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Stochastic Exploration

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*The portion starting with  
p. 4. may be of interest  
as it deals with  
Swinn Lake  
data.  
Babington*

In this paper I will report the results of a statistical study of data garnered during a practical geochemical effort that was sponsored by a major mining company. With apology to all computer oriented persons I wish to honestly admit at the outset that no device more esoteric than a desk calculator was used. I therefor seek to justify presentation of this paper only under the heading "operational research".

W. E. Duckworth has defined operational research as "... an attitude of mind. The attitude of mind of an enquiring scientist who is not content with accepting a system as it is, but who wants to analyse it, find out what makes it tick, see how it responds to stimuli and encourage it to evolve in the best direction." It would seem that the aim of the operations scientist, thus stated, is synonymous with the desires of any mining executive. However, there is the ever present danger in such high minded intentions that what appears to be the best direction for the large company operator may not be the best for the smaller operator, and, furthermore, that the small company cannot as a rule afford the luxury of experimental trials that pave the road to success. Slichter in 1960 made this latter point quite clear in his A.I.M.E. lecture titled "The need of a new philosophy of prospecting". In it he pointed out that the "gambler's ruin" is thru not having sufficient capital to continue playing at the favorable odds.

One reason we are meeting here in Golden is, I am sure, to convince the mining industry of the value of greater application of

computer techniques in the business of mining. And it is in this area of computer application that I would like to suggest operational caution because the computer and statistical formats are now available to the small mining company thru time sharing. From the "gambler's ruin" point of view the operational statistics that are developed for large company programs may not apply in small programs where large number theory may not be at all applicable.

Mineral exploration is the life blood of the mining industry, and the key to mineral exploration is stochastics. Whether geologists recognize the fact or not, most practical exploration programs play some sort of probabilistic game. The stochastic exploration game with which this geologist is somewhat familiar is geochemistry. I am convinced that the game should not be played the same by the big and the small.

In exploration geochemistry it is difficult to tell normal random scatter from a significant anomaly. This problem can be resolved statistically by taking sufficient samples to generate a large volume of data. A large sampling operation could be cost-prohibitive for a small exploration company, and, as we shall note, could be avoided by not resorting to computerized massive data or to large number geo-statistics.

To illustrate the contention that one successful statistical operation cannot be applied with equal success at all magnitude levels let us model the magnitude after the two, now classic, games of coin tossing and Russian roulette.

It is common knowlege that in a sufficiently large number of coin tossing trials the percentage of heads to be expected approaches ever more closely the percentage of tails. Also, the larger the number of trials the larger the disparity in the absolute number of heads and tails. Large number theory protects the equality of the

percentages but not the equality of the numbers. All tosses have an equal and independent opportunity to be a head or a tail, and, because the choice is random, there can be a string of "bad luck" or "good luck" in the early trials. If the gambler is small in bank, the first trials could ruin his bank.

Russian roulette, a game played with a six cylinder revolver and a single bullet, is also a game model of significance for the mineral explorer. If we were to allow a thousand players to play this game, each player one time only, and each using a single bullet and tumbling the cylinder before firing, we could expect a residue population near 833 or 5/6 of the original. If we had a smaller group, say five, we would have good statistical reason to expect anything from all survivors to all dead. There is no basis at all for estimating the outcome with a single player, because percentages cannot be meaningful where the game is only played once; win or lose, the game is over. The operational moral of this, if we may be permitted, is that many a small mine operator has shot himself out of the exploration game because he mimiced the big company method to achieve the big company percentage. In a small game of mineral exploration as in showdown Russian roulette the critical question is not the percentage probability of large number statistics, but the question of whether or not the gun is loaded. For the limited exploration effort the question of the probability of success in a search effort is not as critical as the question about the probability of there being any ore at all in the area under search; the basic stochastic question in the big exploration effort and the small one is not the same. In the thousand game roulette of our model we would have to know only how many guns had a particular chamber empty to calculate the expected fatalities,

whereas in the single game the same information would be useless if presented in the same way. For the single player five of the six chambers are redundant and the game is really a coin toss; either the gun is loaded or it is not.

So as not to speak entirely in parable, let us now visualize 100 mining claims of which 10 contain ore bodies worthy of locating. If the large company, A, were rich enough to explore all claims and its exploration technique were 100% affective in all instances, it would be certain of locating all 10 orebodies. If its exploration were 50% reliable it might find 5 mines. Another company, B, we will say can only investigate 10 claims which it elects from the same group of 100 with no geological bias. The probability that its ten claims has an orebody is 1/10, and if its technique is as good as A it would be half that as a probability of discovery. The percentages in both cases are the same but the probability of discovery of an orebody per unit of claim cost is at least 50 times as high for A as B, simply because A stands to discover five ore bodies for its expenditure whereas B will probably find only one.

In the summer of 1967 I was involved in a geochemical program of exploration which I am not at liberty to reveal. This sampling resulted in an impressive amount of analytical data from soil samples for a group of 72 (approximately 1500 x 1500 feet) contiguous mining claims. Although I am not at liberty to give the location I must in order to make my point state that it was difficult and expensive sampling in the Canadian bush. The average lead value in over 1000 samples was 46 ppm. and the average zinc value was 111 ppm. The values for each claim were also averaged independently and the average claim was 44 and 111 ppm. respectively for lead and zinc. The values obtained are very close to the mean indicated for typical soils according to Hawkes and Webb, and is also close to the

46 and 122 ppm value given for the same metals in average metamorphic rock by Dahlberg and Mackenzie at Pennsylvania State University.

A zinc-lead ratio was computed for each of 62 claims and the ratios obtained were studied for normality of distribution. The ratio values, with the exception of claim number 69, are normally distributed around a value between  $\frac{1}{2}$  and  $\frac{1}{3}$ , and this is in agreement with the anticipated normal lead-zinc ratio for soil and metamorphic rock. Claim 69 was abnormally high in lead for its zinc content.

When the claim averages for lead and zinc were compared with a theoretical normal distribution curve in such a way that the arithmetic average for the claim was equated to the theoretical mean for a normal distribution, a number of claims had absolute values for lead or zinc which were larger than a normal distribution would allow. Claims 25, 26, and 28 were absolutely anomalous in both lead and zinc, whereas claims 24, 39, and 41 were absolutely anomalous in zinc. The latter claims were downslope from the former and all were downslope from a known orebody and are presumed to be related to it. The strictly zinc anomaly is probably due to the greater mobility of zinc ions. Claims 14, 15, and 16 are absolutely anomalous in lead and bear no topographic relation to known orebodies but fall in an apparent structural alignment with the orebody. It is not yet known, but is certainly indicated geochemically, that another orebody may be present in this new area.

Now to the point of the argument we introduced earlier. It occurred to me often during the course of the tedious sampling effort that needless work and expense was being employed by the company to gain the degree of geochemical knowledge of the area that would be necessary for initial exploration. To test this notion I randomly sampled the data we had generated. With no more than 25 samples selected at random from the area and five samples selected randomly from each of the claims I arrived at the same information any

geochemical prospector would wish to learn as a first step - the information that claims 14, 15, 16, 24, 25, 26, and 28, and possibly 69 had chemical conditions that could not be rationalized statistically and would therefor have to be explained geologically.

I am convinced that grid sampling over large exploration targets is a big company game that will eventually prove too costly for the small operator. I am not convinced that grid sampling is required to gain the same exploration ends. I believe the same end can be accomplished by the small explorer if he avoids the trap of computer blindness and the equal trap of thinking large numbers are necessary for statistical reasoning.