Can Glacial Till be Mined for Gold in Nova Scotia?

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Introduction

The question posed in the title of this report was sparked by the discovery in 2003 of a previously unknown adit sunk into glacial till in Tangier, Halifax County (NTS 11D/15). The adit was found during excavation of a gravel pit 300 m southeast of the main mining district (Figs. 1, 2). The tunnel is ~60 m long and was dug into a stony till deposit (Beaver River Till) at the contact with an underlying reddish, silty till (Lawrencetown Till). Panning of the upper till in the adit revealed abundant fine gold and some millimetre size nuggets. Further exploratory panning revealed gold in the Beaver River Till across the entire face (~125 m) of the gravel pit.

The adit could have been an exploratory tunnel for a lode-gold source or a form of placer mine. The elevated gold in till adjacent to the adit and the lack of evidence for bedrock veins along strike of the adit, suggest the placer mine possibility. A wood fragment (plank) and 'artifact' were found in the tunnel by property owner Graham Cooper (Fig. 2). The 'artifact' is a 2" by 6" piece of board with holes cut in either end, perhaps an end board of a cart (P. Finck, personal communication, 2004). The plank fragment was radiocarbon dated and found to be modern, based on virtually 100% of the radiocarbon activity of the oxalic acid standard (GSC- 6844; R. McNeely, personal communication, 2005). This 'modern' age designation can accommodate ages as old as the 1920s or 30s, based on the error margins of the radiocarbon date, but unlikely much before that time. The adit may predate the wood, if the wood was introduced by a later exploration, but Graham Cooper (personal communication, 2004) has no recollection of any tunnel on his property. Unfortunately there appears to be no oral or written record of placer mining activity or exploratory adits in Tangier at that time. The Nova Scotia Annual Report of Mines (1867), however, documents placer gold workings in the vicinity of Tangier, including the discovery of a 27 oz. nugget. The location of these placer workings are uncertain and may have been in the vicinity of Copper Lake (Fig. 1).

Mining of tills in Nova Scotia is not a new idea. A newspaper report in the 1880s (NSDNR, 1887) describes the mining of glacial till at the Moose River Gold Mine (parentheses are our comments):

> "On six or seven areas the surface soil (**till**) down to the bedrock, an average of over seven feet, is gold-bearing, and will all pay to crush when Mr. Touquoy completes a ten stamp mill, which he is now preparing to put up. One hundred and forty-seven tons, quarried from different places on the surface, yielded 12 oz., 12 dwts., 10 grs., different lots yielding from $1.00 to $3.50 a ton (**1880 prices!**). Mr Touquoy estimates that it could be mined and milled for 50 cents a ton."

Bouldery deposits of glacial till cover most of the 64 lode-gold districts in the Meguma Terrane. During the last glaciation, local ice caps left a trail of eroded and transported gold-rich debris. Prospecting in the till led to the first documented bedrock gold discovery in the mid 1800s. Since that time till deposits have been used as an effective prospecting tool for lode deposits, but are generally considered to be a hindrance in mine development. It is the purpose of this paper to evaluate the economic potential of a placer gold deposit at Tangier and, by analogy, elsewhere on the Meguma Terrane. The study will have the added benefit of enhancing the understanding of glacier dispersal processes of gold in till and, therefore, will aid in the search for buried lode-gold sources.

Geology of the Tangier Gold District

It is reported that the discovery of lode gold at Tangier was the first in Nova Scotia, dating back to 1860 (Malcolm, 1929). The main development at the district took place from the Kent Shaft, which is

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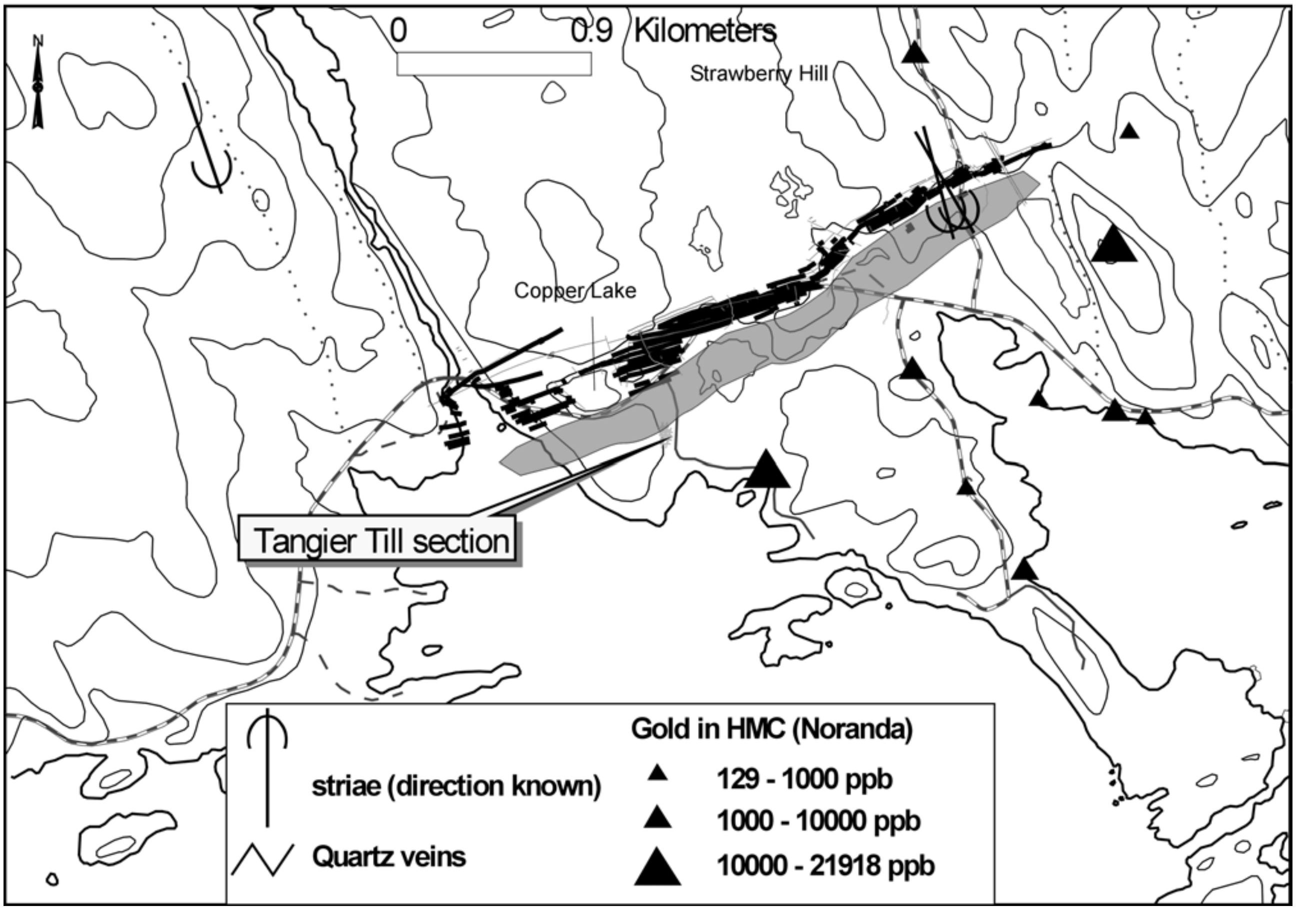

Figure 1. Map of the Tangier Gold District, showing gold veins and location of the till section analyzed in this study. The shaded region represents the potentially mineable "window" of till deposits down-ice of the Tangier Gold District. Data on gold in heavy mineral concentrates (HMC) are from a previous survey (Dimmel, 1983).

located immediately east of the present Blueberry Hill mine in the village of Tangier along the north side of Highway #7 (Fig. 1). Approximately 70 gold-bearing veins have been identified in the vicinity of the Blueberry Hill mine, producing 26,000 oz. of gold. In addition to other smaller veins that occur within the mine sequence adjacent to these veins, numerous others occur along strike toward the east in the Strawberry Hill and East Zone areas (Fig. 1).

The deposit is hosted by slate and metagreywacke of the Cambro-Ordovician Meguma Group, which is characterized by tight, upright regional folding with penetrative slaty and pressure solution cleavages. Regional biotite facies metamorphism is common throughout the district. Auriferous veins have been affected by both regional deformation and metamorphism. In addition, locally developed shear deformation is superimposed on both veins and host rocks, in part, leading to mylonitic textures in some mineralized veins (e.g. Marker Vein; Smith, 2002).

Carbonatization, sulphidization and sericitization are the main alteration types recognized at the deposit. Carbonate alteration is dominated by calcite and ankerite with lesser dolomite and traces of siderite also present. Although the limits of alteration have not been defined, the mineralized zone extends along strike for more than 3 km.

Gold is primarily restricted to quartz veins, although low-grade gold levels (~1 ppm) are known from some wall rocks (both slate and metawacke). Associated sulphide minerals are arsenopyrite, pyrrhotite, galena, chalcopyite and pyrite with minor sphalerite. Carbonates, biotite, chlorite and minor muscovite are the dominant gangue minerals in the quartz veins.

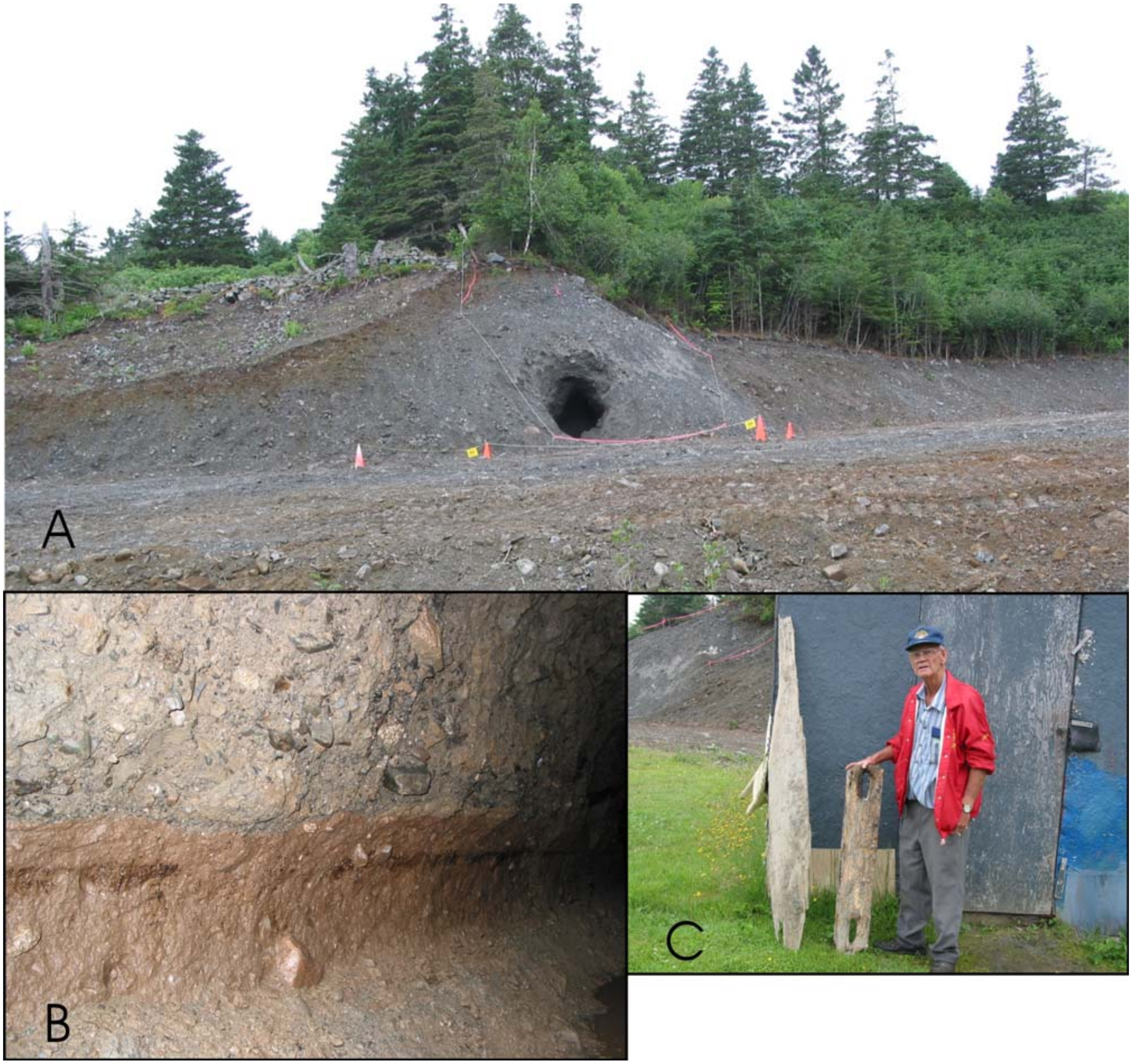

Figure 2. (A) view of the Tangier till section and the adit. (B) Close-up of the lower Lawrencetown Till (with pink granite boulder) and the upper cobbly Beaver River Till on the adit walls. (C) Wood artifacts recovered from inside the adit by Graham Cooper of Tangier (in photo).

Methods

In order to assess the economic viability of gold in till, the Quaternary section near the Tangier adit was sampled in five discreet vertical sections, using an excavator. All the sections are overlain by a well-developed soil horizon, ensuring that the section was *in situ*. Twenty-eight ~10 kg till samples were obtained from the five sections (Fig. 3). These samples were evaluated for free gold content by Overburden Drilling Management Limited (ODM). The samples were screened to separate the +2.00 mm size fraction, then tabled to obtain a crude heavy mineral concentrate (HMC). The table feed was then further enriched using a heavy liquid separation (s.g. 3.3 g/cm^3). Gold grains were counted from the heavy mineral separates, classified into size and shape categories, and an estimated gold grade was reported based on the size and number of gold grains in the sample.

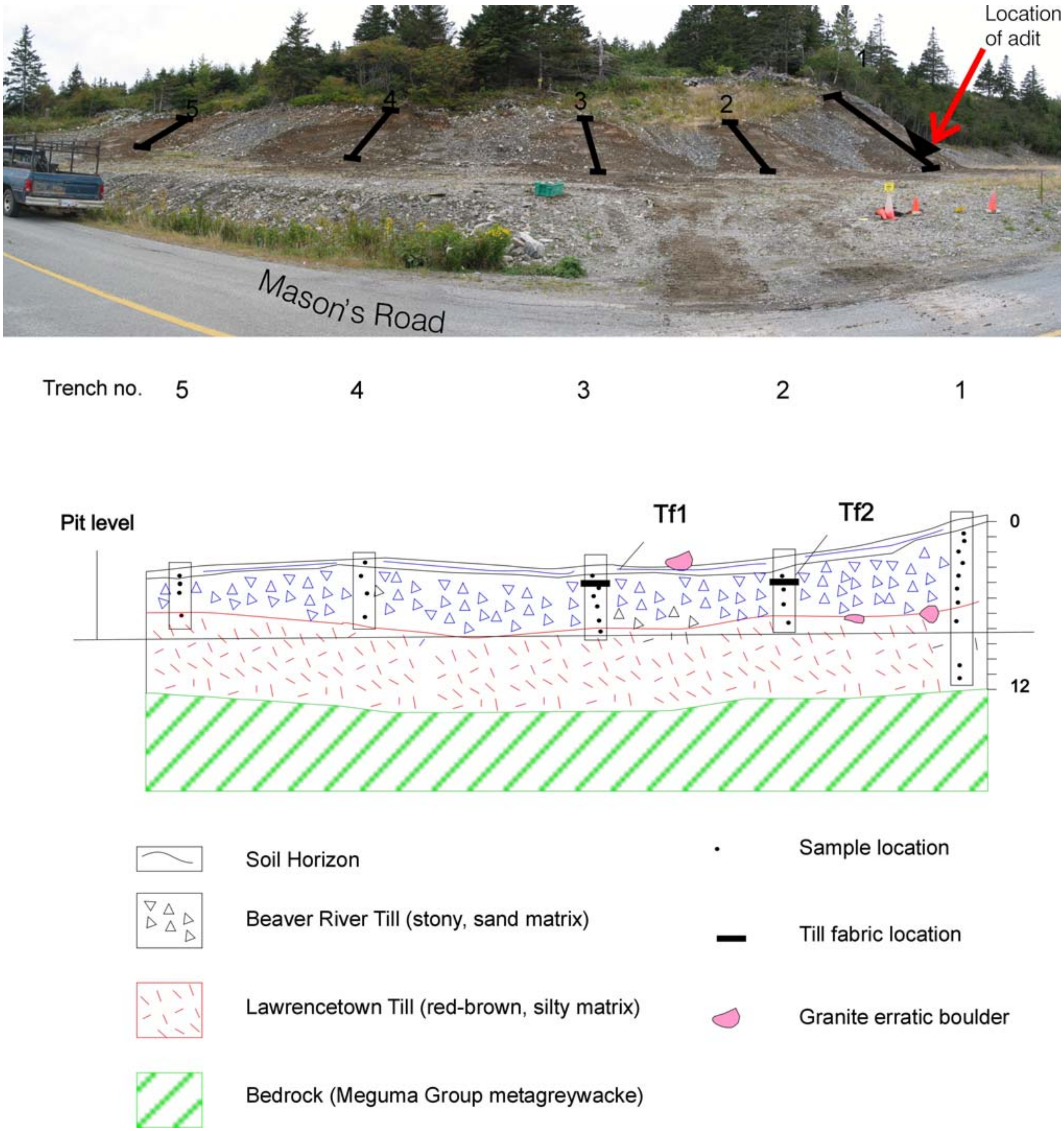

Figure 3. Schematic section and photograph of the Tangier till section. Twenty-eight samples (10 kg each) were obtained, both laterally and vertically in the till section.

The gold grades calculated for the HMCs were then 'normalized' to a bulk grade by multiplying the HMC grade by the weight dilution ratio of the HMCs, divided by the wet bulk table feed. The clast fraction (<2 mm) was subdivided by rock type and counted.

Two of the five trenches (T1 and T2) were channel sampled from near top to bottom and then processed through a sluice (see Mills *et al.*, this volume). For an evaluation of bulk till gold content, splits of all till samples in the Beaver River Till from Trench 1 (Fig. 3) were combined and processed for a heavy mineral separate at ODM, then analyzed by fire assay at Activation Laboratories in Ancaster, Ontario. This HMC gold assay was also normalized to a bulk grade by the weight ratio method described above. A second bulk channel sample from Trench 2 was obtained using an excavator and processed by Kuryluk Developments Inc, using a Kuryluk hydraulic separator (described in Stea *et al.*, 1993) to get a more quantitative estimate of placer grades and assess the efficiency of the sluice (Mills *et al.*, this volume, p. 61-67). The Trench 2 bulk sample was dried, weighed and separated into three main size fractions for further analyses (>10 mesh; 2 mm; <20 mesh>100 mesh; 0.15 mm ; <100 mesh). The >10 mesh (gravel) size fraction was crushed to <230 mesh (0.063 mm) and a portion retained for gold geochemical analysis. The <20 - >100 mesh (sand) fraction was processed through a Kuryluk separator for heavy mineral separates, later analyzed for gold. The <100 mesh size fraction was further sieved to <230 mesh (silt+clay) for eventual gold geochemical analysis. Gold analyses of the Trench 2 samples were conducted using fire assay atomic absorption (analyses by the Mineral Engineering Centre, Dalhousie University).

The till section was mapped in detail and two standard till fabric analyses (e.g. Evenson, 1971) were completed to evaluate the flow directions of the ice sheet that formed the gold-bearing surface till. In the Tangier area several new striation sites were mapped (Fig. 1), also indicating flow directions of the last ice sheets to have eroded the vein arrays of the Tangier Gold District (Fig. 1).

Tangier Till Section

The section is located ~0.3 km south of Highway 7 on Mason's Road (Fig. 3). The pit face is part of a south-sloping hill that was excavated for road fill. The section is approximately 100 m wide and 5-10 m in height, with a mature soil profile developed at the top of the exposure.

Stratigraphy

The section revealed two Quaternary till units resting on Cambro-Ordovician metasandstone of the Meguma Group. The lower Quaternary unit is a 3-4 m thick, greyish-brown to reddish-brown, sandy to silty diamicton termed the Lawrencetown Till, overlain by a blue-grey, stony, sandy till termed the Beaver River Till (Williams *et al.*, 1984). Bedrock was encountered at a depth of 4 m below Trench 1 (Figs. 3, 4). The main gold-bearing unit is the Beaver River Till, which varies from 3 to 5 m thick across the section. It contains a predominance of locally derived, Meguma Group metasedimentary clasts (metagreywacke, metasiltstone, slate), including quartz vein material, and lesser amounts (< 5%) of granite boulders and pebbles derived from the Musquodoboit Batholith ~4 km to the north. The concentrations of granite erratics increase markedly (~ 40-50%) in the boulder mantle at the top of the section, but erratics are rare in the till just beneath.

Till fabric measurements on pebble long-axes from Trench 2 and Trench 3 in the Beaver River Till produced weak, girdling fabrics with an east-west trend and no discernable plunge direction (Fig. 4). These fabrics are nearly perpendicular to the flow directions, as implied by granite clast dispersal (south to southeast) and local bedrock striations (south to southeast - Fig. 1). The discrepancy between fabric and other ice flow indicators may be attributed to compressive ice flow, as discussed later.

Regional Ice Flow Directions

Rock outcrops in the vicinity of the gold district (Fig. 1) showed two sets of glacier striations. An early set of striae trending 151° is preserved in bevelled facets on the metagreywacke surface. A later, predominant set of striations on the upper surface trends 162-167°. The earlier set likely relates to the earliest southeastward Wisconsinan ice flow in the area, termed the Caledonia Phase, whereas the later set relates to formation of the ice divide over Nova Scotia and southeastward ice flow during the Scotian Phase (Stea, 2004).

Gold Distribution in the Tangier Till Section

The sampling results of the Tangier till section are shown graphically in Figure 5 and in tabular form in Tables 1-4. The highest concentrations are in the upper Beaver River Till which varies from 89 to

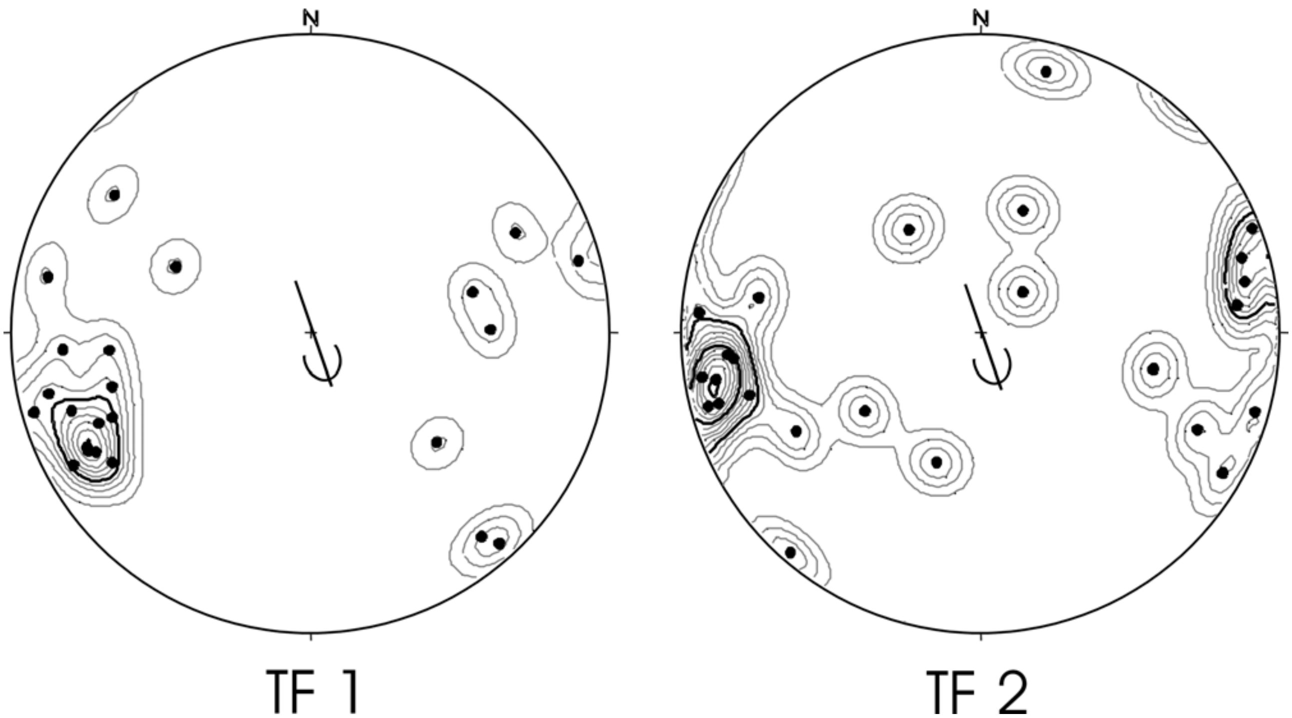

Figure 4. Lower hemispheric Schmidt net projections of the trend and plunge of the long axes of 25 clasts at two sites from the Tangier till section (Fig. 3). The symbols indicate the direction of ice flow (SE) as determined by glacial striations and clast provenance.

657 individual gold grains per sample, translating to a calculated grade of 13 to 455 ppm for the heavy mineral separates, respectively (Table 1). Grades normalized to the weight of wet table feed ranged throughout the section from 6 to 689 ppb (<0.005-0.02 oz./ton) with an average of 75 ppb. Sample 8 in Trench 1 had the highest gold count (657) and also contained the largest nugget, with dimensions of (length) 0.7l mm x (width) 0.6 mm x (thickness) 0.4 mm (Table 3). Gold assays calculated from gold grain counts must be considered as minimum levels only because of the counting method used to establish gold content. Gold tied up in sulphides and in rock fragments was not evaluated by the ODM method.

The gold levels in all trenches (Fig. 5) increase up section in the Beaver River Till to a peak within 1-3 m of the surface. It is important to note that soil samples revealed little visible gold (0-1 grains) in spite of elevated levels in the tills just beneath. A down-ice trend of decreasing overall gold levels was observed from Trench 1 (proximal to gold district) to Trench 5 (distal). The Beaver River Till contains almost exclusively Meguma metasedimentary clasts, varying from 95-99%. Granite and quartz clasts remain below 1% in the sections, except at the contact with the Lawrencetown Till (5% granite) and at the top of the section where the ablation boulder mantle consists of between 40% and 50% granites.

Contrasting with the auriferous Beaver River Till, the underlying red Lawrencetown Till displayed significantly lower gold counts, ranging from 4-30 grains per sample with a mean of 14 (Fig. 5; Table 1) and with normalized grades of 0.02-1 ppb. These lower gold levels correspond to much lower percentages of Meguma metasedimentary rocks (35-60%) compared to the Beaver River Till (Table 1).

Bulk Sampling Results

Seven samples (111-04-4 to 111-04-10 TR1) in Trench 1, weighing 79 kg, were individually processed for heavy mineral concentrates then combined and assayed. The bulk assay result of 98 700 ppb was normalized to 202 ppb (0.007 oz./ ton) using the total wet weight of table feed (28.7 kg). This concentration is significantly higher than the bulk average derived from gold counts (163 ppb-Fig. 5).

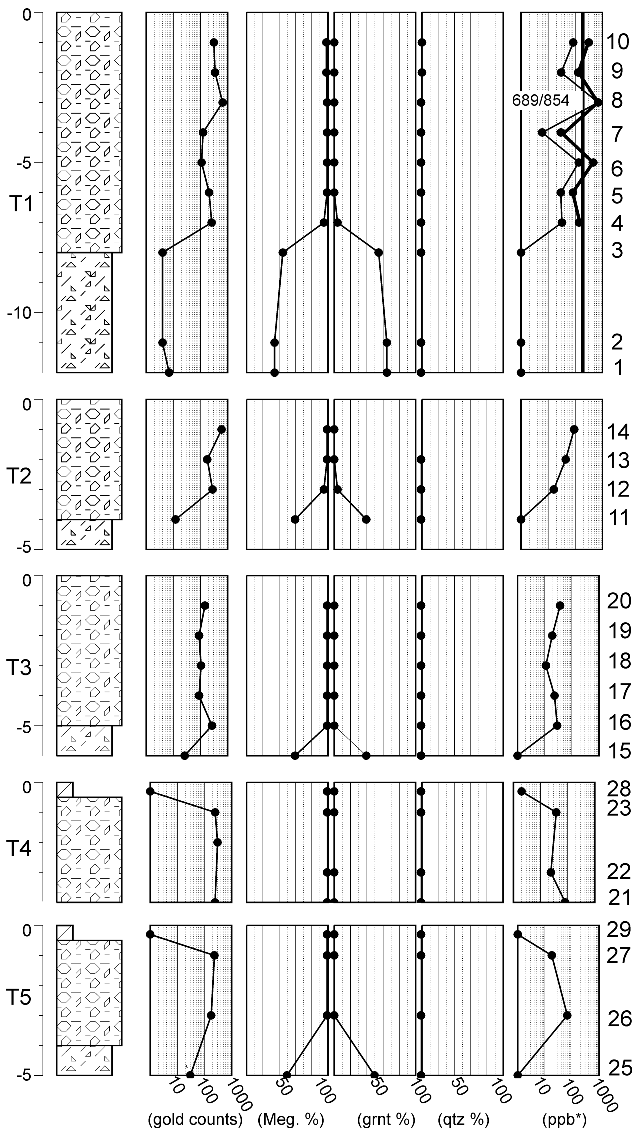

Figure 5. Stratigraphy, pebble lithology and gold distribution in trenches 1-5. Gold grain counts and parts per billion (ppb) are presented using a logarithmic scale. Gold abundance (ppb) was calculated using the estimated grades from grain counts and the total weight (wet) of table feed (Table 2). The heavy line curve to the right of the gold abundance curve in Trench 1 represents "corrected" grades based on the ratio of the average gold abundance in Trench 1 determined by fire assay and calculated by grain counts (202 ppb/ 163 ppb=1.24). The solid line represents the average corrected gold grade in Trench 1 (202 ppb). Sample numbers (Table 1) on the right.

A 109 kg bulk sample from Trench 2 was processed and analyzed as described in the Methods section. Gold analyses were obtained from heavy mineral separates, from a crushed portion of the coarse gravel fraction, and from a sieved portion of the fine fraction (Table 4). Approximately 50% of the sample was gravel-sized (granule, pebble and cobble; +10 mesh), ~ 40% sand-sized material (-20+100 mesh), and the remaining 10% in the fine fraction (silt +clay). Interestingly, high levels (185-350 ppb/0.005-0.01 oz./ton) were obtained from the coarse fraction (+10 mesh) which was crushed to -230 mesh. The gold level obtained by fire assay of hydrostatic gold separates of the sand fraction was 170 ppb (0.005 oz./ton; Table 4). The grades calculated from gold grain counts of individual samples in Trench 2 averaged 58 ppb, significantly lower than the assay grades of a bulk sample of the same trench (351 ppb).

The sieved, fine fraction of the bulk sample recorded the lowest gold levels (8-125 ppb). The variability between sample duplicates (Table 4) can be ascribed to the nugget effect (cf. MacEachern and Stea, 1985).

Discussion

Genesis of the Beaver River Till

The Beaver River Till (Grant, 1980; Finck and Stea, 1995) makes up a landscape unit termed the stony till plain (Stea *et al.*, 1992), characterized by irregular, hummocky topography or ribbed moraine and large slate, quartzite or granite boulders (from <1 m up to 20 m in diameter) strewn on the surface. This till facies was originally interpreted as an ablation till, based on its looseness and coarse texture (Nielsen, 1976).

Beaver River Till is dominated by a single local bedrock-derived, clast lithology, with percentages generally > 90%. Deviations from this idealized clast lithology reflect reworking from underlying drumlin tills or the proximity of variable up-ice bedrock units. Clast lithology of the Beaver River Till can be used as an accurate tool to map bedrock geology (MacDonald and Horne, 1987).

The renewal distance, as defined by Peltoniemi (1985), is the distance down-ice over bedrock contacts in which the proportion of a new rock type increases in the till from 0% to 50%. Renewal distances calculated for the Beaver River Till average between 0.2 and 1 km (Stea and Finck, 2001). These extremely low renewal distances (e.g.

Table 1. Gold grain counts and shapes, and calculated assay concentrations of the heavy mineral concentrates.

Sample Number	Till Type	Number of visible gold grains				Weight (g) HMC	Calculated gold (ppb)
		Total	Reshaped	Modified	Pristine		
111-04-1TGR-TR-1	LT	7	2	4	1	14.4	193
111-04-2TGR-TR-1	LT	4	4	0	0	19.2	29
111-04-3TGR-TR-1	LT	4	1	3	0	14.0	224
111-04-4TGR-TR-1	BRT	259	20	77	162	17.2	7513
111-04-5TGR-TR-1	BRT	207	2	25	180	7.2	15992
111-04-6TGR-TR-1	BRT	110	1	1	108	2.6	15371
111-04-7TGR-TR-1	BRT	125	1	2	122	3.8	5235
111-04-8TGR-TR-1	BRT	657	0	2	655	5.6	455344
111-04-9TGR-TR-1	BRT	345	0	6	339	13.8	12567
111-04-10TGR-TR-1	BRT	314	1	2	311	8.4	49722
111-04-11TGR-TR-2	LT	12	2	0	10	19.4	300
111-04-12TGR-TR-2	BRT	279	7	68	204	16.7	4922
111-04-13TGR-TR-2	BRT	178	4	43	131	11.0	20806
111-04-14TGR-TR-2	BRT	599	12	125	462	10.6	47867
111-04-15TGR-TR-3	LT	26	11	6	9	18.5	183
111-04-16TGR-TR-3	BRT	266	12	55	199	20.1	8779
111-04-17TGR-TR-3	BRT	89	14	30	45	5.2	13600
111-04-18TGR-TR-3	BRT	105	19	31	55	6.5	7195
111-04-19TGR-TR-3	BRT	89	2	12	75	7.6	10837
111-04-20TGR-TR-3	BRT	146	5	31	110	8.7	17100
111-04-21TGR-TR-4	BRT	245	10	60	175	12.1	33155
111-04-22TGR-TR-4	BRT	303	1	23	279	12.2	10266
111-04-23TGR-TR-4	BRT	249	2	42	205	12.1	15567
111-04-25TGR-TR-5	LT	30	1	4	25	6.7	456
111-04-26TGR-TR-5	BRT	177	6	25	146	11.2	28116
111-04-27TGR-TR-5	BRT	233	0	28	205	8.9	8864
28SoilTR-4		1	0	1	0	0.1	3731
29SoilTR-5		0	0	0	0	0.2	0

Scandinavian tills average 5-20 km; Peltoniemi, 1985) are indicative of low-velocity basal ice conditions in proximity to an ice divide (Stea *et al.*, 1989). The angular nature, lack of striae on the clasts, and the predominance of clast modes, suggest that quarrying and fracturing are dominant mechanisms in the formation of the Beaver River Till, rather than abrasion. Low sliding velocities are implied by the negligible dispersal, reinforcing the idea that these tills were deposited near or under the Scotian Ice Divide across the axis of Nova Scotia (Stea, 2004). These can be considered ‘immature’ tills (cf. Dreimanis and Vagners, 1971), implying that they were formed in a relatively short period of time and not given the chance to develop a fine-grained matrix component through comminution and abrasion. These stony local tills are common near former ice centres in central New Brunswick (Broster *et al.*, 1997) and throughout the shield areas of Canada (Dredge, 1983).

This lithologic discrepancy of the granite-dominated ablation boulder mantle and the locally derived underlying till can be attributed to the process of long-distance, englacial transport of these large boulders. In fact, the layer of surface boulders likely represents a matrix-less ablation till as described by Shilts (1981). The lack of matrix in the surface ‘ablation till’ also reflects the short-lived activity of the local ice divide. Prospectors must also consider the fact that the boulder cover of the stony till plain is usually farther travelled than the underlying Beaver River Till. An auriferous

Table 2. Sample weights, weights of heavy mineral concentrates, and clast percentages.

Sample Number	Weight (kg wet)				<2.0 mm Table Concentrate Weight (g dry)					Clast percentages (>2mm)		
	Total (wet)	Table Split	<2mm clasts	Table Feed	Total	Heavy Liquid Separation (S.G. 3.3)				Meguma meta-ss	Granite	Quartz
						Lights	Heavy minerals (HMC)					
							Total	Non Mag	Mag			
111-04-1TGR-TR-1	16.3	15.5	3.7	11.8	501.7	485.8	15.9	14.4	1.50	35	65	Tr
111-04-2TGR-TR-1	17.3	16.5	3.4	13.1	494.9	474.1	20.8	19.2	1.60	35	65	Tr
111-04-3TGR-TR-1	9.1	8.3	1.9	6.4	314.2	298.9	15.3	14.0	1.30	45	55	Tr
111-04-4TGR-TR-1	10.7	9.9	5.8	4.1	444.5	426.4	18.1	17.2	0.90	95	5	Tr
111-04-5TGR-TR-1	9.6	8.8	4.8	4.0	276.5	268.9	7.6	7.2	0.40	100	Tr	Tr
111-04-6TGR-TR-1	11.1	10.3	7.3	3.0	241.2	238.4	2.8	2.6	0.20	100	Tr	Tr
111-04-7TGR-TR-1	9.9	9.1	5.9	3.2	369.5	365.4	4.1	3.8	0.30	100	Tr	Tr
111-04-8TGR-TR-1	12.1	11.3	7.6	3.7	353.4	347.3	6.1	5.6	0.50	100	Tr	Tr
111-04-9TGR-TR-1	10.8	10.0	4.3	5.7	249.9	235.4	14.5	13.8	0.70	100	Tr	Tr
111-04-10TGR-TR-1	11.8	11.0	6.0	5.0	285.2	276.5	8.7	8.4	0.30	100	Tr	Tr
111-04-11TGR-TR-2	11.5	10.7	1.5	9.2	372.7	351.7	21.0	19.4	1.60	60	40	Tr
111-04-12TGR-TR-2	12.5	11.7	6.4	5.3	310.3	292.6	17.7	16.7	1.00	95	5	Tr
111-04-13TGR-TR-2	13.0	12.2	7.0	5.2	322.6	310.6	12.0	11.0	1.00	100	Tr	Tr
111-04-14TGR-TR-2	14.7	13.9	8.3	5.6	311.7	300.5	11.2	10.6	0.60	100	Tr	Tr
111-04-15TGR-TR-3	10.3	9.5	2.6	6.9	368.8	348.8	20.0	18.5	1.50	60	40	Tr
111-04-16TGR-TR-3	12.5	11.7	5.5	6.2	465.8	444.4	21.4	20.1	1.30	100	Tr	Tr
111-04-17TGR-TR-3	8.4	7.6	4.5	3.1	208.6	203.1	5.5	5.2	0.30	100	Tr	Tr
111-04-18TGR-TR-3	11.6	10.8	6.6	4.2	330.4	323.5	6.9	6.5	0.40	100	Tr	Tr
111-04-19TGR-TR-3	10.9	10.1	5.7	4.4	311.5	303.4	8.1	7.6	0.50	100	Tr	Tr
111-04-20TGR-TR-3	11.5	10.7	6.7	4.0	327.1	317.6	9.5	8.7	0.80	100	Tr	Tr
111-04-21TGR-TR-4	11.2	10.4	5.4	5.0	296.3	283.1	13.2	12.1	1.10	100	Tr	Tr
111-04-22TGR-TR-4	13.0	12.2	7.0	5.2	344.2	331.2	13.0	12.2	0.80	100	Tr	Tr
111-04-23TGR-TR-4	8.8	8.0	3.1	4.9	288.3	275.3	13.0	12.1	0.90	100	Tr	Tr
111-04-25TGR-TR-5	4.4	3.6	0.8	2.8	142.9	135.7	7.2	6.7	0.50	50	50	Tr
111-04-26TGR-TR-5	10.7	9.9	5.2	4.7	420.2	408.2	12.0	11.2	0.80	100	Tr	Tr
111-04-27TGR-TR-5	11.4	10.6	6.2	4.4	319.1	309.6	9.5	8.9	0.60	100	Tr	Tr
28SoilTR-4	1.0	0.7	0.5	0.2	55.1	55.0	0.1	0.1	0.02	100	0	Tr
29SoilTR-5	0.8	0.5	0.3	0.2	109.7	109.5	0.2	0.2	0.02	100	0	Tr

Table 3. Size distribution of gold in till sample 8 with the highest gold counts and assay level.

111-04-8TGR-TR-1 visible gold grains			
Dimensions (microns)			
Thickness	Width	Length	Total grains
2	10	10	53
4	15	25	142
5	25	25	181
8	25	50	133
10	50	50	68
13	50	75	31
15	50	100	10
18	50	125	3
15	75	75	9
18	75	100	5
20	75	125	6
22	75	150	3
22	100	125	1
25	100	150	4
100	100	250	1
27	125	150	1
150	250	250	1
59	300	375	1
100	300	600	1
200	375	375	1
300	500	600	1
400	600	700	1
			657

quartz vein in a surface boulder, for example, may be derived from a source up to 4 km away, whereas the underlying basal till may have a much more proximal source, as demonstrated in this study.

The transverse fabrics obtained in the till at Tangier (Fig. 5) are not uncommon in basal melt-out tills, especially in areas of compressive ice flow (Boulton, 1970). The compressive flow may have been induced as the ice was forced to override a drumlin obstacle composed of Lawrencetown Till just south of Tangier. Mallinson (1988) described the results of till fabric analysis from two trenches from the Dufferin Gold District in which he obtained easterly and southeasterly modes (63°-125°) in the Beaver River Till, also nearly perpendicular to regional ice flow directions.

The lack of comminution of the Beaver River Till is aptly demonstrated not only by the angular, unstriated clasts but by the pristine or relatively unabraded gold grains (Fig. 6; Table 3) that make up the vast majority of gold grains in the till samples. A transport distance of <500 m is indicated by the shape distribution of these gold grains (DiLabio, 1990).

The Concept of Potentially Mineable Till Down-ice of Gold Districts

The increased concentration of gold grains and auriferous debris at the top of the Tangier trench sections is consistent with the up-section migration of mineralized debris from a lode source in a classic dispersal plume (Fig. 6; e.g. Miller, 1984). The decrease in concentration of gold in till away from the vein sources in both section and plan-view follows an exponential law (Klassen, 2001). Goodwin (this volume, p. 15-26) has obtained gold grain counts in surface till from a transect across the Beaver Dam Gold District that verify this property of gold dispersal. He observed a rapid increase in levels across the gold district to a maximum (161 grains), immediately down-ice of the last known vein. The gold counts then exhibit a sharp exponential decrease down-ice from the highest concentration levelling out at 25 grains 1.4 km from source. Similar patterns of exponential decrease were observed in different size fractions analyzed by fire assay at Beaver Dam and other Nova Scotia gold districts (DiLabio, 1982; Coker *et al.*, 1988).

The evaluation of a potential economic window of gold-bearing till down-ice of the Tangier Gold District must be based on the pattern of exponential decrease in gold levels from the source. Since there is no dispersal curve for the Tangier Gold District, the dispersal curve for the Beaver Dam district will be used as a proxy. Figure 7 shows the increase and decrease of gold grains down-ice of Beaver Dam, with gold grain counts normalized to 100%. This normalization procedure produces an idealized dispersal curve which to some extent compensates for variations in vein thickness and gold content inherent in the gold districts. The Tangier till section is located ~300 m down-ice of the last gold-bearing veins at Tangier, which corresponds to the rapidly decreasing slope of the exponential dispersal curve (Fig. 7). Gold levels should therefore increase in the Beaver River Till as one approaches the gold-bearing veins of the Tangier

Table 4. Fire assay gold analyses from Trench 1 and 2, bulk channel samples. The bulk assay* was normalized back to the weights of sand feed producing the heavy mineral concentrates. The bulk assay was calculated by multiplying the HMC assay by the weight dilution factor (HMC/table feed). In Trench 2 duplicate analyses are from analytical splits of the prepared sample.

Bulk channel sample (samples 4-10T1) Trench 1 (76 kg)			
Size Fraction	weight (g)	Analyses (ppb)	
table feed/ HMC bulk assay	28 700/58.6	98 700 202*	
Bulk channel sample Trench 2 (109.266 kg)			
Size Fraction	dry weight (g)	Analyses (ppb)	
+10 mesh (gravel)	55 000	185	350
sand feed/ HMC bulk assay	53 176/ 7.7	2 424 000 351	
<230 mesh (silt + clay)	1 090	8	125

Gold District (Fig. 7). The bulk assay from Trench 1 (0.007 oz./ton) should, therefore, increase by ~30% to a peak of 0.01 oz./ton then decrease again with proximity to the lode deposit. The average grade calculated under this economic window would be ~0.0085 oz./ton.

There are obviously not enough data in the second and third dimension to calculate tonnages in the down-ice till window, as defined in Figure 1, but "potential" tonnages can be extrapolated using two assumptions:

(1) the gold content of till follows the exponential dispersal law down-ice of the gold district; and

(2) gold levels in the till are consistent both vertically and laterally along strike.

The first assumption is undoubtedly valid because the patterns of down-ice dispersal have been verified at several gold districts (e.g. Coker *et al.*, 1988).

The second assumption requires further testing, as the gold content in the vein systems of the Tangier Gold District is highly variable along strike (Malcolm, 1929). The Tangier section is down-ice of the main producing gold veins north of the town of Tangier, so grades in till are likely to decrease to the east (Fig. 1). Gold anomalies in previous surveys (Dimmell, 1983) down-ice from the eastern portion of the Tangier district, however, verify that gold is found in till in the dispersal zone right across the district. Eroded gold debris from lode sources tends to migrate up-section (Fig. 6), as demonstrated in the increases in gold content towards the tops of trenches 1-5. These dispersal plumes will be stacked one on top of another in the case of multiple vein sets, producing a thicker gold-enriched till section. This may be the case at Tangier and other similar, larger districts where gold was extracted from multiple vein systems.

The bulk testing results from Trench 2 (Table 4) revealed that the crushed, coarse fraction of till contained comparable levels of gold to the hydrostatically separated gold, approaching 0.01 oz./ton. It is important to remember that till is not a 'placer' deposit, that is material hydro-dynamically sorted by running water. Till is essentially the product of incomplete crushing of the lode source, with the addition of adjacent bedrock as a filler, and transportation en masse by glacier ice. Crushing and heap leaching of till to extract gold must be considered when evaluating till as an ore source. This method proved effective at Moose River at the turn of the Twentieth Century.

Tonnages in the model window are calculated by determining the volume of the zone depicted in Figure 1 (Length x Width x Thickness), converted to weight (metric tonnes) using a standard bulk density (weight per unit volume) value for glacial till of 2.0 tonnes (t)/m^3.

V=L x W x T
T= the average thickness of the Beaver River Till (4 m)
L= strike length of the gold-producing veins (Fig. 1; 2500 m)
W= economic 'window' width under the dispersal curve (Fig. 1; 300 m)

Volume = 3×10^6 cubic metres
Weight = volume x bulk density
= $3 \times 10^6\ m^3 \times 2.0\ t/m^3$
= 6×10^6 t

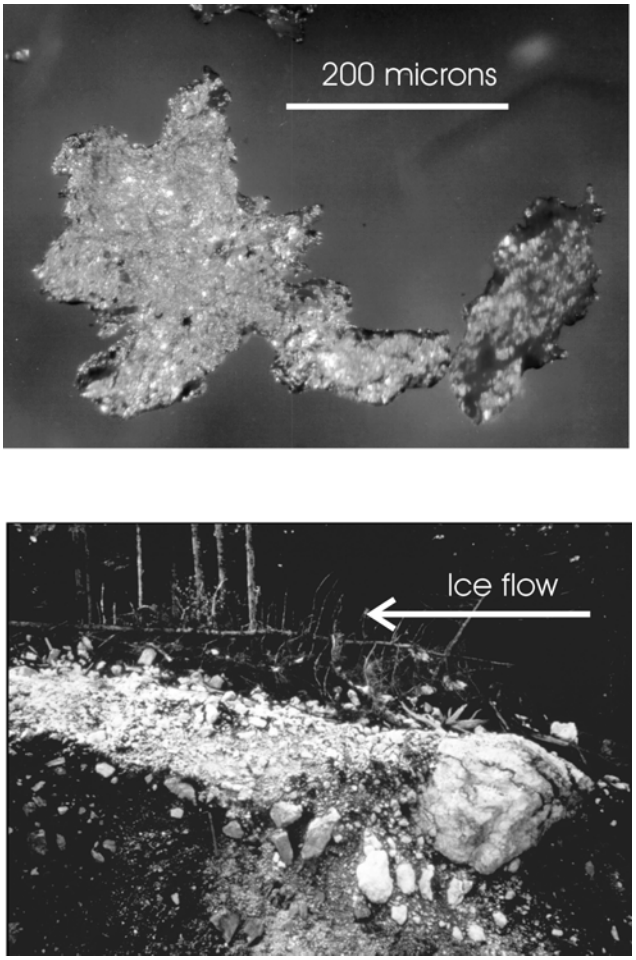

Figure 6. (Top) 'Pristine' gold grain from the Tangier till section (length 400 microns). (Bottom) Dispersal plume of quartz in the Beaver River Till at the Beaver Dam Gold District. Note how the quartz debris is distributed up-section and down-ice of the vein source.

Heap leach or bulk extraction till model (0.01 oz./ton)

= 6 x 10^6 tonne x 0.01 oz./tonne

=60,000 oz.

Placer till model (0.0085 oz./tonne) (calculated from sand fraction ~50% of the total weight):

= 6 x 10^6 tonne/2 x .0085 oz./tonne

= 25,500 oz.

These calculations are only meant to serve as a theoretical model for the potential of till as a viable gold deposit. They cannot be used as an actual resource or reserve calculation.

Recommendations

In essence, till deposits south of the gold districts are made up of crushed, gold-bearing rock that was transported just south of the mines and dumped by a glacier. They may be considered as tailings piles that have not been processed. In order to evaluate the validity of our till mining model explorationists should undertake further testing in the potentially economic zone down-ice of gold districts. In the Tangier District, unfortunately, much of the gold-bearing till underlies the town, but the principles established in this study could be applied along strike of the main Blueberry Hill deposit, or in similar gold districts elsewhere. The economic window of gold-bearing till may be wider or narrower depending on the grades, strike lengths, numbers and widths of the gold vein systems (see Horne *et al.*, this volume). Evaluation of the down-ice till deposits is best done by excavation of till in the window and bulk sampling. In some gold districts previously excavated borrow pits are already available for sampling. A sluice can be set up in some areas as a means of further exploration and gold recovery (see Mills *et al.*, this volume). Extraction of gold by crushing and heap leaching of till may be considered, as well as the potential for sand and gravel by-products from a larger scale operation.

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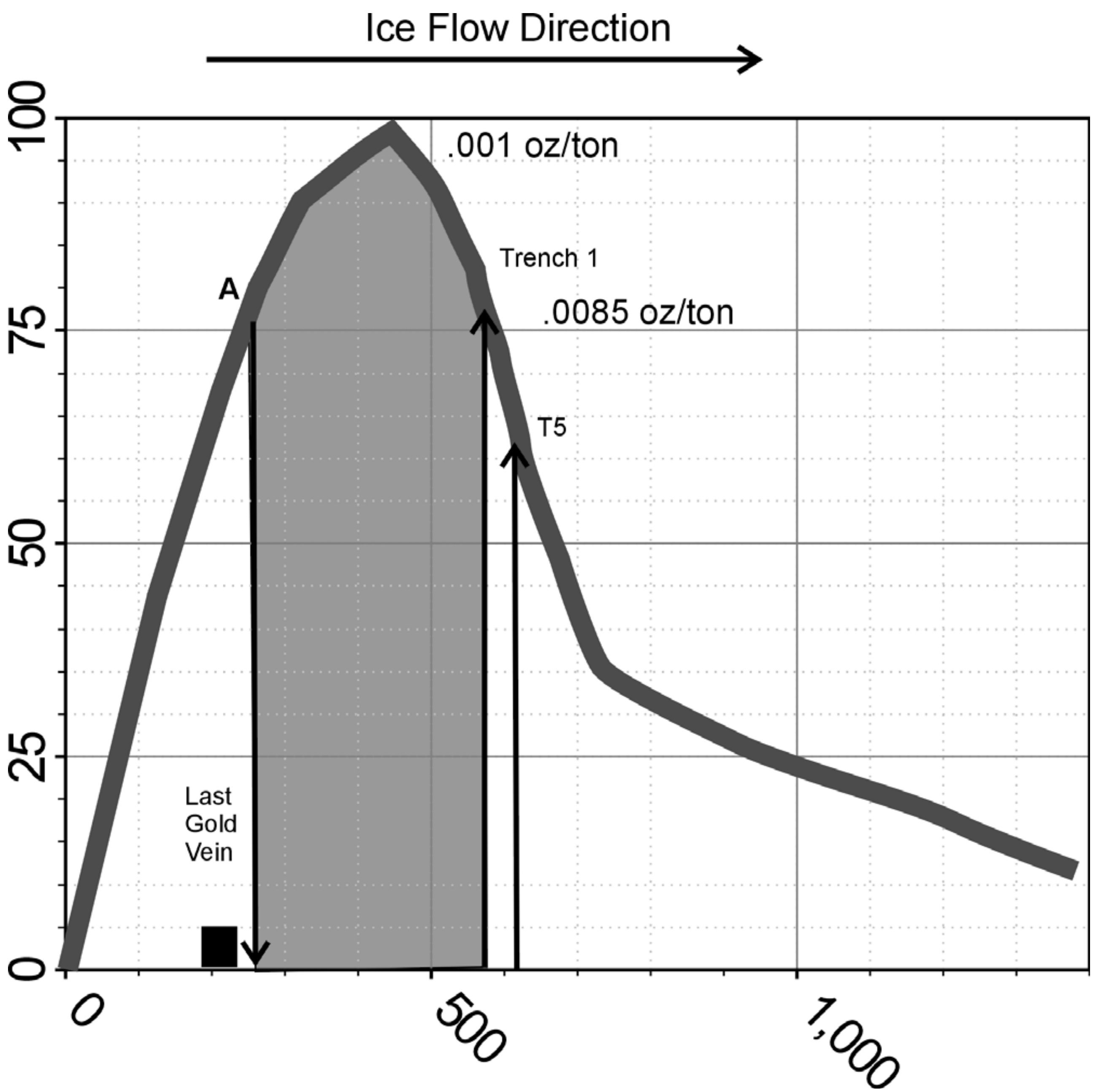

Figure 7. Dispersal curve of the Beaver Dam gold district (Goodwin, this volume), normalized to 100%. This curve is transposed to the Tangier Gold District and the location of the Tangier section is plotted on the curve. The area under the curve is a potential economic ‘window’ of gold in till.

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