Adoption of common data reporting standards for metallurgical, geometallurgical and mineralogical data

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The transition to a low carbon economy will require large quantities of minerals and metals to replace fossil-fuel based technology and infrastructure. BHP forecasts that the global economy will need almost twice as much steel, twice as much mined copper, twice as much potash fertiliser and four times as much primary nickel over the next 30 years, compared to the past 30 years under a Paris 1.5-degree scenario. However, the discovery of large economic deposits is becoming rarer, with new greenfield discoveries expected to be deeper and more complex. To address these productivity headwinds, we need to improve the way we characterise and evaluate mineral deposits at all stages of a deposit's life cycle and enable the integration of knowledge across the value chain, to maximise its value. We propose the development and implementation of common data reporting standards for metallurgical, geometallurgical and mineralogical data to improve efficiency, enable development of commercial software and enable the application of data science tools and technologies. Data reporting standards help to improve the data we have available, making our industry more efficient and are a key enabler for downstream data analysis and decision making.

INTRODUCTION

It is widely acknowledged that the transition to a low carbon economy will require large quantities of minerals and metals to replace fossil-fuel based technology and infrastructure. BHP forecasts that the global economy would need almost twice as much steel, twice as much mined copper, twice as much potash fertiliser and four times as much primary nickel over the next 30 years, compared to the past 30 years under a Paris 1.5-degree scenario (BHP, 2023).

Demand must be met by a mining industry that is facing productivity headwinds from declining grades, deeper mines, and more complex deposits (mineralogy, geotechnical etc.) as well as transitioning itself to low carbon operations through the adoption of innovative technologies. At the juncture of these economic and environmental megatrends is the need for better resource characterisation.

We need to improve the way we characterise and evaluate mineral deposits at all stages of a deposit's life cycle and enable the integration of knowledge across the value chain, to maximise its value.

Data propagation will require an industry-wide approach to data management, with a specific focus on the standardisation of data that we collect. A key enabler of better resource characterisation and higher productivity is to change how our industry reports, stores and uses metallurgical, geometallurgical and mineralogical data.

Data Management
A fundamental principle of geometallurgy is to test a large number (high volume) of samples and to relate metallurgical response to ore properties (Liebezeit *et. al.*, 2011). From experience, geologists and mining engineering can choose from a wide range of commercial software applications that enable the management of geological, mine planning and scheduling data systems.

Metallurgists, process engineers and geometallurgists typically work in Microsoft Excel despite repeated findings that Excel is not an acceptable solution for data management or analysis (Vagens, 2021). Some large teams, like BHP Olympic Dam, have customised commercial applications to create bespoke data management platforms. Liebezeit *et al.,* (2011) provides a detailed description of the Olympic Dam data management solution that allows for the geometallurgical and mineralogical data to be structured, collected, and stored to facilitate analysis and understanding.

One limitation to scaling the Olympic Dam data solution can be attributed to the third party metallurgical, chemical, and mineralogical laboratories that do the majority of the test work for geometallurgy programmes. As described by Liebezeit, "At the start of each phase of work, the geometallurgical team liaises with laboratories to create a workable template that will be used to report the data results."

The programme's data flow, shown in Figure 1, is supported by the rigorous definition of programme parameters such as *phase*, *laboratory*, *procedure* and *samples* and enabled by standardised reports that facilitate embedded routines and automated workflows such as sample despatch, data import and quality assurance procedures.

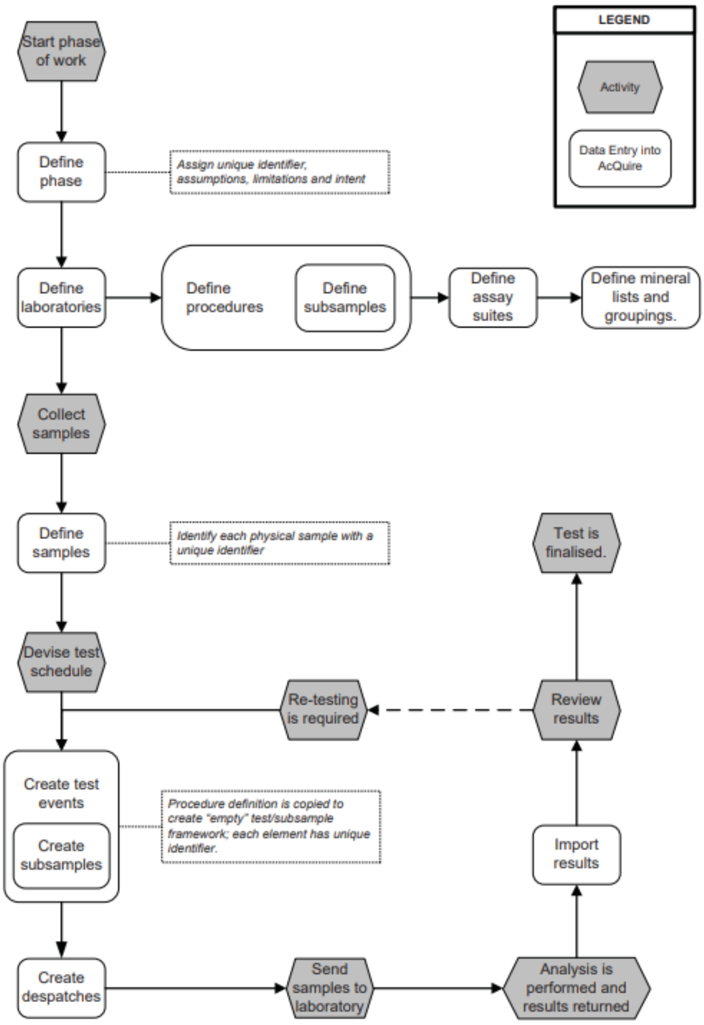

Figure 1. Olympic Dam geometallurgy data flow (From Liebezeit et al., *2011).*

Data Report Standardisation

Standardisation underpins the infrastructure of modern life from shipping containers to financial markets and health sciences. The European Commission goes as far as to say that standards are the silent foundation of the EU Single Market that help ensure the interoperability of products and services, reduce costs, improve safety, and foster innovation (European Commission, 2022).

Data reporting standards are documented agreements on representation, format, definition, structuring, tagging, transmission, manipulation, use, and management of common data (Geoscience Australia, 2023). Standardised reporting is essential to compare and aggregate data from multiple sources, across time, within and between companies and projects.

The data value chain consists of five main links: collection, organisation, analysis, storage, and use (Galt and Rubinfeld, 2019). The focus of this paper is on improving the collection of data as an enabler of better organisation, analysis, storage, and use. Ghorbani *et al.*, (2020) acknowledges that there is little in terms of data standardisation across the mining industry. This is a major issue that requires an integrated approach to be taken, to at least develop a rigorous standard that is usable across the industry.

The development of common data reporting standards for metallurgical, geometallurgical and mineralogical data is overdue. We propose a collaboration to develop reporting standards for metallurgical, geometallurgical and mineralogical data reporting to unlock value through interoperability, enable the adoption of databases for data storage, prevent duplication and waste and promote more efficient and effective use of data.

CASE STUDIES

Standardised data reporting is a challenge across many industries including finance, health, and information technology. In the mining industry data reporting standards have been developed or are being developed in disciplines from geophysics to heavy mobile equipment. Successful implementation of industry-wide reporting standards has usually been facilitated by governments or multilateral agencies e.g., the Organisation for Economic Co-operation and Development, or through a collaborative approach led by industry or a not-for-profit membership organisation such as the Australasian Institute of Mining and Metallurgy (AusIMM), Global Mining Guidelines group (GMG) or the International Organisation for Standards.

One challenge in reporting metallurgical test data is the near-infinite combination of test conditions for some types of tests e.g. flotation and leaching tests. This could be overcome through standardised but flexible report formats. Nevertheless, there are also many accepted industry standard tests, such as the Bond ball mill Work index (BWi), for which a standardised reporting format could quite easily be implemented.

Another challenge for standardised reporting is that the rationale for a test needs to be recorded and retained. This description and commentary would need to be saved as metadata. A similar challenge to maintaining additional metadata was encountered with reporting of genomic data in the health science sector. According to Quackenbush (2011) an early data reporting standard for genomics failed to fully solve the problem of experimental annotation, i.e., describing the 'how and what' behind the work. However, this was to be amended when data reporting standards were revised, pointing to the need for regular scheduled reviews and improvements.

Two case studies reviewing the implementation of standardised reporting standards in the mining industry are discussed:

Case Study 1: Open Mining Format

A working group focused on mining data and interoperability, under the auspices of the Global Mining Guidelines Group, has developed the Open Mining Format (OMF). This is an open-source file specification format designed to support data interchange across software systems for geological and topological data used across several business functions of mining operations (GMG, 2023).

The working group identified the many challenges with integration, interoperability, and the overall management of data within the mining industry. Specifically, moving complex data between different proprietary software formats was time-consuming and prone to error. The solution was a standardised format. With public commitment from at least five major software companies, the first version of OMF was released in 2017, and the second version is under development (GMG, 2019).

The capability uplift from implementing OMF is significant and will continue to grow in the future as more software is developed with OMF capability. OMF not only unlocks the propagation of data and knowledge through the mining value chain but enables rapid data access and recall for near real time decision making and reconciliation applications.

The OMF is available on Github free of charge and explicitly allows users the right to use, copy, modify, merge, publish, distribute, sublicence, and/or sell copies of the software, without restriction under the permissive open-source MIT Licence (Github, 2023).

Case Study 2: AusIMM CoalLog standard

CoalLog is an Australian industry-developed standard for coal logging. Prior to its development there were around 30 different data formats and over 100 different dictionaries being used for the capture of geological and geotechnical data from boreholes across the Australian coal industry. Furthermore, each of the major Australian geological software companies used different conventions for the transferal of this data. These different formats, dictionaries and transferal conventions led to major inefficiencies and barriers to interoperability in the collection, transfer, and analysis of coal borehole data (AusIMM, 2023).

The CoalLog standard was developed cooperatively by representatives of coal exploration and mining companies, consultants, and software providers, and enables the recording of consistent and standardised borehole data. The standard includes multiple resources to assist in its use and implementation of the standard including data entry sheets templates (Figure 2) and standard dictionaries of code lookup tables for coal borehole lithology, water flow, geotechnical and quality data. The standard also includes a format for the transfer of data and a training manual (AusIMM, 2023). To maintain utility and relevance the standard is regularly reviewed and updated.

Both case studies demonstrate the successful implementation of complex data reporting standardisation projects within the mining industry, facilitated by a not-for-profit membership organisation. Importantly both CoalLog and OMF continue to be updated and developed to ensure that they maintain relevance and to introduce improvements.

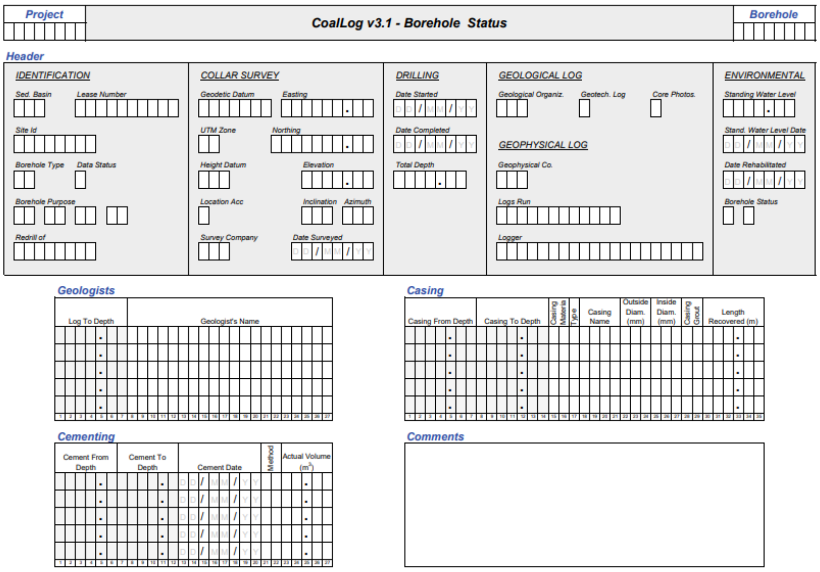

Figure 2. CoalLog standard logging sheet (AusIMM, 2023).

DATA REPORT STANDARDISATION

We propose establishment of a technical working group under a not-for-profit membership organisation, such as the AusIMM or within the Data and Interoperability working group of the GMG Group, to develop royalty free, publicly available, open data reporting standards and potentially templates and user guides for the most common metallurgical, geometallurgical and mineralogical tests including comminution, flotation, leaching, mineralogy (X-Ray diffraction, TESCAN TIMA) and hyperspectral analysis.

In an approach similar to the development of CoalLog, collaboration between exploration and mining companies, consultants, software developers and testing laboratories can focus on standardising reporting as a key enabler of delivering sustainable data management. The easiest reporting to standardise would be the industry accepted standard tests such as Bond Work index (BWi) for ball mill design and tests with simple output tables such as XRD results.

Each report would contain three types of data in an agreed format, metadata e.g. date laboratory name, sample ID, date, operator, job number etc., test conditions: pH, Eh, temperature, reagents, p80 etc. and test results e.g. weight, BWi, Ai, mass deportment etc.

It is proposed that alternatives to relational databases are investigated and assessed. Non-tabular databases such as NoSQL have arisen with recent technology trends 'Big Data', 'Cloud Computing' and 'Data Science'. Examples of these include Google's Bigtable, and the open-source MongoDB.

Outcomes

There are a range of outcomes that are derived from the development and widespread implementation of data reporting standards.

Efficiency

Standardisation is an enabler of simplification, making data easier to find, understand, and reuse. Metallurgists and geometallurgists often spend significant amounts of time importing, consolidating, and cleaning data before they can develop geometallurgical regressions and models or to visualise or report on results. This is often compounded by the absence of embedded quality assurance and quality control (QA/QC) processes that allow for errors to propagate, further increasing the time required to review data and generate results.

Data standardisation improves efficiency. Gal and Rubinfeld (2019) note that the first known data standard was created in response to logistical bottlenecks during the 1948 Berlin Airlift. To address this, a standardised system of codes was created to allow for faster cargo movements.

From a laboratory perspective, metallurgical testing laboratories often have to change reporting formats to meet the requirements of individual clients. A standard format would help to minimise the reporting burden.

Automated QA/QC

Data storage and analysis in Microsoft Excel is error prone, can have poor reproducibility and has no audit trail. Standardised reporting allows for the implementation of automated QA/QC processes to identify data errors at both the testing laboratory and the receiving client resulting in improved data quality.

Automated processes, machine learning and AI

At the heart of geometallurgy is a focus on spatial variations in the ore body and the development of models to connect deposit information to the process, products, or economics. Advancements in data science, including machine learning, deep learning, and artificial intelligence (AI), have increased our capacity to reveal interesting relationships from large data sets. However, the way many organisations collect and store their metallurgical, mineralogical or geometallurgical data prevents application of current data analysis techniques.

Once data is organised and stored in a database it removes barriers for a wide range of analysis and visualisation tools and methodologies, including collaborative innovation, embedded reconciliation and continuous improvement and machine learning and AI.

Sustainability

Standardised data reporting should be seen as a key enabler of sustainability in mining and mineral processing. Data that is stored as Excel or PDF files should be considered as ungoverned, without any validation or control of data quality, data security or data usage. The data can also be considered orphaned, and unable to be transferred between generations of personnel or between companies; for example through mergers and acquisitions, without the loss of context and utility. Where mines may exist for decades, the treatment of valuable technical data as transient can undermine efforts to extract maximum resources with minimal impact.

Promote Application Development

One of the fundamental limitations to the development of commercial metallurgical, geometallurgical and mineralogical software applications can be attributed to the lack of report standardisation for test data. Standardisation should remove a significant barrier to the development of commercial software applications to enable advanced geometallurgical data analysis.

Considerations

Judge and Berner (2019) provide excellent insight into the costs and challenges to standardising data and the costs incurred. They note that developing standards, testing them, modifying existing systems or developing new systems, and working through the implementation and update cycles through a collaborative approach requires significant effort and clarity of purpose. Furthermore, costs are typically incurred upfront while benefits that follow, often with a considerable lag, can be hard to fully value and aren't restricted to those who incurred the bulk of the costs (Judge and Berner 2019)

An important consideration for developing industry standards through a member-based industry organisations is to ensure rigorous compliance with anti-trust legislation (GMG, 2023). Member-based industry organisations are usually comprised of competitors and must therefore be aware of antitrust implications and take necessary precautions to ensure that all activities are compliant with the law.

CONCLUSIONS

Data report standardisation is important and should be prioritised. To deliver the resources required by the global economy over the next decades the mining industry will need to address challenging headwinds. An enabler to unlock value will be to maximise the use of the large quantities of metallurgical, geometallurgical and mineralogical data that we collect.

We need to ensure that the investment we make in generating data is not wasted (Quackenbush, 2009). Data reporting standards help to make the data we have available better, it makes our industry more efficient and is a key enabler for downstream data analysis and decision making. To sustain the effort to collaborate and change how we work will requires a conscious decision to invest in standards and to see the long-term value.

The development of common data standards for the reporting of metallurgical, geometallurgical and mineralogical data is overdue. The only practical way to achieve this goal would be through a collaborative approach from mining companies, consultants, software providers and metallurgical and mineralogical testing laboratories. A successful pathway to develop practical, useful standards has been shown through the development of the CoalLog standards and the Open Mining Format.

Once implemented, a common data reporting standard will enable next generation data science, improve the efficiency of critical disciplines that analyse and provide insights that underpin billions of dollars of investments.

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