

CALENDAR

■ Mines and Money London 2009

November 30 – December 2, 2009
London West Hotel and
Convention Centre
Hammersmith
London, United Kingdom
Email: melina.day@mining-journal.com

■ NWMA 2009 Annual Meeting and Exposition

December 1 – 5, 2009
John Ascuaga's Nugget Casino Resort
Reno, Nevada
Email: mheywood@nwma.org

■ Mineral Exploration Roundup 2010

January 18 – 21, 2010
Westin Bayshore Resort & Marina
Vancouver, BC, Canada
Email: shendry@amebc.ca

■ Mining Indaba 2010

February 1 – 4, 2010
Cape Town International Convention
Centre
Cape Town, South Africa
Email: csmith@iiconf.com

■ 2010 SME Annual Meeting and Exhibit

February 28 – March 3, 2010
Phoenix Convention Center
Phoenix, Arizona
Email: meetings@smenet.org

■ PDAC 2010 - International Convention, Trade Show and Investors Exchange

March 7 – 10, 2010
Metro Toronto Convention Centre
Toronto, ON, Canada
Email: mkwasnycia@pdac.ca

Mineral Resource Classification Schemes: Some Thoughts

While evaluating resource estimates for a given mineral deposit, the estimated resource may be classified into *measured*, *indicated* or, *inferred* categories. This classification is based on the results of various mathematical calculations and the level of confidence that the estimator has in his / her ability to accurately estimate the grade based on the underlying data. In most jurisdictions, the “estimator” of a mineral resource is required to be a “Qualified Person” (QP¹) as is the case under the Canadian NI43-101 regulatory standard. Generally, the QP assigns a confidence level to the estimated resources following standard industry practices and procedures. Although such standards are described in some detail by numerous industry and quasi government organizations, there is no set standard defining precisely what is to be included in these classifications. The QP must have sufficient training and experience to determine and defend the classification.

If the QP is very confident with portions of the mineral deposit, that portion of the deposit may be classified as *measured*. If the confidence level is somewhat lower than the *measured* category, then that portion of the deposit may be classified in the *indicated* category. We may ask, what is

a *high* confidence level? A QP may answer this question based on a number of critical factors including geology, sample density and reproducibility of sample results. When statistical confidence levels exceed 90%, the QP may feel that the ability to estimate the resource is high and should be classified as a *measured* resource. Similarly, a confidence level exceeding 80 to 85% can be attached to the *indicated* category while a 60% or greater confidence level may be used for the *inferred* category. This presents the problem of subjectivity in determination of the category of classification. It is important to note that despite the subjective judgment of the QP, a resource classification scheme designed using standard industry practices is defensible and works effectively. Further, the “quantification” of the confidence level is also another problem of subjectivity. Therefore, it is important to note that despite the subjectivity factors, a resource classification scheme must be defensible, but should be treated as an estimate.

INDUSTRY PRACTICES

The definitions of different resource categories are published by the leading professional organizations in the international mining-industry, such as the

¹ Example: [http://www.bcsc.bc.ca/uploadedFiles/NI43-101\(1\).pdf](http://www.bcsc.bc.ca/uploadedFiles/NI43-101(1).pdf)

Canadian Institute of Mining, Metallurgy and Petroleum (CIM)² and the Australasian Joint Ore Reserves Committee (JORC)³. These definitions are generalized and meant to provide guidelines for the QP (Competent Person, CP, in some jurisdictions); and are not meant to provide a prescriptive quantitative methodology for resource classification. Because each mineral deposit possesses unique geological and economic characteristics, there cannot be a single set of resource classification criteria applicable for all commodities or, different deposit types of one commodity, e.g., volcanogenic nickel sulfide deposits versus lateritic nickel deposits.

The QP's estimate of confidence in a resource is based on the QP's experience being applied to the interpretation of four major factors:

- i. continuity of lithology and mineralization,
- ii. reliability and representativeness of the assay and lithological data,
- iii. the density of the underlying sample data and
- iv. quality of the resource estimation

In detail, the confidence level for these four factors depends on the quality and accuracy of the various underlying sets of information including: physical access to the deposit, topographic surveys, drill-hole survey information, density data, sample handling/security procedures, and the quality of analytical or radiometric determination of grade as supported by QA/QC analysis, etc.

Commonly Used Resource Classification Schemes:

Usually different schemes for resource classifications are considered taking into account the type of deposit under study. The commonly used resource classification schemes are based on the criteria discussed below. These schemes are mathematical and computational in nature and provide general guidance for resource classification. The continuity of lithology and mineralization and other attributes should be considered while adapting the scheme or combination of schemes into a reasonable resource classification.

Distance Criteria: After verification of the continuity of lithology and mineralization, and the resource estimation has been completed using standard industry procedures, the distance between the center of the block and the sample composites (distance, d) may be used as a criterion for resource classification. The distance (d) can be related to the sample - drill-hole spacing and/or to the range of the variogram model. However, using only distance as the criterion may result in the classified resources forming concentric, cylindrical shapes surrounding the drill-holes. In deposits where drill holes are widely spaced, a plan view of such a classification may appear as circular spots covering the deposit (Figure 1). Often in geometrically-complex metallic mineral deposits classification of resources based only on sample – distances may be difficult to justify. However, in deposits with strong stratigraphic continuity, such as oil shale or certain coal deposits, this simple classification scheme may be applicable.

Sample-Distance Criteria: After verification of the continuity of lithology and mineralization and the resource

² http://www.cim.org/committees/CIMDefStds_Dec11_05.pdf
³ http://www.jorc.org/pdf/jorc2004print_v2.pdf

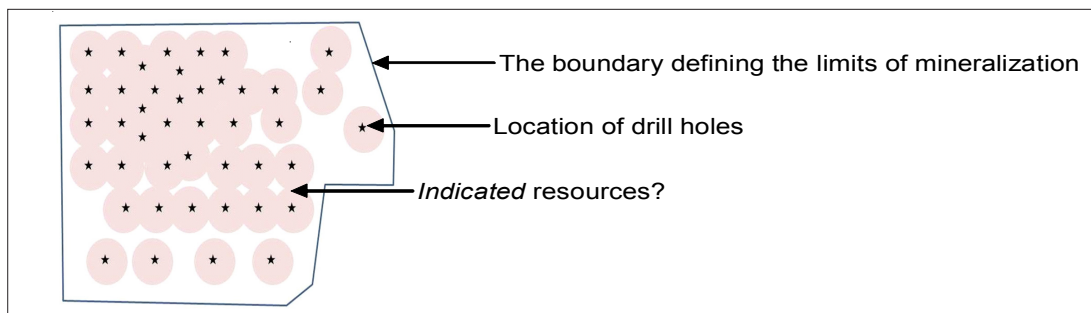


FIGURE 1: A map illustrating a resource classification scheme using only distance criteria. The solid-stars represent the location of drill holes. The filled circles represent the area covered by the search parameters surrounding a hole. The filled circles may represent the portion of a deposit, potentially classified as *indicated* resources.

estimation has been completed using standard industry procedures, the QP may elect to specify number of samples (sample) and distance (d) criterion. The sample-distance criterion is often combined with conditions that specify the minimum and maximum number of samples and number of drill holes required for estimation of a block and resource classification. Depending on the size of the sample population (support), the size of a block in the model and spatial distribution of the drill-hole data, the sample criteria can be established. An example of potential distance-sample criteria for an advanced stage exploration project is shown in Table 1.

As shown in Table 1, the resource classification is based on the variogram range, which serves as a guide for the distance criterion. In scenario 1, the sample criterion for the *indicated* category requires a minimum of 3 samples. Depending on the size of

the sample population and search parameters (search ellipsoids), it is possible to estimate and categorize a block as *indicated* utilizing three samples from one drill hole. In scenario 2, a block may be estimated and classified as *indicated* resource using a minimum of three samples from a minimum of two holes. In this case, an *indicated* category block requires having at least two holes in the vicinity, hence providing evidence of continuity of mineralization. The critical parameters that affect the classification in this scenario are the dimensions and orientations of the search ellipsoids used in this process.

As shown in Figure-2a, scenario 1 classifies the pink “blocks” as *indicated* category, even though likely only one hole was used to estimate a block in this category. A block estimated using only one hole is obviously not evidence of continuity and hence reflects a lower confidence level. It would be preferable

to re-classify the pink blocks in 2a into the *inferred* category. Classifying these blocks as *indicated* on Figure 2a is a misclassification. Scenario 2, illustrated by Figure 2b, shows a smaller volume of *indicated* resource; however, it implies a higher confidence level since a minimum of 2 holes and 3 samples are required to estimate and classify the block.

Using Drilling Density: Based on the experience of project personnel or variogram analyses, drill hole density may be used for classifying *measured*, *indicated* and *inferred* resources. As an example, a decision is made to categorize all blocks estimated in an area where the drill hole spacing is equal to or less than the variogram range as *indicated* (including the *measured* category) and all other remaining mineralization is classified as *inferred* (Figure 3). This may result in drill holes with little or no mineralization being included in the *indicated* area simply because they are part of the drill pattern.

TABLE 1
An example of resource classification scheme for a project in advanced exploration/operational stage

| Project Status | Scenarios | Resource Classification | Distance | Sample | Holes |
|---|------------|-------------------------|-----------------------------|-------------------------|----------------|
| Advanced exploration/ Pre-feasibility Stage | Scenario 1 | <i>Indicated</i> | 100% of the variogram range | Minimum 3 Maximum 12 | No restriction |
| | | <i>Inferred</i> | Beyond 100% variogram range | Minimum 2 Maximum 40 | No restriction |
| | Scenario 2 | <i>Indicated</i> | 100% of the variogram range | Minimum 3 Maximum 12 | Minimum 2 |
| | | <i>Inferred</i> | Beyond 100% variogram range | Minimum 2 Maximum 40 | No restriction |

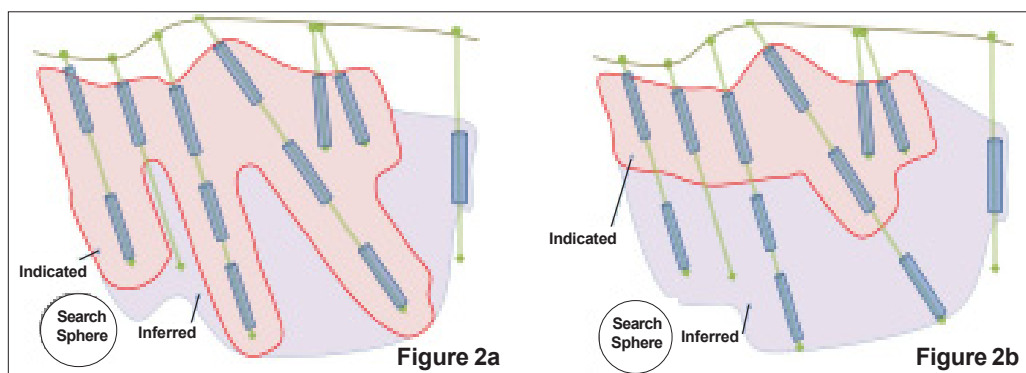


FIGURE 2: Illustration showing potential classification scenarios with reference to Table 1

This will over estimate the total *inferred* resource and demonstrates the need for the application of geological interpretation in addition to the simple distribution of drill holes.

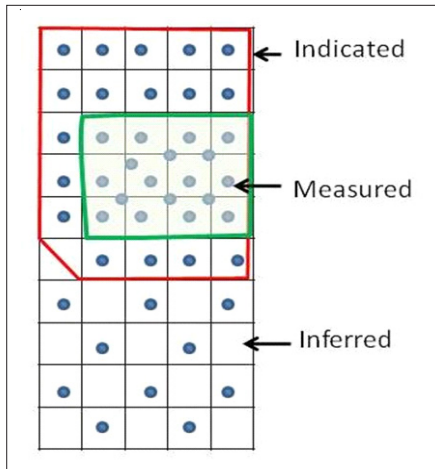


FIGURE 3: Illustration displaying resource classification based on drill-hole spacing.

Use of Estimated Risk Factors: Often programs used for resource estimation provide the risk factors in terms of errors of estimation. These parameters may be any one or any combination of the followings: variance of estimation, standard deviation of estimation, errors of estimation and slope. When geostatistical interpolation methods (kriging) are used, kriging variance is frequently estimated. Kriging variance has been used as the sole parameter for resource classification. This type of classification scheme may create a salt and pepper type pattern, i.e., few blocks of *inferred* category in the middle of all *indicated* category blocks. This is not an acceptable way of classifying resources, because the *measured/ indicated*

resources need to be continuous in space. Further, the decision on the cutoff value of kriging-variance is often debatable and not supported by defensible data. The other parameters (slope, standard-deviation, etc.) may also result in similar situations. However, the risk factors can be used to assess the quality of estimation and serves as a guide to develop a resource classification scheme for the deposit.

DISCUSSION: So, what is the best way of classifying resources?

All of the above discussed techniques provide guidance for classifying resources. The resource classification is dependent on the confidence that the qualified person has in the representativeness, quality and integrity of the data. Depending on the level of knowledge on local geology and mineralization, the QP may need to adopt additional criteria for resource classification. Such criteria may be drill-hole/ sample spacing, location and depth of samples used to gain enhanced confidence for the classification. In all cases, the confidence on the established continuity of geology and mineralization should be given the highest priority.

Literature studies suggest many other mathematical and computational techniques exist for resource classification, such as indicator kriging. However, based on the confidence attached to the continuity of geological domains and mineralization, the computational criteria, such as distance

and number of samples, may vary. For example, a decision to use a minimum of two holes to estimate a block may provide a certain degree of assurance of continuity for classifying part of the deposit as an *indicated* resource. In case of clustered drill hole data, using the octant search⁴ method can potentially reduce the possibilities of using drill holes very close to each other; which may help in refining the classification scheme.

The quality of resource estimation should be carefully considered as one of the resource classification criteria. It is important to note that necessary preliminary data analyses made prior to resource estimation are also very important in the resource classification.

PAH does not make general recommendation for resource classification schemes as this strongly depends on the type of deposit being evaluated and the confidence level attached to the quality and representativeness of the information available for resource estimation.

Acknowledgements:

This month's article was provided by Abani Samal, Ph.D., Geologist/Geostatistician abani.samal@pincock.com. Thanks to the geology team of PAH for their review and comments. Special thanks to Mr. Ross Conner, Mr. Craig Horlacher, and Mr. Barton Stone for their critical comments, which helped to improve the quality of this article.

⁴ The search ellipse is divided into eight equal sectors, hence the name.