amc software explanation sheet

'Goldmine', an analytical strategy game

- *Goldmine* **is a strategy game, for analytical chemists and others, that reinforces the importance of a proper consideration of the uncertainty from sampling. It demonstrates, with financial constraints, the interactions between sampling uncertainty, analytical uncertainty, and the cost effectiveness of the outcome. Although the game is based in the context of prospecting for gold, the principles illustrated apply to most applications of chemical analysis.**

- **You play** *Goldmine* **initially as a one-off exercise, but you can subsequently determine the average cost of the strategy you select, or try different strategies on the same geological situation. Each time the game is initiated, the geological context of the anomaly is different, so a different strategy may be optimal.**

- **Before you start you need to know the basic information about the area to be investigated, the likely size of a prospect, and also the costs involved in sampling, analysis, and follow-up study. Then you can formulate your initial strategy.**

- **Uncertainty from sampling is often an important contributor to the total uncertainty surrounding an analytical result, because the customer nearly always needs to base a decision on the composition of the target, rather than that of the sample taken from it.**

The scenario

You are a geochemical prospector. Your task is to locate a gold prospect in a given area for mining by taking samples of soil at various locations and analysing them for gold. Locations with anomalous (unexpectedly high) concentrations of gold are automatically "followed up", that is, drilled to see if there is truly gold at depth. Your immediate goal is to identify anomalous sites (i.e., those with unusually high analytical result for gold) that require a follow-up study to see if there is really gold there. Three or more adjacent successful follow-up sites identifies a prospect that you can sell for €k100. If your selected strategy costs less than that you have made a profit.

- You can specify the sampling pattern (see Figure 1 overleaf), the sampling density, the precision of sampling and the analytical precision that you require.
- You are charged for the costs of sampling, analysis and follow-up (details below), but the smaller the uncertainty (in this instance the precision) on each result, the greater the cost.
- If you specify too low a sampling density, there is a risk of failing to identify a prospect. If the sampling density is too high, you pay excessively for sampling, analysis and follow-up.
- You are penalised automatically for false negatives (when you fail to identify a truly anomalous site) because you spend money but fail to find a prospect.
- You are penalised also for false positives (when your result incorrectly identifies a site as anomalous for follow-up).

How to run the program

- The game is written here as a Minitab macro, so you need to have Minitab 14 installed and open. (You can download Minitab free for a trial period from the website if you haven't got it.)
- If you save the macro as goldmine.mac in a subdirectory of Minitab called macros, you can launch the game simply by typing
  %gold14
  at the Minitab prompt in the session window. If you save the macro file elsewhere (say in c:\myfiles), you launch the game by typing
  %c:\myfiles\gold14.
  (If no prompt is showing, you open the session window, and select 'Enable command language' from the Editor menu.)
- You will then be prompted to enter the parameters defining your strategy, namely sampling pattern, number of samples, sampling precision, and analytical precision. (It's probably a good idea to think about this briefly before you launch the game for the first time. Examples of sampling patterns are shown in Figure 1.)
- The initial outputs are:
  (i) a map of the area showing the sample sites and the concentrations of gold found (by a colour code);
  (ii) a list of anomalous sites, the gold concentrations found, and the result of the follow-up ('Hit = gold ore found by drilling, 'Miss' = no ore found);
  (iii) a statement of costs incurred.
- Then you have the option of getting an approximate average cost of finding a prospect using you defined strategy in similar circumstances. (You may have been lucky in the first instance by finding a prospect with a defective strategy, or unlucky by missing a prospect with a normally good strategy.)
- Finally you then have the option of repeating the game with a modified strategy. You should aim to minimise the average cost of finding a prospect.

The options and costs

- The area to be explored is about 100 km^2, and typical mineralised areas are about 1 km^2 in this type of terrain. You can choose different patterns of sampling (regular grid, stratified random, or random (examples in Figure 1)).
- The cost of taking a sample is €50 plus an extra amount that depends on the sampling precision you specify. (This cost comprises the sum of the cost of travelling between sites and the cost of working at a site.) The cost of working at a site depends on the precision required: a sampling RSD of 10% costs €50. The cost varies inversely with the square of the RSD (*i.e.*, if you want an RSD of 5%, the cost is €200).
- The analytical method can be adjusted to provide any precision within a reasonable range. The cost varies inversely with the square of the RSD. An analysis with an RSD of 10% costs €50.
- Each apparently anomalous site is automatically followed up at a cost of €10,000, but the cost of following up a group of close anomalies is limited to €30,000.

Some players may be relatively unfamiliar with the notion of sampling uncertainty, which is in turn largely determined by the heterogeneity of the sampling target. (In *Goldmine* the 'target' is a single site within the area to be prospected.) Because the target is heterogeneous, each sample taken by a randomised procedure within the site is different in composition. This variation in composition in a number of such samples taken from a site is characterised by the sampling standard deviation.

When a sample is analysed, an extra uncertainty caused by variations in the analytical process is incurred. Thus the total uncertainty in the composition of the target is a combination of the uncertainty from sampling and the analytical uncertainty.
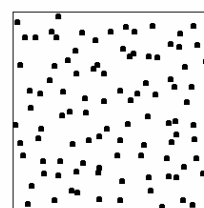
For further information on uncertainty from sampling see AMC Background Paper No. 1.
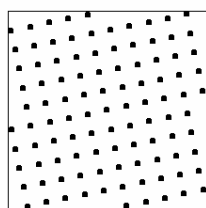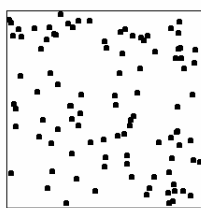
Square grid   Random   Stratified random

Figure 1. Sampling patterns available in *Goldmine*. The three examples have the same average sampling density.