Geostatistics and Sample Numbers from an Acid and Metalliferous Drainage Perspective

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Introduction

Various Australian and international regulatory bodies (Environmental Protection Authority, 2015) require an early assessment of the geochemistry of waste rock. This usually includes estimates of the locations and volumes of potentially acid forming (PAF) materials and requires sampling of the waste rock zones as well as submitting the samples for a series of tests. We know that the required number of samples will vary depending on rock type, mean sulfur levels and spatial variability of sulfur as well as total volume. The key question is how do we know when we have enough samples?

This extended abstract describes the application of geostatistical methods to examine how sample numbers and sample locations influence the preliminary conclusions that may be drawn for early stage waste characterisation.

Background

Many exploration and resource evaluation drill hole data sets include assays of total sulfur content. In preliminary assessments for the potential for acid and/or metalliferous drainage (AMD), it is common practice to use the distribution of sulfur as an indicator of PAF material. Often a sulfur cut-off threshold is used to classify materials, whereby materials with sulfur contents below the threshold are considered to represent a low risk of acid generation. Identification of a defendable sulfur cut-off requires site- specific assessment of the availability of acid neutralising capacity (ANC). Final AMD assessments are therefore supported by more rigorous geochemical characterisation that includes examination of ANC and sulfur speciation within the mined materials.

Geostatistical methods were applied to a large exploration drill hole data set from an iron ore deposit to illustrate the relationship between sample numbers, sample locations and levels of confidence on AMD assessment outcomes based on sulfur content.

Analysis of the total sulfur content of the shale, a lithological unit known to both host sulfide mineralisation and pose an AMD risk, is presented.

Statistical Analysis

The total sulfur content of the samples forms a highly positively skewed distribution. The majority of samples had low total sulfur contents of less than 0.1 per cent. A small proportion of samples have a relatively large sulfur content between 1-10 wt per cent (Figure 1).

To examine changes in statistics with increasing numbers of appropriately spaced samples, a subsampling procedure utilising a 3D grid was applied to the total data set (Figure 2). Within each grid cell the sample closest to a randomly generated location within the cell is chosen. The grid spacing starts very wide, at approximately half the dimension of the data extents and consequently only a few samples are chosen. The grid size gradually steps down until the grid size approximates the actual data spacing thereby selecting almost all of the samples. At each grid size the mean total sulfur content, the standard deviation and the proportion of samples with total sulfur content greater than 0.1 wt per cent, were calculated (Figure 3).

The sample selection was repeated three times for different random locations within each cell. The resulting mean total sulfur values for the four sets of calculations are presented in Figure 4. Relatively large variations in the mean total sulfur values occur when the number of samples is less than approximately 150.

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It is interesting to consider the conclusions that would have been drawn based on the different subsets of data for a given cut-off value, say 0.1 wt per cent S. Consider the situation where eight samples were selected and analysed. For each case the mean total sulfur content is less than the cut-off value. Based on each of these limited data sets, it could be concluded that the Mt McRae unit is unlikely to be a source of AMD.

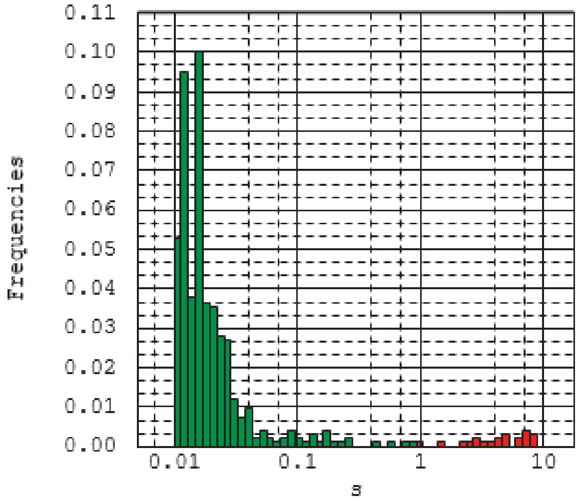

FIG 1 – Histogram of sulfur with grades above one per cent highlighted.

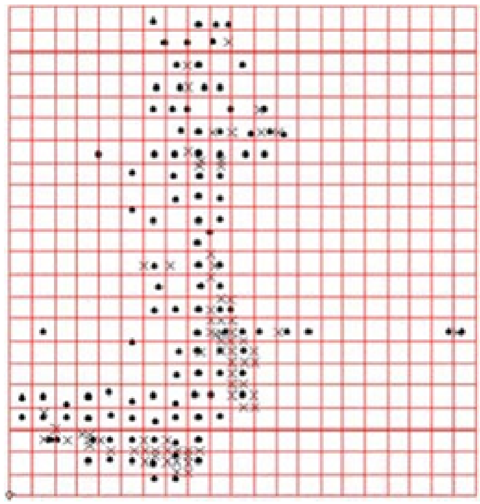

FIG 2 – Example of a sampling grid, samples (x) and random locations per cell (dot).

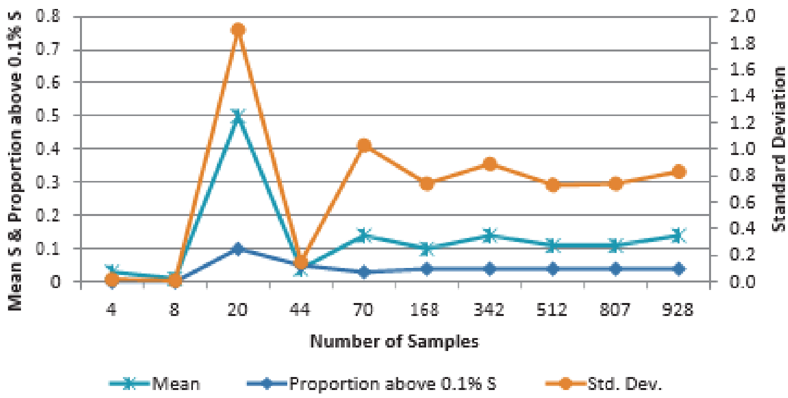

FIG 3 – Mean, standard deviation and proportion >1 wt per cent sulfur with increasing sample numbers, all samples.

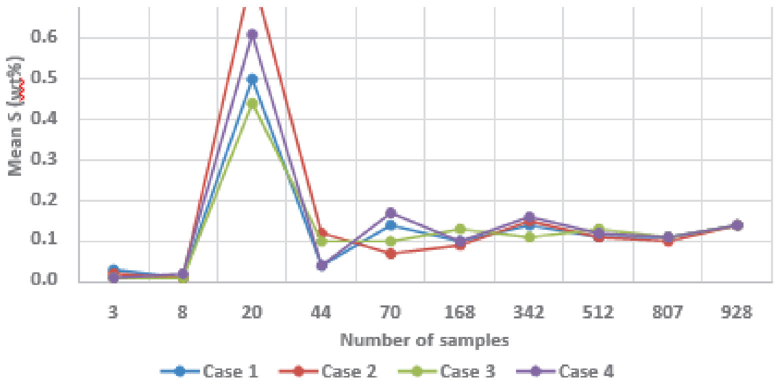

FIG 4 – Mean sulfur with increasing sample numbers, four outcomes with different random locations.

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However, if 20 samples were selected and analysed for each case, the mean total sulfur contents exceed the cut-off value by a factor of at least four. It could be concluded that testing of other geochemical characteristics is required to clarify the AMD potential of the Mt McRae unit, for example sulfur speciation and neutralisation potential.

Considering a third sample size of 44 samples; Cases 1 and 4 give mean sulfur contents less than the cut-off, and for Case 2 and 3 the mean is greater than or equal to the cut- off. Therefore, for Cases 1 and 4 some might conclude that the unit does not have AMD potential, whereas for Cases 1 and 3 it may be concluded that further testing is required.

Overall (based on 928 samples) the unit has a mean total sulfur content of 0.14 wt per cent, which is greater than the cut-off and therefore the AMD potential requires further investigation.

Spatial Analysis

There is a consistent spike in the statistics at around 20 samples. Further examination of the data showed a single, spatially isolated, sample with a relatively high sulfur content of 0.83 wt per cent was selected irrespective of the random location within the cell. In practice this would be a warning to revisit the data set and investigate possible miscoding during logging, and question the absence of nearby samples.

A review of the locations of all of the high total sulfur content (>1 per cent) samples showed that they were clustered (Figure 5). This may imply that they are part of a distinct volume within the shale that requires separate treatment both physically and statistically.

The process of sample selection and statistical analysis was repeated after removal of the high sulfur cluster samples from the data set. Results (Figure 6) show that the mean total sulfur content is significantly reduced to 0.03 wt per cent. Additionally, the mean total sulfur content is less than the 0.1 wt per cent cut-off for all numbers of samples, indicating that waste rock represented by the low sulfur samples can likely be managed as non-acid forming (NAF).

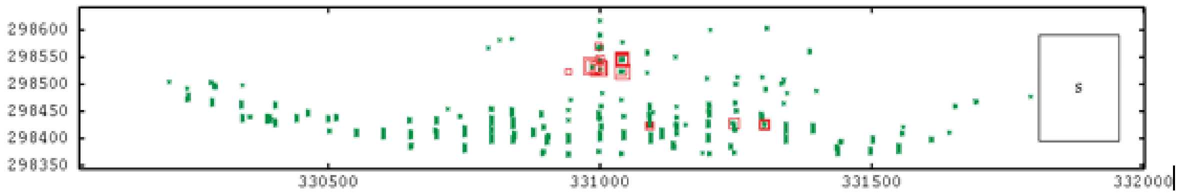

FIG 5 – Plan view of samples with sulfur content above one per cent highlighted (red squares).

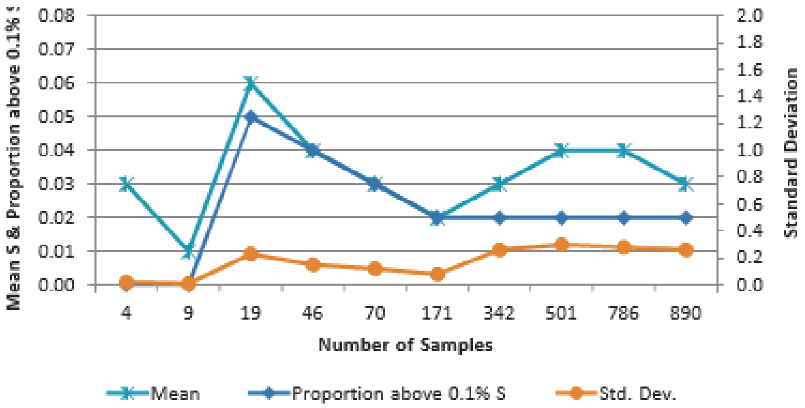

FIG 6 – Mean, standard deviation and proportion >1 wt per cent sulfur with increasing sample numbers, excluding high-grade cluster.

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Conclusions

This study indicates that:

- Decisions based on a small number of samples are more likely to be inappropriate. For the data set considered, less than 150 samples may be considered a small number. It is worth noting that, in the authors' experience, for any one rock type, this number of samples is larger than would be typical at the early stages of mine planning.
- Spatial analysis can reveal issues that would otherwise not be identified. In the example presented, spatial analysis identified:
  - the cause of the consistent spike in mean sulfur content observed at around 20 samples
  - the spatial clustering of the high-grade sulfur samples.
- A consequence of small sample numbers is the potential to misclassify waste as NAF, when it is actually PAF. A possible outcome is that PAF materials are not identified and not managed to limit or prevent the production of AMD.
- A relatively small percentage of samples with high parameter values can have a disproportionate influence on mean values. The samples may belong to a spatially separate and statistically identifiable material, which may be of relatively small volume. Conclusions drawn of the wider data set and larger volume of material without taking account of any high-grade clustering may result in the unnecessary additional cost of handling large amounts of material that have been incorrectly classified as a potential source of AMD.
- Even with high sulfur content clusters removed from the analysed data, the number of samples required for stabilisation of statistics did not decrease. The number remained at around 150 for the example presented, though the mean total sulfur content was significantly reduced and well below the 0.1 wt per cent threshold of interest.

References

Environmental Protection Authority (EPA), 2015. Guidelines for preparing mine closure plans, Department of Mines and Petroleum, EPA, Government of Western Australia.