MINERAL RESOURCE CLASSIFICATION – IT'S TIME TO SHOOT THE "SPOTTED DOG"!

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ABSTRACT

Classification of mineral resource estimates is one of the most important responsibilities of the Competent Person. In recent years, classification decisions have been driven more by the detailed block-by-block attributes generated by the now widely applied geostatistical estimation methods, and less by a general geological overview. This is increasingly resulting in "spotted dog" outputs, in which blocks of Inferred Resources or unclassified material separate blocks of Measured and/or Indicated Resources, or individual drillholes are surrounded by annuli of Measured and Indicated Resource blocks. Not only are such outputs potentially misleading since they ignore fundamentals such as continuity of geology and mineralisation between drillholes and the imprecise nature of resource estimation, they can also cause substantial problems for engineers undertaking mine designs and estimating ore reserves, particularly for underground mines. Competent Persons for mineral resources must keep in mind the purpose of their work, and should use their experience and judgment to avoid or smooth out "spotted dog" classifications, providing a result commensurate with the level of geological and resource estimation confidence. For their part, ore reserve Competent Persons must understand the resource estimation and classification process, and should question resource classifications that are not consistent with the level of geological and resource estimation confidence.

INTRODUCTION

AMC Consultants Pty Ltd ("AMC") has become increasingly concerned in recent years with mineral resource classification practices that lack both common sense geologically and cause significant difficulties during mine design and conversion to ore reserves, particularly for underground mines. This paper has been prepared by a group of AMC geologists and mining engineers as a practical contribution to the 6th International Mine Geology Conference being held in Darwin in August 2006. It is hoped that the issues highlighted and real examples provided will encourage a more sensible approach to resource classification and make life easier for all concerned.

MINERAL RESOURCE CLASSIFICATION – A GEOLOGICAL PERSPECTIVE

Introduction

The Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (the "JORC Code" 2004) allows for classification of mineral resource estimates into Inferred, Indicated and Measured Resource categories based on increasing geological confidence in the estimate (JORC, 2004). The JORC Code is deliberately not prescriptive as to how that confidence is determined and relies on the experience and competence of Competent Persons to judge, firstly (if necessary, in conjunction with others), that part of a resource estimate for which there are reasonable prospects for eventual economic extraction and, secondly, the level of confidence that can be attributed to the estimate. In undertaking these functions, it is very important that geologists appreciate why they are required to classify the mineral resource estimates and the uses to which their work will be put. Just as importantly, ore reserve Competent Persons must take the time to understand the resource estimation and classification process, and to communicate to geologists their needs in terms of output.

On a related topic, it is still (unfortunately) reasonably common practice for geologists rather than mining engineers to sign off as Competent Persons on ore reserve estimates. This has an historical basis, as resource / reserve estimation was often seen as a single integrated process and the responsibility of geologists. However, the conversion from mineral resources to ore reserves involves mainly mining-related decisions, in fact, it is often the output from the preparation of a mine plan. It should only be undertaken by those with the required qualifications and experience, particularly given the serious responsibilities attached to acting as Competent Persons (see for example, Phillips, 2000). The authors encourage geologists to think carefully before they sign off as Competent Persons for ore reserve estimates, and encourage mining engineers to accept responsibility as Competent Persons for these estimates.

Methods of Mineral Resource Classification

Most resource estimation software packages produce values that can be used to indicate the reliability of the grade estimated into individual model cells. Such values include:

- the number of data points used to estimate grade;
- the number of drillholes used to source data for estimation;
- the estimation pass that successfully informed the cell;
- the kriging variance of the estimate;
- the slope of regression of the “true” block grade on the “estimated” block grade (Vann, Jackson and Bertoli, 2003); and
- the relative distance from a data point based on the range of a variogram

The values can change with different variogram parameters and other estimation inputs such as the search ellipse radii and orientation, the maximum or minimum number of data points for successful estimation, the degree of geological (or domain) control on the estimate and the expansion ratio of consecutive estimation passes.

These values are useful as an indication of the confidence in the grade estimate, but they are not an absolute measure of small-scale (block) reliability, and should not be treated as such. There are no absolute values that are correct, and the subdivision of the deposit into blocks is only done as a geometric aid to resource estimation, not because the blocks themselves represent discrete geological units with separate, clearly distinguishable grade and reliability characteristics.

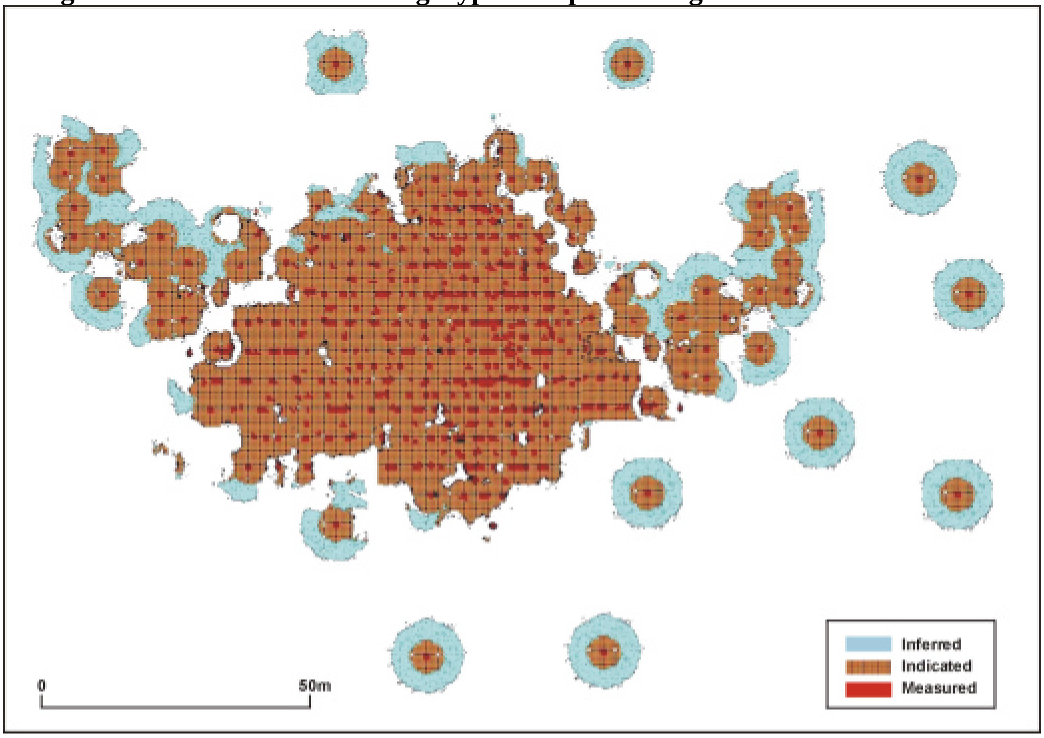
The attraction of using such estimation values is that they are repeatable and the same criteria can be applied to different estimates. However, while this is a legitimate use for such data, it is only part of the story. It is very important that resource classification also takes into account broader aspects such as confidence in the geological interpretation and in the amount, distribution and quality of data. Not to do so is an abrogation of one of the geologists’ key responsibilities and can lead to the erratic “spotted dog” (also sometimes referred to as “striped zebra”) classifications that are increasingly prevalent these days.

Use of certain cell attributes as a guide to resource classification should be seen only as a step on the way to producing a more smoothed classification that properly reflects the broader geological and data-related aspects.

Examples of "Spotted Dog" Classifications

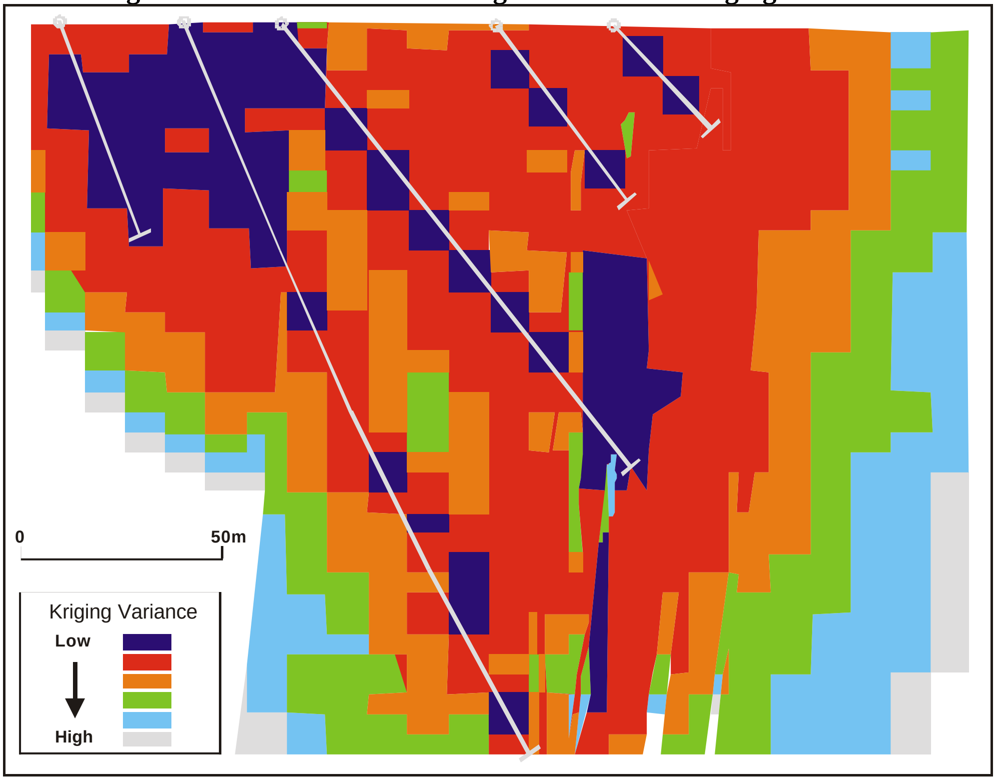
The following illustrations are based on real life examples, modified to prevent identification, while maintaining the essence of the issue.

Figure 1. Level Plan Illustrating Typical "Spotted Dog" Resource Classification



In Figure 1, each drillhole is surrounded by annuli of Measured and Indicated Resources, and for more distal holes, Inferred Resources.

Figure 2 – Cross Section showing Variations in Kriging Variance



In Figure 2, corridors of low kriging variance following otherwise isolated drillholes. Kriging variance is one of the block parameters that is sometimes translated directly into resource classifications.

Figure 3. Cross Section showing Classification following Drillholes and also being Artificially Influenced by Search Parameters

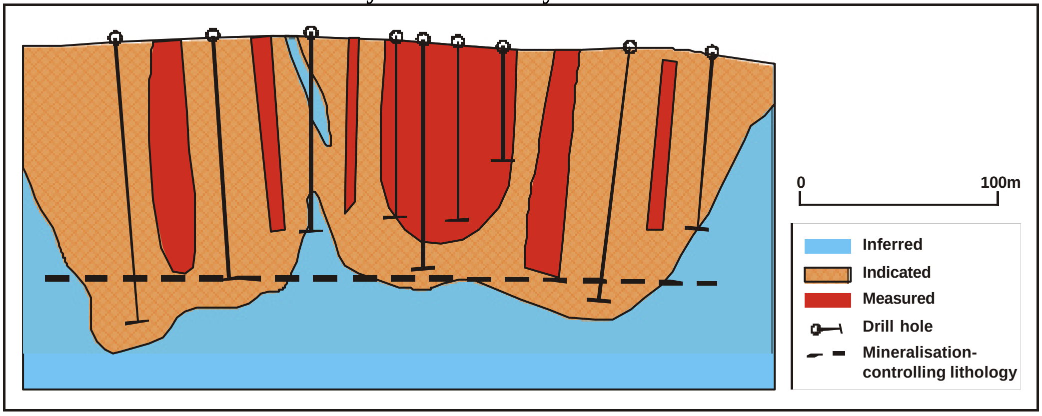


Figure 3 is a particularly interesting example of resource classification. In this case zones of Measured and Indicated Resources surround and follow individual drillholes and trend almost at right angles to the mineralisation-controlling lithology. In addition much of the Measured Resources occur **between** the drillholes due, presumably, to an artifact of the search ellipse.

Geological Problems with the "Spotted-Dog" Approach

In AMC's view, these classifications fail geologically in three main ways.

Firstly, they usually take no account of uncertainty in the geological interpretation or in the quality of data, both of which may substantially affect resource classification.

Secondly, they imply an unjustified degree of reliance on the attributes of each block, a problem exacerbated when, as is often the case these days, the blocks are very small relative to the drillhole spacing.

Thirdly, they may be inconsistent with the requirements of reporting standards such as the JORC Code, SAMREC Code, Reporting Code, NI 43-101 / CIM Standards and even Industry Guide 7 of the SEC. All of these standards discuss continuity of geology and grade in terms of drillholes plural, implying correlation **between** drillholes, not around individual drillholes. For example, the definition of a Measured Resource in the 2004 JORC Code states "*The locations* (of drillholes, workings etc) *are spaced closely enough to confirm geological and grade continuity*".

Why the Increase in Spotted Dogs?

The increased occurrence of this style of classification can be attributed to various causes:

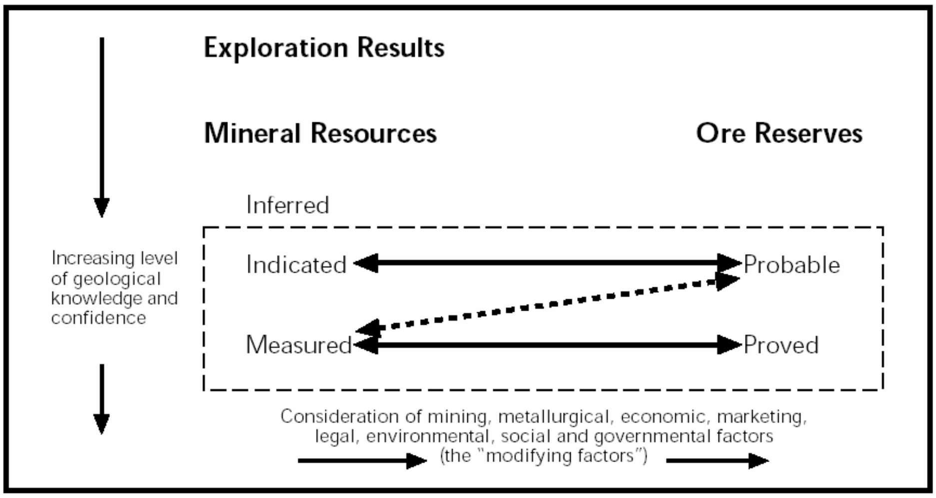
- increased use of geostatistics for grade estimation giving a greater ability to generate and make use of block-by-block parameters and attributes;
- geologists spending more time with the details of a block model and less (often no) time examining and interpreting hard copy cross sections and plans;
- increased workloads and tighter deadlines caused by fewer available geologists, changed working environments (e.g. fly-in fly-out), never-ending operating cost pressures, etc.; and
- lack of experienced mentors to guide younger geologists and provide reality checks.

MINERAL RESOURCE CLASSIFICATION – A MINING PERSPECTIVE

Introduction

Mineral resources are converted to ore reserves in accordance with principles such as those set out diagrammatically in Figure 4 (Figure 1 of the JORC Code) and in similar overseas reporting standards.

Figure 4. Relationship between Mineral Resources and Ore Reserves (Figure 1, 2004 JORC Code)



Only Measured and Indicated Resources may be converted to ore reserves. Inferred Resources may not be converted to ore reserves and therefore create a difficulty for the mining engineer if present within a stope or pit design.

The Mine Design and Ore Reserve Estimation Process for Underground Mines

There are two main approaches to mine design and ore reserve estimation for underground mines[1].

In the first, which is generally limited to conceptual or scoping studies though sometimes applied at the pre-feasibility study stage, high level dilution and mining recovery conversion factors are applied to the mineral resources based on the usually limited knowledge of the deposit available at this stage, and the mining engineer's judgement and experience with similar deposits and mining methods.

In the second, which is usually applied from the pre-feasibility through to final feasibility study level, mine designs are prepared for individual stopes and access development. Dilution (planned, unplanned, back fill, floor etc) and mining recovery factors or parameters are applied which take into account aspects such as back fill method, geological structures, geotechnically advised dimensions, extraction sequences, equipment capabilities, corporate requirements and so on. The outputs (usually tonnes and grade) are scheduled, costs and revenue assumptions applied and an economic evaluation is undertaken. Those stopes that meet the company's economic requirements, after taking into consideration metallurgical, marketing, legal, environmental, social and governmental factors, may be classified as ore reserves

[1] Although "spotted-dog" resource classifications also affect resource to reserve conversion for open pit mines, the impact is less severe than for underground mines

Underground Mining Resource to Reserve Conversion – Then …………

In the past the mining engineer would receive a resource model from the geologist, which might have been a block model but was more commonly a set of hard copy cross sections and plans showing resource outlines, and, based on the criteria discussed above, would design stopes. The resource classification was not a contentious issue as the classification was generally broad enough that an individual stope contained only one resource classification. This made it simple for the engineer to determine if the stope was included in the Proved or Probable Reserve category.

……and Now

In recent years with the modern approach of resource classifications, the mining engineer finds himself attempting to determine the reserve category where there is a mixture of two to five categories of mineral resources and other material (e.g. Measured, Indicated and Inferred Resources, unclassified material and waste) within an individual stope. Engineers usually deal with this in one of two ways, each with its own drawbacks.

The first, and perhaps more common approach, is to determine the weighted average of the resource classifications and apply the appropriate reserve category. For example:

- If a stope consists of resources classified 60% Inferred Resources and 40% Indicated Resources, the stope would be downgraded and not included in the reserve. However, this would lead to a substantial number of Indicated Resource blocks not being converted to reserves.
- If the stope consists of 60% Indicated Resources and 40% Inferred Resources, then the entire stope would be flagged as Probable Reserve. However, this would result in Inferred Resources being converted to ore reserves, which is contrary to the JORC Code (refer to Figure 4 and the 2004 JORC Code).
- The worst case scenario with this approach is when there is a stope with greater than 50% Measured Resource and a combination of Inferred and Indicated Resources. This stope could be flagged as a Proved Reserve, but this would be upgrading the Indicated and Inferred Resources, which is clearly unacceptable. Even if the stope was downgraded to a Probable Reserve, the Inferred Resource would still be converted to an ore reserve, in contravention of the JORC Code.

The second approach is to determine the tonnes and grade of the resource categories within a stope and carry the individual resources through to the appropriate reserve categories. Designs can be produced such that the economics of any one stope is not dependent on the Inferred or unclassified material enclosed within and / or does not contain greater than a nominal percentage, generally advised by the client (say for example 20%). While this approach ensures that no resource is converted to an inappropriate reserve category, it still leaves the problem of how to deal with and report Inferred Resources and unclassified material that falls within the stope design. Should they be treated as internal dilution at the estimated grade or as waste?

THE SOLUTION

The solution is relatively simple (and for that reason, its description is relatively brief). Block-by-block resource classifications should be smoothed into geologically sensible and coherent zones that reflect a realistic level of geological and grade estimation confidence taking into account the amount, distribution and quality of data.

There are various ways of implementing this "smoothing" process, perhaps the most common being to create resource classification wireframes based on block estimation attributes and the broader geological and data considerations previously discussed, and then to adjust the classifications of all blocks falling within the wireframes. Another process called "closing" in Isatis geostatistical software utilises "dilation" and "erosion" to combine contiguous areas of one classification and to remove small inliers of another classification.

However it is done (and it needs geological rather than purely mathematical input), the important point is that it must be seen as an integral part of the resource classification process, not something that "would be nice to do if we had the time". The authors acknowledge that resource geologists are often under intense time pressures these days, but believe that production of sensible resource classifications is simply too important for this final step not to be implemented.

CONCLUSION

It is important when estimating and classifying mineral resources using a block model to understand the whole resource / reserve process, and particularly to appreciate the purpose behind resource classification and the uses to which the resource estimates will be put. Resource Competent Persons must not abrogate their responsibility to make experience-based classification judgements by basing classification purely on block criteria generated during the grade interpolation process without any further thought or adjustment. Equally, ore reserve Competent Persons must take time to fully understand the resource estimation process and must communicate relevant mining issues to the geologist. "Spotted-dog" resource classifications should be unacceptable to both geologists and mining engineers. A final smoothing step to produce resource classifications commensurate with a realistic level of geological and grade estimation confidence should be seen as a necessary and integral part of the resource estimation process.

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REFERENCES

Canadian Securities Administrators, February 2001, revised January 2003. National Instrument 43-101 – Standards of Disclosure for Mineral Projects

Institution of Mining and Metallurgy Working Group on Resources and Reserves, European Federation of Geologists and Institute of Geologists of Ireland, October 2001. Code for Reporting of Mineral Exploration Results, Mineral Resources and Mineral Reserves (The Reporting Code)

Joint Ore Reserves Committee of The Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia (JORC), 2004. Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves.

Philips, R, 2000. The Liability of Company Directors and Competent Persons for Resource / Reserve Disclosure, in *Proceedings of The Codes Forum*, pp 110-118, Mineral Industry Consultants Association, Sydney.

South African Mineral Resource Committee (SAMREC), under the Auspices of the South African Institute of Mining and Metallurgy, March 2000. South African Code for Reporting of Mineral Resources and Mineral Reserves (The SAMREC Code)

United States Securities and Exchange Commission, undated. Description of Property by Issuers Engaged or to Be Engaged in Significant Mining Operations (Industry Guide 7)

Vann, J, Jackson, S and Bertoli, O, 2003. Quantitative Kriging Neighbourhood Analysis for the Mining Geologist – A Description of the Method with Worked Case Examples, in *Proceedings Fifth International Mining Geology Conference*, pp 215-233 (The Australasian Institute of Mining and Metallurgy: Melbourne).