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CORRESPONDENCE

COMPUTER BASED MODELLING AND GEOSTATISTICAL METHODS IN MINERAL EXPLORATION

We read with interest the article by A.K. Talapatra et al. (*JGSI*, v.57, pp.231-237) entitled "A scheme of Computer Based Mineral Deposit Modelling and Resource Evaluation of Precambrian Terrains". The author opined that at times continuous exposures of fresh *in situ* rock are generally very difficult to find. Therefore it is equally very difficult to draw inference on the occurrence of ore deposits. It is also possible that the likely occurrences of concealed ore deposits do not show any surface signatures of mineralisation. In such conditions non-conventional methods of exploration based on multivariate statistical analysis may be of help in establishing the characteristic interrelationships between various geological, geochemical and geophysical parameters to enable prediction of new exploration targets at low cost. Certainly, Geographic Information System is an useful tool facilitating integration of input data layers to generate thematic maps of different mineralized belts. However, the author should have forced his arguments by quoting real examples.

This paper attracted criticism by Mr. J.V. Subbaraman (*JGSI*, v.57, p.84). Mr. Subbaraman in a sweeping remark dismissed the applicability/utility of computer based modelling/geostatistical techniques in ore body assessment and prediction. In Mr. Subbaraman's opinion any study conducted in isolation of geological inputs *viz.*, lithology, structure, variation of grades is bound to be sterile.

It is common knowledge that when we are applying some techniques to mineral resource assessment/orebody modelling, we should also consider the geology of the area. This does not mean that geology alone is the panacea for all problems. An integrated approach involving a study of geology of the area, pattern recognition/geostatistical techniques is worth trying. In support of his apathy for the applications of these types of techniques, Mr. Subbaraman

quotes his experience in BGML. One would have appreciated, if he had given the full facts of the study.

A study was taken up to explore the possibility of identifying a few gap areas in the Champion Lode System of Kolar Gold Fields where there was no stoping, while the immediate adjoining areas had. The question arose whether the Britishers who were in charge of this company for a considerable length of time, did not bother to mine these 'gap areas' because these areas were not giving reasonable grade at that time, which would become economical now.

It is in this context a study team comprising three groups drawn from different institutions was constituted. **Group I** comprised the late Prof. A.K. Saha, S.V.L.N. Rao – distinguished Professors of Geology, Shri Sanker Sen an experienced Mining Geologist drawn from Hindustan Copper Limited and Shri B.K. Dhruva Rao, yet another noted Exploration geologist who worked with MECL for a number of years and later joined the BGML, as their Chief Mining Geologist. **Group II** was headed by Dr. D.D. Sarma, Scientist (NGRI) and **Group III** was headed by Dr. A. Ghosal, Scientist and Joint Advisor from CSIR. At every stage, geological inputs were available. The teams used to meet frequently and gave presentations before the management on the results. Mr. Subbaraman was the Convenor of these meetings.

The research findings were supported by visits to sites wherever possible and taking into account the lithology, structure etc. The gap areas at times, were devoid of assay values for large stretches of strike length. Let us look at the table below produced by Subbaraman. The results were applicable to gap areas occurring between levels 26th - 48th (i.e., levels 2500 to 4800 ft depth).

Method used	Predicted grade
Population statistics	>60 in-dwt
Semi-Variogram	High nugget effect with poor values
Polynominal Trend Surface	>60 in-dwt in 50% of the area
Harmonic Trend Analysis	>70 in-dwt in most of the area
Neighbourhood simulation	100-320 in-dwt
Markov Chain Analysis	Partly prospective up to 100 in-dwt

The following points need to be noted:

Population Statistics = 60 in-dwts. An accumulation of 60 in-dwts at 48" stoping width gives a grade of slightly more than 1 dwt (1 dwt = 1.55517 g/t of ore)

Semi-variogram has high nugget effect: This means that there is high variation in the accumulation. Mr. Subbaraman seems to have not understood this concept properly.

Markovian Model Analysis suggested partly prospective up to 100 inch-dwts. It may be noted from above that no certainty was indicated. The above may be read in conjunction with the results given in the following table (Unpublished technical report submitted to BGML by Group II).

Blockwise Statistics: Test Area II

Table below shows the zones of influence when block-wise data were processed by the application of Markovian model approach.

Favourable Rows in the gap area	Depth (ft)	Favourable area (strike length)	Likely acccumulation (Inch-dwt)
9	1120-1215	18300-18500	75
10	1215-1310	17900-18400	75
11	1310-1405	16900-17900	60
12	1405-1500	17100-17800	75
13	1500-1595	16200-17300	75
14	1595-1690	16400-17000	60
15	1690-1785	15800-16100	75
16	1785-1880	16500-17200	60
17	1880-1975	15800-17400	75
18	1975-2070	15800-17600	60
28	2925-3020	16100-16800	60
29	3020-3115	15800-16600	60
32	3305-3400	15800-16200	60
33	3400-3495	15800-16200	60
34	3495-3590	15800-16400	60
35	3590-3685	15800-16300	60
37	3780-3875	15800-16100	60
38	3875-3970	15800-16100	60
39	3780-3875	19100-19600	120
41	4065-4160	19100-19300	120
42	4160-4255	19100-19300	120
46	4540-4635	19100-19200	120
55	5395-5490	19100-20000	120

The following inferences could be drawn. In most of these cases, the predicted accumulation was 60-75 inch-dwt and the probability of meeting success was only 0.5. *In other words there was 50% chance of not meeting the expected accumulation.* Just as one should have consideration for lithology, structure, etc., and a study without these would be sterile, any sweeping remark without understanding the facts and the concepts of probability and statistics would be unfair. Due consideration was given to lithology etc., by the eminent geologists of the study team(s). The other point

worth mentioning is when the lodes were drilled for testing, it would have been worth while if the study teams were also consulted prior to drilling. As per Mr. Subbaraman, out of the nine holes suggested four holes were drilled and these could not meet with success. What about the remaining five? In this context, we draw the attention of Mr. Subbaraman to the fact that this is a situation where Gambler's Ruin model is applicable. One has to try and try.

It is worth clarifying that when one makes a statement that there are fifty percent chances of finding ore or accumulation around say 60 inch-dwts, there are also 50% chances of not meeting this requirement. The risk is high. Even if we say that the chances of finding ore of accumulation of say, 60 inch-dwts is 95%, still there are 5% chances of not meeting this requirement. Further, the inference one draws is a direct function of the quality of data that is available. A proper appreciation and understanding of the utility and limitations of various techniques employed is therefore of utmost importance.

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A.K. Talapatra's response:

The undersigned has gone through the correspondence made by Shri J.V. Subbaraman (*JGSI*, v.58, p.84) narrating the BGML experience about computer based mineral deposit modelling in Kolar gold mines with reference to the paper under discussion (*JGSI*, v.57, pp.231-237). Since the publication of this paper, a number of letters of appreciation have been received by the undersigned along with the comments of Drs. D.D. Sarma and A. Ghosal. These definitely indicate the interest evoked by the scheme suggested in the paper for computer based mineral deposit modelling and resource evaluation.

In this context it may be mentioned here that Shri Subbaraman was subsequently convinced (*Personal Communication*, July, 2001) and agreed that the geological and related inputs were used in the three different mineralized belts of India studies (*vide* Talapatra and Mukhopadhyay, 1993) and that the identification of some new areas/cells as potential areas in these belts is acceptable. However, the work was initiated by the undersigned and his colleagues in 80's of last century and due to frequent change of assignments in GSI, further study of these potential areas could not be taken up to generate a complete case history as suggested. It was, of course, mentioned in p.235 of the paper under discussion that a few such areas have actually shown some ore potential as revealed by the subsequent work of GSI and other areas are to be tested by the future workers to arrive at the logical conclusion.

As regards the comments of Drs. Sarma and Ghosal, I must congratulate them for realizing the main theme of the paper which outlines a broad scheme of computer based mineral deposit modelling. Real life case histories with GIS applications in this line are definitely expected from the new generation of workers in future and the undersigned is very much hopeful about this. With reference to 'BGML experience on Mineral Deposit Modelling' the full facts of the study carried out by the Expert Groups for ore body assessment and prediction along a few gap areas in the Champion Lode System of Kolar Gold mines have not been outlined neither by Shri Subbaraman nor by Drs. Sarma and Ghosal in their discussions. They have not even cited any published reference on this work. As such the research findings of the Expert Groups are not clear to the readers. It would have been better if a short account of the test areas of the mine blocks studies with a location map was given in the discussion along with a short note on the nature of data used and results of statistical analysis carried out. It is, however, true that prediction made from such statistical studies cannot be 100% correct, nor can this be ruled out by the failure of sub-surface exploration done by scout drilling. Quality and quantity of available multi-disciplinary data analysed during the study will definitely influence the logical conclusion derived. Further application of such computer based modelling along the different known mineralized belts and their extension areas is expected to refine the technique for ore body assessment and prediction to a great extent.

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J.V. Subbaraman's response to Sarma and Ghosal:

At the outset I wish to express my apologies to Sarma and Ghosal if my conclusion "any geostatistical and computer modelling of ore body carried out in total isolation of basic geological inputs is bound to be sterile" has hurt their feelings. I want to assure these two scientists that the BGML appreciated their contribution to the success of the project, as it was the first ever S/T project attempted by eminent geologists and scientists connected with gold exploration. This was also a new experience for

BGML geologists like me, Dhruva Rao and others. The three teams headed by (1) A.K. Saha, S.V.L.N. Rao and Shankar Sen; (2) D.D. Sarma and (3) A. Ghosal were supplied with only one input i.e. the width of the ore body in inches and the grade of the ore body in Penny weights (dwt) at 10 feet intervals along the strike and 100 feet intervals along depth. No other underground geological data was available with BGML because BGML never employed any geologists right from 1884 to 1977. The three teams synthesised the data into panels of 100' x 100' and applied various geostatistical methods to understand the behaviour of Champion Lode. The gap areas selected by the three teams are not really barren of gold but represented either poorly mineralized zones or narrow ore body which could not be stoped economically. Sarma and Ghosal being non-geoscientists perhaps have not fully appreciated the utility and dimensions of various geological inputs. But A.K. Saha and others were noted geoscientists and probably ignored some of the geological inputs as these were not available in BGML. In my opinion, this is the single factor which diluted the findings of the three teams.

During 1984-86 under a UNDP assisted programme several international specialists in geology, mining geology, structural geology, geochemistry, geostatistics, ore dressing etc. visited BGML and studied mine workings and mine data. Even these experts could not give any advise on the possibility of finding any new ore body. Dr. R.W. Boyle, an authority on the geochemistry of gold deposits remarked in a lighter mood "Gold is there where you find it". It can be taken either as a joke or seriously.

Dhruva Rao and Subbaraman of BGML presented a paper entitled "Computer Applications and Mathematical Modelling for locating possible undiscovered ore bodies in Kolar Gold Mines" at the UN Interregional seminar on gold exploration and development held in February 1985 at Bangalore. This paper described in detail the work carried out by the three teams together with graphs, charts and figures and concluded that "Geomathematical methods do not have much value when applied in isolation but provide a lot of extra strength when used in conjunction with geological and geochemical methods".

In the light of the above explanation, I hope Sarma and Ghosal will no longer feel that they have been let down by BGML.

I would like to share my experience with other geoscientists on the significance of geological inputs in Kolar gold mines. Although these mines have been developed for 10 km along the strike and to a maximum depth of 3.2 km, there were no resident geologists to collect and compile the geological data from more than 1000 km underground tunnels etc. It is a great loss to the science of geology because nowhere else the metavolcanic rocks have been made accessible up to 3.2 km depth by mining activity. Unfortunately this was not utilized for any scientific study. The stoping gaps in the entire Kolar Gold Mine remained an enigma as for as geology is concerned. Hence to understand the geological significance of these stoping gaps in 1979, I mapped the tunnels from 600' level to 4000' level in Mysore mine. This mapping indicated the following reasons for the gaps: (1) the grade of the ore body was very low, (2) the width of the ore body was very narrow, (3) absence of quartz vein, (4) absence of host rock (Komatiite), (5) presence of a fault zone and (6) area represented a dyke or pegmatite or champion gneiss. In the light of these findings it is possible that the gap areas tested by these three teams could represent any one of the above geological factors.

Response to A.K. Talapatra's letter:

It is true that I expressed my appreciation of his work after he indicated the use of geological, geochemical and geophysical inputs which helped him in the identification of some new areas/cells as potential areas. Talapatra's helplessness at not continuing his work any further is understandable because of frequent changes in his assignments in GSI.

In the end I wish to conclude that the BGML is now dead. The 1000 km of tunnels are submerged in water from 1600' below the surface to 106000' depth. All the scientists who were involved in this project are now retired and some are no more. It serves no purpose to prolong the discussions any further. But the fact still remains that the geological inputs are a basic necessity in any ore body modelling exercise.

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(As rightly pointed out by Shri J.V. Subbaraman further discussion/correspondence on this topic serves no purpose and hence closed - Editor)