

Magnetic mentor

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Depth interpretation part 3: Interactive inversion

Interactive, parametric inversion allows you to quickly test different geological concepts that will help you decide on the most probable and defensible geological solution. I focus on survey line data from simulated surveys to demonstrate the strengths and weaknesses of inversion. For young career geophysicists, practice on what you know with a model survey, before launching into the unknown. Remember that an inversion is just one of an infinite number of possible solutions that is only defensible with geological guidance.

Prism depth inversion

Parametric models have sharp property boundaries that work well at normal survey elevations. There are many possible shapes that I use, but for depth interpretation, simple shapes such as the semi-linear formation (or dyke) elliptic pipe and edge models are a good choice. I am starting with a tabular prism, which is useful in a broad range of geological domains. You can aggregate individual prisms to build more complex geological models like those in **Figure 1**. Prism model properties include:

- Thickness (T) and distance (X,Y)
- Depth below the sensor (Z)
- Azimuth and length (fixed)
- Dip (D)
- Magnetic susceptibility (P)
- Magnetisation vector
- Depth extent (fixed)
- XPTZD (**Tables 1 and 2**).

Figure 2 shows four discrete steps in the inversion of a single line of simulated anomalous magnetic intensity (AMI) data over a simple vertical prism. Both the first vertical derivative (FVD) and (AMI) are presented above each depth section. A quick seed prism (a) is inserted manually into the section (unshaded) and the computed anomaly is offset to the north of the target. I am using a Marquardt-Levenberg algorithm for iterative non-linear least squares inversion. It works well with interactive methods where you are creating a geologically plausible starting model (**Figure 2a**).

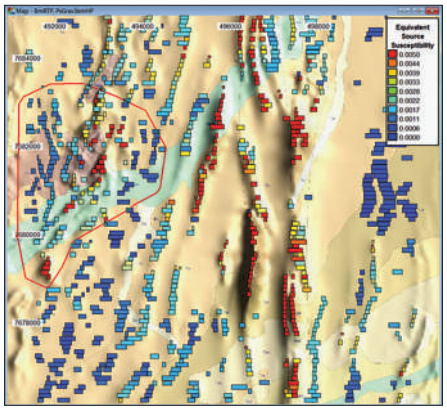


Figure 1. *A complex model example using aggregated prisms.*

You free the shape and properties interactively and it is instructive to see immediate changes in the anomaly shape and amplitude. With theoretical data, you can do the full inversion in a single pass, but you don't learn anything about the sensitivities of the parameters. I freed the distance and property parameters which correctly positioned the prism (b) and then freed thickness (c). Depth inversion (d) is last to make sure that the inversion is focussed on the best global minimum. Note the width of the FVD anomaly is much narrower than the AMI where the anomaly tails don't reach the

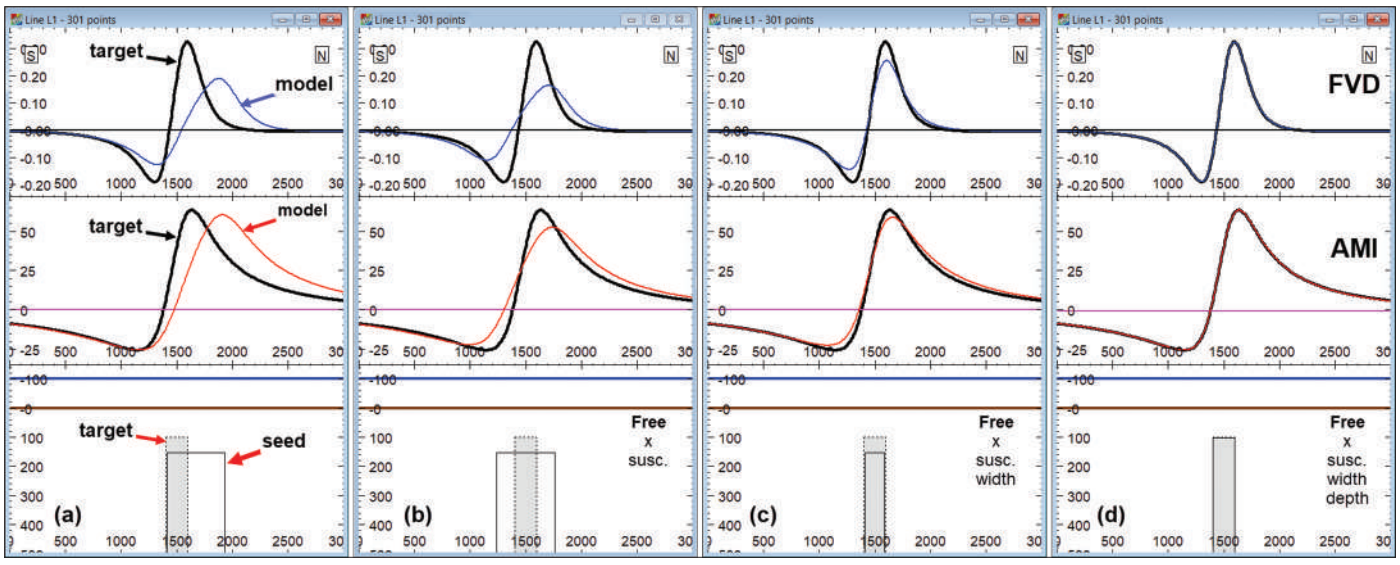


Figure 2. *An example of a vertical prism interactive inversion where each frame represents an inversion step with selected free parameters. The final inversion achieved an RMS mismatch of 0.2% and depth error of 2 m. IGRF Inc. = -60, Dec. = 0, line azimuth = 5⁰.*

background field. Importantly, you now have a defensible geological interpretation aided by inversion. **Table 1** shows the parameters at each inversion pass. Note: Zerr is the inversion depth error, and RMS is the inversion mismatch as a percentage of the anomaly range.

Depth and dip inversion

In this second example (**Figure 3**), I want to demonstrate the ability to recover dip and depth but also show that errors increase with the number of free parameters. The target model has the same apparent thickness, but the dip was changed to 150 degrees relative to north to create a symmetric AMI anomaly. The anomaly produced by the seed model (Pass 1) is clearly asymmetric and should alert you to the fact that either the dip is non-vertical or the target is remanently magnetised. In practice symmetric anomalies are rare, but differences in asymmetry are a good guide to the existence of dip or remanence.

Pass 2 allows position (X,Y) and magnetic susceptibility to change and the fit is very poor with an RMS mismatch of 17.5%. Pass 3 frees up thickness with only a minor change and RMS of 17.4%. The major improvement occurs when dip is free and the RMS mismatch immediately drops to 0.4%. However, there is now a 10 m error in the depth compared with 2 m in the vertical prism case and I have five parameters instead of four. Each free parameter adds another dimension to the search space which means it is looking for a global minimum in a five-dimensional space.

Note: in this example the sensor is at 100 m above the ground and the depth to the unconformity surface is 100 m, so the error is 5% of the depth below the sensor. Of course, from a geologist's perspective, the drilling error is 10% and that is what you will have to defend. It is possible to decrease the error by decreasing the total data area and inverting on the FVD. I will examine the use of the FVD in the next *Magnetic mentor*.

Table 1. Vertical prism case.

Pass	FREE	ZBS	ZBG	Zerr	RMS	Width	Susc.	East	North	Dip
1	OOOO	254	154	54	16.7	517	0.0054	20015	5171	90
2	XPOO	254	154	54	7.3	517	0.0047	20000	5000	90
3	XPTO	254	154	54	3.2	170	0.0134	20000	5000	90
4	XPTZ	202	102	2	0.2	198	0.0102	20000	5000	90
0	Model	200	100	0	0	200	0.01	20000	5000	90

Table 2. Dipping prism case.

Pass	FREE	ZBS	ZBG	Zerr	RMS	Width	Susc.	East	North	Dip
1	OOOO	254	154	54	43.6	517	0.003	20000	5171	90
2	XPOO	254	154	54	17.5	517	0.0021	19958	4687	90
3	XPTO	254	154	54	17.4	591	0.0021	19956	4662	90
4	XPTZD	190	90	-10	0.4	232	0.0081	19985	4998	149
0	Model	200	100	0	0	200	0.01	20000	5000	150

Summary

Interactive inversion is an important tool to assist your interpretation, but not an answer unless it is based on defensible geological constraints that may be soft (inferred) or hard from drilling or outcrop.

Use synthetic surveys to create trial models where you test your ability to recover the model and learn how to constrain your inversions.

Depth is computed relative to the magnetic sensor, so make allowances when estimating errors for depth below ground.

Go to the Magnetic Mentor series link to download data and related information.

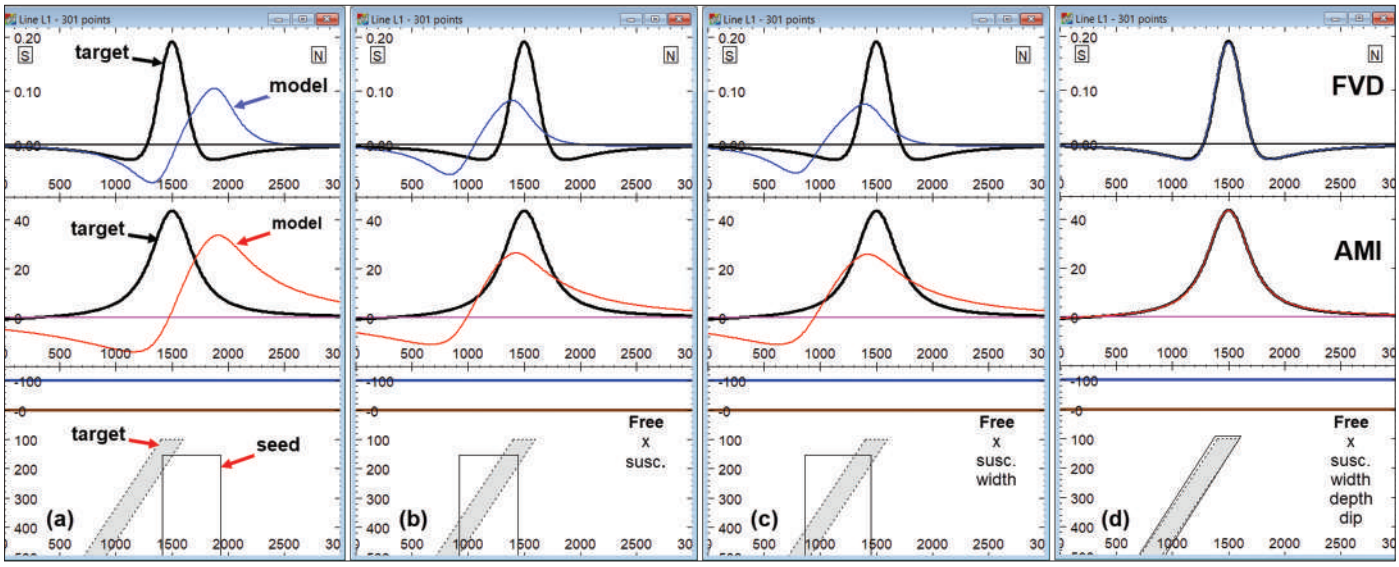


Figure 3. *An example of a dipping prism interactive inversion where each frame represents an inversion step with selected free parameters. The final inversion achieved an RMS mismatch of 0.4% and depth error of 10 m.*