

Drift prospecting for gold in the southeastern Shield of Saskatchewan, Canada*

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ABSTRACT

The La Ronge, Kisseynew, Glennie Lake and Flin Flon domains, the main focus for gold exploration in the southeast part of the Saskatchewan Shield, were subject to continental glacial ice advances from the northeast during the Quaternary. Based on forty-four auger holes along with surficial mapping, the general Quaternary stratigraphy in this area is observed to be composed of a lower till unit, an overlying stratified unit of glaciofluvial sand and gravel and/or a glaciolacustrine silt-clay unit, an upper till, and an upper stratified unit.

The lower till is commonly found throughout the geological domains except where it has been eroded in glaciofluvial or fluvial channels. Glacial Lake Agassiz formerly covered most of these prospective domains. The lacustrine deposits associated with the lake impede surficial geochemical surveys including soil, lake sediment, and biogeochemical surveys, although, biogeochemical surveys may be effective in areas of thin clay cover (<2 m) where tills cannot be sampled at the surface. The approximate extent of clay cover can be predicted from beach elevations. For instance, in the Waddy Lake volcanic belt, clay is not known to occur above about 1,400 feet (425 m) elevation. Exploration techniques are hampered by clay cover in at least one third of the area. This influence is indicated by the fact that nearly all gold prospects found to date are located above 1,400 feet (425 m) while the

area of clay cover is virtually unexplored.

The upper till is related to a minor ice readvance. This till is the medium often sampled during soil surveys in the area. Its value as a geochemical sampling medium is dependent on the extent of erosional contact with bedrock highs or the lower till.

Those areas which are relatively free of lacustrine and fluvial deposits are those where surface geochemical methods work best. In the Waddy Lake volcanic belt approximately 25-50% of the area may be suitable for surficial surveys. The area of the Star Lake deposit occurs above the 1,500 foot (460 m) elevation and was not covered by Lake Agassiz.

The effectiveness of till sampling as a surface sampling medium was tested in those areas above the clay level. Till orientation surveys were carried out at the Star Lake property and the Tower Lake prospect (Waddy Lake area) within the La Ronge Domain. Gold grain counts and analyses of heavy mineral concentrates from 7 kg surface till samples were used to delineate dispersion trains down-ice from mineralization. In addition, the clay fraction and a 30 g (-80 mesh) subsample from the same till sample, were analyzed for gold.

In the Star Lake area, ice direction is subparallel to the strike of several narrow northeast trending auriferous structures. Narrow dispersion trains down-ice from known mineralization are defined in till samples by 10 or more gold grains per sample or by gold

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values of 4 g/tonne or greater in the heavy mineral concentrate. Down-ice of the 21 zone gold deposit, the dispersion train is 75-100 m wide and at least 300 m long.

In the Tower Lake area the ice direction intersects the east-west trending auriferous structure at a high angle. The main dispersion train is outlined by 20 or more gold grains per sample and by values of 8 g/tonne or greater in the heavy mineral concentrate. The main dispersion train is up to 150 m wide and 600 m long.

A poor correlation exists between the large distinct dispersion trains defined by gold grain counts and heavy mineral analyses versus the restricted patterns defined by gold contents in small samples of the clay and -80 mesh fractions. Anomalies in the latter fractions are confined to the immediate area of mineralization where gold grain counts in till are highest. Analyses of the finer fraction of the till (fine sand to clay) are promising in detailed follow-up surveys where fine gold constitutes a significant proportion of the target mineralization.

Fractionation tests on four till samples indicate that up to 66% of the free gold occurs in the silt-size fraction. Also, 9-63% of the total gold may be lost during the heavy mineral concentration procedure. All clay size gold is lost but this fraction accounts for less than 6% of the total gold because northern Saskatchewan tills are clay deficient.

Most of the gold loss can be accounted for by occluded gold probably in quartz and therefore not separable by gravity means. The loss of free gold grains (including silt sized gold) appears negligible during the heavy mineral procedure.

INTRODUCTION

At present the La Ronge, Glennie Lake, Flin Flon and Kiseynew domains in the southeastern portion of the Shield are the main focus for gold exploration in Saskatchewan (Figure 1). In this area, surface geochemical surveys are continuing to play an important part in exploration. These surveys, including soil and bio-

geochemical sampling, are usually dependent on the presence of bedrock or locally derived till at or near the surface. Glaciolacustrine silts and clays related to glacial Lake Agassiz cover a significant portion of the prospective area and are a serious impediment to exploration. Glaciofluvial material occurs as a masking veneer over smaller areas, and within channels, where till deposits may be scoured away.

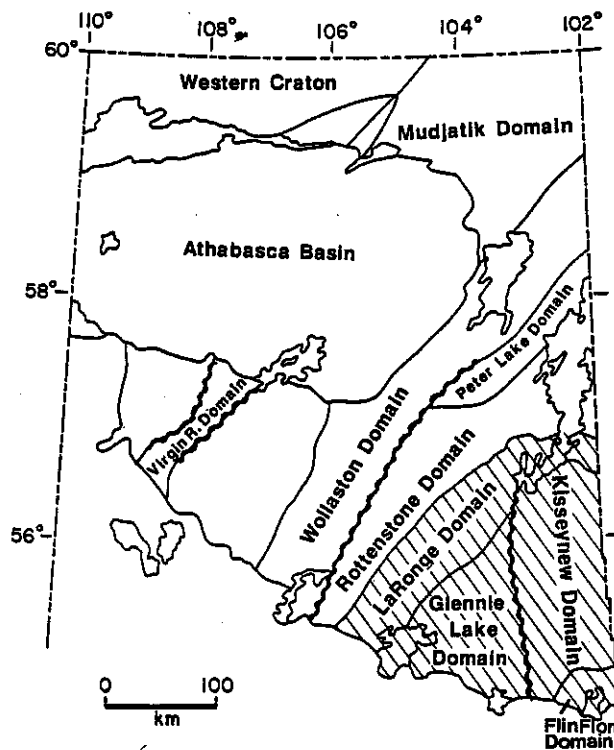


Fig. 1 Major geological subdivisions of the Saskatchewan Shield.¹ Area of interest is cross-hatched.

Almost all known gold mineralization has been found through related showings in outcrop or anomalous expressions in basal till. The areas covered by fluvial and lacustrine deposits are essentially unexplored.

Recently overburden drilling programs employing hand held drilling equipment have been used to penetrate the masking layers, but these programs are plagued by the difficulty of drilling through boulder lags, the inconsistency in obtaining a representative sample, and often the absence of till, particularly in glaciofluvial channels.

The selection of a geochemical survey method is dependent to a large degree on the nature of the overburden cover; therefore, the first part of this paper will deal with the Quaternary geology of the prospective gold area. The second part will deal with the nature and distribution of gold in surface till samples collected mainly from the La Ronge Domain.

QUATERNARY GEOLOGY

Surface Deposits

The first systematic reconnaissance study of the Quaternary geology of the Precambrian Shield of Saskatchewan was carried out between 1974 and 1980.² Twenty maps at a scale of

1:250 000, along with a computer printout of site specific data, document the surficial geology and basic stratigraphy while a comprehensive report including a 1:1 million scale map summarizes the geology on a regional scale. The scale of information does not provide the detail necessary to evaluate the most suitable geochemical survey to use on any one grid; however, a model or framework of information has been established within which more detailed exploration projects can be developed.

The distribution of surficial deposits in the area of interest in the southeastern portion of the Precambrian Shield is shown in Figure 2. Thin moraine (till deposits) together

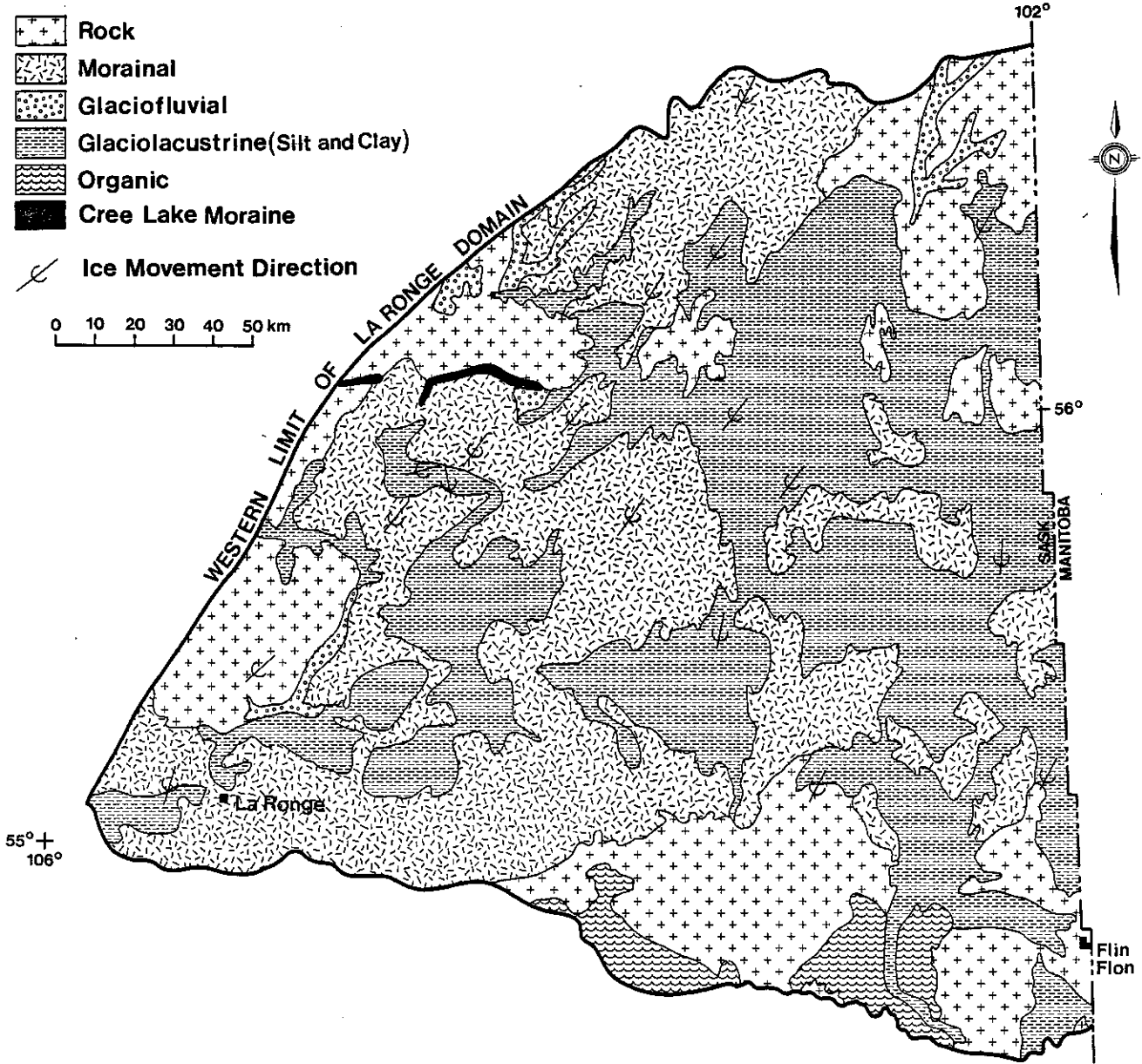


Fig. 2 Surface Quaternary geology for the southeastern Precambrian Shield². Only the dominant surface materials are shown.

with outcrop is interdispersed with large patches of glaciolacustrine material. This area contrasts with the western portion of the Saskatchewan Shield where large volumes of glacial debris were derived from the Athabasca Basin. The result is much thicker and sandier deposits of till, abundant fluvial-outwash cover and the formation of numerous landforms such as drumlins and eskers which are relatively few in the area of study.

Ice Movement Directions

Continental glaciers advanced and retreated several times across this area during the Quaternary Period. Generally the last glacial advance obliterated many features and eroded deposits of the earlier advances.

In the eastern part of the area the direction of ice movement is south-southwest, while in the western part it shifts to a southwesterly direction commonly paralleling the regional structural fabric of the rocks (Figure 2). There are rare but notable occurrences of glacial striae trending west to northwest in the northern portion of the study area³ and crossing striations trending nearly east-west in the central portion of the area along Highway 102.⁴

The fact that the ice direction is generally parallel to the regional structure has several implications for exploration. In particular, the glacial dispersion trains found to date are generally long and narrow and restricted to ridge and valley topography parallel to the ice direction.

Drift Stratigraphy

The generalized stratigraphy of the drift in the area comprises a lower till unit, an overlying stratified unit of glaciofluvial sands and gravels, and/or a glaciolacustrine silt and clay unit. An upper till unit and an upper stratified unit, occur at a few locations. This generalized stratigraphy was obtained from information in 53 auger holes along roads in the area, roadside exposures, excavations and overburden geochemical surveys. Location of auger holes from areas where the upper till unit is present are shown in Figure 3 and the stratigraphy of these holes is shown in Figure 4.

The lower till was encountered in most of the 53 holes. Subdivision into two distinct units was made in only two holes and in excavations in the Stanley Mission area.⁵ The lower till in the auger holes has an average minimum thickness of 1.75 m (range 0.5-15 m), which agrees with overburden surveys in the La Ronge and Flin Flon domains. Thus the till is regionally thin. No correlation of this lower till has been attempted over the study area due to the paucity of information and the extreme irregularity in relief.

The lower stratified glaciofluvial sands and gravels related to ice recession are found in 12 of the 53 auger holes. On the surficial map, glaciofluvial material accounts for less than 5% of the surficial deposits. The high proportion of this material in the auger holes can be attributed to the fact that the holes were drilled along roads that follow deposits of stratified material.

Despite the fact that glaciofluvial material accounts for less than 5% of the surficial material, a thin patchy veneer of silty sand of fluvial origin overlies till on a much broader scale. This veneer may only be a half metre thick or less, but it was the sampling medium for many B horizon soil surveys in this part of Saskatchewan. The seemingly ubiquitous veneer is likely the result of ablation and fluvial processes during ice recession.

Glaciolacustrine silts and clays are found in 41 of the 53 auger holes. Most of these sediments were deposited in glacial Lake Agassiz which covered most of the area.⁶ This is a high proportion relative to their occurrence on the surficial map and may be related to the fact that drill holes were located in the areas of thicker drift and where buried subsurface deposits would likely be encountered. Average thickness of the sediments in the auger holes is 5.6 m (maximum 25 m). This unit represents the main deterrent to the success of surface geochemical surveys. Fortunately, it is a relatively thin unit particularly in the western portion of the study area which coincides with the western limits of Lake Agassiz.

A thin upper till unit (<2 m) related to a

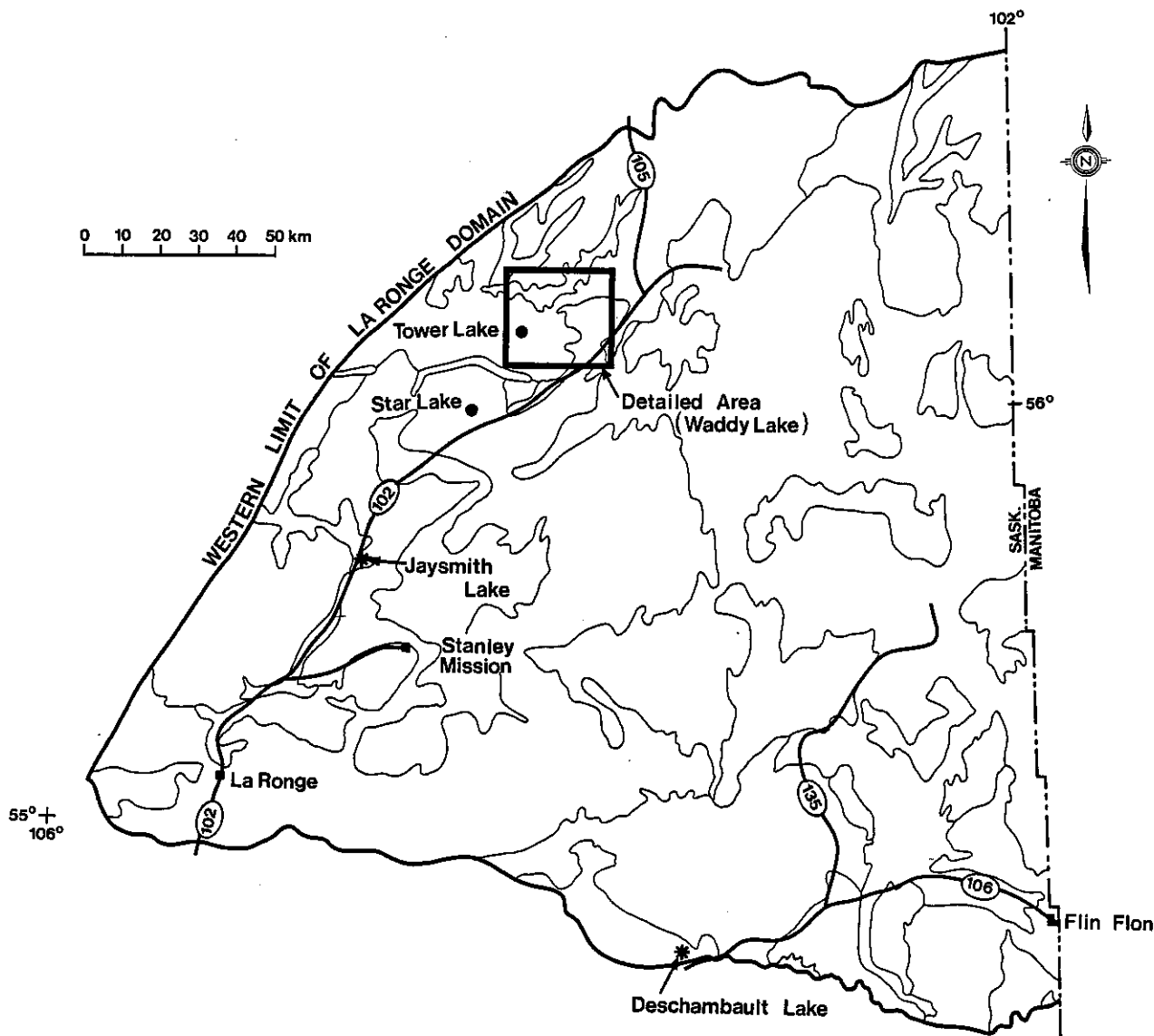


Fig. 3 Location of investigation sites, the auger holes and the outline of Waddy Lake gold area.

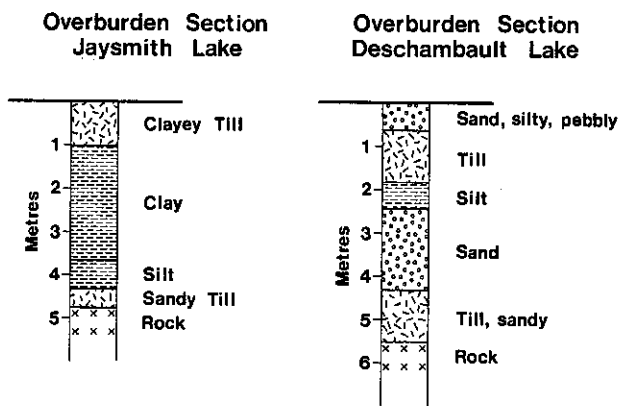


Fig. 4 Overburden sections from auger holes at Deschambault and Jaysmith Lakes.

minor readvance of the ice is found over the glaciolacustrine silts and clays at a few locations. This till, found in only 3 of the 53 auger holes and at least two roadside exposures, is being recognized with greater frequency in surface geochemical surveys. It is expected that the upper till rarely contacts bedrock or lower till except where these units are exposed above the lower glaciofluvial and glaciolacustrine layers. As such the unit may be a tenuous sampling medium in many areas. Generally, the upper till can be distinguished from the lower till by higher silt and clay contents. The silt and clay are derived from the underlying glaciolacustrine material.

In the auger holes the upper stratified unit is distinguishable above the upper till unit. Where the upper stratified unit occurs over lower stratified sediments it is not possible to separate these two units. The glaciolacustrine sediments commonly show a fining upward sequence with sands at the base grading to silt and clay indicating a retreating source of sediment (ice recession). In a few cases this sequence is reversed in the upper part of the section suggesting a re-advance of the ice into the lake basin which likely coincides with the deposition of the upper till.

Glacial Landforms

In the area east of the La Ronge domain the dominant glacial landform is thin ground moraine. This ground moraine is composed primarily of sandy ablation till. Drumlins and eskers are rare here but are more common north and west of the La Ronge domain in thicker drift areas associated with the Athabasca Basin.

The Cree Lake Moraine, a prominent and significant end moraine cuts the La Ronge domain approximately 20 km south of Waddy Lake (Figure 2). This moraine can be traced for 800 km across the Shield east into Manitoba and northwest into Alberta. The moraine represents a major still stand of ice in northern Saskatchewan,⁷ and is associated with regional features such as sandy outwash plains. As such, the Cree Lake moraine impedes surface geochemical exploration. However, its sphere of influence appears to be restricted to a 2 km wide belt at maximum.

The main glacial landforms which cover or have eroded bedrock and till and are an impedance to geochemical surveys are eskers, ice walled channels, buried valleys, kettles and kames. In the area of interest, the combination of these deposits appears to comprise less than 5% of the total surface area.

Large quantities of ice contact stratified drift in a belt along Highway 102 north of La Ronge are thought to have been deposited by melt water flowing into Lake Agassiz through an ice walled channel.⁸

Proglacial Landforms

The main proglacial influence was Lake Agassiz which covered the southwestern portion of the map area. The area covered by the lake corresponds approximately to the area outlined by the extent of the glaciolacustrine clays and silts (Figure 2). The western limit is just west of the La Ronge domain. Lacustrine material is also common in bogs and lakes, below the elevation of highest known beaches, within those areas mapped as dominantly moraine and bedrock.

Near Waddy Lake proper, lacustrine deposits predictably occur below 425 m elevation. This prediction results from information on beach elevations north of Waddy Lake.³ In the Waddy Lake area, lacustrine material was mapped up to the 425±3 m elevation (Figure 5). In at least one third of this area, surface exploration techniques will be affected by clay. Nearly all gold prospects found to date in the area are located above 425 m elevation (Figure 5).

The Byers fault system is a major structure which can be traced for at least 10 kilometres across the area (Figure 5).⁹ Gold prospects are located at several points along the structure. Note that the northeast trending portion of the fault mostly falls below the 425 m level while the east-west trending portion falls above the level and should be silt and clay free for the most part.

Till Textures

The most common till type is a sandy till as opposed to a very sandy till west of the La Ronge domain (Figure 6). Generally sand comprises 50-90%, silt 5-40%, and clay traces to 10% of the matrix. Silty till is common in areas underlain by volcanic rocks. Silt contents can be as high as 65% and average 50% while sand comprises 35 to 55% and clay less than 10%. "Clayey till" which is the upper till unit previously mentioned averages about 39% sand, 38% silt and 23% clay. Although the clay fraction is not dominant it is much higher than is the other till types and therefore referred to as "clayey till".²

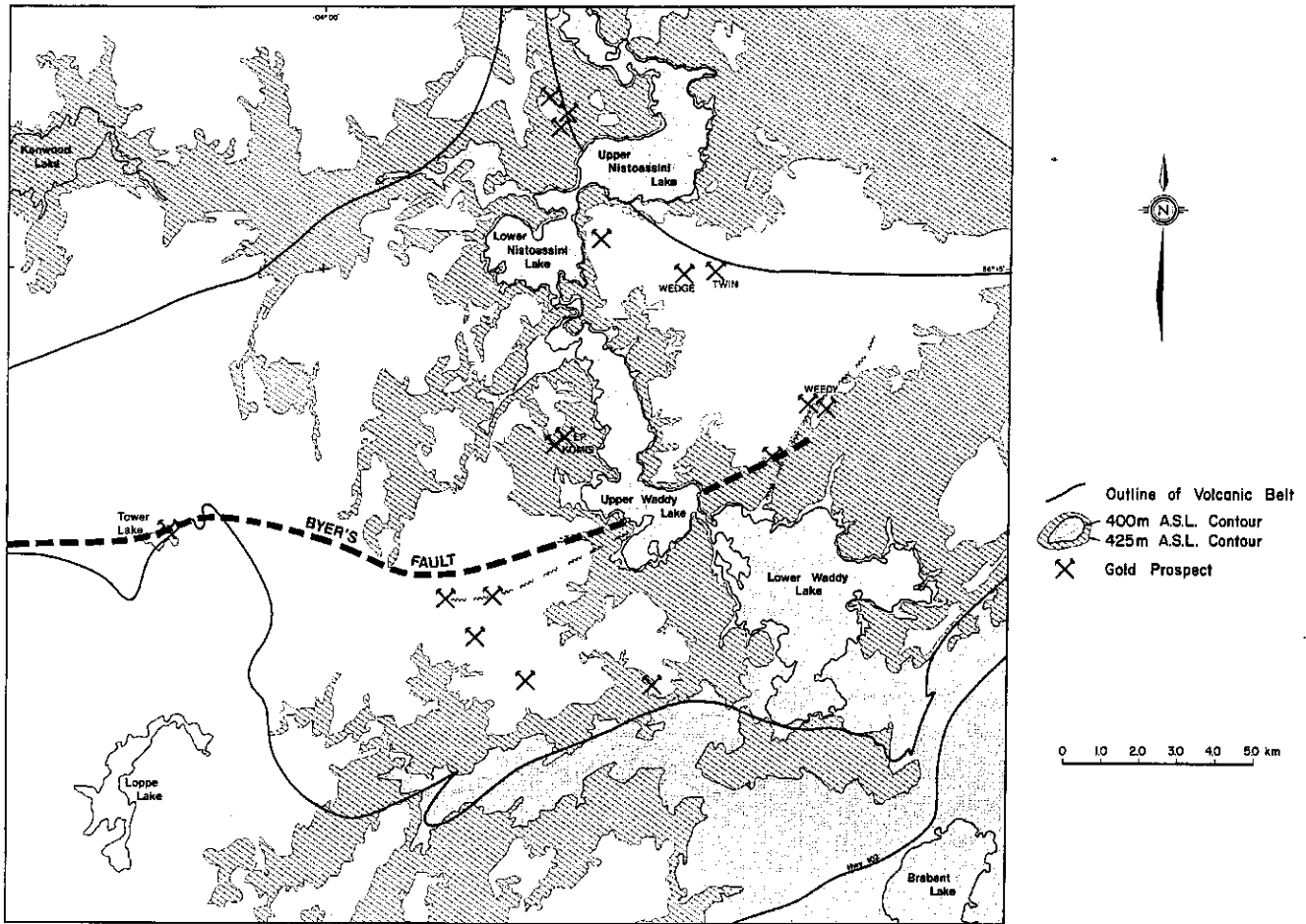


Fig. 5 Lacustrine clay distribution in the Waddy Lake gold area.

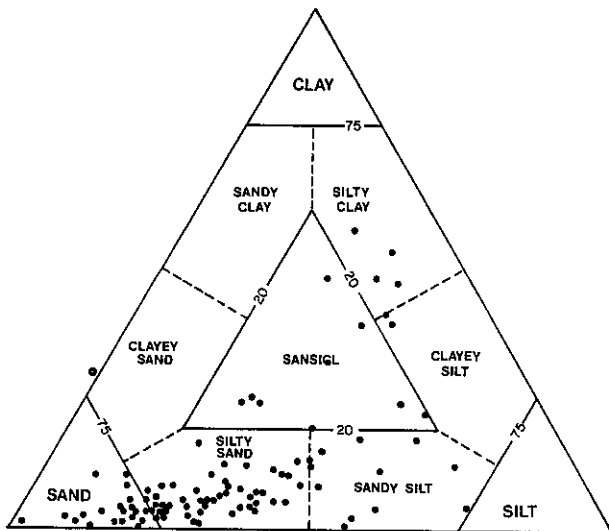


Fig. 6 Till textural diagram for samples taken in NTS 63M, N².

Discussion

Surface geochemical methods should work well above the lacustrine level in most of the prospective area in the southeastern Shield. In areas where the silt and clay cover is less than 1.5 m thick, deeper pits could be excavated by hand or backhoe to intersect the lowertill unit. Surface biogeochemical methods do hold some promise in characterizing thinly buried tills. One feature which impedes surveys throughout the morainal areas is the presence of a thin veneer of fluvial and eolian silty sand material which bears little resemblance to the underlying till, yet is often sampled during B horizon soil surveys.

Large areas of the prospective volcanic belts are silt or clay covered. The only effective way to test these areas is to employ overburden drilling equipment. On average,

this equipment should be capable of penetrating 15-25 m of combined lacustrine and fluvial material, a thin boulder layer on top of the till, and a lower till unit generally less than 3 m thick.

This stratigraphic succession was encountered in the Waddy Lake area while using a skid mounted roto sonic drill which successfully located the source of an anomalous till beneath 10 m of lacustrine material.¹⁰

The problems posed by fluvial and upper till cover must be dealt with on a grid by grid basis. Fortunately, thick fluvial cover constitutes less than 5% of the prospective area.

TILL ORIENTATION SURVEYS

Introduction

Gold in till orientation surveys were carried out over the Star Lake (21 and Rush Lake zones) and the Tower Lake properties within the La Ronge Domain (Figure 3). As

well, regional till samples were collected from portions of the La Ronge, Glennie Lake and Flin Flon domains. In all 150 surface till samples were collected.

Laboratory Procedure

The laboratory procedure is outlined in Figure 7. Large till samples (5-8 kg) and preconcentration methods were used to overcome sample representivity problems.¹¹ Procedure A involved the use of a shaking table and methylene iodide to produce a heavy mineral concentrate of the 5-8 kg till samples. This work was done by Overburden Drilling Management Limited (ODM). Panning was utilized to separate, count and measure gold grains and to classify grains as delicate, irregular and abraded. Delicate grains exhibit numerous primary crystal edges and pitted leaf surfaces implying short glacial travel distances. On the other extreme, abraded grains are presumably far travelled.

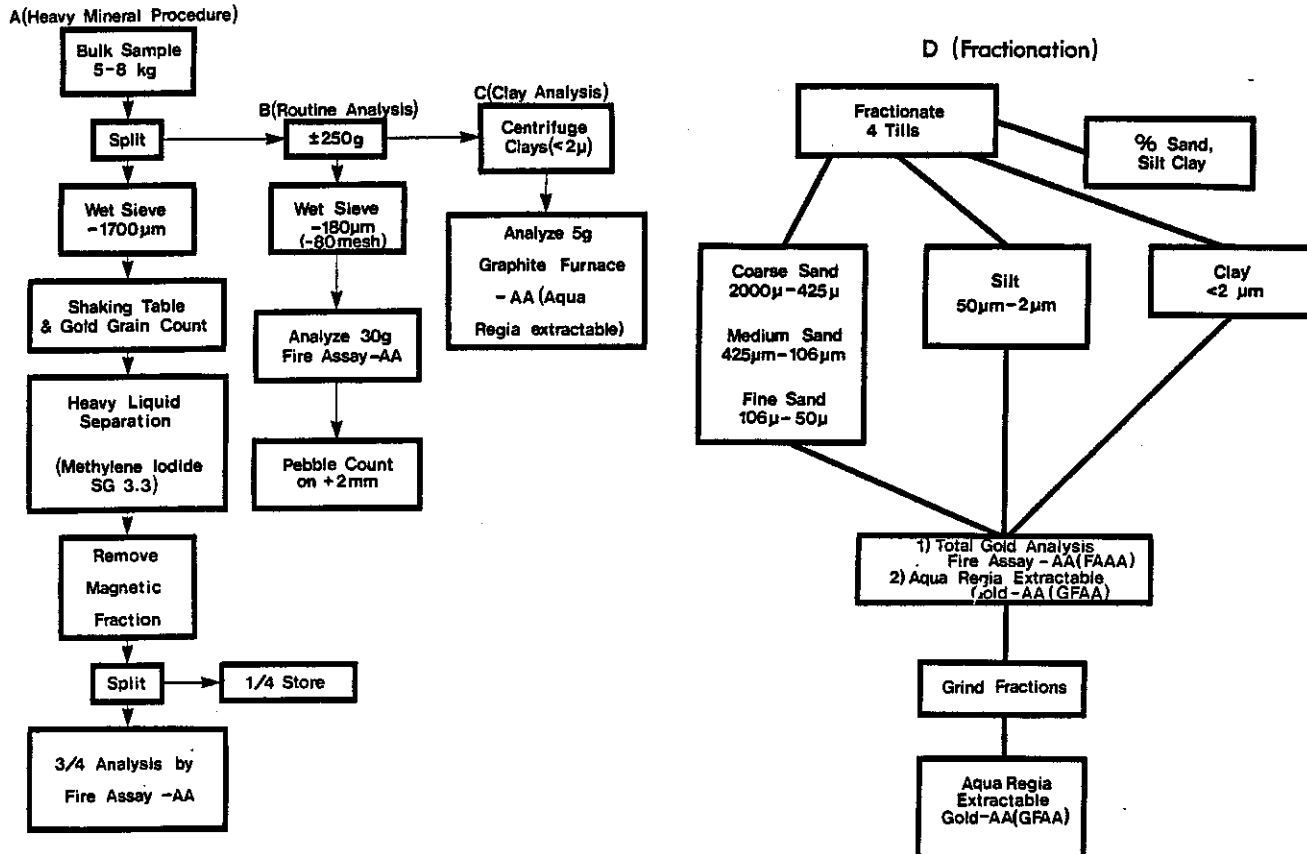


Fig. 7 Flow diagram showing sample preparation and analytical techniques used in this study. (Fractionation studies apply only to four till samples.)

A 3/4 split of the heavy minerals was analyzed for gold by a fire assay - atomic absorption method (FAAA) at Bondar Clegg Laboratories in Ottawa.

Procedure B involved Au analysis of a 30 g -180 μm (-80 mesh) portion of the till sample at TSL Laboratories in Saskatoon. The FAAA method was again employed. This procedure is consistent with many soil surveys previously undertaken in the area.

Procedure C involved the separation of clay (-2 μm , -400 mesh) from the till by sieve and centrifuge at the Saskatchewan Research Council (SRC). Two grams of clay were analyzed for gold by the graphite-furnace atomic absorption method after extraction by aqua regia (GFAA).

Procedure D involved a separate sieve-centrifuge fractionation of four till samples at SRC. Samples were separated into coarse sand (2000 μm to 425 μm), medium sand (425 μm to 106 μm), fine sand (106 μm to 50 μm), silt (50 μm to 2 μm) and clay (less than 2 μm). Splits of each fraction were analyzed for gold by both the FAAA procedure and the GFAA procedure. In addition, each fraction of two till samples was ground for three minutes in a tungsten-carbide shatter box and analyzed again by the GFAA procedure.

Sampling Procedure - Quaternary Setting

The Star Lake and Tower Lake areas are above the upper limits of Lake Agassiz deposition. Both areas are characterized by a thin sandy till deposit (Figure 8) generally no more than 2-3 m thick.

The 21 Zone at Star Lake occurs in a bog area approximately 50-75 m across, surrounded on both sides by outcrop-till ridges extending up to 10 m above the level of the bog. Within and adjacent to the bog, stratified heavy mineral-rich fluvial sand deposits occur to depths of one metre. Regionally, deposits of this type often form the B horizon of the soil profile and have been sampled in past soil surveys. Oxidized discontinuous sandy till deposits (>75% sand fraction) occur in the outcrop depressions at the 21 Zone and are up to 2.0 m thick. The remainder of the Star Lake property is characterized by a more continuous

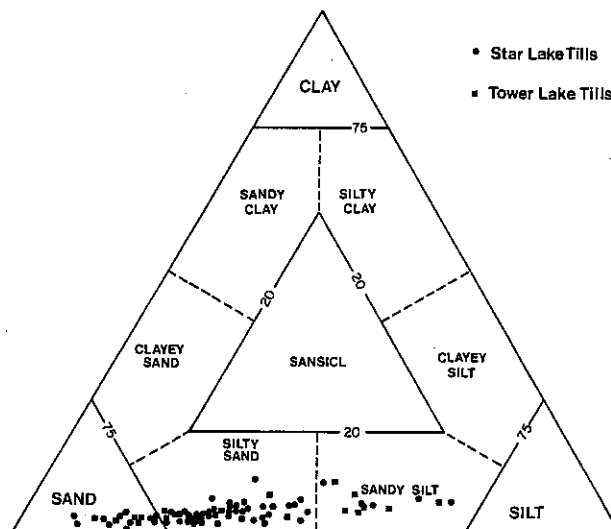


Fig. 8 Textural diagram¹² for Star Lake - Tower Lake till samples (minus 2.0 mm fraction).

veneer of silty sand till deposits.

Tills were sampled from 0.7-1.0 m deep pits generally within oxidized material. Samples were collected at 50-100 m spacings on lines 100 m apart.

At Tower Lake, till samples from 0.5-1.0 m deep were generally less oxidized and often more silty. Again a thin veneer of till occurred over the area. Coarse fluvial material interrupted sampling east of Tower Lake. Occurrences of a thin (<1 m) upper till unit were noted at two sites. This till overlies a lower fluvial sand unit. At these sites the lower till, if present, could not be sampled.

At Star Lake, the ice-flow direction is toward the southwest, subparallel to the gold bearing structures. Ice-flow direction at Tower Lake is toward the south-southwest intersecting the mineral structure at a high angle.

Past Sampling Problems

In the Star-Tower-Waddy Lake area the thin fluvial sand layer overlying the lower till bears no apparent relationship to the till. This layer occurs commonly throughout the area and in the past was probably the main sampling medium for several B horizon soil surveys.

The soil-till profile at a trench approximately 150 m down-ice from the EP-zone on the

Waddy Lake Resources property at Waddy Lake is shown in Figure 9. This is a portion of the anomalous exposure termed the 'Riddle Till' which led to the discovery of the EP zone by Waddy Lake Resources.¹⁰ The Quaternary stratigraphy as determined by rotosonic drilling and sampling, indicated up to 10 m of glacio-lacustrine clays and silts in the low area, underlain by 1-2 m of fluvial or beach sand and up to 2 m of basal till.

In terms of gold particle contents, the upper silt unit contains one particle, the B horizon (ablation) till 109 particles and the C horizon (lodgement) till 123 particles. Heavy mineral assays are 1, 171 and 221 g/tonne, respectively (background <1.0 g/tonne). Both the -180 µm split and the clay component are anomalous in the upper silt unit (75 ppb versus background contents of 5-20 ppb in -180 µm fraction and 53 ppb versus background contents

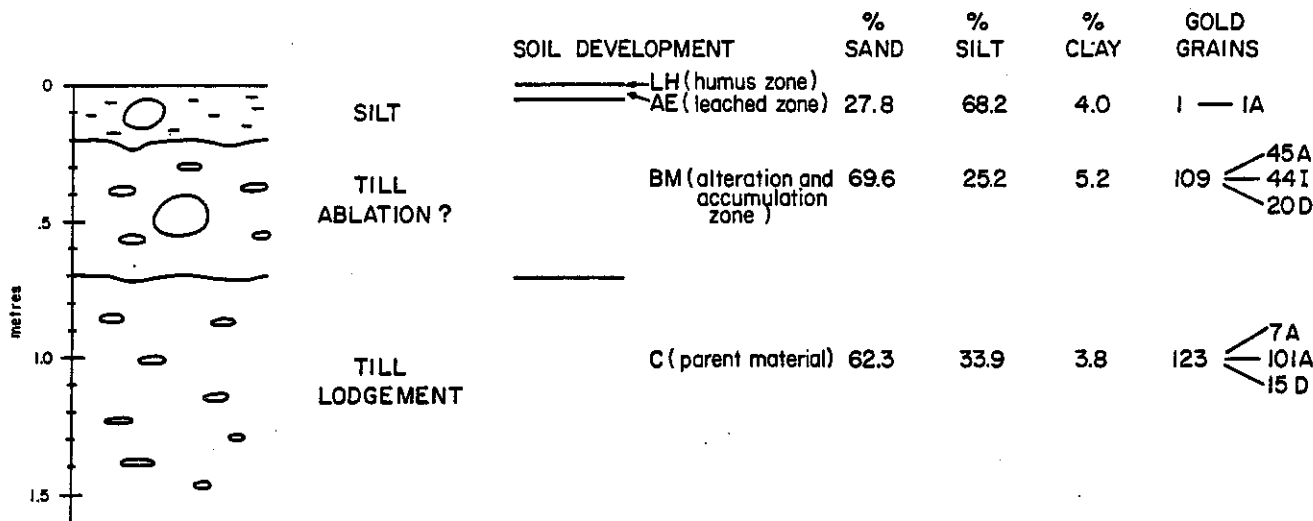


Fig. 9 Soil-till profile from a trench down-ice from the EP zone, Waddy Lake Resources property (A = abraded, I = irregular, D = delicate).

On surface, a silt-rich layer equivalent to the buried fluvial sand layer dominates the upper B horizon beneath a thin (<5 cm) humus layer (LH) and a thin (<10 cm) leached mineral layer (AE). The B horizon occurs at a depth of 1 m in the silty sand till. The C horizon is similar in texture to the B horizon except for the presence of occasional large rounded granitic boulders in the B horizon. The B and C horizons are virtually identical in terms of their textural analyses except for the higher silt content in the C horizon (33.9% versus 25.2% silt).

Similar and more pronounced translocation of the silt component from the upper B horizon to lower B and C horizons has been noted in other pits in the region. This process is manifested by a heavy silt coating on the upper side of pebbles in the C horizon. The effect of translocation on gold has not been evaluated to date.

of 24 ppb in clay fraction). However, these analyses do not accurately reflect the extremely anomalous nature of the underlying till. Collection of a combination of fluvial and till samples would greatly complicate the interpretation of a geochemical survey in this area.

The Star Lake Mineralization (21 Zone)

The 21 Zone mineralization occurs along a mylonite zone within a bog which crosscuts a zoned igneous pluton ranging in composition from diorite to granite (Figure 10). The deposit itself occurs within quartz monzonite and granitic rocks as a tabular to pencil shaped quartz body up to 80 m long and 10 m thick, plunging to the southeast at a steep angle. The subcrop expression beneath a bog is estimated to be 25 - 30 m in length by 5 - 10 m thick. Reserves indicated are 230 000 tonnes containing 16 g/tonne gold.¹⁴

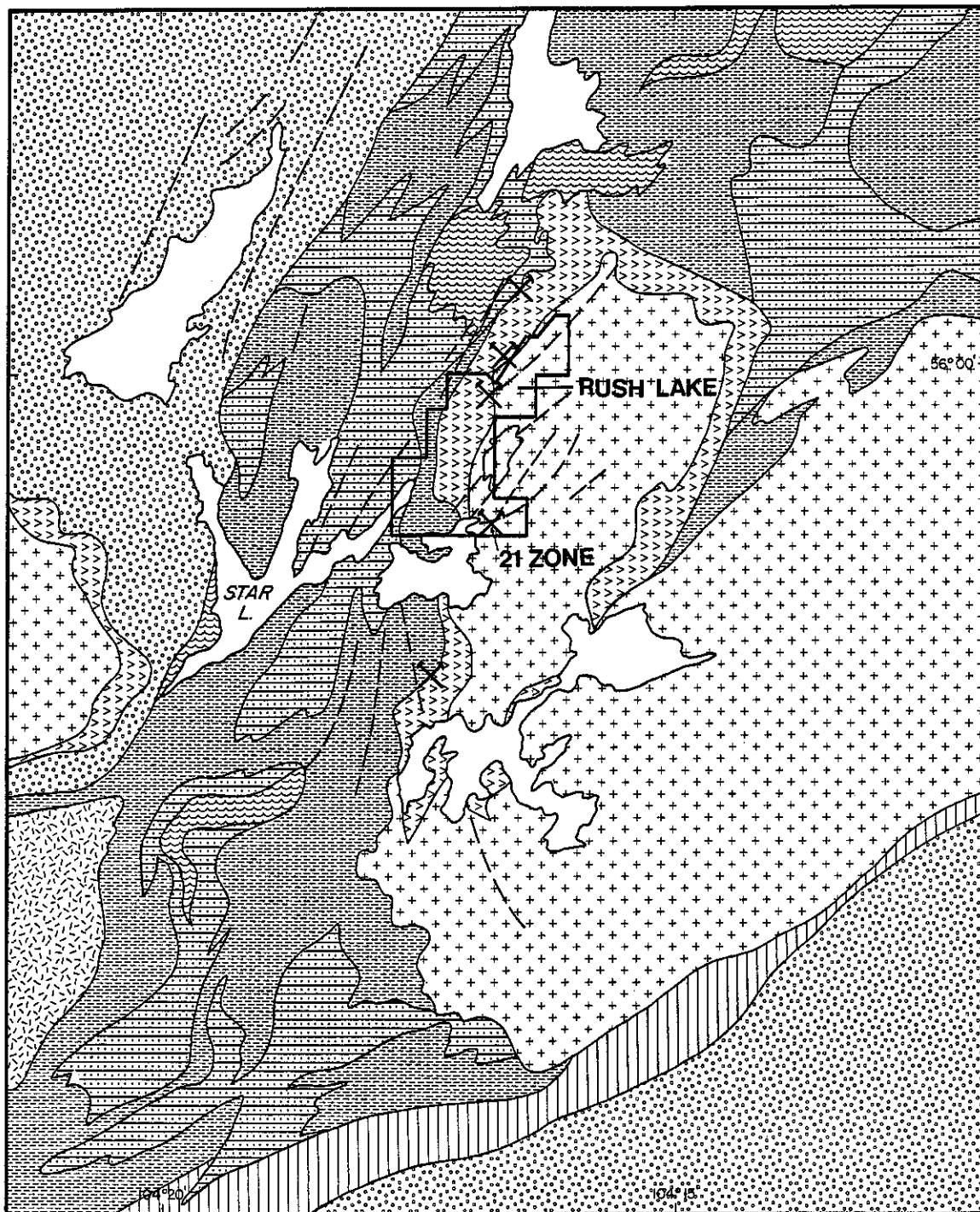


Fig. 10 Generalized geology of the Star Lake area ¹³. (The Star Lake property is outlined.)

The mineralization falls along a northeast trending lineament. Several of these lineaments occur on the property and crosscut all lithologies in the area with the possible exception of late stage mafic dykes which parallel the shear structures. It is important to realize that the ice flow direction in the area is roughly parallel to these lineaments.

Gold at the 21 Zone is typically fine grained, generally 50 microns in size although particles up to 250 microns are present. Examination of polished sections indicates that gold occurs along quartz grain boundaries and also as isolated grains in pyrite. Shearing resulted in redistribution of gold in fractures in the pyrite and quartz.

Chalcopyrite and arsenopyrite rarely have been noted in association with the higher grade intersections. Electron probe work

reveals trace amounts of a probable lead telluride (altaite, Pb Te) associated with gold grains.

At the Rush Lake zone, the main pod of quartz vein related mineralization is exposed over 5 - 10 m at the bedrock surface. Reserves to date are estimated at $\pm 15\ 000$ tonnes grading 10 g/tonne. The nature of the gold is not well known.

Tower Lake Mineralization

The Tower Lake prospect lies along an east-west fault zone (Tower Lake Fault) which crosscuts the contact of granitic intrusive and intermediate to mafic volcanic rocks (Figure 11). Reserves are estimated at 400,000 tons grading 3-4 g/tonne (The Prospect, August, 1985, vol. 1, no. 2). Mineralized intersections occur at least over 60 m in the hanging wall of the fault under the east end of Tower Lake.

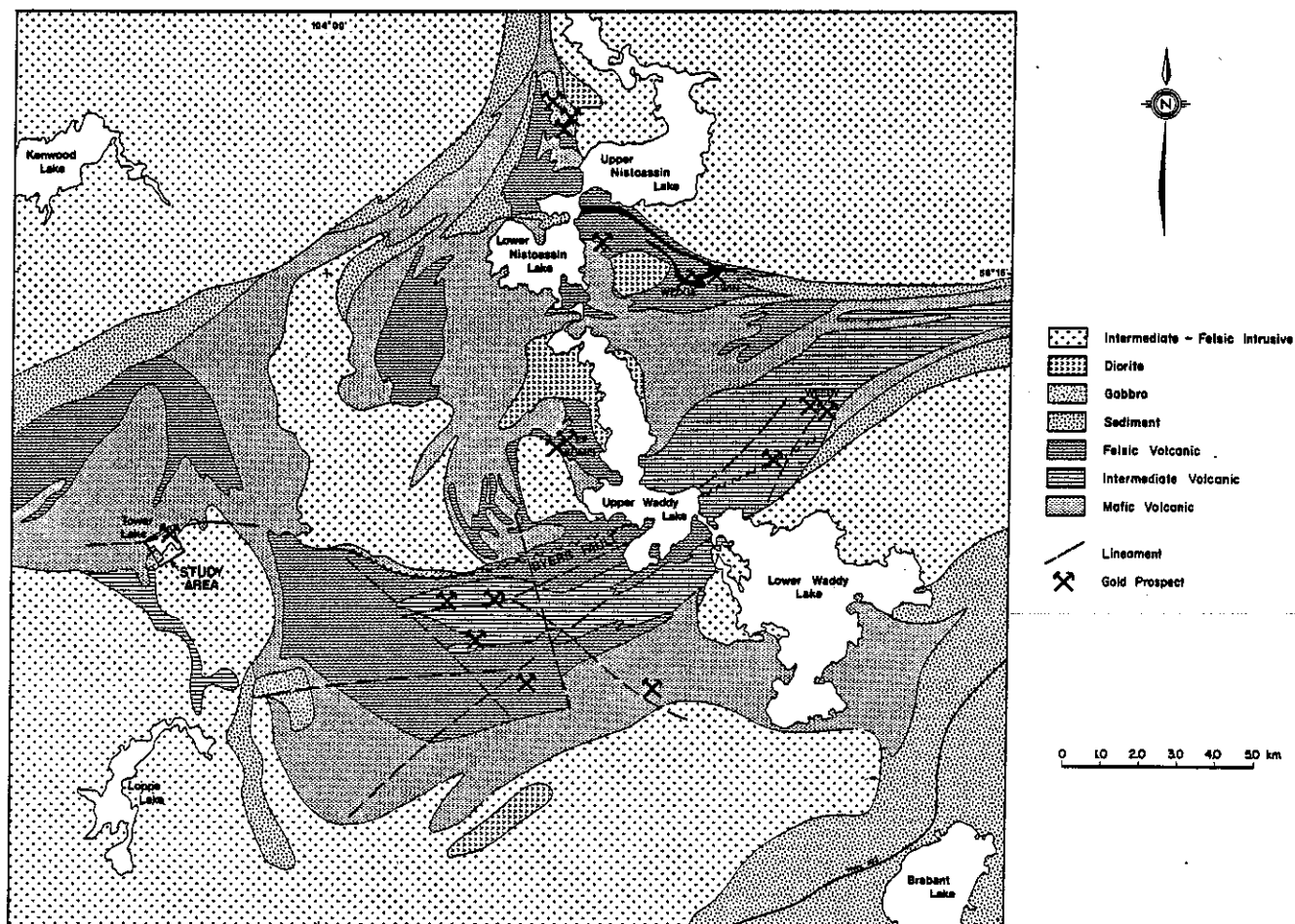


Fig. 11 Generalized geology of the Waddy Lake area ^{9,15}. (The Tower Lake study area is outlined.)

Gold occurs as 30-60 micron grains within limonite in the higher grade intersections. Highly fractured, limonitic volcanic and intrusive rocks host the mineralization. The limonite alteration (after pyrite) occurs to depths of at least 100 m and the possibility exists that the limonite is related to preglacial weathering.

Alteration - Lithochemical Studies

To evaluate the nature of any wallrock alteration or mineralization characteristics which may be of use in a till survey, forty samples from each of two holes through both the 21 Zone and Tower Lake mineralization were analyzed for a variety of major, and trace elements. Analyses for SiO_2 , Al_2O_3 , Fe_2O_3 , MgO , K_2O , Na_2O , TiO_2 , MnO_2 , P_2O_5 , Cu, Ni, Co, Pb, Zn, Mn, Cd, Cr, V, Be, Y, Sr, and Ba by the Inductively Coupled Plasma (ICP) method. In addition Ag and As were analyzed by atomic absorption, B by ICP (KOH fusion), S by Leco sulphur analyzer, Au by neutron activation, W by the colorimetric method, Hg by flameless - AA and F by specific ion electrode. CO_2 was also determined and loss on ignition was measured at 900° C.

At the 21 Zone, no significant mineralogical or geochemical haloes exist in wall rocks more than 1-2 m from mineralization. Alteration within the granitic rocks adjacent to mineralization consists mainly of minor sericitization of feldspars, hematization and epidotization. Carbonate alteration is generally lacking.

Gold content in wall rock is less than 2 ppb only 2 m from high grade intersections. Four mineralized samples do contain elevated levels of Cu (196 ppm), W (101 ppm), As (8.5 ppm) and Te (22.0 ppm).

At Tower Lake the dominant mineralogical alteration associated with mineralization is hematization and limonitization after pyrite. Limonite also occurs as impregnations between silicates and along hairline fractures. Yellow 'earthy' illite stringers are also associated with weakly sericitized wall rocks within one metre of mineralized intersections.

Gold contents are elevated (>30 ppb) in all samples over the 100 m length of the hole.

Elevated values of Mo (25 ppm), W (49 ppm), and F (.34%) are spatially associated with mineralized intersections.

On the basis of the present mineralogical-lithochemical studies, gold itself appears to be the best pathfinder to both mineralized zones in terms of drift prospecting.

Orientation Results

Gold grain counts

In the Star Lake area, gold grain counts in till were effective in outlining the 21 Zone and associated mineralization and also the Rush Lake zone (Figure 12A). Ten particles or more define a 75-100 m wide dispersion train extending at least 300 m down-ice from the 21 Zone before interruption by David Lake. Along the Rush Lake zone a dispersion train 300 m long by 75-100 m wide is defined.

In addition, gold grain counts indicate other smaller less impressive trains including Train A south of the 21 Zone and Train B north of the 21 Zone.

In the Tower Lake area, a high background gold grain count (>10 particles) is apparent south of the Tower Lake structure indicating that the whole structure may be mineralized to varying degrees (Figure 13A). The main known pod of mineralization is defined by greater than 20 gold grains (Train A). Dispersion train dimensions are at least 600 m long by 150 m wide.

In addition, another potential train with elevated gold grain counts (Train B) occurs at the western end of Tower Lake.

Gold grain size

In the Star Lake area, gold particle sizes in the 21 Zone tills are predominantly in the silt-size category (Figure 14). Gold size distribution corresponds with the distribution in the deposits.

In the Tower Lake area, the majority of gold grains in Train A are of silt size. Limited polished section work indicates the gold grains in the source are also of silt size.

Delicacy measurements

In the Star Lake area, most of the gold grains (>95%) in all tills sampled are irre-

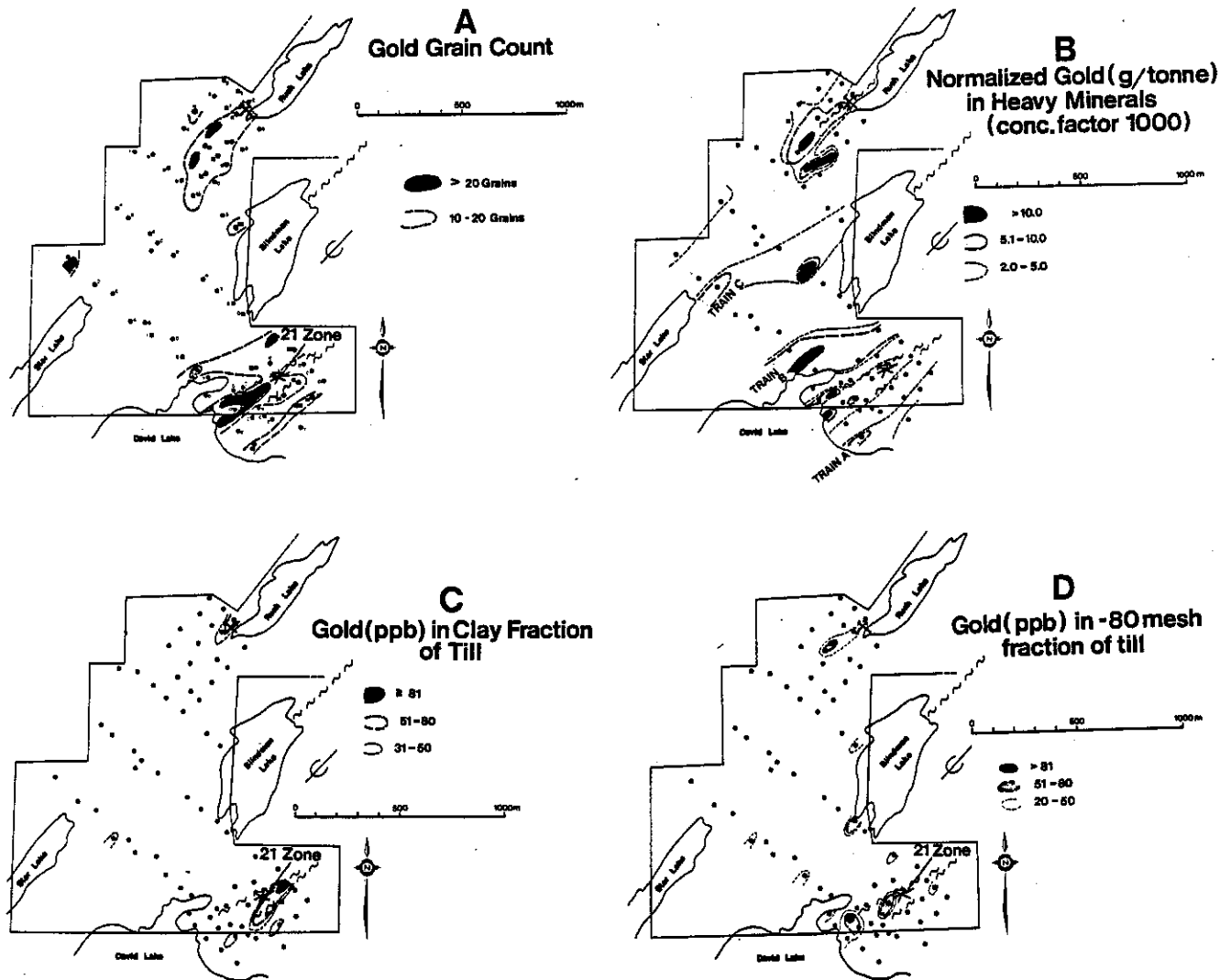


Fig. 12 Star Lake property orientation results.

gular or delicate, meaning relatively short travel (<500 m). However, considering the characteristic fine size of the gold grains, delicacy measurements may be tenuous under the binocular microscope.

At the Rush Lake zone, greater than 80% of the grains noted are delicate to a distance of 75 m down-ice from the zone. Greater than 50% of the grains are irregular to the limits of the train (Figure 15A).

At the 21 Zone, greater than 80% of the grains noted are delicate near the deposit (<50 m). A majority of irregular grains are, however, noted 100 m from the zone (Figure 15A).

In the Tower Lake area, all gold grains in

the area are classified as delicate and irregular (Figure 15B). Greater than 50% of the gold grains in Train A are classified as irregular. The two samples closest to the presumed source feature >80% delicate gold grains. The dominance of irregular grains in the remainder of the train fits the travel distances involved (100 - 600 m). At the extreme southern end of the train an increase in delicate grains may suggest another gold source. Delicacy measurements for these fine gold sizes should be verified by scanning electron microscope work.

Normalized Assay of the Heavy Mineral Concentrate

In the Star Lake area, the mean concentration factor (weight of the table feed divided by

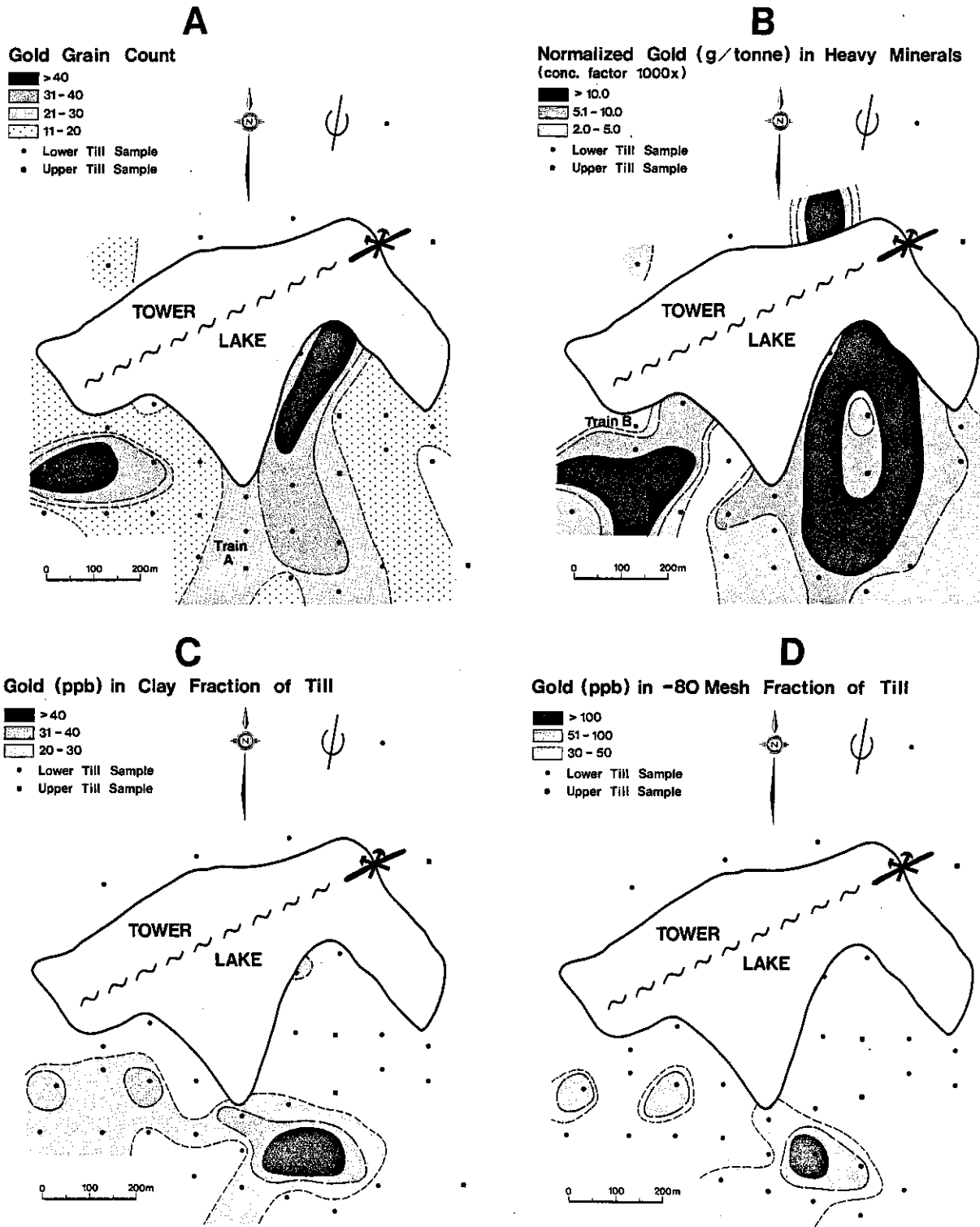


Fig. 13 Tower Lake property orientation results.

the weight of the non magnetic heavy mineral fraction) is 1100. Due to a wide variation in the actual concentration factor (range 300 to 1500) the gold assays are normalized to 1000 concentration. This is considered a necessary step in the treatment of data particularly for

oxidized surface samples where heavy minerals are selectively destroyed or for tills derived from a variety of rock types some featuring an abundance of heavy minerals such as garnets which would effectively dilute gold values.

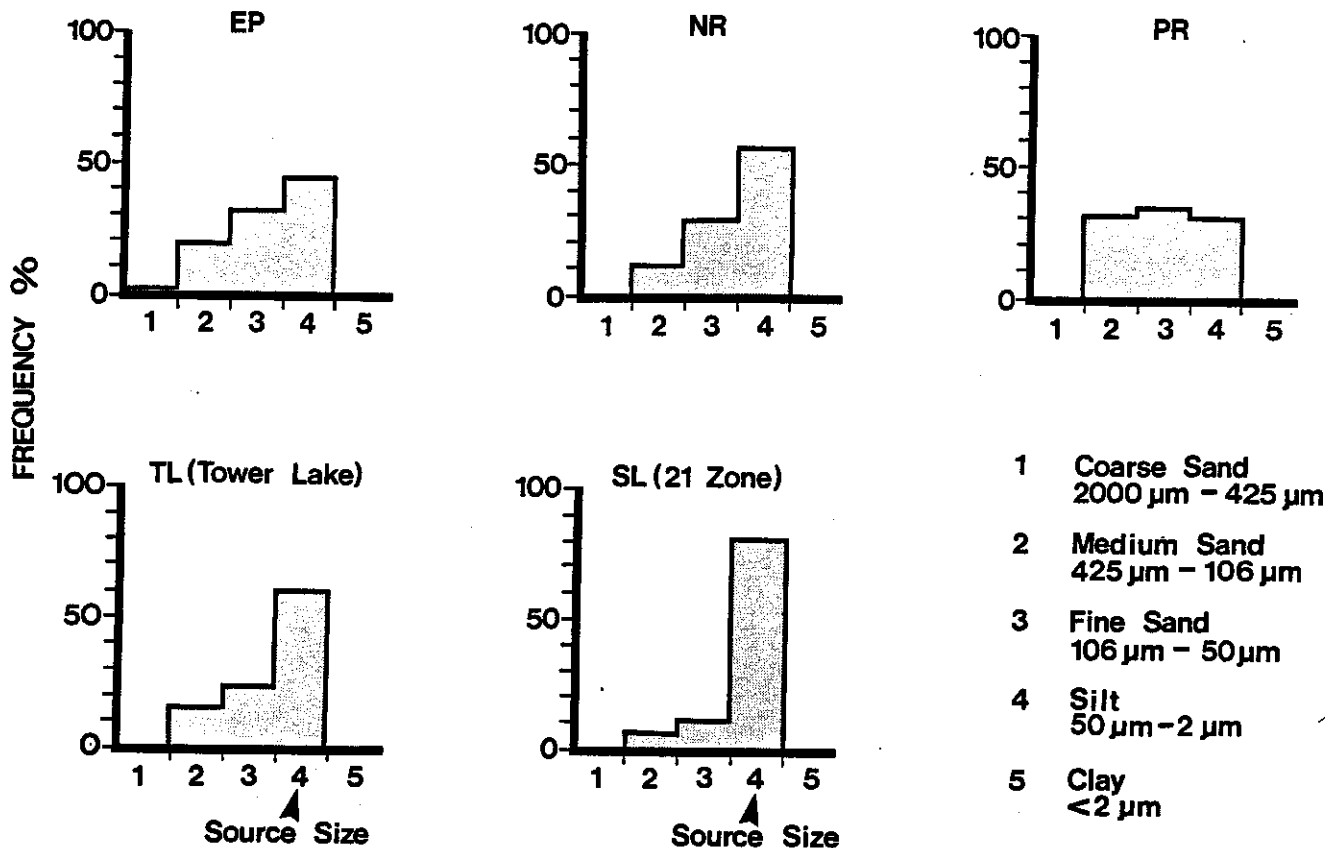


Fig. 14 Gold grain size distribution in selected till samples. TL - Tower Lake, SL - Star Lake, EP - EP zone (Waddy Lake Resources property), NR - Waddy Lake area, PR - Glennie Lake domain.

The 4 g/tonne contour roughly corresponds with the >10 gold particle contour in both the 21 Zone and Rush Lake trains and in Trains A and B (Figure 12B). Another potential train (Train C) is not verified by gold particle counts.

In the Tower Lake area, the mean concentration factor is 952 (range 300 to 1200). The heavy mineral assays were again normalized to 1000 concentration. The 8 g/tonne contour interval defines the main dispersion trains identified by gold grains (Figure 13B). High background values are located at all points south of the extrapolation of the Tower Lake fault zone.

Comparison of Gold in Clay (Procedure C) with -180 µm Fraction (Procedure B)

At Star Lake, anomalous values in both the clay and the -180 µm fractions (-80 mesh) occur sporadically through the area and directly over the known mineralization (Figures 12C, 12D). The gold content of the heavy

minerals and the gold particle counts are clearly superior in their definition of the dispersion trains. Only a weak correlation exists between the gold contents of the heavy minerals, the clay and the -180 µm fractions. Background gold contents for the clay and -180 µm fractions are 20 ppb and 5 ppb, respectively.

In the Tower Lake area, a moderate correlation exists between the gold contents of the heavy minerals, clay and -180 µm fractions of the till. The gold content of the heavy mineral concentrate and the gold grains themselves are again superior in defining the dispersion trains. However, the gold in the clay and the -180 µm fractions does define a broad zone of elevated gold contents south of the Tower Lake structure (Figures 13C, 13D). Background gold contents for the clay and -180 µm fractions are 15 ppb and 5 ppb, respectively.

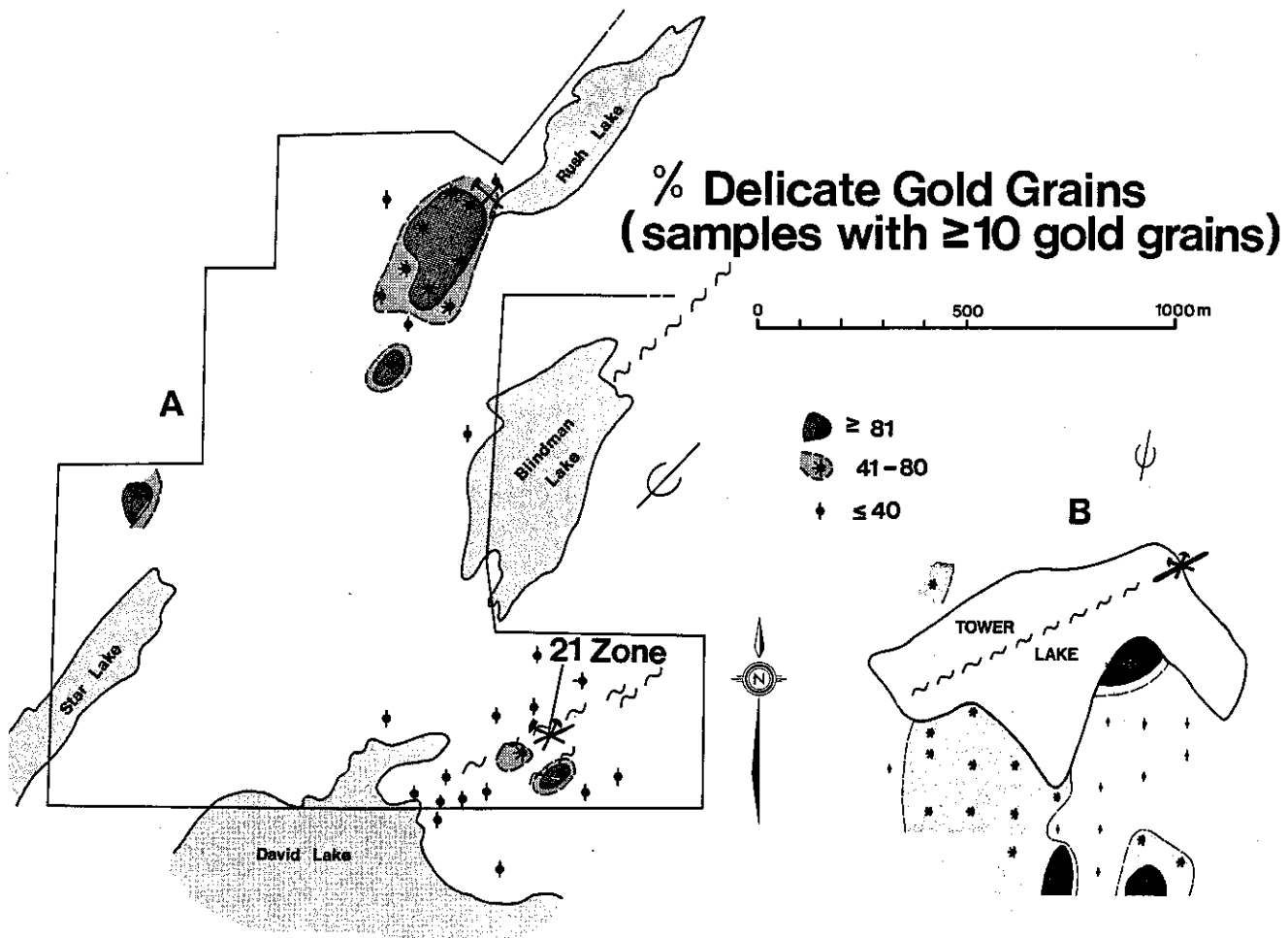


Fig. 15 Percent delicate gold grains.

Comparison of Calculated and Measured Gold Contents in the Heavy Mineral Concentrate.

Gold contents in the heavy mineral concentrate were calculated using the dimensions of the observed gold grains assuming a thickness factor. The thickness factor was determined using a published equation developed at ODM¹⁰ as follows:

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

where 'd' is the diameter of the gold grains in microns up to a maximum of 1000 microns.

A plot of calculated gold contents for panned samples versus the analyzed gold content of the 3/4 split of the heavy mineral concentrate is shown in Figure 16. Generally, the calculated gold content is within ±50% of the gold analyses. However, a significant number of samples fall above and below the 50% limits. Certain samples are characterized by higher

calculated assays. These samples commonly contain large gold grains (>300 microns) and the discrepancy could be explained by the "nugget effect" during the splitting of the heavy mineral concentrate before analyses (3/4 split sent for analyses).

In some cases, assays are high where no visible gold was seen on the shaking table. These are problem samples and the remaining one quarter split of heavy mineral concentrates should be examined closely for an explanation. Possibly the gold is very fine grained or the analysis could be in error. On the other hand, one coarse particle of gold, not seen on the shaking table could explain the analytical results. In four samples, gold grains not seen on the table or in panning were located along fractures and as inclusions in garnet porphyroblasts within sulphide facies iron formation. In this case, gold

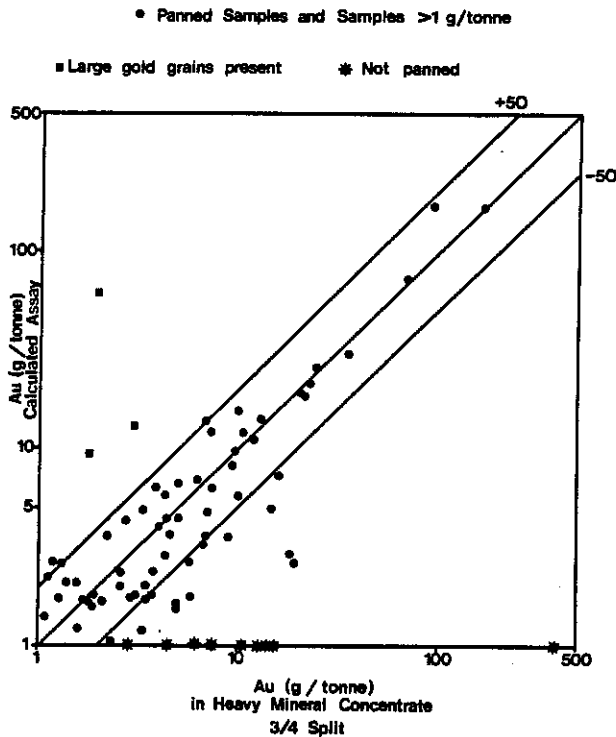


Fig. 16 Calculated gold contents. (Based on observed gold grain sizes versus measured gold contents determined by fire assay-atomic absorption analysis. The 3/4 split of the heavy mineral concentrate of 74 till samples was analyzed.)

contents in the heavy mineral concentrate were higher by a factor of 2 to 3 times over the calculated gold contents based on observed grains. These problem samples may be a good reason for using the non-destructive neutron activation technique for gold analysis on the total heavy mineral concentrate. Also, the inclusion of a gold bearing rock standard every five or so samples should control analytical problems. The inclusion of these standard samples at the suggested frequency is important in light of the cost of collecting the original sample and the fact field duplicates will probably be few.

Field and Analytical Variability

Six tills were sampled in duplicate from the same field pits and processed at different times. Plots of normalized gold contents for the heavy mineral concentrate and gold grain counts exhibit a precision to within $\pm 50\%$ (Figure 17). Gold in the clay fraction shows

a precision of $\pm 40\%$. The variance exhibited is a combination of field and analytical variability.

FRACTIONATION OF GOLD IN TILL

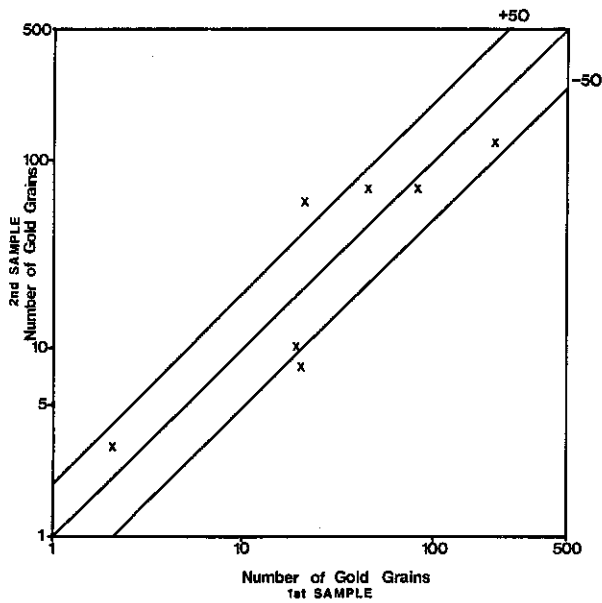
Introduction

Gold fractionation studies are important in assessing which fraction of the till is most representative of the sampling medium. In addition, these studies are valuable in assessing the effectiveness of the shaking table - methylene iodide heavy mineral concentration procedure. Results of fractionation studies on till samples were reported by Shelp and Nichol,¹⁶ who contended that significant gold is lost during the heavy mineral concentration procedure, particularly from the silt and clay fractions. Significant gold loss may also occur in the light fraction of the methylene iodide concentrate if fine gold is found in coarse quartz particles.

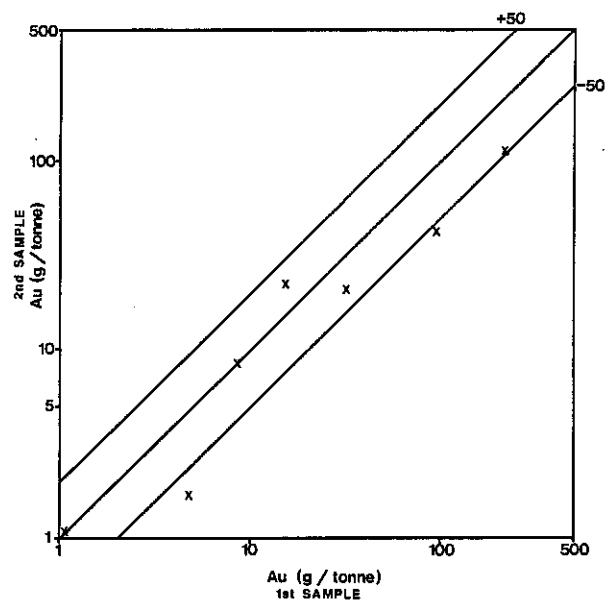
Four till samples were collected for gold fractionation studies. A sample was collected from the highly anomalous 'Riddle' till on the Waddy lake Mines property,¹⁰ herein referred to as the EP sample. Another sample was collected from the Tower Lake A train and is referred to as the TL sample. A third sample was collected from the Waddy lake area, referred to as NR, and a fourth from the Glennie Lake domain (Figure 1), referred to as PR. All samples are characterized by high gold grain counts in the range 63 - 123 grains and all are silty sand-rich tills (Figure 18). The proportions of coarse, medium and fine sand were determined by wet sieving and weighing each dried fraction while the proportions of silt and clay were determined using a Sedi-graph Particle Size Analyzer on all material less than 50 μm . Size analysis for the heavy mineral concentrate is also shown in Figure 18.

Samples were processed and analyzed following procedure D outlined in Figure 7. The FAAA procedure involves a fire assay - atomic absorption analysis for the total gold content. The GFAA procedure involves graphite furnace - atomic absorption analysis of aqua regia extractable gold.

FIELD DUPLICATES
Normalized Gold
Grain Counts (7 kg)



FIELD DUPLICATES
Au in Heavy Minerals
Fire Assay 3/4 Split
1000x Concentration



FIELD DUPLICATES
Gold in Clay Fraction

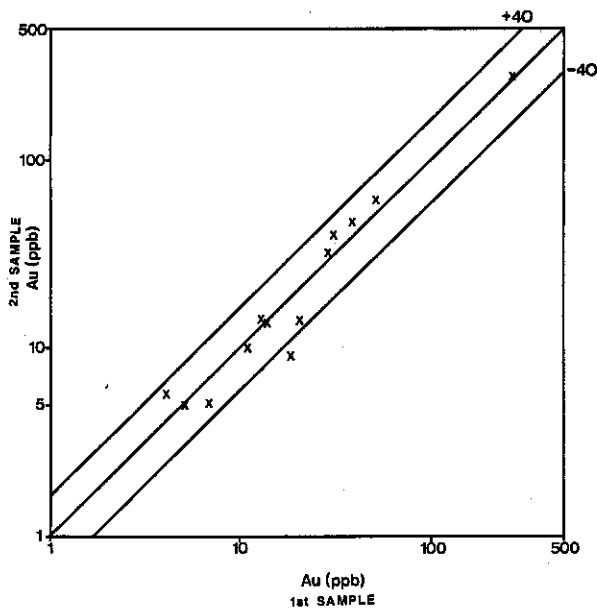


Fig. 17 Combination of field and analytical variability. (Based on duplicate till samples taken within one metre of the original sample site.)

Results of Fractionation Tests

Results of the gold analyses on each fraction are presented in Table 1 which lists the gold contributed by each fraction to the total gold content of the -2000 μ m (-9 mesh) till matrix. It should be noted that the highest proportion of gold according to the GFAA method occurs in the silt component of all tills. In the silt component, the gold contents obtained by the FAAA and GFAA procedures are similar.

However, in the coarse to fine sand fractions of the till the FAAA values are higher than the equivalent GFAA values. The proportion of gold contributed by the silt fraction therefore decreases in the FAAA procedure. Figure 19 shows that the proportion of gold contained in the overall sample moves away from the silt fraction toward the sand fraction using the FAAA procedure for three of the four till samples.

for the ground GFAA procedure and the unground FAAA procedure (Figure 20).

The gold content of the -2000 µm fraction of the till was calculated from the heavy mineral analyses after dividing the heavy mineral analyses by the concentration factor. These results were compared to gold contents determined by the fractionation results (Figures 20 and 21). Note that samples PR and EP show marked variation in the estimation of gold content based on the heavy mineral prediction.

Gold contents for the -2000 µm fraction obtained by GFAA on the unground sample are similar to the mean value determined by the heavy mineral concentrate; meanwhile, the gold contents determined by FAAA in the -2000 µm fraction are 9 to 63% higher than the values determined by the heavy minerals for all four

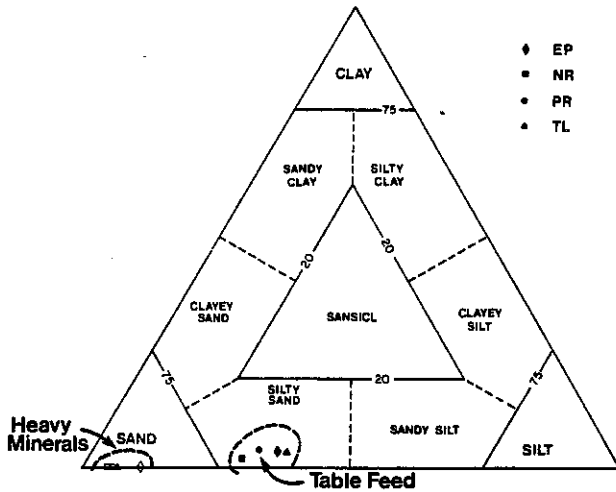


Fig. 18 Textural diagram for EP, TL, NR and PR till samples (minus 2.0 mm fraction and heavy mineral concentrate).

Sample	Till Fraction	Fraction in Till	Sand Fraction	F A A A PROCEDURE			G F A A PROCEDURE			GFAA PROCEDURE (ground fraction)		
				Au (ppb) in Fraction	Gold Contributed Au ppb (range)	% Au	Au (ppb) in Fraction	Gold Contributed Au ppb (range)	% Au	Au (ppb) in Fraction	Gold Contributed Au ppb (range)	% Au
EP	1	31.2	62.3	156	49 (37-62)	26.5	21	7 (3-14)	5.7	195	61	30.7
	2	20.8		160	33 (23-44)	17.8	80	17 (11-27)	13.8	220	46	23.1
	3	10.3		155	16 (14-18)	8.7	132	14 (7-25)	11.4	190	20	10.1
	4	33.9		225	76 (75-78)	41.1	219	74 (64-85)	60.2	180	61	30.7
	5	3.8		292	11 -	6.0	292	11 (9-12)	8.9	292	11	5.5
				Total			Total			Total		
				185 (149-202)			123 (94-163)			199		
NR	1	32.6	69.8	40	13 (5-20)	22.8	14	5 (4-6)	17.2	47	15 (10-20)	23.8
	2	25.0		46	12 (8-16)	21.1	10	3 (2-4)	10.3	46	12 (9-15)	19.1
	3	12.2		60	7 (4-10)	12.3	11	1 (1-2)	3.5	56	7 (7-7)	11.1
	4	28.1		85	24 (14-34)	42.1	69	19 (17-23)	65.5	97	28 (21-34)	44.4
	5	2.1		54	1 -	1.8	54	1 -	3.5	61	1 -	1.6
				Total			Total			Total		
				57 (32-81)			29 (25-35)			63 (48-77)		
PR	1	20.2	65.9	115	23 (20-26)	25.0	31	6 (3-9)	15.4			
	2	27.5		58	16 (14-18)	17.4	16	4 (1-7)	10.3			
	3	18.2		75	14 (12-15)	15.2	33	6 (2-11)	15.4			
	4	31.5		123	38 (30-47)	41.3	70	22 (21-33)	56.4			
	5	2.6		39	1 -	1.1	39	1 -	2.6			
				Total			Total					
				92 (76-106)			39 (27-60)					
TL	1	17.2	60.1	28	5 (3-7)	13.5	12	2 (1-2)	11.1			
	2	25.5		33	8 (8-9)	21.6	16	4 (2-8)	22.2			
	3	17.4		63	11 (7-15)	29.7	33	6 (3-8)	33.3			
	4	36.8		35	13 (7-18)	35.1	15	6 (4-9)	33.3			
	5	3.1		9	<1 -	<1	9	<1 -	<1			
				Total			Total					
				37 (25-49)			18 (10-27)					

Table 1 Gold contents contributed by till fractions. (All fractions were analyzed 3-4 times for each procedure except the EP till GFAA ground fractions which were analyzed only once (1 = coarse sand, 2 = medium sand, 3 = fine sand, 4 = silt, 5 = clay. Values are reported in parts per billion and percent contributed.)

GFAA analyses on the ground fractions of the EP till and NR samples are also shown for comparison. Note that the analyses are similar

samples. If the FAAA procedure is a measure of the total gold in a sample, then 9 to 63% of the gold is being lost during the heavy

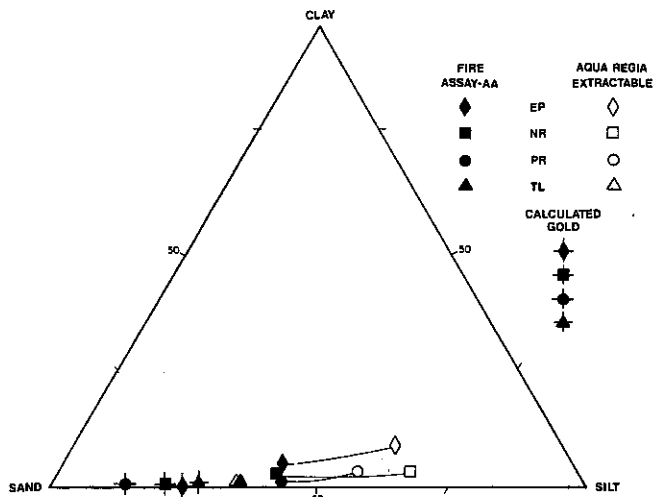


Fig. 19 Proportion of gold contained in sand, silt and clay fractions in four till samples, based on different preparation and analytical procedures. Calculated proportions based on observed grain sizes are also plotted.

mineral procedure. The difference between the FAAA procedure and the GFAA procedure on the unground fraction suggests that up to 58% of the gold may be occluded probably in silicates.

Gold in Clay Loss During Heavy Mineral Preparation

Particle size analysis completed on the four heavy mineral concentrates indicated a marked enrichment in the sand fraction of the concentrates relative to the table feed (Figure 18). No detectable clay fraction is present in the heavy mineral concentrate. All gold in clay is apparently lost in the heavy mineral preparation procedure. In these four samples, less than 6% of the total gold in the -2000 µm till matrix is contained in the clay fraction (Table 1); therefore the maximum gold loss attributable to clay loss during processing is 6 per cent. A till sample with greater clay contents could exhibit significant gold losses.

DISCUSSION OF TILL ORIENTATION AND FRACTIONATION RESULTS

Results from orientation surveys have been outlined. In the Star Lake area, the ice direction is subparallel to the strike of the auriferous structures. Several narrow dispersion trains are defined in till samples

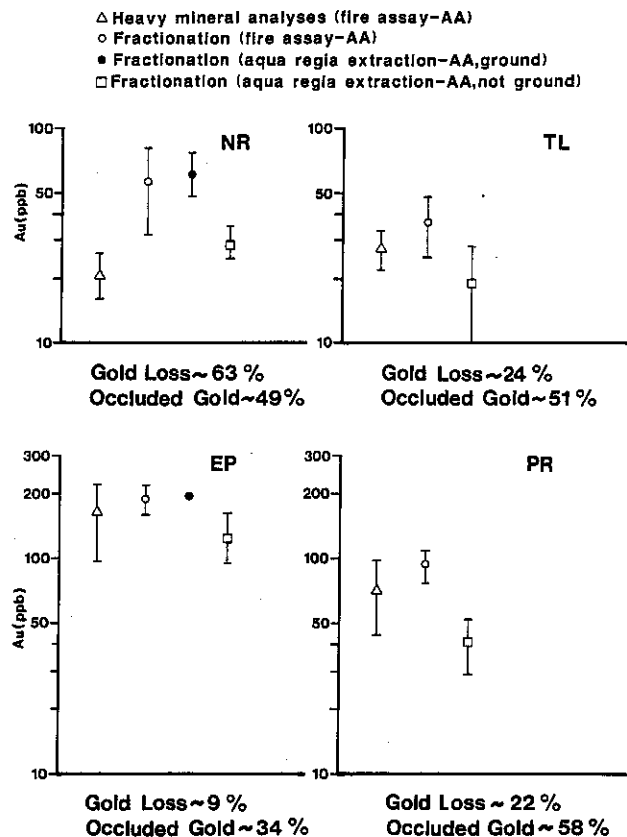


Fig. 20 Range of gold values in the minus 2000 µm fraction as determined by four procedures. (Bars indicate range of analyses obtained. Gold loss [on the shaker table] in percent is the difference between the total gold determined by fire assay - AA and the gold content determined by heavy mineral analyses. Occluded gold in percent is the difference between the total gold determined by fire assay - AA and the gold determined by graphite furnace - AA after aqua regia extraction on the unground sample.)

by 10 or more gold grains per sample or by values of 4 g/tonne gold or greater in the heavy mineral concentrate. The dispersion trains are 75-100 m wide, at least 300 m long and are delineated by 86 sample sites in an area of 2 km². They are not as readily apparent in analyses from the -180 µm (-80 mesh) or clay-size fractions of the till.

In the Tower Lake area, the ice direction intersects the east-west trending auriferous Tower Lake fault at a high angle. A broad zone of gold enrichment in till (>900 m across) is evident down-ice from the fault in the heavy

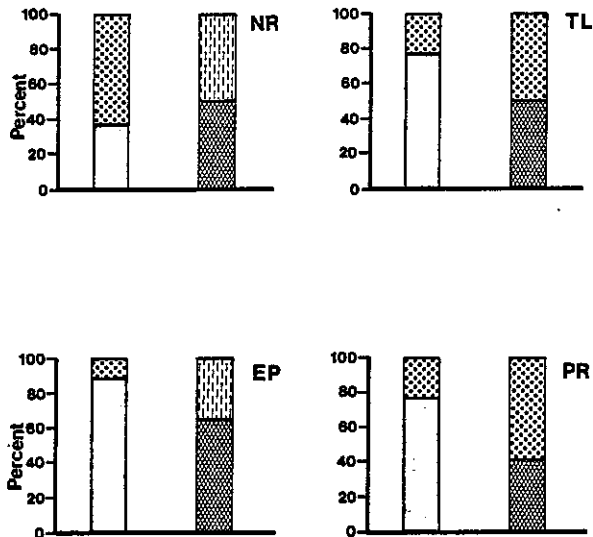
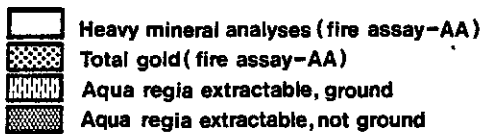


Fig. 27 Percent gold relative to total gold in the minus 2000 μm fraction. (Determined by different preparation and analytical procedures. The fire assay - AA or total gold procedure is assumed to represent 100%.)

mineral, $-180 \mu\text{m}$ and clay fractions. Within the broad enriched zone, a dispersion train related to the main known pod of mineralization under the lake is readily apparent in the heavy mineral fraction only. The dispersion train is outlined by 20 or more gold grains per sample and by values of 8 g/tonne gold or greater in the heavy mineral concentrate. The main dispersion train is up to 150 m wide and 600 m long. At Tower Lake, the dispersion train was outlined with only 40 samples collected over 1 km^2 .

The till sampling procedure, heavy mineral separation, and counts and descriptions of the gold grains is a direct approach to finding significant gold concentrations in till. This method also characterizes the gold with respect to distance from the source and style of mineralization. In contrast, analyses of the clay or the $-180 \mu\text{m}$ fractions of the till (procedures C and B, respectively), provides relatively indirect geochemical information.

Both the Star Lake area and the Waddy Lake area feature high background gold levels in till. This arises in part from the frequency of gold showings particularly along numerous linear structures. The problem becomes one of recognizing anomalies related to significant gold sources. For instance, is a gold-in-soil anomaly related to one large abraded gold grain or to several tens of smaller delicate grains of equivalent gold content? Under these circumstances the till method (procedure A) provides some of the answers. At Star Lake, one long narrow gold-in-till dispersion train may be related to two or more mineralized pods along one or more structures trending parallel to the ice direction. Gold along the linear structures is often of two types, fine grained invisible gold ($<50 \mu\text{m}$) such as that found in the 21 Zone mineralization and coarser visible gold ($>150 \mu\text{m}$) associated with numerous smaller quartz vein showings. The fine grained style of gold mineralization which appears to be more important in economic terms, is readily recognized in the heavy mineral concentrates.

The advantages of collecting large till samples (5-8 kg) in combination with the heavy mineral preconcentration procedure (procedure A) over analyses of small samples are obvious in terms of samples being more statistically representative as discussed by Clifton et al.¹¹ The results of the orientation surveys suggests that small samples of the clay and $-180 \mu\text{m}$ fractions are not as useful as the heavy mineral concentrate in depicting meaningful dispersion trains at significant distances ($>100 \text{ m}$) from mineralization. However, analysis of the finer fractions of the till offers promise in detailed follow-up surveys once the dispersion train or mineralization has been identified, particularly in mineralized tills characterized by abundant gold in the fine sand and silt-size ranges. The silt and clay component is a homogeneous sampling medium and is useful when fine gold constitutes a significant proportion of the mineralization as is the case at Tower Lake and Star Lake.

The use of associated pathfinder elements such as arsenic in surveys involving small till samples or biogeochemical methods are also valuable. In the case of Star and Tower Lake, however, gold itself appears to be the best pathfinder to gold mineralization.

Fraction studies of four anomalous till samples suggest that the silt component of the tills contains a high proportion of the free gold (33-66%) and total gold (35-42%). These tests also indicate that 9 to 63% of the gold in four anomalous till samples may be lost during the heavy mineral concentration procedure. Size analysis of the heavy mineral concentrates indicate all clay sized gold is lost. This accounts for less than 6% of the total gold loss because the samples are clay deficient. In most Saskatchewan tills, gold in clay loss is not likely to be a problem as clay contents in lower tills seldom exceed 10%.

A comparison of fractionation results by the FAAA method (total gold) and the GFAA method (aqua regia extractable) suggests that most of the gold loss can be accounted for by occluded gold probably in quartz and not separable by gravity means. Occluded gold in the four samples ranges from 34 to 58%. Thus the loss of free (liberated) gold grains on the shaking table appears to be negligible, even in the silt fraction. There may be instances whereby a substantial proportion of gold is lost on the shaker table particularly in the clay size fraction of clay-rich tills. Depending on the target characteristics, an analysis of the fine fraction of the till is recommended as an inexpensive step in addition to the collection of a large till sample for subsequent heavy mineral concentration and analysis and gold grain counts.

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