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Drift-prospecting investigations in the Yellowknife Greenstone Belt, Northwest Territories

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Abstract

Surficial geology studies and geochemical analyses of till and organic materials provide new baseline data for mineral exploration in the Yellowknife Greenstone Belt. The mapped pattern of ice-flow indicators throughout the study area is generally consistent with the dominant regional flow and confirms a generally southwestward ice movement. Minor variations indicate local late-glacial flow ranging from west-northwestward to west-southwestward. Pebble-lithology studies indicate that dispersal patterns in till reflect the last southwestward flow. Metasedimentary and volcanic (nongranitic) clasts predominate in most areas underlain by both metasedimentary–volcanic and granitic bedrock, and suggest transport distances of at least 25 km for some clasts. Gold-grain counts of the heavy-mineral fraction of till indicate that background values over granitic terrain for each sample is approximately 0 to 1 grain/10 kg of till. Anomalous concentrations of 19 gold grains/sample in granitic terrain southeast of Drybones Bay are currently being investigated.

Résumé :

Les études des dépôts meubles et les analyses géochimiques du till et des matières organiques fournissent de nouvelles données de base pour la prospection glacio-sédimentaire dans la ceinture de roches vertes de Yellowknife. Les résultats de la cartographie des marques d'écoulement glaciaire dans la région concordent grosso modo avec l'écoulement régional prédominant et confirment un écoulement glaciaire généralement vers le sud-ouest. Des variations mineures témoignent d'un écoulement tardiglaciaire local vers l'ouest-nord-ouest jusqu'à l'ouest-sud-ouest. L'étude lithologique des cailloux indique que le modèle de dispersion glaciaire du till reflète le dernier écoulement vers le sud-ouest. Les clastes sédimentaires et volcaniques (non granitiques) prédominent dans la plupart des secteurs ayant un substratum rocheux sédimentaire-volcanique et granitique, et laissent croire que certains clastes ont été transportés sur au moins 25 km. Le comptage des grains d'or dans la fraction de minéraux lourds du till indique que les valeurs de base régionales pour chaque échantillon provenant de terrain granitique sont d'environ 0 à 1 grain d'or pour 10 kg de till. Des concentrations anomales de 19 grains d'or par échantillon dans un terrain granitique au sud-est de la baie Drybones font l'objet d'études.

INTRODUCTION

In response to declining ore reserves at producing gold mines and reduced mineral exploration in the Yellowknife area, the Geological Survey of Canada, the Northwest Territories Geology Division (Indian and Northern Affairs Canada), and private industry developed the Yellowknife EXTECH Program. EXTECH III is a multidisciplinary, integrated geoscientific study aimed at augmenting the geoscience database to support exploration and development. Preliminary surficial geology studies (Kerr and Wilson, 2000) began in 1999 (NTS 85 J/7, 8, 9, 10, 11, 16; 85-I/ 4, 5, 12, 13; 85-O/1 and 85 P/4) to provide baseline data on surficial materials, ice-flow history, and soil geochemistry. Follow-up investigations were undertaken in 2000 to improve the till geochemistry and biogeochemical databases over the Yellowknife Greenstone Belt (NTS 85 J/8, 9, 16; 85-O/1 and 85 P/4), as well as to further assess glacial provenance (Fig. 1). Contracts were issued for additional kimberlite indicator mineral and gold grain sampling in the Drybones Bay area (NTS 85-I/4; Fig. 1) by D. Smith, and biogeochemical samples were collected in the Yellowknife area by D. Nickerson.

METHODS

To provide uniform, regional coverage in this study, the area was surveyed using road access and helicopter-assisted traversing. From 68 regional stations (Fig. 2), 67 ten-kilogram soil samples were collected to document the range and background concentrations of gold grains over the Yellowknife Greenstone Belt, covering an area from the Octopus Lake area south of Con mine, northward to Discovery mine and Nicholas Lake. Soil samples were collected from hand-dug pits or excavated sections at depths of 0.1 to 0.7 m (Fig. 3a). Although till is the preferred parent material for soil sampling, a range of sediment types was encountered and sampled, including stony glaciolacustrine clayey silt, sandy glacial diamicton (probably till), and sandy glaciofluvial outwash. In the regional biogeochemical study, ten spruce bark samples were collected, together with four leaf litter fall and four humus samples, for comparison with sites closer to Yellowknife sampled in 1999. Approximately 50 pebbles (2 to 6 cm in diameter) were collected from 65 sites for provenance and glacial-transport investigations. Soil-profile studies were undertaken to document postdepositional mobilization of selected elements in three locations near the Con and Giant mine sites. For the soil-profile studies, samples include 19 two-kilogram till samples for trace-element and grain-size analyses to document changes with depth, 6 humus samples, 2 litter fall samples, 3 spruce bark samples, 2 Labrador tea samples, and 2 mineralized bedrock samples. At 44 regional locations, glacial striae were measured and rock type was noted; at approximately 20 other locations, surface weathering of volcanic bedrock outcrops has prevented the preservation of striae (Fig. 3b).

An additional 25 twenty-kilogram till samples have been submitted for kimberlite indicator-mineral and gold-grain analyses as part of a detailed dispersal study in the Drybones Bay kimberlite area, southeast of Yellowknife (**Fig. 2**). The Drybones Bay kimberlite was discovered in 1994 and has diamonds of commercial quality (Kretschmar, 1997). Preliminary results of gold-grain and kimberlite indicator-mineral studies from the 1999 field season are provided in Kerr et al. (2000).

Biogeochemical orientation surveys were conducted in the vicinity of Yellowknife to document three case studies in which Labrador tea and spruce bark are assessed as exploration tools. A total of fifty-six 400 g samples of Labrador tea stems and thirty-three 200 g samples of spruce bark have been submitted for geochemical analyses. To estimate pre-mining baseline concentrations of elements, 18 black spruce tree-ring samples from two locations near the Giant mine roaster were taken; the tree ring samples represent ten-year increments from 1900 and 1920 to the present. Lastly, two bulk samples (1 kg) of Labrador tea and spruce bark were collected to compare sample preparation and analytical methods (washed vs unwashed and maceration vs ashing). Nickerson (1999) presents the results of a 1999 preliminary biogeochemical survey around Yellowknife.

REGIONAL SETTING AND SURFICIAL SEDIMENTS

The Yellowknife Greenstone Belt lies in the southwestern Slave structural Province. Elevations rise gradually from 157 m (Great Slave Lake) to 350 to 400 m north of Thistlethwaite Lake (**Fig. 3c**). Much of the terrain southwest and southeast of Yellowknife is generally of low relief and under 200 m a.s.l. Local terrain consists mainly of bare rocky outcrops with glacial and glaciolacustrine sediments in topographic lows between outcrops. The study area lies south of the treeline and supports open to dense forests of black spruce, jack pine, larch, trembling aspen, and paper birch mixed with marshes, fens, and peat bogs in low-lying areas. The Yellowknife Greenstone Belt is characterized by abundant bedrock outcrops that may cover up to 75% or more of a given area. Gossans are relatively common (**Fig. 3d**). Outcrops are commonly separated by steep, drift-filled draws of varied depths.

Till is the prevalent surficial sediment in the study area. It is a loosely compact, stony, matrix-supported diamicton, with the matrix ranging from coarse to fine sand with minor amounts of silt. Clasts of varied rock types range in size from small pebbles to large boulders and are subangular to subrounded. The till contains up to 60% clasts, but most exposures have between 20% and 40%. It is generally under 2 m thick and forms a discontinuous veneer over bedrock outcrops (**Fig. 3e**). Some of the till below 280 m a.s.l. has been reworked by glaciolacustrine and glaciofluvial processes.

Glaciofluvial sediments are relatively uncommon and consist of fine sand to cobbles in the form of eskers, kames, and subaqueous outwash. Eskers are linear to slightly sinuous and generally trend parallel to the glacial flow direction defined by striae, i.e. southwestward. Their crests are rounded to flat topped. They range from small ridges or mounds a few tens of metres long to larger systems up to 2 km long and 10 to 15 m high. Many eskers and kames are commonly flanked by meltwater corridors containing boulder lags and scoured bedrock. Meltwater channels carved in bedrock may also be found linking esker segments together, forming part of the subglacial drainage network. Important subaqueous outwash deposits occur in the Yellowknife airport area.

Glaciolacustrine deposits consist of poorly to moderately sorted, coarse to fine sand, silt, and clay estimated to be up to 20 m thick, with varied amounts of pebbles, cobbles, and boulders, and occur preferentially in topographic lows. Stratigraphically, these sediments may overlie till, outwash, and bedrock. Wave-washed bouldery till surfaces occur up to 100 m (275–280 m a.s.l.) above the present level of Great Slave Lake and as far as 70 km or more inland from the lake. Glaciolacustrine deposits are associated with Glacial Lake McConnell, which inundated the area during deglaciation (Craig, 1965).

Organic sediments consist of peat formed by the accumulation of fibrous, woody, and mossy vegetative matter. Peat is up to 1 m thick or more in bogs and other wetlands underlain by fine-grained glaciolacustrine sediments. Sedges, shrubs, and open forests of stunted black spruce grow on these sediments. Yellowknife lies within the zone of discontinuous permafrost, where permafrost is localized or absent (Wolfe, 1998).

ICE-FLOW INDICATORS

A basic understanding of ice-flow history is necessary in any drift-prospecting investigation. **Figure 4** is an ice-flow diagram based on striae measurements at 44 sites; approximately one third of the sample sites in 2000 yielded no striae. The inset represents regional ice flow based on airphoto interpretation, striae measurements at 66 sites, and regional observations made by Jolliffe (1942), Henderson (1985), Kerr (1990), and Boyce (1998). The more detailed mapping of ice-flow indicators throughout the study area carried out in 2000 gave results that are generally consistent with the regional dominant flow across the area, and did not reveal any significant new directions of ice movement. Minor striae variations of less than 10° are common at most sites. Large-scale ice-flow indicators such as crag-and-tail and fluted outcrops (roches moutonnées) typically reflect the dominant flow across the region. All glacial indicators are believed to relate to the Late Wisconsin Glaciation (Dyke and Prest, 1987).

From south to north, the new striae data reflect a generally consistent southwest flow. Yellowknife Bay is characterized by a few examples of striae with greater variation (230° to 275°), possibly due to topographic control over ice flow in this area of moderate relief. Two other sites north of Yellowknife Bay also record southwestward to westward flows (Fig. 4), although no age relationships could be determined. In one location at Nicholas Lake, evidence exists of a southwest flow being crosscut by a west-southwest flow (Fig. 3f). The westward flows reported at four widely separated locations are unlikely to relate to a single, widespread glacial advance to the west distinct from the major southwestward ice flow.

PEBBLE-PROVENANCE STUDIES

As an aid to mineral exploration, the lithology of pebbles in till was examined to illustrate patterns of glacial dispersal and estimate transport distances. Granitoid rocks were chosen as an indicator rock type because they have a clearly defined source area, and because granitoid clasts can be distinguished easily from metasedimentary and metavolcanic rocks. However, the lack of distinctive 'marker' rocks and the visual similarities between metasedimentary and metavolcanic clasts in the 1 to 3 cm size range remain an obstacle for provenance studies. In the study area, the various bedrock types form complex geological structures where lithological contacts are convoluted and irregular. These conditions are not conducive to regional provenance studies or to mapping well defined dispersal trains. Figure 5 shows the percentage (by count) and distribution of granitoid pebbles in till over the area. This figure incorporates data from 65 sites sampled in 2000, as well as 47 regional sites from 1999 (Kerr and Wilson, 2000).

The highest concentrations (up to 86%) of granitoid clasts in till occur in four regions underlain by granitoid plutons, the Nicholas lake area (81–86%) in the northernmost map region, the central part of the pluton that extends along the western boundary of the study area (66–72%), the pluton between Prelude and Duncan lakes (45–69%), and the granitic terrain east and south of Yellowknife Bay (58–64%) in the Defeat Lake area. Many of the highest granitic values decrease to 30% or less over 6 to 8 km with increasing distance away from their source, not only along the margins of granitic plutons, but also where outcrops are exposed for hundreds of square kilometres.

The lowest concentrations of granitoid clasts in till (0 to <20%) are found overlying volcanic and metasedimentary bedrock. These clasts were absent at eight sites underlain by volcanic rocks west and northwest of Prosperous Lake, and northwest of Duncan Lake. Regions with <10% granitoid clasts include west of Yellowknife Bay, the north end of Yellowknife Bay, and a large area north of Duncan Lake.

Volcanic and metasedimentary rocks dominate the clast fraction of till across the study area on all bedrock types, with few exceptions. The dilution of granitoid clasts in till, even in areas underlain by granitoid bedrock, shows the ease with which other rock types were glacially eroded, fragmented, and transported. In contrast, the granite plutons appear to have yielded less debris than the volcanic and metasedimentary rocks. The changing ratios of pebble types (granitic versus metasedimentary and volcanic) can be observed along the path of ice flow, from northeast to southwest. This produces a pronounced overlap in pebble types between adjacent bedrock types, but obscures any potential well defined patterns of glacial dispersal, as observed in clast distribution (**Fig. 5**).

A typical or average glacial transport distance is difficult to estimate because of the dominance of metasedimentary and volcanic clasts throughout the region. Granitoid clast concentrations reach up to 40% as much as 25 km down-ice (southwest) of their source, whereas a few sample sites underlain by granite contain up to 60% to 70% metasedimentary clasts, indicating that some clasts were transported 25 to 35 km or more. Distinctive Proterozoic sedimentary erratics originate 125 to 150 km or more to the east and southeast. Because ice flow was generally from the northeast, these erratics were likely ice rafted in Glacial Lake McConnell.

GOLD GRAINS IN TILL

A preliminary analysis of heavy-mineral concentrates (<2 mm fraction) from 11 regional bulk till samples (*see* Kerr et al., 2000) in areas underlain by granite and metasedimentary rocks suggests that the background value for visible gold grains in till is approximately 0 to 1 in 10 kg of till. Five samples from the northern and central study area were barren, two samples west of Yellowknife each contained 1 gold grain, two samples north and east of Drybones Bay contained 1 and 0 gold grain respectively, and one sample immediately west of the Drybones kimberlite pipe yielded 2 gold grains. An anomalous concentration of gold grains (n=19) was discovered in a till sample in granitic terrain southeast of Drybones Bay. The source of the gold remains unknown. The till in this area has been reworked to some degree by Glacial Lake McConnell, but the gold likely originates up-ice of the site (to the northeast), possibly from gold-bearing quartz veins in granite, similar to the Nicholas Lake property, but obscured by surficial sediments in this area. An additional 17 of 25 bulk till samples from the Mud Lake area (**Fig. 6**) southeast of Drybones Bay were also highly anomalous. Abundance, size, and morphology of these gold grains are given in Kerr et al. (2000).

The 67 bulk till samples collected in 2000 will provide a better indication of background gold-grain values in areas underlain predominantly by volcanic rocks. Sample sites vary from areas of no recorded gold showings, to down-ice of past producing mines, to directly overlying undeveloped properties such as Nicholas Lake. Another 25 till samples from the Drybones Bay area will also be examined for gold-grain content. This wide range of geological settings provides important baseline data for mineral exploration.

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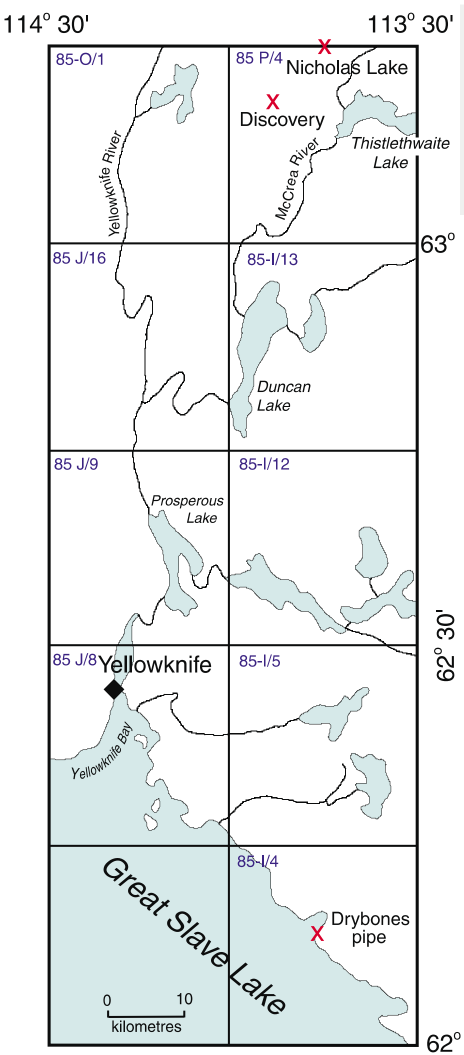

Figure 1. Location of the study region with corresponding 1:50 000 scale map areas.

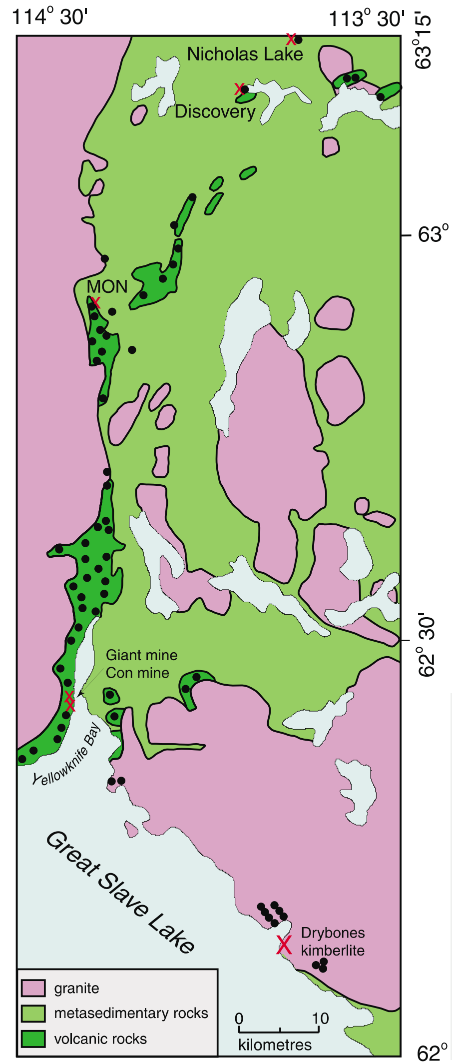

Figure 2. Location of sample sites (black dots) and generalized bedrock geology with selected mineral deposits; *modified from* Jolliffe (1942), Henderson (1985), and Stubley (1997).

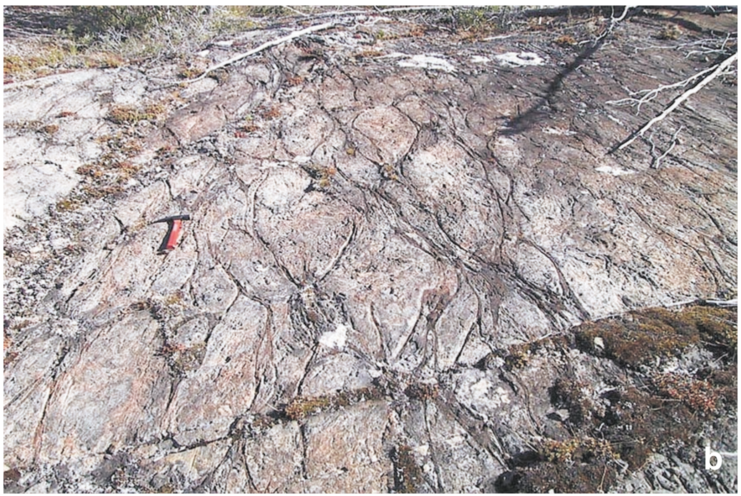

Figure 3. a) Hand-dug pit in till from which bulk samples for gold grains and pebbles are collected; subrounded cobbles in a sandy matrix are common. **b)** Highly weathered pillowed volcanic rocks outcropping 4 km northeast of the Discovery mine. **c)** Rugged terrain north of Thistlethwaite Lake with relief in the order of 60 to 70 m; note the many dead spruce trees resulting from a recent forest fire.

Figure 3. d) One of the many weathered gossans associated with the Yellowknife Greenstone Belt, 2 km southwest of the Discovery mine. **e)** Shallow trench excavated in till veneer overlying granitic bedrock with convoluted metasedimentary rocks and quartz veins, Nicholas Lake. **f)** Granitic bedrock showing evidence of striae at 260° (upper and lower sections of photograph) crosscutting older striae at 235° (central section of photograph), Nicholas Lake.

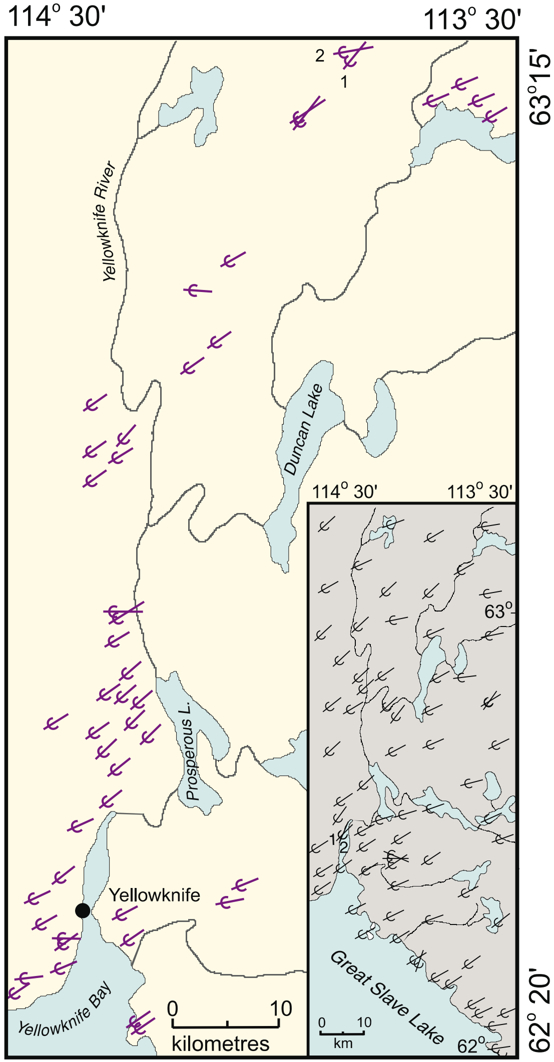

Figure 4. Detailed ice-flow summary diagram over the Yellowknife Greenstone Belt; 1 = oldest, 2 = youngest. Inset map shows regional ice flow.

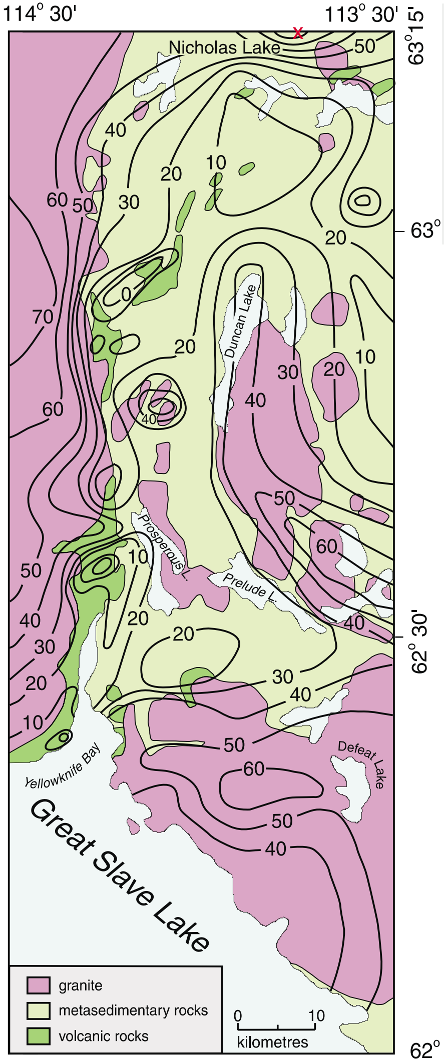

Figure 5. Clast lithology map showing contoured percentages (by count) of granitoid pebbles in till.

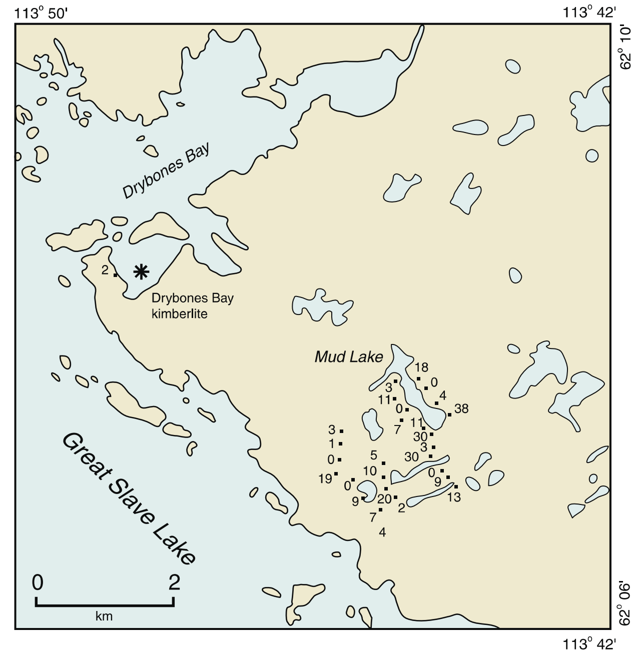

Figure 6. Gold grain abundances in till, Mud Lake–Drybones Bay area. Data are raw counts and have not been normalized.