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DRILLING, SAMPLING AND SAMPLE PROCESSING METHODS FOR DEEP TILL GEOCHEMISTRY SURVEYS:

MAKING THE RIGHT CHOICES

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obtain representative, reproducible gold geochemical results within these trains.

The criticism most commonly leveled at reverse circulation drills is that the overburden stratigraphy cannot be deciphered from disturbed samples with one-chance-only logging at the high penetration speeds that characterize these drills. However, good stratigraphic information can be obtained if several simple parameters that recognize the disturbed nature of the sample and the harried working conditions are systematically logged throughout the hole. In fact, the Quaternary stratigraphy of the Abitibi region, as it is presently understood (Table 3; Werniuk, 1986), was first identified by reverse circulation drilling and has simply been confirmed -- not significantly modified -- by rotasonic core drilling (DiLabio et al., 1988). Moreover all of the important mineral discoveries that have been made by overburden drilling were made using the reverse circulation method.

The four parameters that our company uses to differentiate till from gravel, and to recognize different ages of till and gravel, include two clast parameters and two matrix parameters. These parameters are:

1. The size of the largest clasts in the section (pebbles or cobbles or boulders; size is recognizable both by the bounce of the drill rods and by the lithology of the cuttings in the slurry sample);
2. The percentages of clasts of each major lithology (in the Abitibi region, these comprise Archean volcanics, turbidites and granitoids and Paleozoic carbonates);
3. The principal particle size of the mineral grains in the matrix (clay or silt-fine sand for till; medium sand, coarse sand or granules for gravel);
4. The colour of the matrix (gray or green clay-silt or buff-grey silt-sand for unweathered till; buff sand for unweathered gravel; red or ochre overprint for weathered till or gravel).

An example of a reverse circulation drill log made using these parameters is shown in Figure 5. Note that we prefer to use formational names, even if formal names have not been established, because this procedure requires the geologist to think in terms of glacial events and environments.

Current reverse circulation drilling costs are $220 to $240 per hour plus mobilization, down-the-hole consumables, road clearing and helicopter servicing costs (if required). On reconnaissance projects having a hole spacing of 300 to 400 m, this generally translates into $45 to $60/metre ($14 to $18/foot). The lowest costs are achieved on projects of 50 or more holes where helicopter support is not required and the overburden is of moderate thickness (20 to 30 m).

3.2 Rotasonic Drills

The rotasonic coring method is based upon technology that was originally devised for pile driving applications. Resonant vibrations (approximately 5000 cycles per minute) and slow rotation are used to effect bit entry with minimum sample compaction or disturbance. The hole is cased as it advances, preventing caving and cross-contamination of samples. No drilling fluid is required except in hard rock, and truly representative cores of all material from the softest clays to the hardest boulders and bedrock can be obtained. The core diameter is 9 cm, resulting in samples that are slightly larger than those obtained by reverse circulation drilling.

Oscillator heads or "tubs" for rotasonic drills are manufactured by Hawker Siddeley Canada Limited. Midwest Drilling of Winnipeg has developed a practical overburden exploration drill rig using the Hawker Siddeley head, and other companies now offer similar equipment. A major feature of these rigs is an efficient rod handling system that permits rapid casing insertion and core withdrawal after each 3 to 9 m (one to three rods) of advance. The rod handling system involves a hydraulically operated dual rod/casing breakout/holding tool, a hydraulic tilting mechanism on the drill head and a horizontal rod/casing storage bench. The rods and casing have also been strengthened to withstand prolonged resonant vibrations.

The coring string generally consists of the following:

1. A 12 cm O.D. x 9 cm I.D. bit;
2. One to three 3 m long x 12 cm O.D. x 10 cm I.D. core barrels.
3. A series of 3 m long x 9 cm O.D. x 6 cm I.D. rods.

Casing of 14 cm O.D. x 12 cm I.D. must be driven flush with the coring bit after each coring run to prevent caving during core withdrawal. The purpose of the small diameter of the rods relative to that of the core barrels is to reduce weight and improve rod handling efficiency. However, the rods must not be driven below the casing because caving at the shoulder of the core barrel would prevent withdrawal. The coring and casing bits are of the open shoe type and are faced with tungsten carbide buttons. These buttons are pressure set like those on reverse circulation tricone bits because brazed settings would cause Cu-Zn sample contamination.

In general, the following procedures are used to drill a rotasonic hole:

1. Core barrels are resonated/rotated 3 m (1 length), or multiples thereof, into the formation being tested;

2. Casing is resonated/rotated to the bit face using water flushing to clear cuttings and sand from the annulus between the casing and the core barrel;

3. The rods and core barrels are withdrawn from the cased hole;

4. Core is resonated from the barrel into a plastic sleeve;
5. Procedures 1 to 4 are repeated until the desired depth is reached.

In practice, many refinements are made to the above procedures. If the work is not continuously supervised by a geologist, these refinements may be geared toward productivity rather than sample quality; for example the casing procedure may be omitted. An experienced geologist will monitor the drilling carefully and specify procedures that enhance sample recovery. Three such procedures are:

1. On starting the hole, to drill only 2 m before pulling the core. This will prevent major displacement of underlying material by roots and dry surface clay which often block the bit opening.
2. On encountering a boulder in till or gravel, to withdraw any core in the barrel and switch from dry coring to fluid coring. This will prevent the boulder from being driven downward by the resonance of the drill through as much as 3 vertical metres of the underlying section, with corresponding sample loss.
3. On encountering saturated sand, to core completely through the section and block the bit with compact till or clay from an underlying horizon before withdrawing the core. This will prevent the loose sand from falling out of the bottom of the core barrel.

There is another important role for the geologist at the drill -- he must interpret the actual depths from which the core is obtained because the core length is seldom the same as the distance drilled. The main reason for this is that the coring bit has a kerf of 1 cm and displaces a volume of material equal to 30 percent of the volume of the core. If the material being drilled is compact clay or till, inward displacement occurs and the core is too long. If the material is loose sand or gravel, outward displacement occurs and the core is of the correct length. Core shortening sometimes occurs when saturated sand is discharged into the plastic sleeve because the inner diameter of this sleeve is larger than that of the core barrel. In general, however, core shortening indicates core loss, which can be caused by any of the following:

1. Blockage of the bit on the first run by roots and dry surface clay;
2. Loss of saturated sand and gravel from the bottom of the core barrel while the barrel is being withdrawn from the hole;
3. Restriction of the core barrel opening by a flap valve, if one is used when drilling saturated silt or sand;
4. Resistance of hard boulders or pebble beds to coring,

resulting in downward movement of the clasts with concomitant displacement of underlying material.

Our company has developed a core recovery log (Fig. 6) which we have used very successfully to establish true core positions in the hole. This log requires the recording of three parameters plus interpretive notes. The three parameters are:

1. The resistance of the section to penetration while being drilled;

2. The type of core recovered;

3. The length of core recovered relative to the distance drilled.

With an accurate core recovery log in hand, the geologist can later log the core geologically and make confident and meaningful stratigraphic interpretations.

Rotasonic drilling costs, on an hourly basis, are approximately equal to reverse circulation drilling costs but productivity is, at best, two-thirds as high due to the need to repeatedly pull the core and re-enter the hole. As a result, actual rotasonic costs are at least 50 percent higher.

3.3 Other Drills

Auger drilling costs are not significantly lower than reverse circulation rotary drilling costs (Table 2). However, auger drills are more readily available and are sometimes used for projects where the cost of mobilizing a reverse circulation drill is prohibitive.

The diameter of an auger hole is generally 10 to 15 cm; therefore the samples obtained are as large as reverse circulation or rotasonic samples. The main disadvantages of augering are:

1) Inability to penetrate boulders or bedrock;

2) Frequent blockage of the bit and lower auger flights by sticky clay or till, requiring repeated withdrawal of the drill string to obtain the sample;

3) Caving in saturated sand and gravel;

4) Continuous inter-sample contamination caused both by caving and by material sticking to the auger flights.

Our company has developed a modification that allows a small amount of drilling fluid to be injected through 10 cm solid-core augers to the bit face. This procedure lubricates the bit and auger flights, thereby preventing sample sticking, reducing bit and auger wear, and helping deflect the augers around boulders. Under ideal conditions a hole can be drilled continuously from surface to bedrock, with the sample being collected first at the hole collar and then from the flights when the augers are withdrawn from the hole. However, the fact that the bedrock cannot be sampled without the added expense of casing the hole and switching to diamond core drilling limits the value of the overburden samples that are obtained.

Man-portable percussion drills include two types:

1. Low frequency hammer drills, such as the Pionjar, Wacker and Cobra, which use small diameter rods and a short (0.3 m) flow-through ejector bit of 2 to 3 cm I.D. to take a single sample at the bottom of the drill hole;

2. High frequency sonic (not rotasonic) drills, which use pipe of varying diameter (3.5 to 6 cm I.D.) and can obtain a continuous core but often use a flow-through ejector bit to obtain a single sample at the bottom of the hole.

Neither type can drill bedrock or penetrate compact material such as dry sand, interglacial clay, or subglacially deposited till. Claims that basal till is being sampled are common but are unfounded except in areas where only one till horizon is present and this till horizon is less than 2 m thick. The sample obtained with the flow-though sampler on the hammer drills is so small (±200 grams of matrix material) that it cannot yield meaningful gold geochemical data if visible gold is present. Even if the target is auriferous sulphides or base metal sulphides, so few heavy minerals are present that concentrates of low specific gravity and correspondingly low sensitivity are often prepared, effectively shortening the length of the target dispersal train. If continuous vertical sampling is not done and bedrock is not reached, many dispersal trains will obviously be missed (Fig. 3). In short, portable drills should not be used on regional or reconnaissance surveys or on gold surveys but can be used to evaluate conductors for base metals if one thin till layer is present and the holes are drilled very close to the conductor. The Louvem Cu-Zn survey near Val d'Or (Gleeson and Cormier, 1971) is an example of a successful survey using this methodology.

4. SAMPLING METHODS

4.1. Sample Interval

In surface till sampling programs, the samples are generally collected at a depth of less than 1.5 m because it is impractical to dig deeper pits by hand. Klassen (Fig. 7, 1984) has shown that the best geochemical response in the clay fraction of the till is obtained from the top of the C horizon, not the B horizon that has been popularized in soil surveys. The B/C transition in Canada is generally encountered at a depth of 0.6 to 0.8 m and is recognized by a colour change from deep red or ochre to pale shades of the same colours. Conveniently, the top of the C horizon also gives a better geochemical response in the heavy mineral fraction than the

B horizon, although sulphide minerals are rarely if ever preserved. Clast decomposition is also minimal in the C horizon, minimizing the potential for the generation of false matrix anomalies.

Till encountered below a depth of 3 m in backhoe pits and drill holes is generally unoxidized. In this fresh till, the entire section must be sampled because a dispersal train may occur at any level in the till (Fig. 3). In choosing the sampling interval, the geologist should be aware of three facts:

1. Till horizons are typically 1 to 10 m thick;
2. The average thickness of known dispersal trains, including the gold trains of Table 1, is about 3 m;
3. One of the most important parameters for differentiating a true dispersal train anomaly from background geochemical noise is vertical continuity of the anomaly through two or more consecutive samples of a till horizon.

It should be apparent that the ideal sampling interval is 1 to 1.5 m, and that samples should not cross stratigraphic contacts. The 1.5 m interval is commonly used because it represents one-half of a standard 3 m drill rod.

4.2 Sample Size

Since the effective size of a dispersal train depends on the size of sample collected, at least in the case of a visible gold dispersal train, the choice of sample size should be geared to maximizing the size of the dispersal train.

Our company has established that visible gold background levels in till can range up to 1 grain per kg of matrix (equivalent to 2500 grains/m^3, Fig. 8; Averill, 1988) with the highest levels being attained where the glacier has crossed the most kilometres of volcanosedimentary terrain. Thus the dispersal train threshold is 1 to 2 gold grains per kg of matrix. Background and dispersal train gold grains have different morphologies (Fig. 9) and a population of about 10 grains is required to accurately establish these morphologies. Therefore a sample weight of about 10 kg should be used on gold exploration programs. From the twelve case histories of Table 1, we have established that samples weighing 8 to 10 kg give reproducible gold grain counts and heavy mineral gold assays even in the low grade tail of a dispersal train. They cannot, of course, give reproducible data at background levels of visible gold due to the severe particle sparsity and nugget effects that are present.

A much smaller sample would suffice for base metal exploration, but base metal exploration programs are rarely performed today without also analyzing for gold. Moreover, the drills that are employed generally deliver large samples, and a heavy mineral concentrate can be prepared for a 10 kg sample as cheaply as for a 1 kg sample.

4.3 Sampling Bias on Reverse Circulation Drills

Considerable loss of till fines can occur on a reverse circulation drill, where the sample is returned as a turbulent slurry. Our company has performed tests which show that the loss of -63 micron material (clay-silt) is about 70 percent if the slurry is simply discharged into a bucket and the bucket is allowed to overflow. The volume of water used is large; therefore it is not practical to retain the water and settle the fines. However we have devised a 2-bucket system with a special outlet configuration to encourage the settling process (Fig. 4). Using this system, the loss of clay-silt is reduced to about 30 percent.

One interesting discovery of the above tests is that silt-sized gold grains are lost to the same degree as the silt-sized feldspar and quartz grains which constitute most of the till matrix. The reason for this is that at silt size, particle settling rates are not governed by specific gravity to a significant extent (Stokes Law). Since gold loss occurs in proportion to silt loss, geochemical analysis of the silt fraction of a reverse circulation sample should give the same results as analysis of the silt fraction of a rotasonic sample. However, the heavy mineral fraction of a reverse circulation sample would contain fewer silt-sized gold grains than the heavy mineral fraction of a rotasonic sample because the reverse circulation sample contains less silt.

4.4. Contamination Problems

Reverse circulation and rotasonic drill bits are free of contaminants other than: a) tungsten and cobalt in the tungsten carbide buttons; and b) nickel and molybdenum in the steel. If heavy mineral concentrates are prepared, the steel is readily removed by a simple magnetic separation.

Auger bits normally have tungsten carbide teeth which are brazed onto steel mounts. Abrasion of the joints produces brass filings which can cause severe Cu-Zn contamination, especially in heavy mineral concentrates. The brass filings also resemble gold grains, making it difficult to identify true gold. Similar filings appear in reverse circulation and rotasonic samples whenever brass air or water valves or bushings in the water swivel are replaced. They can be removed from the circulation system by flushing it thoroughly whenever a repair is made.

Certain specialized greases used on drill pipe threads contain up to 50 percent metallic copper, lead or molybdenum, and can severely contaminate samples. When starting a drilling project, the rod threads should be inspected and any suspicious grease should be removed using a toothbrush and solvent followed by thorough rinsing. Our company has analyzed several types of grease and recommends the two brands listed in Table 4.

5. SAMPLE PROCESSING METHODS

5.1. Choosing the Analytical Fraction

As noted by Coker and DiLabio (1989), few workers agree on whether a heavy mineral concentrate (HMC) or the fine fraction of the till gives the best geochemical response, and on whether the fine fraction should be -177 microns (80 mesh), -63 microns (silt and clay) or -2 microns (clay alone). Undoubtedly the reason for this dissention is that any fraction will work well under certain conditions but may be completely ineffective in other circumstances. It is the experience of our company that:

1. For visible gold, HMCs give an excellent response whether the till is fresh or weathered, whereas fines analysis may give a poor response even if the till is weathered (Fig. 2);

2. For occluded gold and micron gold, HMCs give a superior response if the till is fresh and the gold host is a heavy mineral such as pyrite or arsenopyrite, but fines analysis gives a superior response if a) the till is weathered, or b) the gold is hosted in a mineral of low specific gravity such as quartz, or c) the gold is hosted in sulphide grains which are themselves micron sized (such deposits are generally not economic);

3. For base metals, HMCs give a superior response if the till is fresh but little or no response if the till is weathered, whereas fines analysis may give a strong response in weathered till;

4. If visible gold is present, in either background or dispersal train concentrations, -63 micron gold analyses are more representative than -177 micron gold analyses because a) most gold grains in till are silt-sized (Averill, 1988) and b) the -63 micron fraction is less subject to nugget interference from any coarse grains that are present.

In summary, if the target is visible gold or if the till is unweathered, as is the case on most overburden drilling programs, HMCs should be analyzed because they will give the largest dispersal trains. Moreover, the actual minerals of economic interest, regardless of their size, will be collected into the HMC where they can be examined to determine the potential of the source before an expensive follow-up campaign is mounted. On the other hand, fines analysis should be used when collecting surface samples of weathered till on occluded gold or base metal surveys, but the sampling pattern must be more detailed than in a heavy mineral survey.

5.2. Preparing Heavy Mineral Concentrates

The standard method for preparing heavy mineral concentrates from the matrix of till samples is shaking table preconcentration followed by final concentration in methylene iodide -- the heaviest of the common separatory liquids with a specific gravity of 3.3 -- as shown in the flow chart of Figure 10.

Our shaking tables have been modified to enhance gold recovery and to assist the separation of gold grains from the other heavy minerals. Tests have shown that the recovery rate is about 50 percent for grains of 10 to 50 microns size and nearly 100 percent for coarser grains. Free micron gold is not recovered. All grains that are sighted are picked from the deck, placed under a binocular microscope, measured to obtain an estimate of their contribution to the eventual assay of the concentrate (Table 5), and classified as pristine, modified or reshaped (Fig. 9; DiLabio, in press; formerly classified as delicate, irregular and abraded, respectively) to determine the approximate distance of glacial transport.

Magnetite, with a specific gravity of 5.2, is the heaviest of the common minerals and normally forms the top mineral band on the table above garnet and epidote/pyroxene (Fig. 11). Common flake gold coarser than 125 microns separates completely from the magnetite and is readily counted. Fine gold, thick gold and delicate gold travel with the magnetite due to size and shape effects, and are not sighted as readily on the table. Gold particles can also be obscured by pyrite which, if it is abundant, tends to cross the table in the gold path. However, our company has developed a special panning technique to recover the hidden particles together with some copper, lead and arsenic pathfinder minerals. Samples are normally panned if two or more gold particles are sighted on the table or if any delicate gold is seen or if the table concentrate contains more than 10 percent pyrite.

The gold grains may be retained separately or returned to the concentrate. A magnetic separation is performed to remove magnetite and further raise the sensitivity of the concentrate; any drill steel contamination is also removed. Whether the analysis is to be by a destructive method or by instrumental neutron activation (INA), a 1/4 split of the concentrate should be retained as insurance against shipping loss and for mineralogical examination and check assaying in the event that a) an unexpected anomaly is obtained, or b) sample contamination occurs at the analytical laboratory. Some workers (e.g. Coker and DiLabio, 1989) have argued that concentrates should not be split on gold programs on grounds that unrepresentative assays will be obtained. However, if 8 to 10 kg samples are used and dispersal train concentrations of gold grains are present, a 3/4 concentrate assay will duplicate the whole concentrate assay, and even the whole concentrate will not give a representative assay if only background concentrations of gold grains are present. If a high assay is unexpectedly obtained from the 3/4 concentrate, the cause of the anomaly (background nugget vs. fine visible gold vs. occluded gold) is easily established by panning and assaying the retained 1/4 concentrate.

Coker and DiLabio (1989) also argue that "caution must be exercised in utilizing the shape of gold grains as an indication of the distance of transport because of variability in the original shape and form of the grains and in the style of glacial transport, either over short distances in the active basal zone or over long distances in the passive englacial zone of the ice". This may be true for a single gold grain, but we have found that the transport distances of Figure 9 are very reliable for the twelve case histories of Table 1, and we are not aware of any other case histories on which Coker and DiLabio could base their arguments.

5.3. Preparing Till Fines

The -177 micron fraction of till is readily obtained by dry sieving, and a -2 micron clay separation can be made by centrifuging. Preparation of a -63 micron subsample is more difficult, and this fraction is the one that is most widely used in till surveys. A comparative test by our company on highly weathered sand samples, using dry sieving on a mechanical sieve shaker and wet sieving by hand, resulted in only 5 to 50 percent of the -63 micron fraction being recovered in 20 minutes by dry sieving (Table 6). These results probably explain why explorationists often complain that insufficient -63 micron material is present in till to obtain a good subsample for analysis at a practical cost, and use the coarser and less desirable -177 micron fraction instead. Another finding of our tests is that all silt-sized gold grains present in the sample immediately pass through the sieve. Apparently the sieve shaker acts as a jig, and the -63 fraction is actually a gold concentrate! In fact, when we spiked a till sample with a group of coarser gold grains 100 to 200 microns long and 50 to 60 microns wide, every one of these grains also passed through the 63 micron sieve openings. Considering that any one of these grains would give a 100 ppb assay in a 15 gram subsample (Table 5), the results raise questions as to the significance of the gold spikes that are commonly reported in regional -63 micron gold surveys (e.g. Kaszycki, 1989). The solution is not necessarily to switch to the -2 micron clay fraction, as dispersal trains containing abundant silt-sized gold grains could be missed or understated. Wet sieving may be helpful. Also, if the -63 micron fraction is analyzed by INA, it can be retrieved and panned to locate gold particles if an analytical spike is obtained. Alternatively, a new -63 micron subsample can be prepared and analyzed to confirm the anomaly.

6. CONCLUSIONS

Of the available overburden drilling methods, only reverse circulation rotary and rotasonic drilling obtain large, clean till samples and also supply the bedrock information that serves as a foundation for interpreting till anomalies in areas where few outcrops are present. Rotasonic drills provide superior stratigraphic information as well as samples that are not depleted in silt-sized particles. However, the cost of reverse circulation drilling is 35 to 50 percent lower and if proper logging and sample collection procedures are adopted on reverse circulation drills, the stratigraphy can be established with confidence and the loss of silt is not sufficient to adversely influence the till geochemistry.

Pit samples of till should be obtained from the top of the C horizon and drill samples should be collected over 1 to 1.5 m sections through each till horizon. If gold is a target metal, 8 to 10 kg of till matrix should be saved. Care must be taken not to introduce metallic contaminants into the samples, especially from brass fittings and drill grease.

Wherever possible, heavy mineral concentrates should be prepared and analyzed to maximize the size of glacial dispersal trains. If visible gold is present in the train, the heavy mineral fraction is the only fraction that will give representative and reproducible gold data. Also, the morphology of the gold grains can be used very effectively to determine the location of the source. If the till is weathered and the target is occluded gold, micron gold or base metal mineralization, the till fines should be analyzed. Dry sieve shakers, which are commonly used to separate the till fines, act as jigs and concentrate gold particles. Therefore the cause of any gold anomaly reported in the till fines should be established before any follow-up is undertaken.

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7. REFERENCES

Averill, S.A.
1988: Regional variations in the gold content of till in Canada; Prospecting in areas of glaciated terrain - 1988; CIM proceedings 1988, Halifax, pp. 271-284.

Averill, S.A.,
MacNeil, K.A.,
Huneault, R.G.,
Baker, C.L.
1986: Rotasonic drilling operation (1984) and overburden geochemical sampling in Marter, Catherine, McElroy, Skead, Gauthier, and Hearst Townships, District of Timiskaming; Ontario Geological Survey, Open File Report 5569, 61 p.

Coker, W.B.,
DiLabio, R.N.
1989: Geochemical exploration in glaciated terrain: geochemical responses; Proceedings of exploration '87: third dicennial international conference on geophysical and geochemical exploration of minerals and groundwater, G.D. Garland (ed.), Ontario Geological Survey, Special Volume 3, pp. 336-383.

DiLabio, R.N.
in press: Classification of shapes and surface textures of gold grains from till on the Canadian Shield; Geological Survey of Canada, Current Research, Paper 91-C.

DiLabio, R.N.
Miller, R.F.,
Mott, R.J.,
Coker, W.B.
1988: The Quaternary stratigraphy of the Timmins area, Ontario, as an aid to mineral exploration by drift prospecting; Current Research, Part C, Geological Survey of Canada, Paper 88-1C, pp. 61-65.

Geddes, R.S.
1982: The Vixen Lake indicator train, Northern Saskatchewan; Prospecting in areas of glaciated terrain - 1982, edited by P.H. Davenport, Canadian Institute of Mining and Metallurgy, p. 264-283

Gleeson, C.F.,
Cormier, R.
1971: Evaluation by geochemistry of geophysical anomalies and geological targets using overburden sampling at depth; Institute Canadien des Mines et de la Métallurgie; 3e Symposium International sur la Géochimie Liée à l'Exploration; Volume Spécial No. 11, p. 159-165.

Gray, R.S.
1983: Overburden drilling as a tool for gold exploration; paper presented at the 85th Annual General Meeting of the Canadian Institute of Mining and Metallurgy, Winnipeg, Manitoba, April 17-20.

Kaszycki, C.A.
1989: Surficial geology and till composition: Northwestern Manitoba; Geological Survey of Canada, Open File 2118, 48 p. and various maps.

Klassen, R.A.
1984: A preliminary report on drift prospecting studies in Labrador, part II; Geological Survey of Canada, Current Research, Part A, Paper 84-1a, p. 247-254.

Sauerbrei, J.A.,
Pattison, E.F.,
Averill, S.A.
1987: Till sampling in the Casa-Berardi area, Quebec: A case history in orientation and discovery; Geochemical Exploration 1985, Part 1, edited by R.G. Garrett, Journal of Geochemical Exploration, Volume 28, p. 297-314

Shilts, W.W.
1976: Glacial till and mineral exploration; Glacial till: an interdisciplinary study, edited by R.F. Legget, Royal Society of Canada, Special Publication Number 12, p. 205-224.

Sopuck, V.J.,
Schreiner, B.T.,
Averill, S.A.
1986: Drift prospecting for gold in the southeastern shield of Saskatchewan, Canada; Prospecting in areas of glaciated terrain 1986, Institution of Mining and Metallurgy, London, p. 217-240

Werniuk, J.
1986: Casa Berardi: Quebec's hinterland revealing its wealth; Canadian Mining Journal, April 1986, p. 9-19.

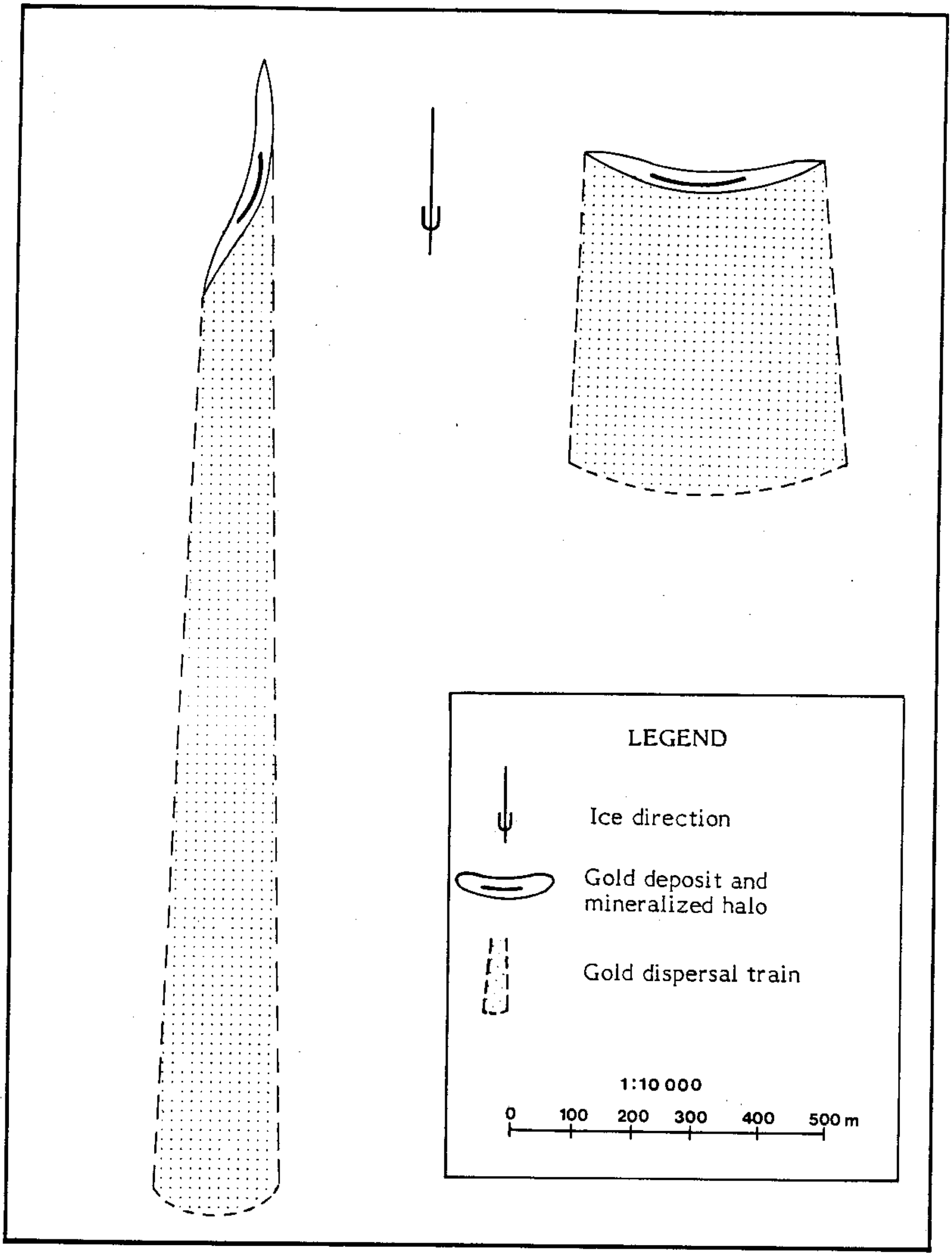


Figure 1 - Typical sizes and shapes of dispersal trains for ice-parallel and cross-ice trending bedrock sources

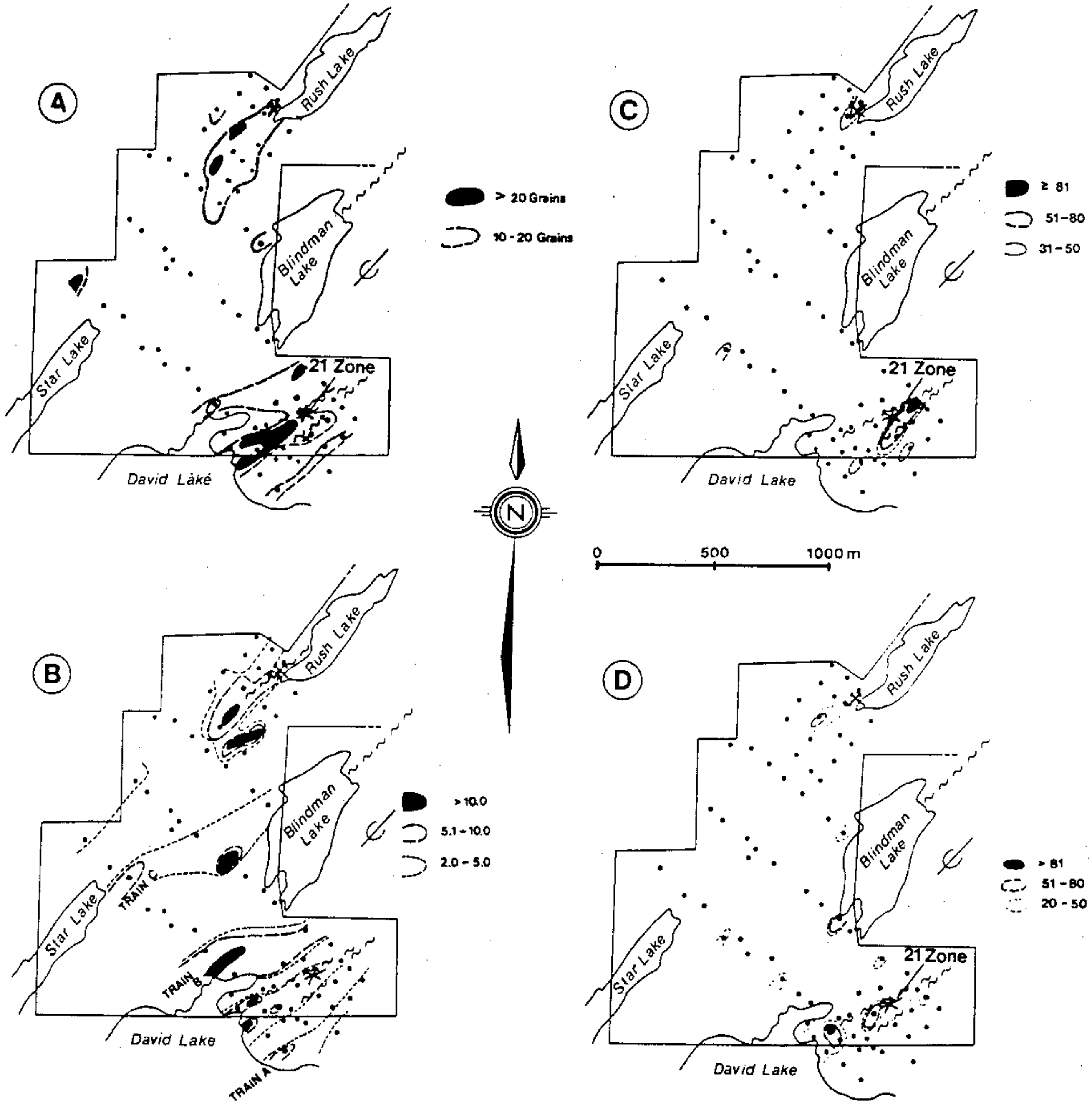


Figure 2 - Till geochemistry of Star Lake property, Saskatchewan: A) Gold grain counts; B) Normalized gold (g/tonne) in heavy mineral concentrate; C) Gold (ppb) in clay fraction of till; D) Gold (ppb) in -80 mesh fraction of till. (Source: Sopuck et al., 1986)

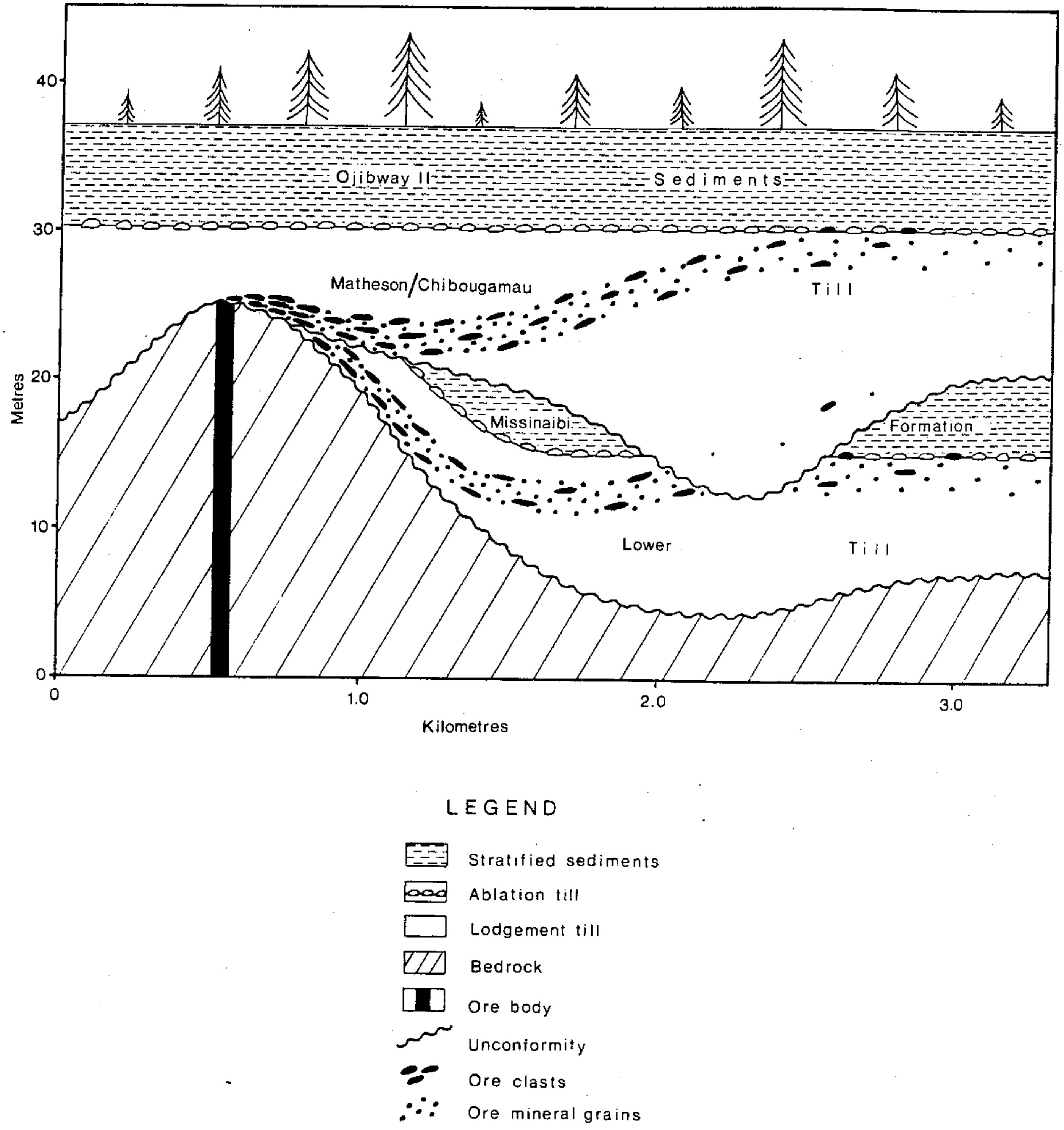


Figure 3 - Idealized cross section of a dispersal train in two-till stratigraphy with the source on a bedrock high

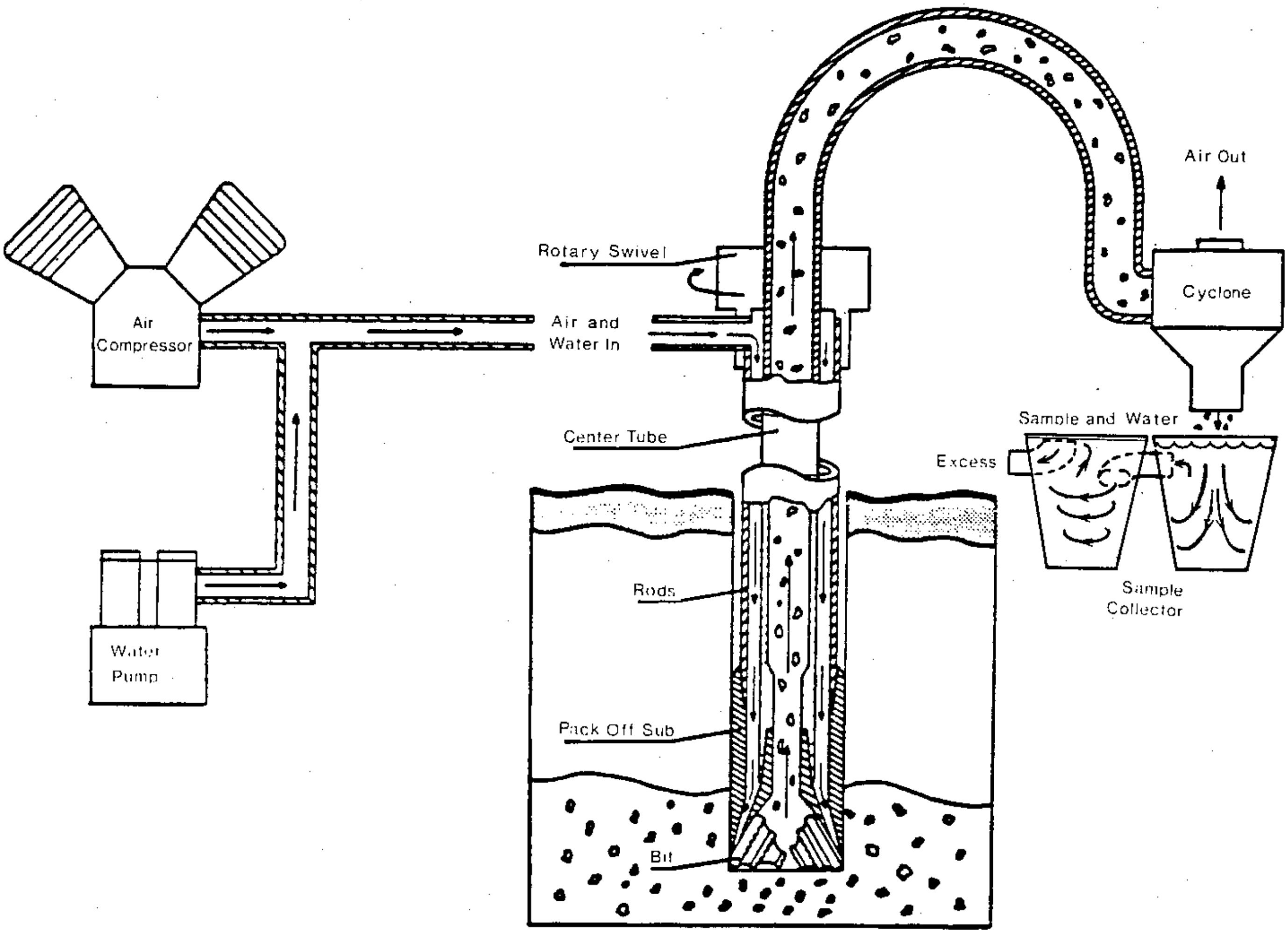
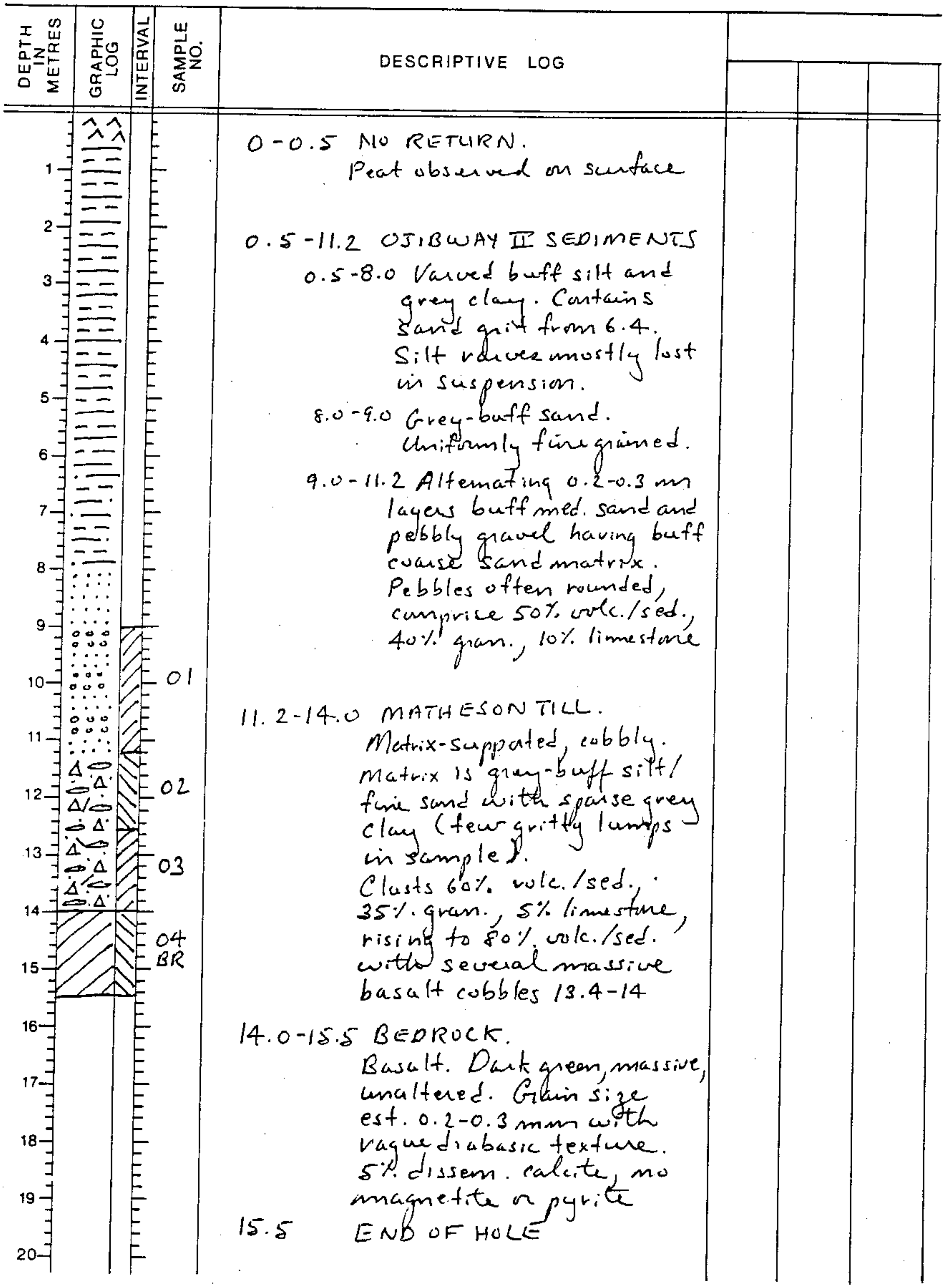


Figure 4 - Schematic diagram of a typical reverse circulation rotary drilling system



0-0.5 NO RETURN.
Peat observed on surface

0.5-11.2 OJIBWAY II SEDIMENTS
0.5-8.0 Varved buff silt and grey clay. Contains sand grit from 6.4. Silt varves mostly lost in suspension.
8.0-9.0 Grey-buff sand. Uniformly fine grained.
9.0-11.2 Alternating 0.2-0.3 m layers buff med. sand and pebbly gravel having buff coarse sand matrix. Pebbles often rounded, comprise 50% volc./sed., 40% gran., 10% limestone

11.2-14.0 MATHESON TILL.
Matrix-supported, cobbly. Matrix is grey-buff silt/fine sand with sparse grey clay (few gritty lumps in sample). Clasts 60% volc./sed., 35% gran., 5% limestone, rising to 80% volc./sed. with several massive basalt cobbles 13.4-14

14.0-15.5 BEDROCK.
Basalt. Dark green, massive, unaltered. Grain size est. 0.2-0.3 mm with vague diabasic texture. 5% dissem. calcite, no magnetite or pyrite

15.5 END OF HOLE

Figure 5 - Example of reverse circulation rotary drill log

DEPTH (m)	RUN# R	RUN# C	RESISTANCE	CORE RECOV.	CORE TYPE	REMARKS
				0.4/0.4	Hard clay, roots	Bit blocked at surface. Missing section = clay (bracketed by clay).
1	1	1		0/1.6	Lost	
2						
3						
4			Low, even		Varved clay & silt	Excess core due to stretching
	2	2		7.0/5.2		
5						
6						
7						
				0/0.8	Lost	Lower 0.8 m of barrel empty indicating sand section
8						
				1/1	Sand	Cored completely through sand and 1 m into till to block bit. Added special 1 m section of casing to std. 3 m to match 4 m coring run
9						
10	3	3	Low, uneven	2.2/2.2	Thinly layered sand and gravel	
11						
				1.1/0.8		
12						
13	4	4	Tight, uneven	2.6/2.0	Till with cobbles	Removed 1 m casing section and added 3 m section
14						
	5		High, even	1.5/1.5	Bedrock	Cored using water
15						
						END OF HOLE
16						

Figure 6 - Example of rotasonic core recovery log

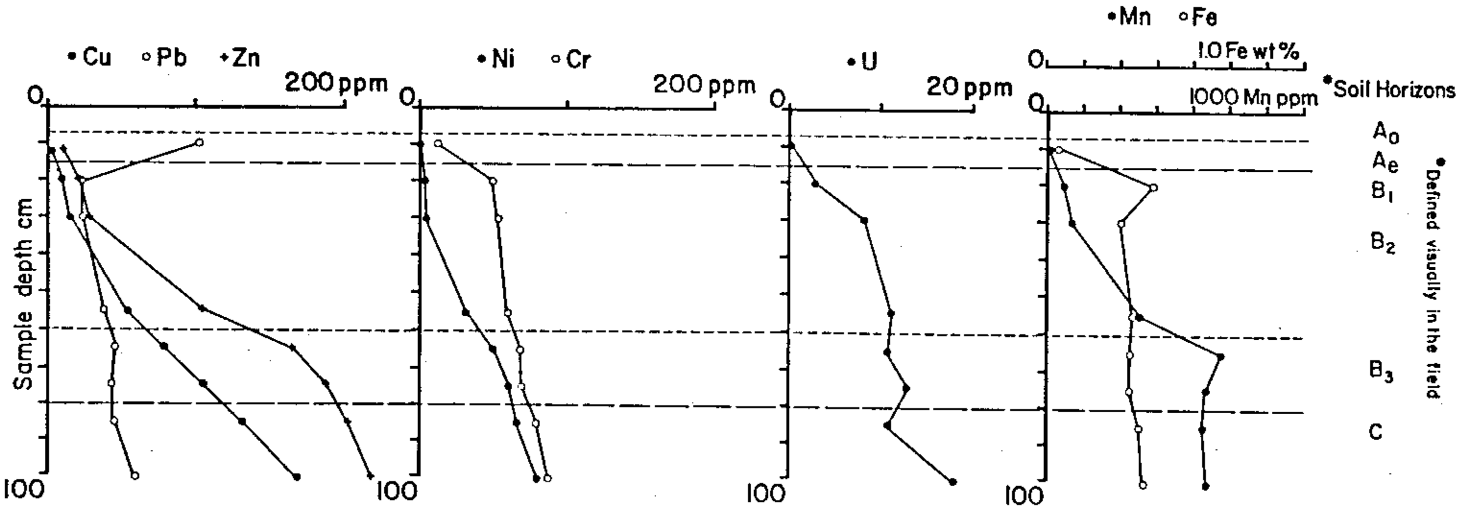


Figure 7 - Influence of the soil profile on till geochemistry (-2 micron fraction), Labrador (source: Klassen, 1984)

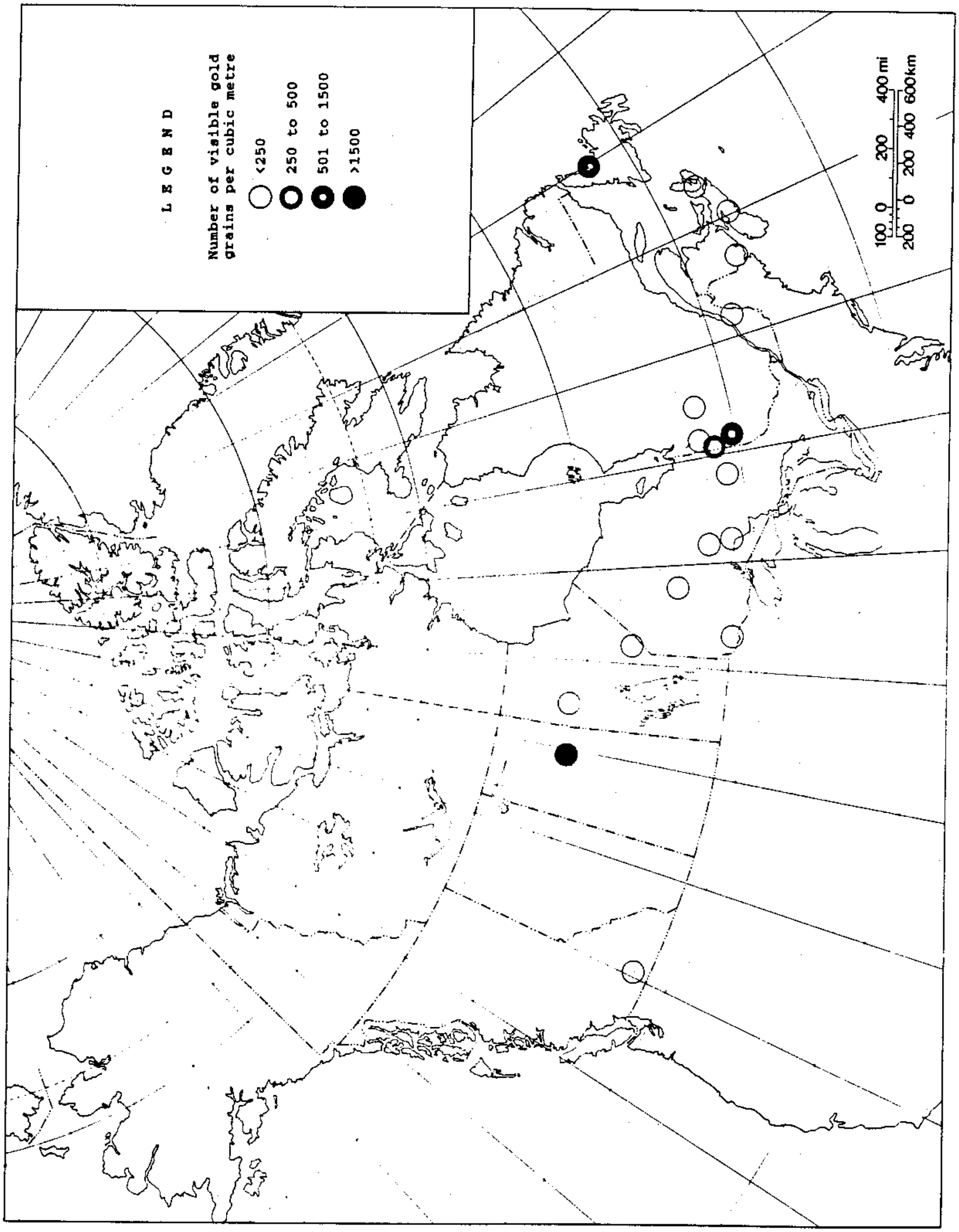


Figure 8 - Background abundance of visible gold in till (Source: Averill, 1988)

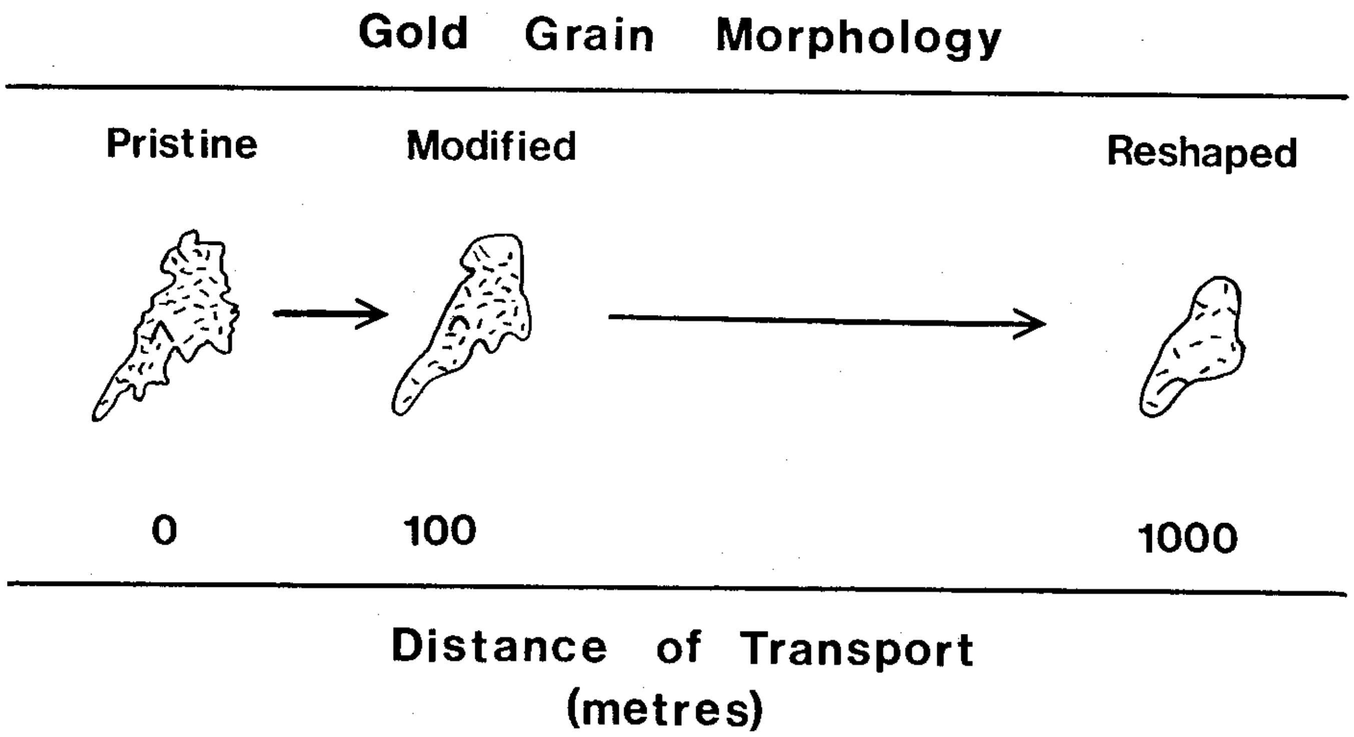


Figure 9 - Effects of glacial transport on gold particle size and shape

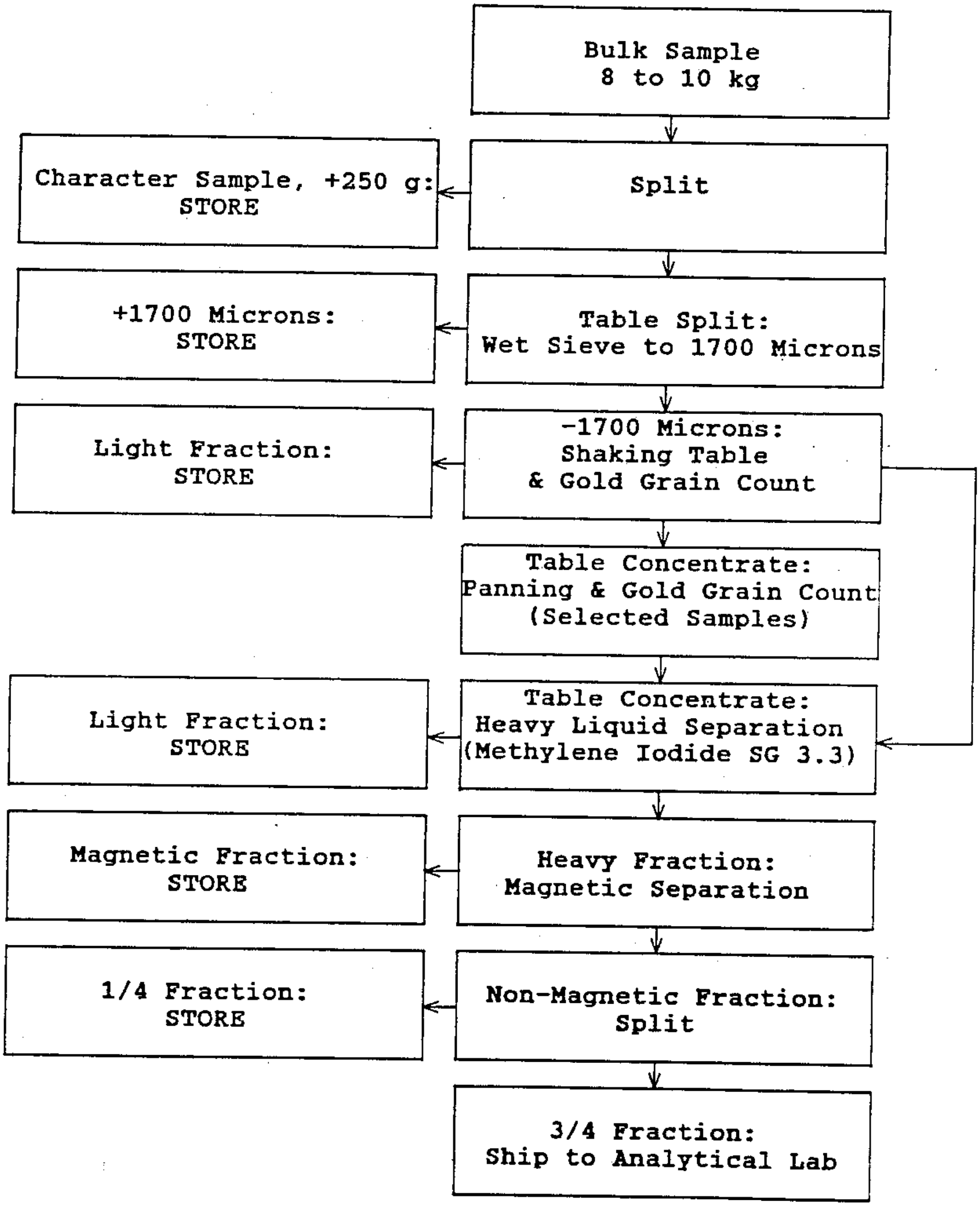


Figure 10 - Heavy mineral sample processing flow sheet

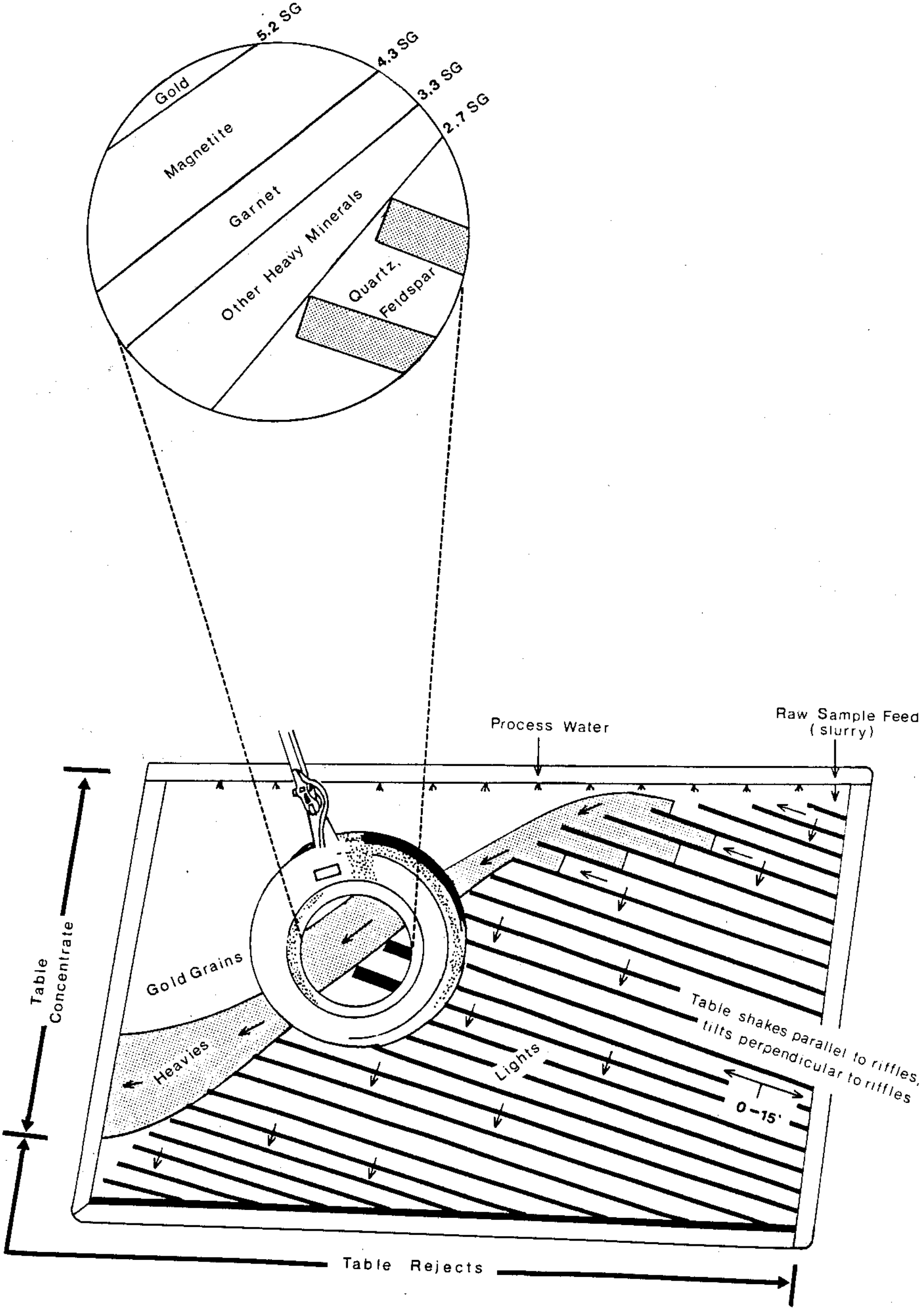


Figure 11 - Plan view of mineral separation on a shaking table

PROVINCE	GOLD DEPOSIT	TRAIN LENGTH[1](m) TRACED	TRAIN LENGTH[1](m) EST. TOTAL
Saskatchewan	Star Lake	300	800
Saskatchewan	Tower Lake	500	700
Saskatchewan	EP2	600	2000
Ontario	McCool	300	400
Quebec	Cooke Mine[3]	800	1000
Quebec	Golden Pond West	300	400[4]
Quebec	Golden Pond	400	500[4]
Quebec	Golden Pond East	800	1000[4]
Quebec	Orenada	100	200
Quebec	Kiena	100	300
Quebec	Chimo	600	1000
Newfoundland	Devil's Cove	2000	2000

1 - Based on minimum 10 gold grains of similar size and shape per 8 kg sample for free gold trains and on coincident high gold and base metal assays for invisible gold trains

2 - Deposit oriented parallel to glacial ice advance

3 - Occluded gold deposit

4 - Train foreshortened and/or gapped by erosion in last ice advance

Table 1 - Heavy mineral gold dispersal trains identified by Overburden Drilling Management Limited Laboratory

	Reverse Circulation Drills (Longyear or Acker) (Nodwell Mounted)	Rotasonic Drills (Nodwell or Truck Mounted)	Small Percussion and Vibrasonic Drills (Various)	Auger Drills (Various)
1. Production cost estimate per: - day (10 hrs) - metre	 $1,800 – $2,000 $25 – $40	 $3,000 – $4,000 $50 – $80	 $500 – $1,000 $20 – $40	 $800 – $1,500 $25 – $50
2. Penetration depth	Unlimited (125 m?)	Unlimited (125 m?)	10 – 20 metres (greater?)	15 to 30 metres (boulder free)
3. Environmental damage	5 metre wide trails (may have to be cut in areas of larger trees)	5 metres wide cut trails	nil	2 – 3 metre wide cut trails (Nodwell, muskeg, all terrain vehicle mounted quite manoeuverable)
4. Size of sample	5 kg (wet)	Continuous core	300 g (dry), or continuous core	3 – 6 kg (dry or wet)
5. Sample of bedrock	Yes (chips)	Yes (core)	Yes (chips) if reached	Unlikely, if hollow auger, split spock sampler can be used for chips
6. Sample recovery a) till b) stratified drift	 Good Moderate	 Excellent Excellent	 Good Good	 Good Poor to moderate
7. Holes per day (10 hrs)	4 @ 15 – 20 metres 1 @ 60 – 80 metres	4 @ 15 – 20 metres 1 @ 60 – 80 metres	5 @ 6 to 10 metres	1 to 3 @ 15 to 20 metres
8. Metres per day (10 hrs)	60 – 80 metres	60 80 metres	30 to 50 metres	20 to 60 metres
9. Time to pull rods	10 min @ 15 metres	10 min @ 15 metres	30 to 60 min @ 15 metres	20 to 40 minutes @ 15 metres
10. Time to move	10 - 20 minutes	15 - 30 minutes	30 minutes	15 to 60 minutes
11. Negotiability	Good	Moderate	Good (poor if manually carried on wet terrain)	Good to reasonable
12. Trails required	Yes, may have to be cut in areas of larger forest	Yes, must be cut	No	Yes and no
13. Ease in collecting sample	Good	Excellent, continuous core	Sometimes difficult to extract from sampler	Good (contamination?)
14. Type of bit	Milltooth or tungsten carbide tricone	Tungsten carbide ring bits	Flow through sampler, continuous coring	Auger with tungsten carbide teeth
15. Type of power	Hydraulic-rotary	Hydraulic-rotasonic	Hydraulic percussion (gas engine percussion, vibrasonic)	Hydraulic-rotary
16. Method of pulling rods	Hydraulic	Hydraulic	Hydraulic jack, hand jack or winch	Winch or hydraulics
17. Ability to penetrate boulders	Excellent	Excellent, cores bedrock	Poor	Poor to moderate
18. Texture of sample	Slurry (disturbed sample)	Original texture (core can be shortened, lengthened and/or contorted)	Original texture	Original texture (dry) to slurry (wet)
19. Contamination of sample	Nil, fines lost (tungsten)	Nil (tungsten)	Nil (tungsten)	Nil to high (tungsten)

Table 2 - Features of various overburden drilling systems (averages based on 1985 data; Source: Coker and Dilabio, 1989)

Present		**HOLOCENE**
	7	Holocene sediments 7b - forest-peat member 7a - lacustrine-clay member
10,000 Years B.P.		**PLEISTOCENE**
		LATE WISCONSINAN
	6	Cochrane Till
	5	Ojibway II Sediments 5e - littoral and aeolian member 5d - Cochrane member 5c - glaciolacustrine clay member 5b - glaciolacustrine sand member 5a - glaciofluvial member
	4	Chibougamau/Matheson Till
100,000 Years B.P.		EARLY WISCONSINAN AND SANGAMON
	3	Missinaibi Formation 3c - Ojibway I member 3b - forest-peat member 3a - fluvial member
		ILLINOIAN
	2	Lower Till and Sediments
1,000,000 Years B.P.		YARMOUTH AND KANSAN
	1	Older Till and Sediments

Table 3 - Quaternary formations for the Abitibi region

Grease Brand Name	ppm Cu	Pb	Zn	Mo	Ni
Esso Unitol	ND	18	3740	2	7
Shell Extrema	4	193	6	31	0

Table 4 - Selected metal concentrations in two greases

Size Classification	Flake Diameter (microns)	ppb Au
Very Fine	50	10
"	100	100
Fine	150	330
"	200	760
Medium	300	2,400
"	400	5,400
"	500	10,000
Coarse	600	16,200
"	700	24,000
"	800	33,300
"	900	43,700
"	1,000	55,000
Very Coarse	1,000+	55,000+

Table 5 - Geochemical contribution of one gold grain to a fifteen gram sample

Sample Number	Percentage Minus 63 Micron Material Total (by wet sieving)	Recovered (by dry sieving)	Dry Sieve Recovery Rate (%)
01	32.1	11.3	35
02	55.9	24.5	44
03	33.6	5.9	18
04	15.6	0.9	6
05	11.3	3.7	33
06	27.6	3.6	13
07	16.8	0.9	5
08	69.0	15.9	23
09	16.5	2.8	17
10	10.4	4.9	47
11	1.5	0.5	33
12	10.7	4.8	45

Table 6 - **Comparison of recovery of -63 micron material using wet and dry sieving**