Observing graphical signatures of economic commodities within a geological domain with the aid of holistic modelling

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Abstract Economic quality parameters are extremely critical to the revenue projections of mining projects. Yet, this industry frequently demonstrates difficulty achieving a reliable handle on the economic quality parameters within the rock mass that it is exploiting or plans to exploit. To achieve better estimates, one prime aspect of the solution adopted commonly by the industry is to acquire more appropriate data. This can be very expensive, particularly if the estimates suggest, that geological domain is uneconomic. **An alternative strategy before seeking further data is to ensure that the data already collected has been utilised to gain the most extensive insights to the behaviour of the economic commodities within the geological domain.** In using a holistic modelling approach to the collected geochemical drilling data, it is possible to identify a variety of unique graphical signatures associated with the economic quality parameters within the geological domain. These signatures will always require far less data than current 'industry best practice' associated with mineral resource estimating procedures. Once, these signatures are identified, it should be possible to achieve realistic overall estimates of the economic commodities concentrations associated with the domain. In the case of Bre-X's Busang ,where some 60 ounces of gold turned into a $6 billion fraud, this fraud would have been far more difficult to achieve if 'best industry practices' included verifying the data with graphical signatures of the gold within geological domains.

1. Introduction

The mining industry considers the exercise of achieving reliable economic quality estimates to be very difficult, because the process or processes that created the concentrations are seen to be very complex. However, the common approach, within industry for many decades, has been directed primarily at deriving a detailed interpretation based on the collected data as the starting point in determining an overall estimate of the economic quality parameters. This approach tends to result in a constant desire for more data while being swamped by the aspiration to gain an even greater appreciation of the detail, while losing sight of the lack of change in the bigger picture, particularly with regard to the economic quality parameters. Normally, the overall economics are far more sensitive to the economic quality parameters than their extent within the rock mass.

2. Geological Domain

The key to economic mining ventures is to find abnormal concentrations of economic commodities that are reasonably accessible within the earth's crust. These concentrations will comprise of one or more geological domains.

To be effective in domaining the data, there is a need to do some interpretation of the data gathered, but the extent of the interpretation is to merely identify to what domain the data relates.

It is important to appreciate that geological domaining of the concentration can be undertaken to achieve a variety of different needs. For example, they may be domained to identify different blasting requirements, or they may be domained for mineral processing characteristics, or again for ground support requirements, or estimating the economic quality parameters associated with the mining venture.

A geological domain is distinguished by the fact that all the rock within it has similar characteristics. For example, the mineral composition is similar; the texture is similar and the structure is similar. While they are similar, there are still differences. However, within the domain, these differences are reasonably predictable.

It is essential to appreciate what has been the prime objective in the domaining process. For example, it may very well be inappropriate to use the domaining used to identify areas of similar ground support requirements, as the same domaining that relates to areas that have similar character of an economic quality parameter.

Geological domaining in the context of this paper relates to the separation of the interested part of the rock into domains where the quality parameter for an economic commodity has similar character.

Where a mining venture is dependent on extracting a number of commodities (eg uranium, copper and gold) from the same rock mass, it may be necessary to consider different boundary limits in domaining the rock mass for each of the commodities as their distributions through the rock mass are not necessarily mutually dependent.

Operations that compromise on the extent of their geological domaining for the sake of simplicity can incur a significant hidden cost and threaten the real project's viability.

Very commonly, the allocation of geological domains is limited to rock type eg granite, sandstone, shale, etc. In some situations, this will be adequate, but in many cases it will not.

It is essential when endeavouring to derive reliable economic quality estimates within a rock mass that the domaining is not compromised by competing objectives. The primary domaining objective in this case should be to identify and segregate data such that the characters of the economic quality parameters within domains are demonstrably similar.

Where more than one domain exists, the differences between domains can be extremely obvious, but they can also be very subtle. Being able to effectively domain a mineralisation which is to be exploited for mining can be extremely critical to the ultimate economic effectiveness of a mining venture.

Frequently, multiple domaining within a mineralisation is overlooked because the assessment is predominantly, if not completely, determined subjectively, and/or the differences are either overlooked or ignored. The economic impact of this practice nearly always results in a less than optimally run operation that impacts on the shareholder's return.

3. Dynamics within a Domain

A common tool of geologists when summarising geochemical data from routine sampling, such as drilling, are the identified zones of economic concentrations. The spatial relationship of these zones can contribute significantly to the appreciation of the deposit. Normally, the geologist will use sections and plans to present the sampling, zoning and interpretation of this data.

Frequently, the power of this tool is under utilised. In some cases, this occurs because the routine zone summary that develops over time can involve a variety of people, and the criteria, on which the zone limits are determined, are not consistent. Often, where downhole zones are routinely used to appreciate the deposit and domain it, the interpretation is based on zones that basically have similar cutoff criteria. Further, the cutoff criteria are often related to economics that are more favourable than what will be experienced if the operation is to operate to the board's desired profitability.

While there is some merit in considering a cutoff that is subeconomic during the initial stages of the property's geological analysis, it is not appropriate during stages that will determine its economic viability. {Generally, the complexity of interpretation and domaining diminishes as one decreases the cutoff.}

But the power of the tool of zoning is dramatically enhanced when it is used with standard criteria across the data set and at a series of cutoffs.

Undertaking a series of interpretations of the data at a series of cutoffs is done, but **it is not a common practice. It should be.** It would be significantly beneficial to every mining project and it would have the potential of being very beneficial to the project's shareholders.

With increasing cutoffs, it will often become more difficult to identify the interpretation which reflects what is there, from the alternative interpretations that appear reasonably feasible, based on the data available. What links with what? can be a challenge.

The prime motivation behind obtaining an interpretation of the data that best reflects the actual rock mass is to ensure that the detail of the economic commodity concentration modelling and the economic modelling on which it is based, is an adequate reflection of what is there and what will occur within the economic assumptions made.

While the spatial relationships, along with extensive data, are important for detailed realistic modelling of the economic commodities within the rock mass, it is possible to gain a realistic overall appreciation of the economic commodities within a geological domain without spatial details and a large amount of data.

4. Graphical Signatures

4.1 Introduction

Appreciating patterns is an important part in any attempt to estimate what will happen when the available data is extremely limited. Nature consistently operates to patterns, even when the situation appears to be chaotic. This is often the description given to the economic commodity quality parameters within a rock mass within a geological domain. But as has been noted in the past four decades, in many scientific disciplines, that even processes that are perceived to be chaotic, do have patterns. These patterns become more evident when one looks at the collected data in an all embracing fashion. In other words, the data is reviewed in a holistic way.

The patterns associated with a geological domain as a result of holistic modelling of the data can also be described as unique signatures of the geological domain. These signatures can be demonstrated to be independent of the spatial relationships of the data collected within the domain.

A way of affirming that appropriate domaining has occurred with the data is via the depiction of graphical signatures with a systematically selected portion of the data.

The signatures of interest here are the numerical trends that can be observed in association with downhole zone reviews at a series of cutoffs.

4.2 Quality Parameter Distributions

The distribution of a quality parameter within a geological domain can be determined; by first, identifying all the downhole zones by a similar sampling process for a constant criteria for identifying zones. Now, compute composites of constant length (eg similar in length to the most frequent sample interval) along the length of each zone. With this complete, the composites are grouped into classes of various amounts of the quality parameter. Then a frequency percentage is computed in each class. (The size of each group is not critical, the smaller the better without being excessive.)

Table 1

g/t Au	Number	Frequency %
0.5 to 1.0	7	0.31
1.0 to 1.5	136	6.10
1.5 to 2.0	337	15.12
2.0 to 2.5	495	22.20
2.5 to 3.0	415	18.62
3.0 to 3.5	140	6.28
3.5 to 4.0	224	10.05
4.0 to 4.5	244	10.94
4.5 to 5.0	72	3.23
5.0 to 5.5	74	3.32
5.5 to 6.0	85	3.81

An example is presented in Table 1. In this case, it relates to 2m composites within 'significant intersections' associated with 13 holes reported by Bre-X at its Busang property on section line 49.

Very frequently, the distribution of an economic quality parameter within a rock mass is log normal in shape and these distributions tend to be unique to the domain. Hence, they remain relatively constant once sufficient data has been collected.

The amount of data required to adequately represent the distribution of the quality parameter is primarily a function of its variability. But it will always be the case, that enough data has been collected to describe the distribution within the geological domain well before sufficient data exists to produce a reliable detailed model of this parameter within the rock mass.

A graphical presentation of quality parameter

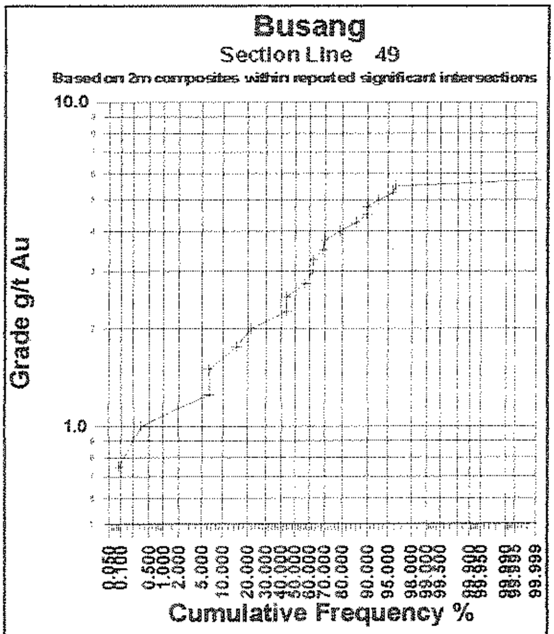

Figure 1

distributions associated with the rock mass with typically log normal distributions can be very effectively presented with a log probability graph. Figure 1 presents basically the data within Table 1; however, the Figure 1 is based on a class interval of 0.25 g/t rather than 0.5 g/t in Table 1.

One can conclude that the distribution in Figure 1 is basically log normal, because the overall trend is linear. There is a slight saw tooth component to the trend. Typically, this reduces as the data set increases. However, in this case, since it is based on a public data summary, the data is coarse. For example, one of the significant intersections is 301m at 4.24 g/t Au. Therefore, it has to be assumed that each of the 150 composites is 4.24 g/t when in fact they would vary quite a bit.

If the distribution plots show that the trend is obviously not linear, it means that either the distribution is not log normal or the data has not been domained effectively and the distribution represents more than one population. In most mineral property cases, the latter will be the most common explanation.

The log probability graph is a valuable tool to compare domain distributions or subsets within a domain eg the North half versus the South half, etc or sampling procedures against another.

Sometimes the distributions of domain subsets will not have the same signatures. This should be treated with concern as one at least is not truly representing the domain. This can happen when the economic quality parameter is extremely variable and erratic. In this case, the distribution trend associated with the large sample diameter has the greater likelihood of more correctly reflecting the domain.

4.3 Distribution of Zone Lengths

The distribution of zone lengths within a geological domain can also be a graphical signature. In Figure 2, the reported 'significant intersections' associated with section lines 44 and 49 at Busang are compared. (There are 9 and 13 holes reported respectively associated with these lines in which there are 35 and 48 intersections respectively. Normally, one would use a more random data subset rather than merely data on one section line in comparison to another.)

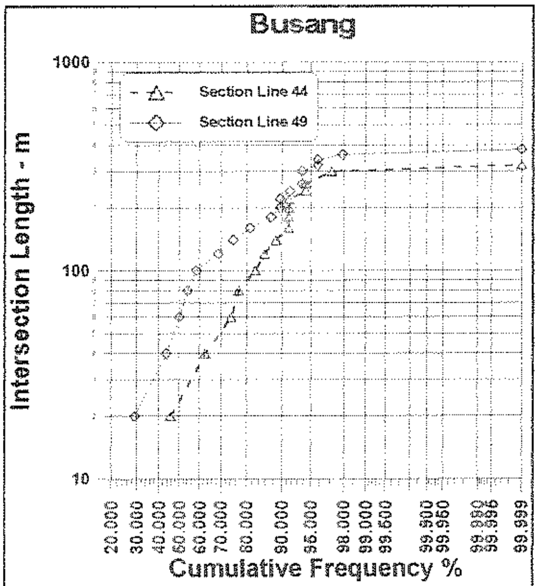

Figure 2

The trends are quite different. Yet, they are reported as part of the same zone. Based on the trends in Figure 2, it is difficult to believe unless the criteria is different; more likely, they are different domains, or there is insufficient data or the data is suspect. The trend in the case of section line 49 is arguably made up of two straight lines. The steeper gradient is not dissimilar to the linear trend associated with section line 44.

4.4 Average and Median Trends

The plotting of trends in the overall median and average grade of zones at a series of cutoffs provide further unique graphical signatures associated with a geological domain which are beneficial in appreciating some aspects of the economic quality parameter dynamics.

The mining industry pays a lot of attention to weighted averages when summarising sampling data. However, with log normal distributions, the weighted average of the quality parameter is very often a poor indication of the overall value of the quality parameter within the domain. If the distribution values are a realistic reflection of the domain, then the average quality parameter will overstate the overall quality parameter if the majority of the distribution is some what less than the average value. (This is very often the case in most mining projects.)

The industry has developed a variety of ways to adjust the estimate(eg use of mine call factors, using a high grade cuts, conservative dilution factors etc) in endeavouring to cope with this problem. However, the median (50% of the distribution lies above and

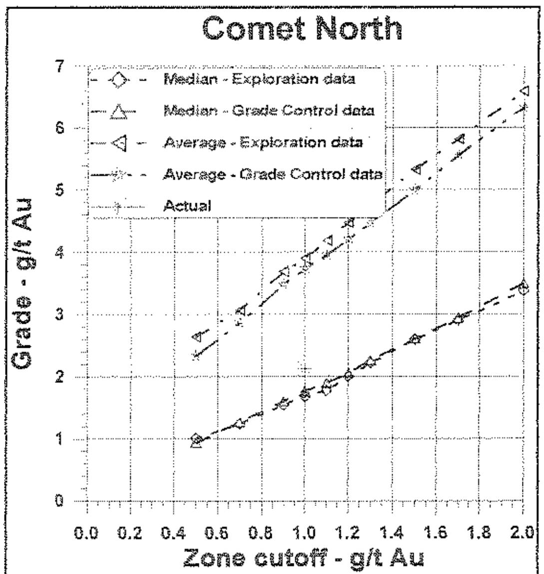

Figure 3

below the value) is a robust statistical parameter in these situations. Further, the overall value of the economic parameter within geological domains, where the majority of the distribution is some what less than the average value, will be closer to the median of the distribution than the average. At higher cutoffs, the overall value will be even below the median zone value.

In Figure 3, two different sampling regimes are depicted with the associated median and average trends for each. The grade control data was significantly larger and acquired during the production phase, while the exploration data was collected before the development decision to mine, was made. All four trends are linear. This suggests that the data probably relates to one geological domain. Note that median trends are far more compatible than the average trends. As previously stated, this is no surprise.

The average trend of the grade control is slightly lower than the exploration data. This is also a common trend as the grade control tends to give more even coverage and can be associated with larger diameter sampling.

It is also evident from Figure 3 that the overall economic quality parameter is closer to the median value than the average value. Yet, the production of gold from Comet North resulted in the operation producing less than half the gold than was expected. In fact, over time the grade estimate reduced with the accumulation of more data and mining experience. But Figure 3 suggests that the additional data was merely reflecting the data gathered in the exploration phase. Hence, in taking cues to the overall value of a quality parameter, it is better to be guided by the median value than the average value from a sampling set, when the majority of the distribution is some what less than the average value.

Obviously, the amount of data available to contribute to each point in these trends decreases with increasing zone cutoff. Yet there is no significant divergence between the trends as zone cutoff increases. This provides additional support to the suggestion that relatively little data is necessary to establish these various graphical signatures and they are quite unique to each geological domain.

With only the distribution data such as Table 1, it is possible to produce a plot similar to Figure 3. While this is not as effective as the product in Figure 3 which was based on zoning all the data at a series of cutoffs, it can provide a valuable indicative picture of the dynamics of the economic parameter within the geological domain.

It is extremely valuable to plot the summary of a detailed model against the data like Figure 3 where one simply plots cutoff against overall grade. Unfortunately, it is too often assumed because the detailed model is based on the gathered data, then it maintains integrity with it. This is untrue most of the time. A comparison as suggested here, will enable one to see if the detailed model does maintain integrity with the data on which it is based.

4.5 Impact of Cutoff on What Remains

In 4.4, the attention was placed on the relationship between zone cutoff and the economic quality parameter. But obviously, as the cutoff increases the data within zones decreases. What is the trend in the overall length remaining as a percentage of a base case? Similarly, how much of the economic commodity remains? These trends are in fact additional graphical signatures of a geological domain.

The data used to produce Figure 3 has been represented in a different form in Figure 4. The trends of the two data regimes could be more similar; however, the character of both sets is quite similar for both length and gold.

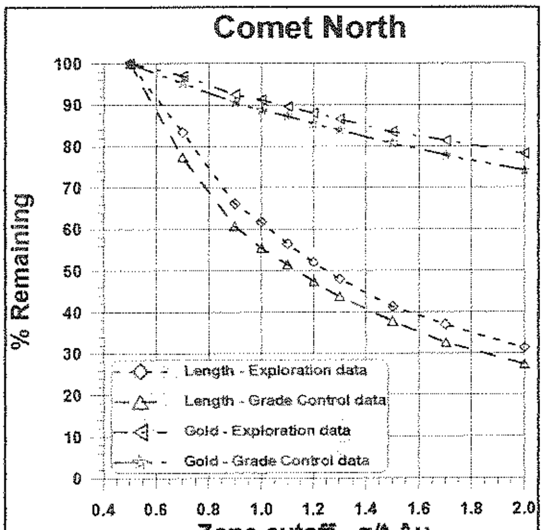

Figure 4

Greater compatibility in these trends will be experienced when subsets of the same sampling method within a domain are presented. Consequently, these are further examples of graphical signatures of a geological domain.

It is interesting to observe from Figure 4 that some 30% of the intersections above 0.5 g/t Au contain over 75% of the gold. This relationship can be very critical when the detailed modelling occurs, as the effective modelling of this portion of the data will bear heavily on the perceived economic benefits of the project.

5. Summary and Conclusions

Operations that compromise on the extent of their geological domaining for the sake of simplicity can incur a significant hidden cost and threaten the project's viability.

It is essential when endeavouring to derive reliable economic quality estimates within a rock mass that the domaining is not compromised by competing objectives.

The primary domaining objective in this case should be to identify and segregate data such that the characters of the economic quality parameters within domains are demonstrably similar.

Frequently, multiple domaining within a mineralisation is overlooked because the assessment is predominantly, if not completely, determined subjectively, and/or the differences are either overlooked or ignored. The economic impact of this practice nearly always results in less than an optimally run operation that impacts on the shareholder's return.

The power of the tool of zoning is dramatically enhanced when it is used with standard criteria across the data set and at a series of cutoffs.

Undertaking a series of interpretations of the data at a series of cutoffs is sometimes done, but it is not a common practice. It should be.

It is possible to gain a realistic overall appreciation of the economic commodities within a geological domain without spatial details and a large amount of data.

Appreciating patterns is an important part in any attempt to estimate what will happen when the available data is extremely limited.

These patterns become more evident when one looks at the collected data in an all embracing fashion. In other words, the data is reviewed in a holistic way.

Very frequently, the distribution of an economic quality parameter within a rock mass is log normal in shape and these distributions tend to be unique to the domain. Hence, they remain relatively constant once sufficient data has been collected.

Unfortunately, it is assumed because the detailed model is based on the gathered data it maintains integrity with it. Most of the time, this is untrue. Comparing the detailed model summary with these graphical signatures would provide demonstrable proof of the model's integrity with the data.

In the Interim Report by Strathcona Mineral Services Limited, it was concluded that the sample tampering at Busang was undertaken by people who '*had a very good understanding of the geology of the Busang property and have the knowledge required to determine the very small amounts of gold required to result in sample assays that would be compatible with the geologic interpretation*'. Figures 1 and 2 reflect this conclusion. However, it would have been far more difficult to maintain this pretence for so long if the use of graphical signatures had been sought in association with the data generated by Bre-X both publically and privately.

6. References

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