	55	18	4	4
75 01 7407	76	16	4	23
75 01 7507	48	10	4	6
75 01 6009	42	10	4	4
75 01 6109	41	11	4	5
75 01 6209	44	8	5	6
75 01 6309	45	12	3	5
75 01 6409	40	7	5	4
75 01 6509	46	21	4	4
75 02 6509 02	30	5	4	4
75 01 6609	44	18	4	4
75 01 6709	34	8	3	4
75 01 6809	41	7	4	4
75 01 6909	35	7	4	4
75 01 7009	59	13	4	4
75 01 7509	58	8	3	13

Sample No.	Nickel Clay	Nickel Silt and Clay	Nickel Sand	Nickel Pebbles
75 01 6007	42	16	10	8
75 01 6107	34	6	4	6
75 01 6207	29	6	19	4
75 01 6307	20	15	4	6
75 01 6407	47	10	6	7
75 01 6507	30	8	35	6
75 01 6607	29	10	5	3
75 01 6607 01	28	8		
75 01 6707	28	9	6	4
75 01 6807	29	9	4	6
75 01 6907	29	10	4	4
75 02 6907 01	27	5	3	3
75 01 7007	30	6	7	4
75 01 7107	26	12	5	4
75 01 7207	28	12	4	5
75 01 7207 01	28	5	3	11
75 01 7307	36	12	4	24
75 01 7407	41	9	3	7
75 01 7507	31	6	3	7
75 01 6009	28	8	3	6
75 01 6109	28	7	4	5
75 01 6209	38	6	10	8
75 01 6309	41	7	37	8
75 01 6409	26	5	47	4
75 01 6509	28	14	4	5
75 02 6509 02	29	4	110	13
75 01 6609	34	12	51	9
75 01 6709	38	5	39	14
75 01 6809	24	4	2	5
75 01 6909	34	5	5	5
75 01 7009	40	8	8	6
75 01 7509	39	5	7	7

Sample No.	Manganese Clay	Manganese Silt and Clay	Manganese Sand	Manganese Pebbles
75 01 6007	316	90	45	50
75 01 6107	435	50	30	60
75 01 6207	244	70	35	20
75 01 6307	418	275	30	40
75 01 6407	430	105	55	80
75 01 6507	195	70	160	40
75 01 6607	251	105	35	10
75 01 6607 01	158	70		
75 01 6707	231	90	45	40
75 01 6807	253	80	40	35
75 01 6907	238	100	50	30
75 02 6907 01	244	40	25	20
75 01 7007	388	110	50	40
75 01 7107	403	260	290	125
75 01 7207	252	110	50	35
75 01 7207 01	275	45	40	55
75 01 7307	299	145	30	20
75 01 7407	404	80	25	20
75 01 7507	368	70	35	45
75 01 6009	235	90	30	30
75 01 6109	323	55	40	40
75 01 6209	448	45	80	90
75 01 6309	350	55	30	35
75 01 6409	278	65	35	20
75 01 6509	248	115	95	40
75 02 6509 02	363	50	120	30
75 01 6609	329	230	35	25
75 01 6709	415	60	50	35
75 01 6809	178	30	25	30
75 01 6909	440	50	55	20
75 01 7009	381	80	30	15
75 01 7509	294	35	23	58

Sample No.	Iron (wt.%) Clay	Iron (wt.%) Silt and Clay	Iron (wt.%) Sand	Iron (wt.%) Pebbles
75 01 6007	2.66	0.72	0.31	0.22
75 01 6107	2.99	0.36	0.12	0.18
75 01 6207	2.2	0.37	0.17	0.09
75 01 6307	1.65	1.12	0.24	0.14
75 01 6407	3.16	0.65	0.27	0.3
75 01 6507	2.1	0.52	0.41	0.14
75 01 6607	2.56	0.67	0.1	0.1
75 01 6607 01	2.68	0.55		
75 01 6707	2.02	0.61	0.15	0.16
75 01 6807	2.46	0.62	0.12	0.14
75 01 6907	2.55	0.7	0.14	0.16
75 02 6907 01	2.43	0.32	0.12	0.15
75 01 7007	2.35	0.47	0.15	0.14
75 01 7107	2.39	0.73	0.09	0.08
75 01 7207	2.71	0.88	0.14	0.17
75 01 7207 01	2.65	0.4	0.09	0.19
75 01 7307	3.28	0.75	0.18	0.16
75 01 7407	3.34	0.58	0.13	0.14
75 01 7507	2.68	0.43	0.13	0.15
75 01 6009	2.33	0.5	0.1	0.12
75 01 6109	3.36	0.43	0.13	0.11
75 01 6209	3.63	0.4	0.26	0.16
75 01 6309	3.23	0.45	0.16	0.14
75 01 6409	2.39	0.32	0.12	0.11
75 01 6509	2.39	0.89	0.14	0.18
75 02 6509 02	2.56	0.42	0.15	0.18
75 01 6609	2.1	0.78	0.16	0.16
75 01 6709	2.72	0.42	0.15	0.15
75 01 6809	2.26	0.33	0.1	0.25
75 01 6909	2.48	0.35	0.14	0.08
75 01 7009	2.94	0.6	0.16	0.09
75 01 7509	2.5	0.31	0.13	0.3

Sample No.	Uranium Clay	Uranium Silt and Clay	Uranium Sand	Uranium Pebbles
75 01 6007	4	1.5	0.5	1
75 01 6107	2	0.7	0.3	0.5
75 01 6207	1	1	0.5	0.5
75 01 6307	1	1.5	0.5	0.5
75 01 6407	2	0.5	0.3	0.6
75 01 6507	1	1.3	1.3	0.6
75 01 6607	2	1	0.2	0.1
75 01 6607 01	2	1.2		
75 01 6707	2	1.2	0.5	0.3
75 01 6807	2	1.2	0.6	0.6
75 01 6907	4	0.9	0	0.1
75 02 6907 01	2	1.2	0.3	0.3
75 01 7007	2	1.2	0.1	0.5
75 01 7107	1	0.9	0.6	0.3
75 01 7207	3	1.8	0.4	0.5
75 01 7207 01	9	0.9	0.1	0.5
75 01 7307	2	0.9	0.3	0.6
75 01 7407	3	1.1	0.3	0.3
75 01 7507	2	0.5	0	0.3
75 01 6009	2	0.7	0.1	0.4
75 01 6109	4	1	0.3	0.6
75 01 6209	4	0.9	0.3	0.5
75 01 6309	4	0.7	0.1	0.6
75 01 6409	21	0.9	0.1	0.1
75 01 6509	2	1.2	0	0.5
75 02 6509 02	6	1.5	0.1	0.1
75 01 6609	2	1.2	0.4	0
75 01 6709	55	0.9	0.3	0.3
75 01 6809	10	0.7	0.1	0.3
75 01 6909	2	0.7	0.3	0.3
75 01 7009	2	1.2	0.1	0.1
75 01 7509	2	0.5	0.1	0.9

APPENDIX 3

Pebble (4-5.6 mm) lithology for till of the study area.

Sample No.	UTM Zone	East metres	North metres	Pebbles (4-5.6 mm) (wt. %) Dubawnt Group (undifferentiated)	Thelon Sandstone	Volcanic (Pitz)	Volcanic (Other)	Crystalline
7501 1614	14	590131	7078004	30	7	14	22	27
7501 2014	14	596300	7078387	53	8	18	12	9
7501 2414	14	602818	7078441	45	9	16	13	17
7501 2814	14	609167	7078090	62	4	12	7	15
7501 3002	14	612894	7058724	47	13	2	5	33
7501 3206	14	616395	7065422	34	4	3	8	51
7501 3214	14	615300	7078400	46	13	9	11	21
7501 3352	14	618466	7051386	29	6	6	8	51
7501 3402	14	620487	7059721	53	4	9	23	11
7501 3411	14	619844	7074142	42	9	13	20	16
7501 3607	14	622254	7067975	43	2	4	6	45
7501 3614	14	621603	7078998	22	30	19	9	20
7501 3650	14	622808	7054189	26	1	0	1	72
7501 3803	14	625979	7060893	39	10	0	25	26
7501 3811	14	625872	7073924	33	39	5	7	16
7501 3913	14	628573	7077407	33	24	7	10	26
7501 4006	14	629087	7066266	54	1	4	4	37
7501 4016	14	628517	7082151	29	27	16	10	18
7501 4152	14	631232	7051684	30	4	2	5	59
7501 4202	14	632639	7060217	28	4	3	16	49
7501 4211	14	632149	7074011	23	25	20	16	16
7501 4406	14	635363	7066397	17	15	3	1	64
7501 4414	14	634882	7079072	36	22	7	22	13
7501 4450	14	636298	7055118	27	3	1	2	67
7501 4602	14	638762	7060981	45	5	5	17	28
7501 4611	14	638177	7074398	34	35	10	7	14
7501 4806	14	641710	7066752	26	13	0	4	57
7501 4813	14	640561	7077232	28	46	3	5	18
7501 5002	14	644989	7060361	16	5	13	6	60
7501 5011	14	644418	7074382	34	22	3	11	30
7501 5206	15	351916	7066488	36	26	6	6	26
7501 5213	15	352526	7077984	40	26	4	7	23
7501 5402	15	354413	7059915	22	18	6	22	32
7501 5411	15	355288	7074648	47	21	0	9	23
7501 5606	15	357932	7066315	38	20	3	6	33
7501 5713	15	360167	7077463	25	31	0	15	29
7501 5803	15	360171	7061777	32	29	6	12	21
7501 5811	15	361853	7074472	27	47	1	5	20
7501 6007	15	364301	7067233	49	23	4	4	20
7501 6014	15	364900	7078755	45	28	1	0	26
7501 6019	15	365515	7087499	56	13	1	1	29
7501 6202	15	367979	7059647	39	18	3	5	35
7501 6211	15	368157	7074666	44	22	5	2	27
7501 6406	15	371126	7065761	48	28	4	3	17
7501 6414	15	371341	7078643	48	22	1	1	28
7501 6416	15	371680	7082079	46	20	0	1	33
7501 6602	15	373753	7059462	45	25	1	2	27
7501 6611	15	374532	7073830	42	21	1	1	35
7501 6619	15	375299	7086555	40	17	0	2	41
7501 6807	15	376878	7067285	46	17	4	2	31
7501 6814	15	378108	7078449	49	17	1	4	29
7501 6816	15	378140	7081851	56	10	0	0	34
7501 7002	15	380301	7058974	20	2	6	17	55
7501 7011	15	380856	7073680	42	23	1	0	34
7501 7019	15	381125	7086871	33	15	0	2	50
7501 7206	15	383841	7065768	46	15	0	2	37
7501 7214	15	384365	7078723	47	11	0	2	40
7501 7216	15	384899	7081753	35	11	0	0	54
7501 7402	15	386709	7059214	46	10	1	2	41
7501 7419	15	388534	7086521	35	11	0	0	54
7501 7606	15	390217	7066347	47	7	1	2	43
7501 7614	15	390704	7077908	48	14	0	2	36
7501 7623	15	367226	7091810	40	17	0	3	40
7501 7716	15	392369	7081585	35	19	1	0	45
7501 7810	15	393616	7071925	39	10	0	0	51
7501 7818	15	394700	7084300	49	11	0	0	40
7501 7923	15	372227	7091457	58	11	0	1	30
7501 8006	15	396640	7065439	42	11	1	1	45
7501 8014	15	396917	7077827	36	5	0	1	58
7501 8016	15	397442	7081177	34	6	0	0	60
7501 8210	15	400374	7071560	36	8	0	1	55
7501 8219	15	400331	7086279	30	11	0	0	59
7501 8406	15	403097	7065154	41	18	0	1	40
7501 8414	15	403647	7077884	42	6	0	3	49

				Pebbles (4-5.6 mm) (wt. %)				
Sample No.	UTM Zone	East metres	North metres	Dubawnt Group (undifferentiated)	Thelon Sandstone	Volcanic (Pitz)	Volcanic (Other)	Crystalline
7501 8416	15	403935	7081087	38	10	0	1	51
7501 8423	15	379728	7091638	32	38	0	0	30
7501 8610	15	406273	7071579	56	11	0	0	33
7501 8618	15	407200	7084200	42	19	0	0	39
7501 8723	15	385058	7091732	27	16	0	0	57
7501 8813	15	409952	7075994	46	6	0	2	46
7501 8816	15	409774	7080459	48	4	0	0	48
7501 9010	15	413200	7071500	42	8	0	0	50
7501 9118	15	414907	7083967	25	3	1	0	71
76PL 1519	14	587340	7085395	58	11	5	18	8
76PL 1550	14	589722	7053784	59	4	0	0	37
76PL 1606	14	590245	7064486	42	3	7	7	41
76PL 1608	14	590327	7068279	24	3	3	6	64
76PL 1623	14	589628	7092237	34	15	31	8	12
76PL 1726	14	590790	7096091	60	3	14	0	23
76PL 1750	14	592454	7054100	25	5	0	0	70
76PL 1802	14	594197	7059104	31	5	6	14	44
76PL 1808	14	592524	7067765	27	13	2	29	29
76PL 1810	14	593462	7071310	44	2	4	12	38
76PL 1816	14	592391	7081401	46	8	16	13	17
76PL 1824	14	592719	7094012	43	19	18	6	14
76PL 1920	14	594309	7087402	53	14	9	15	9
76PL 1953	14	596174	7048912	22	2	5	9	62
76PL 2006	14	597375	7065118	28	2	7	11	52
76PL 2008	14	596425	7068169	28	5	6	15	46
76PL 2023	14	596242	7092473	57	7	15	8	13
76PL 2052	14	597557	7050827	19	3	1	5	72
76PL 2117	14	597620	7083132	33	16	20	24	7
76PL 2126	14	596972	7097143	32	29	12	0	27
76PL 2150	14	599437	7054405	30	0	19	4	47
76PL 2152	14	599647	7050617	33	10	4	8	45
76PL 2153	14	598935	7048936	31	3	1	14	51
76PL 2202	14	600570	7059356	14	5	5	17	59
76PL 2207	14	599962	7066618	45	8	7	18	22
76PL 2210	14	600264	7071753	51	2	7	9	31
76PL 2219	14	599238	7086337	35	14	33	3	15
76PL 2224	14	598737	7094130	47	19	11	9	14
76PL 2406	14	604828	7065514	37	3	17	35	8
76PL 2408	14	602451	7068619	41	3	6	36	14
76PL 2418	14	602875	7084902	61	13	9	7	10
76PL 2524	14	603718	7093844	38	17	20	10	15
76PL 2525	14	603802	7095782	45	16	21	9	9
76PL 2526	14	603456	7097606	35	27	15	7	16
76PL 2550	14	605631	7053857	16	8	2	16	58
76PL 2608	14	606317	7068781	52	7	10	12	19
76PL 2610	14	607145	7072082	45	4	4	11	36
76PL 2616	14	605803	7081582	45	10	19	11	15
76PL 2619	14	605320	7086450	35	21	17	8	19
76PL 2621	14	605085	7089321	42	12	23	6	17
76PL 2624	14	604853	7094479	45	16	16	7	16
76PL 2625	14	605028	7095521	38	15	19	10	18
76PL 2806	14	611338	7065073	36	5	6	13	40
76PL 2807	14	609735	7066698	43	6	10	11	30
76PL 2818	14	608795	7084802	20	47	17	5	11
76PL 2823	14	608263	7092104	30	20	17	10	23
76PL 2850	14	610398	7054224	35	6	4	8	47
76PL 2926	14	609879	7097915	24	27	10	16	23
76PL 3024	14	611735	7094738	30	32	9	9	20
76PL 3116	14	613650	7081939	36	19	22	7	16
76PL 3618	14	621700	7085300	18	66	5	4	7
76PL 4119	14	638000	7086700	28	43	5	3	21
76PL 4125	14	628764	7096403	36	19	3	18	24
76PL 4223	14	631453	7092844	32	46	1	1	20
76PL 4319	14	633300	7087300	34	35	6	1	24
76PL 4325	14	632449	7096798	37	20	5	1	37
76PL 4327	14	632529	7100255	30	41	4	1	24
76PL 4418	14	634800	7085700	33	33	10	3	21
76PL 4423	14	634304	7093729	28	44	2	1	25
76PL 4525	14	635936	7096833	38	52	1	1	8
76PL 4619	14	637824	7087411	29	18	8	14	31
76PL 4818	14	641252	7086336	41	15	2	20	22
76PL 4823	14	640644	7093617	36	61	0	0	3
76PL 4927	14	642608	7100359	31	30	0	5	34
76PL 5020	14	643728	7089178	54	20	9	1	16

Appendix 3 (cont.)

Sample No.	UTM Zone	East metres	North metres	Pebbles (4-5.6 mm) (wt. %) Dubawnt Group (undifferentiated)	Thelon Sandstone	Volcanic (Pitz)	Volcanic (Other)	Crystalline
76PL 5024	14	643326	7095488	44	23	0	1	32
76PL 5116	14	646046	7082490	37	19	9	2	33
76PL 5223	14	647000	7093800	44	21	1	4	30
76PL 5326	15	354920	7099458	59	16	0	0	25
76PL 5419	15	356691	7087329	49	15	1	2	33
76PL 5424	15	355739	7095880	59	16	1	1	23
76PL 5516	15	356862	7082577	41	20	4	6	29
76PL 5727	15	361579	7100336	44	16	1	2	37
76PL 5819	15	362790	7088034	63	11	7	5	14
76PL 5916	15	364003	7081508	25	14	41	0	20
76PL 6226	15	369112	7098055	28	44	0	0	28
76PL 6624	15	376037	7095054	23	56	0	0	21
76PL 6726	15	377358	7097849	34	39	0	3	24
76PL 7126	15	384013	7097733	34	17	0	0	49
76PL 7526	15	390126	7097498	15	10	0	2	73
76PL 7627	15	392225	7099522	43	6	0	0	51
76PL 7726	15	393706	7097375	42	18	0	1	39
76PL 7826	15	394914	7097300	24	11	0	0	65
76PL 7827	15	395113	7098824	37	17	1	0	45
76PL 8022	15	397726	7090857	31	9	0	1	59
76PL 8025	15	398633	7095706	40	4	0	52	4
76PL 8026	15	398676	7097494	39	5	0	0	56
76PL 8205	15	399895	7063767	44	14	0	0	42
76PL 8422	15	404233	7090588	30	15	0	1	54
76PL 8425	15	404688	7095832	30	28	0	0	42
76PL 8503	15	404310	7060130	37	31	0	0	32
76PL 8602	15	406027	7058570	33	11	1	1	54
76PL 8603	15	406162	7060161	42	2	0	1	55
76PL 8607	15	405904	7066401	47	3	0	1	49
76PL 8627	15	407979	7098529	22	51	0	2	25
76PL 8702	15	407465	7058502	37	7	0	1	55
76PL 8703	15	407397	7060346	38	3	0	0	59
76PL 8806	15	409332	7064362	40	24	0	0	36
76PL 8822	15	410634	7090492	46	4	0	0	50
76PL 8907	15	411380	7066417	56	3	0	0	41
76PL 8925	15	412370	7095093	34	9	0	1	56
76PL 9025	15	414200	7094704	28	3	0	0	69
76PL 9026	15	414633	7096625	35	5	0	1	59
76PL 9027	15	414680	7098010	29	1	0	0	70
76PL 9106	15	414169	7064622	49	2	0	0	49
76PL 9125	15	415820	7094447	33	4	0	0	63
76PL 9127	15	416399	7097933	9	4	0	0	87