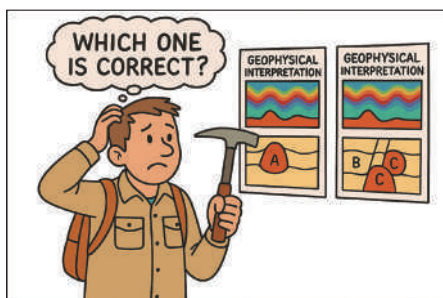


## Magnetic mentor

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### Non-uniqueness, equivalence and applied geology

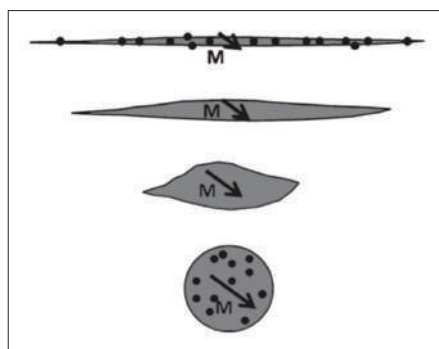
The widespread use of magnetic inversion technology makes it easy to forget that for every magnetic anomaly there is an infinite number of possible geological solutions. This is an *inconvenient truth* that is often overlooked, but essential to communication with non-geophysicists. To avoid expensive mistakes with subsequent decision making, we need *defensible interpretations*. We are applied geophysicists, and I will show you how the application of basic geological principles puts you back in control. I focus on the magnetic method, but much of what I will discuss is also applicable to gravity data.

### Equivalent source concept

The concept of equivalent sources is well published and based on sound mathematical theory (Dampney 1969, Blakely 1996 and Clark 2014). Kit Dampney's groundbreaking publication demonstrated that a model created beneath the original survey could be used to compute the response at different levels above the original survey. While his publication was for gravity, it is equally applicable to a layer of magnetic sources. The theory forms the foundation of modern FFT transformation such as upward continuation, reduction to pole and susceptibility estimation. Blakely (1996) provides an excellent resource that covers the underlying theory and Fortran source code for many of the

transformations. It is also a good start to explain the non-unique character of magnetic and gravity anomalies.

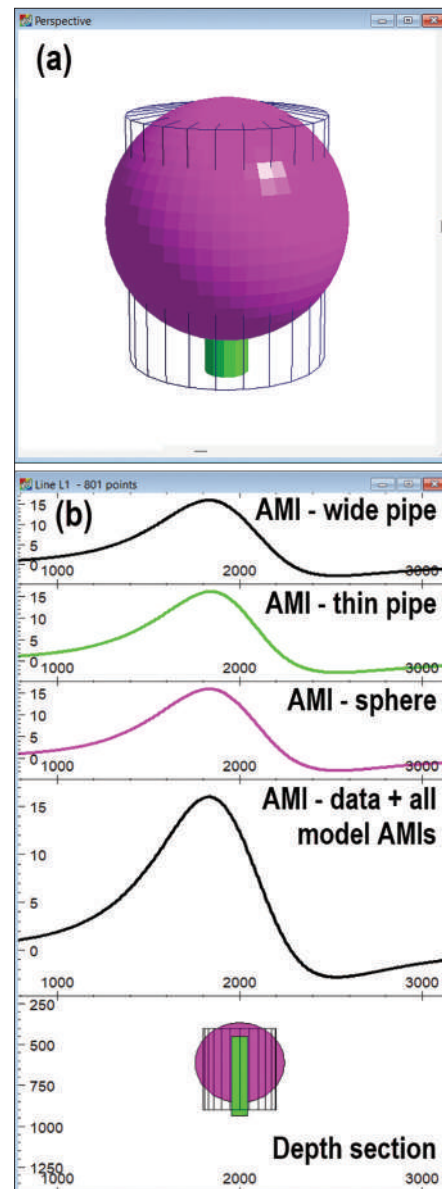
So, any model that satisfies the data is an equivalent source. Dave Clark has used **Figure 1** as a schematic illustration of the equivalence between a series of lenses and a sphere, positioned at different depths.



**Figure 1.** Schematic illustration of equivalent lenses at different depths. (from Clark 2014).

### Non-uniqueness

The equivalent source concept gives you a way of describing the non-unique nature of any model that satisfies the measured data. In my February 2026 review of the CSIRO publication *Exploration Magnetics*, I created a [short video](#) demonstrating how an inversion gave three different results for the same magnetic anomaly. **Figure 2** shows the anomalous magnetic intensity (AMI) results for the three different target geometries where each inversion achieved an RMS mismatch of better than 0.5%. Each inversion started with a different assumption. The non-uniqueness occurs when we have no constraints to apply. In the case of the vertical pipe, if the width/depth ratio is less than 1.0, we cannot resolve the width, and the shape of the magnetic anomaly cannot be distinguished easily from a sphere. As the pipe diameter increases, we start to see the edge of the pipe in



**Figure 2.** 3D model perspective (a) and section (b) views with identical responses for a wide pipe (black lines), thin pipe (green) and sphere (magenta). Individual colour traces show the inverted responses for each coloured body shown in the cross-section. The original magnetic data and computed model output appears above the cross-section.

the magnetic response. The anomaly is caused by a compact source where the effective centre of magnetisation is at the centre of an equivalent sphere.

Geological constraints are applied by assuming the anomaly is caused by a truncated intrusive pipe (shown as the black vector outline), but why is it correct? In exploration, we typically have a background geological context. When we are exploring under cover,

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this context is normally provided by geologists. If we are mapping basement, exploring for diamond pipes or blue metal aggregate the pipe model is appropriate. Alternatively, if we are looking for IOCG style mineral deposits, the sphere or an ellipsoid is likely to be the appropriate choice. If you believe the top surface of the ellipsoid is truncated by an unconformity, then the pipe model will produce a valid depth.

Formation thickness equivalence

Extended strike length sub-vertical magnetic formations and dykes exhibit equivalence problems when the width is less than the depth. Here you compute the susceptibility-width product from an inversion. Nearby geology may allow you to infer the thickness and thereby estimate the susceptibility.

Voxel and lithology models

Figure 3 provides a comparison of direct lithology model, pure property, single layer and four-layer voxel model inversions where each achieves an RMS data match of better than 1%. The same magnetic susceptibility colour bar is used for each section. This is a clear demonstration of the non-uniqueness of magnetic data inversions. In Figure 3(a) the geological constraints are based on semi-linear formations (lithology) inferred from the magnetic map. The inversion then provides defensible estimates of depth, width, dip and magnetic susceptibility. Because the upper surface dominates the inversion, the most reliable information is near the bedrock unconformity. Figure 3(b) is a single layer of voxels that demonstrates the equivalent layer concept introduced by Dampney. In this context, susceptibilities are not very helpful for geological interpretation because the properties are diluted by neighbouring cells that are drawn into the inversion. Figure 3(c) shows four layers of voxels where the

properties of the first layer are little changed from the single layer model, but there appears to be some structure evolving in the lower three layers. The voxel inversions are performed with ModelVision using an optimised, but unweighted algorithm for susceptibility estimation. Popular large scale voxel inversions use depth weighting to compensate for the dominance of the upper model surface.

Summary

- Defensible interpretations use geological principles as soft geological constraints to reduce the range of possible solutions and derive practical information such as depth and dip.
- Lithology inversions recover dip and susceptibility data but take care with narrow formations and interference from nearby anomalies.

- The application of lithology model constraints provides compact, high-resolution results when compared with pure property voxel models.

See the [Magnetic Mentor series](#) link to download data and related information for this and previous editions.

References

Blakely, R.J. 1996. *Potential theory in gravity and magnetic applications*. Cambridge University Press.

Clark D.A. 2014. Methods for determining remanent and total magnetisations of magnetic sources – a review. *Exploration Geophysics*, 45: 271–304 <http://dx.doi.org/10.1071/EG14013>

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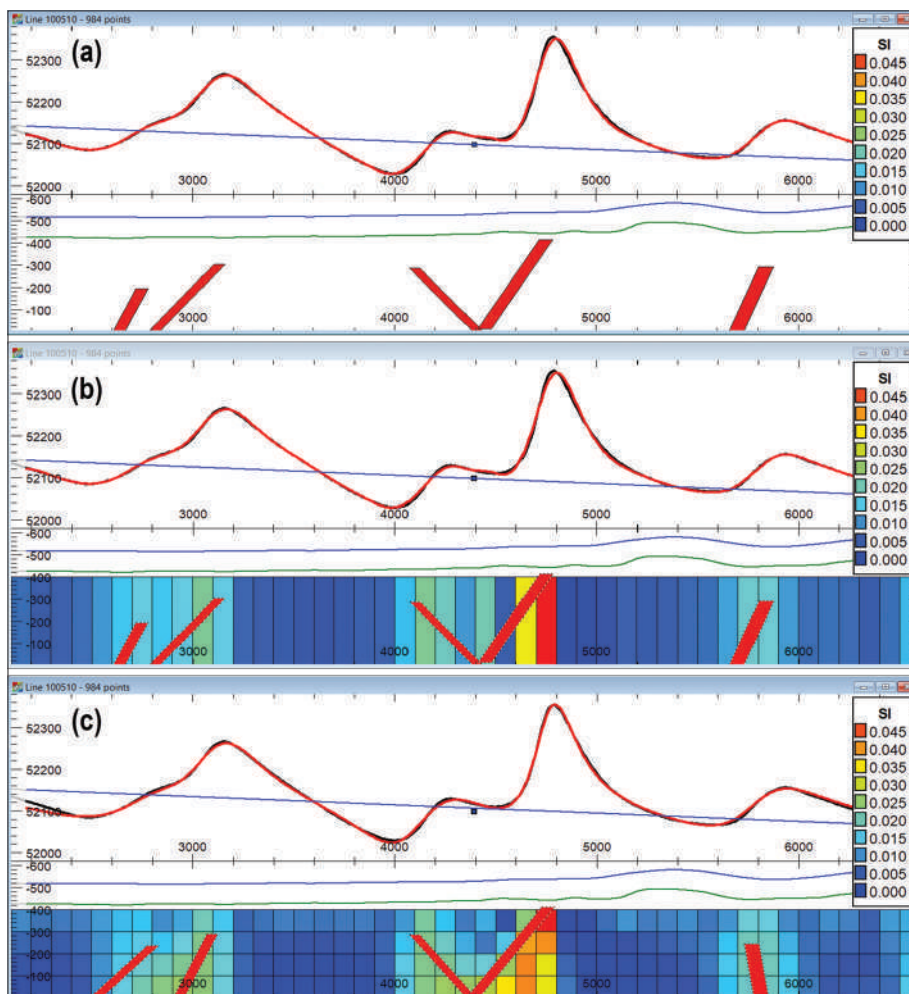


Figure 3. An example of three equivalent sources where the forward model matches the original data. (a) shows a lithology model with five dipping formations. (b) is a single layer of voxels that is equivalent to Dampney's method and (c) uses four layers to match the same data. The curve tracks show AMI (black), model (red) and regional (blue). For reference, the lithology model is overlain on the voxel models.

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