DRILLING FOR INDUSTRIAL MINERALS: QUALITY PROCEDURES AND THE END USER

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INTRODUCTION

Industrial minerals are normally classified and specified according to their end uses. Common examples are gypsum in wallboard and talc in body powder, where properties such as colour and chemical purity are important. It is essential to understand the mineral quality and mineral distribution of a deposit in order to meet the specifications as defined by a manufacturer or end user.

For any type of industrial mineral project, the main economic driver will be the market available for the mineral's non-metallurgical properties.

Classification of industrial mineral deposits requires an understanding of exploration drilling procedures, given that drilling methods could affect intrinsic properties of minerals.

Good control on the quality of data generated during the exploration drilling and project evaluation phase is vital. It is the data produced during a drilling campaign that forms the basis for all subsequent decision making on the specific end uses of an industrial mineral.

QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC) PROCEDURES IN INDUSTRIAL MINERAL EXPLORATION DRILLING PROGRAMS.

Publicly traded companies are now required by the Australian Securities Exchange (ASX), and other bourses, to release data that is accompanied by an outline of sampling and QA/QC procedures used during the collection and analysis of exploration samples. Many financial institutions now require an impartial audit.

Work carried out on graphite and vermiculite drilling projects detail the fact that a good QA/QC program is one that is active and regularly reviewed throughout the data collection process (Scogings and Coombes, 2014). This ensures quality information flow for end use study.

Twinned Holes

One method used to verify the quality of sampling and assaying on exploration projects is the use of twinned holes. This is used to compare the results from a reverse circulation (RC) rock chip drillhole by twining the hole with a diamond drill (DD) hole producing core.

Twinned holes are specifically referred to in the JORC Code (JORC, 2012) Table 1for the verification of sampling and assaying, and are traditionally drilled for verification of historic data or confirmation of drillhole data during geological 'due diligence' studies.

"Twinned holes are typically drilled less than 5 metres apart and are best compared according to geological units, individual samples or equal-length composites. Repeatability of analytical results and bias must be statistically quantified. Compositing of short and or variable length samples into composites of a larger size converts samples into common length data, necessary for geostatistical evaluation. In addition, grouping samples to larger composites (by geological boundary) helps to minimise the noise exhibited by individual samples," (Abzolov, 2009).

Case Study: Graphite Twinned Holes

QC work carried out on an African graphite project used the process of twinning drillholes to check drilling results (Scogings and Coombes, 2014). Three pairs of twinned holes were drilled to compare the percentage of graphitic carbon (% Cg) in RC vs DD samples. A visual comparison of mineralised intersections in the twinned RC and DD holes suggests an overall similar representation of the mineralisation (see Figure 1 for an example of one pair), especially when the 1 m samples are composted to 3 m lengths to reduce noise. The similarity in assay results is evidenced in a quantile-quantile (QQ) plot comparing the grade percentile

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from the two data sets (Figure 2). On the basis of the similarity between the RC and DD twinned drilling results, it was concluded that RC and DD data could be combined for resource estimation purposes (% Cg only, not flake size or quality) since there is no significant bias between the twinned drillholes.

Figure 1. Two comparisons of twinned RC (left borehole) and DD (right borehole) showing % Cg assay results. Left hand side pair shows 1 m sample intervals (logged barren intervals in DD hole were not sampled). Right hand side pair shows samples composited to 3 m lengths (Scogings and Coombes, 2014).

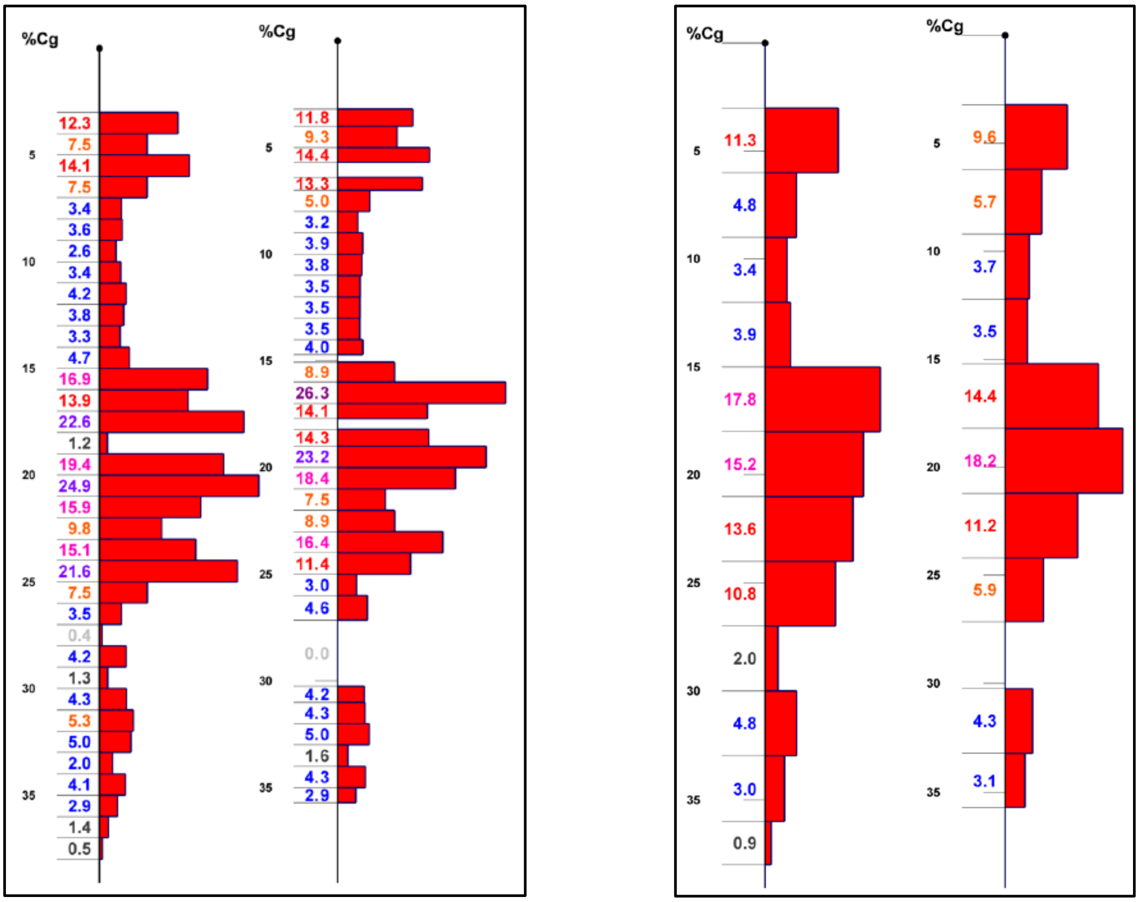
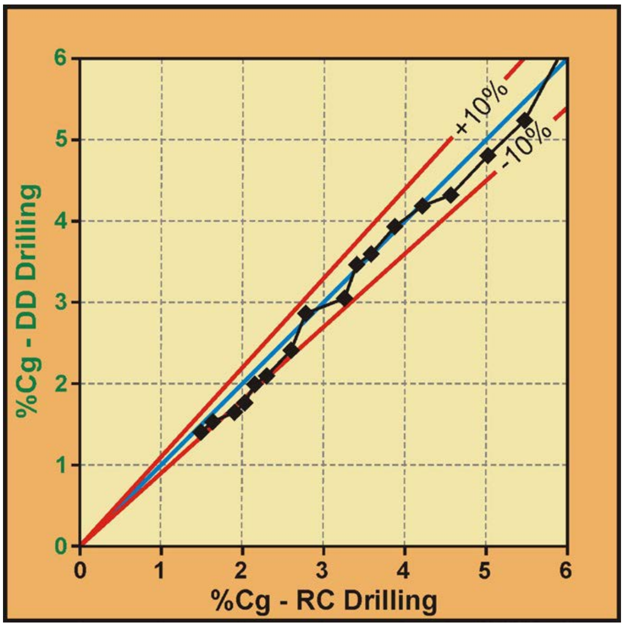


Figure 2. QQ plot comparing % graphitic carbon in twinned RC and DD holes (Scogings and Coombes, 2014).



Assuring Quality Data from a Laboratory

Other methods used to verify the quality of sampling and assaying on exploration projects are the use of standards, blanks, duplicates and external laboratory checks.

Standards or certified reference materials (CRMs) are samples of known or accepted value that are submitted to assess the accuracy of a laboratory. A systematic difference from the expected CRM result indicates a bias within or between assay batches.

Standard samples may be purchased commercially or may be prepared internally and it is recommended to submit standards that span the practical range of likely assay values (e.g., % Cg) or market performance tests (e.g., bentonite fluid loss).

Abzolov (2008) recommends insertion of 3-5% of the standard(s) in each sample batch to identify bias, whereas Verly (2012) suggests 6% (Table 1).

Table 1. QA/QC sample insertion rates suggested by Verly (2012).

Sample Type	Sample sub-type	Insertion rate	
Duplicates	Field samples	2%	6%
	Coarse duplicates	2%	
	Pulp duplicates	2%	
CRMs	CRMs	6%	6%
Blanks	Coarse blanks	2%	4%
	Pulp blanks	2%	
Checks	Check (umpire) samples	4%	4%

Source: Scogings and Coombes, 2014.

Blanks are barren samples with an expected low grade (value) relative to the mineralisation being evaluated and are submitted to check for contamination during sample preparation or assaying of major and trace elements. Although blanks are commonly used during exploration for precious metals, base metals and some industrial minerals such as graphite (Cg), phosphates (P_2O_5) and potash (K_2O, MgO, NaCl), they are less likely to be used for other industrial minerals where market performance is generally more important than elemental analysis.

Blanks are effectively another type of CRM, albeit with very low values of the element(s) in question. Verly (2012) suggests an insertion rate of 4% blanks (Table 1).

Duplicates are samples collected, prepared and assayed in an identical manner to an original sample, to provide a measure of the total error of sampling. There are several types of duplicates possible: field duplicates are collected at the drill rig or trench, while laboratory duplicates may be produced by taking a second split after crushing, before the pulverising stage, or a third split of pulp after pulverising (e.g., 90% passing 75 micron).

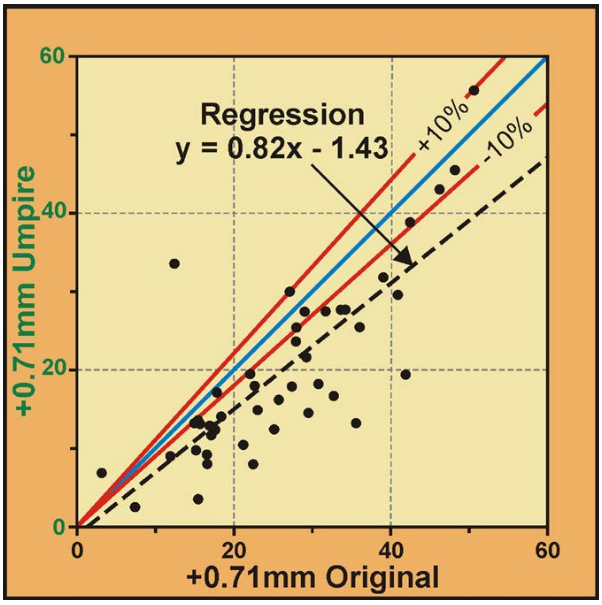
Importance of Laboratory Checks

External laboratory checks generally rely on pairs of pulverised exploration samples (also known as umpire samples) to define inter-laboratory precision and bias. It is suggested that at least 5% of samples be tested by an umpire laboratory.

Recent work on a vermiculite project highlights the importance of using an umpire laboratory (Scogings and Coombes, 2014). During the QA/QC process it was noted that an external laboratory used a surfactant that gave artificially low values – this demonstrates how crucial it is to use consistent laboratory methods.

A comparison between 46 samples from an external laboratory and the original samples showed an overall difference in mean grade. A scatterplot between the check samples and corresponding original laboratory shows a significant positive bias towards the original laboratory (Figure 3).

Figure 3. Scatterplot between vermiculite original and umpire samples. Correlation coefficient = 0.8 (Scogings and Coombes, 2014).



This bias between the sample data sets was also evident on comparative histograms and a QQ plot. Further investigation into the bias highlighted differences in analytical procedures, with the original lab reporting vermiculite inclusive of some entrained impurities and un-exfoliated material, whereas the umpire laboratory process produced a more refined product and hence lower recoveries as is evidenced in the statistical plots. Such umpire data may be used to adjust the original data by means of regression, which is the process of fitting a line to data and applying the best-fit equation, for example y = 0.82x + 1.43 (Figure 3).

Drilling With the End User in Mind

Procedures used in a high purity quartz (HPQ) project in Northern Queensland show the importance of selecting the right drilling method to classify the deposit considering the highly specialist end user requirements.

The project owner had requested a cheaper reconnaissance drilling method such as RC for the initial testing and sampling of the deposit area. A review of the market specifications (see Table 2) for HPQ indicated that very high levels of sample quality would be required by the drilling method.

Table 2. Typical silica sand and quartz specifications by market.

Type or Application	SiO2 minimum %	Other Elements maximum %	Other Elements maximum ppm
Clear glass grade sand	99.5	0.5	5,000
Semi-conductor filler, LCD and optical glass	99.8	0.2	2,000
‘Low grade’ HPQ	99.95	0.05	500
‘Medium Grade’ HPQ	99.99	0.01	100
‘High Grade’ HPQ	99.997	0.003	30

Modified from Richard Flook and the December 2013 Issue of the Industrial Minerals Magazine (p25)

The only drilling method capable of producing the quality of sample required was DD. The project owner realigned their budget and exploration approach based on the highly specific end user requirements.

Recent work on a vermiculite project further highlights the importance of choosing the right drilling method. In this case, the initial exploration on the project had been carried out using the air core (AC) drilling method. During the QA/QC phase to check on the quality of the information produced for end user commercial assessment, two of the AC holes were twinned with DD holes.

When plotting QQ graphs for the fractions (in mm ranges) of sieved vermiculite material, it was noted that there was a positive bias for AC fraction 0.425 to 0.71 mm (fines). It was also noted that the bias changes as the size fraction increases.

It was concluded that the AC drilling method shreds vermiculite flakes and reduces their size relative to flakes in core samples and that samples with a large proportion of vermiculite flakes appear to be most affected by the AC method. Hence more extensive DD drilling was recommended to produce the required flake size analysis to satisfy the end users requirements.

Case Study: Drilling for Bulk Density

Industrial mineral resource estimations rely on three main inputs: i) grade, ii) volume and iii) bulk density, of which the latter is often relatively neglected during exploration. A study of exploration drilling work on a sodium bentonite mine in Queensland, demonstrates the importance of selecting the correct drilling and sampling technique for the estimation of bulk density.

The bentonite beds were deposited within a high energy fluvial/lacustrine environment of Upper Jurassic to Lower Cretaceous age. Several bentonite beds have been identified on the property; these range up to ~4 m in thickness and consist predominantly of dioctahedral smectite (montmorillonite) with accessory minerals including feldspar, kaolinite, quartz and zeolite (Scogings, 2014). The beds are capped by volcaniclastic rocks identified petrographically as either tuff or ignimbrite in addition to cross-bedded volcanogenic sandstone.

Measuring the in-situ bulk density (ISBD) of sodium bentonite presents a whole set of challenges related to the fact that such material absorbs water and swells; therefore, direct immersion in water cannot be used with much confidence.

All exploration drilling was carried out by an open hole method known as rotary air blast (RAB) using a bladed bit, which results in small drill chips unsuitable for water immersion or the calliper method. An alternative drilling method was considered in order to measure ISBD and after discussion with the contractor, the RAB rig was modified to drill core (without water) at several strategic locations. On reclaiming the cores, all samples were sealed in plastic bags to retain in-situ moisture before estimating density. The core samples were then trimmed with a hacksaw to yield regular cylindrical shapes from which volumes could be estimated using the calliper method (Figure 4), and moisture content derived from the ‘shavings’. Density values of between 1.72 and 1.84 t/m3 were obtained and it was elected to use 1.8 t/m3 for estimation of in-situ ‘wet’ bentonite resources (Scogings, 2015).

Figure 4. Bentonite core trimmed for calliper method. The core ‘shavings’ were used for moisture analysis.

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