USE OF THE MINING ROCK MASS RATING (MRMR) CLASSIFICATION: INDUSTRY EXPERIENCE

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ABSTRACT

In 2000, Laubscher's Mining Rock Mass Rating (MRMR) classification system was updated and published. The new system brought a few fundamental changes that were in direct response to the challenges and problems encountered when applying the classification system in the mining environment, specifically caving operations. The fundamental changes introduced into the MRMR system in 2000 were the abandonment of the Rock Quality Designation (RQD) as an input parameter, accounting for healed and cemented joints, and the concept of rock block strength.

The objective of this paper is not to discuss the role and usefulness of classification systems; the fact that classification systems are widely used in every stage of mining projects speaks for itself. This paper discusses some of the experiences gained with the MRMR 2000 system in various mining projects and shows how the changes to the system have resulted in improved assessment of rock mass conditions. Issues related to core logging for rock mass assessment are also presented.

INTRODUCTION

Laubscher's Mining Rock Mass Rating (MRMR) system was introduced in 1975 [Laubscher 1975] and has been modified and expanded several times since then [Laubscher 1990, 1993; Laubscher and Taylor 1976]. The last update was released in 2000 [Laubscher and Jakubec 2001]. The principal changes in the new In Situ Rock Mass Rating (IRMR) included the concept of rock block strength, which accounts for the effect of cemented joints and veins. All of the changes were in direct response to the challenges encountered when applying the classification system in the mining environment, specifically caving operations in Chile and Australia.

If rock mass classification is to reflect reality, it is important that all of the critical parameters influencing the rock mass behavior are accounted for. Ignoring strength reduction due to microfractures or ignoring the presence of cemented joints could result in the misclassification of the rock mass competency and can have serious safety and/or economic consequences.

As with any empirically based system, it is important that experiences from new projects are analyzed and the classification system is further refined and calibrated. Although some of the rules and relationships used in MRMR and its applications are "crude," it is our view that it is better to use a simplistic method than to ignore the issues. To quote John Maynard Keynes: "It is better to be roughly right than precisely wrong."

Unfortunately, in the real world, the rock masses are inherently variable and do not conform to an ideal pattern. The issue of appropriate site-specific geotechnical evaluation of rock masses was recently discussed by Murphy and Campbell [in press]. In order to ensure that rock mass classification reflects reality, a certain amount of engineering judgment/interpretation is required. A classification system can provide guidelines for design, but the mining practitioner must ensure that the system is applied correctly. The role of the classification system as a communication tool between operation, engineering, geology, and management cannot be stressed enough. Unfortunately, a failure in communication is often one of the root causes of the problem.

This paper discusses some of the experience with Laubscher's IRMR/MRMR system as introduced in 2000.

THE MRMR CLASSIFICATION SYSTEM: AN OVERVIEW

There are currently three main classification systems used in the metal mining industry: Bieniawski's RMR [Bieniawski 1973], Barton's Q [Barton et al. 1974], and Laubscher's MRMR [Laubscher and Jakubec 2001]. A rough comparison of these systems in terms of required input parameters is shown in Table 1. The main differentiators of the MRMR 2000 system compared to previous versions of the MRMR, Q-system, and Bieniawski RMR systems are:

- Scale concept in material strength (intact rock > rock block > rock mass)
- Inclusion of cemented joints and veinlets
- Abandonment of the Rock Quality Designation (RQD) as an input parameter
- Mining adjustments (in comparison to Q)

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Table 1.—Comparison of main classification systems used in the mining industry

Category	Parameters	Beniawski RMR	Barton Q	Laubscher 90	Laubscher 2000
Intact rock strength	UCS	x	x	x	x
Open joint frequency	RQD	x	x	x	-
	FF/m	x	-	x	x
	Joint set (Jn)	x	x	x	x
Open Joint strength	Roughness (Jr)	x	x	x	x
	Alteration (Ja)	x	x	x	x
	Infill (Ja)	x	x	x	x
Cemented joints	CJ/m	-	-	-	x
quantity and strength	CJ strength	-	-	-	x

Another system that is occasionally encountered in metal-mining projects is the Geological Strength Index (GSI) [Hoek et al. 1995]. Since this system cannot be easily "decoded" and individual parameters assessed separately, it was not used for comparison in Table 1. The objective of this paper is not to discuss which system is more suitable, nor is it to describe every detail of the MRMR system. It is recommended that the reader refer to Laubscher and Jakubec [2001], where the MRMR 2000 system is fully discussed. Flowsheets illustrating the different parts of the MRMR 2000 system are shown in Figures 1–2. Figure 1 illustrates the parameters used to determine the IRMR, and mining adjustments that produce the final MRMR value are presented in Figure 2.

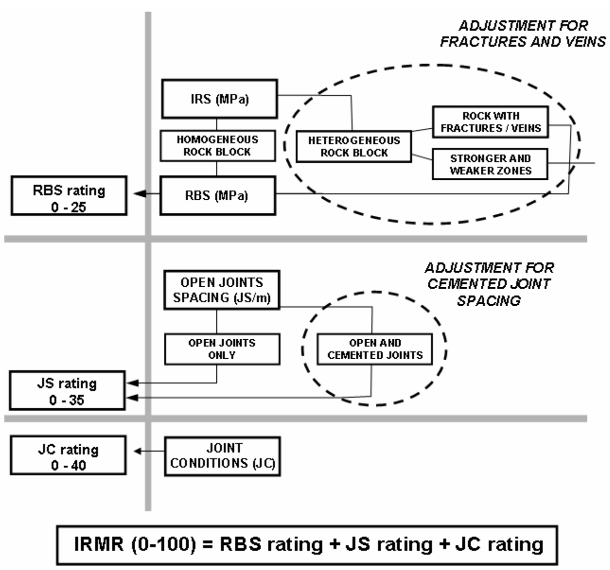

Figure 1.—IRMR 2000 flowsheet.

The application of the MRMR system in mine design is presented in the paper "Planning Mass Mining Operations" [Laubscher 1993]. The main design recommendations and guidelines include:

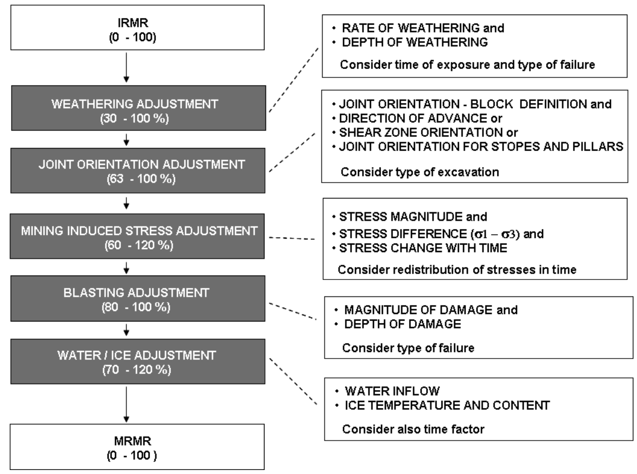

Figure 2.—Mining adjustments.

- Support design
- Cavability diagrams and stability of open stopes
- Extent of cave and failure zones
- Caving fragmentation
- Caving rates and mining sequence
- Pit slope guidelines

The design charts and associated recommendations are based on experience gained in mining projects around the world and have found wide acceptance within the mining industry.

THE CONCEPT OF A ROCK BLOCK

The MRMR 2000 system accounts for the effect of scale in its assessment of rock strength, recognizing that small-scale intact rock samples do not necessarily reflect the strength of the larger rock blocks bounded by throughgoing joints. The concept of a rock block is illustrated in Figure 3. A rock block is defined as the rock material bounded by throughgoing joints and can contain discontinuous fractures and veinlets. It is important to separate continuous "block-bounding" joints from discontinuous fractures and veinlets, especially for mass mining methods where cavability and fragmentation assessment are fundamental to the design.

The scale concept, which addresses the material strength from small intact rock samples that can be tested directly in the laboratory, through rock block strength that is influenced by discontinuous fractures and veinlets, to the full-scale rock mass strength, is illustrated in Figure 4.

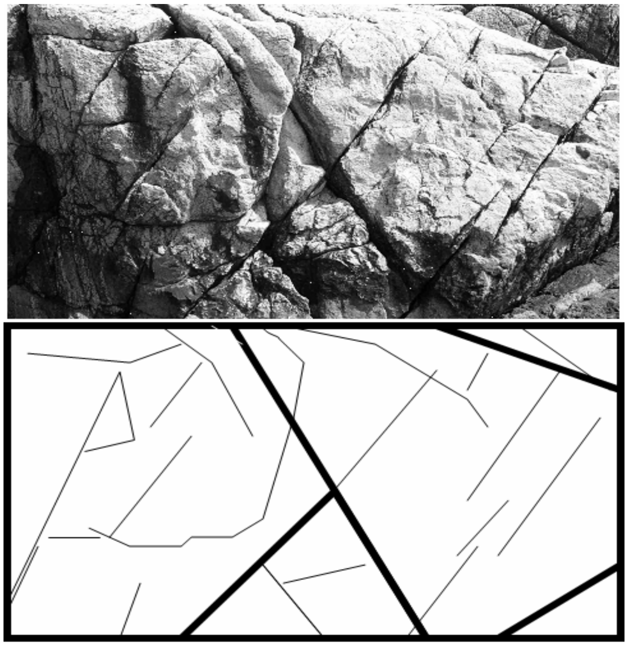

Figure 3.—Example of a rock mass that contains throughgoing joints (thick lines) as well as discontinuous fractures (thin lines). Rock blocks are bounded by the throughgoing joints.

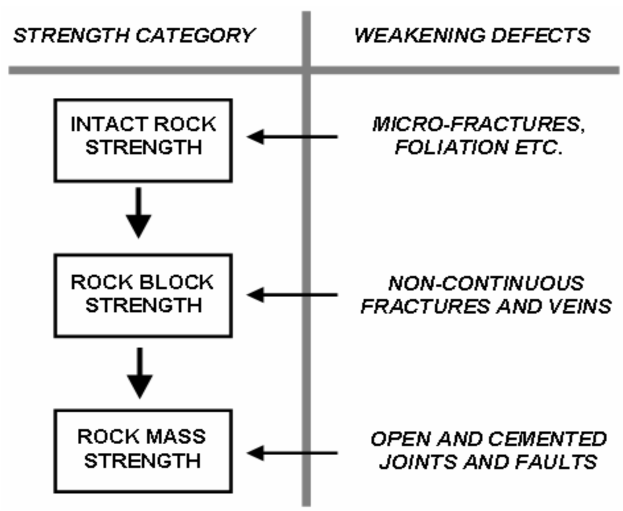

Figure 4.—Scale concept used in MRMR classification.

The challenge is to assign appropriate strength reduction factors to account for the cemented joints (Figure 5), fractures, and veinlets that may be present in rock blocks. It is clear that if a classification system ignores such features, the rock mass strength is overestimated, or if they are forced into the open joint category, the rock mass is underestimated.

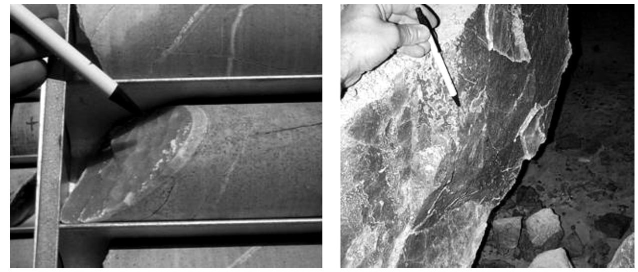

Figure 5.—Cemented joints in the core *(left)* could significantly influence rock block strength and fragmentation in a caving environment *(right)*.

ACCOUNTING FOR CEMENTED JOINTS AND VEINLETS

The MRMR 2000 system introduced empirical charts where the impact of the quantity and quality of cemented joints and veinlets on rock block strength can be assessed. The method is based on the Mohs hardness number of the infill materials and the frequency of the filled joints and veinlets.

It should be noted that the suggested Mohs hardness number for estimating the strength of the infill is only a field guideline, and effort should be made to better define the strength of such defects. The use of laboratory tests, back analysis, and numerical models (such as Itasca's Particle Flow Code (PFC)) could be very useful in better understanding the role of healed discontinuities with regard to rock block strength.

The effect of cemented joints and veinlets can have a significant impact on the caving process in block caving or sublevel caving operations. Figure 6 illustrates the difference in the predicted fragmentation for a rock mass that contains healed, calcite-filled veinlets based on two methods of assessing the IRMR value. The Block Cave Fragmentation (BCF) [Esterhuizen 2003] software package was used to conduct the analyses. The software makes use of joint set data, uniaxial compressive strength of the rock, stress field, and characteristics of small-scale fractures and veinlets to estimate rock fragmentation during block caving. The rock block strength is calculated as part of the process and affects stress-related fracturing. The lower curve in Figure 6 shows the predicted fragmentation if the presence of fractures and cemented veinlets is ignored in the assessment of rock strength. These results indicate very coarse fragmentation, with about 25% of the rock fragments being less than 2 m^3 in size. The upper curve shows the results if the fractures and veinlets are accounted for. In this case, the predicted fragmentation is good, with about 90% of the rock fragments predicted to be less than 2 m^3. The difference in predicted fragmentation is largely due to the effect of the field stress on the rock blocks. If the fractures and veinlets are ignored, the rock block strength is overestimated, and coarse fragmentation is predicted.

When the effects of these features are included, the assigned rock block strength is reduced, which in turn dramatically reduces the predicted fragmentation. The expected fragmentation has a significant impact on the likely production rates, mine layout, and operational cost of a block-caving operation.

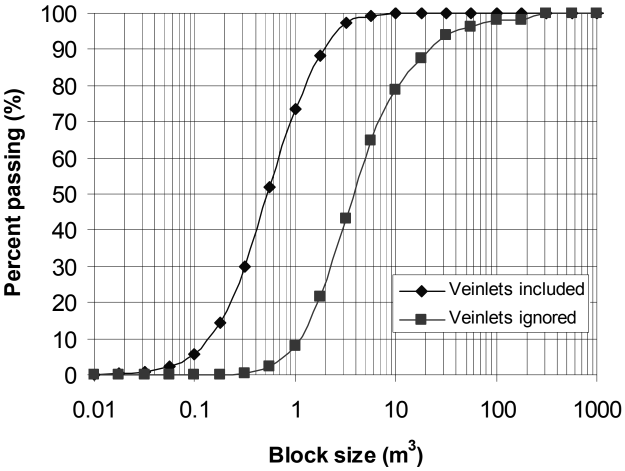

Figure 6.—Effect of calcite-filled veinlets on predicted fragmentation in block caving.

RQD AND FRACTURE FREQUENCY

The other major difference of MRMR compared to other classifications is in the utilization of RQD. The RQD system was originally developed for tunneling conditions and was published in 1967. The fact that it is still used today is a good testimony to Deere, who introduced it 40 years ago.

RQD is a very simple, effective, and quick method to assess the rock mass competency in certain types of rocks. However, besides the lack of accountability for the basic rock mass parameters such as intact rock strength and strength of defects, the tradeoff against its simplicity is its poor reliability in highly fractured, massive, or highly anisotropic conditions. The method simply does not have the resolution that may be required for a more accurate assessment of fragmentation, cavability, and other mine design aspects. Figure 7 illustrates some of the issues related to RQD as a rock mass descriptor, and the RQD is compared to the IRMR obtained from fracture frequency.

If the rock mass character is such that RQD does not reflect the conditions accurately, then, of course, any classification system that uses RQD is exposed to problems. Figure 8 illustrates an example from one of the major block-caving projects in Chile, where the difference in IRMR values obtained by the fracture frequency (FF/m) method versus the RQD method is quite obvious. The comparison was made from drill core logging for a block-caving project in which an accurate assessment of rock mass conditions has a significant impact on the choice of mine layout, operating procedures, and financial investment. In this case, the IRMR calculated from the FF/m was considered to be more representative of the actual rock mass conditions than the values based on the RQD. Third-party review of the outcomes, inspection of exposures in the current open-pit mine, and comparison to values estimated from the GSI rating confirmed this conclusion.

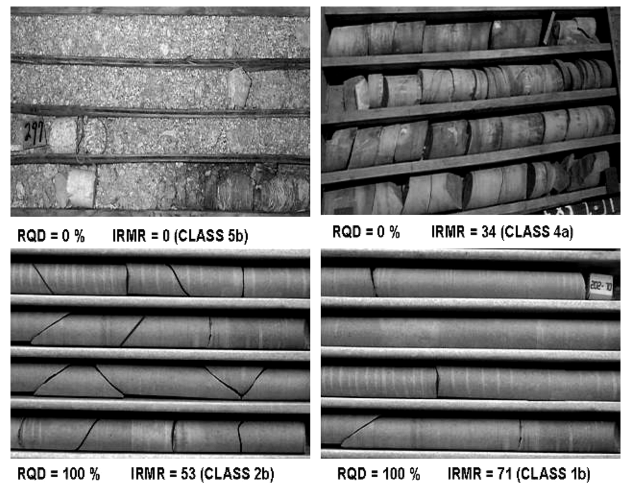

Figure 7.—Example of the problems with RQD assessment of highly fractured or massive rock masses.

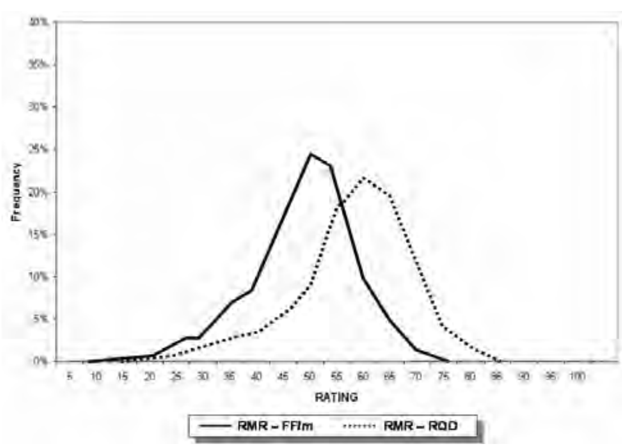

Figure 8.—Example of difference between RQD and fracture frequency-based IRMR. The IRMR based on fracture frequency (solid line) is considered more representative of actual rock mass conditions.

PRACTICAL PROBLEMS WITH ROCK MASS ASSESSMENT RELATED TO DATA COLLECTION METHOD

As discussed above, the difference between the reality and the rock mass competency models could be due to the lack of ability to include specific geological features in our classification systems, e.g., cemented joints and veinlets.

However, if only drill core is used for rock mass assessment, we are exposed to a whole range of biases, and the resulting description of the rock mass could be significantly skewed. The potential problems and pitfalls were described by Laubscher and Jakubec [2001] and Murphy and Campbell [in press]. It is important to realize that rock mass assessment based on drill core only can easily be off by 50%.

The main challenges in rock mass assessment based on core logging, regardless of the classification system used, are:

- *Differentiation between artificially induced breaks and natural defects*. In situ borehole scanners can help to assess in situ conditions.
- *Assessment of discontinuities in foliated or highly laminated rocks.* In such rock masses, the borehole scanner may not be effective.
- *Differentiation between continuous joints and discontinuous fractures*. This problem cannot be successfully resolved without rock mass exposures (see Figure 9).
- *Drilling orientation bias*. Missing or underestimating discontinuity sets subparallel to the drillhole. Different orientation of the drillholes can mitigate the problem.

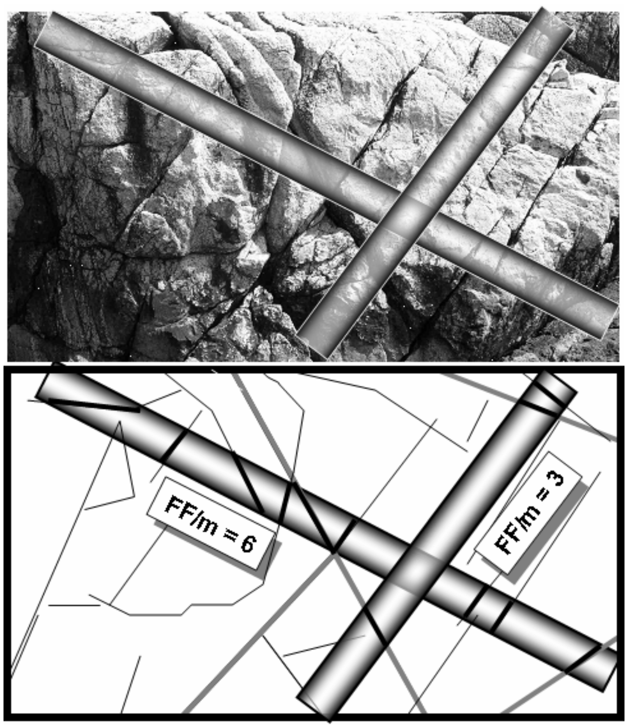

Figure 9.—Picture illustrating the bias that could be introduced by borehole orientation. Also, it is difficult from the core to judge which discontinuities represent continuous joints and which are small-scale fractures.

- *Accurate assessment of weak joint infill* that is washed out in most drilling processes. Triple tube techniques can help to alleviate this problem.
- *Rock strength assessment in weathered/altered sensitive rock types such as kimberlites and mudstones.* Using specialized drilling fluids, very careful sample collection/preservation programs, and speedy delivery to the laboratory can partly mitigate these problems.
- *Material anisotropy.* Assessment of both intact rock strength and discontinuity strength anisotropy from the drill core could be a problem. The core cross-section is simply too small to capture joint geometry. (See the example shown in Figure 10.)

Any of the points mentioned above can have a significant impact on the rock mass assessment, and it is necessary that data be scrutinized in that respect.

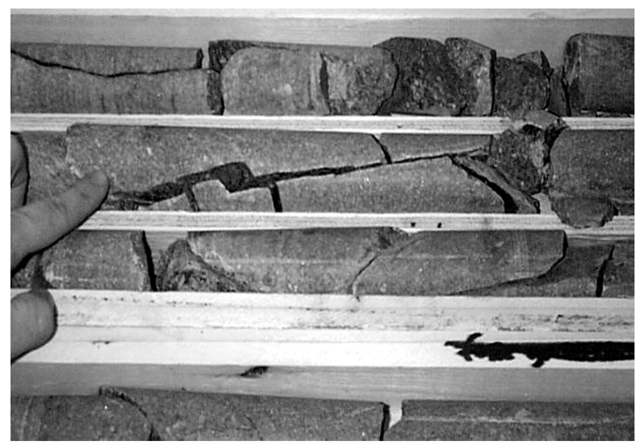

Figure 10.—Joint geometry may not be obvious from the drill core unless the joint is intersected at a very shallow angle.

DISCUSSION AND CONCLUSIONS

Some of the challenges in assessing rock mass conditions have been addressed by the MRMR 2000 system. These include the abandonment of RQD as a parameter, accounting for healed and cemented joints, and the introduction of the concept of rock block strength. This paper shows how these modifications have resulted in improved assessment of critical aspects of rock mass behavior for mine design.

When assessing rock mass behavior (by any method), it is important to remember that we cannot rely only on exact science. The inherent variability of nature does not allow the development of a universal, rigorous rock mass classification system that would be practical at the same time. It is therefore necessary to keep the system flexible and open to adjustments. This raises the issue of whether we should strictly follow the letter of the classification systems or whether we should treat classification systems as a guideline to be used together with engineering judgment. The authors believe that spirit is more important than the letter and that field observations must be accounted for in the final judgment.

Unfortunately, the trend in the mining industry is to shift focus from the field to the office and solve problems "remotely." As our computational skills have increased dramatically, it seems that our observational skills have decreased at the same rate. Also, the discipline and somewhat rigorous process of data collection, visualization, and analysis have broken down. Despite the fact that most of today's projects have rendered three-dimensional models of geology (or at least an artist's image), it is very rare these days to find a proper set of working plans and sections where a "creative thinking" process was applied and geological and geotechnical concepts are tested prior to computerization. We would like to quote Dr. Scott-Smith—"the answers are in the rocks"—to remind us that "reality" checks should be constantly performed on our models.

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