Magnetic mentor

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Depth interpretation part 1

Estimation of the depth to a magnetic source is an important part of magnetic data interpretation and numerous methods can be found in journal articles and geophysical books. How does a young geophysicist make a choice? In general, that decision is made for you by the selection of software available within your organisation. But, do you know if it is suitable for your application? I will attempt to answer some of these questions through illustration and discussion based on practical experience and model testing.

A useful place to start is the shape of magnetic anomalies and the segments that are important for maximum robustness. **Figure 1** is a reproduction of the method proposed by Peters (1949) and it is a useful way of explaining the parts of a magnetic anomaly that are sensitive to depth.

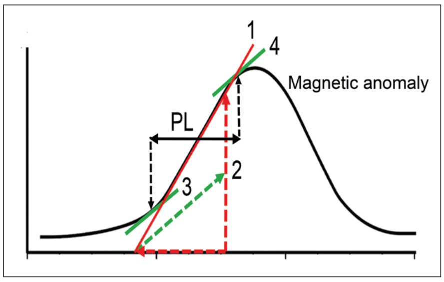

Figure 1. *Schematic illustration of the step sequence for calculating Peters' length (PL).*

The Peters' length method (PL) is easy to implement manually or by software and is performed in four simple steps:

1. Compute maximum gradient,
2. Compute the ½ slope,
3. Locate lower ½ slope point,
4. Locate upper ½ slope point.

The depth is computed simply as **PL/C** where **C** is a geological correction factor between 1.2 and 2.0 that relates to the geometry of the magnetic source. The style of geometry is directly related to the geology which must be interpreted as part of the procedure.

The curvature and shape characteristics are all included in a basic way in the PL method. Points 3 and 4 define the locations of maximum negative and positive curvature. The curvature also contains information on the location of edges. The upper half slope point (4) is the most robust location because it has the least interference from adjacent anomaly sources. The lower half slope point (3) can be subjected to high levels of interference that impacts the quality of the depth estimate. So, for now, I will stick with "Sweet Spot" anomalies where it is assumed that interference is minimal.

Importantly, the PL method uses the maximum gradient segment of the anomaly between the points of maximum curvature which is a small section of the complete anomaly. When designing inversion algorithms, it is important to understand that using the full anomaly in two dimensions will degrade the depth estimate through dilution of the depth sensitive data areas unless there is a bias in the weighting for the depth sensitive regions of the anomaly. It is for this reason that I prefer to use line data for estimation of depth and constrain it with a 3D geological model.

I am not proposing that you use the PL method, but it is a useful tool for highlighting the segments relevant to depth estimation.

Magnetic geology

When I talk about geology for depth interpretation there are some important considerations:

- Unconformity truncation surface,
- Fault truncation,
- Truncation shape.

Rock properties are not directly part of this list, but they may help infer the geological association. For depth interpretation, the shape characteristics of a magnetic anomaly carry the depth information, are scalable and independent of the rock properties.

In **Figure 2**, I have used Gemini AI to create some schematic perspective views to illustrate magnetic lithologies in a range of geological scenarios. In **Figure 2(a, b)** there are steeply dipping formations with some exhibiting anomalous magnetic properties (red) typical of strongly folded geological domains. **Figure 2(c)** has sub-vertical dykes (blue) and an intrusive basic pipe (blue). In the case of the dykes and the magnetic formations, the truncation surfaces create the dominant components of the magnetic anomaly (*Magnetic mentor* October 2025). **Figure 2d** is a sub-vertical edge of a granite which locally will be equivalent to what is called an edge. The magnetic anomaly will drop off more slowly than it does for a dyke or folded formation.

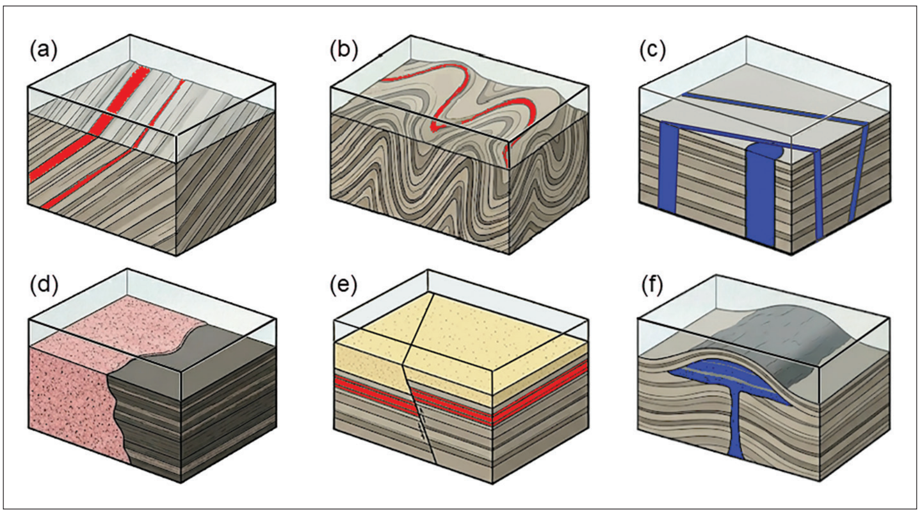

Figure 2. *Schematic illustrations of contrasting geological sections discussed in the text where red, pink and blue colours highlight magnetic rock units.*

Figures 2(e, f) are more challenging scenarios where knowledge of the geological source becomes very important. The reverse fault example has a horizontal magnetic formation that could be an intrusive sill offset on the upthrown side. Both the left and right edges will produce anomalies that interfere with each other, and separation of the two contributions is likely to be difficult. If the sills are not remanently magnetised, you should be able to determine which side is upthrown. **Figure 2 (f)** shows a laccolith (blue) intruding a non-magnetic sedimentary sequence with thickness decreasing on either side. There is no unique depth solution in this case without hard constraints. The depth quality estimates in these cases will be very poor.

There are many other cases to consider, such as intrusion with elongate elliptic shapes where the semi-linear anomalies will approximate the linear formation anomaly near the centre of the intrusion. An important targeting concept in Australia is the IOCG-style deposit which may approximate an ellipsoid. Unless the ellipsoid has been truncated by an unconformity, I am limited to estimating the depth to the effective centre of magnetisation which can be significantly deeper than its upper extent.

Models and geology

When testing the geological characteristics of the magnetic source rocks responsible for a magnetic anomaly, I need simple shapes to rapidly approximate the geology beneath the survey lines. If I am exploring under cover, then I want to estimate depth, boundary locations, dip and magnetic properties. Multiple simple shapes are added to adjacent lines to build more complex models along strike. **Figure 3** shows examples of the anomalous magnetic intensity (AMI) and first vertical derivative (1VD) for five simple shapes. The models have been computed using a southern hemisphere inclination of -60 degrees and declination of 0 degrees along separate north-south profiles.

The tabular body shape **(Fig. 3(a))** is very useful for a wide range of fast modelling and interpretation problems. It is fast to compute and easy to modify the geometry for depth, width, strike length, azimuth and dip. It is well suited to modelling profiles across magnetic formations **(Figures 2(a, b, c))**. The circular and elliptic pipe shapes **(Fig. 3(b))** are suitable for simulation of intrusive pipes and larger plutons.

Figure 3(c) is also a tabular body that could represent a laterally truncated section of an intrusive sill or a drainage system filled with maghaemite. The oblate ellipsoid is a better model to use when the sill thins laterally, but it is difficult to achieve reliable depth estimates in this situation. **Figure 3(d)** shows a wide tabular body to simulate the edge of a large magnetic formation such as a granite **(Fig. 2(d))**. **Figure 3(e)** show a sphere which is a specific subset of the general ellipsoid model class. It is also equivalent to the very simple dipole model of a point source. The challenging case of the faulted horizontal magnetic formations in **Figure 2(e)** can also be modelled using two dipping tabular bodies with finite depth extent.

For more complex models, the polygon is very useful for building cross-sections of sills or irregular upper surfaces. It is also used in mapping irregular boundaries of large intrusions. In the next *Magnetic mentor* article I will discuss some of the operational aspects of depth interpretation and the question of automating geological model detection.

Summary

- The importance of using line data and understanding the components of an anomaly that contribute to recovering depth.
- Reliable depths require geological shape constraints.
- Some geological models are not suitable for depth estimation.
- Interpreting the geology is an integral part of defensible depth estimation.

See the Magnetic Mentor series link to download data and related information for this and previous editions.

Reference

Peters L.J. 1949. The direct approach to magnetic interpretation and its practical application, *Geophysics* 14: 290–320

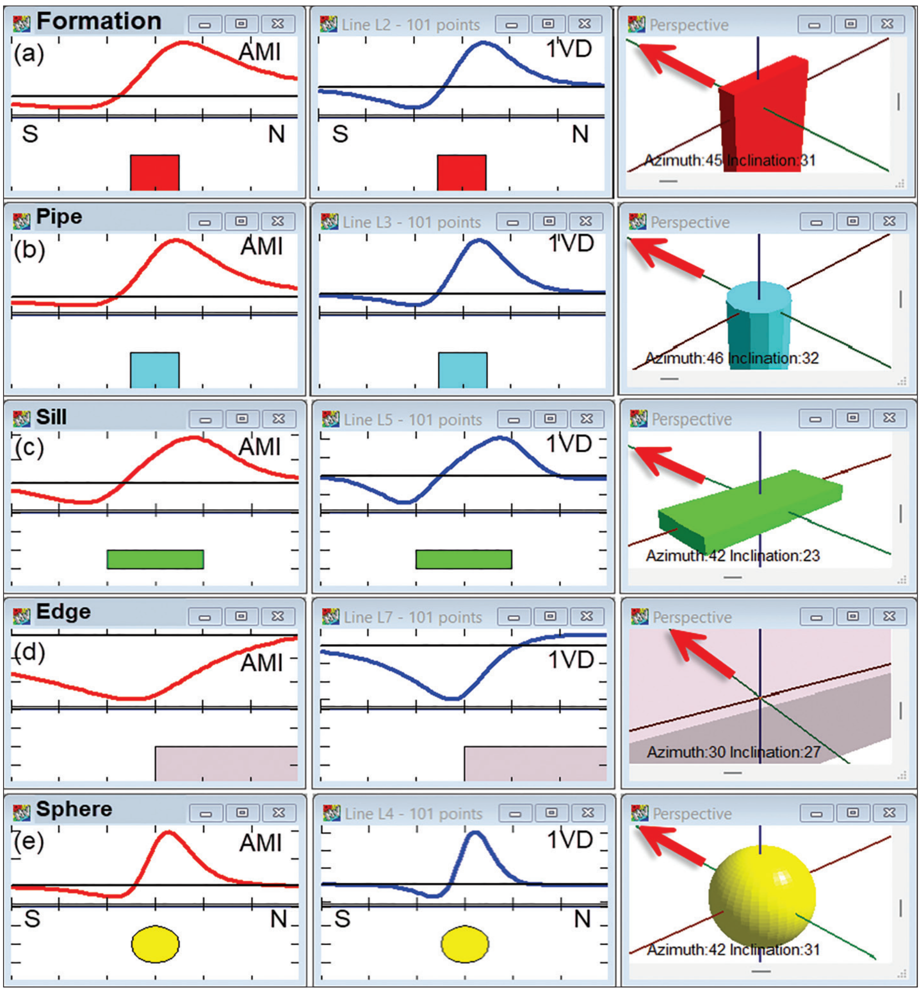

Figure 3. *Five models at 100 m depth showing cross-sections, computed anomalous magnetic intensity and first vertical derivatives along with 3D perspective body views.*