Nova Scotia Gold Grain Study: Background and Anomalous Concentrations of Gold Grains in Till

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Introduction

Regional till sampling programs have been routinely undertaken throughout most of Canada by various levels of government and, of course, mineral exploration companies in their search for gold, diamonds and other minerals of economic importance. As a result of these programs, background concentrations of gold recovered from the heavy mineral concentrate (HMC) from 10 kg till samples are known for many terranes. For example, background concentrations of gold grains in till from across the Abitibi Greenstone Belt range from <1 gold grain in the north to about 10 gold grains in the south (McClenaghan, 2001).

Besides the frequency of occurrence, the gold grain morphology can also be used to estimate the distance of glacial transport from its bedrock source. The morphology of the gold grains recovered from till samples is, generally, classed into three categories: pristine, modified and reshaped (DiLabio, 1990). Pristine grains are indicative of minimal transport from source, ranging from 0 to 100 m, modified gold grains have been glacially transported in the order of 500 m, while reshaped grains have been displaced in excess of 1000 m from source. There are, of course, exceptions (Henderson and Roy, 1995).

Companies engaged in diamond exploration programs use a similar methodology for the recovery and identification of kimberlite indicator minerals (KIMs), kimberlite being the host rock of diamond deposits. The relative abundances of KIMs recovered in till samples are used as indicators of proximity to source, recognizing that individual kimberlite mineralogy varies significantly (McClenaghan and Kjarsgaard, 2001). Similarly, surface features and textures observed on KIMs recovered from the HMC of till samples provide similar clues to the distance of transport. For example, the presence of kelyphite rims on Cr-pyrope grains provides some indication of the relative distance of transport, as does the presence of orange peel texture (McClenaghan and Kjarsgaard, 2001).

To date, there has been no regional evaluation of gold grain concentrations in till for the Meguma Terrane of Nova Scotia. There are, however, very few property-scale studies available that involve the identification and morphological classification of gold grains recovered from till samples. One of these studies involved a reverse-circulation drilling program conducted to map the distribution of gold in the till profile at the Beaver Dam Gold District (Duncan, 1987).

There have also been several studies involving the collection and electron microprobe analysis of gold grains recovered from till from several gold districts within Nova Scotia (MacEachern, 1983; MacEachern and Stea, 1985). The morphological character and composition of individual gold grains recovered from these studies led to the conclusion that there was little evidence of abrasive glacial transport because of the rough, pitted and delicate edges of the gold grains.

During the 2004 field season, twenty 10 kg till samples were collected in order to determine: (1) background concentrations of gold grains from across the province, (2) anomalous gold grain concentrations and the associated dispersal pattern within a known gold district (Beaver Dam) and (3) the morphology of each of the grains recovered, providing an estimate for the distance of glacial transport.

Regional Geology

Bedrock Geology

Mainland Nova Scotia south of the Cobequid-Chedabucto Fault Zone lies within the Meguma Terrane (Fig. 1), which is dominated by the Meguma Group, a 9000 m thick succession of siliciclastics that host most of Nova Scotia's gold deposits (Ryan and Smith, 1998). The Meguma Group consists of two formations: the basal metasandstone-dominated Goldenville Formation, which is conformably overlain by slate and meta-

Goodwin, T. A. 2005: *in* Mineral Resources Branch, Report of Activities 2004; Nova Scotia Department of Natural Resources, Report ME 2005-1, p. 15-26.

siltstone with minor metasandstone of the Halifax Formation (Ryan and Smith, 1998). The Meguma Group metasediments were subsequently intruded by Devonian granitoids, namely granodiorite, monzogranite and leucomonzogranite (MacDonald and Horne, 1987).

Most gold occurrences tend to be spatially associated with thicker than normal slate (argillite) beds interstratified with Goldenville Formation metasandstones (Sangster, 1990). Gold generally occurs in qaurtz veins on the crests and flanks of regional anticlines or domal structures within a gold district, which can measure up to 4 km long and up to 0.5 km wide (Sangster, 1990). Quartz is the dominant vein mineral but carbonates also commonly occur as do lesser amounts of sulphides, such as pyrite, pyrrhotite, arsenopyrite, galena, chalcopyrite and sphalerite (Ryan and Smith, 1998). Arsenopyrite characterizes all the gold districts in variable amounts up to a maximum of about 5%. It is most abundant in wall rocks but also occurs in quartz veins (Sangster, 1990).

Gold in Nova Scotia

The first vein-hosted gold discovery in the Meguma Terrane occurred at Mooseland in 1858 by Lieutenant C. L'Estrange while hunting moose (Malcolm, 1929). This led to a major gold rush for Nova Scotia and by the beginning of the Twentieth Century, the Government of Nova Scotia recognized 60 gold districts throughout the province. Production continued relatively unabated until the beginning of the Second World War in 1939. Since 1939, only limited, sporadic production has occurred, except from 1983 to 1987 when a federal exploration incentive, coupled with relatively steady gold prices, allowed for some consistent production (Ryan and Smith, 1998). For historical and descriptive geological details, Malcolm (1929) summarizes the first 70 years of gold exploration and mine development in the Meguma Terrane of Nova Scotia. Bates (1987) summarizes the historical milling methods used to crush the gold ore, gold extraction methodologies, and historical production from the gold districts.

Bedrock Geology and Mineralization, Beaver Dam Gold District

The Beaver Dam gold deposit is located on the south, overturned limb of the northeast-trending Beaver Dam-Fifteen Mile Stream anticline (Ryan and Smith, 1998). At the district scale, gold occurs in high-grade quartz veins and as disseminated gold in slate beds within the Goldenville Formation metasandstones (Ryan and Smith, 1998). The mineralized zone is displaced by the Mud Lake Fault to the east and by the River Lake Pluton to the west (Coker *et al.*, 1988).

Beaver Dam, like many other gold districts in the Meguma Terrane, is characterized by a thicker than normal package of slate (argillite) beds interstratified with the dominant metasandstones (Sangster, 1990). The slate package consists of the Crouse Argillite, Papke Argillite and the Austen Argillite interstratified with the Hanging Wall Greywacke and the Millet Seed Greywacke (Sangster, 1990). The package has an average thickness of approximately 150 m, of which slate (argillite) constitutes approximately 75% of the total thickness, or about 105 m (Sangster, 1990). Gold occurs in all three slate (argillite) units; however, recent (mid-1980s) underground development primarily focused on the Papke and Austin zones (Ryan and Smith, 1998). A detailed summary of the stratigraphy, mineralization and alteration of the Beaver Dam Gold District is provided by Duncan (1987).

Additionally, numerous small quartz veins hosted in several 3 m thick (average) slate belts are known to contain gold. Unveined slate belts further characterized by the presence of arsenopyrite are also known to contain discrete grains of gold. Grades in these belts vary from 0.5 to 2.5 g Au/t over widths of 5 to 15 m (Ryan and Smith, 1998).

Accessory minerals may include variable amounts of pyrrhotite, galena, sphalerite, chalcopyrite, scheelite, stibnite, argentite, tetrahedrite, loellingite, molybdenite and tellurides (Sangster, 1990). Highly variable silica enrichment visually characterizes the Beaver Dam deposit (Kontak and Smith, 1987).

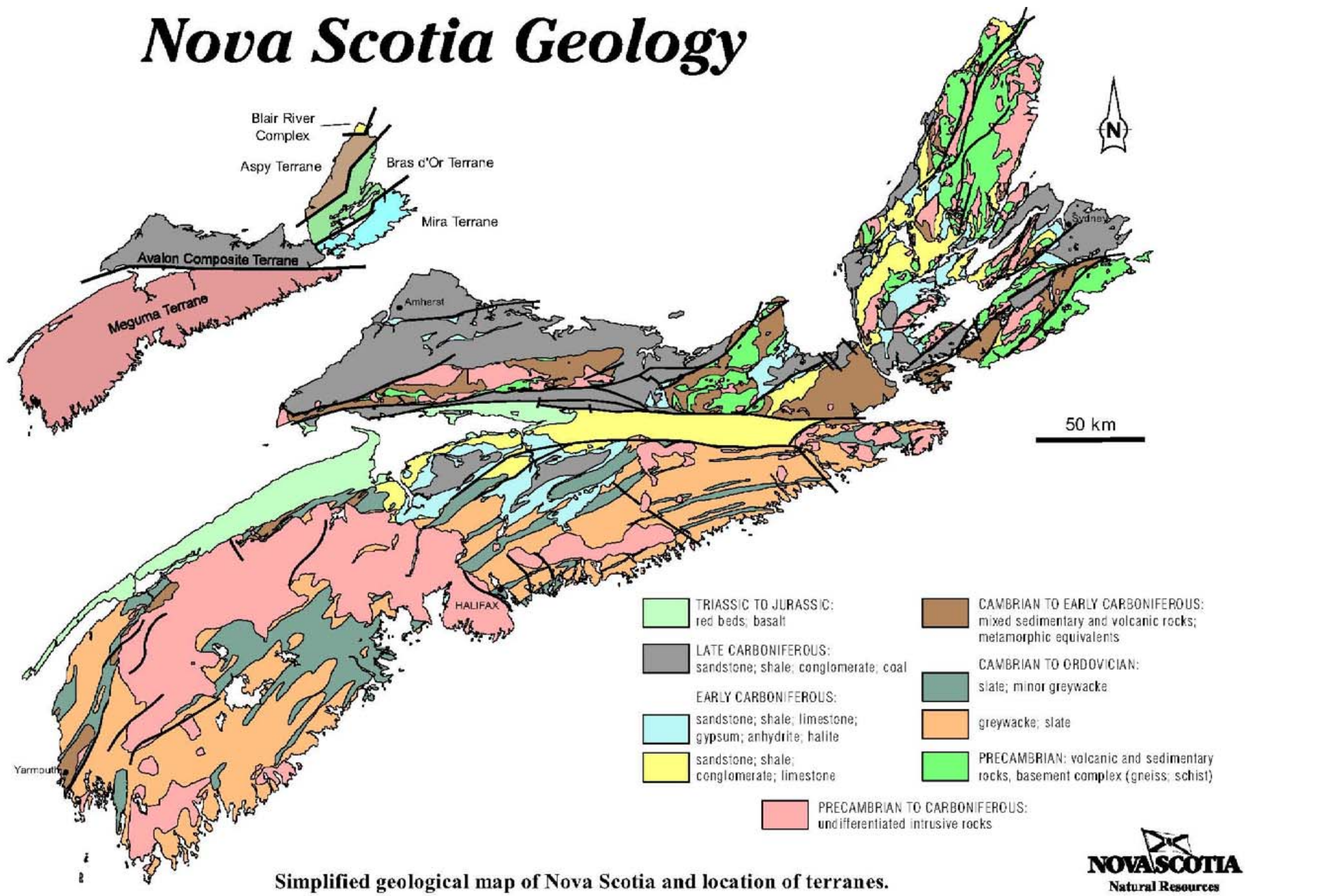

Figure 1. Simplified geological map of Nova Scotia. Inset shows the locations of terranes. The Cobequid-Chedabucto Fault Zone separates the Meguma Terrane to the south from the Avalon Composite Terrane to the north.

History of Gold Exploration and Production, Beaver Dam Gold District

Gold was first reported from the Beaver Dam Gold District in 1868. By 1871 the first 15 stamp mill was erected and two zones of quartz veins were explored (Malcolm, 1929).

Historical production of gold recovered from quartz veins at the Beaver Dam Gold District between 1890-1906 totalled 966 ounces of gold (Sangster, 1990). Malcolm (1929) describes additional exploration and limited production work until the end of 1926. A resurgence in Meguma gold exploration during the 1980s resulted in the production of an additional 11,859 ounces of gold (Sangster, 1990), a portion of which was mined from Beaver Dam.

A detailed summary on the exploration history of the Beaver Dam Gold District is available in Duncan (1987).

Surficial Geology

Generally, most of the surficial deposits and associated landforms throughout Nova Scotia were formed during the Wisconsinan glaciation in the last 70 000 years (Lewis *et al.*, 1998). Superimposed till sheets and various multiple-flow directional indicators have been mapped and indicate that Nova Scotia is characterized by a relatively complex ice flow history (Stea *et al.*, 1992; Stea and Finck, 2001).

The oldest observed ice flow indicators on land show movement toward the east and southeast. This ice flow is responsible for the formation of the Hartlen Till and has been called the Caledonia Phase (75-40 ka). South and southwest flow of the Escuminac Phase (22-18 ka) followed and is responsible for deposition of the Lawrencetown Till. The Scotian Phase (18-15 ka), characterized by an ice divide, affected most of Nova Scotia and the resulting ice flow varied from northwestward in northern Nova Scotia to south and southeast in southern Nova Scotia, followed by the formation of the Beaver River Till. The Chignecto Phase (13-12.5 ka) was characterized by shifting ice flow associated with several small ice caps, the remnants of waning stages of the Scotian Phase glacier (Stea and Finck, 2001).

Enrichment of gold and arsenic, with lesser enrichment of copper, lead, zinc, tungsten, bismuth, tellurium and iron, characterize the bedrock geology of many of the gold deposits of the Meguma Terrane (Kontak and Smith, 1993). These elements are commonly geochemically enriched in soil and till down-ice from known gold occurrences, resulting from mechanical dispersion (erosion, transportation and deposition) by advancing glacial ice (Coker *et al.*, 1988). Glacial dispersal distances vary in Nova Scotia from hundreds of metres to several kilometres down-ice from source (Stea and Finck, 2001).

Surficial Geology, Beaver Dam Gold District

The Beaver Dam Gold District is characterized by relatively thin till (<5 m), although locally it can reach thicknesses of 25 m or more (Coker *et al.*, 1988). The till is characterized by the locally derived Quartzite Till of Stea and Fowler (1979). The Quartzite Till is now referred to as the Beaver River Till, metagreywacke (or metasandstone) facies (Finck and Stea, 1995).

Coker *et al.* (1988) indicate the dominant ice flow direction in the Beaver Dam Gold District is toward the southeast (145°) and this is also the youngest ice flow event recorded in the district (Coker *et al.*, 1988). The oldest recorded ice flow direction, however, is toward the south (180°) with an intermediate ice flow toward the east (090°, Coker *et al.*, 1988).

Methodology

Introduction

During the 2004 field season, fourteen regional C-horizon till samples were collected from randomly selected sites across mainland Nova Scotia (Fig. 2). Most samples were collected from the Meguma Terrane, from which 1,198,619 troy ounces of gold were produced from over 50 gold districts (Bates, 1987). The samples were collected in order to determine background regional gold grain counts for a 10 kg till sample. The fourteen sample sites were chosen to provide (1) a broad aerial

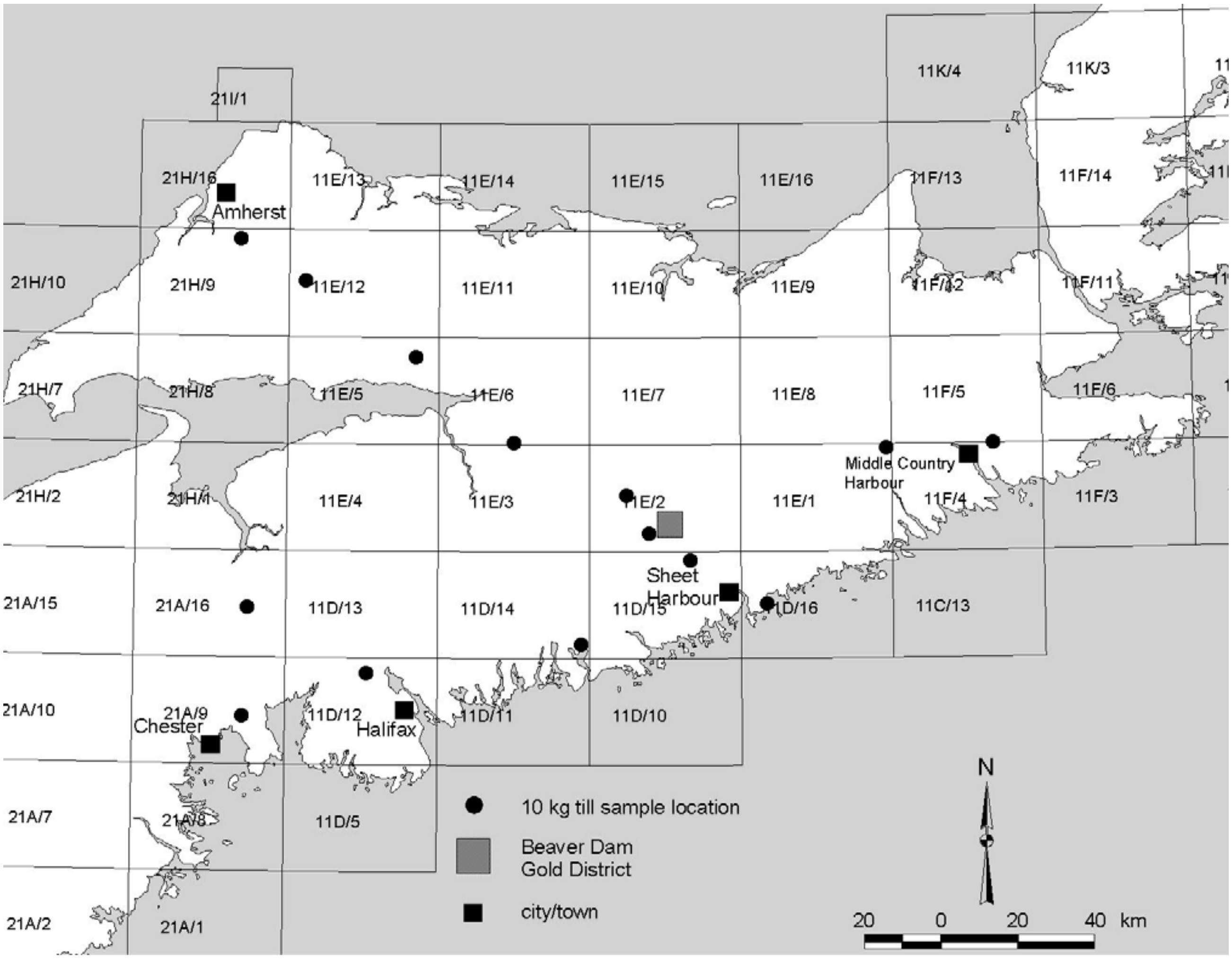

Figure 2. Regional till sample location map. Detailed till samples collected from the Beaver Dam Gold District. Note: All regional till samples reported 0 to 3 gold grains per 10 kg sample.

distribution across mainland Nova Scotia, (2) representative coverage of the major surficial units and (3) easy access by taking advantage of pre-existing roads.

In addition to the fourteen regional samples, six detailed samples were collected from the Beaver Dam Gold District, located along the Eastern Shore of Nova Scotia, approximately 100 km northeast of Halifax (Fig. 2). The samples were collected on a single northwest-southeast line approximately 1400 m in length in order to determine the effects of glacial dispersal on gold grain counts and grain morphology across the Beaver Dam Gold District, and to quantify the dispersal pattern (Fig. 3). The Beaver Dam Gold District was selected because previous geochemical sampling of soil and till identified a well defined, 300 m long dispersal train evident in various sample media immediately down-ice from the Mill Shaft (Coker *et al.*, 1988). Of particular interest to the 2004 gold grain study was the gold anomaly identified in the heavy mineral concentrate of till by Coker *et al.* (1988). The six detailed till samples collected in 2004 were oriented along the previously identified dispersal train, with sampling extended approximately 200 m up-ice from the Mill Shaft and 800 m down-ice beyond the south shore of Crusher Lake. The outer bark scales of red spruce also define a gold and arsenic dispersion train, as well as a currently unknown area of anomalous gold content up-ice from the Mill Shaft (Dunn *et al.*, 1991).

Detailed field descriptions were recorded at each sample site and a digital photograph was taken for future reference. Notes regarding each sample site included sample depth, till type, colour, texture, and clast type and percentage were

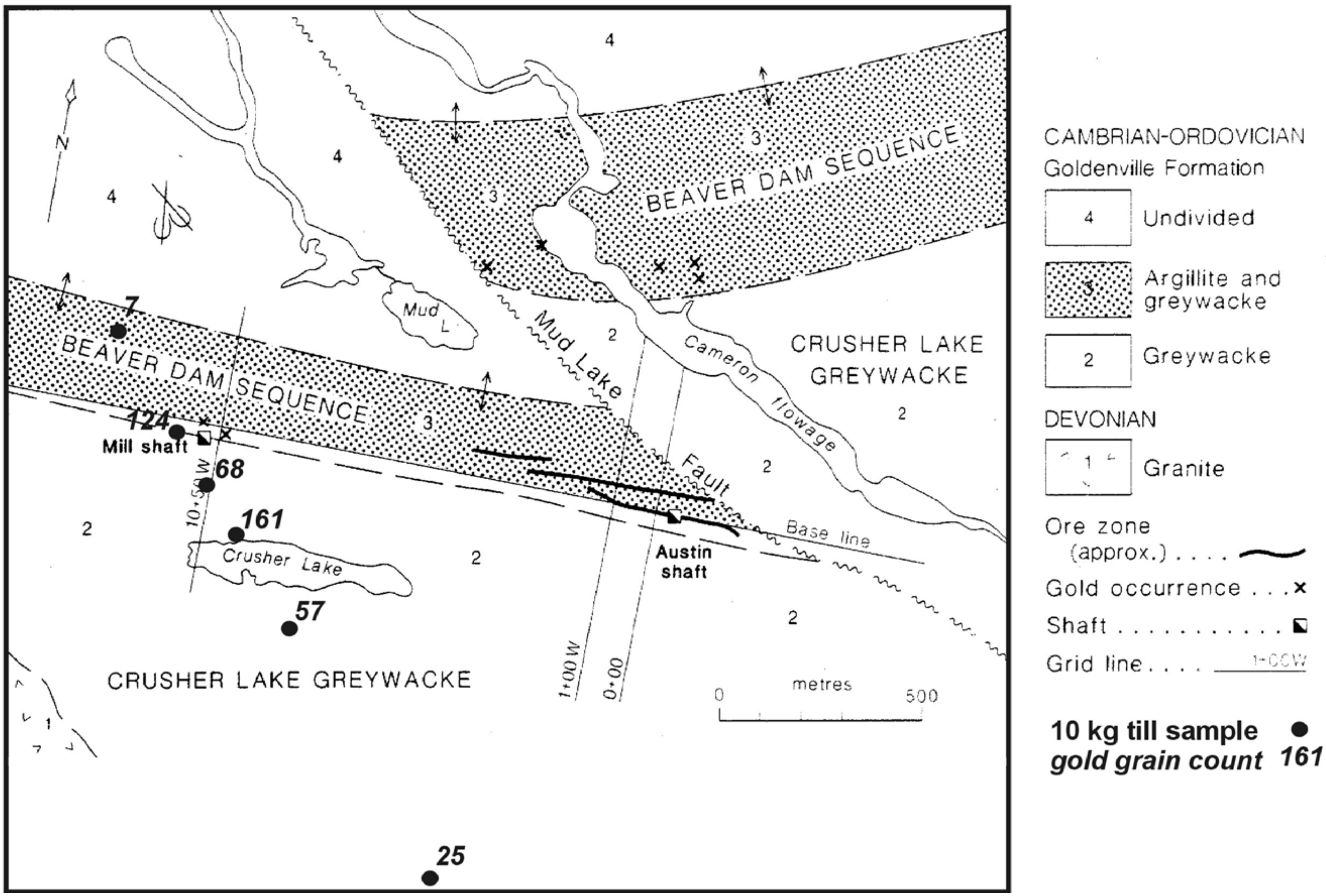

Figure 3. Detailed till sample locations and corresponding gold grain counts for the Beaver Dam Gold District. Modified from Coker *et al.* (1988).

recorded. Sample sites were geo-referenced (NAD 27) to the Universal Transverse Mercator (UTM) grid using the averaging function of a GARMIN 12 GPS (Table 1).

Field Sampling Methodology

A 10 kg till sample was collected at each sample site. Regional samples were typically collected from approximately 1.5 to 2.5 m depth along roadside till exposures. Samples for the detailed sampling program at Beaver Dam were from hand-dug till pits between 1.0 and 1.5 m deep. All samples were collected by shovel and were passed through a 1 cm plastic sieve in the field prior to placement into a 4 mil plastic bag. A fish scale was used to weigh each sample to ensure a minimum of 10 kg of till was collected from each site. The >1 cm clast fraction was washed, clast lithotypes were identified (metasandstone, slate/argillite, quartz vein, granite, Carboniferous sediments or Cobequid Highlands intrusives/volcanics) and estimates of the percentage of each type were recorded in the field.

Laboratory Preparation and Analytical Methodology

All samples collected during the 2004 field season were sent to Overburden Drilling Management (ODM) Limited of Nepean, Ontario. Upon arrival, ODM produced a 30 g sub-sample of the <63 micron size fraction, which was forwarded to ACME Analytical Laboratories of Vancouver, British Columbia, for Au (+ 51 element ICP-MS) analysis for comparison of the geochemical signature with the gold grains recovered, as well as previous multi-element geochemistry reported by Coker *et al.*, 1988.

Overburden Drilling Management processed the 10 kg till samples for the recovery of a heavy mineral concentrate (HMC), gold grain counts, gold morphology description, and >2 mm clast recovery. The >2 mm fraction was removed by wet screening while the <2 mm fraction was preconcentrated by density separation while being passed across a shaking table, and visible gold grains were identified and counted. The >2 mm fraction was subsequently placed into pre-labelled bags for future lithologic identification.

Where necessary, the table concentrate was also (micro) panned and an additional gold grain count was performed. The table concentrate was then subjected to a heavy liquid separation in methylene iodide (S. G. 3.3). A ferromagnetic separation was performed on the resulting HMC and the non-magnetic HMC was weighed and placed into pre-labelled vials.

Overburden Drilling Management recorded sample weights after each processing stage and all material was retained for future reference. All equipment was thoroughly cleaned between samples. ODM is recognized for their ability to recover and describe gold grains from glacial sediments.

Geochemical analysis for gold in the HMC was not completed as part of this study. Estimates of the calculated visible gold grade of the HMC, however, were provided by ODM.

Results

Results of the background and anomalous gold grain counts and associated gold grain morphologies for 10 kg till samples collected from throughout mainland Nova Scotia and from within the Beaver Dam Gold District are being reported here for the first time (Table 2). Table 3 summarizes the tabling and heavy liquid separation test weight results.

Regionally, background gold grain counts for mainland Nova Scotia range from 0 to 3 gold grains (the majority of which were reshaped grains) per 10 kg of till (Table 2). Specifically, the NW-SE profile line from Amherst to Sheet Harbour reported 0 to 1 gold grain per 10 kg till sample. Similarly, 0 to 3 gold grains characterize 10 kg till samples collected from Chester in southwestern Nova Scotia to Middle Country Harbour along the Eastern Shore of mainland Nova Scotia.

Results from the detailed 10 kg till sampling program in the Beaver Dam Gold District indicate gold grain concentrations increase from a minimum of 7 gold grains approximately 250 m up-ice from the Mill Shaft to a maximum of 161 gold grains approximately 300 m down-ice from the shaft. Gold grain counts drop off to 25 gold grains per 10 kg till sample approximately 1200 m down-ice from the Mill Shaft. The gold grain morphologies that characterize the 10 kg till samples collected

Table 1. Till samples with UTM (NAD27) co-ordinates.

SAMPLE #	utm-E27	utm-N27	Comments	Bedrock Geology
GGS2004-01	409562	4940203	regional sample	monzogranite
GGS2004-02	411031	4968490	regional sample	granodiorite
GGS2004-03	480438	5010920	regional sample	Horton Group siliciclastics
GGS2004-04	509664	4997257	regional sample	Meguma Group, metasandstone
GGS2004-05	515634	4987435	regional sample	Meguma Group, metasandstone
GGS2004-06	526350	4980317	regional sample	Meguma Group, metasandstone
GGS2004-07	546244	4969166	regional sample	Meguma Group, metasandstone
GGS2004-08	409507	5064008	regional sample	Cumberland Group, sediments
GGS2004-09	426323	5053164	regional sample	Cumberland Group, sediments
GGS2004-10	454929	5033188	regional sample	Cumberland Group, sediments
GGS2004-11	605036	5011393	regional sample	Meguma Group, metasandstone
GGS2004-12	577139	5009852	regional sample	Meguma Group metasandstone
GGS2004-13	521162	4990014	Beaver Dam sample	Meguma Group, metasandstone
GGS2004-14	521083	4990121	Beaver Dam sample	Meguma Group, metasandstone
GGS2004-15	521010	4990217	Beaver Dam sample	Meguma Group, metasandstone
GGS2004-16	520894	4990399	Beaver Dam sample	Meguma Group, metasandstone
GGS2004-17	521281	4989744	Beaver Dam sample	Meguma Group, metasandstone
GGS2004-18	521602	4989187	Beaver Dam sample	Meguma Group, metasandstone
GGS2004-19	497826	4958441	regional sample	Meguma Group, metasandstone
GGS2004-20	441929	4951184	regional sample	Meguma Group, metasandstone

from the Beaver Dam study area indicate the majority of the gold grains (>80%) are dominated by pristine and modified gold grains, indicating proximity to source (Table 2). Plotted results show a classic head and tail dispersal pattern down-ice from the known gold deposit associated with the Mill Shaft (Fig. 4). There is a corresponding increase in the percentage of reshaped gold grains in the tail position.

Routine pebble estimates were made in the field for all sample locations. Quantitative counts will be performed on the > 2 mm size fraction sometime in the near future.

The potential of the Beaver River Till to host an economic source of gold in the Tangier Gold District is currently being evaluated (Stea *et al.*, this volume, p. 101-115). Gold grains recovered from 10 kg till samples and geochemical analysis of gold in till indicate the till is characterized by anomalous gold concentrations. The Tangier study will further assess the amount, distribution and morphological character of gold recovered from till from in the district.

Conclusions

Regional background gold grain counts for 10 kg till samples collected across mainland Nova Scotia range from 0 to 3 gold grains. Detailed 10 kg till samples collected along a profile line near the Mill

Table 2. Summary of the number of recovered visible gold grains and the calculated content (ppb) of visible gold in the heavy mineral concentrate (HMC).

Sample Number	Number of Visible Gold Grains				Non-magnetic HMC Weight	Calculated ppb visible gold in HMC			
	Total	Reshaped	Modified	Pristine	(g)	Total	Reshaped	Modified	Pristine
GGS2004-01	0	0	0	0	6.5	0	0	0	0
GGS2004-02	0	0	0	0	6.3	0	0	0	0
GGS2004-03	1	0	1	0	14.3	13	0	13	0
GGS2004-04	1	1	0	0	15.9	5	5	0	0
GGS2004-05	0	0	0	0	14.0	0	0	0	0
GGS2004-06	0	0	0	0	38.8	0	0	0	0
GGS2004-07	1	1	0	0	17.3	11	11	0	0
GGS2004-08	1	1	0	0	1.4	58	58	0	0
GGS2004-09	1	1	0	0	16.6	12	12	0	0
GGS2004-10	0	0	0	0	21.5	0	0	0	0
GGS2004-11	3	3	0	0	98.2	17	17	0	0
GGS2004-12	3	1	2	0	19.0	13	10	3	0
GGS2004-13	161	4	43	114	13.2	2710	93	834	1783
GGS2004-14	68	6	16	46	11.1	7989	7198	219	573
GGS2004-15	124	5	37	82	12.0	10498	825	1273	8399
GGS2004-16	7	0	3	4	17.1	30	0	17	12
GGS2004-17	57	3	20	34	13.2	1110	146	717	247
GGS2004-18	25	5	6	14	14.1	118	48	30	39
GGS2004-19	2	0	0	2	8.7	4	0	0	4
GGS2004-20	3	0	1	2	2.8	117	0	29	88

Shaft, located in the Beaver Dam Gold District, indicate gold grain counts range from a low of 7 gold grains approximately 250 m up-ice from the Mill Shaft to a maximum of 161 gold grains approximately 300 m down-ice from the Mill Shaft. The last sample collected 1200 m down-ice from the Mill Shaft contained 25 gold grains recovered from a 10 kg till sample. The gold grains exhibit a classic head and tail dispersal train (Fig. 4).

The morphologies of the majority of the gold grains recovered from the regional sampling program indicate most grains are reshaped, indicating the grains have probably travelled a minimum distance of 1000 m from source. Conversely, the grain morphologies of the vast majority of the gold grains recovered from the Mill Shaft area are pristine (<100 m of glacial transport) and modified (<500 m of glacial transport), suggesting proximity to source.

Additional regional sampling of till is required to confirm background levels for mainland Nova Scotia and Cape Breton Island. Additional sampling at Beaver Dam is also required up-ice from the Mill Shaft until background gold grain counts (3 gold grains or less for a 10 kg till sample) are encountered. Similarly, additional down-ice sampling of till is also required to establish the dispersal length of the anomaly, currently 1400 m long but still open to the south.

Table 3. Summary of the sample weights at the various processing stages.

Sample Number	Weight (kg)				Weight (g) dry				
					-2.0 mm Heavy Liquid Separation (S.G. 3.3)				
							HMC		
	Bulk Rec'd	Table Split	+2.0 mm Clasts	Table Feed	Table Conc.	Lights	Total	Non Mag	Mag
GGS2004-01	9.8	9.0	1.7	7.3	311.2	303.6	7.0	6.5	0.5
GGS2004-02	10.7	9.9	1.6	8.3	351.7	343.6	6.9	6.3	0.6
GGS2004-03	13.5	12.7	2.0	10.7	308.1	291.9	15.1	14.3	0.8
GGS2004-04	10.4	9.6	2.1	7.5	264.7	247.1	16.6	15.9	0.7
GGS2004-05	10.4	9.6	3.7	5.9	325.8	310.1	15.0	14.0	1.0
GGS2004-06	10.3	9.6	2.3	7.3	281.6	239.7	41.2	38.8	2.4
GGS2004-07	10.9	10.1	1.4	8.7	179.2	160.0	18.5	17.3	1.2
GGS2004-08	10.4	9.6	0.2	9.4	264.5	262.5	1.5	1.4	0.1
GGS2004-09	10.6	9.8	0.9	8.9	227.5	209.8	17.1	16.6	0.5
GGS2004-10	11.4	10.8	3.7	7.1	336.2	31.5	25.1	21.5	3.6
GGS2004-11	10.9	10.1	1.8	8.3	279.5	178.6	100.6	98.2	2.4
GGS2004-12	11.4	10.8	2.6	8.2	278.6	257.5	21.0	19.0	2.0
GGS2004-13	9.3	8.6	1.7	6.9	254.7	240.2	13.4	13.2	0.2
GGS2004-14	10.7	9.9	2.0	7.9	219.1	204.1	11.2	11.1	0.1
GGS2004-15	10.4	9.7	3.3	6.4	279.5	265.5	12.5	12.0	0.5
GGS2004-16	13.0	12.2	5.7	6.5	181.2	163.2	17.4	17.1	0.3
GGS2004-17	12.1	11.3	2.0	9.3	254.6	241.5	13.6	13.2	0.4
GGS2004-18	12.5	11.8	2.3	9.5	208.3	193.2	14.3	14.1	0.2
GGS2004-19	10.1	9.3	2.4	6.9	283.9	272.6	10.5	8.7	1.8
GGS2004-20	10.4	9.6	3.7	5.9	347.7	343.8	3.1	2.8	0.3

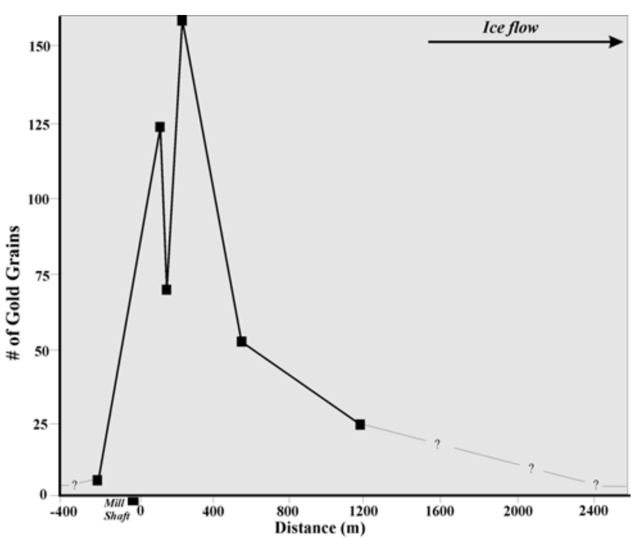

Figure 4. Down-ice dispersal of gold grains recovered from 10 kg till samples from the Beaver Dam Gold Disrtrict.

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