REGIONAL VARIATIONS IN THE GOLD CONTENT OF TILL IN CANADA

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ABSTRACT

Heavy mineral gold geochemical trends determined from more than 50 000 till samples collected across Canada are presented. The samples were obtained from surface pits and deep drill holes over Canadian Shield, Appalachian and Cordilleran volcanic fold belts.

Most background gold in the till occurs as visible grains less than 100 µm in diameter. Scattered coarser grains generate numerous, erratic heavy mineral geochemical anomalies through the nugget effect.

Background gold grains are well-travelled and are normally abraded. Dispersal train gold grains collected down-ice from known gold deposits generally have a more delicate morphology, similar to that of the lode gold in the deposits, because most of the trains are about 500 m long and 1000 m of ice transport is required to produce abraded gold. For the same reason, and also because gold is malleable, the size of the grains does not diminish significantly down-ice. A few trains contain both fine delicate and coarse abraded gold grains; the abraded grains appear to have been precipitated as supergene nuggets in the lode source. Some trains, especially those occurring in oxidized till, contain occluded gold in addition to visible gold. If the till is fresh, occluded gold is rare unless arsenopyrite is present.

The abundance of visible gold in till in background areas is directly proportional to the amount of volcanic terrane present up-ice. The highest background encountered to date is 1500 to 3000 grains per cubic metre over the La Ronge Greenstone Belt in Saskatchewan. Background over the Abitibi Greenstone Belt of Ontario- Quebec varies from 250 grains per cubic metre in the north to 1500 grains per cubic metre in the south. Background over small volcanic belts is generally less than 250 grains per cubic metre.

INTRODUCTION

Till geochemistry is now widely used for gold exploration in the vast regions of Canada that were scoured by the Laurentide ice sheet. It is also a valuable complement to stream sediment geochemistry in areas that were influenced by the Cordilleran and Appalachian ice sheets (Fig. 1).

One of the till geochemistry techniques that is widely used in gold exploration, especially in areas where the glacial sediments are thick and unoxidized, is heavy mineral analysis. In general, the abundance of visible gold grains in the heavy mineral concentrates has proven to be more useful than the concentrate assays for identifying significant gold dispersal trains because most high assays are caused by erratic gold nuggets.

Visible gold concentrations have been documented for several gold

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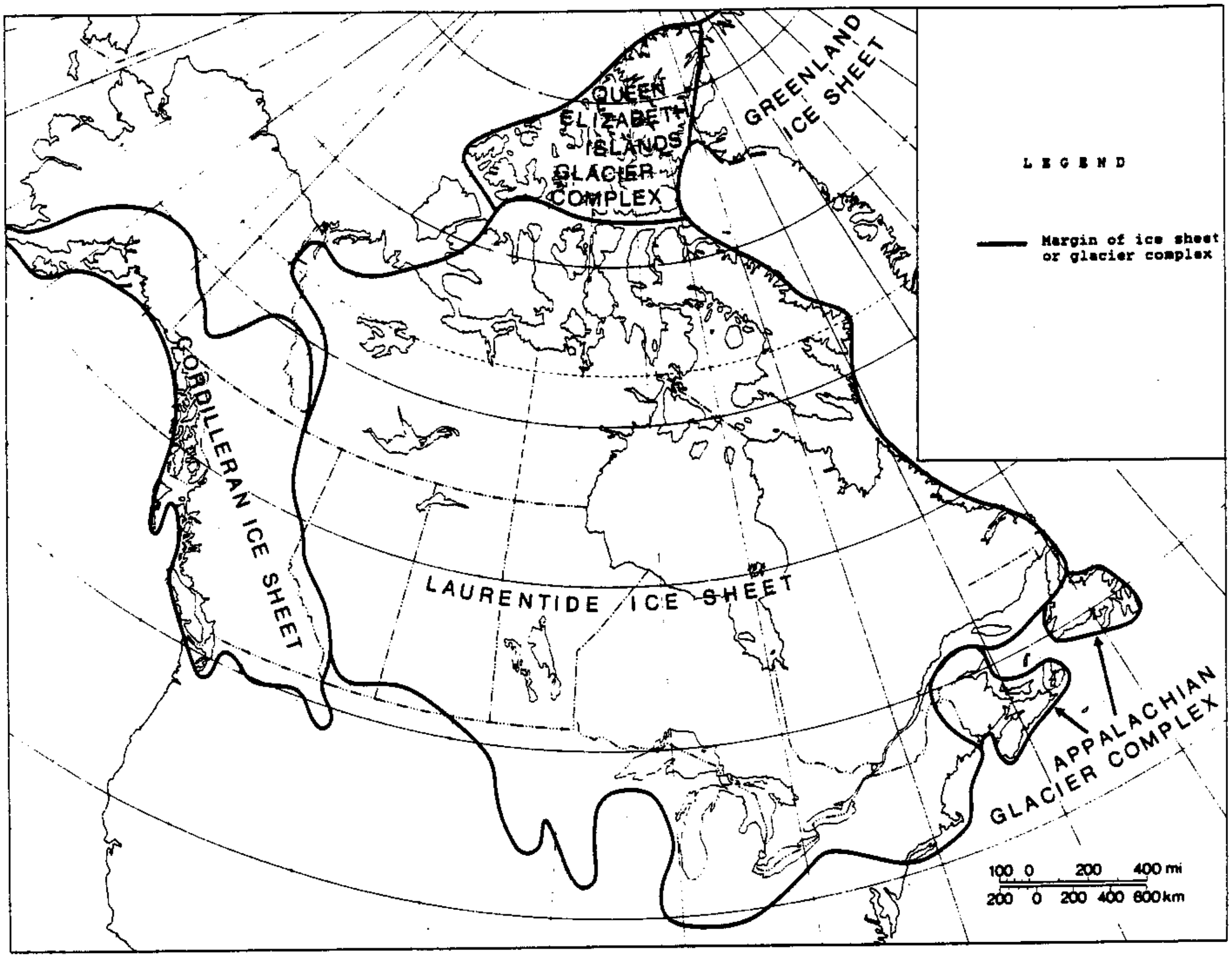

Figure 1. Positions of Late Wisconsinan ice sheets and glacier complexes (after Prest, 1976).

dispersal trains in tills (Sopuck et al., 1986; Sauerbrei et al., 1987; Averill and Zimmerman, 1986), but no studies have been made of the visible gold background of tills. Also, no published comparisons have been made of visible gold background or anomaly threshold levels in tills in different parts of Canada. Partly as a result of this lack of information, wasteful follow-up exploration has been expended on countless heavy mineral gold anomalies that represent nothing more than the normal visible gold background inflated by the use of undersized samples. This paper attempts to set standards for the interpretation of heavy mineral gold anomalies in till samples by providing new information on regional visible gold abundances for many parts of Canada. It is based on gold grain counts made by Overburden Drilling Management Limited on more than 50 000 till samples provided by approximately 50 clients and representing 13 geological terranes.

METHODS

SAMPLE COLLECTION

Ninety per cent of the samples were obtained from till sheets over Canadian Shield volcanic fold belts in the northern parts of Saskatchewan, Manitoba, Ontario and Quebec, especially the Abitibi Greenstone Belt of Ontario-Quebec (Fig. 2). Approxi-

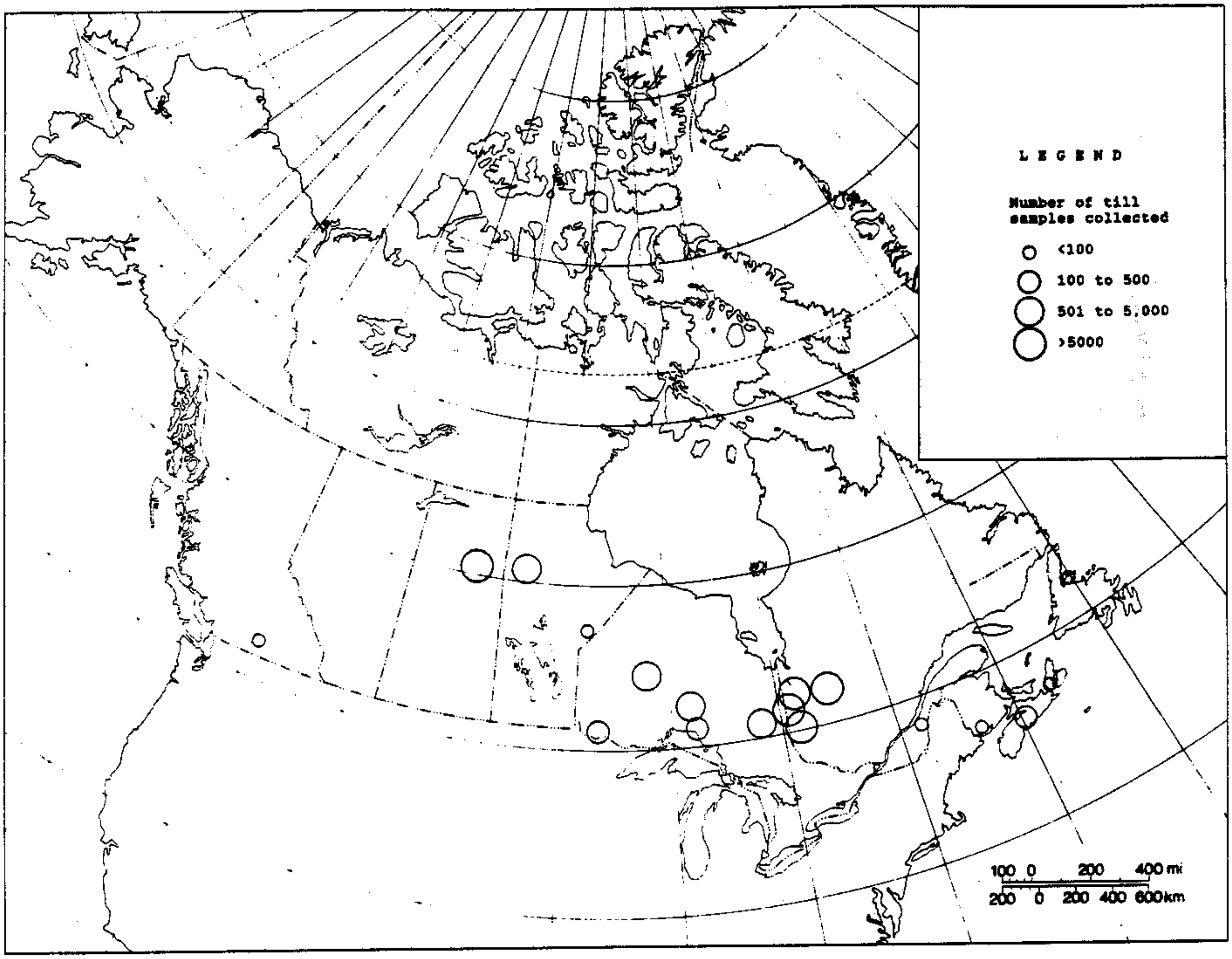

Figure 2. Till sample sites.

mately 10% of the samples were obtained from Appalachian volcanic fold belt areas in southern Quebec, New Brunswick, Nova Scotia and Newfoundland and a few from the Western Cordillera. Most of the samples were collected specifically for gold exploration, but some were collected on government programs where the principal objective was to map Quaternary stratigraphy.

Approximately 70% of the samples were obtained from reverse circulation rotary drill holes, 20% from hand-dug surface pits, and 5% each from rotasonic drill holes and backhoe pits. The reverse circulation samples contained broken clasts and were somewhat depleted in silt and clay whereas the other three sampling methods yielded essentially pristine till. Some clasts were generally discarded in the field with all methods and matrix-biased samples weighing approximately 8 kg and representing about 10 kg of original till were submitted for heavy mineral processing. A sample of this size provides reproducible heavy mineral gold assays if the sample is collected from a dispersal train, but a sample at least 10 times as large would be needed to obtain reproducible assays in background areas. Thus, observing the gold grains during sample processing is critical.

SAMPLE PROCESSING

At the laboratory, a 200 - 300 g

character subsample was separated from each bulk till sample and stored as a library sample. The remainder of the bulk sample was then screened to remove the clasts, and a nonmagnetic heavy mineral concentrate was prepared from the -1700 µm matrix (average 80-90% of sample) using shaking table preconcentration followed by heavy liquid refining (methylene iodide; specific gravity 3.3) and magnetic separation as shown in Figure 3. The shaking tables were conventional Deister ore-processing models modified to accommodate the wide range of particle sizes that are present in tills, to minimize the potential for material carryover between samples and to allow the operator to visually identify as many gold grains as

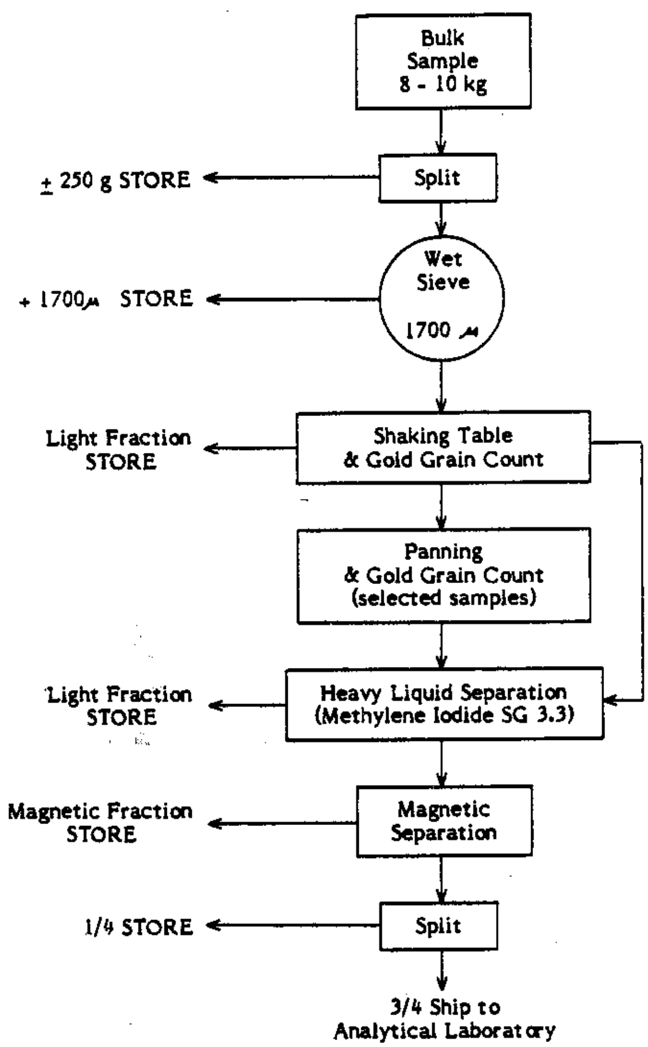

Figure 3. Sample processing flow sheet.

possible. On average, 15 - 20 g of nonmagnetic heavy minerals were obtained from 8 kg field samples representing 10 kg of raw till.

Not all liberated gold grains can be seen on a shaking table. Coarse abraded gold grains are most easily seen but can be covered by pyrite if this mineral is abundant. Most fine gold grains and delicate gold grains are covered by magnetite. To obtain more accurate gold grain counts, most table concentrates that showed more than 10% pyrite, two or more gold grains of abraded or irregular morphology, or any gold grains of delicate morphology were further treated by panning. The panning method employed was developed by Overburden Drilling Management Limited and can separate all gold grains recovered on the table; it is not dependent on grain size or morphology.

GOLD GRAIN COUNTS

The number of gold grains observed on the shaking table and in the pan was recorded for each sample. All grains were examined under a binocular microscope and classified as delicate, irregular or abraded (Fig. 4). This classification provides a rough measure of the distance that the grains have been glacially transported. The length and width of each grain were also recorded.

CALCULATION OF GOLD VALUE OF VISIBLE GOLD GRAINS

Prior to analyzing any concentrate, the gold value of each gold grain in that concentrate was calculated in relation to the weight of the concentrate. Then if the sum of these values matched the gold assay and this assay was high enough to be considered anomalous (generally over 1000 ppb), the anomaly was evaluated on the basis of the number and type of gold grains present. If an anomalous assay was obtained where little or no

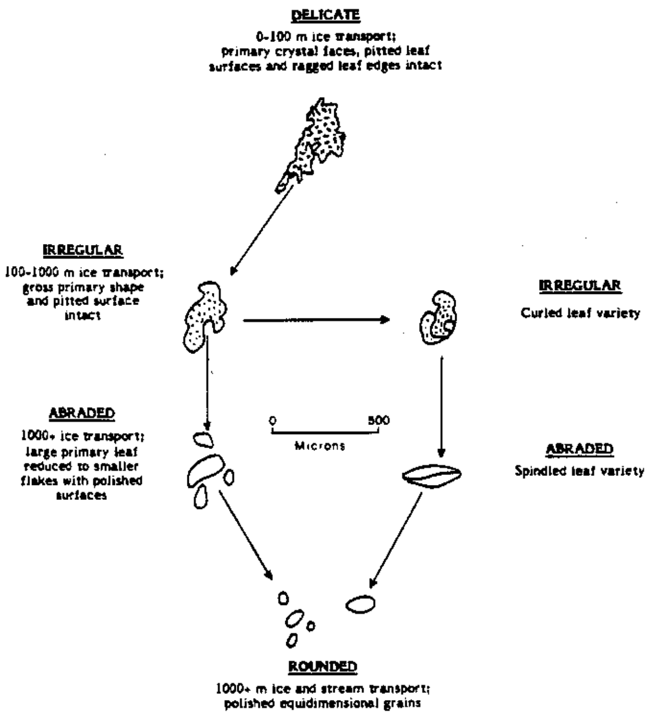

Figure 4. Effects of glacial transport on gold particle size and shape.

visible gold was observed (up to 10% of samples), additional tests were made to determine the cause of the anomaly.

The amount of gold in a given gold grain is calculated from the volume of the grain because most of the grains are too small to be accurately weighed. In making the volume calculation, we use the assumptions of Clifton et al. (1969) that (1) a gold grain can be treated as a disc and (2) a 100 µm grain will contribute approximately 100 ppb of gold to a 15 g concentrate. However, we have found that their assumption that disc thickness (t) is 10% of disc diameter (d) is true only for grains over 1000 µm in diameter and that for finer grains the disc thickness varies according to the following equation:

$$t = 0.2d \quad \frac{0.01(d-100)d}{100}$$

The range of assays produced in a 15 g concentrate by gold grains of various sizes is shown in Table 1.

GOLD ANALYSIS

All gold grains found on the table and in the pan were returned to the concentrate prior to analysis. On most programs a 3/4 split of the concentrate was analyzed by fire assay with atomic absorption finish and the remaining 1/4 concentrate was retained to allow rapid determination of the cause of any unexpected anomalies. If coarse nuggets had been observed in the concentrate, a pulp and metallics assay was often done to offset known difficulties in pulping coarse gold. On some programs the entire concentrate was analyzed by nondestructive instrumental neutron activation which preserves the concentrate for future mineralogical examination but does not provide reliable assays if coarse gold grains are present.

CHECK PANNING AND ANALYSIS

If little or no visible gold was observed and the 3/4 concentrate yielded an anomalous assay, the 1/4 concentrate was generally panned and analyzed by instrumental neutron activation to determine whether the unobserved gold occurred as nuggets, as fine visible gold or as occluded (invisible) gold. Sometimes the -63 µm fraction of the raw till character sample was analyzed to help substantiate the presence of occluded gold (DiLabio, 1985).

OBSERVATIONS

COMPARING GOLD GRAIN COUNTS

The gold grain counts are not amenable to direct statistical analysis for the following reasons:

(1) Most samples contain far fewer than the 20 grains required for statistical representativity (Clifton et al., 1969).

(2) On some programs all table concentrates were panned and on others

Table 1. Geochemical contribution of one gold grain to a 15 g sample.

SIZE CLASSIFICATION	FLAKE DIAMETER (microns)	GOLD VALUE (ppb)
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+

only a few were panned.

(3) The samples were processed over a period of several years and the rate of detection of visible gold on the table improved during this period.

On recent programs where all of the table concentrates were panned (approximately 5000 of the 500 000 samples), it has been found that:

(1) The gold values calculated from the observed visible gold grains closely match the heavy mineral gold assays; thus almost all of the gold recovered on the table is visible gold and all of the grains that are recovered are observed either on the table or when the sample is panned.

(2) Eighty to ninety per cent of the recovered gold grains are between 10 and 100 µm in diameter and only 30 - 40% of these grains are observed on the Table. (Note: 10 µm is generally the lower limit of gold visibility under a nocular microscope. In this paper the term 'micron gold' is used for gold grains finer than 10 µm and the term 'occluded gold' is used collectively for grains of all sizes that are physically held in another mineral and for gold that is chemically adsorbed onto another mineral).

(3) Ten to twenty per cent of the recovered gold grains are coarser than 100 µm and 80 - 90% of these grains are observed on the table.

In comparing these results to those obtained from the same areas on older programs when less gold was observed on the table and only a few of the table concentrates were panned, it is found that:

(1) The heavy mineral gold assays from both periods are very similar, thus the percentage recovery of visible gold grains on the table was constant over the years.

(2) The number of observed gold grains coarser than 100 µm is similar, therefore the recent improvement in

gold grain sighting applies mainly to -100 µm gold.

(3) The visible gold counts for panned samples are similar, thus panning skill has been fairly constant over the years.

Using the above relationships it is possible to derive comparative gold grain abundances for all of the till samples regardless of the year of collection.

Not all visible gold grains are recovered by a shaking table. Wang (1979), for example, indicated that recoveries for placer gold drop from 100% at 250 µm to 50% at 63 µm. However, the percentage of grains recovered from till samples is difficult to check by assaying because the grains are normally different sizes and occluded gold as well as visible gold is sometimes present. An average recovery of about 80% of grains over 10 µm in diameter is suggested by the following three published examples and by other unpublished evidence:

(1) Approximately 90% of total contained gold was recovered for the Ontario Geological Survey on a dispersal train intersected by rotasonic drilling near Matheson, Ontario in the Abitibi Greenstone Belt (Ontario Geological Survey, 1986). The host till was unoxidized and contained only visible gold and the gold grains were of a wide size range.

(2) From 37 - 93% of total contained gold was recovered for the Saskatchewan Mining Development Corporation from samples representing 4 dispersal trains on the La Ronge Greenstone Belt in Saskatchewan (Sopuck et al., 1986). These samples were collected from surface pits and were oxidized. Both visible gold and occluded gold were shown to be present. Tests indicated that most of the gold loss occurred in the occluded portion despite the fact that most of the visible gold occurred as grains less than 50 µm in diameter.

(3) Thirty per cent of total contained gold was recovered for Queen's University on a sample from the Owl Creek dispersal train in the Abitibi Greenstone Belt (Nichol et al., 1985). The host till was deeply buried but contained abundant regolithic material. Only visible gold was recovered and further testing indicated that most of the gold present was micron-sized and(or) occluded in supergene minerals of low specific gravity.

ABUNDANCE OF VISIBLE GOLD VERSUS OCCLUDED GOLD

Since the heavy mineral fraction of a till sample generally contains most of the visible gold but none of the occluded gold, the ratio of visible gold to occluded gold in the raw till can be estimated by analyzing both the heavy mineral fraction and the raw till matrix (a 10 g subsample of the -63 µm fraction is generally sufficient for this purpose; Dilabio, 1985) and comparing the weight of gold present in each. We have found from such studies that:

(1) Unoxidized till samples from drill holes on dispersal trains generally contain only visible gold but may contain occluded gold. All tested trains with occluded gold also contain arsenopyrite but part or all of the gold could be hosted by pyrite which is generally more abundant than arsenopyrite.

(2) Oxidized till samples from surface pits on dispersal trains often contain both visible gold and occluded gold.

(3) Both oxidized and unoxidized till samples from background areas generally contain only visible gold. (Note: In this paper, the first 5 - 10 ppb of a gold analysis, whether in the

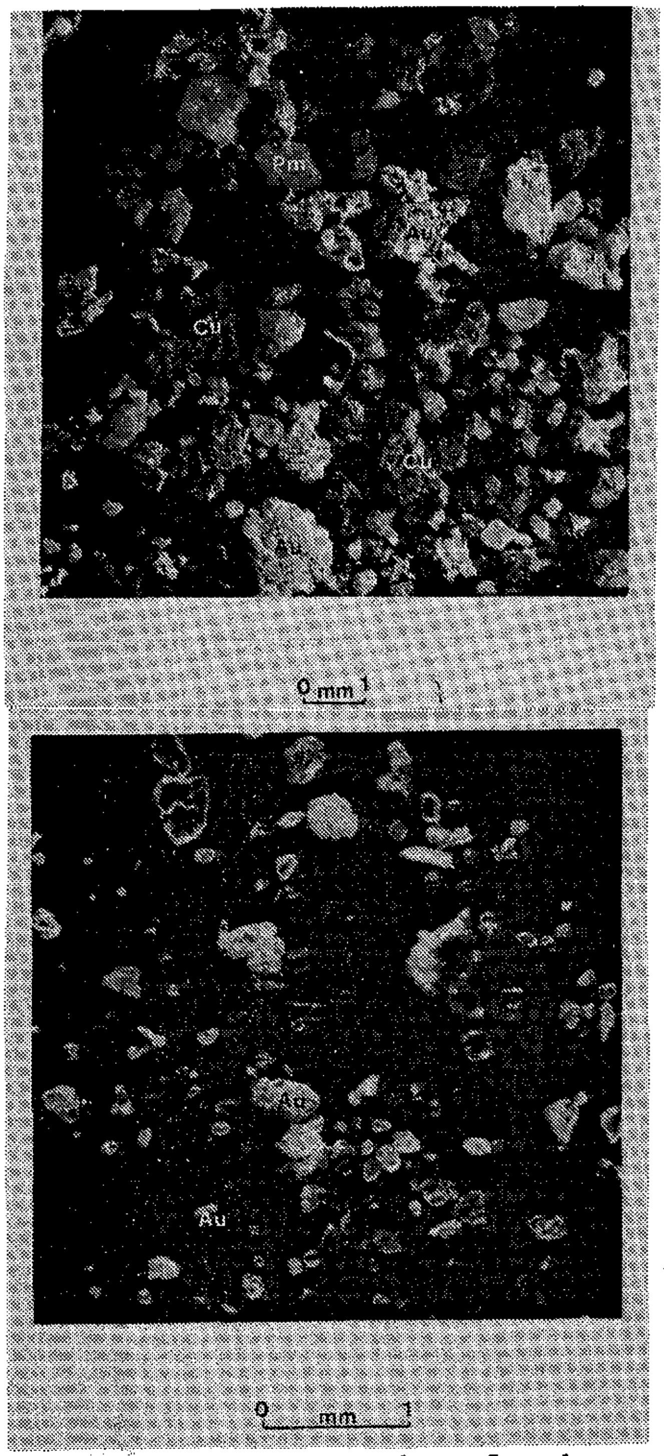

Figure 5. Photomicrographs of heavy mineral concentrates from EP dispersal train at Waddy Lake, Saskatchewan showing chemically unstable pyromorphite (Pm) and native copper (Cu) accompanying native gold (Au) in unoxidized till (1a), but absent in oxidized till (1b).

heavy mineral or -63 µm fraction, is attributed to the detectability limitations of the analytical method and therefore is not accountable as visible gold, micron gold or occluded gold).

Thus the presence of occluded gold is usually a positive indicator of a dispersal train, but the absence of occluded gold is a negative indicator only if the till is oxidized or is derived from oxidized bedrock.

PRIMARY VERSUS SECONDARY GOLD GRAINS

Lode gold grains have a delicate morphology. In till, more than 90% of dispersal train gold grains have a delicate to irregular morphology and more than 90% of background gold grains have an abraded morphology (Fig. 4).

When a till is oxidized, any sulphide or other chemically unstable mineral grains occurring with the visible gold grains are leached out. This is well illustrated by the contrasting compositions of the heavy mineral concentrates of oxidized and unoxidized till samples from the EP dispersal train at Waddy Lake, Saskatchewan in the La Ronge Greenstone Belt (Fig. 5).

Due to the fact that oxidized till samples from surface pits on most dispersal trains contain some occluded gold as well as visible gold and because unoxidized till samples from drill holes on most dispersal trains contain only visible gold, the oxidation process must involve some solution of visible gold and precipitation of occluded gold. This process does not appear to visibly change the morphology of the primary gold grains or to form any new gold grains; no grains having spherical, botryoidal, dendritic or other supergene forms have been observed in oxidized till. However, Sopuck (personal communication) has observed supergene gold forms of probable preglacial age in sheared bedrock at Fork Lakes in the La Ronge Greenstone Belt and he cautions that these supergene grains would probably be mistaken for abraded background gold if they were encountered in till.

REGIONAL VARIATIONS IN THE VISIBLE GOLD BACKGROUND

Since the gold background of till is caused almost exclusively by visible gold, this background can be expressed in terms of gold grains. A major advantage of using gold grains rather than gold assays is that there is no nugget effect.

The per sample gold grain counts have been converted to grains per cubic metre to better convey the true natural abundance of visible gold. In making the conversion, till is assumed to have a density of 2.5 such that one cubic metre weighs 2500 kg. Since most of the processed samples represent about 10 kg of raw till, the gold grain counts were generally multiplied by 250 to determine the number of gold grains per cubic metre.

The gold background of tills over volcanic fold belts across Canada ranges from less than 250 grains per cubic metre to about 3000 grains per cubic metre (Fig. 6). The highest background occurs in areas where the greatest expanses of volcanic terrane have been glaciated, i.e. where the ice crossed very wide fold belts or where the direction of the ice movement was parallel to long narrow fold belts. The best example of the former setting is the 200 km wide Abitibi Greenstone Belt and the best example of the latter setting is the 200 km long La Ronge Greenstone Belt. Gold abundance in till over the Abitibi Greenstone Belt increases progressively from 250 grains per cubic metre in the north to 1500 grains per cubic metre in the south and that for the La Ronge Greenstone Belt is 1500 to 3000 grains per cubic metre. Tills over small greenstone belts in predominantly granitoid terrane almost invariably have a gold background of less than 250 grains per cubic metre even if the greenstone belts contain important gold deposits. Examples are the Geraldton-Beardmore, Pickle Lake, Hemlo belts in Ontario, and Lynn Lake belt in Manitoba.

VISIBLE GOLD BACKGROUND VERSUS HEAVY MINERAL GOLD ASSAYS

In areas where the visible gold background of the till is less than 250 grains per cubic metre (one grain per sample), most of the heavy mineral concentrates assay less than 10 ppb gold. The modal assay rises to 30-150 ppb for till with 500 gold grains per cubic metre (two grains per sample) and 100 - 400 ppb for till with 1000-1500 grains per cubic metre (4 - 6 grains per sample).

The modal assays are caused by the -100 µm gold grains that constitute 80 - 90% of the total gold grain population. The remaining +100 µm gold grains are often sufficiently coarse to produce anomalous assays (over 1000 ppb); this is known as the nugget effect.

Since coarse gold grains comprise a fairly constant 10 - 20% of the total background abraded gold grain population, the number of nugget anomalies increases as the gold background increases. In general, about 5% of samples from till horizons having a gold background of 250 grains per cubic metre and 15 - 20% of samples from till horizons having a gold background of 1000 - 1500 grains per cubic metre are anomalous. These abraded nugget anomalies are of no significance, but there are countless examples of follow-up exploration programs based on them. In some cases gold grain counts had not been made or the nuggets had not been observed during sample processing. Often,

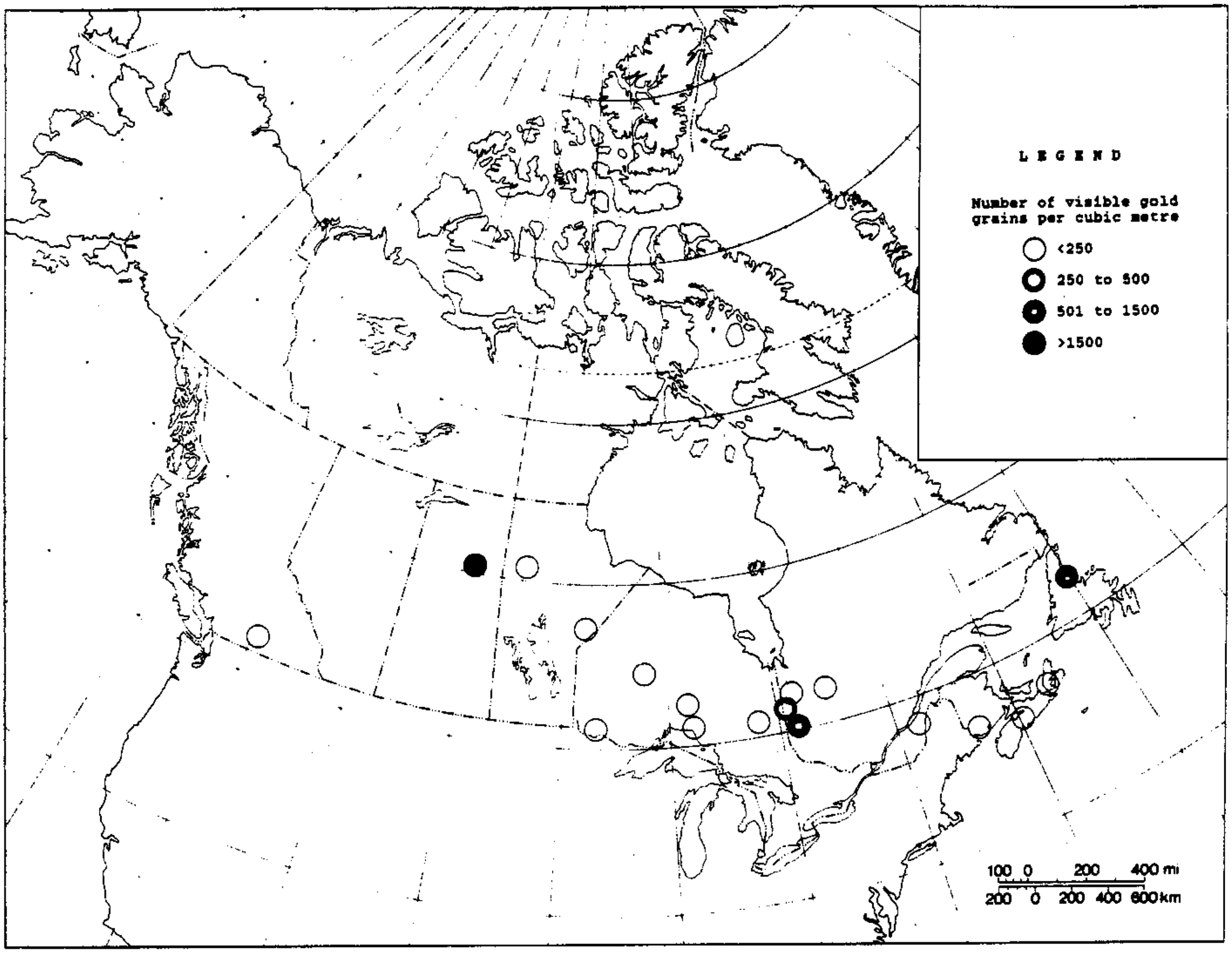

Figure 6. Background abundance of visible gold in till.

however, the presence of the nuggets was known and the interpreters simply did not appreciate that the nuggets were part of the normal gold background.

ABUNDANCE, SIZE AND MORPHOLOGY OF VISIBLE GOLD GRAINS IN DISPERSAL TRAINS

The approximate abundance of visible gold grains in 13 of the best defined dispersal trains encountered during processing of the 50 000 till samples is shown in Table 2. Only one train, the Cooke Mine train in the Abitibi Greenstone Belt, lacks visible gold. The abundance of visible gold in the other 12 trains is over 2500 grains per cubic metre (10 grains per sample).

Within each dispersal train the gold grains are of a limited size range that is controlled by the gold grain size in the lode source. If the lode grains are over 10 µm in diameter, the till grains are the same size as the lode grains. This indicates that the size of the grains does not decrease significantly during the first kilometre of glacial transport and reflects the malleable character of gold. If the average size of the lode grains is less than 10 µm the average size of the till grains is several times larger. This indicates that most

Table 2. Abundance and size of visible gold in dispersal trains.

FOLD BELT DEPOSIT*	TRAIN NAME	LENGTH (m)	GOLD GRAINS/m^3	AVERAGE TRAIN	GRAIN DIAMETER*
La Ronge	EP (Waddy Lake)	4 000	25 000	10 - 100	?
La Ronge	Star Lake	400	5 000	10 - 50	50
La Ronge	Tower Lake	700	8 000	10 - 50	30 - 60
Lynn Lake	Farley Lake	400	3 000	25 - 75	4
Abitibi	Belore	400	4 000	50 - 100	?
Abitibi	Cooke	800	Occluded	--	?
Abitibi	Golden Pond West	400	7 000	50 - 100	**
Abitibi	Golden Pond	500	4 000	50 - 75	**
Abitibi	Golden Pond East	1 000	15 000	25 - 75	**
Abitibi	Orenada	150	5 000	25 - 75	10 - 37
Abitibi	Kiena	300	8 000	10 - 75	7 - 8
Abitibi	Chimo	1 000	10 000	50 - 75	7 - 12
Appalachi	Devil's Cove	2 000	15 000	10 - 100	**

* Average gold grain size in deposit often does not reflect grain size at which main gold values occur; at Farley Lake, for example, the average grain size is 4 µm but 73.8% of the gold is contained in grains coarser than 20 µm.

** Average gold grain size not available; observed range is 1 - 1000+ µm.

of the -10 µm gold, if it is not occluded in another heavy mineral such as arsenopyrite, is lost on the shaking table.

In most dispersal trains, all of the gold grains are of delicate to irregular morphology. This is because the gold grain concentration generally drops to background levels about 500 m from source (Table 2) and gold grains do not become abraded until they have been transported approximately 1000 m (Fig. 4). In a few trains, coarse abraded gold grains and fine delicate gold grains have been found together and the concentration of abraded grains is too great (usually more than 10 grains per sample, or 2500 grains per cubic metre) to be dismissed as a background effect. Possibly these grains are derived from supergene mineralization of the Fork Lakes type.

The above gold grain size and shape patterns are similar to those described by MacEachern and Stea (1985) for the Fifteen Mile Stream and Beaver Dam dispersal trains in Nova Scotia. In contrast, DiLabio (1985) suggested that the size of the gold grains in the Waverley train in the same area decreases substantially in the down-ice direction. However, his conclusion is based on size fraction analysis (Fig. 7), not on direct observation of the gold grains, and the apparent preferential decrease in coarse gold in the down-ice direction could be due to dilution rather than to comminution.

CONCLUSIONS

The findings of the study that have important implications in gold exploration in Canada are:

(1) The gold background of till, whether oxidized or unoxidized, is caused mostly by visible gold grains, not by occluded gold.

(2) Most background gold grains have an abraded morphology.

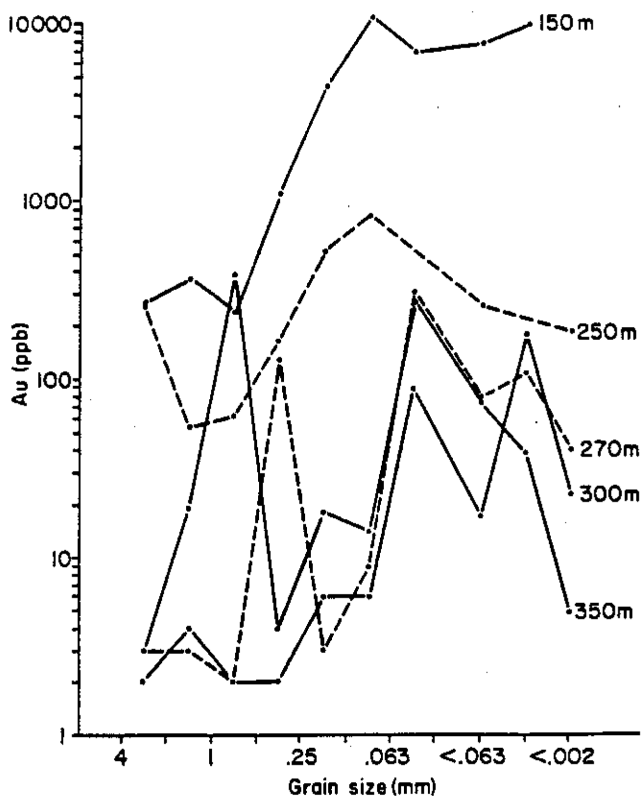

Figure 7. Abundance of gold versus grain size of analyzed fraction of oxidized till at varying distances down-ice from the gold deposit at Waverely, Nova Scotia. Curve for 250 m is the average of data for eight samples; other curves represent one sample each (after DiLabio, 1985).

(3) The concentration of background gold grains in till ranges from less than 250 grains per cubic metre to 3000 grains per cubic metre and is determined mainly by the amount of volcanic terrane present up-ice. The same rule probably applies to regionally auriferous metasedimentary terranes such as the Meguma Terrane of Nova Scotia.

(4) Most background gold grains are 10 - 100 µm in diameter, but some coarse grains are always present. In 10 kg samples these nuggets generate heavy mineral gold assays that are of the same magnitude as dispersal train anomalies (i.e. over 1000 ppb). The frequency of nugget anomalies is directly proportional to the visible gold background and varies from less than 5% to about 20%.

(5) Dispersal train heavy mineral gold anomalies are caused mainly by fine, delicate to irregular visible gold and by occluded gold rather than by coarse abraded visible gold. If the till hosting the dispersal train is unoxidized, it generally contains only visible gold; occluded gold, if present, is contained in arsenopyrite or pyrite and, therefore, is recovered on the shaking table. If the till is oxidized, it generally contains both visible and occluded gold; the occluded gold occurs in minerals of low specific gravity such as limonite and clay and(or) of micron grain size and therefore is not recovered on the shaking table.

(6) In visible gold dispersal trains, the minimum concentration of delicate to irregular gold grains is 2500 grains per cubic metre. In some parts of Canada this is less than the background concentration of abraded gold grains.

(7) A gold grain concentration of 5000 grains per cubic metre (20 grains per sample) is required to obtain a representative gold grain count from a standard 10 kg till sample. This condition is generally met in dispersal trains, but not in background areas. If the background is high, some samples will give unrepresentative gold grain counts as high as those in dispersal trains.

These findings can be used to optimize the effectiveness of geochemical exploration programs for gold in Canada. To use them effectively, it is necessary to collect large till samples, to prepare heavy mineral concentrates from these samples, to determine the number of gold grains present and the size and morphology of each grain, and to assay the concentrates for both gold and arsenic. If the till is oxidized, its -63 μm fraction should also be analyzed for gold.

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