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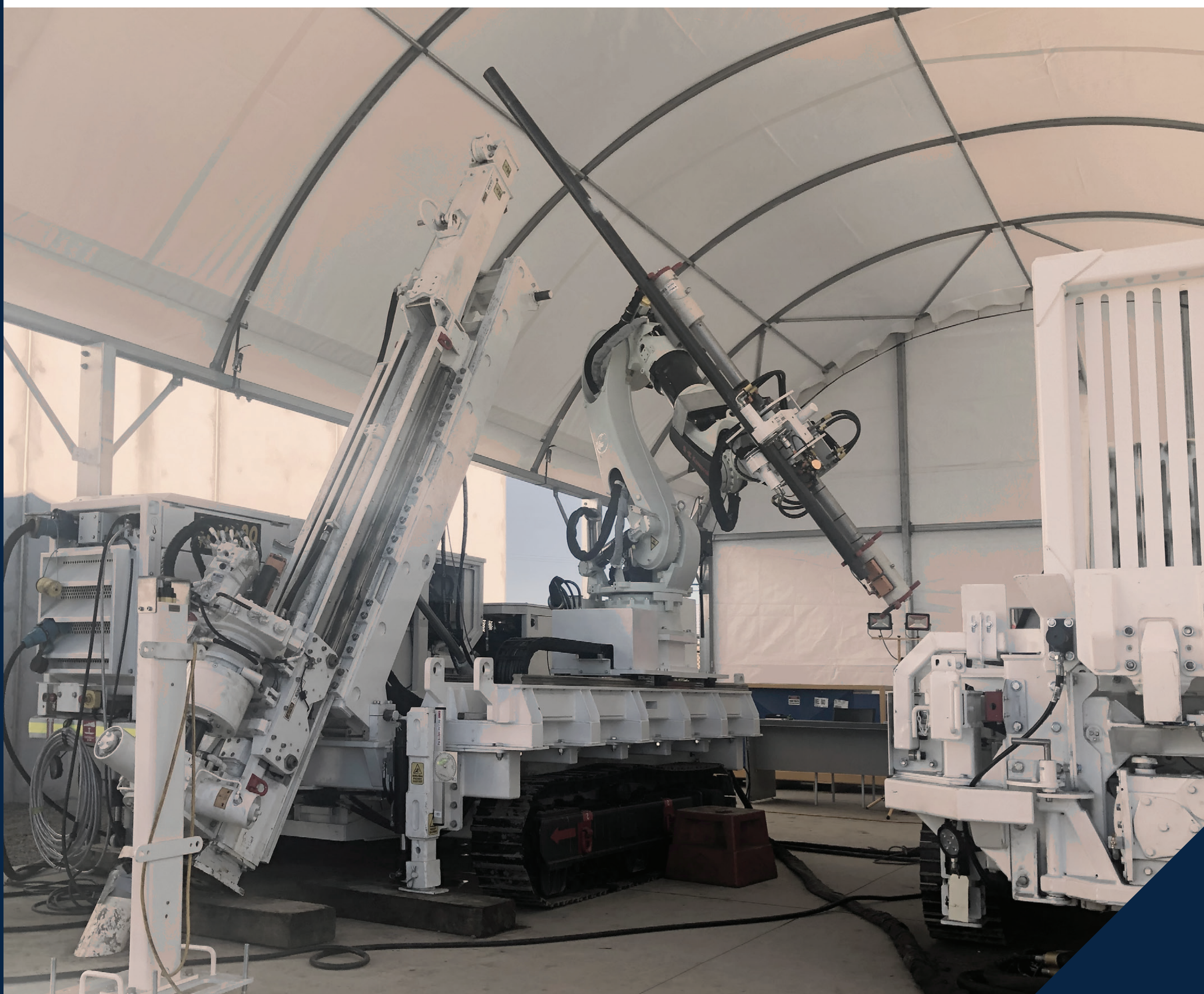

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Exploration Diamond Drilling

Drill Core Storage: Orientation regarding international best practices

PART I

By **Daniel Bortowski Carvalho**, Geologist and CEO at Core Case, **Gláucia Cuchierato**, Geologist and CEO at GeoAnsata, and Professor and Mining Engineer **Ana Carolina Chieregati**

Introduction

The quality and representativeness of data from a mineral deposit or potentially mineralized area is often the subject of much discussion among technicians and academics, especially when the commodity in question is a rare or base metal, as they are ores that have important variables to consider concerning their economic evaluation and extraction.

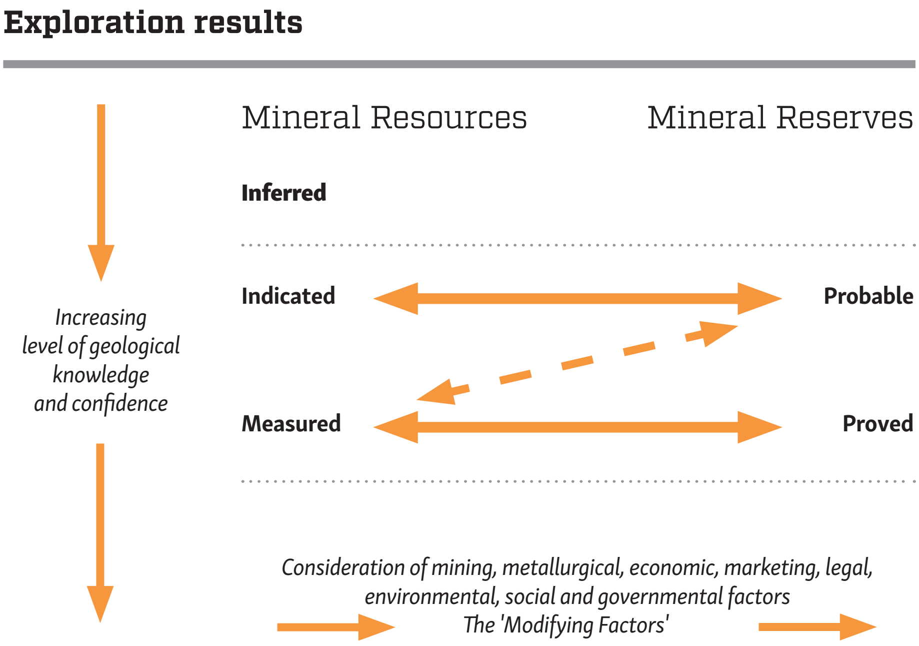

Figure 1 – Relationship between the exploration results, resources, and mineral reserves. Source: CRIRSCO (2006).

Companies adjust each phase and purpose of their operations, such as evaluation, establishment of the geological-metallogenetic model, grade quality control, and ore reconciliation, according to the drilling options on the market. However, we still lack a consensus on the best cost-effective method. In general, qualified professionals are responsible for conducting efforts to plan activities that reflect the highest quality, clarity, and repeatability of the processes, samples, and data, so as to adjust the available information to international standards.

Diamond drilling is considered one of the best practices for achieving this quality because it allows core to be obtained and preserved with several advantages over other methods, including a more representative, continuous, and homogeneous sampling regarding the characteristics of the ore at the mineralized interval, the occurrence depth, the mineralogy, the geological structures, and the amount of collected material.

Activities performed during drilling, through the study of sampling errors, quality assurance and quality control programs (QA/QC), and additional precautions taken to avoid contamination and bias, enable the collection of a better quality of core samples. It is mandatory for the mining industry to evaluate the advantages of the drilling process to reduce the operating costs of drilling campaigns, core management, and occupational risk management.

After considering an infamous case of historical mining fraud and the consequent scientific, economic, and technical-operational issues, this article sets out some crucial points on international reporting standards for defining the best procedures for sampling and the safe storage of information obtained at a mineral site.

Historical context

Recently used as a Hollywood script in the film Gold (2016) directed by Stephen Gaghan, the most famous mining fraud of all time was in fact the foundation for establishing the first international instruments for the public reporting of mineral resources and reserves by companies seeking funding on the financial market.

Bre-X Minerals Ltd, the centerpiece of this worldwide scandal, was a Canadian mining company founded by David Walsh. It was listed on the Alberta Stock Exchange (ASE) in 1989, with shares worth only a few cents, holding a few small prospects in northern Canada. In March of 1993, David Walsh partnered with geologists John Felderhof (who assumed the position of General Manager) and Michael de Guzman (Chief Geologist) for the assessment of a gold deposit in a hydrothermal venular system in northeast Borneo, Indonesia, in a place known as 'Busang' (Nicholls, 1999).

The drilling began in September 1993 with the analysis carried out in laboratories from the Kalimantan province on the island of Borneo. Early studies did not indicate significant positive results at these sites, and from 1994 to 1996 targets were expanded to other locations, where new exploration agreements and labor contracts were reached with the Indonesian government,

Figure 2 – Countries belonging to the CRIRSCO family. Source: CRIRSCO (2019)

with periodic reporting of results that were increasingly promising. In April 1996, the company had its IPO – Initial Public Offering at the Toronto Stock Exchange (TSX), with Bre-X shares traded at prices in above USD 200 per share. In July of that year, reserve estimates were released at 47 million ounces – compared to the world's largest gold reserve (Grasberg) which was estimated at 64.2 million ounces, the Bre-X deposit was considered the second largest in the world at the time.

After some attempts by large gold mining companies to operate in the region (Barrick Gold Corporation and Placer Dome Inc.), and interventions by the Indonesian government throughout 1996, there were suspicions of irregularities, with the annulment of labor contracts in December of that year and threats to the company's credibility, culminating in the recommendation by the Indonesian Minister of Mines and Energy, Ida Bagus Sudjana ('the Minister') to expropriate Bre-X in February of 1997. The previous month (January 1997), a serious fire at the Busang site in the core warehouse and offices destroyed the samples and all material proof.

Under these circumstances, in February 1997 Bre-X announced a joint venture agreement with the participation of the

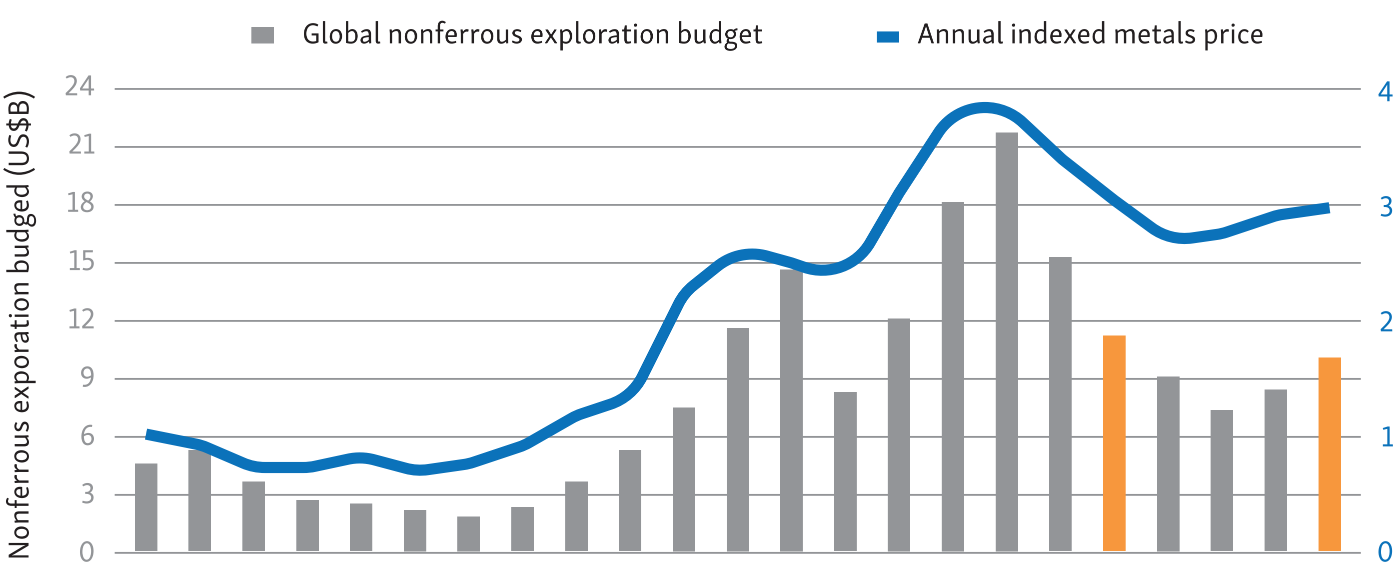

Figure 3 – Global evolution of investments in non-ferrous minerals is USD billions. Source: S&P (2019)

government (10 %), two domestic companies (30 %), and Freeport-McMoRan Copper and Gold Inc. (15 %), and Bre-X holding 45 % of the total shares. At the time of the merger, the resource valuation was updated and validated by the international consulting company Kilborn SNC Lavalin at 70.95 million ounces of gold. Freeport began their due diligence, and the initial results did not compare to amounts declared by Bre-X. Immediately, the managers and shareholders were informed and requested the presence of the responsible geologists. Before the meeting took place, geologist Michael de Guzman allegedly committed suicide during a helicopter flight on March 19, 1997.

The consulting company Strathcona Mineral Services was then commissioned to perform the official audit, and after finalizing the reanalysis of the samples, they stated in their report that there was unprecedented tampering and they held 'the firm opinion that an economic gold deposit has not been identified in the Southeast Zone of the Busang property, and is unlikely to be' (Nicholls, 1999, p. 185). Among the reported inconsistencies, the audit found a number of problems in sample preparation (such as the entire core being crushed) and in analysis techniques, but what most backed up the suspicion of tampering was the listing of the mineralogical characteristics of the gold ore as alluvial or placer, not hydrothermal, as was the case with the supposed original genetic geological model.

Although there were already some standard definitions of resource and mineral reserves reporting in several countries at that time – published by organizations such as JORC (Australasia), SME (United States), SAMREC (South Africa) and NI 43-101 (Canada), groups which were brought together by the creation of the CRIRSCO (Committee for Mineral Reserves International Reporting Standards) in 1994 – after the Bre-X fraud case the topic gained international notoriety, hastening the development of a new standard that could guarantee credibility for mineral asset statements and classification.

In response, CRIRSCO finalized the first international model for terminology and classification consolidation in 2006 with the publishing of the International Reporting Template for the Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves (CRIRSCO, 2006). With the Template, the classification already adopted by JORC and NI 43-101 was made official and consolidated internationally (see Figure 1).

Figure 4 – Distribution of global mineral research investment in 2017. Source: S&P (2018)

After its publication, countries that wanted to participate in CRIRSCO produced codes adhering to the Template, as was done by Brazil, which established the Brazilian Commission of Resources and Reserves (CBRR), made up of the Brazilian Association of Mineral Research Companies (ABPM), the Brazilian Agency for Technological Development of the Mineral Industry (ADIMB) and IBRAM, with the purpose of becoming the National Committee. In November 2015, at the CRIRSCO International Annual Meeting, held in Brasilia, this Committee formally accepted Brazil's membership, making it the 9th member country. The current CRIRSCO signatory countries are listed in Figure 2.

Economic context

The global budget for 2018 invested in non-ferrous mineral exploration was estimated at USD 10.1 billion, with 19 % per year growth, compared to the USD 8.5 billion investment in 2017, according to the World Exploration Trends report, presented by S&P Global Market Intelligence during the Prospectors and Developers Association of Canada (PDAC) Annual Convention in Toronto, in March of 2019 (S&P, 2019). Notably, there is optimism in the sector, where investment values are expected to increase at growth rates of 5 % to 10 % over the next few years.
Figure 3 shows the amounts invested in non-ferrous metal exploration since 1996, compared to the metal price index, highlighting the major cycles and the market recovery trend. Figure 4 illustrates the top destinations for investment in mineral exploration around the world in 2017 (S&P, 2018).

In Part 2, next issue, we will discuss the present international reporting standards and what they mean for core sampling, packaging, and storage.

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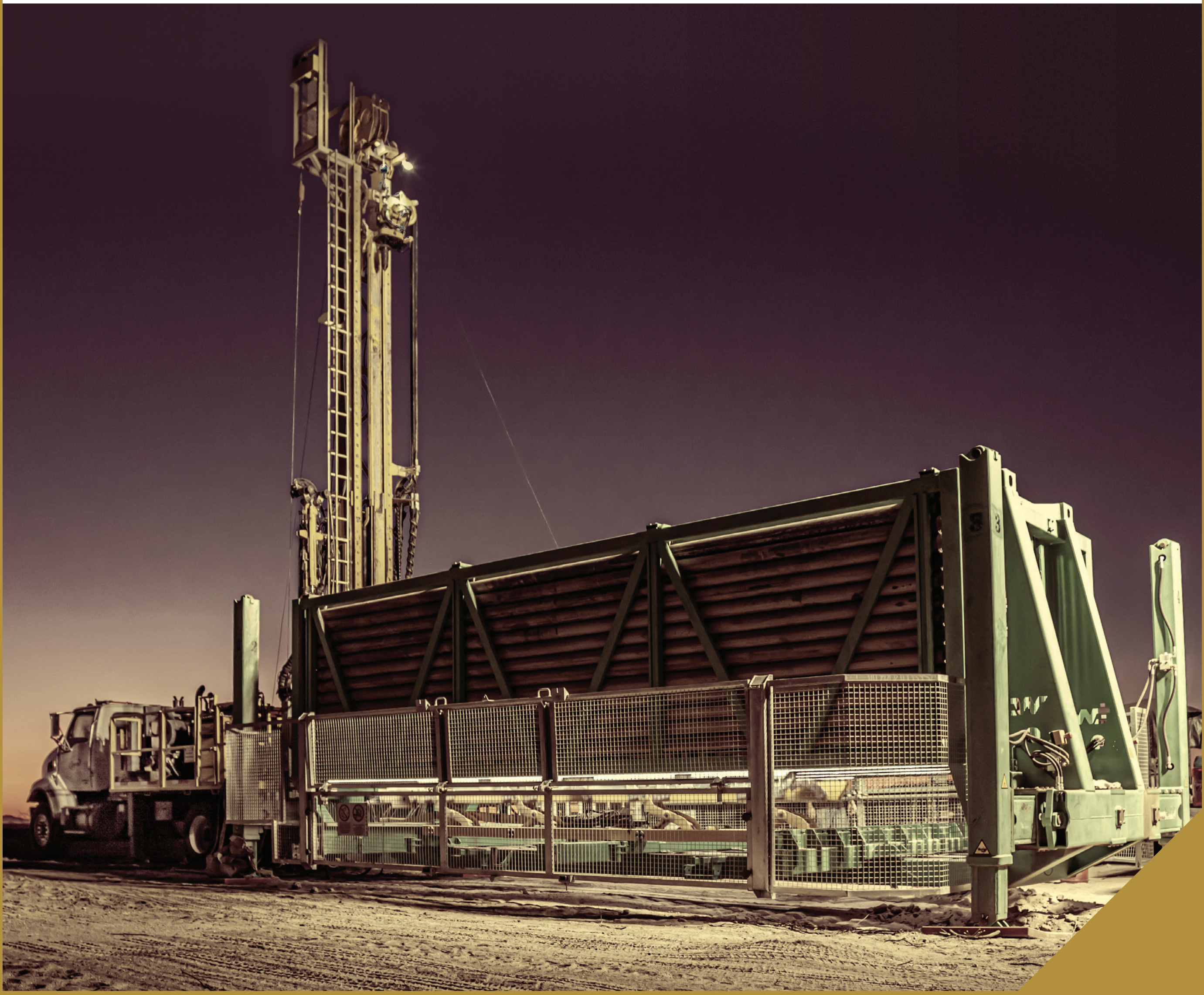

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Drill core storage: Orientation regarding international best practices

PART II

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Defining international standards

International reporting standards provide guidelines and best practice recommendations for the public reporting of exploration results, mineral resources and mineral reserves. Standardization of these codes is one of many advantages of adopting a methodology and systematization that is both equivalent and dynamic globally. Standardization enables comparison and benchmarking of similar projects using a shared presentation approach, as investors increasingly rely on quality information pertaining to financial markets.

All codes are based on three fundamentally important principles, as outlined within the Brazilian Commission for Resources and Reserves (CBRR, 2015, p.4):

- **Materiality:** Reports must contain relevant information that investors and their professional advisors would require and expect for the purpose of making a reasoned and balanced judgement regarding the exploration results, mineral resources and mineral reserves being reported. Explanation and justification as to the exclusion of relevant information must be provided.
- **Transparency:** Public reports must be easy to understand, clearly presented and contain sufficient and unambiguous information. Content should not mislead through omission of information known to the qualified professional.
- **Competency:** Public reports are based on work undertaken by suitably qualified, experienced professionals who adhere to a code of ethics and are bound by professional conduct.

Information regarding recommendations of materiality codes should be relevant to investor and advisor interests, enabling balanced and sound judgment as to the inherent business risk. Storage of data and information, both digital and physical including drill cores and samples, should be undertaken with priority afforded to security – controlled and defined by recognized and validated methodologies and criteria.

As for transparency, data should be presented clearly, effectively and unambiguously so that readers can understand the content, avoid misunderstanding, and not be misled, either by the information provided or through omission of insider information.

Competence is assigned to professionals who conduct, plan, supervise, execute and sign public reporting. Such professionals possess experience and impartiality to define the best techniques and methodologies in mining exploration, evaluation, and operation – all the while remaining conscious that they will have to justify their choices to their peers regarding theories on origin, type of mineral deposit and geological context or other discipline expertise.

In Brazil, a qualified mineral industry professional must register with CBRR or a recognized professional organization (RPO), possessing at least 10 years professional experience, of which at least five years' experience was obtained in the specific style of mineralization or type of deposit being considered, and the activity for which the person intends to assume responsibility; including at least three years in a position of responsibility (CBRR, 2015).

Other known names for such professionals include:

- Competent person: JORC (Australasia) / SME (USA) / SAMREC (South Africa) / PERC (Western Europe) / CRIRSCO
- Qualified person (QP): NI 43-101 (Canada) / CIM Standards Definitions (Canada) / SEC SK1300 (Canada)
- Persona competente (PC): Codigo CM 20235 (Chile), CCRR (Colombia)

The acronym, CP is often incorrectly used and previously granted to the category of 'Chartered Professional' by Australian RPO, Australian Institute of Mining and Metallurgy (AusIMM).

Image 1 – Examples of unsound core sample storage.

International reporting codes – regarded as solid market practice guides – make no specific recommendations regarding data and information density, drilling spacing or mesh, number of samples, quality control rates (QA/QC), or any other metrics, nor do they define forms of calculation or level of reliability/uncertainty associated with estimates. Any decision on how and what data will be collected or accepted by historical data validation, is made by the qualified professional (QP), according to their experience in mineralization, technical skills, and professional judgment.

A series of practice is recommended during data acquisition stages, allowing for project auditability as to the adoption of operational procedures at all stages to reduce and control potential errors during the drilling process, core description, sampling, sample preparation and laboratory analysis, packaging and storage. Such practice assigns credibility and reliability, while setting parameters for controls, validations and verifications.

The category into which the project is classified – exploration results, mineral resource or mineral reserve varies depending on the degree of confidence of the geological information supplied for the mineral deposit, the quantity and quality of available data, its interpretation and the project's technical and economic detail.

Sampling

Defined as a sequence of operations that aims to take a significant part, or sample, from a given universe. According to GY (1998), the sole purpose of sampling is to reduce the mass of a lot (L) without introducing significant changes in its other properties. Samples usually consist of a series of increments, taken from the universe, or lot, at different times. According to Chieregati (2007), the main objective of any sampling process is to select a representative or accurate and precise sample whose content is called $\mathbf{a}_s$. The $\mathbf{a}_s$ estimate should provide an accurate and unbiased estimate of the real and unknown content $\mathbf{a}_L$ of lot **L**. It can be difficult to reach this objective, as a lot of particulate material contains a certain amount of heterogeneity – the greater the material heterogeneity, the greater the difficulty of the sampling operation, leading to increased errors.

A suitable sampling plan is one that reconciles sampling costs with the accuracy required for the results, as they are directly proportional elements. It is, however, pointless and illusory to return an analytical result to three or four supposedly significant decimal places if the sample analyzed is insufficiently representative, and even more pointless if it is biased (GY, 1998). Improvements in the sensitivity, accuracy and reproducibility of the analyses are not limited to the quality of equipment or skill of the analyst, but by the difficulty of submitting representative samples to the laboratories, particularly at low or very low concentrations, such as gold ore (Ferreira, 1989 apud Chieregati, 2007).

Experts (CHIEREGATI, 2007; Chieregati et al., 2019; Piard, 2009; Esbensen & Minkkinen, 2004; Esbensen et al. 2012; DS 3077, 2013) have for a long time, given tremendous attention to the theoretical and practical problems of sampling materials containing precious metals. Relatively small amounts of this type of material can involve large amounts of money, therefore accuracy and precision soon become the primary concern. There is probably no other material for which accuracy and precision of sampling is as critical as for precious metals, especially gold, which presents sampling difficulties that must be studied and resolved in a specific way for each type of deposit to avoid sampling errors.

Heterogeneity is a unique characteristic associated with each material type and critical to all sampling (GY 1998; Pitard, 1993; Esbensen & Minkkinen, 2004). Heterogeneous materials interact with any usual sampling procedure, representative or not, causing various sampling errors with different manifestations. It is quantified as the total sampling error (TSE), specifically contributing to total analytical error (TAE), and should always be considered in overall estimation error (OEE) calculations. Primary factors that influence sampling include sample collection procedures and heterogeneity. In addition, close attention should be paid to the procedures for storing the data obtained by sampling. These can often be used in the future due to technological advancement, discovery and invention of new analysis methods. Improper data storage can impact the best data handling and analysis procedures, thereby causing errors, as is often the case within drill core sheds, where boxes contain rocks and sample pulp previously analyzed in the laboratory.

Sampling is the most important aspect of an exploration or mining company as it determines the value, or lack thereof of company efforts. An important aspect of the process is to uphold quality assurance and sample accuracy. Sampling process recommendations described within the CBRR Brazilian Guide (CBRR, 2015, p.32) are outlined below.

- Description of the sample type and method of sample collection (manual, trench, canal, fragment, core, diamond drill or reverse circulation, large volume sample).
- Discussion of sample quality, size, representativeness (sample recovery, biased sample, contamination or selective loss) and any other factors that may result in sample bias.
- The quantity and quality of sample data is critical to the reliability of resource estimates and should be well documented. Particular attention should be paid to this information.

The Canadian Institute of Mining, Metallurgy and Petroleum published the CIM Mineral Exploration Best Practice Guidelines (CIM) in late 2018 with the following sampling recommendations.

- Sampling programs should be conducted with care and diligence, using scientifically established practices, designed and tested to ensure representative and reliable results.
- A geologist should oversee sample collection and ensure a chain of custody is established and recorded. Supervision of sample preparation for analysis should ensure that any work by employees, contractors or consultants is undertaken by trained, competent staff and appropriate QA/QC programs and safety procedures are followed.
- Whenever multiple people perform similar tasks, or when data is collected over a period of time, a geologist should refer to a system of checks and controls to ensure data quality and consistency.
- Sample preparation procedures used in each mineral exploration program should be appropriate to the program's specific objectives.
- When the volume of individual field samples is reduced prior to submission to a laboratory for analysis, non-biased split procedures for representative subsamples should be tested, verified and then applied.
- Appropriate sample preparation procedures should apply when testing materials and analyzing elements.
- Representative material fractions should be retained for a specific period of time, determined by the geologist, company policy or regulatory requirement.

Chain of custody

One of the most relevant international conduct concerns in relation to materiality is to ensure against fraud, negligence and procedural errors that includes (CBRR, 2015, p.35):

- measures to properly document sample and chain of custody security;
- retention of remaining sample waste, pulp and core.

Sample safety is one fundamental component for quality assurance of the sampling process, from collection to analysis, and it is the responsibility of the qualified professional to observe the chain of custody, through establishing well-defined and implemented protocols. Obviously, the level of safety and requirements must be appropriate to local characteristics such as location (greenfield, brownfield, near mine or operation), facilities, and the type of deposit/mineralization. Sample safety extends to batch control and respective shipping, and those responsible for all stages – shipping company, employees and people who are accountable for receiving samples at laboratories, both external and internal.

Packaging and storage

As for precautions to materiality preservation, international best practices (CIM, 2018) indicate exploration programs should retain and archive a representative fraction of survey core material for future reference. If the material is used for the purposes of checking, duplicates, audits, and metallurgical testing, it's important to document why it was not retained, and to include an image (photograph) and detailed description of the mineralized intervals. Drill core sheds must abide by a system that includes access control, organization of the entire collection and full-time oversight.

Archiving of pulp and check samples, certified standards and blanks should be controlled by a responsible professional to prevent accidental or fraudulent handling. Each company sets its deadline for storing materiality – samples, certificates and drill cores – remembering that preserving information in junior companies is vital. In general, companies discard drill cores of unmineralized intervals, negative holes and those of already extracted portions that don't represent the regional geology.

An aspect of the data quality process that is often overlooked by mining and geoscience companies and practitioners concerns the procedures for final drill core packaging and storage. Just as digital databases must be well managed and utilize systems and software, the same applies to physical drill core storage. The cores must be properly stored in boxes, drill core sheds and lithothecas, especially as there is no way to back-up materials and re-drilling is costly and laborious.

It is not uncommon to observe totally inappropriate situations from the scientific point of view – either due to the physical structure of the sheds, poorly trained technical staff, and especially due to the use of drill core boxes susceptible to rapid degradation (image 1). It is astounding that even today, companies are extremely careless at this stage of the process despite investing millions of dollars in drilling campaigns and applying extensive technical effort toward drilling quality, the environment and occupational safety issues.

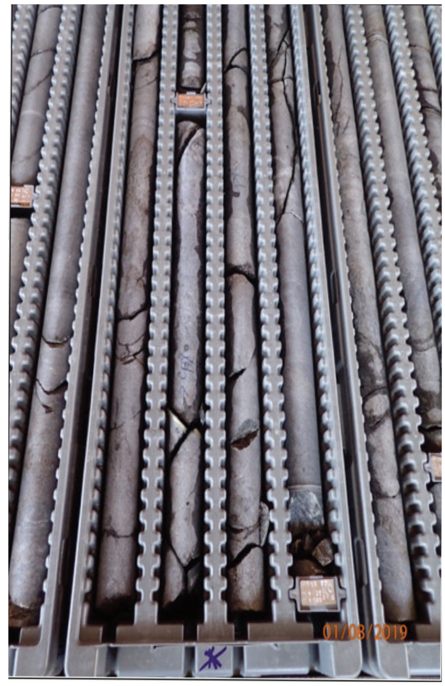

Image 2 – Examples of boxes and proper procedures for storing drill holes. *Archive images provided by Core Case.*

The choice of drill core storage box is what often compromises data quality. Whether due to cost, ease of sourcing, pragmatism by decision makers, or for any other reason, boxes are most likely to deteriorate due to weathering and insects, resulting in collapsed boxes with drill cores from different intervals and holes inadvertently combining. This is most commonly observed with wooden crates, although metal crates rust, waxed cardboard and corrugated cardboard collapse, and plastic boxes warp or crack due to the significant weight of the core samples.

When collapse occurs and core mixes together, it is impossible to rearrange them in the boxes, often losing intervals or even an entire drill hole. In other words, not only is there a big loss with the value invested to obtain the drill core, but also precious information is lost as to the mineral deposit, which may lead to deletion of information from the database, depending on the level of requirements by the professional that audits the data. It is apparent that geological and mineral research companies and professionals often incorrectly select drill core boxes based on cost-benefit assessment rather than opting for reliable products that would minimize risk of loss. Considering this fact, and irrespective of the type and brand of box, the value of the product does not even represent 5 % of the cost of the drill hole. It is therefore advisable to invest in the best core storage products that are durable and resistant to weather and insects, ergonomic and environmentally friendly (image 2).

Final considerations

From time to time, debate resumes regarding the real need for companies to review storage and conservation procedures for drill cores at operational sites. Controversy remains as to the high cost of infrastructure, labor, building maintenance and occupational safety issues. In addition, mining companies generally have restricted areas close to the mining operation or research project, and establishing additional remote facilities for this purpose would result in added expense with moving personnel, equipment and materials.

In order to equalize such problems, some possibilities have been considered, such as the use of scanners to capture 360-degree digital images of the cores; evaluate core disposal in areas characterized as 'sterile', or even establish criteria for determining a maximum percentage of drill core preservation. It can be challenging to convince geologists and managers alike that such behavior results in the permanent disposal of rock material.

In the meantime, some argue that there is no need to retain physical cores once description, data acquisition, sampling and digital scanning has occurred. However, most geoscience professionals argue that it would be a scientific 'crime' to permanently dispose of rocks in both mineralized and sterile zones. They argue that both geological knowledge and technological advancement evolve over time, and that the interval considered sterile in the future, may be viable as ore, due to new methods of analysis and ore extraction, as well as the variation in commodity prices. Aside from mineralization, vital data relating to a site or even a region can be further explored via drill core testing if and when advancement in structural, geochronological or geochemical techniques or analysis occurs.

It is therefore the auditor's responsibility to decide storage and preservation requirements of drill cores in warehouses and lithotecas, considering they adhere to international standards practiced during the audit and reporting of company mineral resources and reserves. Since these standards still outline that drill cores should be retained, it is very unlikely that these procedures will be altered, even with the use of scanners or other photographic archiving and/or digitization technologies.

This is a topic of great importance for the mineral sector and one that requires further discussion and exploration as to potential solutions.

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