Geological Society of CIM

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SUBJECT: YOUR INQUIRIES - FAX dated December 12, 1998

Mr Merks

It took me a long while to answer your inquiries, partly because of a heavy work load, partly because the answers you request in a rather cavalier manner are, in good part, already available in texts I worked on, alone or with colleagues, as well as in other papers or publications. Your memo, as well as you letter to the Northern Miner editor in January 1999 confirm you have launched a new controversy out of one sentence taken from a letter I sent to the Northern Miner Editor last October. This letter made a balanced review of the causes of the estimation problems encountered by a number of mining projects referred to in the Northern Miner editorial and the feature article in late September, which heaped the blame on geostatistics for failures of mining projects dating back to the mid-1980s, and proposed your brand of applied statistics and analysis of variance as a panacea. I do not question its utility, but considers its application is more limited than reported. Nevertheless, I will try and respond to your queries.

Your most recent comments in the Northern Miner regarding CIM also indicate a misunderstanding of this Institute. CIM Council and CIM Executives are not a Roman Curia, with an orthodoxy to maintain, protect and impose on constituents and members. CIM must be viewed as a synergistic information broker, serving democratically its members in industry and academe, and transmitting the information, technology and practices provided by its members regrouped in the technical Societies and Divisions. Each of these constituents is supported by the specialists it regroups. As a member and current president of the Geological Society of CIM, I do my best, as proposed in our mission statement to: "*stimulate and advance the application of geoscience in the search, discovery, appraisal and exploitation of mineral deposits.*"

Responses and comments I have received from several Geological Society members following the publication of my Letter to the Editor of the Northern Miner on November 2, 1998 endorse my position. They agree that deposit and reserve estimation brings together geological and sampling/assaying information (plus engineering and economic information for reserve) and that cannot be restricted to either applied statistics and analysis of variance or geostatistics. They also agreed that the lack of "**ENOUGH DATA, OF APPROPRIATE QUALITY**" often is the main

cause of the estimation and mining problems that are too frequently encountered [these five words were capitalized and bolded in the text sent to the Northern Miner]. Geological Society members, and most geostatisticians do not object to applied statistics, including the analysis of variance. On the contrary, they view them, as I do, as a first and important step in reviewing quantitative data, in conjunction with geological interpretation and modelling. However, they do not stop there, nor make a fetish of it. The same perspective was presented by Al Sinclair and myself in the paper given at the CIM AGM in Vancouver in May 1997 and published as a Forum contribution in the July-August 1997 issue of *CIM Bulletin*, pages 76 to 79. I have presented similar views in a number of papers. Estimation is more than statistics: the projections of sampling values derived from the geological framework and applied to the sample network are essential to establish the tonnage and grade of a resource or reserve. Similarly, applied statistics encompass more than analysis of variance; for instance this domain also includes the analysis of correlation, to which the semivariogram is related.

Your question (1) refers to an example from page 286 in *Geostatistical Ore Estimation* by Michel David, where 16 points are estimated in a cell among 4 immediately surrounding drill holes and 5 more remote ones. I cannot carry out a more detailed analysis of this case for now, as I have lent my copy of David's book it to one of my daughters, who is working on a PhD in remote sensing that involves correlation of agricultural sampling data. However, I can answer from a different perspective. The strategy I have developed to deal with such cases is to require information on the measured range of the semivariogram in the plane perpendicular to the drill hole (the plane of the map), not on the semivariogram estimated in 3D from the deposit model based on the 9 holes. Maybe it is completely unrealistic to try and estimate 16 cells within each larger one, without sampling/assaying information adequate to support semivariograms in the horizontal plane? See figure 1, in "*Continuity: an Essential Element* ", in EMG, Vol 3, N° 2, p 95-108, which illustrates this problem with semivariograms in three directions at Princeton Mine. In practice, both geostatisticians and geologists too often carry out estimations in 3D with data from widely spaced drill holes that only allow for actual correlation in 1D (along the hole axis, with sparse sampling coverage and little or no quantification of continuity in the other two dimensions. Of course, this criticism would also apply to the traditional estimation methods, with or without the use of applied statistics and analysis of variance. I have first referred to this problem in 1986 (in the *Ore Reserve Estimation: Methods, Models and Reality* Symposium) and repeatedly since 1993, notably in papers with Al Sinclair, in relation to the appropriateness of estimations carried out with such incomplete data

The answer to your question (2) is contained in the summary of the Armstrong and Champigny text. Both the kriging variance and the correlation with actual results drop off whenever the sample spacing is much larger than the semivariogram range. In their words, "*For a semivariogram range less than half the sample spacing, the kriged block estimates were found to be uncorrelated with the actual grade* " This is the problem I was referring to, in the letter to the Northern Miner, when I wrote: "*The basic estimation problem lies with the frequent lack of belief in the need for* ***"ENOUGH DATA, OF APPROPRIATE QUALITY.***

Your question n° 3, is "what happened to degrees of freedom in geostatistics". The quotations from geostatisticians you have provided carry their answers based on their understanding of geostatistics and geology. It is obvious you disagree with the opinion degrees of freedom are not significant. As I am neither a geostatistician nor a statistician, I will stand with the advice I received many years ago from a consulting statistician (not a geostatistician) regarding degrees of freedom. He told me this notion should be used very cautiously in deposit estimation, because deposit sampling strategies are of the stratified type and because the influence of samples or sample groups

(intersections) is weighted based upon geological and volume considerations. He saw this situation as being quite different from the sampling of bulk crushed or granular materials.

As a mining geologist, I prefer to look at problems as they occur in the field or the mine and work my way from there, based upon geological, statistical and geostatistical considerations. Too often, the basic estimation problem lies with the **quantity**, **quality** and **distribution** of the data available. Geologists (as well as geostatisticians) have to exercise more rigorously their responsibility regarding the appropriateness of sampling grids for deposit and reserve estimation. They have to ensure quantitative verification of continuity (and semivariogram range) in the second and the third dimension, perpendicular to the drill hole directions, as Journel and Huijbregts recommended in *Mining Geostatistics* (1978). When geologists do so, geostatisticians will have enough data to support geostatistical estimation methods which are appropriately related to the sampling geometry.

The development of geostatistical estimation methods has been affected by the same problem as other estimation aspects: insufficient concerns for quality control, except for occasional comments like that of Journel and Huijbregts (ibid.), the chapter on sample preparation and gold assaying in David's "*Geostatistical Ore Reserve Estimation*", suggestions and case studies by Sides, and other instances including your comments and mine. In most cases, the sampling grids that were used for traditional estimation methods were mostly accepted, gaps, warts and all, as appropriate for the implementation of geostatistics.

In the mining geology perspective, each and every field of science and technology, geology, applied statistics, sampling, assaying, statistics, geostatistics, etc. should be used and judged according to its contribution to estimation methods and mineral development objectives. Geology supplies the framework and the unifying tread, but needs support from the others. The use of every tool should be integrated into the geological system, focussed on the appraisal, feasibility and production objectives, and submitted to careful and systematic quality control procedures. In the broader mining system, similar integration is required between geology, engineering and economics appraisal practices.

You can see from these comments that I am far from being an uncritical user or admirer of geostatistics. We both have criticized geostatistics, you from a theoretical standpoint, myself from a practical perspective, using different methods. Time will tell which strategy is the more effective one.

Yours truly,

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