CRC ORE

Optimising Resource Extraction

GRADE ENGINEERING

P1A-052 A Review of Preferential Grade by Size Deportment Data Analysis Procedures and Comparative Ranking Methods

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Commercial in confidence

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BACKGROUND CONTEXT TO GRADE ENGINEERING

Grade Engineering seeks to improve unit metal productivity as a means of delivering system-value to the life-of-mine. This involves a range of integrated technologies and operating protocols for improving effective feed grades through early coarse rejection of low value components prior to energy intensive and costly processing activities. Grade Engineering has the potential to significantly increase value by reducing the cost, energy and water requirements per unit of metal, transforming the economics of large, low grade mining operations. The overall technical and economic aspects of Grade Engineering are detailed in a range of CRC ORE publications.

Four levers are recognized that can drive increased grade of new feed streams as a result of coarse rejection (Figure 1). Improvements in feed quality are an outcome of intrinsic rock characteristics and in-situ heterogeneity, combined with operational integration of the most effective levers. Optimisation involves knowledge of the relative yield-response of specific ore types or domains for each lever. This requires routine laboratory scale testing and production scale surveys to provide results that can be used to populate the resource model with separation attributes. The most common outcome of testing is recognition of specific domains within a resource that are most amenable to a Grade Engineering solution.

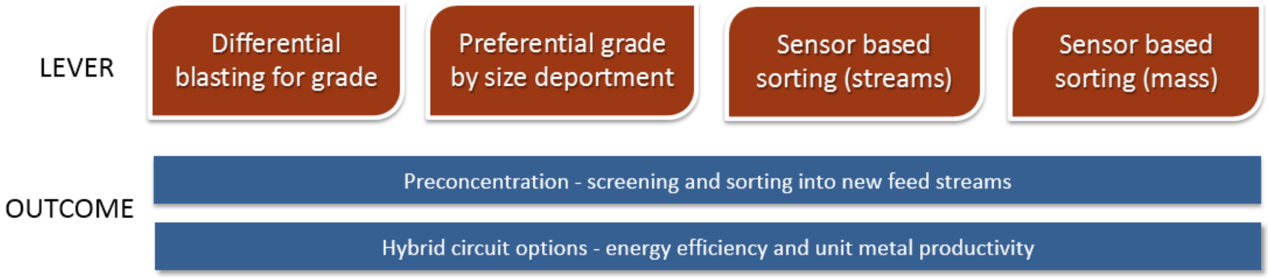


Figure 1 – Summary of the four main separation levers in Grade Engineering

The current report outlines the results of laboratory testing specifically for grade by size response. Outcomes are presented using a comparative ranking approach which can be used to benchmark grade by size response within and between deposits, and also to compare opportunity for separation driven by grade by size against other separation levers.

OVERVIEW OF PREFERENTIAL GRADE BY SIZE DEPORTMENT

Grade by size testing involves screening or sieving of a particle size distribution resulting from sampling production scale blasting (+/- primary crushing) material, or from crushing drill core using a defined protocol. In the majority of cases coarse assay preparation residues (typically with a P80 of ~2 mm or #10 mesh) can be used as the feed material for drill core scale testing. Individual size fractions are then assayed to produce a series of grade by size results for each sample. A minimum of four size fractions are recommended to calculate a statistically meaningful grade by size response curve. A protocol to determine optimal size fractions/fraction mass to support QA/QC particularly for coarse assay residues is provided in Appendix A.

A typical set of drill core scale grade by size results is shown in Figure 2. Preferential grade by size deportment is evident where there is a systematic change in grade across size fractions. For base and precious metal deposits this typically involves an increase in chalcophile elements into the finer fractions.

CRC ORE has developed a methodology for transforming raw sizing and assay data into a set of cumulative responses that can be used to rank and compare magnitude of preferential deportment. For drill core scale testing this involves Response Rankings (RR) which need to be scaled up to represent production scale Upgrade Rankings (UR). Rankings are functions that can be passed into simulation and modelling packages to optimise circuits and develop a Grade Engineering business case.

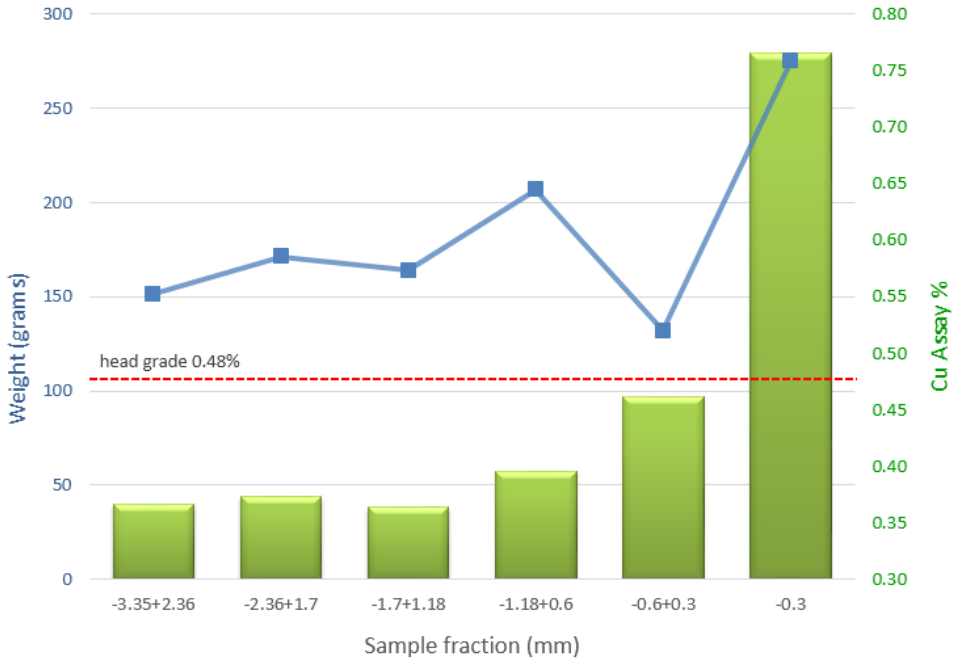


Figure 2 – Example of raw grade by size assay and fraction mass data

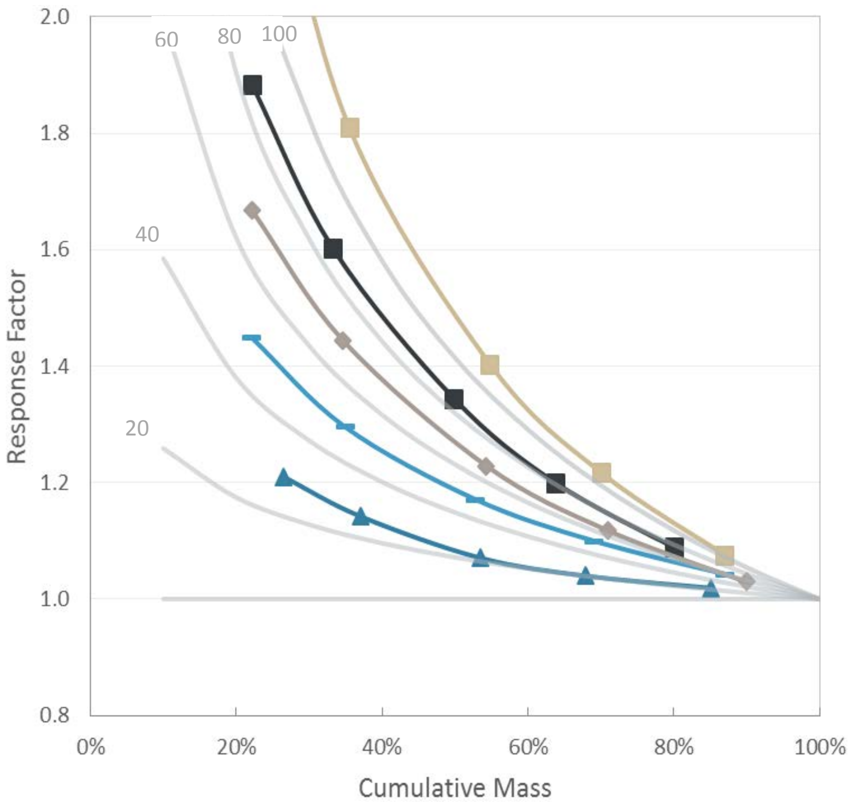


Figure 3 – Example of calculated grade by size Response Curve for drill core testing pale grey lines are Response Ranking reference curves

Examples of resulting grade by size Response Curves based on six size fractions for drill core coarse residue testing are shown in Figure 3, together with reference curves that represent the fitting function. Curve fits generate Response Rankings from 0-200 representing a theoretical preferential grade by size deportment maxima. Response Rankings over 80 for drill core testing indicate top priority results that indicate grade by size is likely to be a dominant Grade Engineering lever for specific ore types or domains. A statistical measure of curve fit for actual data versus the underlying Response Ranking fitting function provides QA/QC.

Poor curve fits result from a number of factors. This includes a combination of inappropriate screen or sieve size fractions that do not cover sufficient cumulative mass range; use of analytical data close to detection levels; representative sub-sampling issues particularly for precious metals; and laboratory sample handling errors. For production scale samples poor quality curve fits can also be a function of mixing size distributions that did not represent the same intact rock mass. This is particularly evident for samples that are being reclaimed from stockpiles.

Once individual results have been assessed using curve fitting QA/QC criteria with rejection of data that does not meet standards, Response Rankings can be assigned to samples and used to routinely compare and benchmark results. This is undertaken using standardized plots that are shown in subsequent sections.

DATA PROCESSING AND RANKING

1. Inputting Analytical Data and Sample Information

Raw assay data by size fraction together with sample fraction weights and associated sample ID information need to be entered into a centralized database to facilitate calculation of Response Rankings and QA/QC. CRC ORE has developed an Excel-based engine to facilitate data processing. This is currently only in beta form and in the short term it is recommended that raw data is provided to CRC ORE for processing and return to client in the form of a job or site specific Database Viewer at no cost. It is important that strict data formats or transforms are followed such as element versus oxide, ppm versus percent or use of preferred values, together with provision of metadata such as assay methods.

2. QA/QC Data Analysis

QA/QC is a measure of curve fit to the mathematical model function which can be expressed as standard deviation against the Response Ranking. Curve shape and associated response attributes can be displayed using the Grade by Size Data Viewer. A snapshot of the user interface (Figure 4) indicates the key functionalities. Any sample or element in the analytical suite can be selected for visualization. Examples of acceptable and non-acceptable QA/QC results are illustrated in Figure 6.

It should be noted that other analytical elements (as proxies for mineralogy) can exhibit different Response Rankings as a function of different preferential breakage and textural associations coupled with analytical precision. Intra-sample Response Ranking differences between elements become more pronounced when specific elements reflect increasingly diverse mineralogies. Examples include Fe which can be associated with a wide range of sulphides, oxides, silicates and carbonates.

Response Ranking Standard Deviations less than 0.05 are considered to be high quality; results between 0.05-0.10 are acceptable but are typically individually assessed; whereas values over 0.1 for drill core testing are regarded as failing QA/QC. The aim is to provide data points across the cumulative mass range especially in the region below 30% mass as this improves the fitting of response Rankings and associated QA/QC. A protocol to determine optimal size fractions/fraction mass to support QA/QC particularly for coarse assay residues is provided in Appendix A.

Element		Cu ppm	Response Ranking	StDev	Sample Type	Sample Type Details	Location	Site ID	CRC ID	Hole	From	To	Lithology	Main Alteration	Mineralisation Type	Deposit Type	Origin
Sample1	62	- 2010-01506	41.9	0.02	Drill Core	1/4 core NQ		2010-01506	CL050-F	LB2610	135.9	153.2	BXIG	Qtz sericite	0	Porphyry Cu	
Sample2	63	- 2010-01672	62.5	0.00	Drill Core	1/4 core NQ		2010-01672	CL054-F	LB3010	159.9	185.15	QM	Potassic	0	Porphyry Cu	
Sample3	64	- 2010-01675	101.0	0.10	Drill Core	1/4 core NQ		2010-01675	CL055-F	LB3110	0	12.4	QM	Qtz sericite	0	Porphyry Cu	
Sample4	65	- 2010-01676	112.3	0.03	Drill Core	1/4 core NQ		2010-01676	CL056-F	LB3110	12.4	29.7	QM	Qtz sericite	0	Porphyry Cu	
Sample5	66	- 2010-01678	65.7	0.06	Drill Core	1/4 core NQ		2010-01678	CL057-F	LB3110	29.7	47	BXTC	Qtz sericite	0	Porphyry Cu	
Sample6	67	- 2010-01679	49.7	0.05	Drill Core	1/4 core NQ		2010-01679	CL168-F	LB3110	47	64.3	QM	Qtz sericite	0	Porphyry Cu	
Sample7	71	- 2010-01685	24.2	0.02	Drill Core	1/4 core NQ		2010-01685	CL061-F	LB3110	133.6	150.9	PQMD	Qtz sericite	0	Porphyry Cu	
Sample8	72	- 2010-01687	41.0	0.03	Drill Core	1/4 core NQ		2010-01687	CL062-F	LB3110	168.2	185.6	QM	Qtz sericite	0	Porphyry Cu	
Sample9	76	- 2010-01692	51.9	0.03	Drill Core	1/4 core NQ		2010-01692	CL169-F	LB3110	254.8	272.2	QM	Qtz sericite	0	Porphyry Cu	
Sample10	10	- 2002-00955	90.3	0.03	Drill Core	1/4 core NQ		2002-00955	CL008-F	107000	79.2	84.2	BXD	No info	0	Porphyry Cu	

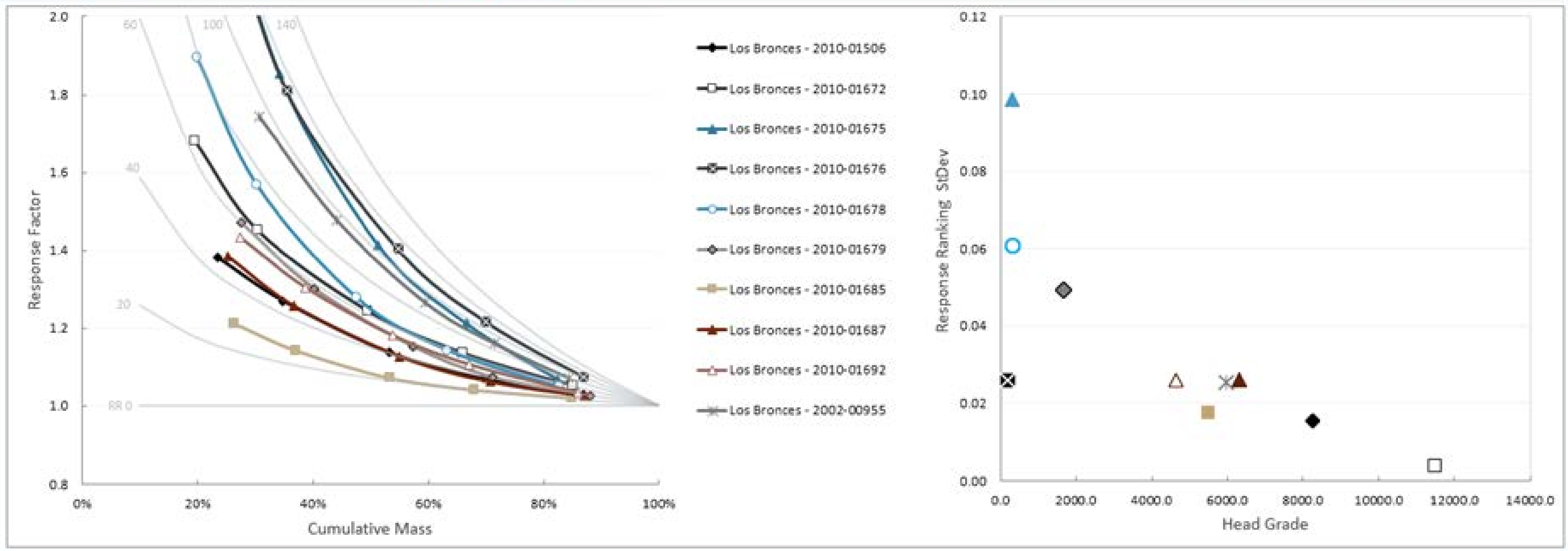


Figure 4 – Snapshot of Grade Size Data Viewer

3. Comparative Benchmarking of Response Rankings

Response Rankings that have passed QA/QC can be used as to compare and benchmark responses for selected assay elements and element associations. A routine scatterplot of Response Rankings for selected elements can be used used for first order analysis of grade by size variability (Figure 6). These have been developed using the ioGAS software and xml-based standard diagrams can be provided on request.

Diagonal lines represent fixed ratio references where the two elements show similar preferential deportment behaviors. The central zone outlined in red indicates where the two elements broadly maintain initial ratio of the head grades. Results plotting above this zone in Figure 6 indicate that S is concentrating at a higher rate than Cu and vice versa. This is useful for tracking mineralogical signatures of preferential deportment. For example, if significant amounts of pyrite were preferentially deporting by size compared to initial mineralogy of the head sample, it would be expected that the Response Ranking S:Cu ratio would increase. Conversely if high Cu-sulphide phases such as bornite or chalcocite were preferentially deporting then the Response Ranking S:Cu ratio would decrease.

The coloured Response Ranking reference zones shown on Figure 6 can be used to compare and benchmark responses. Based on extensive CRC ORE testing and Grade Engineering assessment across a range of deposits and deposit types, Response Rankings above 60 for drill core scale testing are considered to show potential for grade by size as a dominant Grade Engineering value driver. Response Rankings of 20-60 for drill core scale testing are considered to indicate that integration of grade by size response with an additional lever such as differential blasting for grade will be required to deliver Grade Engineering value. Response Rankings below 20 for drill core scale testing are considered to indicate that grade by size response will not be a significant driver for Grade Engineering.

A plot of calculated head grade and response ranking (Figure 7) is a useful comparison. In the extensive data sets developed in CRC ORE projects to-date, no relationship between head grade and RR has been observed. This reflects the dominant control between association and paragenesis rather than abundance. Work is ongoing to determine fundamental geological controls on variable grade by size response to develop predictive models.

Diversity of geological control is reflected in significant variability of Response Ranking evident for typical testing programs (e.g. Figure 6). It is recommended that for initial assessment of grade by size typically developed using drill core residues; composite sample intervals similar to metallurgical composites or nominal bench height are used. As an initial assessment a sample selection matrix of different ore types/lithologies, alteration styles and grade classes should be developed until more coherent RR groupings are recognized as discrete domains. This typically involves a minimum of 100 samples to adequately cover a sample selection matrix. As for any geometallurgical style attribute or domaining exercise an extensive sampling and testing program eventually involving thousands of samples, may be required to support domaining in situations of high variability. As the database grows assignment of average RR by geological category is generally undertaken (Figure 8).

For extensive multi-element data RR's for individual elements can be comparatively ranked to highlight associations which typically provide information on probable controls (Figure 9-10). In the case of the mesothermal gold example (Figure 9) a very strong correlation between high RR for Au, Bi, Ag and S is evident. In the case of the porphyry Cu example (Figure 10) Mo shows high RR while Cu, Zn, Ag, S, Pb and Cu show a closeting of moderate RR. This may indicate that the moderate Cu RR response is related to late stage base metal-bearing veins rather than earlier paragenetic Cu associations in veins or disseminations which are not reporting as preferential grade by size related breakage.

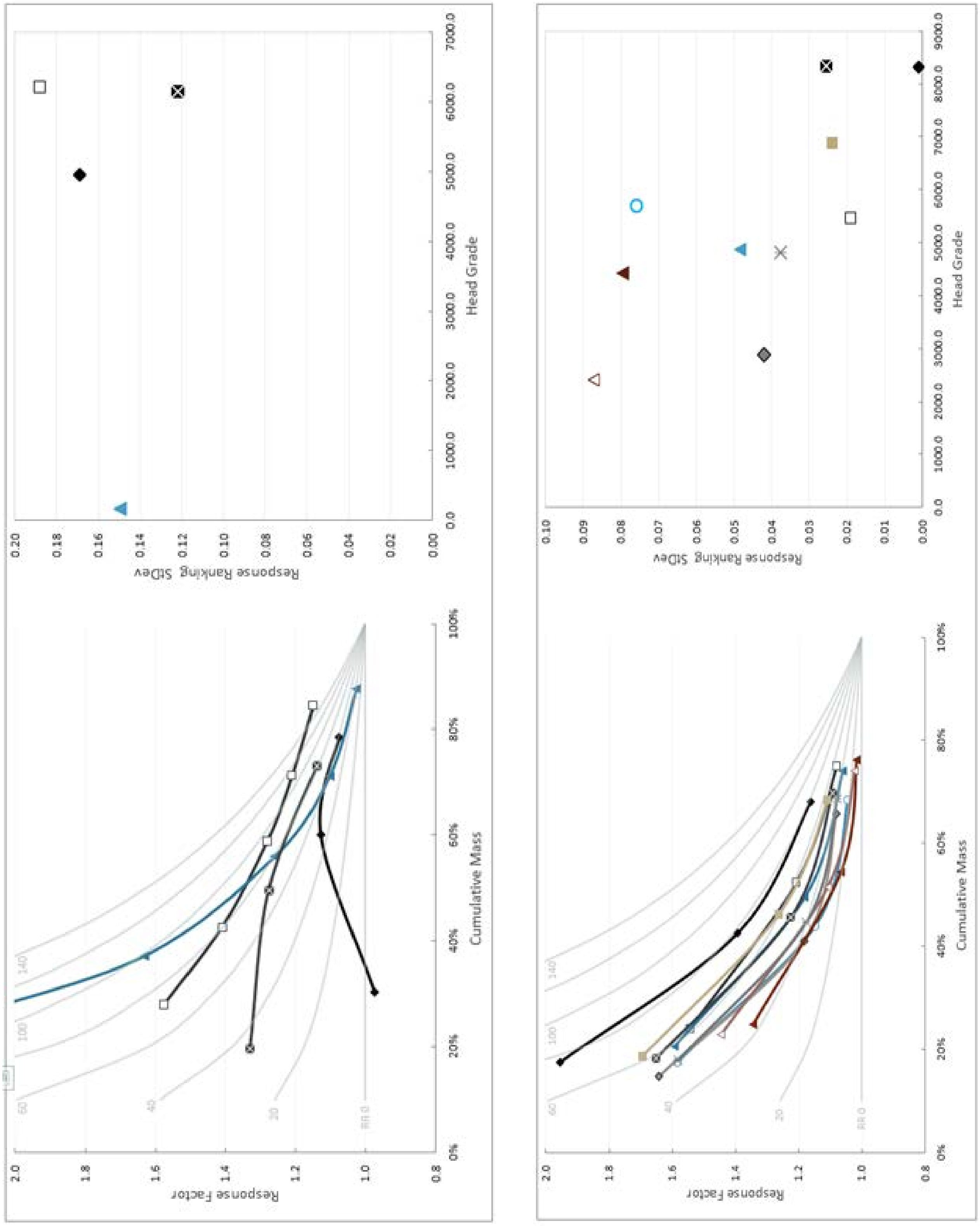


Figure 5 – Examples of drill core with acceptable QA/QC (bottom) and unacceptable QA/QC (top)

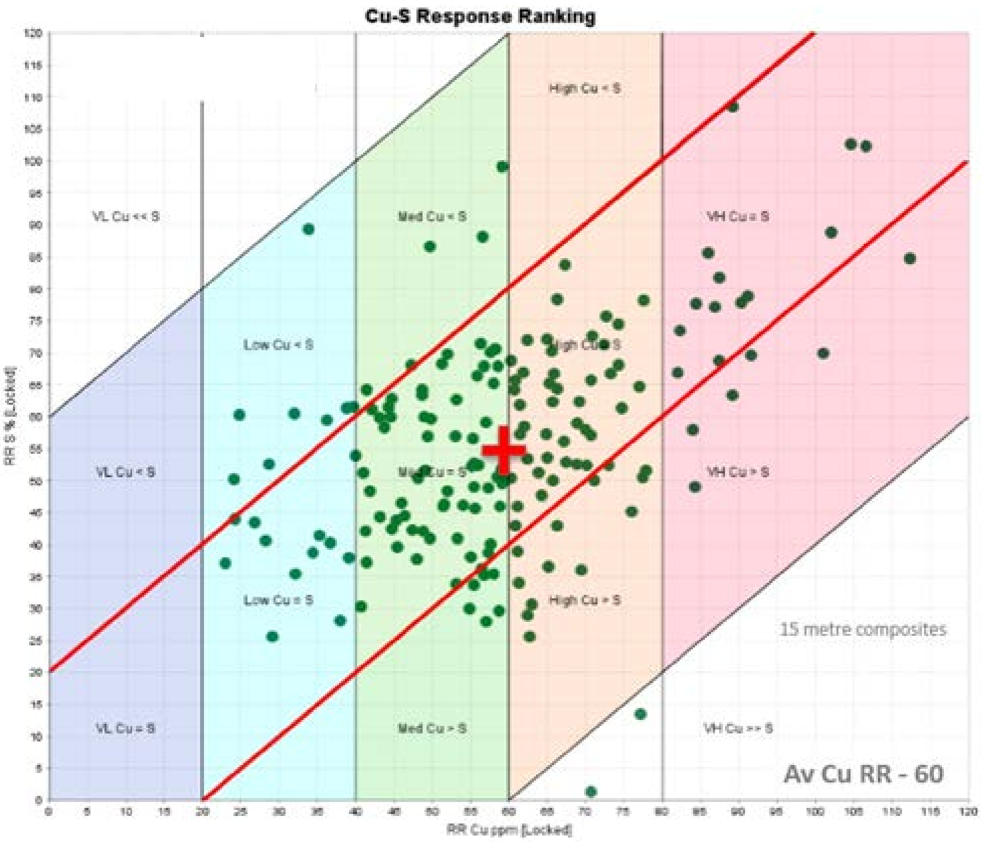


Figure 6 – Example of a Cu-S RR Ranking plot

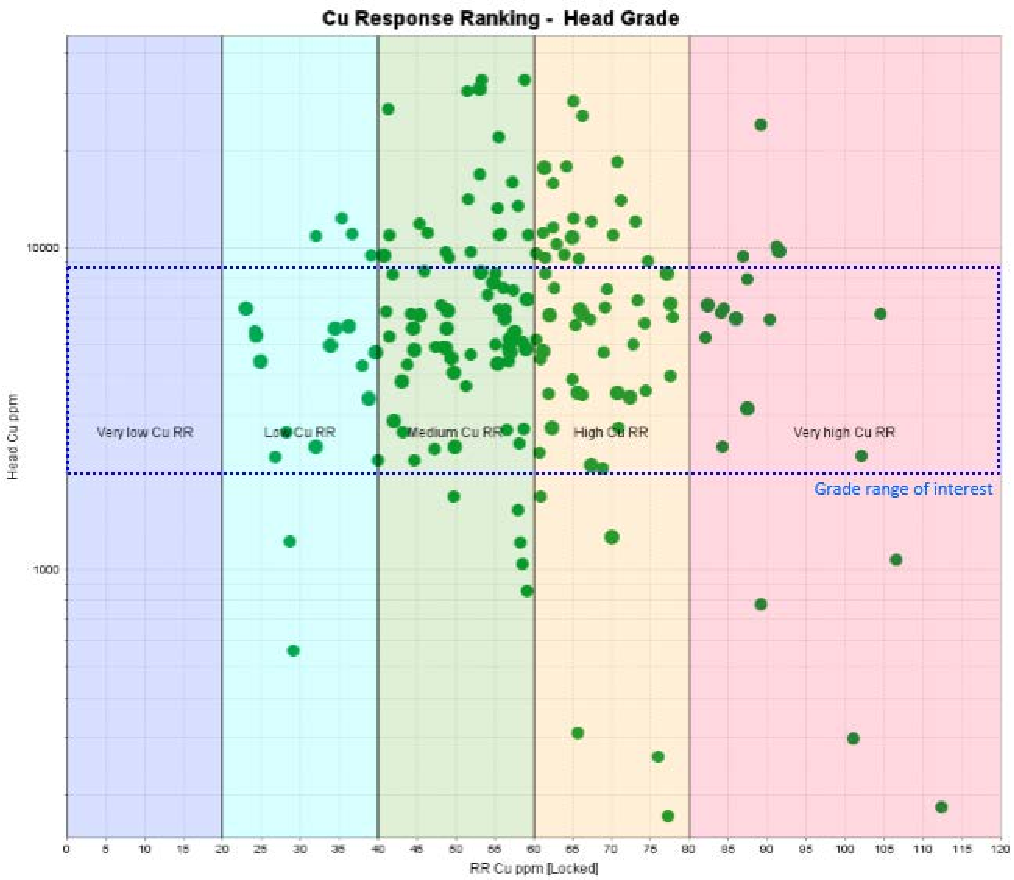


Figure 7 – Example of head grade versus RR response plot

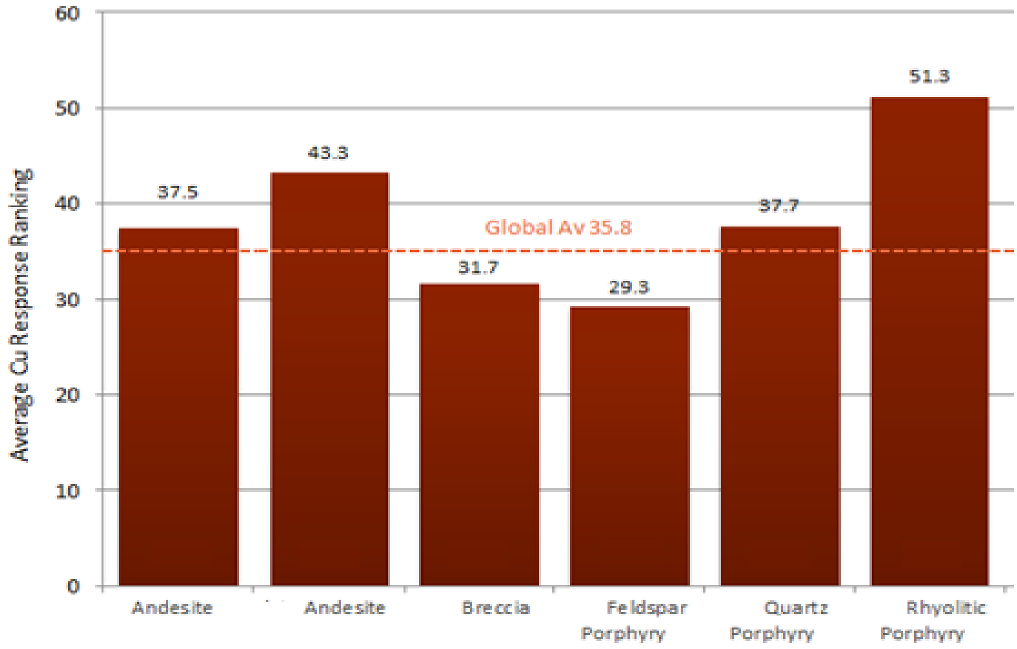


Figure 8 – Example of classification of average RR by geological category

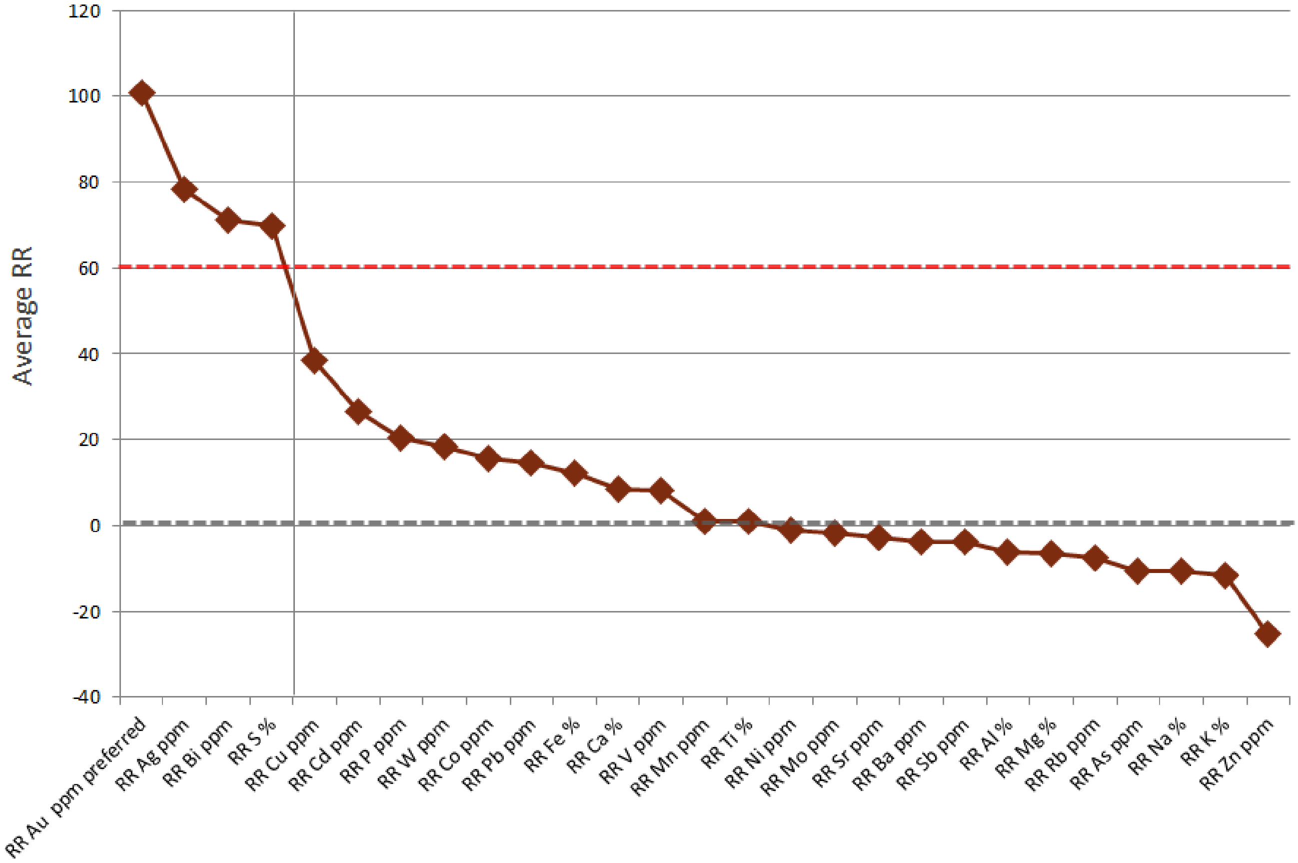


Figure 9 – Example of ranked multi-element RR's for a mesothermal Au deposit showing associations

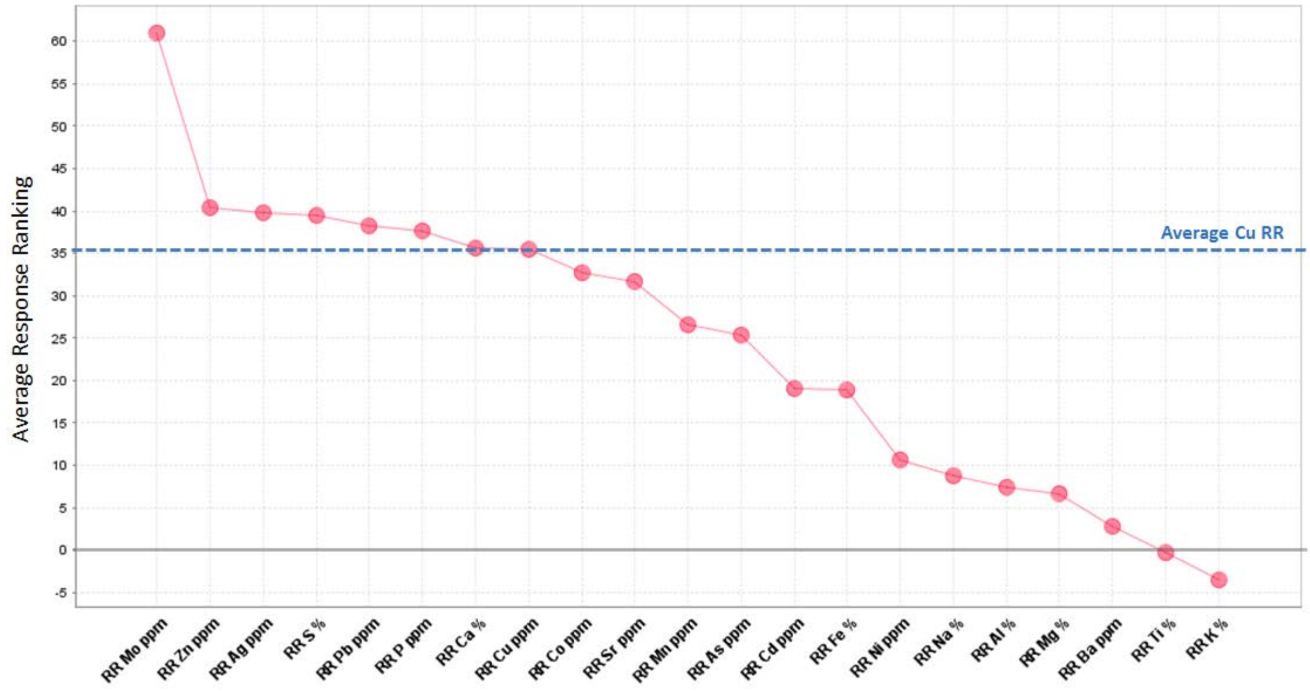


Figure 10 – Example of ranked multi-element RR's for a Cu porphyry deposit showing associations

CONCLUSIONS AND APPLICATION

The Response Ranking approach developed by CRC ORE allows grade by size data to be systematically and routinely processed and interpreted for QA/QC. This facilitates comparative ranking between deposits and definition of variability and domaining within deposits. Comparative ranking is particularly suited for testing of coarse assay residues where the residues have been generated using a constrained sample preparation and size reduction approach.

Although generating grade by size data and more recently processing and interpreting this data is relatively straightforward, systematic databases of grade by size data from drill core testing, production scale testing (e.g. belt cuts or trucks) or mill surveys, remains rare in the industry. This lack of data means that grade by size opportunity is typically overlooked on most operations stressing the importance of undertaking rapid assessment programs. CRC ORE continues to generate a significant centralized database of grade by size data across a range of deposit styles and sample types which can increasingly be used to rank and compare individual sites against a global dataset (Figure 11). Response Rankings above 60 for drill core scale testing indicate potential for grade by size to be considered as a dominant Grade Engineering value driver.

Response Rankings are mathematical functions that can be used as inputs into a range of CRC ORE modelling and simulation software to determine operational Grade Engineering scenarios and value. Response Rankings are not related to or dependent on head grade, which acts as a modifying attribute. The higher the RR the higher the potential to use grade by size and resulting screening to separate new accept and reject type feed streams. RR by itself does not indicate what mass pull gives optimum upgrade or what grade categories it should be applied to. These are dynamic operational decisions driven by RR but optimized by operational considerations and economics.

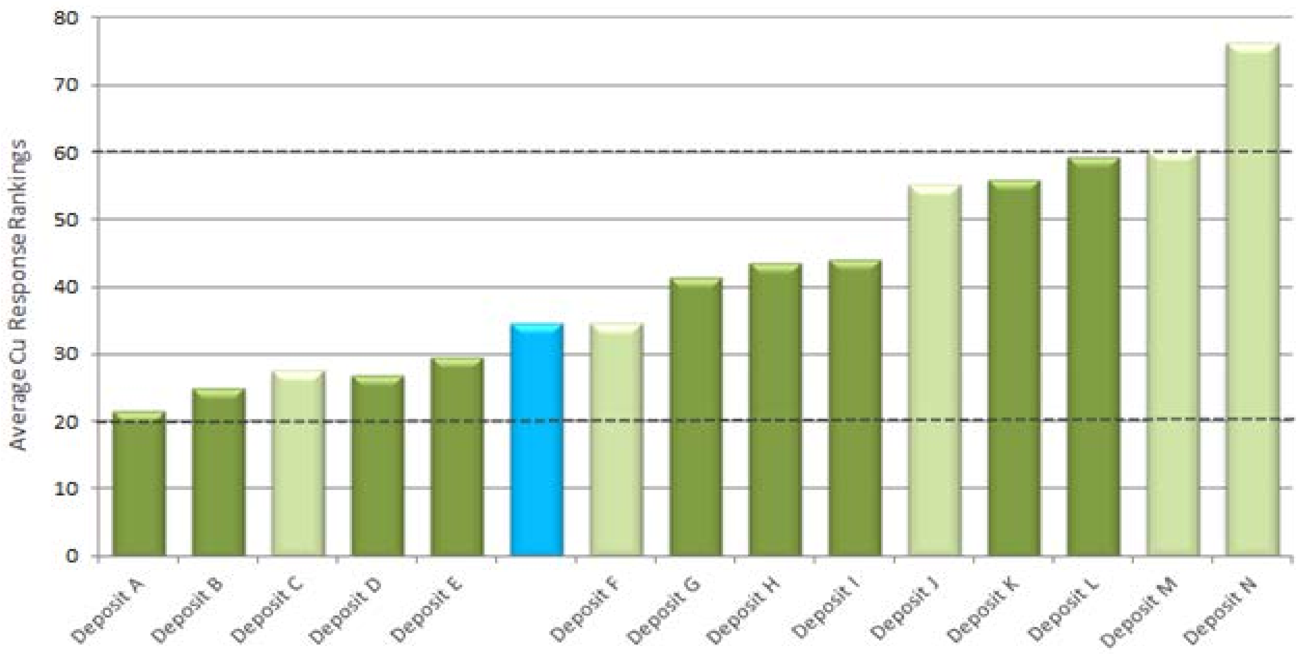
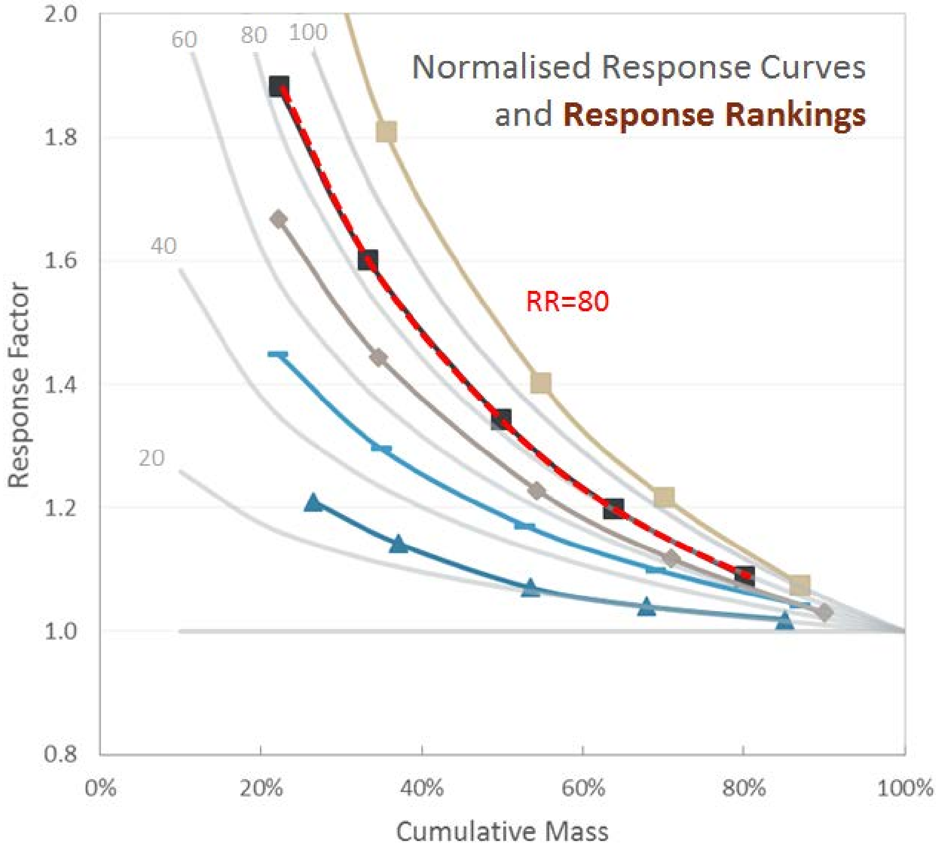


Figure 11 – Example of Cu RR response for a deposit assessment against global drill core testing database

This is illustrated in Figure 12 where a Cu Response Ranking of 80 is used to define a separation yield response curve for a specified marginal feed grade of 0.3%. The decision of what mass to use for the accept stream and the optimum accept/reject feed grades is dynamic and driven by the RR function and operational requirements. In this case a mass pull of 35% would deliver an accept upgrade of 1.7 with a new stream grade of 0.5% Cu. This would be sufficient to change the processing destination of the accept stream and to generate a definite waste stream as opposed to the marginal head grade prior to separation.

RR's are therefore crucial inputs into simulation and optimisation of dynamic separation opportunity for Grade Engineering application. While the current review and application are based on grade by size response, the same principles and ranking approach can be applied to any separation lever as part of grade Engineering Assessment.



Mass	Metal%	Upgrade	Accept Grade	Reject Grade
35	59	1.7	0.5	0.2

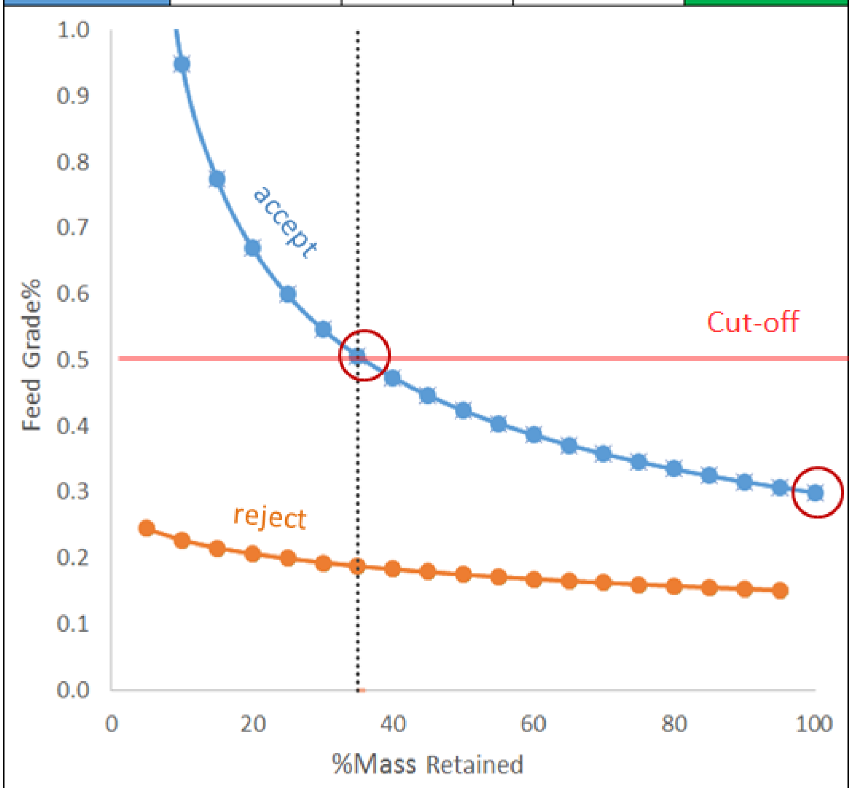


Figure 12– Example of using an RR to model a separation response for a specified feed grade