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A Checklist for Mining Prospects

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Article abstract

This checklist is intended to help geologists collect or review geological data on mining prospects in a manner that will conform to the increasingly stringent reporting requirements. Survey, assay, and geological data are the key initial inputs required to build a robust computer-based resource model. Once the resource model is built, a geologist reviewing the model should understand the methods and assumptions used in interpolating from the initial data to the gridded resource model. Closer cooperation between project geologists and resource modellers should improve the way data are collected initially as well as identifying biases, weakness and inconsistencies within the resource model.

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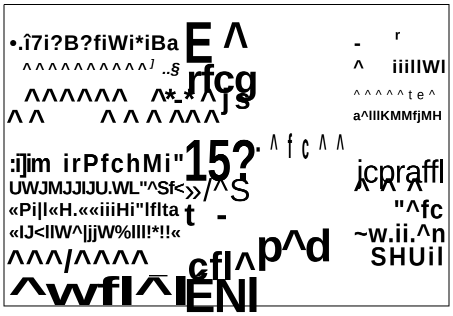

Are Your Data Good Enough: A Checklist for Mining Prospects

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SUMMARY

This checklist is intended to help geologists collect or review geological data on mining prospects in a manner that will conform to the increasingly stringent reporting requirements. Survey, assay, and geological data are the key initial inputs required to build a robust computer-based resource model. Once the resource model is built, a geologist reviewing the model should understand the methods and assumptions used in interpolating from the initial data to the gridded resource model. Closer cooperation between project geologists and resource modellers should improve the way data are collected initially as well as identifying biases, weakness and inconsistencies within the resource model.

SOMMAIRE

Voici une liste de vérification à l'intention des géologues qui ont à collecter et analyser les données de gisements minéraux, liste qui leur permettra de se conformer aux normes de compte rendu de plus en plus strictes. Les données de levés, de teneur et de géologie constituent les éléments clés initiaux indispensables pour l'élaboration d'un modèle informatisé de la ressource fiable. Le modèle de ressource retenu doit permettre au géologue de comprendre la méthode suivie ainsi que les hypothèses d'interpolation appliquées aux données initiales conduisant au modèle matriciel de la ressource. Une meilleure collaboration entre les géologues de projet et les modélisateurs de la ressource devrait permettre d'améliorer la qualité des données initiales collectées et de repérer les biais, faiblesses et incongruités du modèle de la ressource.

INTRODUCTION

The vast increase in computing power during the last few decades have resulted in geostatistical and geological visualization software becoming widely available. Such software can be used to build sophisticated three-dimensional models from which an estimate of the size of the resource can be derived. However, any model is only as good as the data and assumptions upon which it is built. Following the Bre-X scandal, resource and reserve definitions were formally defined by the CIM [http://www.cim.org//committees/CIMDefStds_Dec11_05.pdf]; now security regulators and lending institutions commonly require a robust resource model based upon these definitions before a reserve can be stated and money raised to finance a project. While the standards for reserve reporting are now very well defined, the standards for the building of resource models need to be strengthened.

The goal of this article is to provide a checklist that will ensure relevant and reliable data are used to produce the resource model, and thus minimize the amount of wasted effort.

The project geologist controls the quality of location data, lithological classification, sample integrity and adequacy of sampling (sample size, density); yet, the geologist commonly has little understanding of whether these data comply with the increasingly stringent standards for resource estimation. All too often, the information collected during the earliest phases of exploration is not sufficiently rigorous to be used during subsequent resource estimates. The shortcoming is understandable; most exploration projects prove to be uneconomic, and it seems wasteful to spend time and money collecting data that may never be used. When a project does turn out to be potentially economic and a resource or reserve estimate is required for financing, the initial exploration data are typically thrown out of the modelling process because they are not up to the standards of current resource evaluations. This can lead to delays while holes are re-drilled or re-assayed, and resource models are rebuilt.

RESOURCE MODEL

Building computerized resource models is a specialized task and project geologists will almost certainly send their geological and geochemical data to an in-house expert or to an external consultant for resource evaluation. The resource modeller is generally unfamiliar with the details of the geology of the property. This lack of familiarity with the property may introduce errors or inaccuracies that the project geologist could identify; hence, there needs to be cooperative and constructive collaboration between the project geologist and the resource modeller, from the earliest stages of the project. If the geological interpretation, built into the resource model, and the geological reasonableness of the interpolated grade are not checked regularly enough by the geologist most familiar with the deposit, inaccurate resource estimates may result or exploration opportunities may be lost.

A resource model is built via a number of steps. The first step is data collection by the on-site geologist, who builds a geological database from drill core, geophysical measurement and mapping, and sample assays for the metal content. The database is then verified and a computer model designed. Next, the resource modeller breaks the mining property into a series of small blocks, each of which can carry a number of model items, for instance, rock type and ore grade. A three-dimensional array is formed that will take the known assays or geological data and interpolate them to areas for which there are no hard data. This process of transforming point data (e.g. drill hole) into gridded data (block model) will hopefully lead to success in modelling what is actually in the rock. A resource model has many variables; hence a number of iterations are required to document the sensitivity of the model to various parameters. Identifying the most important unknowns allows the geologist to focus on what additional data need to be collected, and allows the company to assess the up- and down-sides of proceeding with the project. Model output can include geological cross sections and isopach maps, as well as grade and tonnage estimates.

DATA CHECKLIST

The checklist below is intended to help the geologist who is on-site controlling data collection, as well as geologists who are reviewing or doing due diligence on a project, by ensuring that all the data required to generate a reasonable geological picture of a mining prospect are present. Excellent additional resources abound: links to the Canadian Securities Administrators National Instrument 43-101, and the CIM Exploration Best Practices, can be found on the Internet [http://www.cim.org/committees/guidelinesStandards_main.cfm], and there are numerous thoughtful articles on the role of geology and geologists in accurately assessing resources (e.g. Hodgson 1990; Lawrence 1997; Sinclair 2001; Sinclair and Postolski 1999, Smith 1994; Smith and Hancock 1995; Stone and Dunn 2002; and Vallée 2000). None, however, presents an itemized list of checks that need to be made. The following checklist is divided into two parts: Part A refers to geological data and has nine subheadings; part B is specific to the resource model and has five subheadings. The checklist is by no means comprehensive, but if all the questions can be answered, then the resulting model will be reasonable and the deficiencies clear.

PART A – GEOLOGICAL DATA

Data Trail

Is there an easy-to-follow audit trail for each dataset that includes:

- Date
- Source (laboratory, service company, operator, etc.)
- Input parameters
- Standards and blanks
- Output parameters, and
- Statistics?

Topography

With regard to topography:

- Is it sufficiently detailed to make accurate estimates of volumes in open-pit scenarios?
- Are property, political boundaries, hydrographical and cultural features current?
- Are topographic data compatible with the property grid?
- Do contours cut from the digital elevation model (DEM) compare well with originals?

Exploration Grids

With regard to exploration grids:

- Is each one orthogonal, i.e. with the base line oriented parallel or sub-parallel to strike?
- Is there a conversion between grid coordinates and Universal Transverse Mercator (UTM) coordinates?

Drilling

With regard to drilling, there are two aspects to consider:

1. The drill hole and
2. The drill core.

For each drill hole:

- Which technique (diamond drill, reverse circulation, tricone, wet, dry) and hole diameter were used?
- Does the drill collar survey include the hole name, Easting, Northing, elevation, total depth and start and end dates?
- Does the collar elevation match the topography?
- Are there down-hole surveys, with drill-hole ID, depth from, depth to, azimuth, and dip?
- Was the completed drill hole cemented (particularly in underground scenarios)?

For diamond drill cores:

- What was the percentage recovery and are any missing intervals listed?
- Do the drill logs compare well with known geology and/or down-hole geophysics?
- Have cores (or photos of same) been examined to verify the major geological contacts?

Assays

With regard to assays, there are three aspects to consider:

1. Sampling
2. Analytical precision and accuracy
3. Treatment of analytical data

For sampling:

- Which techniques were used to acquire the samples, i.e. diamond-drill hole, reverse-circulation hole, blast hole, trench, channel, chip, grab?
- What are the sampling protocols for each sample type?
- Are the samples representative in their location, orientation, and size in relation to mineralization?
- Were samples collected honouring geological contacts (sharp or gradational) and ore boundaries?
- Were samples of low-grade material adjacent to ore collected for dilution calcula-

tions?

C Are the security protocols and chain of command documented?

For analytical precision and accuracy:

C Were standards (certified or in-house) submitted with each batch of samples?

C Are lab standards and duplicates for each batch within an acceptable range?

C Has a check assay program been run, i.e. duplicates submitted with original batch, existing samples re-assayed in a different lab, or re-sampled and -assayed, if ssary?

C Have internal checks of grade, including univariate statistics and bivariate plots of commodity types, been performed?

C Are the errors systematic or random?

For treatment of analytical data:

C Does the assay database contain drill-hole ID, from, to, length, grade, missing core intervals, and sample type?

C How are missing assay intervals tagged and filled, i.e. are they assigned an average value or a length-weighted average of adjacent samples?

C How are assays below detection limit tagged?

C Are extreme values capped or cut; how realistic are they, based on probability plots and historical production data?

C Are there quality parameters or reverse cut-offs for contaminants or heavy metals?

C Do original assay certificates, including the highest 1% of assays, compare well with those in the assay database? (check 5% of data to validate).

C Is there a correlation between grade and core recovery, grade and drilling technique, grade and date of assay?

Geological Interpretation

With regard to geological interpretation:

C Is surface mapping included in the geology files, including the location of outcrops and contacts, as well as structural and lithological data?

C Do sections show interpretation between drill holes including rock units, structure, limits of mineralization, grade, and alteration types?

C Do plan maps show the limits of mineralization and alteration and/or isopachs of mineralization?

C Is the geological model supported by the cross sections, isopach maps, geophysics, geochemistry, geochronology, etc.?

C Are there alternate geological models: i.e. has the geology been critically reviewed; have there been changes in geological interpretation since earlier reporting; has there been a site visit?

C How much is the geological model guiding the resource?

C Is the density of drilling sufficient in high-grade zones?

C Do drill holes at the margins of the deposit have a disproportionate areal influence?

C Are there gaps or overlaps in the geological solids in the computer model?

C How is the ore classified metallurgically, i.e. oxide, sulfide, mixed, refractory?

C What are the grade statistics within each ore class?

C Are there statistical differences among ore classes?

C What are the spatial distribution and continuity of ore classes?

Density/Tonnage Factor

For the density/tonnage factor:

C What were the size and number of samples; were they wet or dry?

C Are the locations of samples representative of geological units and ore classes?

C Can an equation be derived between density and grade?

Metallurgical Recovery

For metallurgical recovery:

C What were the size and number of samples?

C Are samples representative of the ore classes?

C What type and scale of test was performed, i.e. bottle roll, pilot plant, grindability?

PART B – RESOURCE MODEL

Compositing

With regard to compositing samples:

C What type of composite was used, i.e. bench height, fixed length, honouring geology, or some combination of these parameters?

C Is there a change in core diameter or sample size within composite assays?

C How do average grade and grade distribution of the composite assays compare to the individual assays?

C Are the composites of optimum length, i.e. short enough to be relatively homogeneous with respect to lithology?

C How are short composites treated, e.g. stitched into the previous composite?

C How is the internal dilution treated i.e. is the grade diluted or is the ore percentage tracked?

NOTE: Compositing assays into larger units helps to speed calculation and smooth grades.

Grade Interpolation

With regard to grade interpolation, there are two categories of questions:

1. Those related to spatial distribution, and
2. Those related to samples.

For those related to spatial distribution:

C What is the drill-hole spacing and the area of influence of each drill hole; are the drill holes evenly distributed or are they clumped together?

C Has the spatial continuity of the ore been determined by 2-dimensional or omnidirectional variograms?

C What are the axes of anisotropy and statistically viable distance of correlation?

C Do structural or stratigraphic

controls need to be factored in?
- What search neighbourhoods were used?
- What interpolation technique was used (polygonal, $1/d^n$, kriging, etc.)?
- Are the data quantum or continuous variables?

For those related to samples:
- What is the best number of samples to use?
- Are nearby samples redundant (quadrant vs octant searches)?
- Are nearby samples relevant, i.e. same population type or matching rock types?
- How are short composites interpolated?
- Has the nugget effect been determined?
- Are the blocks being filled by composites of the same ore class, and if so, from how far away?
- How do the grades of the blocks compare to the grades of the assays and composites?
- What is the volume-variance relationship?

Tonnes Estimation

With regard to tonnes estimation, there are three categories of questions:

1. Those related to the ore body
2. Those related to gridded surfaces
3. Those related to models and blocks

For those related to the ore body:
- What is the shape of the mineralized zone?
- How much ore is held in the projected extension beyond the last drill holes?
- How is external dilution factored in?

For those related to gridded surfaces:
- Are they stratigraphic or grade surfaces?
- Are they conformable or unconformable?
- What is their continuity?
- How bumpy is the surface, i.e. is it folded, faulted, or channelized, and is the drill-hole spacing adequate to see short wavelength features?
- How much smoothing has occurred at longer wavelengths due to the influence of distant drill holes?
- Are surfaces rationalized below each other?

For those related to models and blocks:
- What model type was used, i.e. serial slices, gridded seam, block, solid, or mathematical functions, and is it appropriate?
- Are models constrained by geological interpretation?
- How was block size determined, i.e. half drill spacing, mining equipment criteria, standard mining unit, pit optimization, etc.?
- Is the block height fixed, and does sub- or super-blocking occur?
- How well does the block fill match control surfaces?

NOTE: Block models are good for steep-dipping beds, non-bedded or irregular shapes, and will run floating cone pit optimization. Gridded seams have variable height and variable tops and are best for flat lying or bedded deposits, variable bench heights, or sloping benches.

Interpolation Passes

For interpolation passes:
- Are interpolation passes limited to ore classification types?
- Are different interpolation parameters needed for each ore type?

NOTE: A model may need multiple interpolation passes.

Model Validation

With regard to model validation, there are two categories of questions:

1. Those related to tracking, and
2. Those related to cross-comparisons.

For those related to tracking:
- Does the block model track the percentage of each block above topography and below the ore footwall?
- Is the ore percentage correctly filled from composites?
- Are the grade items correctly filled?
- Does the geology in the blocks match the geology in cross sections?
- Is the specific gravity correct for tonnage calculations?
- Are recovery factors tracked?
- Is the number of composites used in interpolation and the distance between composites being tracked?
- How are missing values for each parameter tracked?
- Is each model output (e.g. sections, maps, tables) date stamped, with an appropriate legend, location map, and author/operator/laboratory identified?

For those related to cross-comparisons:
- Does the total volume versus sum of ore and waste volumes match?
- Does the total volume versus sum of lithotype volumes match?
- Do bivariate plots of grade items match assay data?
- Do grade versus thickness plots for the model match the drill-hole data?
- How do grades and tonnes compare to similar deposits and previous estimates?

NOTES:
- For section and bench maps, verify that the grade between drill holes is being filled correctly.
- For cross validation, remove a drill hole and compare interpolated values.
- Check against historical production data, if available.

CONCLUSIONS

Commonly, there is a lack of feedback between the data collection and the data analysis ends of a mining project, due to the limits of time and budget. Workflows are typically developed on a project-by-project basis. The feedback protocols need to be strengthened to ensure that relevant and reliable data produce models that are consistent and comparable to similar deposits elsewhere.

This can be achieved by grouping the workflow in sections that will ensure consistency and completeness in the way data are collected and reported over the life of a project. By properly documenting the data gathered and analyzed – survey, assay, geology, ore classification, metallurgy and density; compositing, interpolation, and validation – an easy-to-follow audit trail is produced showing that reliable data were used, that the appropriate methods were implemented, and that verifications were performed.

By better documenting the many steps required to build a resource estimate, and by leaving a clear audit trail, critical review of the model becomes relatively simple and much quicker. Both the project team and external auditors will be able to review the work that has been done and to make their own checks.

This checklist will require modification to meet the needs of specific projects; however, it can form the basis of a paper trail leading to improved data collection, a more accurate resource model, and a simplified audit process.

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