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VERY FINE STREAM SEDIMENT SAMPLING FOR GOLD

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VERY FINE SEDIMENT SAMPLING FOR GOLD

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ABSTRACT

In theory, very fine sediment sampling (<53 microns) has the potential to improve the usefulness of stream sediment data for gold. The key theoretical advantages over traditional techniques are less local sample site variation, improved reproducibility, and the potential to preferentially define anomalies associated with significant bedrock mineralization. An orientation survey is required to test the actual effectiveness of these techniques and to establish practical sampling and processing procedures.

RESUME

En theorie, les echantillons de sediments tres fins (<53 microns) ont le potentiel d'ameliorer l'utilisation des donnees d'or dan les sediments provenant des ruisseaux. Les avantages cles theoriques par rapport aux techniques traditionnelles sont les suivants: moins de variations locales dans les sites d'essai, l'amelioration de la reproductibilite et le potentiel de definir les anomalies associees a une mineralisation significative, en comparaison a toute autre source d'or. Un sondage d'orientation est necessaire afin de determiner l'efficacite reelle de ces techniques et d'etablir une procedure relative aux modalites d'echantillonnage et de traitement des sediments.

INTRODUCTION

Companies involved in gold exploration require a sediment sampling technique for gold that can preferentially highlight anomalies associated with potentially economic bedrock sources of gold and downgrade anomalies associated with transported gold or insignificant bedrock sources. This would allow explorationists to spend their anomaly follow-up budgets more efficiently and with a greater confidence of success.

Research by government and academic geologists supports the sampling of very fine sediment to overcome the problems that traditional techniques have in meeting these requirements. This paper outlines the potential for very fine sediment sampling to aid in the exploration and discovery of new ore deposits in Yukon.

BACKGROUND

Mining has always held a very important position in the Yukon economy. The future of economic development and the goal of a self sufficient Yukon will depend on the mineral exploration industry's ability to discover new and economically viable ore deposits. This will require the industry to develop new and innovative exploration techniques and to critically review the present techniques and philosophies.

Yukon hosts a wide range of mineral deposit types with good potential for ore discovery. However the lack of infrastructure and the high capital costs inhibit potential development for many of these deposit types.

Smaller infrastructure requirements and lower capital costs favour development of gold over base metal deposits. Bulk mineable gold deposits that are amenable to heap leach technology have capital costs commonly less than one tenth of the capital costs of base metal mines, and produce a product which does not require the shipment of a concentrate to a smelter.

Unlike many base metal deposit types bulk mineable gold deposits do not respond well to remote sensing exploration techniques such as airborne geophysics. Discovery of these deposits in Yukon will rely heavily on geochemical sampling.

Silt Sampling

Standard stream sediment sampling techniques used in exploration for gold by explorationists and the government-funded Regional Geochemical Surveys (RGS) use <177 micron (<80 mesh) silt sampling. A 200 to 500 gram field sample is collected, dried and sieved to <177 microns. That sample is then pulverized and a 5 or 10 gram split is taken for analysis. In the late 1980's the RGS program began to perform standard repeat analysis on anomalous samples by analysing a second split from the pulverized sample. This procedure highlighted erratic results for gold analysis of <177 micron sediment.

This problem was previously demonstrated by Harris (1982) in his study of silt sampling in southern British Columbia. Three 5 g splits were taken from the pulps of 96 <177 micron sediment samples. These splits were analyzed by atomic absorption following aqua-regia digestion; this is the most common technique still used although 10 g splits are now the standard. The results of the 26 samples that returned at least one anomalous value show that only four samples were anomalous in all three analytical runs (Table 1). This brings into question the logic of widespread use of <177 micron silt sampling to direct gold exploration efforts.

Table 1

Results of analytical re-runs on southern British Columbia reconnaissance silt samples.
(from Harris, 1982)

	Au Analysis (ppb)				Au Analysis (ppb)		
Sample #	1st run	2nd run	3rd run	Sample #	1st run	2nd run	3rd run
L79	40	<10	34	T388	80	<10	N/S
L81	<10	<10	76	T389	80	22	60
L82	<10	<10	2230	T405	<10	240	<10
L86	<10	22	370	T408	20	1460	<10
L87	10	60	<10	T410	24	<10	<10
L96	490	<10	<10	T411	168	<10	<10
L97	700	<10	<10	K611	520	7300	6400
L98	<10	340	320	K613	660	220	166
T376	<10	16	26	K614	120	<10	320
T377	<10	22	40	K615	30	14	<10
T385	<10	380	360	K621	20	<10	32
T387	44	32	24	K624	<10	24	<10

* N/S - insufficient sample

Heavy Mineral Concentrate Sampling

This technique relies on the high specific gravity of the minerals of interest allowing them to be separated from the bulk sample. The procedure would typically involve the collection of a 20 kilogram bulk sample which would be panned down to 50 grams of concentrate. That concentrate would then be sent to a lab for analysis.

The hydraulic action of the stream pre-concentrates the heavy minerals in the high energy sections of the stream. Farther away from the source, as the minerals are reworked by the stream, this effect creates an increase in the anomaly size (Paopongsawan and Fletcher, 1993). Therefore it would not be unusual for samples taken a long way downstream from an insignificant gold source to return a high concentration of gold in the heavy mineral concentrate.

Heavy mineral sampling of streams that have erratic <177 micron gold values would also be expected to return high gold values in heavy mineral concentrate samples, as the erratic values in <177 micron samples are likely caused by rare coarse grains.

The potential for heavy mineral sampling to highlight anomalies that are sourced from insignificant mineralization wastes valuable anomaly follow-up resources. The inability of heavy mineral concentrate sampling to recover very fine gold indicates the potential for this technique to miss "Carlin style" gold deposits entirely (Wiltse, 1988).

Heavy mineral concentrate sampling has often been recommended as an appropriate gold exploration technique (Boronowski, 1986), (Nuchanong and Nichol, 1992) on the basis of its ability to identify coarse gold bearing streams without thought to the source of the gold. This technique may be appropriate for placer exploration but the potential to generate large anomalies from insignificant bedrock sources, and to miss deposits associated with very fine gold, raises doubts as to the usefulness of heavy mineral sampling in gold ore exploration.

TECHNICAL REQUIREMENTS

The goal of any sediment sampling program is to obtain a guide to potential ore deposits in the drainage being sampled. To achieve that goal a sample medium must be representative of the element of interest in the drainage, provide good anomaly contrast and be practical to collect and prepare for analysis. It is also useful if the dispersion train shows an increase in the element of interest closer to the source. The behaviour of gold in stream sediments presents unique problems and opportunities that traditional techniques have been unable to address.

Representative Sample

Gold's high specific gravity, resistance to chemical dissolution, and particle sparsity creates sampling problems unlike those faced in the search for base metals. The style of gold occurrence in the ore deposit also provides a unique opportunity for more effective targeting of the exploration effort. The first requirement for an effective regional geochemical technique is to acquire a sample that is representative of the element being sought.

Because of its particular characteristics gold is not distributed evenly among bedforms or along the longitudinal profile of drainages. This makes the problem of acquiring a representative sample very difficult. To further complicate the problem, major flow events have been shown to strongly affect gold distribution (Day and Fletcher, 1987), creating anomalies that disappear in follow-up surveys conducted at a different time of year. These effects are caused by hydraulic sorting of heavy minerals.

Work summarized by Fletcher (1990) suggests that very fine grained sediment (<53 micron (<270 mesh)) is only weakly affected by hydraulic sorting and can provide a sampling material that approaches homogeneity within the stream. Weak enrichment of gold in <53 micron fraction at high energy sites (Fletcher, 1990) could result from abrasion of the enriched coarser gold fraction. This is supported by work on glacial tills that demonstrated a reduction in size of nuggets down ice from the source (Bajc, 1991).

By sampling <53 micron stream sediment, and avoiding high energy environments, it should be possible to collect a sample that is representative of the gold content of that fraction. Therefore, although the total gold content of the stream sediment is not distributed evenly, by selecting only the very fine fraction sediment sampling problems caused by hydraulic sorting are minimized and a representative sample is attained. Heavy mineral concentrate and <177 micron samples are affected by hydraulic sorting in the stream. Therefore the location of the sample site will strongly affect results.

Statistical Relevance

If the sample to be analyzed is to have a relative sampling error better than +/-50% at the 95% confidence limit it must contain a minimum of 20 equally sized gold grains (Clifton et al, 1969). The very fine grain size of the <53 micron (<270 mesh) fraction dramatically increases the number of discrete grains in the sample, increasing the likelihood of any anomaly having more than 20 gold grains. The much smaller target size for gold grains also dramatically reduces the size of the sample required (Table 2). The presence of rare grains near the maximum size in the fraction will still create erratic results (nugget effect), however this effect will be much less than with techniques that sample coarser grain sizes.

Table 2

Variation of necessary sample weight in grams according to concentration and size of gold particles to provide approximately +/-50% precision at the 95% confidence level.
(modified from Nichol et al., 1992)

	Gold Content (ppb)					
Grain Size (microns)	1000	250	64	16	4	1
250	950	3800	15000	59000	240000	950000
125	120	470	1900	7400	30000	120000
63	15	61	230	950	3800	15000
32	2.0	7.9	31	120	500	2000
16	0.250	0.99	3.9	16	62	250
8	0.031	0.12	0.49	1.9	7.8	31
4	0.0039	0.016	0.061	0.24	0.97	3.9

Anomaly Definition

It is suspected that when reproducible results are acquired by <177 micron sediment sampling the gold in those samples is very fine (S.B. Balentyne, pers. com. 1992). If, in those cases, only the very fine fraction had been analyzed much greater anomaly definition would have been expected. It must be noted that a significant portion of the fine gold may be contained within larger grains and not occur in the very fine fraction sediment. However, work on stream sediments downstream of known mineralization by Nuchanong et al. (1991) and Delany (1993) demonstrated that the majority of the very fine gold does report to the very fine fraction.

Sampling for gold that occurs in the very fine fraction should enhance anomalies associated with ore deposits where gold occurs in very fine grain sizes and downgrade anomalies associated with occurrences that contain primarily coarser gold. The vast majority of economic gold ore deposits contain gold in very fine grain sizes, regardless of whether coarse gold is also present. This presents an opportunity to target follow-up exploration at anomalies that are more likely to be sourced from potentially economic ore deposits, as opposed to anomalies that are sourced from placer or other coarse gold sources (Wiltse, 1988).

An ideal target for this technique in Yukon is bulk mineable "sediment hosted" or "volcanic hosted" deposits similar to those found in Nevada. A Yukon example of such a deposit may be Brewery Creek east of Dawson City. A key characteristic these deposits share is the exceedingly fine grain size of the gold in the unoxidized host, usually less than one micron in "sediment hosted" deposits (Bagby and Berger, 1985) and commonly less than 10 microns in the "volcanic hosted" deposits. This gold occurs primarily in fine grained easily oxidized sulfides. When these sulfides are oxidized the gold is released as discrete grains or is adsorbed on to very fine grained iron oxides and clays.

Work on gold distribution in till down-ice of known gold deposits in the Canadian shield demonstrated that in oxidized till, gold is most common in the <63 micron fraction. (DiLabio,1985).

In nine samples taken along a one kilometer stretch of a stream draining the Phu Tham Phra copper gold mineralization in Thailand, Nuchanong et al. (1991) found that the <63 micron fraction consistently contained the highest proportion of gold. The <63 micron fraction also showed an expected dispersion train with gold values decreasing over the first 750m (5 samples) below the deposit past the break in slope.

Forty kilometers from Phu Tham Phra, the Huai Hin Lab gold bearing drainage was found to contain the highest percentage of gold in coarse fractions and little gold in the <63 micron fraction (Nuchanong and Nichol, 1992). Further work on this drainage by Paopongsawan and Fletcher (1993) demonstrated an increased concentration in the gold content of the coarse fraction downstream from the proposed source area. This is a reverse dispersion to that which may be expected and is a result of the hydraulic effect progressively concentrating heavy minerals.

Initial analysis of the <53 micron fraction at Huai Hin Lab returned detection limit values. Further analysis using very low detection limit techniques showed a pattern in the <53 micron fraction similar to that found in the heavy mineral concentrates (Fletcher, pers. com. 1993). This pattern could represent erosion of coarser gold particles in the stream, creating <53 micron gold, or could result from a very weak hydraulic effect on the very fine grained gold.

Minor exploration in this area has failed to locate the source of the gold. A possible conclusion is that hydraulic concentration of the heavy mineral fraction is creating a very strong anomaly associated with relatively insignificant mineralization.

At the Doi Tung gold prospect in northern Thailand coarse grained gold was also observed. However, soil sampling on a 10m by 20m grid over the mineralization returned erratic results (Nuchanong and Nichol, 1992) indicating that this target likely has limited exploration potential. A stream draining this target might be expected to show an anomaly in the heavy mineral fraction similar to Huai Hin Lab because of the concentrating effects within the stream, while at the same time it may not show a fine fraction anomaly because of the small size of the mineralization.

Delany (1993) sampled streams draining two disseminated gold deposits: Brewery Creek deposit in Yukon and Kinsley Mountain deposit in Nevada. In eight samples of <212 micron material, between 71.37% and 94.09% of the gold was contained in the <53 micron fraction. In three similar samples collected at the Fish Lake porphyry copper/gold deposit in British

Columbia, between 41.72% and 79.85% of the gold was contained in the <53 micron fraction. This demonstrated that streams draining known mineralization contain significant amounts of gold in the very fine fraction, while they may or may not contain significant gold in other fractions.

The gold concentration in each size/density fraction is shown in Table 3. The large anomalies in the heavy mineral fraction represent only a small percentage of the overall gold content of the sample. When heavy mineral sampling is done by using heavy liquids to separate the heavy minerals from the sample the final results can be influenced by the size of the heavy mineral fraction (Nichol et al., 1992).

Table 3

Concentration of gold in each size/density fraction of stream sediments as determined by fire assay. Light Mineral Fraction (LMF) Heavy Mineral Fraction (HMF) (modified from Delany, 1993)

Location	Size Fraction (microns)				
	<212 >106		<106 >53		<53
	LMF	HMF	LMF	HMF	
Kinsley					
1	5	65	<5	60	25
2	25	160	20	100	65
3	70	280	80	320	325
Brewery					
1	5	10	<5	390	15
2	<5	<280	<5	<45	30
3	25	<20	15	20	60
4	30	<60	20	4770	70
5	25	240	15	490	80
Fish Lake					
1	<5	<20	<5	<30	<5
2	<5	<30	<5	70	15
3	35	8810	30	7340	400

The grain size of ash and loess surficial deposits in Yukon tends to be less than 53 microns in size. This material will act to dilute geochemical anomalies. However, since it is the very fine gold that is significant to exploration, sampling a coarser fraction will act to further dilute the anomalies. Loess and ash surficial deposits create an interpretation problem by reducing anomaly definition and shortening dispersion patterns.

This evidence suggests that <53 micron stream sediment will show much better anomaly definition than techniques presently being employed and has the potential to highlight ore deposits as opposed to gold anomalies.

Practical Application

Very fine fraction sediment provides a representative and reproducible sample that should provide good anomaly definition. The goal now is to design a sampling technique that is simple, practical and effective.

The key questions are how large the primary sample must be to ensure an adequate amount of minus 53 micron material, how to separate the minus 53 micron fraction from coarser material and which analytical technique will provide the most reliable results.

Sample Size

Work by Fletcher (1990) in glaciated terrain in southern British Columbia showed that <5000 micron stream sediment contains approximately 0.5% <53 micron material by weight if high energy sites are avoided. Therefore, to achieve a 30 g sample of <53 micron material it would be necessary to collect 6 kg of <5000 micron stream sediment as a primary sample.

Sampling by Nuchanong et al. (1991) in northeastern Thailand showed that in unglaciated terrain <2000 micron stream sediment contained more than 18% <63 micron sediment by weight. Therefore in that area the minimum sample size required to recover 30 g of <63 micron sediment from a bulk sample of <2000 micron sediment would be 167 g (Nuchanong et al., 1991).

Delany (1993) demonstrated that in stream sediment samples taken from glaciated and unglaciated regions the <2000 micron fraction contained a minimum of 4.09% <53 micron material. This suggests a minimum sample size required would be 750 g of <2000 micron material to achieve a minimum of 30 grams of <53 micron material.

A nearly ten fold reduction in primary sample size can be achieved by screening the bulk sample to <2000 microns rather than <5000 microns at the sample site. This suggests that a conservative primary sample of 2 kg of <2000 micron sediment would need to be collected at the sample site to ensure a minimum of 30 g of <53 micron material for analysis (Table 4).

The increased time required at the sample site to acquire <2000 micron sediment would be offset by a more manageable sample for transport and sieving.

The largest factor influencing the percentage of <53 micron sediment in the sample is expected to be the size of the pre-screening at the sample site. However, the effect of stream gradient has not been considered and is also expected to have a strong influence.

Table 4

Weight percent <53 micron fraction of stream sediment

	# of Samples	Primary Sample in microns	Average % <53 microns
Fletcher (1990)	14	<5000	0.68%
Nuchanong et al (1991)	9	<2000	29*
Delany (1993)	12	<2000	12.16%

* <63 micron fraction estimated from a bar graph.

Sample Separation

Rejection of >2000 micron material at the sample site is accomplished by fitting the primary sample container with a <2000 micron screen.

Wet sieving of the <2000 micron material to <53 microns is recommended to avoid the need to dry large primary samples. As well, caking of the clay fraction during drying would require the sample to be lightly pulverized prior to sieving, and possibly leading to contamination of the fine fraction by gold abraded off erratic coarse nuggets (Nichol et al., 1992).

A multi-stage mechanical sieve fitted with a low volume sprinkler is recommended to reduce sample handling and labour.

The final sample would then require drying in a dust free environment.

Analytical Technique

Standard aqua-regia digestion followed by atomic absorption should provide results that have good anomaly definition with a detection limit of 5 ppb. The array of other techniques available may be used in special cases. Very low detection limit techniques should be considered where material derived outside of the drainage basin (ie. volcanic ash, loess) may dilute anomalies below detection limits of standard techniques. Broad application of very low detection limit techniques may be appropriate, however caution must be taken not to mistake variations in gold background for true anomalies. This is a problem with the cyanide extraction technique (BLEG) where detection limits are commonly reported in parts per trillion (Birrell, 1992).

CONCLUSION

Very fine sediment sampling techniques for gold can greatly improve the usefulness of gold geochemical data for locating ore deposits. More representative, reproducible and reliable data can be collected. However, a detailed orientation survey is required to establish confidence in the ability of very fine grained sediment sampling to highlight potential ore. An orientation survey is also required to answer the more practical questions relating to sampling, processing and analytical techniques. Yukon specific problems of glaciated versus unglaciated terrains and effects of surficial deposits such as loess and ash must also be addressed. The ability of the mineral exploration industry to discover and develop new ore deposits in Yukon will rely on the development and rigourous scientific testing of new, innovative and practical exploration techniques such as very fine sediment sampling.

The importance of creating practical exploration techniques out of the valuable body of research that has been done by academics and government geologists cannot be overstated. Likewise the value of creating and testing these techniques in the public forum, with regular public reporting, where they are open to critical review is essential in developing rigourous exploration techniques that will aid in the discovery of ore deposits.

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