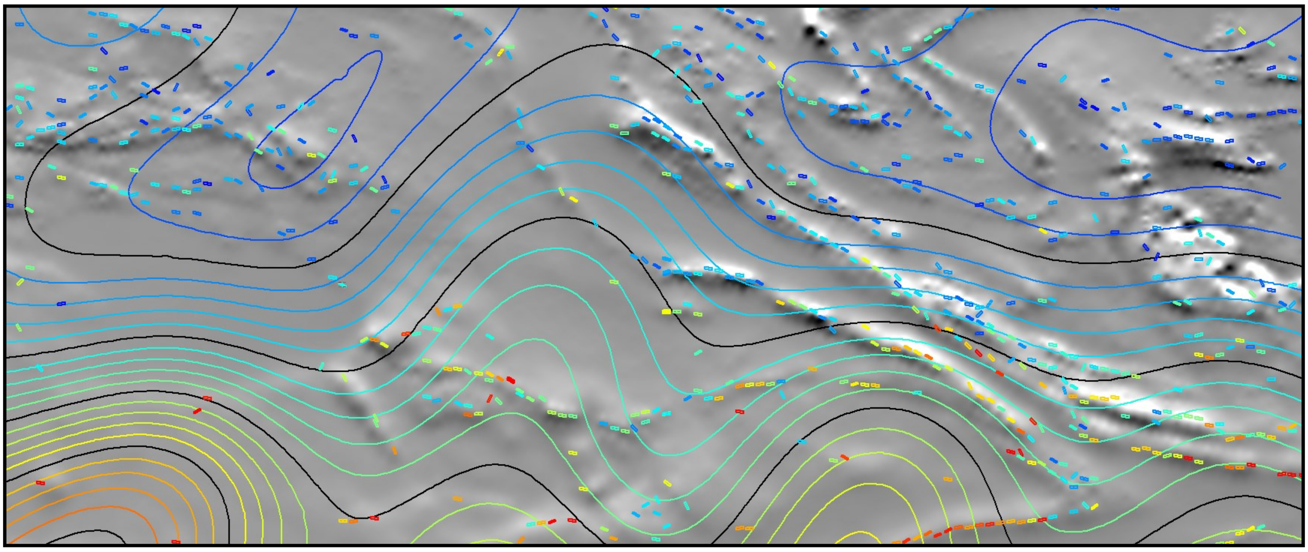
Tensor Research

Depth Interpretation

Module for ModelVision

QuickDepth AI assisted anomaly depths

AutoMag Automated depth estimation



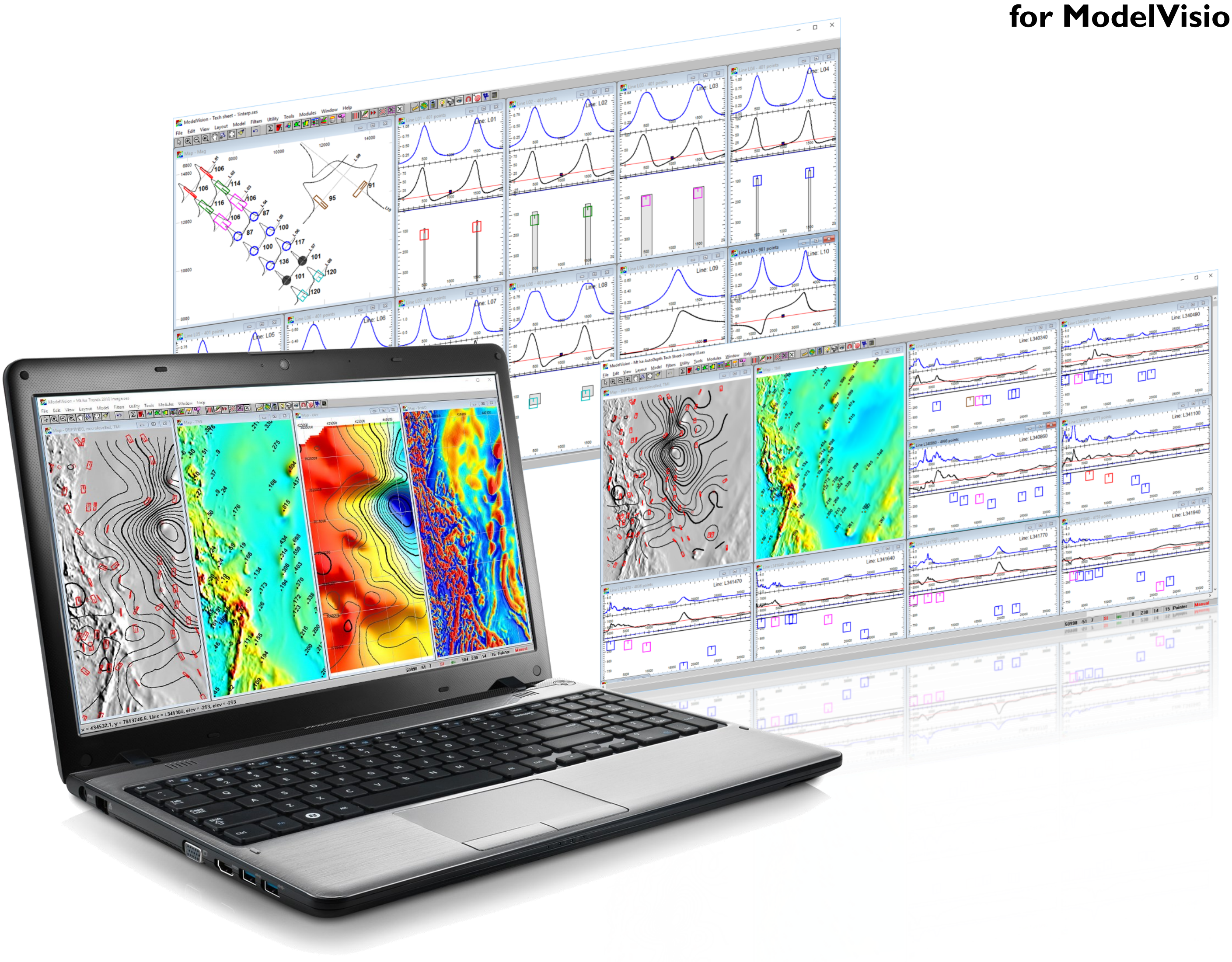
Map showing a segment of the Elkedra AutoMag depth results with 20m contours of a LP filtered depth surface.

QuickDepth fast depth estimates for selected magnetic anomalies

AutoMag batch processing of linear formations for depth, dip and strike

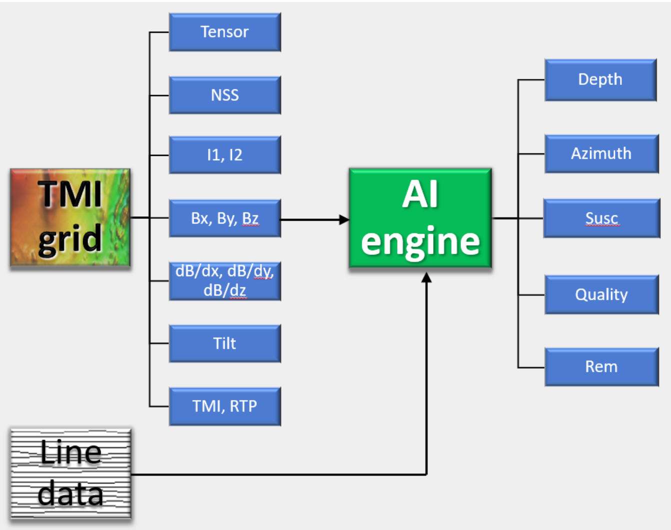
QuickDepth

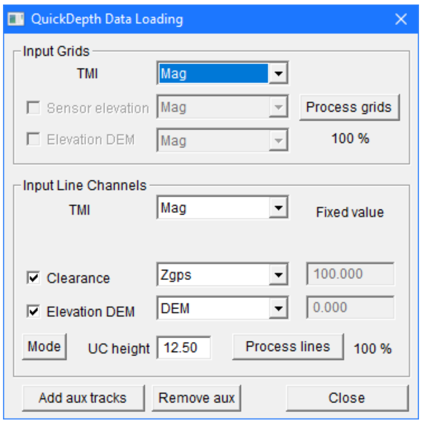
for ModelVision

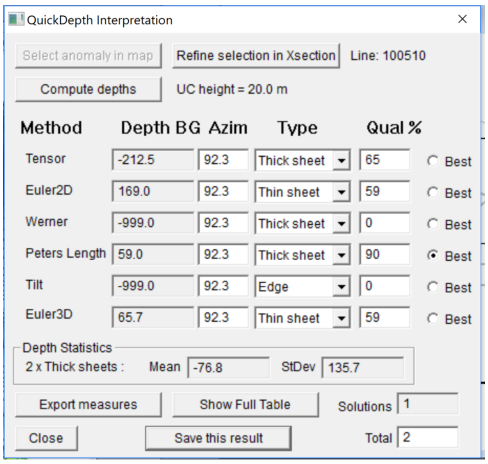


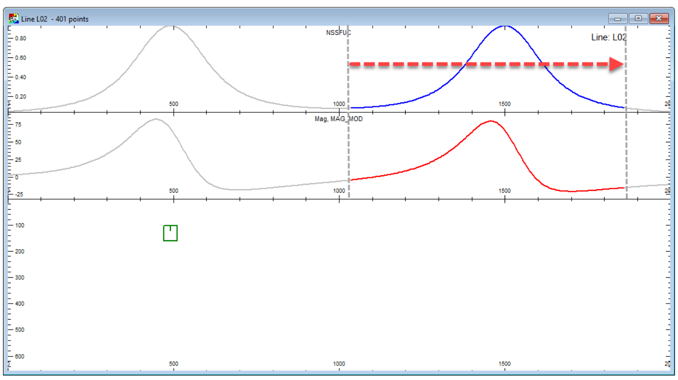
AI assisted depth interpretation

- Creates a full tensor (FTMG) line and grid dataset from a TMI survey
- Use the FTMG grids and other specialised grids for map interpretation
  - NSS, RTP, 1VD, Trend, Confidence, Bxx, Byy, Bzz, Bxy, Bxz, Byz, Bx, By, Bz
- AI assist uses the magnetic tensor for 3D shape detection
- AI assist suggests the best estimation method
- AI assist lets you know when an anomaly is unsuitable for depth estimation
- FTMG line data provides maximum depth resolution
- Compare results from the Tensor, Euler, Werner, Peters' Length, and Tilt methods









QuickDepth

QuickDepth applies AI principles to the estimation of depth, magnetic properties and geological style from magnetic data. Not only does AI speed up the interpretation process, it leaves the interpreter in control of the geological interpretation. It uses both the line data for the highest possible depth precision and the associated grids to gather intelligence on the shape characteristics of each anomaly. This intelligence is also used to estimate interference from overlapping anomalies to help in the assessment of depth quality or confidence.

Data preparation phase

By extracting all the information that influences the depth, shape, and physical property estimation we have been able to pre-train the system against a wide range of models. This avoids the need for the end-user to train a complex system on each new survey.

The data preparation phase must be run prior to starting the depth interpretation and the results are then available for the current and future sessions. The total magnetic intensity grid is used to derive the 2D estimates of the magnetic tensor, tensor invariants, normalised source strength, magnetic field components, total field gradients and reduction to pole of the total magnetic field. The 3D attributes of the full magnetic tensor implicitly carries a lot of shape information such as elongation or dimensionality and strike direction.

Depth interpretation phase

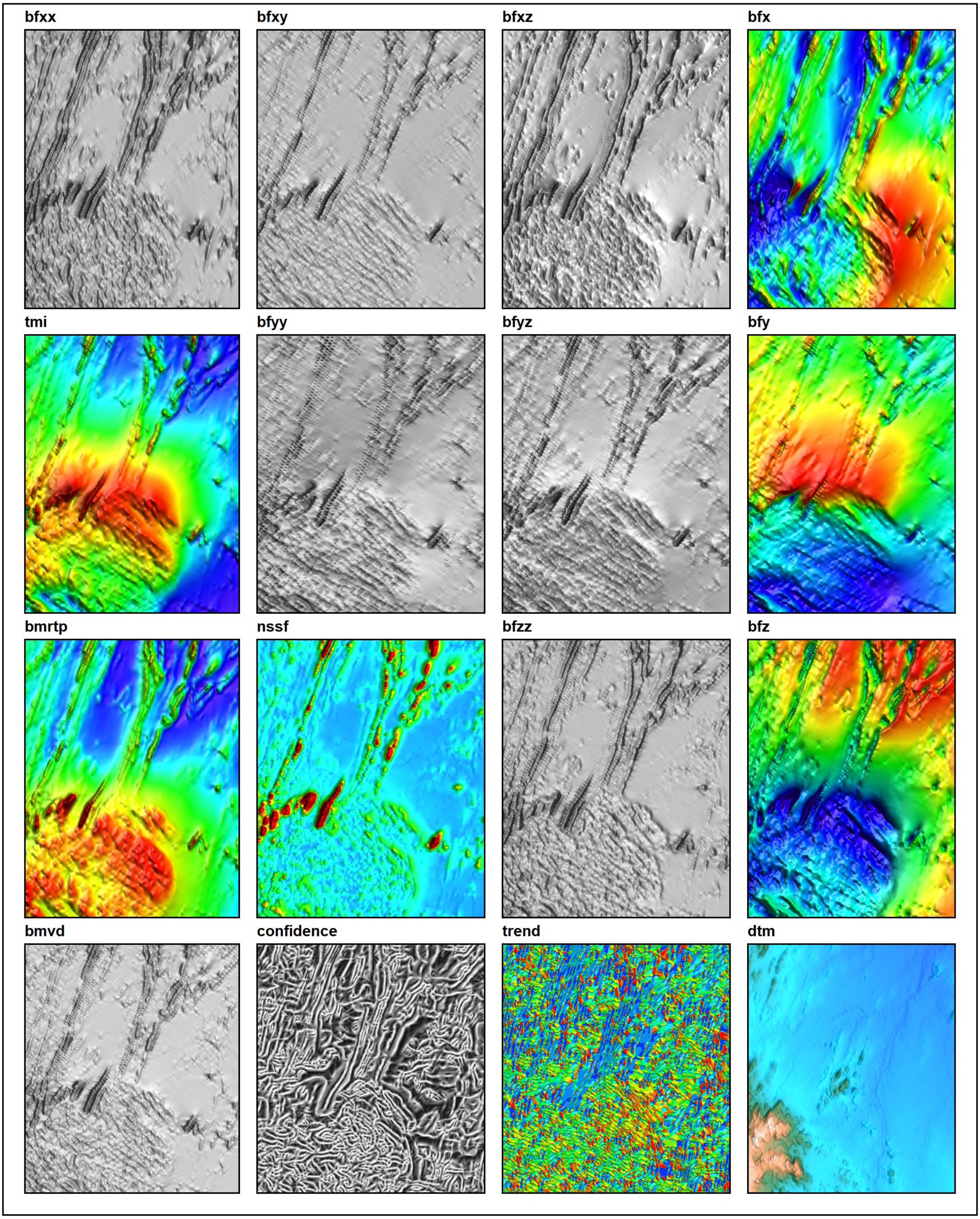
You simply select an anomaly in a cross-section view and QuickDepth uses the AI engine to analyse the shape characteristics to infer the geological style. Geological styles are defined in terms of intrusive pipes, sheets, dykes, edges, sills and ellipsoids. Most of the time the inferred geological style will be correct, but you can override the selection if you think another style is more appropriate.

The accuracy of magnetic depth interpretation is highly dependent on the selection of the correct anomaly style as the target shape has a large influence on the anomaly characteristics and depth estimate. The AI engine uses the pre-conditioned data to estimate the shape and then uses one or more depth estimation methods to obtain a depth value for the selected shape.

The process is repeated for each anomaly with the following steps:

1) Select a data range across the target anomaly in a cross-section view.
2) Compute the depths.
3) Select the most appropriate (best) method.
4) Adjust the auto-detected body type (if required).
5) Save the depth solution.

Learn about full tensor magnetic gradients (FTMG), NSS, field components and trend estimation with the automated QuickDepth data preparation phase. (*Image created in PA*)



Estimation Methods

The magnetic tensor measures the curvature of the magnetic field and consequently contains significant 3D information and just one measurement can tell you the direction to the magnetic source. Add more readings and you can resolve the distance, body shape information, azimuth and properties.

The tensor of the total magnetic field is used to derive geological characteristics such as strike direction, body type, centre of magnetisation and depth to the top of the magnetic unit. This information is used to constrain and improve the precision of the following depth estimation methods:

- **Tensor**
- **Euler 2D**
- **Peters' Length**
- **Werner Deconvolution**
- **Tilt Depth**
- **Euler 3D**

ModelVision uses the peak of the normalised source strength (NSS) from Clark (2014) to define the horizontal (X, Y) location of the centre of magnetisation which simplifies the calculations of depth for the Euler 2D, Werner and Tilt Depth methods. The strike direction of the anomaly (Pederson & Rasmussen, 1990) is used to correct the depth estimates for the Tensor, Peters' Length, Werner Deconvolution and Tilt Depth methods.

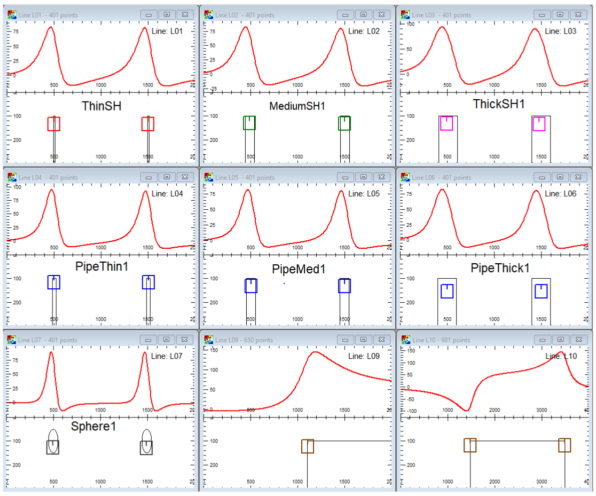
Tensor analysis also provides a dimensionality index which automatically differentiates between pipe-like magnetic sources and linear magnetic formations or dykes. This allows for different depth correction techniques to be applied according to the geology. The tensor provides some information about the width of the magnetic source and classifies it as thin, intermediate or thick.

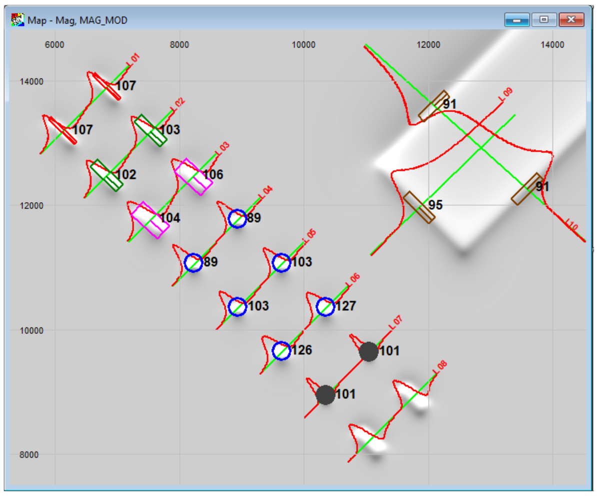
A quality estimator is presented as a guide only and is based on principles that rely heavily on interference estimation and robustness of the tensor method. The user is able to overrule the best method if the interpreted geology matches a different method and body type.

The best method option determines which body will be included in the QuickDepth point data set which preserves the best outcome based on your interpretation of the geology. You can export the best results for each depth method if required, but in general it is better to preserve your preferred interpretation because you have invested time interpreting the probable geology at that anomaly location.

As you interpret each anomaly and save the solution, a symbol representing the top centre of the target (excluding the ellipsoid) is posted in the cross-section. In the case of the sphere or ellipsoid, only the centre of magnetisation can be estimated.

You can export the solutions as a point dataset to a Geosoft GDB database or CSV file for use in other applications. The data can be imported into ModelVision using the Convert Point to Body option for display of bodies in cross-section and map views.





DEPTHBG	QDELEV	SUSC	DIPAZIM	STRIKEAZIM	THICKNESS
106	-106	0.00134	224	134	150
106	-106	0.00134	224	134	150
116	-116	0.00139	224	134	191
114	-114	0.00138	224	134	191
106	-106	0.00124	223	133	303
106	-106	0.00124	223	133	303
87	-87	0.00158	181	91	143
87	-87	0.00160	182	92	142
100	-100	0.00142	181	91	170
100	-100	0.00142	181	91	169
136	-136	0.00143	182	92	267
117	-117	0.00122	181	91	268
101	-101	0.0			
101	-101	0.0			
120	-120	0.0			
120	-120	0.0			
95	-95	0.0			
91	-91	0.0			

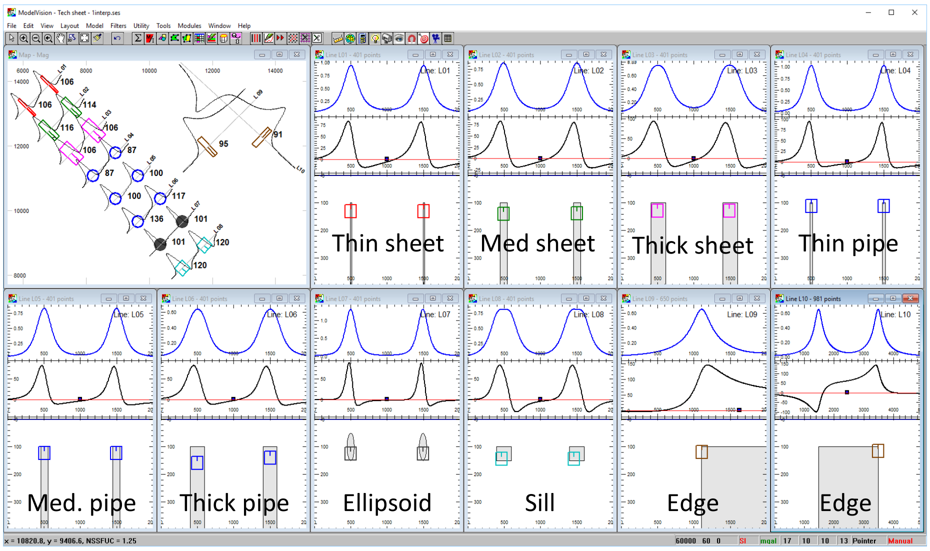
REM	DPTHXTNT	SI	DI	QUAL	DBGAV	DBGSD
2	1065	1	0.07	92	96	9.6
2	1063	1	0.07	93	97	9.1
2	1252	1	0.09	92	116	0.0
2	1228	1	0.09	92	114	0.0
2	1289	1	0.26	88	106	0.0
2	1289	1	0.26	88	106	0.0
2	941	2	0.99	95	111	28.1
2	939	2	0.99	96	112	30.5
2	1079	2	0.99	95	125	31.9
2	1077	2	0.99	95	127	35.4
2	1460	2	0.99	92	169	49.1
2	1260	2	0.99	92	167	58.3
2	695	3	1.00	90	120	29.5
2	694	3	1.00	90	101	0.0
2	935	2	0.13	69	143	25.7
2	1136	2	0.14	90	172	40.4
2	1612	0.5	0.13	85	102	10.2
0	1603	0.5	0.08	85	97	5.5

Examples

Experimental Survey

ModelVision provides tools that allow you to create experimental surveys over any geological model. This example shows a geological model composed of all the body shapes that can be supported by QuickDepth with lines that are at 45 degrees and elongate bodies that are perpendicular to the line direction.

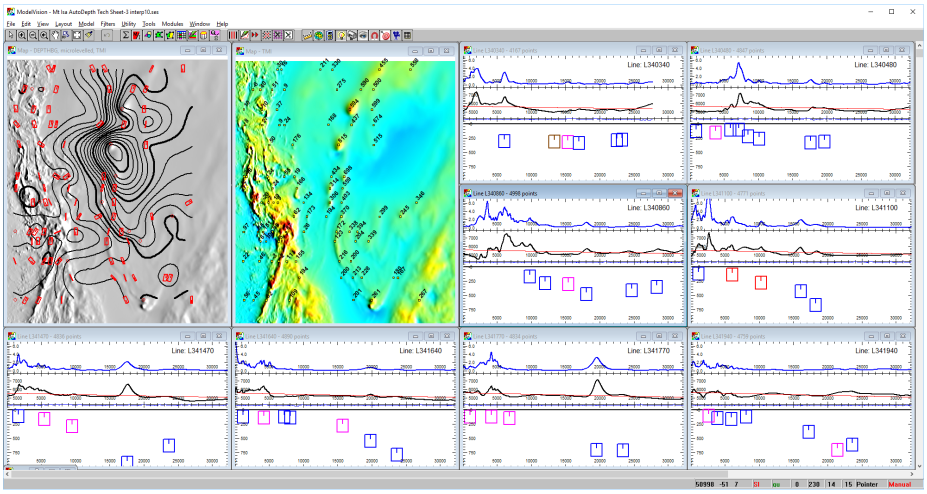
In this example, the true depth is within 5 to 15% of the true depth when the correct body type is selected. In cases where there is no appropriate model from the original AI training, such as the thick pipe, you can expect an overestimation of the depth. The strike direction is estimated within two degrees of the true direction.



Mt Isa Region Example

QuickDepth was applied to the magnetic data in the Mt Isa-Cloncurry region of western Queensland where the sedimentary cover dips below cover to the north-east. A subset of the lines was selected for depth interpretation to provide a quick indication of depths across the survey area.

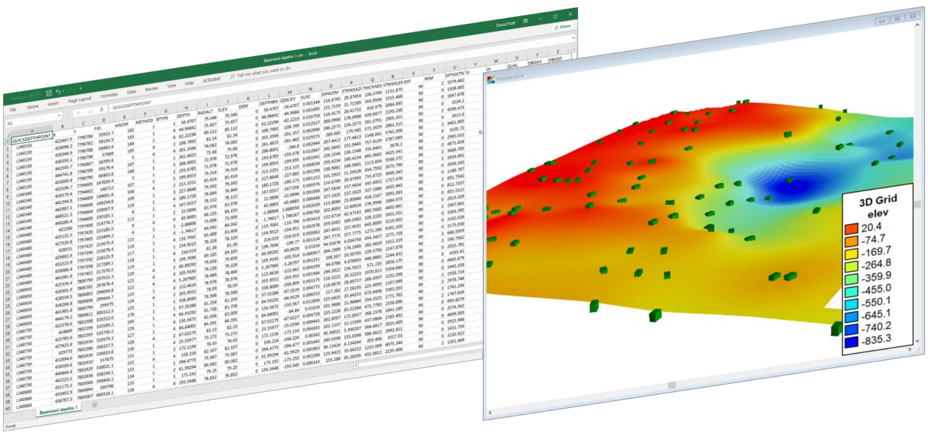
Depth below ground values were then gridded and contoured to show regions more prospective for exploration drilling.



Visualisation and Export

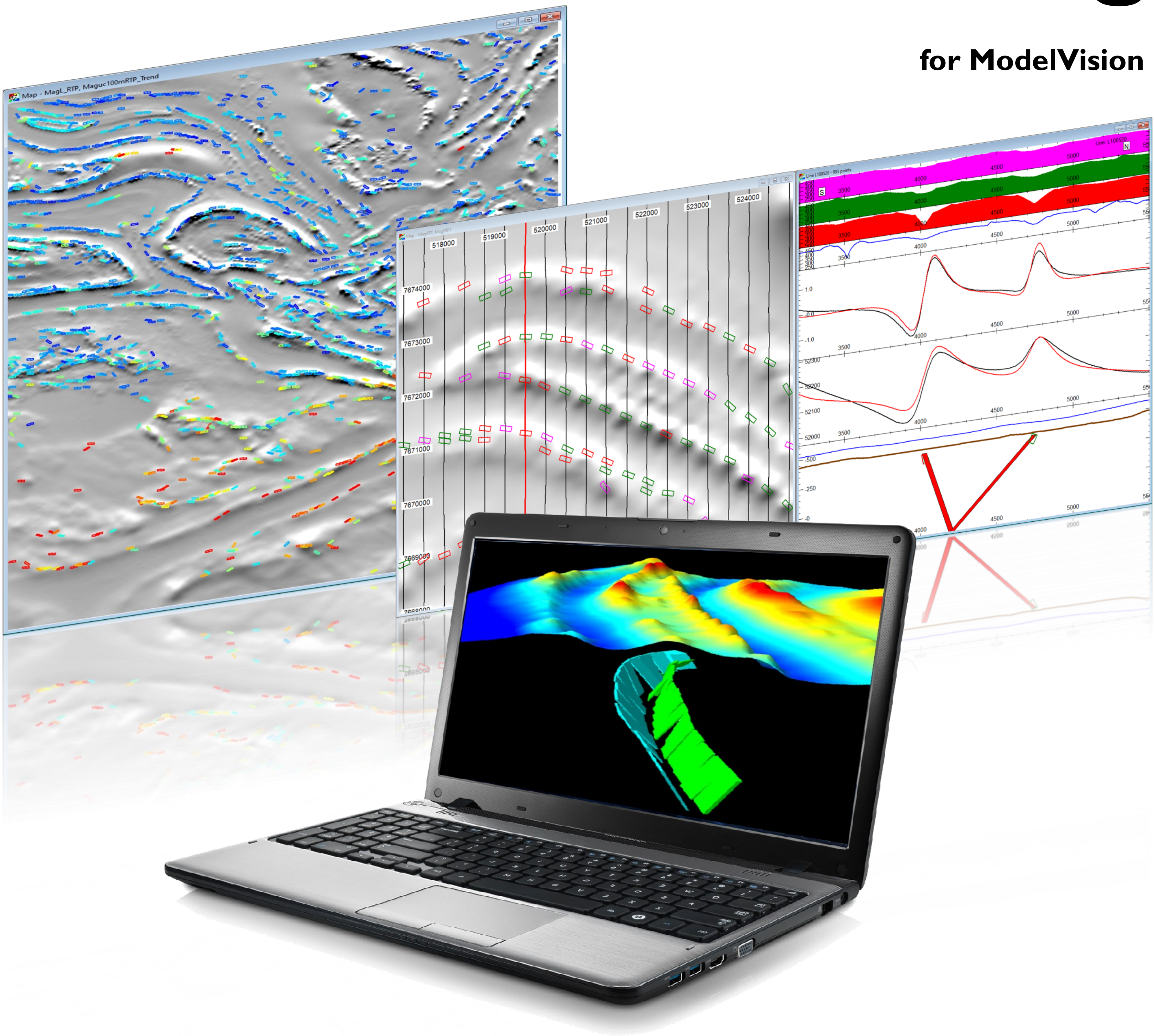
There are many ways to visualise the result of your QuickDepth interpretation sessions. The solutions are automatically displayed in your depth sections and are easy to add to a map view. Explore the use of other parameters such as magnetic susceptibility, azimuth, dimensionality and structural index (SI).

It is simple to export your depth points as a spreadsheet or GDB file for use in other products.



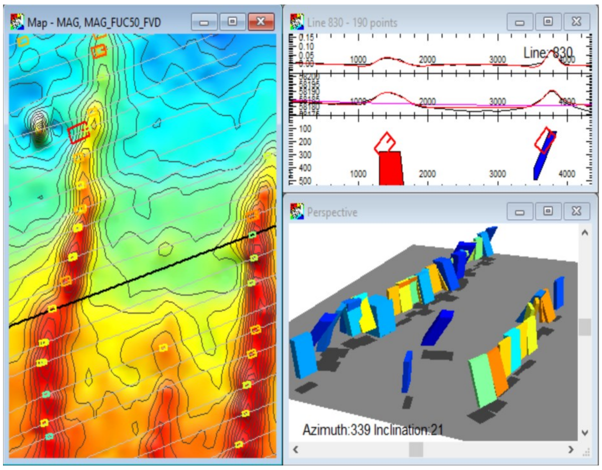
AutoMag

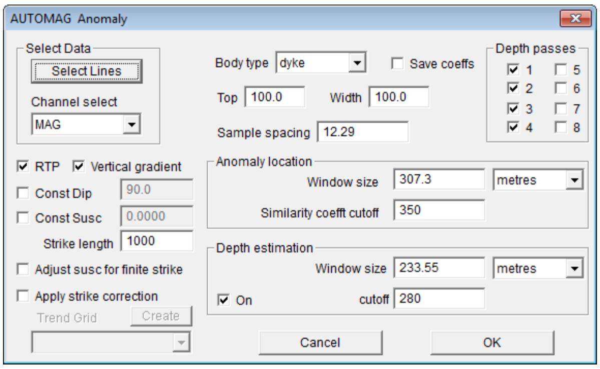
for ModelVision

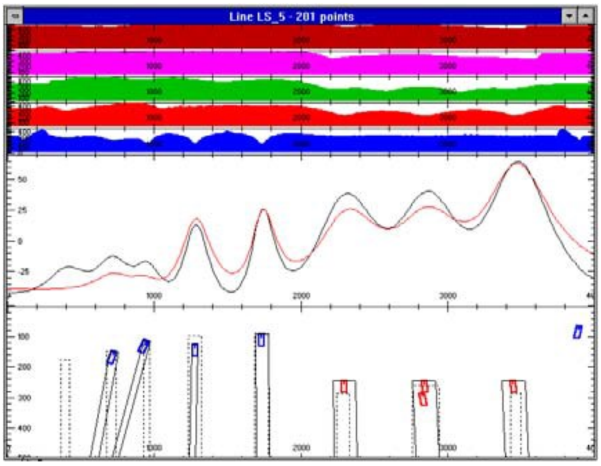


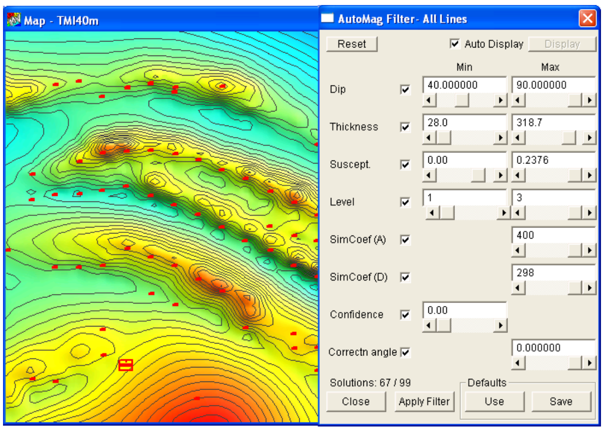
Automated magnetic depth interpretation of magnetic survey line data

- Large scale depth estimation using a modified Naudy inversion algorithm
- Depth, azimuth, dip, thickness, magnetic susceptibility
- Thick sheet, thin sheet and edge
- Batch processing, auto-strike correction
- Dynamic filter clean-up of low quality solutions in map and section views
- Convert selected point solutions to bodies for validation modelling or inversion
- Interactive solution editor for map and section views









AutoMag is an automated magnetic source depth estimator for airborne data based on the Dipping Tabular Body inversion method (Naudy 1971). AutoMag operates on a profile basis and is tightly integrated into the ModelVision modelling environment. Profiles can be analysed using original flight line data or traverses selected from gridded data. Large aeromagnetic surveys can be efficiently processed in batch mode with AutoMag.

What can AutoMag do?

- Cut large project times from days to hours
- Match suitable anomalies with high precision
- Select anomalies from sources in a specified depth range of interest
- Use first vertical derivative to improve depth estimation precision and anomaly isolation
- Interactively tune parameters on control lines and then process the full survey automatically
- Grid and contour your results at any time for QC analysis
- Pass the solutions to the ModelVision inversion module for refinement
- Link bodies in map view to apply strike adjustment to depth, dip and susceptibility
- Export your solutions to other applications

Batch Operation

You can use the mouse to select regions for analysis and set AutoMag to run in batch mode. Run times for surveys are fast and typically range from 5 to 30 minutes on a Pentium PC for surveys of 10,000 to 100,000 line kilometres.

Visualise Solutions

AutoMag solutions and correlation coefficients are displayed in a model cross-section. Individual solutions have attributes of X, Y, Depth, Susceptibility, Thickness, Dip and Azimuth. You can use the mouse or toolbar to convert selected solutions to a solid model for direct and immediate computation of the magnetic response.

Filtering of Solutions

By choosing loose constraints during the tuning stage, many solutions can be produced which can then be filtered based on reasonable geological criteria to quickly give a subset of realistic solutions. The dynamic solution filtering removes solutions from the display in real time when thresholds are changed on parameters such as dip, thickness, susceptibility, correlation thresholds, upward continuation level and anomaly trend direction and trend confidence. The immediate feedback of the live filtering allows you to quickly converge on realistic solutions for the given parameters and known geology. Further refinement can be performed with direct forward modelling and inversion in the core software, ModelVision.

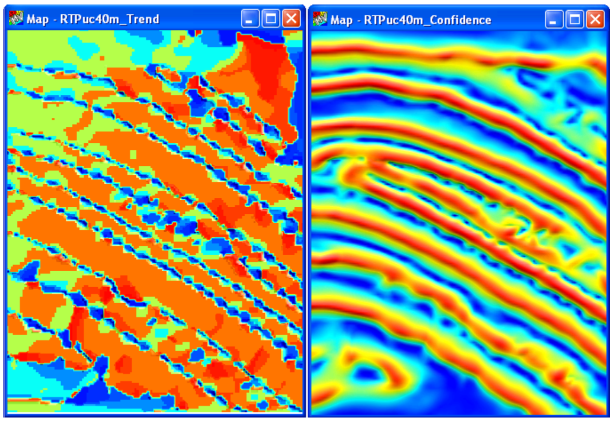
Trend Gridding for Strike Adjustment

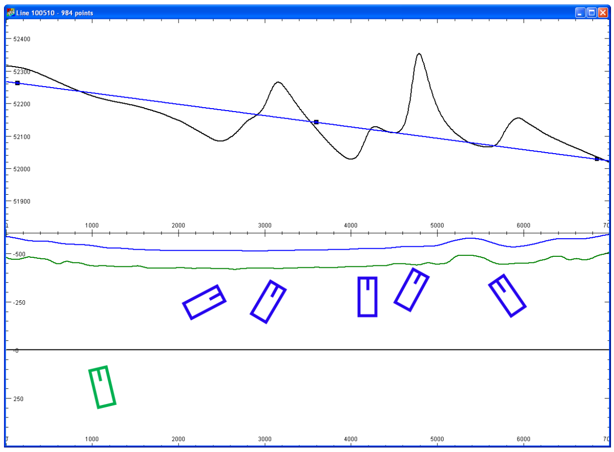
AutoMag solutions are initially created with a strike perpendicular to the line direction. Correction to a more accurate strike direction from the input TMI grid can be made using an automatic trend correction function available in the Grid Utility of ModelVision.

AutoMag uses the azimuth and confidence grids generated by the internal Trend Grid Utility application for strike correction and filtering of the AutoMag solutions.

The Trend Grid Utility analyses trends within the input TMI grid and outputs an azimuth grid (Trend) showing the geological strike (0-180 degrees) for these trends. The trends are binned within 15 degree arcs from zero to 180 degrees. The trend azimuth grid is then used to apply strike corrections to the AutoMag solutions automatically.

The Trend Grid Utility also outputs a Confidence grid which graphically shows the level of confidence between 0 and 1 that is similar to a correlation coefficient in curve fitting. The higher the number the greater confidence that the trend azimuth value has been resolved correctly for that grid point.

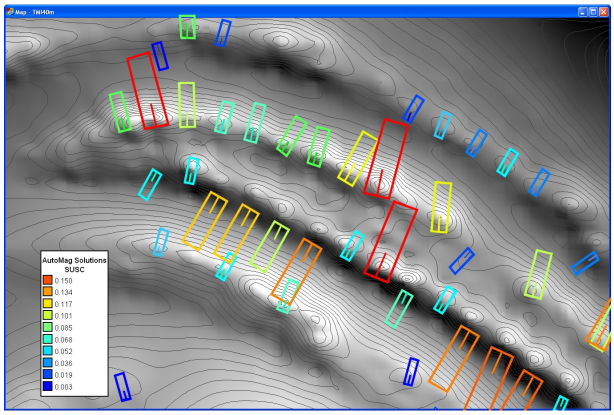




Map Presentation

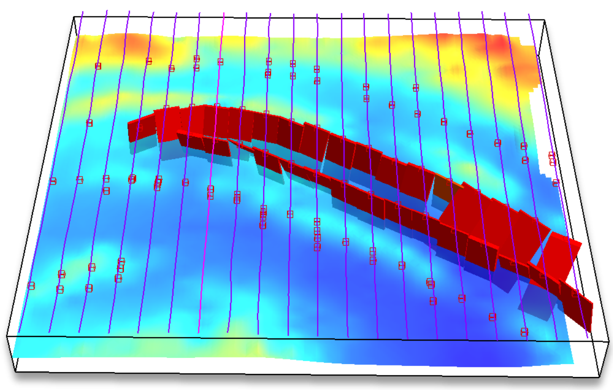
AutoMag solutions can be displayed in map view along the flight lines, with a choice of stacked profiles, contours or images of any appropriate parameter, such as total magnetic intensity or elevation. Symbols representing the solutions can be modulated in size and colour by properties such as depth, susceptibility and azimuth.

Your final set of AutoMag points can be gridded and displayed as contour maps or images of magnetic source depth together with the annotated solutions. A geological assessment of the solutions can then be used to cull any spurious values. Solutions can be refined through modelling and inversion.



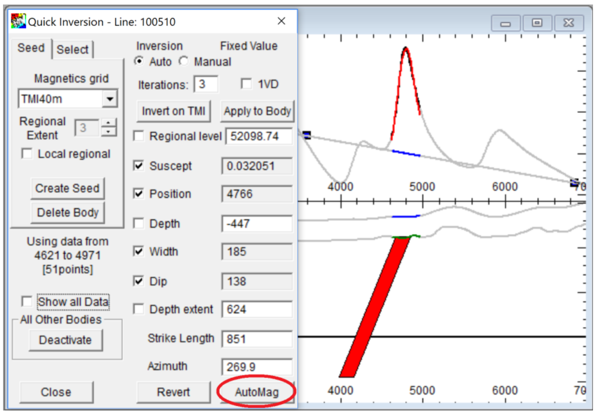
Import/Export Solutions

Solutions generated by AutoMag can be converted to tabular bodies and exported as a ModelVision .TKM model file or AutoCAD .DXF. The solutions can also be converted to standard points for display in a ModelVision perspective view or exported as an ASCII table (.CSV) for use in other presentation software, such as Datamine's PA Explorer and Discover 3D, or for inclusion in written reports.



Quick Inversion

The QuickInvert tool in ModelVision is a great pre-cursor to AutoMag as an alternative to setting up the search parameters manually or by trial-and-error. Run QuickInvert on a typical anomaly in the area and have it generate AutoMag parameters from the QuickInvert solution and initiate the AutoMag interface directly from the QuickInvert dialog.



QuickInvert is a productivity tool that is optimised for inversion of single magnetic anomalies using a tabular body source. It is easy to learn because it automates many of the steps used in Standard Inversion. This includes a single control dialog that automates the use of a 2D regional magnetic field, easy toggling between TMI and first vertical derivative inversion methods and the setting of geological constraints.

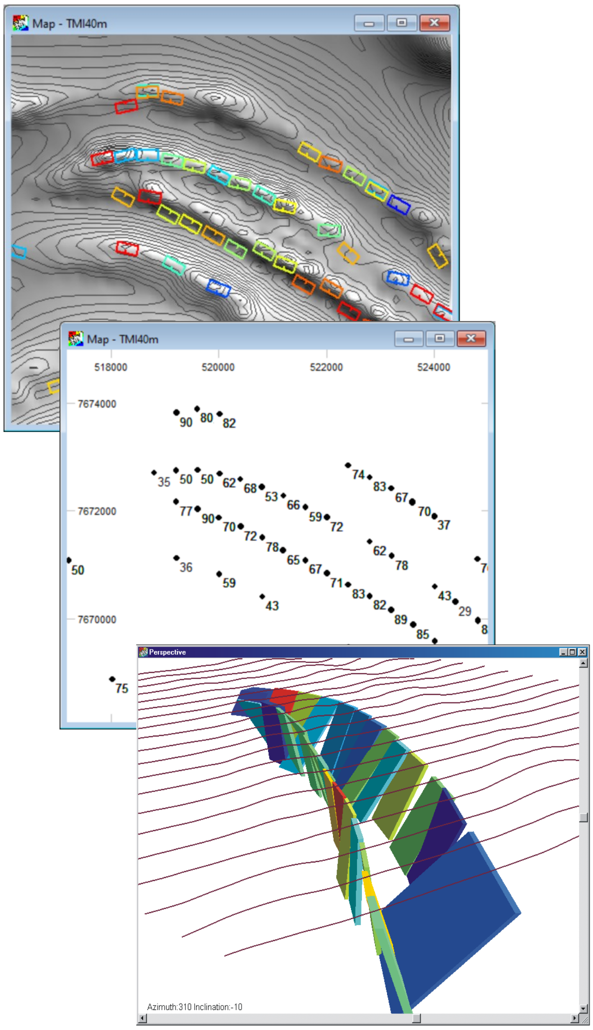
AutoMag Applications

- Quick depth estimates on individual anomalies
- Automated depth estimates along profiles
- Overburden thickness studies to select shallow targets
- Alluvial channel mapping for diamond, gold and groundwater
- Regional mapping of basins and grabens
- Cross-section analysis

Elkedra, NT Example

AutoMag was applied to the interpretation of structural dip from modelled airborne magnetic TMI data in the Elkedra area of Northern Territory, Australia. The modelled bodies were derived automatically using AutoMag,

Initial analysis of a single line of the survey using AutoMag addressed the three-dimensional issue of cross-profile variation by tracking the anomaly in map view and applying an automatic strike correction using a Trend grid to each body as it is rotated. Although lacking independent information with which to confirm the dip values, internal consistency suggests that they were correct to within at least 10° to 15°.



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