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GATHERING COORDINATES OF THE GEOLOGICAL AND GEOTECHNICAL LOCATION OF THE MINE

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Abstract

The identification and mitigation of adverse geologic conditions are critical to the safety and productivity of underground coal mining operations. To anticipate and mitigate adverse geologic conditions, a formal method to evaluate geotechnical factors must be established. Each mine is unique and has its own separate approach for defining what an adverse geological condition consists of. The collection of geologic data is a first critical step to creating a geological database to map these hazards efficiently and effectively. Many considerations must be taken into account, such as lithology of immediate roof and floor strata, seam height, gas and oil wells, faults, depressions in the mine floor (water) and increases in floor elevation (gas), overburden, streams and horizontal stress directions, amongst many other factors. Once geologic data is collected, it can be refined and integrated into a database that can be used to develop maps showing the trend, orientation, and extent of the adverse geological conditions. This information, delivered in a timely manner, allows mining personnel to be proactive in mine planning and support implementations, ultimately reducing the impacts of these features. This paper covers geologic exploratory methods, data organization, and the value of collecting and interpreting geologic information in coal mines to enhance safety and production. The implementation of the methods described above has been proven effective in predicting and mitigating adverse geologic conditions in underground coal mining. Consistent re-evaluation of data collection methods, geologic interpretations, mapping procedures, and communication techniques ensures continuous improvement in the accuracy of predictions and mitigation of adverse geologic conditions. Providing a concise record of the work previously done to track geologic conditions at a mine will allow for the smoothest transition during employee turnover and transitions. With refinements and standardization of data collection methods, such as those described in this paper, along with improvement in technology, the evaluation of adverse geologic conditions

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will evolve and continue to improve the safety and productivity of underground coal mining.

Keywords: Geotechnology, geotechnical structure, geological map model, engineering geologists,mining technology, geotechnical processes.

Introduction

The geotechnical model, together with its four components, the geological, structural, rock mass and hydrogeological models, is the cornerstone of open pit slope design. As illustrated in Figure 1, the model must be in place before the successive steps of setting up the geotechnical domains, allocating design sectors and preparing the final slope designs can commence. Populating the geotechnical model with relevant field data requires not only keen observation and attention to detail, but also strict adherence to field data gathering protocols from day one in the development of the project. In this process, it is expected that the reader will be aware of the wide variety of traditional and newly developed data collection methods available to the industry. Nonetheless, it cannot be emphasised enough that those who are responsible for project site investigations must be aware of the mainstream technologies available to them, and how and when they should be applied to provide a functional engineering classification of the rock mass for slope design purposes. For geological and structural models these technologies can range from direct or digital mapping and sampling of surface outcrops, trenches and adits to direct and indirect geophysical surveys, rotary augering and core drilling. For the rock mass model they can include a plethora of field and laboratory tests. For the hydrogeological model they can include everything from historical regional hydrogeological data, to the collection of hydrogeological data 'piggy-backed' on mineral exploration and resources drilling programs and routine water level monitoring programs in specifically installed groundwater observation wells and/or piezometers. Providing an exhaustive list of each and every technology is beyond the scope of this book. However, it is possible to outline the availability and application of the mainstream technologies used to provide a functional engineering classification of the rock mass for slope design purposes.

Determining the coordinates of the dimensions of the location of the mine

Outcrop mapping is fundamental to all the activities pursued by the teams responsible for designing and managing the pit slopes. It includes regional and minescale surface outcrop mapping during development prior to mining and bench mapping once mining has commenced. Preferably it should be carried out only by properly trained geologists, engineering geologists, geological engineers or specialist geotechnicians, assisted by specialists from other disciplines as needed. Historically, the mapped data were recorded by hand on paper sheets and/or field notebooks, but advances in electronic software and hardware mean that this is increasingly replaced by electronic data recording directly into handheld tablets and/or laptop computers. Both systems have their merits, but the electronic system has the advantage that it eliminates the tedious transfer of paper data into an electronic format. It produces data that can be almost instantly transmitted for further analysis and checking in Autocad or similar systems. On the other hand, if there is not an effective file backup and saving procedure, the data are at risk of being lost in a split second. There could also be some issues with the auditing process since no field mapping sheets are available.

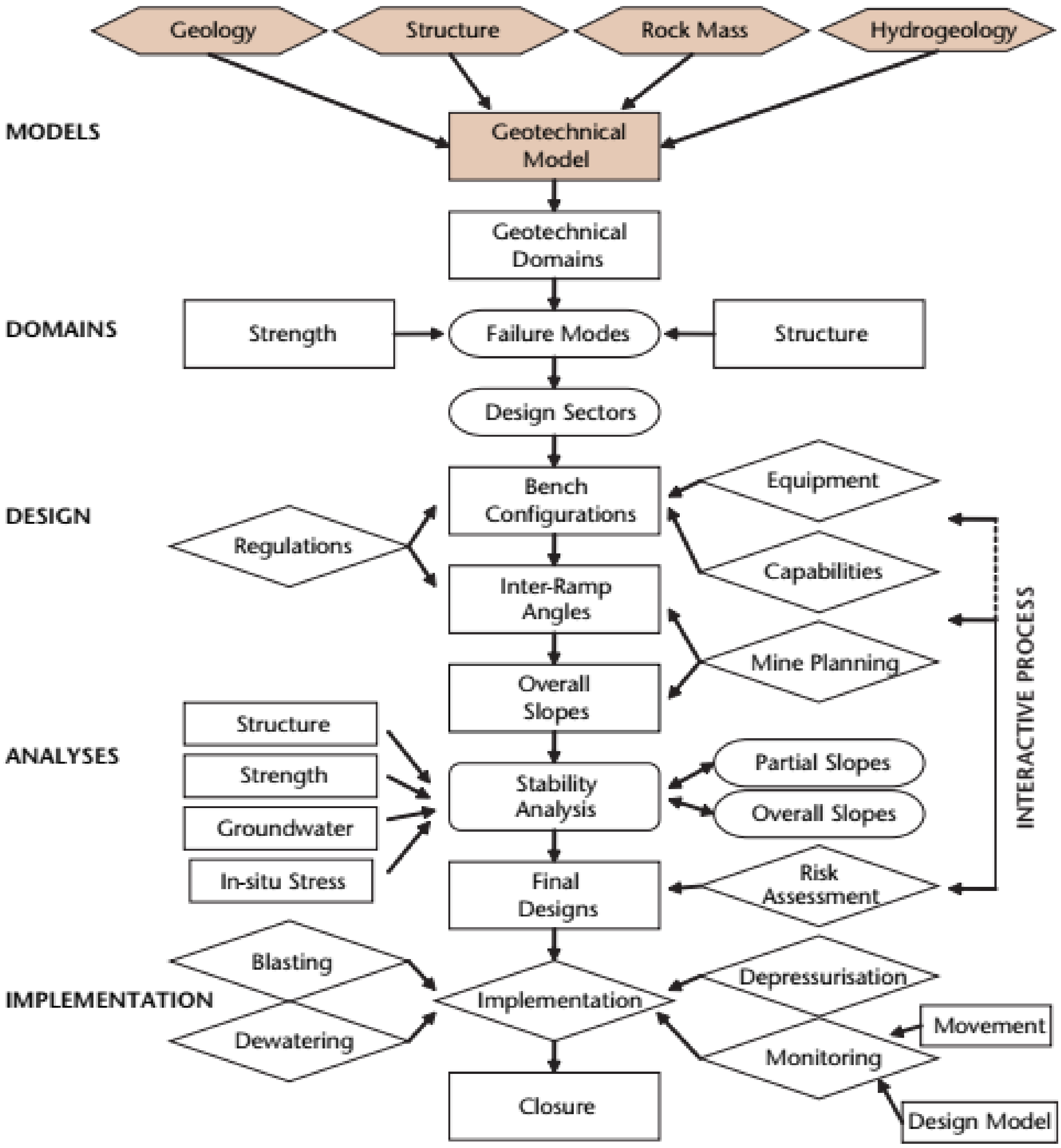

Figure 1: Slope design process

More recently, an area that has increased in importance is the in situ characterisation of the ore body and its surrounds by surface-based geophysical methods prior to mining. High-resolution penetrative methods can be used to assist in locating and understanding the structural setting and petrophysical properties of both the

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mineralised body and its surrounding materials. During this process there is an opportunity to extract valuable geotechnical information, because the petrophysical properties so determined are essentially volumetrically continuous and are from undisturbed materials. The geophysically derived determinations can be recalibrated against actual measurements taken from drill core materials or samples collected during the mining process. Regardless of how it is recorded, it is important that all the geotechnical data captured are capable of supporting the principal rock mass classification and strength assessment methods used by the industry today. Similarly, although the level of detail captured must at least be relevant to the level of investigation, there is no reason not to collect the most comprehensive set of data even in the earliest stages of investigation. This section therefore outlines the data that must be collected, the procedures that are followed and the terminology and classification systems that are used.

General geotechnical processes

As noted above, outcrop mapping includes both regional and mine-scale surface outcrop mapping during development prior to mining and bench mapping once mining has commenced. Accordingly, the level of detail captured must not only be relevant to the level of investigation, but must also be presented at the appropriate scale. This requires thought and careful planning to set the scene before any mapping is performed. Scene setting includes understanding the geology that is to be mapped, determining what is relevant to the task in hand, setting the appropriate scale, preparing the field logging sheet, deciding on the level of data that is to be recorded and selecting the right mapping tools. In all cases the data recorded on the field logging sheet must include at least the following items.

1) The identification of the exposure being mapped, including the northing and easting coordinates and reduced level of a reference mapping point, the mapping scale, the name of the person who carried out
the Processing and the date logged.

2) The rock type, the degree of weathering and/or alteration and the strength of the intact rock. Most mine sites will have a two or three letter alphanumeric code to describe the rock type.

3) The nature of the structural defects that occur in the exposure. This should include:

*Orientation (dip and dip direction);
*Frequency, spacing and persistence (observed length);
*Aperture (width of opening);
*Roughness;
*Thickness and nature of any infilling;
*If a fault, the width of the zone of influence of the fault to either side of the fault plane.

Digital imaging

The use of 3D digital photogrammetric and laser imaging technology for structural mapping in open pit mines has increased dramatically within the last few years. The Sirojoint®1 and 3DM Analyst®2 digital photogrammetric systems in particular have become firmly established as routine methods of mapping exposed rock faces in both open cut and underground environments. The technology is illustrated in Figures 2 and 3. Digital photogrammetry integrates 3D spatial data with 2D visual data to create spatially accurate representations of the surface topology of the rock. Structural properties such as orientation, length, spacing, surface roughness and distribution type can be determined remotely and accurately over long distances and in areas where access is difficult and/or unsafe. Reported accuracies range from the order of 2 cm at distances of 50 m to 10 cm at distances of up to 3 km. These features have enabled rapid, accurate, safe and low-cost geological mapping at bench and multi-bench scale using the system software or by downloading the data into mine planning software such as Vulcan™, DataMine™, MineSite™ and Surpac™. The integration of the imaging software with such mine planning systems provides the additional benefit that the data can be used in real time for mine design, mine planning and mine operating purposes.

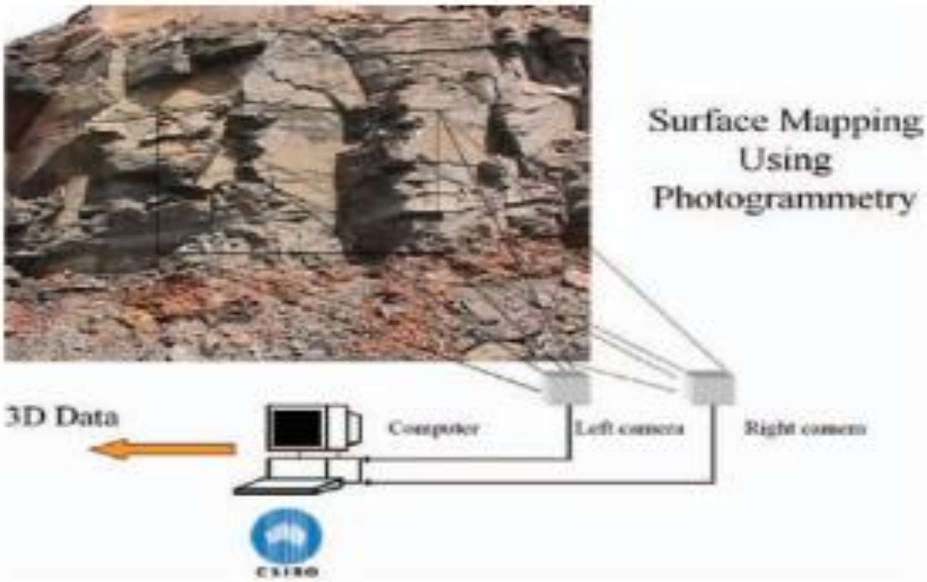

Figure 2: Gathering a digital photographic image of an outcrop Source: Courtesy CSIRO.

Practical considerations

Sampling bias and orientation measurement errors are the traditional line and window mapping issues, on the surface and underground. In open pit mining, worker safety and the time taken to map scanlines and/or windows along the benches have also become issues.

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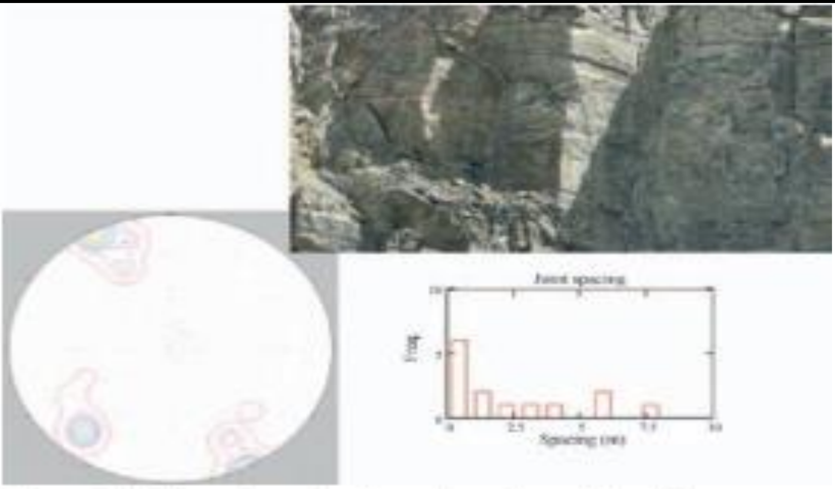

Figure 3: Joint orientation (equal area, lower hemisphere projection) and spacing information provided from a stereographic image of an outcrop Source: Courtesy CSIRO

In scanlines and windows four types of sampling bias are recognised.

1. Orientation bias;
2. Size bias;
3. Truncation or cut-off bias;
4. Censoring bias.

Orientation bias depends on the orientation of the scanline or window relative to the orientation of the structure. Clearly, if a structure is parallel to a scanline or window then few members of that set will be recorded. When considering size bias, the larger the structure, the more likely it is to be sampled by the scanline or window. Inversely, if a small cut-off size is used, then the size distribution of all of the structures along the scanline or inside the window may not be properly accounted for. Understanding the nature and effect of censoring bias is important, especially when collecting data that will eventually be used in Discrete Fracture Network (DFN) modelling. The censor window is the area within which the trace lengths can be accurately measured. Joint traces that extend outside these sections are said to be censored. If both ends of the trace terminate within the window (i.e. the trace is uncensored), then something is known about the joint's persistence and size. If the trace length to termination cannot be seen or measured, then a lot less is known about its persistence. To prepare a valid DFN model there must be enough uncensored (or measured) data to arrive at a statistically viable joint size. The DFN modelling process cannot work if too many joints are censored or if censoring information is not available. Digital photogrammetry has simplified these issues, particularly with respect to orientation accuracy, orientation bias, trace lengths (cut-off size and censoring), efficiency of mapping and worker safety. Measurement errors in scanline and window mapping have been reported to be as much as ±10° for dip direction and ±5° for dip angle. Inaccuracies of this order have been overcome by digital photogrammetry, with differences of only ±1° now being reported for dip direction and dip angle. The ability to vary the scale of mapping from bench to inter-ramp to overall pit scale from the one location is another major advantage of digital photogrammetry. This flexibility gives the user the means to examine the structural fabric at bench scale or to map large structures over multiple benches, which helps to reduce cut-off size and censoring biases. Orientation bias will always be difficult to overcome, but it is possible to address this issue by moving the camera to positions where structures visible in the ends of benches and re-entrants in the wall can be captured. Other major benefits of digital photogrammetry are its flexibility and remote access capability, which can significantly reduce the time taken to gather the field data and remove the operators from potentially hazardous situations (Figure 3). In many jurisdictions, it is no longer allowable to work directly beneath open pit mine benches.

Figure 3: Potentially hazardous bench mapping conditions

The disadvantages of digital imaging systems are that they still require ground proofing and cannot be used to determine the physical features of the structures, particularly surface roughness and the thickness and nature of any infillings. Their ability to accurately define flat-lying and vertically inclined structures is also questionable. However, these disadvantages can be minimised with a well-planned ground proofing and sampling program when the mapping and structural assessment process has been completed.

Conclusions

Seismic reflection methods have been used successfully in both sedimentary and hard rock environments for mine planning purposes. However, traditional seismic methodologies that were successful for petroleum resources have had to be extensively modified for hard rock applications. While there is a perception that seismic methods are expensive, the acoustic impedance (density and seismic velocity) information they provide can be invaluable as it essentially is a 3D image of the subsurface. For coal mining purposes, analysis of seismic data can provide detailed structural information including the location, nature and throw of faults, definition of fracture zones and the identification of seam splitting and thickness. Also, amplitude information has been related to methane desorption. For hard rock metalliferous mining purposes, most seismic studies to date have concentrated on deposits that currently would not be considered suitable for open cut operations. However, useful pre-mining information can be gained in nearly any situation. For example, seismic studies at the Witwatersrand Basin and Bushveld Complex provided structural and lithologic information that was not viable by other means. More recently, high-resolution imaging of near-surface deposits has been demonstrated. Specialist near-surface seismic methodologies have been developed. For example, in sedimentary coal sequences 'Converted-Wave (PS) Seismic' can provide independent validation of mapped structures and clearer, more coherent near-surface images. 'Surface Wave Seismic' is a seismic refraction technique that has been specifically developed to provide surface hardness and velocity information, which should be creatable with open pit mining parameters such as diggability and blastability.

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