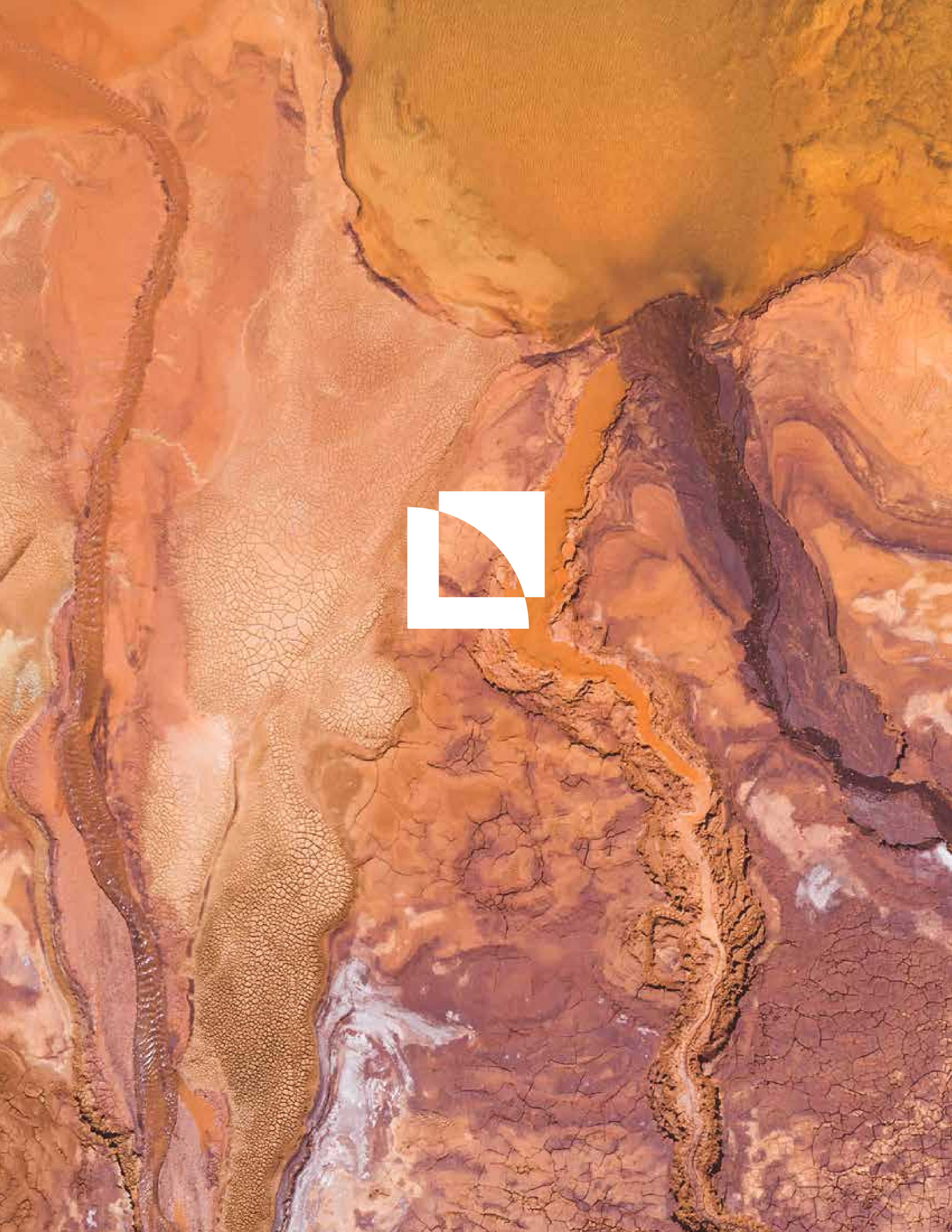
Next Generation Geological Knowledge

Why Geologists Hold the Keys to the Next Stage of Mining Efficiency and Social Performance



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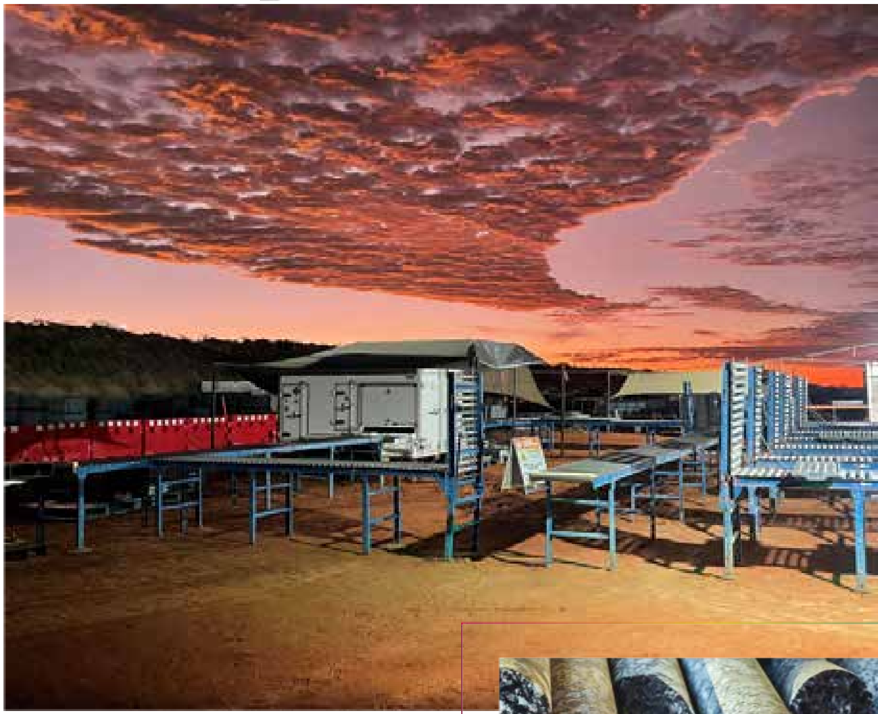
Executive Summary

The mining industry is undergoing a significant transformation, driven by the need to meet increasing global metal demands and higher environmental and social standards. To address these challenges, the industry must change its approach to geological data collection, processing, and utilization. A crucial element of this transformation is the adoption of automated core scanning technologies like Scan by Veracio. These technologies offer opportunities to streamline data collection, enhance data quality, and support advanced analytics.

Traditionally, the mining industry has followed established practices guided by codes like the JORC (Joint Ore Reserves Committee) code. But, these practices face resistance to change, a mindset challenge, inconsistency in data collection, and a shortage of skilled professionals. Many resist new technologies, mistakenly believing they are non-compliant with existing codes.



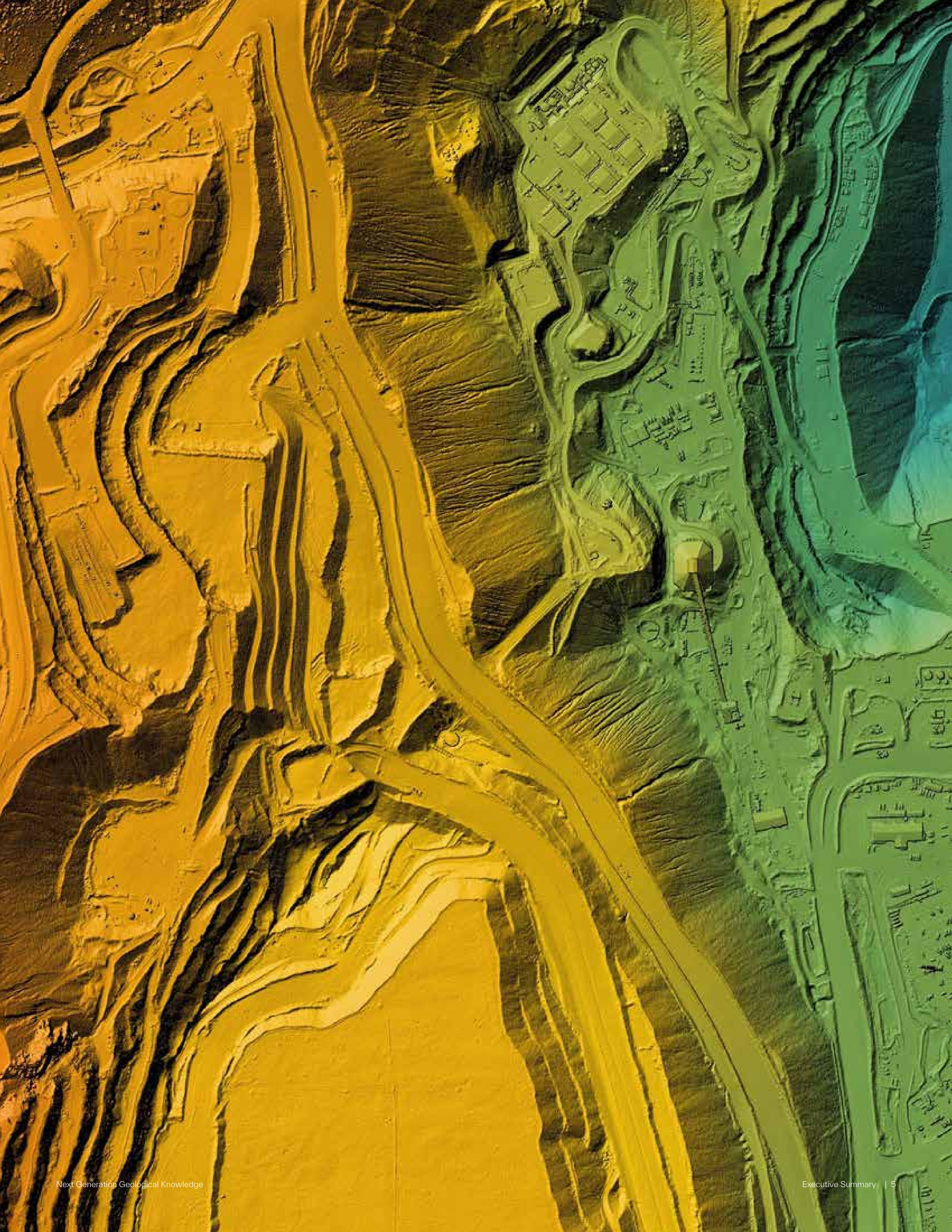
Automated core scanning provides a solution to these challenges. It simplifies and accelerates geological data collection, offering near real-time, consistent, accurate, and granular data. This streamlines the process, reduces costs, and minimises errors and bias when compared to traditional methods. Automated core scanning also eliminates the subjectivity of geological logging and offers a permanent record of the fresh core through high-resolution core photography.

Furthermore, these technologies facilitate the collection of a comprehensive dataset on the same basis, eliminating issues related to data fusion and resolution loss. This rich dataset supports advanced analytics, including machine learning and AI applications. It aligns with the requirements of the "Mine of the Future," where technology advancements demand more detailed geological knowledge at every stage of the mining value chain.

In modern mine design, achieving a richer and more realistic digital representation of the orebody is essential. Traditional models often smooth data into large blocks, limiting their ability to inform decision-making. Both greenfield and brownfield mining projects require accurate geological knowledge. Greenfield developments, in particular, rely solely on core data and geological interpretations, making precise orebody understanding crucial for securing substantial investments.

Automated core scanning, represented by technology like Scan by Veracio, offers a groundbreaking solution to meet the industry's increasing need for comprehensive, consistent, and granular geological data. It enhances accuracy and precision in chemical analysis through the elimination of sampling and sample preparation (the largest source of error) and through automated real time QA/QC procedures, whilst also improving geological logging through objective measures. Moreover, automated core scanning provides high-resolution core photography and contributes to more comprehensive structural logging.

In conclusion, the adoption of automated core scanning represents a vital step toward achieving the mining industry's goals of efficiency, sustainability, and responsible resource development in the rapidly evolving landscape of the Mine of the Future. These technologies enable mining professionals to better understand orebodies, make more informed decisions, optimize processes, and meet the increasing expectations of environmental and social stakeholders.



PART 1:

The Context

Future Mining / Data Step-Change / Machine Readability / Ready for AI

The modern mining operation is book-ended by two immovable (and often opposing) objects; the economic constraints of making profitable metal and the Environmental, Social and Governance (ESG) expectations of all stakeholders. The complexity and effort needed to evaluate potential new mines (or extension to an existing mine) has never been greater.

The orebodies available to supply the minerals needed to support a flourishing society are becoming deeper, more complex, and lower grade, requiring new and novel methods of extraction and processing. To plan and operate these methods of extraction and processing, significantly enhanced and different information about the orebody is required.

The traditional approach to geological knowledge (data collection and modelling) is proving to be hopelessly inadequate for the modern mine.

The Energy Transition is Driving Demand

Our energy transition demands more copper, nickel, cobalt whilst our emerging economies demand more steel, and the scientifically complex world around us demands more critical minerals and rare earth elements, in greater and greater quantities.

To meet this demand successfully, mining companies are innovating, through their existing operations and in new projects. They are selecting from an array of new extraction and processing methods, and equipment. They are also evaluating the appropriate scale of mining, the best layout, methods and equipment to support the development. Increased attention on technologies such as ore sorting, leaching (both chemical and biological) are allowing mine life extensions and stranded deposits are being unlocked via the adoption of new and novel technologies.

The Drive to Enhance Decision-Making

The myriad of interrelated decisions and trade-offs that are required to develop a mine are fundamentally impacted by and based off the knowledge we have about the orebody. Whilst the traditional approach of focussing on delivering the best unbiased average grade of the primary economic metal has been adequate in the past, a modern mine needs to be informed by far more geological knowledge than the average grade. To inform the complex decisions required from exploration through development to operations requires a significant step change in the resource characterisation and geological knowledge from that which has been traditionally used. This in turn requires both an increase in the amount of data about the orebody, its resolution and granularity, as well as requiring a much wider array of measurements of the properties for both the ore and the waste.

In addition to the primary economic mineral or metal, it is necessary today to maximise the production of co-products and by-products. We also must deal with waste in ways that meet societal expectations around land use and impact, energy and water.

New methods of data acquisition, measurements and novel data analytics to infer additional attributes are needed to inform the interpretation of the orebody. These high-resolution datasets are needed to allow geological models to be created as a high fidelity, multi-attribute 3D picture that characterises and describes the orebody in a way that honours the data, its spatial variability, and heterogeneity at the scale necessary for the liberation of valuable minerals. They must also account for the uncertainty in predictions. The focus must be on predicting the recovery after extraction and processing, not simply what is in the ground.

The Impact of AI

AI and machine learning is increasingly being used by the mining industry to extend the interpretation and make more from the available data. New geoscience data acquisition needs to be “AI ready”, and this requires that the data is captured differently than has been done until now. For data to be “AI ready” it must be collected consistently and on the same basis, so that attributes can be combined without a loss of resolution. It is no longer enough for the data to be of known accuracy and precision, it must be error-free and validated.

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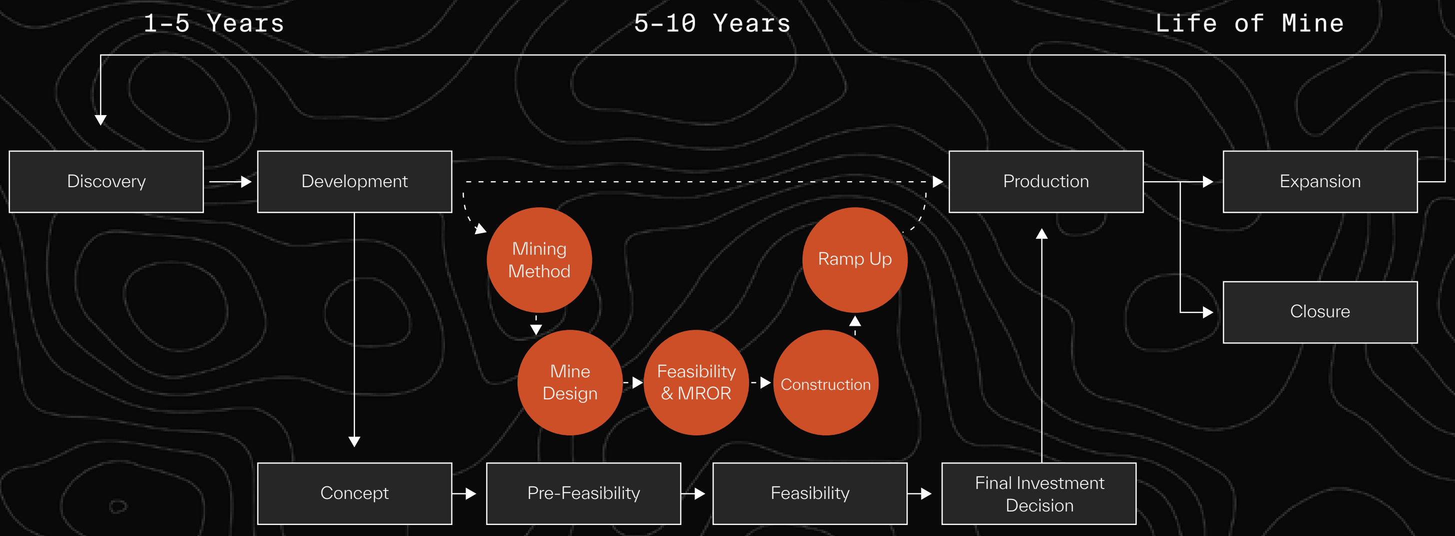
The Development Dilemma

`New mines can take years, if not decades to reach production. Our need for critical minerals is more urgent than that.`

Evaluating and developing new orebodies is time consuming, with many of the tasks being serial in nature. The traditional sampling and laboratory assaying approach is known for holding up projects. It is common to wait for months to receive assay data from overwhelmed laboratories. By the time the data arrives, the drill rig has moved on and the logical connection the geologist makes between the assay data and the logging has been lost.

Collecting comprehensive digital data while the drill rig is on site enables near-real-time decisions to be made—optimising hole completion as well as targeting future holes. Scanning core in-field with technologies like Scan by Veracio radically improves data capture by providing same-day feedback on the rock being encountered at the drill bit. It can provide assay data as well as logging data, along with a rich suite of additional attributes. Development schedules are compressed, allowing evaluation and planning tasks to be carried out in parallel and iteratively.



PART 2:

The Challenge

Change in Process / Mindset / Reporting

The Statutory Reporting Challenge

The mining industry faces an ongoing challenge to ensure that the statutory reporting of geological data aligns with contemporary standards and practices. Historically, the industry has been marked by periods of insufficient reporting, notably during the high-profile market booms of the 1960s. These instances underscored the need for a robust framework for reporting that would instill confidence in stakeholders and the market at large.

In response to this need, the industry has implemented comprehensive reporting codes, under the guidance of CRIRSCO, to standardize the disclosure of exploration results, Mineral Resources and Ore Reserves. These codes are underpinned by principles of Competency, Transparency and Materiality. They are intentionally designed to be non-prescriptive, providing the flexibility needed to adopt various methods of data collection, analysis and modelling deemed necessary by the competent professionals to address the material aspects of the orebody and its potential for economic extraction. Whilst the codes are non-prescriptive, professionals have developed historical "norms" of practice around how data has been collected, analysed and modelled. These "norms" are now out of date. The needs of the the industry and its stakeholders are demanding new methods of acquisition and analysis be developed that provide a significant step change in the quality, quantity and variety of data that can now be collected, analysed and modelled. These "norms" however have inadvertently led to a form of inertia among some industry professionals who continue to rely on traditional processes and there is a misconception that adherence to these "norms" is mandated by the reporting codes. This misconception has had the effect of maintaining the status quo at a time where the industry desperately needs to improve the geological knowledge that underpins the complex resource development facing the industry. Innovative methods that enhance data quality and efficiency are being prematurely and wrongly dismissed as being "non-compliant". This resistance to change is a significant barrier to progress. Many of these innovative methods for data collection, analysis and modelling are not only compatible with the intent of the reporting codes but often provide enhancements over the traditional methods.

The Mindset Challenge

The challenge lies in adopting these new methodologies which requires a shift in the mindset of industry professionals. If adopted, these new methods can lead to improved outcomes, such as increased accuracy and precision, fewer errors, more comprehensive data, and expedited processes, ultimately supporting the industry's goal to ensure reports competently cover all of the material aspects of the orebody in a transparent manner.

If we are going to meet society's demands for metals, the adoption of new methods of geological data acquisition are going to be required, and this will require a change to the way professionals work. Professionals are often threatened by the new technology, with some believing their jobs may be at risk, or their expertise devalued. There is an alternate way to view these technologies however, as an opportunity to explore new and exciting ways of doing things that have never been possible, leading to the modelling of orebodies to a level of detail not previously achievable, and better-inform key planning decisions.

We are at the cusp of a new generation of geological knowledge; The challenge lies with the industry professionals to adopt and deploy these new tools and methods for the maximum impact for the industry.

> *"There's a common bond between everyone in Veracio that we truly believe we're changing mineral exploration and mining with digital sensing and AI."*
>
> **— Mike Ravella, Chief Innovation Officer**

The Consistency Challenge

For a mining operation, up to

70%

of the geological human resources are consumed in collecting data — even higher for development projects.

The collection of comprehensive and accurate data to inform our knowledge of an orebody is time consuming and requires a high level of skill and perseverance. Geological data collection by geologists has always been subjective. For large or long-lived projects, where multiple people are involved, even with training and controls, consistency and subjectivity has always been a problem. For a mining operation, up to 70% of the geological human resources are consumed in collecting data — even higher for development projects. This is a huge investment for much of that data to be error prone, subjective and then ignored in the modelling of the orebody. It is common for many of the logs or attributes collected to not be incorporated into the geological model as it is either inaccurate or incompatible with other data being modelled or simply too hard to model. If this data is not incorporated into the geological model it will not inform the mine-planning and development decisions.

With so much time being spent collecting data, geologists often have limited time to analyse the complete set of data. Rarely are they able to utilise the full multivariate nature of the data set. Collecting geological data to a high standard is technically challenging, however we often put our most inexperienced staff on this task and due to other work pressures, they are often poorly trained and supervised. This results in poor quality of data being collected, yet this is the data that underpins the major investment decision for a mine development.

The Skills Challenge

The mining industry is experiencing a major skills challenge. Fewer students are graduating with mining related degrees; The demographic of the industry has a large cohort of technical professionals at retirement age and exiting from the industry. Vacancy rates are high, time to fill positions has blown out and turnover has increased. Most operations having difficulty securing enough staff to carry out the basic tasks. If a geologist is left logging core for too long, they invariably leave for a more interesting job. This high turnover among geological staff further impacts the consistency of the data collection. Having teams of geologists working long shifts in remote location often in extreme conditions, laboriously logging and sampling core is no longer possible. New graduates are resisting remote postings and are wanting more challenge from their jobs than just collecting data.

The adoption of automated data capture technology can drastically reduce the headcount required to collect data whilst also increasing the data attributes, their resolution, their consistency and their accuracy and precision. This means the valuable geological human resources can be applied to interpreting the data and building high fidelity models to better inform mine and process design, development and operation.

Digital scanning and assistive logging makes geological work fundamentally more interesting for geoscientists at every experience level. This will create a positive impact on attraction and retention of key geological staff at a time when recruitment is difficult and expensive.

We now have the technology through automated core scanning (Scan by Veracio) to collect a vast array of comprehensive, consistent, objective, accurate, precise and highly granular geological data in a controlled and repeatable manner under the supervision of a field technician. This has the potential to assist in the skills shortage. Rather than having many geologists spending enormous time collecting data, the data is instead presented to the experienced resource geologist as a high quality multi attribute dataset, allowing them to perform automated QA/QC checks on the data (due to its consistent basis) and move straight into the more interesting and valuable tasks of analytics, interpretation and modelling. QA/QC benefits from both the comprehensive nature of the data and the fact that the data is presented on the same basis.

The use of this technology eliminates manual subjective core logging, error-prone manual sampling and sample preparation steps. The subjective estimation of mineral abundances by the geologist is replaced by an actual measurement of each mineral abundance and then cross checked or validated by the rock chemistry. Multiple passes of logging for lithology, structure and geotechnical measures are no longer needed, as all of this data is acquired automatically in a single pass through the scanner, under the supervision of a field technician. This massively reduces the labour required to get to a far superior result.

A Strategic Perspective

To understand the geological knowledge opportunity across the mining value chain, we interviewed Gavin Yeates, industry futurist, board director and former VP of Mine Optimisation at BHP.

Gavin is an established mining industry executive and thought leader in strategy and technology. Passionate about helping organizations leverage technology into their business, Gavin's career boasts a track record of delivering strategies (from inception to implementation) to deliver profound change to organizations.

PART 3:

The Opportunity

Sampling / Automation / Digitization / Design

Technology and the Mine of the Future

Technology advancements are now being deployed in mining that are changing the way we develop and operate mines both in extraction and in processing. The Mine of the Future is rapidly becoming a reality. These advancements require new and more detailed knowledge about the orebody both in the project planning phase to estimate the impact of these new approaches and in operations to control the ore feed to these new processes. The application of new technologies applies to almost every step in the mining value chain, and every step in the value chain is impacted by some aspect of the orebody.

Modern Mine Extraction

Beginning with drill and blast where we can now dial up fragmentation, controlling breakage according to known rock hardness and fracture patterns using electronic detonation and variable density explosives coupled with new simulation tools that are calibrated with fragmentation and movement measurement tools. These new blasting tools demand much greater understanding of lithology and structures such as fractures and weaknesses. These drill and blast technologies are impacting the achievable fragmentation as well as dilution and ore recovery which are both now a function of the amount of geological knowledge fed into the process at the start. Fragmentation that is optimal for comminution also optimises energy and CO^2 emissions whilst minimising the generation of fines and ultra-fines, which in turn helps with water usage. The business need in this area is growing.

The load and haul process is now being impacted by virtual dig lines via heads-up displays and face scanning technologies that provide the operator with information about the orebody they are digging as they are digging it. As the material is loaded into trucks, it is tagged with both its predicted grade (from orebody model, and grade control model) as well as additional sensing and measurements taken in the loader bucket or even in the truck. It is then tracked to its destination where it is either stockpiled or it begins the processing steps e.g. crusher. The payoff for this technology is in improved ore recovery and reduced dilution coming from the ability to follow complex geological and grade boundaries within a bench without visual control. These new mining technologies require far more detailed geological understanding (within bench scale) for them to reach their full potential in reducing ore loss and dilution thus maximising grade in the feed and recovery from the resource.

Grade control is advancing with real-time geochemistry and mineralogy becoming more widely accessible.

PRODUCTION MINES NEED:
Real-time geochemistry and mineralogy to support their pursuit of grade control.

Ore Sorting

Many new projects and existing operations are considering and evaluating the use of pre-concentration (Ore sorting) to reduce the capital intensity and to increase head grades. Ore sorting is the rejection of waste, either through natural deportment (size) or by the use of sensors detecting material properties on a belt ahead of a means of classification — a diverter. The sensors typically used include XRF, XRT, PGNAA, PFTNA, magnetic resonance, or optical sensors . Pre-concentration is now successfully deployed in a range of commodities and geological settings and is having a fundamental impact on the economics of projects where it has been deployed. There is, however, a significant shortcoming in our ability to predict the impact of a preconcentration step in the project or planning phase. It is required that the rate of rejection along with the grade deportment is estimated. The grade and proportion of the "accepted" material needs to be estimated as part of any resource evaluation and Ore Reserve estimation.

To do this in a manner that would meet the JORC or SAMREC codes for Ore Reserve reporting requires measures of geological heterogeneity at a scale relevant to the scale at which the sorting will occur. Traditional geological modelling severely smooths (averages) grades into large blocks which cannot inform the heterogeneity estimate. New methods are required to take detailed (at the scale of sorting) measurements of the rock using a similar or analogous technology that is to be used in the sensor used for sorting, to inform these estimates. Traditional approaches of using global averages or based on a handful of bench scale tests are inadequate for prediction of these crucial economic inputs which are known to vary spatially. Estimates need to be prepared that provide the proportion of the material that will be rejected and thus the proportion accepted along with the predicted grade deportment. This estimate will need to be specific to the geological unit, plus mineralogy, as well as scale at which the sorting is applied and will need to be informed by data collected that specifically matches these requirements.

PROJECTS NEED:
To understand metal deportment and mineralogy at a sub-block scale to inform selective mining unit, capital inputs and the impact waste, water and tailings.

Progressive Mineral Processing

Comminution is moving from jaw and gyratory crushers to roll crushers and then from large SAG and ball mills to vertical roller mills with the aim of reducing the energy to break rock to achieve liberation of the valuable mineral whilst minimising fines and ultra-fines which consume water and require tailings dams to store. It is clear that the driver of these techniques is energy and emissions, coupled with water recovery and the need to dry stack waste. To evaluate the effectiveness of these techniques, new and different information about the orebody at the scale of the comminution and liberation is critical. Evaluation is carried out by digital simulation of spatially modelled rock properties that has been calibrated by empirical testing of ore types.

The future of flotation is in coarse particle flotation, where separation occurs at much coarser size fractions, eliminating the need for fine grinding of the bulk of the feed saving on energy and emissions. It also ensures the tailings are free-draining, increasing water recovery such that they are dry-stackable, thus eliminating the need for tailings dams. To evaluate success and and control these new coarse particle flotation methods, much more detail is needed about the mineralogy, grain size and the associations and texture of the minerals present.

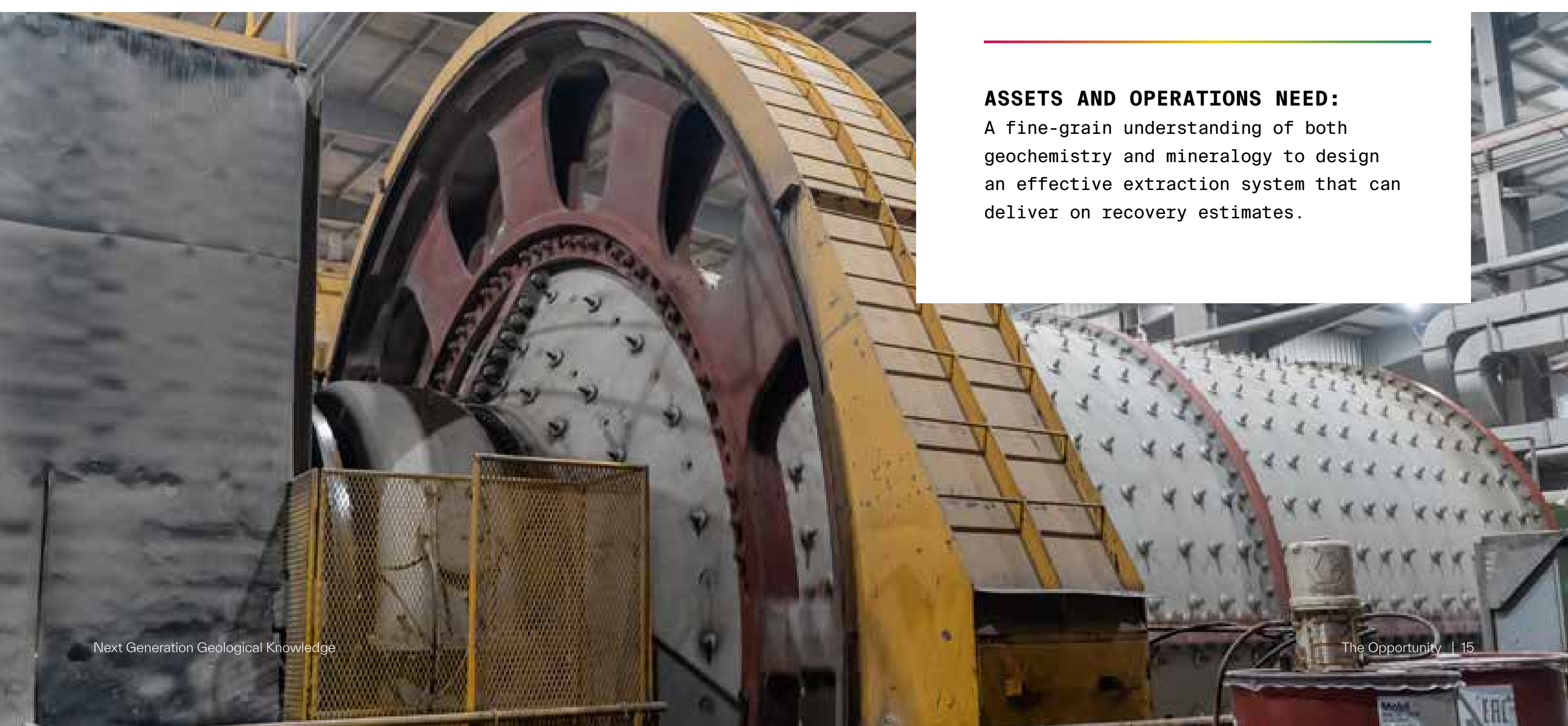
PROCESSING TEAMS NEED:
More detail than ever about grain size, mineraology and texture to ensure the energy and water savings don't come at the cost of recovery.

Leaching

Chemical leaching is also being increasingly applied, either in situ, on heaps or pads of "run of mine" ore, or in vats or tanks with prepared feeds or even concentrates. Leaching provides a cheaper and less energy and carbon-intense route to metal for some minerals. It is being driven by the decline in grades from the remaining available orebodies available and the need to produce metal in-country rather than shipping concentrates. Some new chemistry (such as Deep Eutectic Solvents) is showing potential to be very specific to a mineral in its extraction thus dealing with heavily contaminated or complex ores. Here again, these methods require more detailed and richer understanding of orebody — particularly its chemistry, mineralogy, structure and texture.

Biological leaching has been applied in some minerals for decades, however recent advancements in both catalysts and in synthetic biology is resulting in these techniques now being applied in mainstream applications for a wider range of minerals. The knowledge of the chemistry and mineralogy of valuable minerals as well as the gangue is critical.

ASSETS AND OPERATIONS NEED:
A fine-grain understanding of both geochemistry and mineralogy to design an effective extraction system that can deliver on recovery estimates.



The Role of Geological Knowledge in Mine Design

The mine of the future is taking shape before our eyes with modification to existing operations as well as in the chosen configurations of new development projects. In every case, the application of new mining or processing technology requires more geological knowledge, not less.

Just as mining extraction and minerals processing is leveraging a range of new technologies which in turn is driving the need for a significant step change in geological knowledge, the technology being used to acquire geological knowledge has also recently made a significant step change. This is allowing us to collect a wider array of attributes about the orebody, at orders of magnitude higher data density at a fraction of the time and effort and thus cost.

Geological knowledge forms the basis for all mining studies, be they expansions to existing operations or the development of new mines. Central to geological knowledge is creation of an orebody model, a digital representation of orebody. Traditional orebody models have focused on getting an accurate or unbiased estimate of the average grade of the deposit, and for the most part they've done this successfully. This is achieved by heavily smoothing the data into large blocks using a weighted averaging technique that applies weights according to the spatial variance. This provides the best unbiased estimate of the average grade of large parcels. The problem is, this technique destroys the local variance or heterogeneity. For the modern mine design or study, the average grade is useless; It provides little information at the scale at which the ore and waste is selected and can provide grossly inaccurate assessments of the tonnes and grade above a cutoff. Methods such as (multiple) conditional simulation have been used to try to improve the estimate of heterogeneity, but there are a limited number of professionals with the skills, experience and time to carry out these simulations. There are even fewer engineers and metallurgists with the skills to use the resultant models. Even conditional simulation approaches ultimately are limited by the resolution of the data they are fed.

Modern mine design desperately needs a richer and more realistic digital representation of the orebody — a representation that not only honours the data but provides a realistic view of the heterogeneity or variability. It needs to show in addition to grade, geological boundaries, structures, mineralogy, alteration, water table and any other characteristics that are pertinent to any of the myriad of decisions and trade-offs that engineers and metallurgists need to make when developing a new mine or expanding an old one.

Some of our most complex orebody models today have in excess of 200 attributes modelled, accounting for geology, structure, geochemistry, geotechnical and geometallurgical as well as increasingly environmental aspects. A closer look at these models reveals that they are based on a very limited data set; often only a few tests whose results have been interpolated or worse extrapolated spatially to provide a number at a location in space. This approach invariably leads to inaccurate or misleading views of the orebody that will result in wrong development decisions being made.

The need for comprehensive consistent multi-attribute data has never been higher.

Greenfield vs Brownfield Geological Knowledge

A greenfield mine development represents the most difficult challenge. Typically these days the orebody has no surface expression so the only knowledge of the orebody is that which can be gleaned from drill core. The entire investment, often in the billions of dollars is based on a limited set of sparsely spaced cores which are then logged and measured in rudimentary ways to create a “picture” of the orebody that can then be communicated first to investors, and then to engineers who are required to design and then estimate the capital and operating cost of the development and the operation such that the return on the investment meets the investors expectations, whilst also meeting the ESG requirements of stakeholders.

The consequences of getting the development decisions wrong are high or extreme. All these decisions and estimates have their basis in the “picture” of the orebody. This “picture” is fundamentally based on the data available coupled with the skill of the geologist to take the data and turn it into a 3D model in order to communicate their understanding of all of the aspects of the orebody that are material in a transparent manner to stakeholders, engineers and metallurgists.

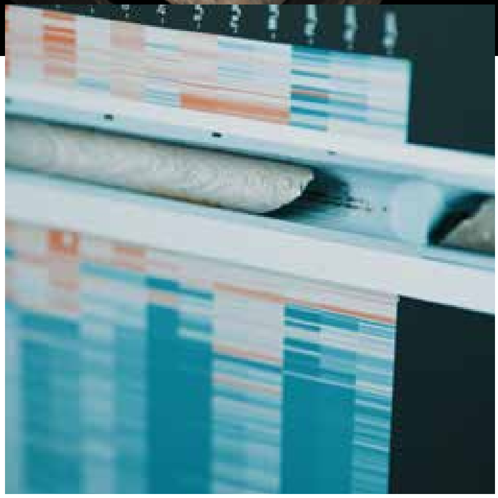
A brownfield setting provides a slightly easier use case than greenfield, given that the orebody will have been seen, experienced and a level of understanding and knowledge will have been derived from more than just the drill core. There are traps in this thinking, however, as orebody extensions are rarely identical to previously mined orebody and an understanding of these differences is critical to success of any brownfield expansion. Brownfield developments also often contain some technological innovation or improvement that means operations will be different and the success of this new technology is dependent on aspects of the orebody that need to be known and understood.

“The consequences of getting development decisions wrong are high or extreme. All these decisions and estimates have their basis in the ‘picture’ of the orebody.”


SITE USE
ONLY

The Role of Core Scanning in Resource Definition and Mine Design of the Future

Core scanning represents a solution to meet the increased need from projects and operations for near- real-time, comprehensive and consistent, rich and granular data at a time when there is a shortage of geological skills along with shortened development timelines. Core Scanning represent a significant step-change in both the workflow to collect geological data, reducing the time to data, and in the range and detail of the data collected.



New scanning technology such as Scan by Veracio delivers a significant increase in the accuracy and precision of chemical analysis through the elimination of sampling errors and biases and through the automated and controlled QA/QC checks and guaranteed chain of custody coupled with matrix calibration that can be further improved over time.

Such scanning technology (Scan by Veracio) is a step-change in geological logging and in the acquisition of structural measurements. The elimination of the subjective bias of the logger and the consistent objective measurement of attributes to inform multivariate classification of the core provides objective geological logs that will survive beyond the personnel undertaking the logging.

The provision of high quality, high resolution wet and dry core photography, coupled with all of the other measurements of the undisturbed core has the potential to eliminate the need for long term storage, saving cost and provides a virtual core library accessible anywhere anytime.

Core scanning has developed to meet the increased needs of the industry. We now have a solution that provides more data that is more accurate and delivered much quicker and is taken on the same basis so it is more useable. It will save costs on site with reduced core handling and sampling, reduce labour for logging and provide data quicker than traditional approaches to data acquisition.

PART 4:

The Solution

Sensor Fusion / Process Improvement / Data Governance / Scale and Fidelity / Human Augmentation

Step-Change Logging on the Same Basis

Data fusions and comprehensive data sets for comparative analysis has a long history in geology, from light tables used to overlay one data set on another, to multi-variate modelling to assist in the understanding and interpretation of the orebody. Logging is not a new science. The systems and methods used to date however have failed to achieve the true fusion of data due to each data set being collected on a different basis (from/to depth down the hole). If data from different bases were merged there would always be a loss of resolution of one of the attributes. As a result, many of the available data sets are not used in the development of an orebody model.

Core Scanning enables the collection of multiple data sets (attributes) on the same basis such that they are ready for use in analysis and statistical processing including machine learning and AI.

Process

The current process for geological data collection and preparation through to the development of a comprehensive geological model involves many convoluted steps. Each of these steps have the potential to introduce errors or inconsistencies and is often dependent on the individual geologist carrying out the work. This process is labour intensive, involves manual handling and has been shown to be error prone. Many of the steps involve quite separate activities that are carried out independently and without the knowledge of the other data collection activities, which — if more integrated — would lead to a better result. A key example of this is where core logging would benefit from the knowledge of the rock chemistry and mineral abundance data, but in the manual world this is rarely available when the logging is carried out. In the core scanning world all data is integrated, thus one data set improves the quality of the next dataset.

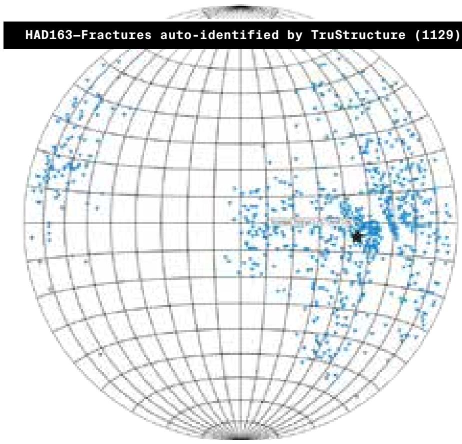
Machine-Readable Photography

Core scanning — particularly with Scan by Veracio and Minalogger, provides a platform for consistent high resolution wet and dry, cleaned core photography that can then be used as a visual reference by both man and machine. This enables future data enquiry and acquisition without detail loss through the use of high-quality lighting and digital cameras. In addition, this captures the core before it has oxidised and can largely eliminate the need to keep or store core in the long term. It is significantly cheaper and easier to look up a digital core library to inspect the core than travel to the core shed, find the core tray of interest, remove it from the stacks and carry out the inspection of highly disturbed core that has been cut, sampled and oxidised.

Structural logging is an extremely important step in the evaluation of many orebodies, given the fact that many orebodies are structurally controlled. For geotechnical analysis, fracture frequency, orientation, surface description and infill are critical for design work, as is comprehensive RQD data. This data is often collected in a labour-intensive campaign to inform a design decision and then ignored.

The use of machine-readable images can increase the measurement of dips, strikes, lineations of a variety of geological and structural features relative to oriented core axis. This automated process provides a comprehensive data set as opposed to a smaller selective (biased) set of time consuming, laborious measurements that are inaccurate. Rarely is structural logging comprehensive and consistent and it often suffers from inadequate classification and description. Structural logging is often difficult to digitise and rarely finds its way into informing the geological model used to evaluate a deposit.

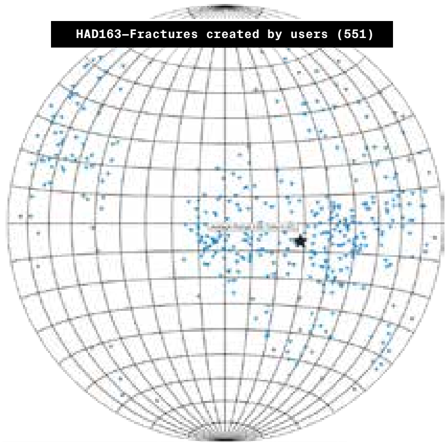
HAD163-Fractures auto-identified by TruStructure (1129)



"Geotechnical logging of a 1,500m hole via manual will commonly capture 200+ features. This is compared to 2,000+ features via machine-assisted geotechnical logging."

– Anthony Harris, Chief Geoscientist, Newcrest (now Newmont)

HAD163-Fractures created by users (551)



Dry Core

Wet Core

To ensure samples are best-placed for downstream data science, strong, machine-readable photography focuses on:

- **Consistency of lighting**
- **Framing**
- **Environment**
- **Color**

Core Scanning and Automated Logging

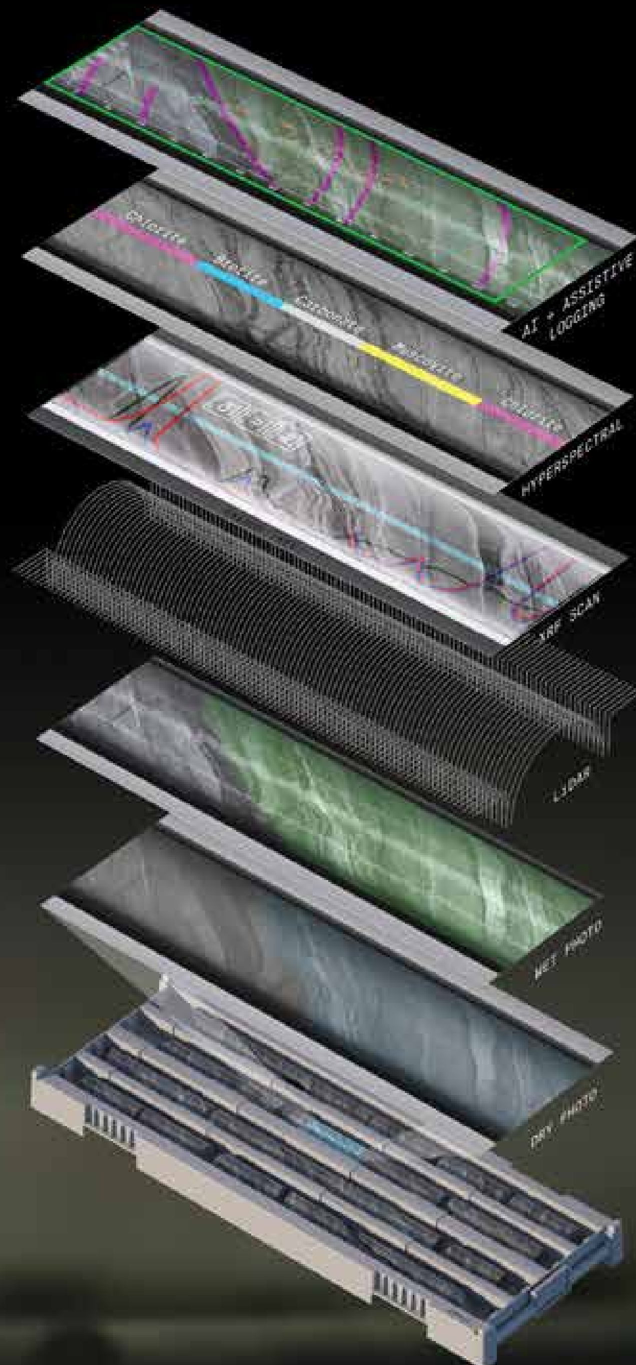
At first, core scanning can seem like it's the answer to everything. And while that may not be the case, more often than not it's core scanning technologies like Scan by Veracio that unlock unrealised potential inside existing projects, orebodies and operations.

By understanding where minerals are located, how much of them there are, and what their properties are, geoscience team can make mining more reliable and profitable. This knowledge also helps choose the best methods for getting minerals out of the ground and processing them. Core scanning can also play a very important role in identifying and measuring harmful elements within mineralised zone. If these harmful elements are not managed, they can reduce margins by causing customer pricing penalties or affect how minerals are processed and recovered.

Drilling, sampling, assaying, designing and drilling again can take a lot of time. Usually this process can take months, delaying decisions because not all necessary information is available. Core scanning gets accurate data quickly in ways that can lower the costs of drilling, project feasibility, mining and processing.

Core Scanning technology can change this by delivering results in minutes rather than months, allowing mining companies to adjust their drilling, mine designs and capital plans as they go.

This enables more adaptive drilling, faster time to first ore, greater precision in grade control; by providing quick information that helps make decisions about "where to next?"



The Traditional Way

Core is collected from the drill rig, transported to a core facility and stacked for later data acquisition;

If the core is oriented then structural measurements and photographs are taken often using an inconsistent setup for core washing, lighting and camera position;

The core is then split by manually selecting individual core pieces and cutting them with a diamond saw. The core at this point is irreversibly damaged and pieces are often replaced in the wrong order or wrong direction. This process becomes difficult when the rock quality is poor.

For the interval that is approximated from the depth readings, "half" of the core is then manually selected and placed into sample bags. This manual process has the potential to introduce subjective bias, as a sampler is more likely to select the more competent half or the "shiny pieces."

Sample bags are given a unique sample identifier and often a physical tag is included in the bag and the relevant from and to interval of the sample is manually recorded for later entry into the database. This step has been shown to be a source of error and mix up.

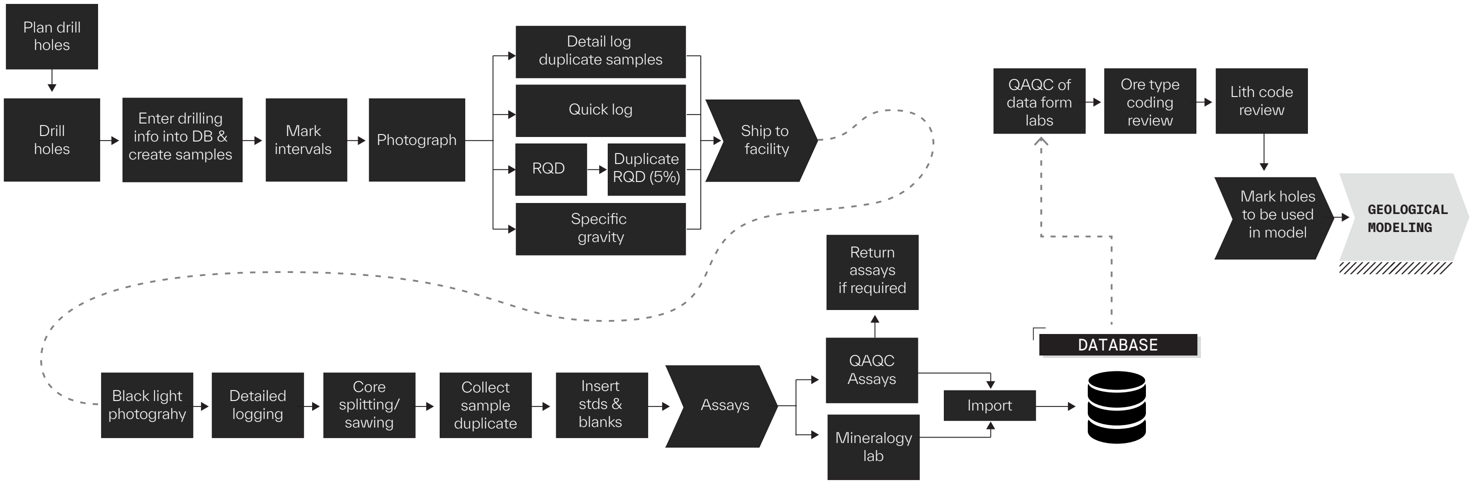
Sample bags are then transported to a laboratory for preparation and analysis, a process which involves numerous error-prone steps. Samples are removed from bags, crushed and ground before being sub-sampled for ultimate assay. Often the subsampling comes down to a few grams of material selected from what is hopefully (but never is) a homogenised sample.

Assays of the contents of each sample bag are then communicated electronically often months later to the geologist. The geologist will then have to import the data comprising sample number and assay and join this with the manually entered hole depth and sample number data.

This time lag is significant as the geologist has invariably moved on from thinking about the geology of that particular hole when they are presented with data to verify and check.

Rarely will a geologist have the time or the opportunity to go back to the core when verifying the assay data, often only rudimentary sense checks are made.

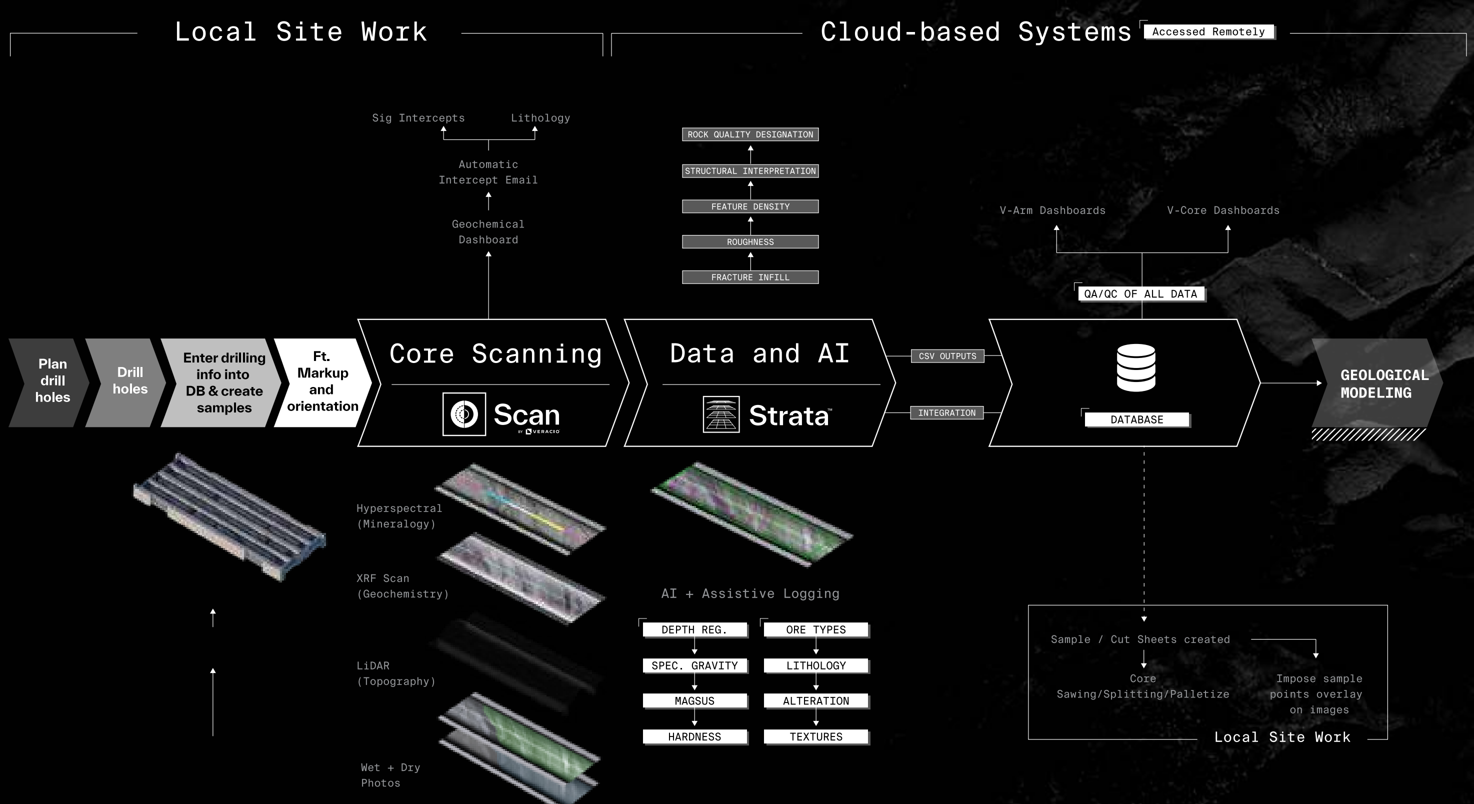
The various attributes for a given drillhole are often collected at different times and on a different basis and thus the opportunity to look at the full set of data at one time is often missed.



The Veracio Way

The alternative to this convoluted and piecemeal process is one that utilises automated core scanning (Scan by Veracio) to collect a vast array of comprehensive, consistent, accurate, and highly granular geological data in a single pass. This is done in an automated, controlled and repeatable manner under the supervision of a single field technician at the drill rig whilst the rig is on the site and passing the full data set onto the geologist in near real time.

This represents a massive step change in efficiency (and cost saving) whilst also providing much more effective result where the comprehensive nature of the attributes can contribute to cross checking and verification resulting in less errors, thus validated data sets. The streamlined process not only speeds the process from hole to data but presents the data already verified with multiple attributes collected on the same basis so that it can be immediately used for orebody modelling or in multivariate statistical processing such as machine learning and AI application that are now becoming common practice.



The Rise of Downhole Digital Geophysics and Surveys

The impacts and benefits to exploration and mining extend further than core samples and scanning. The evolution of digital downhole geophysics in mineral exploration reflects a broader trend toward more integrated, efficient, and responsive geological assessment methods.

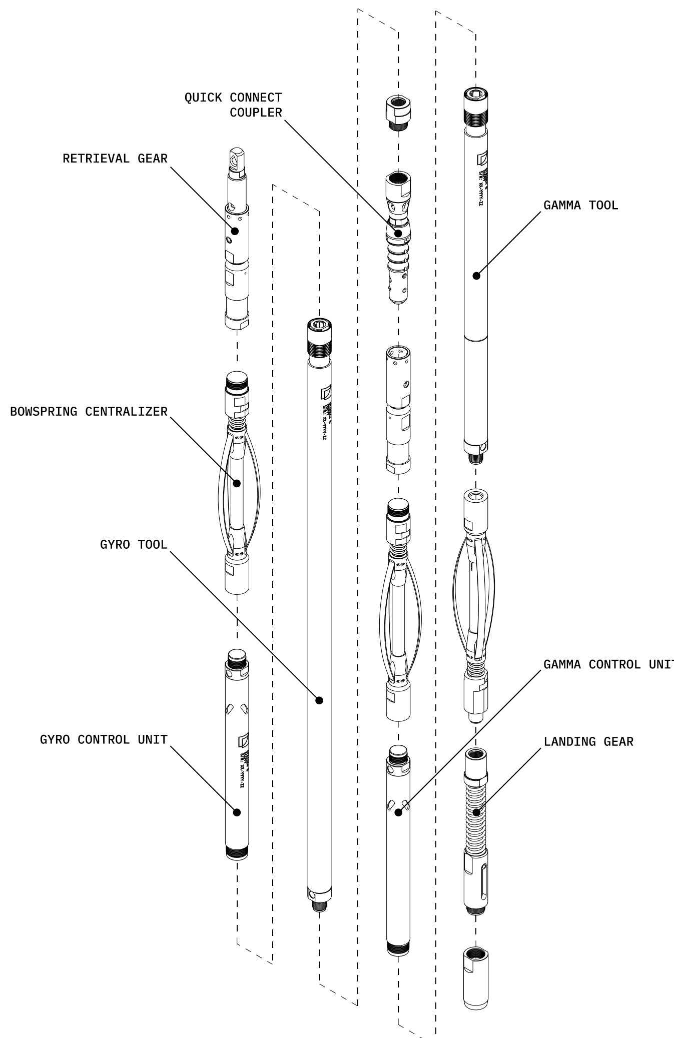
Downhole surveying has traditionally relied on a variety of physical measurements taken within boreholes to infer geological conditions. However, the integration of digital technology has brought about a new era where data from downhole sensors can be gathered, processed, and analyzed with greater speed and accuracy than ever before. Digital downhole tools now incorporate sophisticated sensors that can measure a range of geological parameters.

For instance, modern gyroscopic instruments provide accurate directional data essential for drilling operations, enhancing the precision of borehole placement and trajectory.

Similarly, gamma ray detectors are used to log natural radiation, aiding in the identification of mineral deposits and stratigraphic boundaries.

The rise of Industry 4.0 has facilitated the development of interconnected devices capable of communicating wirelessly, allowing for rapid data transmission from the drilling site to the data center. Data management and accessibility have been revolutionized by cloud storage solutions. Meaning geological data, once confined to the physical logs and paper trails, or at best a USB stick; can now be securely stored, accessed, and shared through cloud-based platforms, facilitating collaboration across different locations and disciplines.

The transition from analog to digital has not only increased the accuracy of geological interpretations but also accelerated the pace at which these insights can be gained and applied, marking a significant step forward in the exploration and mining industries.



ESG Impacts of Advanced Geological Knowledge

In addition to the elimination of physical manual handling of core trays and samples, which reduces the health and safety risk, it also reduces the number of people needed at remote sites. The need to have long-term core storage can be replaced by a comprehensive virtual core library. This leads to significant saving of both capital and operating cost for a result that provides richer, objective, accurate, precise, comprehensive and consistent data.

E Environment

The core scanning process results in a significant reduction in both energy and carbon, with fewer physical samples requiring transport, fewer people travelling remotely and less on site requirements for infrastructure such as core sheds, core sawing, and sample handling. The data provided from core scanning allows the creation of high fidelity orebody models which is enabling precision mine-designs and selective mining methods due to the increased resolution of data and geological knowledge, resulting in mine plans that deliver lower carbon, energy, and land disturbance with less tailings and waste. Better knowledge about deleterious elements such as acid generating materials can inform mine closure plans and assist in gaining regulatory approvals.

S Social

The ability to remotely access a digital virtual core library and allow online collaboration allows the best skills globally to be leveraged regardless of location this enhancing accessibility and diversity of the geological workforce. New labour pools can be tapped-into if data acquisition is no longer a remote site activity. The use of automation in the sample handling, coupled with reduced on-site labour, improves safety; meanwhile, the use of the latest digital processes and tools will enhance organisation culture and retention of highly-skilled staff.

G Governance

Consistent metadata on samples and logs coupled with a full chain of custody for every step in the process provides a significant step change in data governance. Traditional approaches rely on sample numbers assigned to tags and sample bags and the manual reading and labelling of “from” and “to” depths. There is then a complicated process to maintain the sample number or tag with each sample throughout the sample transportation, preparation, sub-sampling and analysis phase. The results are then communicated as a sample number and (hopefully) the corresponding result is then re-merged with the downhole depth to complete the process. This process is convoluted and error prone. The Core Scanning approach maintains the link between hole depth and measurement thus ensuring an auditable chain of custody by eliminating the need for translation to sample numbers and tags then then converting back to depths and the associated errors.

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Not only were metal values available for spatial modeling weeks in advance of final laboratory assays, but the data also helped prioritize intervals (in this case from 342 to 1,062 m) to be rushed to the lab.

Excerpt from SEG paper “Empowering Geologists in the Exploration Process—Maximizing Data Use from Enabling Scanning Technologies”, co-authored by **esteemed Chief Geoscientist of Newmont, Anthony C. Harris** and Veracio geoscientists.

PART 5:

Next-Level Geological Knowledge, Today

Automated Logging / Data Collection / Sensor Fusion / Analysis / Integration

To embark on the path to next-level geological knowledge, mining companies must embrace cutting-edge technologies designed to enhance data collection,

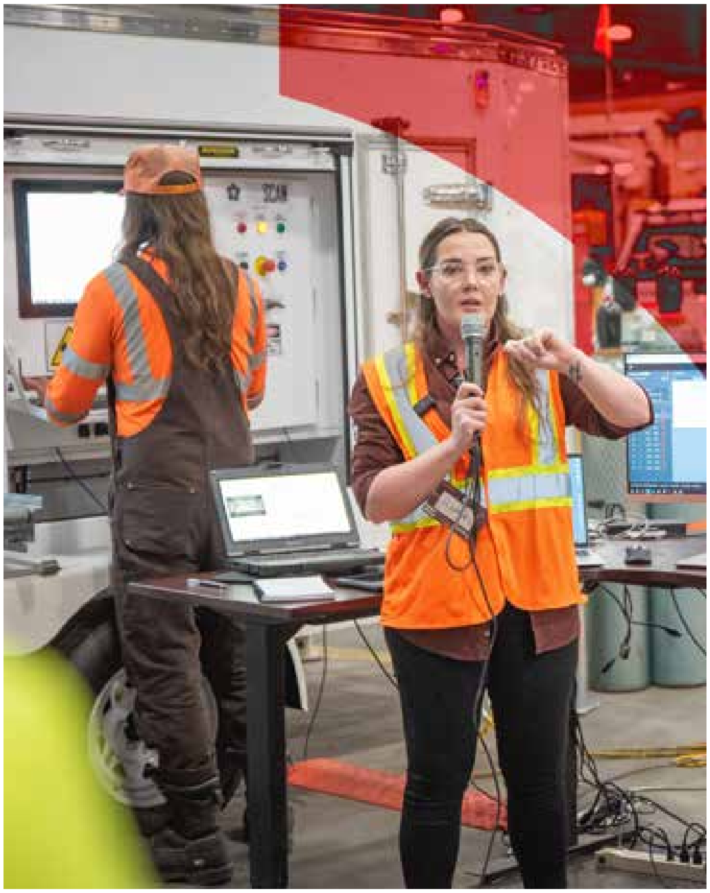
Automated core scanning, exemplified by Scan by Veracio, stands as a beacon of progress in this regard. By automating core logging, structural measurements, and high-resolution photography, this technology not only accelerates data acquisition but also guarantees consistency and accuracy at a much higher granular detail. Its ability to integrate multiple geological attributes on the same basis empowers geologists to construct comprehensive orebody models and provides datasets

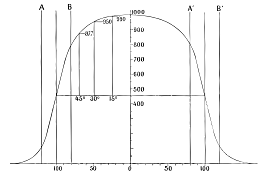
From Resource Characterization to Geological Knowledge

There has been a fundamental shift in the mining industry — the transition from resource characterization to geological knowledge. Traditional resource characterization, often marked by inconsistent data collection and an undue focus on average grades, has evolved. The advent of automated core scanning technologies, exemplified by Scan by Veracio, has empowered the industry to embrace comprehensive geological knowledge. We no longer rely solely on smoothed averages but also consider the rich tapestry of geological attributes, including boundaries, structures, mineralogy, and alteration. This paradigm shift enhances the decision-making capabilities of engineers and metallurgists, equipping them to make informed choices that factor in the intricate details of the orebody.

Data for AI is Not the Same as Data for Humans

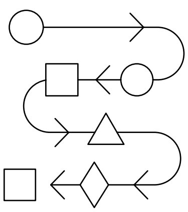
There is a critical distinction between data intended for artificial intelligence (AI) and data meant for human interpretation. Both are indispensable, but they serve distinct purposes. Data for AI requires consistency, objectivity, and machine-readability, attributes perfectly aligned with technologies like automated core scanning. This technology ensures that data collected on the same basis is devoid of subjectivity and ready for analysis. It simultaneously enables geologists to focus on interpretation and modelling, shifting their role from laborious data collectors to insightful analysts. By recognizing this difference, we unlock the potential for AI to augment human expertise, leading to more robust orebody models, predictions, and optimizations.





The Mindset Shift Required to Advance the Industry

Any profound transformation demands a corresponding shift in mindset. The mining industry, historically characterized by tradition and resistance to change, is no exception. The industry's professionals must view emerging technologies as opportunities rather than a threat to their expertise. Overcoming this inertia is a challenge, particularly for experienced geologists and mining experts accustomed to traditional methods. Education and communication are key here. Industry professionals must understand that adopting new approaches enhances efficiency and opens doors to innovative exploration of orebodies. By embracing a mindset of continuous learning and adaptation, we propel the industry forward into an era of unprecedented possibilities.



Realigning Workflows

Next-level Geological Knowledge necessitates a re-evaluation of existing workflows. Traditional approaches, marked by manual data collection, siloed processes, and lengthy turnaround times, are no longer sufficient. Miners must streamline their operations, reassigning geologists from labor-intensive tasks to data analysis and interpretation. In doing so, they empower their teams to focus on the value-added aspects of their work, driving efficiency and innovation.

Additionally, interdisciplinary collaboration is crucial. Geologists, engineers, metallurgists, and data scientists must work in concert to leverage the full potential of geological knowledge. Breaking down departmental barriers and fostering communication is vital for success. By encouraging cross-functional teamwork, mining companies can harness collective expertise to make holistic, well-informed

Why Geologists Hold the Keys to the Next Stage of Mining Efficiency

At last, we recognize the central role that geologists play in driving the next stage of mining efficiency. Geologists, often considered the custodians of geological data, are indispensable in interpreting geological attributes, understanding orebodies, and making informed decisions. Their expertise bridges the gap between data collected by technology and its meaningful interpretation. They become the custodians of geological knowledge. Automated core scanning technologies, such as Scan by Veracio, empower geologists to leverage consistent, accurate, and granular data to create high-fidelity orebody models. These models go beyond traditional grade estimates, incorporating geological boundaries, structures, mineralogy, and more. Moreover, geologists validate and refine AI-driven insights, ensuring that predictions align with geological reality and contribute to sound decision-making.

Geologists are instrumental in addressing the industry's skills challenge. Technologies like automated core scanning make geological work more enticing to a broader talent pool by shifting the focus from laborious data collection to data analysis and interpretation.

Adapting to Change

The transition to next-level geological knowledge may be met with resistance within an organization. Professionals who have grown accustomed to traditional methods may resist change, fearing the displacement of their expertise. Overcoming this resistance requires clear communication and a commitment to education and training. Employees must understand that technology is a tool to enhance their capabilities, not replace them. Demonstrating the benefits of next-level geological knowledge through tangible results can help in winning over skeptics.

Navigating the Regulatory Landscape

As the mining industry evolves, so do the regulatory requirements. Mining companies must ensure that their adoption of advanced technologies aligns with existing regulations and reporting standards, such as as NI43-101 or the JORC Code. Future evolution of these codes are likely to incorporate greater requirements in areas such as ESG. This will in turn require Competent Persons to have collected more data (not less) to transparently inform stakeholders of material ESG impacts. The use of innovative tools like automated core scanning will become the norm for high-quality comprehensive data collection for use in resource reporting.

Realizing the Benefits

The transition to next-level geological knowledge is not without its challenges, but the benefits are substantial. By embracing technology, streamlining workflows, fostering collaboration, and adapting to change, mining companies can unlock new levels of efficiency, sustainability, and profitability.

1. Improved Decision-Making

Next-level geological knowledge provides richer and more detailed geological models, enabling more informed decisions. Whether in mine planning, processing optimization, or environmental management — the enhanced data leads to better outcomes.

2. Efficiency Gains

Automated core scanning reduces the time and labour required for data collection, accelerating the turnaround from exploration to production. This efficiency translates into cost savings and faster project timelines.

3. Sustainability

The reduction in manual core handling, storage, and transportation contributes to a smaller environmental footprint. Additionally, the precise data obtained through automated scanning supports responsible mining practices, minimizing waste and environmental impact.

4. Attracting Talent

The mining industry's appeal to new talent increases when the focus shifts from laborious data collection to data analysis and interpretation. Next-level geological knowledge creates a more engaging and dynamic work environment.

5. Competitive Advantage

Mining companies that embrace next-level geological knowledge gain a competitive edge. They can adapt to changing market conditions more quickly, optimize their operations more effectively, and respond to unforeseen challenges with agility.

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