

# A DISCUSSION ON QAQC IN EXPLORATION

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# Executive Summary

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Although most companies carry out QAQC programmes as an integral part of their exploration projects, the approach for most is usually one of half measures and quite often reactive rather than pro-active and holistic. Results of numerous recent audits and due diligence jobs conducted on exploration and mining projects in South and North America, Asia, Africa and Europe indicate that comprehensive geological quality control programs are still relatively infrequent (Mendez, 2011). A review of a number of exploration projects in Zimbabwe particularly those carried out prior to 2000 show a similar trend. As a result of new regulations governing the reporting of exploration results, most companies are now increasingly keen on implementing such programmes as they are crucial in attracting project investment and/or financing and better asset valuation. Analysis of QAQC systems and results form the first critical step in the validation of exploration results which forms a firm foundation for the estimation of mineral resources and resource classification. Lack of comprehensive QAQC systems and results can result in the downgrading of a project's mineral resources with far reaching consequences on the competitiveness of the mineral asset. This is despite the fact that in most cases QAQC programmes generally cost less than 2% of the overall project cost. The best project is one that integrates a wholesome, best practice quality management system at all stages of the project value chain from the formulation stage, through implementation to the reporting of results.

The purpose of this paper is to discuss the various facets of this very crucial yet often overlooked component of a successful exploration project with a special emphasis on practical, field based aspects that help the Project Geologist successfully manage investor funds from a quality standpoint thereby guaranteeing valid, accurate, representative and reliable results.

# Important to Note

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Michael Thompson, one of the co-designers of the Thompson-Howarth precision plot, said, "All analytical measurements are wrong; it's just a matter of how large the errors are, and whether they are acceptable." In this instance, "errors" refers to the inaccuracies and imprecision of the data. These are not "mistakes" but result from the naturally occurring limitations of selecting small representative samples from large volumes of material and from the sensitivity of analytical methods.

# Importance of a robust QAQC programme

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During the last decade, there has been a marked increase in the requirement for clearly stated policies for sample quality and assurance during all stages of the exploration and pre-development cycle. The regulatory environment has slowly evolved in Canada, culminating in the drafting of National Instrument 43-101 (NI 43-101) – which now governs public disclosure by companies in the mining and minerals exploration sector. While NI 43-101 and its Companion Policy have set out specific responsibilities and duties of the reporting issuers and the independent Qualified Persons, the detail for minimal compliance has been specifically left to the individual issuers

- After a few high profile mining/exploration scams ([Bre-X](#)) the Canadian government, and many others have followed suit, demand a higher caliber and standards for reporting sample data. This falls under NI 43-101 whereby a qualified Professional Geoscientist must review all aspects of the sampling procedures for accuracy and potential issues.
- Implementation of a rigorous well conceived QA/QC program at an early stage allows for the ready acceptance of the data and its conclusions by external organisations and saves both money and time by removing the necessity to back-track at the resource drilling or feasibility study stage in an attempt to obtain reliable and compatible data.
- Following proper QA/QC and sampling methods from the inception of a project through its completion can greatly increase confidence that the data are reliable. As geochemical tools become more available, careful QA/QC procedures become even more important. Analytical techniques are becoming more refined, and detection limits are being reduced. With this refinement, even minor contamination can cause differences in data that can drastically change interpretations and conclusions.
- Keeping lines of communication open with the laboratory is beneficial to all parties. Laboratory managers and analysts may have first-hand experience with techniques that have or have not been successful in the past. Also, the more information that is given to the laboratory, the better the laboratory can tailor the analyses to help achieve the goals of the study. It also helps if a rapport exists among all people involved with the study so that, if problems do arise, they can be handled in a coordinated, professional, and timely manner.

# Quality Assurance vs. Quality Control

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Aspect	Quality Assurance	Quality Control
<b>Definition</b>	QA is a set of activities for ensuring quality in the processes by which products are developed.	QC is a set of activities for ensuring quality in products. The activities focus on identifying defects in the actual products produced.
<b>Focus on</b>	QA aims to prevent defects with a focus on the process used to make the product. It is a proactive quality process.	QC aims to identify (and correct) defects in the finished product. Quality control, therefore, is a reactive process.
<b>Goal</b>	The goal of QA is to improve development and test processes so that defects do not arise when the product is being developed.	The goal of QC is to identify defects after a product is developed and before it's released.
<b>How</b>	Establish a good quality management system and the assessment of its adequacy. Periodic conformance audits of the operations of the system.	Finding & eliminating sources of quality problems through tools & equipment so that customer's requirements are continually met.
<b>What</b>	Prevention of quality problems through planned and systematic activities including documentation.	The activities or techniques used to achieve and maintain the product quality, process and service.
<b>Responsibility</b>	Everyone on the team involved in developing the product is responsible for quality assurance.	Quality control is usually the responsibility of a specific team that tests the product for defects.
<b>Example</b>	Verification is an example of QA	Validation/Software Testing is an example of QC
<b>Statistical Techniques</b>	Statistical Tools & Techniques can be applied in both QA & QC. When they are applied to processes (process inputs & operational parameters), they are called Statistical Process Control (SPC); & it becomes the part of QA.	When statistical tools & techniques are applied to finished products (process outputs), they are called as Statistical Quality Control (SQC) & comes under QC.
<b>As a tool</b>	QA is a managerial tool	QC is a corrective tool

# Why is QAQC so Important

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- Enhances competitiveness
- Reputation is assured
- Compliance
- Saves costs
- Enhances confidence that the results are credible and can be relied upon.

# Definitions

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## 2.0 Definitions

Quality assurance has a broad definition outside the mining industry and has been defined as: “All those planned or systematic actions necessary to provide adequate confidence that a product or service will satisfy given needs” (Kirschling, 1991). Quality control is one aspect of quality assurance. The difference between the two concepts is described by Vaughn (1990), as “Assurance in the quality context is the relief of concern about the quality of a product. Sampling plans and audits—the quality *control devices*—are designed to supply part of this assurance”.

The terms commonly used to discuss geochemical data are defined below.

***Precision: the reproducibility of a result. The results can be said to be of low precision*** when multiple analyses of the same sample or duplicate analyses of single samples show a wide variation in results.

***Accuracy: the relationship between the expected result (particularly of standards) and the result actually achieved from the analysis.***

***Bias: the amount by which the analysis varies from the correct result. The amount of*** bias can only really be determined by a large number of repeat analyses of known standards over a period of time.

A demonstration of the difference between accuracy and precision is provided in Table 1.

# Errors in Analytical Data

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***Errors in analytical data: All analytical data is subject to errors or to bias. Errors can be divided into the following categories:***

- **Random Errors: This type of error is endemic to analytical chemistry and is part** of the functioning of every instrument and technique ever developed. It arises from unstable power supplies, non-reproducible atomization and other fluctuations. While it is not possible to remove random error, it is possible to minimize its magnitude and measure its degree.
- **Systematic Errors: Such errors can arise from solution matrix effects specific to** a particular technique, instrument specific inter-element effects or relative bias associated with variations between sample type and available appropriate standards. Personal bias can also be a source of systematic error, especially when there is a preconceived idea as to the required concentrations in CRMs and in-house standards run with sample batches. One of the few checks to determine systematic error is the use of standards or controls; however, it is advisable not to acquaint the analyst with either the location of these samples in the batch or the expected concentration of analytes in them. In this way, bias can be removed. This approach has a fundamental advantage, in that wrongly certified values soon become known.
- **Gross Error: These errors result in completely incorrect results being obtained.** They are the result of such things as mis-labelling of samples, incorrect preparation procedures, vessels contamination, incorrect instrument set up, bad calculations, *etc.*  
Such errors are usually random, can be identified, and are corrected quickly with the use of quality control procedures such as the submission of blanks, duplicates and controls with samples.

# The Sample

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**Collection of a representative sample is the most important aspect of any exploration programme and anything that happens after that is of no significance if the sample has been collected incorrectly. Thus serious considerations are imperative Prior to Sample Collection. Gathering meaningful data begins long before the laboratory analyst ever receives the samples. It is important to determine what constitutes a representative sample of the material being investigated. Questions to keep in mind include:**

- How many samples are required to answer the scientific question posed?
- Do these samples need to meet some sort of spatial resolution?
- Do the samples need to be representative of something larger than themselves?
- What is the minimum mass or volume of each sample needed to perform all necessary analyses, keeping in mind reserve splits may be necessary?
- What is the minimum number of samples required for statistical significance?
- What sorts of field QA/QC samples (blanks, duplicates, and so forth) are appropriate? Some of these questions may be answered with the assistance of a literature search. Often other researchers have published information on proper sampling methods, preservation methods, potential pitfalls, and analytical techniques on similar topics or study areas.
- Field time is expensive, and developing a thoughtful sampling plan prior to collecting samples gives a Geologist more time in the field to actually be sampling and ensures that the samples that were collected will appropriately address the scientific objectives of the study .

# QAQC Protocols

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**A** company that follows best practice standards should have a robust Quality management system which among other issues include:

- Quality Management Policy
- Utilising Competent, qualified and experienced Personnel.
- Provide adequate and high quality resources-Equipment and Funding for the project.
- Comprehensive QAQC protocols are developed and timeously reviewed as neccessary.
- Acts in real time when a problem arises (QC) before its too late to save money & time.
- Subjects itself to Independent external audits and may include independent professional companies validating its databases as well as carrying out Independent Technical reports to include resource estimations.
- Invests in continual improvement initiatives including training, research and development.
- Uses certified Laboratories for analysis of exploration samples especially where the ultimate is to use the results for public disclosure results and external Capital raising/Investment. Signs a performance agreement with the Lab and audits it regularly.

# QAQC Protocols

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- **Developing robust custom made QAQC protocols is the first major step towards a successful Quality Management System. Each project, operation or deposit is unique and protocols have to be tailor made to suit site specifications. Its is however critical to research and learn from similar best practice operations, adapting where possible and modifying where necessary.**

**The following should form an Intergral part of a diamond drilling QAQC protocol:**

- I. Safety Health and Environmental Management
- II. Use of Standard templates and codes-Logging, Sampling & Assaying
- III. Clear procedures on , siting , drill collar and down hole surveys, sample collection, sampling, splitting, sub-sampling and contamination control.
- IV. Use of Certified reference materials (CRMs), Blanks, Duplicates, dope pills, Check samples
- V. Secure Custody & secure access Measures
- VI. Storage and Preservation measures
- VII. Core Photography
- VIII. Geotechnical assessment-Core recoveries, RQD, core orientation, etc.
- IX. Analytical procedures
- X. Drill core density estimations
- XI. Sample storage and Preservation measures
- XII. Results Pass/Fail protocols
- XIII. Database management including data validation, storage/backup.
- XIV. Treatment of Historical data
- XV. Training

# Certified Reference Materials

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- **Certified Reference Materials (CRMs)**
- **Purpose:** Certified Referenced Materials [CRM] are inserted to measure analytical precision and accuracy of laboratory analyses. CRMs are unaffected by sample preparation procedures and are meant to only test the analytical equipment/procedures that are used in the analysis laboratory.
- **Protocol:** The Geologist should insert CRMs that are sourced from a competent and certified supplier at a rate of at least 1 in 20 (5%) samples being submitted to the assay laboratory. It is recommended to utilize a minimum of 3 different CRMs with assay grades representing a range of values coincident with grade ranges found in a deposit. CRMs will be categorized as Low, Medium and High. CRMs in the Very Low and Very High categories may also be used.
- CRM's grade values and identity will always be submitted blind to the assay laboratory.
- Upon receipt of the assay certificate of analysis the Geologist must compare the results obtained to the stated standard deviations (SD) as listed by the product supplier. Samples that exceed 2 SD will be assigned a warning, samples that exceed 3 SD will be deemed to have failed. Certificates that contain failed CRMs will have a minimum of all samples repeat assayed to verify that errors in analysis up the last BUT excluding the last passed CRM
- **Matrix Matched CRMs**-It is best practice to use reference materials that match or have a similar matrix as that of the routine samples being analysed.
- It is recommended that **ONLY** the Field Geologist or Geological Technician insert QAQC samples into the sample stream to minimise errors related to sample swaps and allocating incorrect sample ID in the sampling form that remains on site.

# Blank Samples

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- **Blank Samples**
- **Purpose:** Blank samples are inserted to measure the level of contamination that may occur during the sample preparation procedure as well as during assaying.
- **Protocol:** One must insert blank samples that are sourced from material that does not contain the intended mineral or contains the mineral in such low quantities that this will be below the analytical detection limit.
- Two types of blanks are recommended, namely coarse and Pulp blanks.
- The coarse blanks will be applied at a rate of a minimum of 1 in 20 (5%) samples being submitted to the laboratory.
- The coarse blank material will be confirmed through prior analysis of the representative portion of the material by a certified laboratory where grades will be confirmed to be below detection limit. The Company will submit a minimum of 0.5 kilograms of non-gold bearing material. It is best to use a coarse (>3cm) material for blank samples that requires sample preparation prior to analysis.
- Coarse blanks should be inserted at the beginning of each batch for quality assurance purposes to check for inter-batch decontamination thereby assessing effectiveness of the Lab decontamination procedure.
- In addition, a coarse blank will also be inserted in the middle of and immediately after the high grade mineralized zone to check for contamination.
- It is good practice to also incorporate Certified blanks (pulp blanks) sourced from a Certified supplier for use in assessing analytical contamination and including sample mix ups.
- Pulp blanks may also be derived from ground up (milled) glass. In order to be effective, the Pulp blanks will also be inserted immediately after high grade samples.
- By so doing the Pulp blanks will be assayed immediately after the high grade sample whereas the coarse blank will be prepared immediately after the high grade sample.
- Blank samples must always be submitted blind to the assay laboratory.

# Duplicate Pulp Analysis

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- **Purpose:** Duplicate pulp analyses are conducted to measure the level of sample bias that may occur during the sample preparation procedure. Broadly if done correctly, it is a measure of nugget effect and overall homogeneity of the milled sample.
- **Protocol:** Duplicate pulp analysis will be conducted at a rate of 1 in 20 samples and indicated to the laboratory by assigning two sample ID's to a single sample during early exploration drilling.
- Upon receipt of the certificate of analysis the Geologist will compare the results of the two pulps. Calculated variation in the samples will be measured and samples with variation that exceeds 100% and with at least one value above 3ppm will be flagged as likely to exhibit nugget effect and will be analyzed using the pulp metallic technique.
- **Procedure:** During core sample preparation a worker will assign two sample ID tags to a single sample as outlined by the geologist on the sample preparation work order. To ensure proper records are maintained the worker will initial to verify the duplicate pulp sample was properly assigned.
- During laboratory sample preparation a worker shall collect two (~300gram) subsamples from the crushed reject and each will be pulped separately for analysis, each pulp being assigned a separate sample ID. The two pulps will be analyzed using identical methods of analysis and in accordance with the Company's normal assay protocol.

# Duplicate Core Analysis

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- The best way of generating duplicate core samples in the field is by collecting the second half of the split core and submitting it for analysis with the original sample under a different sample number. However, most companies would want to retain the second half of the split core for future use and for audit purposes. The way to do it is by collecting the duplicate after the coarse sample preparation stage (crushed duplicate) and then adding this to the sampling stream.
- The use of quarter core for this purpose is not recommended as it introduces a different sub-sampling stream which is biased sampling.
- However, this is different for RC samples where duplicates can be collected in an identical fashion from the original sample.
- In the strict sense circumstances duplicate samples are analysed in the same sample stream as the original samples using the same laboratory, same batch and same time, same equipment and same laboratory personnel under the same conditions.
- It is recommended that some of the samples are analysed this way while some are treated in later batches to help check for sample preparation and analytical errors.

# Check Samples

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- **Purpose:** To evaluate the level of precision, accuracy and analytical errors that may be present at the primary assay laboratory.
- **Protocol:** A Company may submit up to 3% of subsample pulps analyzed at the primary laboratory to a secondary laboratory for analysis utilizing the same or very similar procedures to the primary analysis. The results of each analysis will be compared and where average discrepancies above 50% are noted within a batch of assays the batch will be flagged as having produced irregular results; as a result the batch may be submitted to a 3<sup>rd</sup> independent laboratory (Umpire) for verification. To limit nugget effects only sample pulps will be re-analyzed as they are deemed to be homogenized.
- **Umpire sample**-In the strict sense- an umpire sample is a *sample taken, prepared and stored in an agreed upon manner for the purpose of settling a dispute*. The agreement usually extends beyond the sample to the basis for reaching a decision (e.g. quantity of material from which its taken, use of a third party and criteria serving as the basis for acceptance, rejection or economic adjustment).
- **Procedure:** Upon receipt of the primary assays the company will select at **random** up to 3% of the samples to be re-analyzed at a second laboratory. Ideally pulp sub-samples should be shipped to the secondary laboratory by Company personnel.

# QAQC Insertion Rate Example

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Sample Type	Sample Sub-Type	Suggested Insertion Rate %		Minimum (Mandatory) Insertion Rate %
Duplicates	Twin Samples	2	6	5
	Coarse Duplicates	2		
	Pulp Duplicates	2		
CRMs	CRMs	5	5	5
Blanks	Coarse Blanks	3	6	5
	Pulp Blanks	3		
Check Samples	Check Samples	3	3	
<b>Total</b>	<b>All</b>	<b>20</b>	<b>20</b>	<b>15</b>

# Pass/Fail Protocol

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This should be site specific. The rules should be guided by what is practical. Certain deposits such as those with inherent heterogeneity such as stockwork deposits which have serious nugget effect will almost certainly give challenges in attaining high precision when duplicate samples are analysed. Thus the applicable precision for such a deposit will be evaluated on its unique merits.

Pass/Fail Protocols can be assigned to:

- QAQC samples (CRMs, Blanks, Duplicates, dope pills) against expected values
- Density estimations by comparing against acceptable ranges for different rock types under different degrees of weathering, oxidation and alteration and Mineralisation.

# Pass/Fail Criteria

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Sampling is normally organized into batches of 20 samples or less to make it possible to ring fence any problem that may arise. There is no one size fit all when defining parameters for rejection of results. In all cases common sense should prevail. The acceptance range should not be too wide nor too narrow.

- A whole batch would be rejected if the CRM results were beyond 3 standard deviations from the expected. A rejection would also be carried out if evidence of bias/drift was noticed. Results would be rejected when two consecutive batches show two CRM results were beyond the two-standard deviation limit on the same side of the mean.
- A field blank result greater or equal to a set upper limit would be rejected. A warning limit is also used to attract attention. The upper limit is dependent on how the blank was prepared. For a certified blank, the prescribed upper limit given by the supplier should be used.

**Coarse repeats-** Are useful in monitoring sample batches for poor sample management, contamination and tampering/swapping and laboratory precision. These can also used to assess inherent sample nugget effect. The repeats can be used to detect possible analytical drift. Some workers reject results where % Difference is greater than 30%.

**Pulp repeats-** Higher precision is expected from pulps. Some workers reject results with a % difference greater than 20% . A HARD (Half Absolute Relative Difference) greater than ten could result in rejection if there is sufficient evidence supported by other QC instruments such as CRMs and Blank or if a clear case of possible swapping is noted.

Repeat values proximal to the detection limit not considered failures as analytical precision becomes poorer as one approaches the detection limit

# Treatment of Failed results

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Where a QC sample result is defined as having failed, the process defined below is undertaken for the failed sample and the surrounding analytical sequence. The sequence analysed begins at the sample immediately after the previous QC sample of the same type that did not fail up to immediately before the next QC sample that also did not fail. The QC samples defining the ranges for analysis must be of the same type as the failed QC (i.e. CRM if CRMs failed, Blanks if Blanks failed). Important to note that in the case of the CRM, exactly the same CRM would be used as the failed one, as this will help to compare “apples with apples” when passing/failing the repeated results.

The treatment of failed QC samples involves:

- Initially sample information registered in the field is investigated to eliminate possible errors in the field such as transposition of a routine sample with a QC sample. A detailed audit trail will be established to investigate potential sample mix-ups in the field.
- Data in the database is compared with sample information (logs, sample register, sample tickets etc) to ensure the error was not caused by typographic/transcription errors.
- Once errors in the field and data entry have been eliminated, the QC failure is assumed to have occurred in the Laboratory. In that case the sample sequence surrounding the failed QC sample is sent for re-assay.
- QC samples are inserted into the sequence using the same type of QC samples as the failed original.
- The pulp samples for these sequences with newly inserted QC samples are sent to the original Laboratory for re-analysis.
- If the new results pass the pass-fail protocol then these will be the accepted results and incorporated into the database. If the results still fail, the pulps will again be sent for re-analysis until the results pass. Should the results fail for the third time, then the samples will be sent to a secondary accredited Laboratory.
- The failed results are kept in a separate database for the record.

# Drill core Density Estimations

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- It is good practice where practical to have density measurements estimated for all assayed samples.
- Density scales can be used for accelerated and accurate measurements
- Great care being taken when estimating densities for porous and weathered samples. Here samples can be sealed with cling wrapping paper, or encapsulated in wax.
- Anomalous values should be checked for errors by repeating the measurements.
- Detailed logging can explain true low and high density values on the basis of lithology, alteration, weathering and mineralisation.
- Great care must be taken to ensure the samples are totally dry before density measurements are taken.
- Density data are used in resource modelling and density values interpolated in same way as mineral grade values are interpolated into the resource model.
- Densities can also be checked against expected ranges for various rock units after taking into account the unique features of lithology, alteration, mineralisation and weathering and oxidation.

# Core Photography

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- It is best practice to photograph core using a high resolution camera of over 9 Megapixels. The photographs should be from a fixed mounted camera at a consistent height above the boxes and in similar light conditions and a scale bar included as well as reference colour chart.
- Core Photography is an invaluable tool in preserving drill core information and can be used in validating logging and other parameters in an audit. This includes:
  - Verification of geotechnical information.
  - Verification of Weathering/Oxidation profiles
  - Verification of alteration styles, eg silicification
  - In cases of intense sulphide mineralisation, this can be discernible in core photographs.
  - Verification of drill hole details such as EOH, hole IDs, sampled Intervals (where core is photographed before and after sampling)

# Other quality considerations

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- In a drilling Programme, other important quality considerations include:
  - Optimised drill hole location and drill hole density
  - Accurate drill collar surveys and preservation
  - Accurate down hole surveys
  - Secure sample storage and preservation of samples with unstable minerals.
  - Preservation of samples for future use in Metallurgical and Mineralogical tests.
  - Comprehensive sample chain of custody.
  - Adequate sample storage security.

# QAQC in Exploration Geochemical Surveys

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The principal objective of exploration geochemical surveys is to locate mineral deposits at the lowest possible cost. It is necessary to have reliable survey results so that areas with no apparent geochemical response can be abandoned with confidence.

Misinterpretation, sampling inconsistencies or poor quality analytical data can lead to expenditures on areas with “false anomalies”, which is a waste of time and resources.

# Soil Sampling considerations

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## ● GUIDELINES FOR SAMPLING SOILS

- Soil samples are a widely used geochemical sampling medium
- Soil sampling is generally recommended in the following situations:
  - Areas of residual soil over saprock;
  - Areas with soil developed on *in situ* regolith;
  - Areas with soil developed over transported regolith that is less than 5 m thick.
- Soil sampling may be appropriate in areas of deeper transported cover (up to 10 m thick) where deep-rooted vegetation has been active.
- Most soils in the region contain a transported component (e.g. wind-blown dust/silt, alluvium/colluvium, lag transported by sheetwash) and some consideration needs to be given as to whether this component is likely to be a significant dilutant or contaminant and the extent and direction of transport. Calcrete nodules or finely dispersed carbonate are commonly present in the alkaline soils of the region (particularly in the lower part of the soil profile) and may affect partial extraction techniques that are pH sensitive. Carbonate-bearing zones may have higher gold concentration.
- **Sampling program**
  - Parameters that need to be decided are:
    - Sample spacing;
    - Soil horizon to be sampled, which broadly relates to the depth of sampling;
    - Soil fraction to be sampled and analysed (generally either bulk soil or a particular size fraction);
    - Method of sample digestion and analysis.

- ***Sample spacing***

- Soil samples are generally collected on a rectangular pattern, generally with closer spacing of sample sites along more widely spaced sample lines. Theoretically, the sampling lines are oriented normal, or at a high angle, to the expected longer dimension of the target, but the orientation of a geochemical dispersion pattern is generally not well known, if at all, before sampling.
- The optimum spacing between sampling lines and sample sites will depend on the purpose of the survey and the expected size of the dispersion halo to be detected. Generally the aim is to obtain at least 2 samples from the anomaly on a sampling line. Common sample spacings for reconnaissance soil sampling are 400m by 400m or 200m by 400m. For detailed anomaly detection samples are commonly collected at 100m intervals on 200m spaced lines with infill sampling down to 50m on 100m spaced lines.
- ***Soil horizon to be sampled***
- The near surface layer (< 50 cm) of many of the soils has a large component of wind blown dust or has been partly eroded and disturbed by agricultural activities. Near surface samples may have advantages in areas of deep transported or leached regolith where the target and pathfinder elements have been taken up by deep-rooted vegetation to be deposited and accumulated in the humus component of the upper soil layer (although in some areas this has been eroded away). The near-surface zone of the soil may also contain ferruginous lag fragments which retain a geochemical signature from their source.
- In very shallow soils (e.g. skeletal soils on bedrock rises) it is probably best to sample as close to the base of the soil as possible. For deeper colluvial and alluvial soils (particularly where they have been ploughed) sampling below the plough hard pan (about 50 cm) will give a less disturbed or contaminated clay-rich sample.
- As with most sampling methods, it is important to be as consistent as possible in terms of the type of material collected (but not necessarily the depth of sampling).

# Soil Sampling Considerations

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- **Soil fraction**
- Traditionally, soil geochemical surveys have targeted the finer fraction ( $<120\ \mu\text{m}$ ), clay-rich B horizon, in the belief that cations present will be largely adsorbed onto clays. This will be influenced by the type of clays in the soil, for example kaolinite and illite have very low cation exchange capacities, whereas smectites have high cation exchange capacities.
- The coarser fraction (up to 2-3 mm) will target these soil components and a number of studies have shown that the 0.1-2 mm fraction generally gives a stronger response for most target and pathfinder elements. The simplest option is to take a bulk sample of material less than 3 mm in size, which will include grains of lithic and ferruginised lithic material and the finer clays and granular carbonate. The wind blown component is generally in the 60-80  $\mu\text{m}$  size range so selecting the 100  $\mu\text{m}$  to 3 mm fraction will largely remove this dilutant (mostly quartz and kaolinite) although it may also remove much of the residual clay component, powdery carbonate and fine organic matter.
- **Method of sample digestion and analysis**
- The sample digestion method will depend to some extent on the elements being targeted and their host phase/s. A strong acid digest is most suitable for all round multi-element detection where the target and pathfinder elements are both weakly and strongly bound in ferruginous and weathered lithic components.
- Aqua regia is commonly used because it will dissolve elemental gold, as well as breakdown iron and manganese oxides/oxyhydroxides, carbonates, sulphates, sulphides and many clays. It will not release elements or minerals included within quartz (including silcrete) or other insoluble silicates nor dissolve resistate minerals such as chromite, rutile, cassiterite, ilmenite, zircon.
- Near total digestion of samples, including the silicates (but not resistates), can be achieved with a multi-acid digest of hydrofluoric-perchloric-nitric acids. This is not suitable for gold analysis and has the other disadvantage of producing solutions with high total dissolved solids, which can affect the sensitivity of the analytical method.

# Soil Sampling Considerations

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- Instrumental neutron activation analysis (INAA) or X-ray fluorescence analysis (XRF) can be used for true total multi-element analysis. These methods cover a wide range of elements and have the advantage that the elements do not have to be taken into an aqueous solution. These techniques are also commonly used to independently check analyses obtained by other methods.
- The various options for sample digestion and analysis should be carefully discussed and negotiated with the analytical laboratory providing the service.
- ***Sample location and sampling methods***
- Shallow samples are conveniently collected using a pelican pick (or similar). A planting shovel (with narrow straight blade) may be more efficient in hard soils .
- Deeper samples can be collected with a hand auger (e.g. standard 20 cm diameter soil auger). Practitioners in the region prefer a small diameter (6.5 cm) Jarret or Dormer auger for deep sampling in hard clay-rich soils. Four wheel drive mounted, motorised spiral augers have also been used. These can have difficulties when layers of pisoliths are intersected in the soil.
- For most soil sampling surveys, 300-500 g samples are sufficient, although larger samples (up to 5 kg) may be collected for bulk leach extractable gold (BLEG). Collected samples should be placed in chemical-free paper (geochemical bags) suitable for drying in the sun or a drying oven.
- Sample preparation and sieving should be conducted in areas free from any wind blown contaminants and particularly away from active mine sites.

- END
- MERRY CHRISTMAS
- Thank you and