

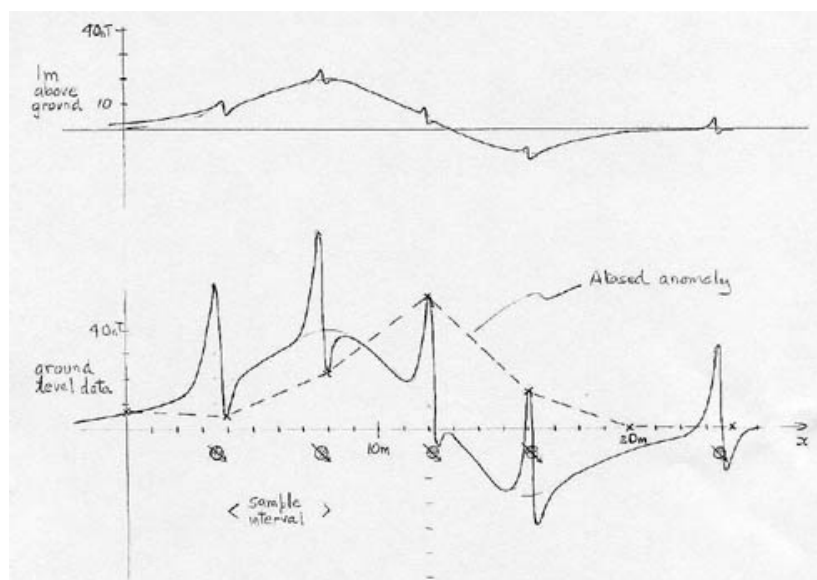
### 3.6 Magnetic surveys

- [Sampling](#)
- [Time variations](#)
- [Gradiometers](#)
- [Processing](#)

#### Sampling

Magnetic surveys can be taken along profiles or, more often, on a grid. The data for a grid is usually taken with fairly frequent sampling along parallel lines where the line spacing is greater than the sampling interval along the line. The sampling interval is the critical element of magnetic survey design. Because small features can have anomalies as big or bigger than larger deeper features the potential for aliasing is great.

The problem is illustrated in the sketch below showing the anomaly of a deep sphere with the anomalies of several shallower spheres superimposed.



If the sampling interval  $\Delta x$  is too large, as shown, the anomaly that is recorded (dashed line) is incorrect. It has been aliased. What has been recorded does not represent the true anomaly and nothing can be done to correct the mistake short of redoing the survey. Basically the anomaly must be sampled with an interval adequate to represent the shortest significant spatial variation. This can place a severe cost burden on a survey. An interval of 5 m might be perfectly adequate to map a 40 nT anomaly of a feature at a depth of 10 m or more but if the surface overburden layer is scattered with magnetite rich stones which have anomalies of 10 to 100 nT, then the whole survey has to be made with an interval of 0.5 m. Not economically reasonable.

A practical solution to this problem is to raise the magnetometer a distance  $h$  above the ground as shown in the above sketch. The amplitudes of anomalies fall off as the inverse cube of the distance. In raising the magnetometer from 1 to 2 meters from a shallow target the original anomaly, which was say 40 nT, is reduced by a factor of 8 to 5 nT. The 40 nT anomaly from a target 10 m deep is reduced in this process by only about **50 percent** or to about 20 nT. Aliasing at this height is not as much of a problem. The shallow features only contribute errors on the order of 5 nT. Raising the magnetometer another meter reduces the shallow anomalies to about 1.5 nT.

Before beginning any survey in a new area it is important to run a few short lines with a small sample interval to determine the spatial variability of the fields. Further, while surveying if sudden large changes are noted it is important to stop, back up, and resample at a closer interval if necessary.

The advantages of getting the magnetometer away from shallow magnetic anomalies is the principle reason for doing magnetic surveys from the air. Airborne magnetic surveys have become an indispensable part of

mineral exploration and geological mapping projects. Most of the U.S. and Canada have been surveyed, as well as large parts of the developing world with mineral and petroleum potential.



### Time variations

Time variations must be removed if they are comparable to the anticipated anomaly and if the duration of that part of the survey covering the anomaly is comparable to the period of the time variation to be corrected. Thus, if the survey for the anomaly of a buried steel tank is to be completed in an hour and the anticipated anomaly is of order 500 nT, the time variation expected might be on the order of 10 nT and so could be neglected. On the other hand a magnetic survey over a large area for alluvial magnetite sands under a thick cover might take all day and the anticipated anomalies might be 100 nT or less. In this case the time variations would be on the order of 30 nT and they would have to be removed.

There are two main methods used to remove time variations.

i) Return to a base station at a time interval small compared to the period of the time variation whose amplitude is to be removed. If we have to have a survey resolution of 1 nT return to a base station every 1000 seconds may be necessary. This may be reasonable since such high-resolution surveys are often on a small scale. The corrections are made in airborne surveys by periodically flying over a base station or by flying cross lines to tie a set of parallel lines to a set of fixed points.

ii) Establish a base station and record the time variations over the duration of the survey. The time varying fields are uniform, that is they don't vary laterally, over 100's of kilometers. Providing the airborne and ground magnetometers have a common accurate time base the variations at the base can simply be subtracted from the airborne readings. This is now common practice for airborne surveys and it is also used for high accuracy ground surveys. On the ground the two magnetometers can be physically connected and the difference in reading is recorded directly.



### Gradiometers

The difference scheme discussed in ii) above can be employed using two magnetometers separated by a small distance  $\Delta x$  or  $\Delta y$  in the horizontal direction or by  $\Delta z$  in the vertical direction. The difference in field,  $\Delta T$ , divided by the spacing is a measure of the derivative or gradient of the field in the spacing direction. Since the time variations are uniform they are removed in the gradient operations. In many applications the gradients are as useful as the field measurements. The gradient operator acts like a high-pass filter - it accentuates short wavelength anomalies and attenuates broad anomalies from deep targets. In this sense gradients tend to remove the regional anomalies from the survey results.



## Processing

After removing the time variations, magnetic data is usually plotted on a 2D map and contoured. Once in this format a number of transformations are possible which enhance certain features in the data. The transformations are made using a mathematical property of potential fields that allows 2D maps of any component of a field to be transformed into maps of the same component at a different elevation (upward or downward continuation) or into maps of another component, or into maps of the gradient of any component.

Yet another transformation permits the conversion of a map taken at a given magnetic latitude into a map of what would have been seen if the data were taken in a vertical inducing field at the magnetic pole. This process is called reduction to the pole. We have seen that the characteristics of magnetic anomalies depend greatly on the direction of the inducing field. Reduction to the pole removes this variable from the maps, putting data taken anywhere on a common footing for interpretation.

