

Down-hole processing

Guide to using the down-hole processing programs DecodeLAS and Raw2XYZ

Richard Almond

This document describes two simple programs that convert tool-referenced down-hole 3-component magnetic data into East, North and Up components. The resultant output file can be used for magnetic modelling using Potent software.

Contents

Overview	1
Quick start.....	1
Using DecodeLAS	2
Using Raw2XYZ.....	3
The problem.....	3
The Raw2XYZ input file	5
Running Raw2XYZ	5
Allowing for different tool roll reference.....	7
Deleting spurious observations	7
Correcting the calculated azimuth values.....	8
Exporting to Potent.....	10

Overview

DecodeLAS and Raw2XYZ comprise a pair of programs designed to create a Potent-compatible data file from raw down-hole magnetic data. Potent is a gravity and magnetic modelling program that has features designed for modelling down-hole data. Refer to <http://www.geoss.com.au/> for more information.

DecodeLAS is a very simple program that takes as input a “LAS” file from a down-hole survey carried out with a Mt Sopris™ magnetic probe and creates a text file suitable for input to the other program in the pair, Raw2XYZ, which creates the actual file required by Potent. This file contains the geographic location of each observation point, along with the three magnetic field components resolved along the geographic East, North and Up axes.

Dividing the functionality in this way means that Raw2XYZ is insulated from issues associated with the input file format. If another format of down-hole data is encountered then all that is required is a new decoding program similar to DecodeLAS. This new program would take different input, but would produce output in exactly the same format as that of DecodeLAS.

Quick start

This document goes into some detail to describe the reasoning behind the programs. In reality there are a few simple steps:

1. Use DecodeLAS to convert the LAS file to a correctly structured txt file.
2. Load the txt file into Raw2XYZ.
3. Confirm the calculated azimuths are sensible. If not, refer to [ALLOWING FOR DIFFERENT TOOL ROLL REFERENCE](#).
4. If necessary clean up spikes in the data using the **Delete observations** command ([DELETING SPURIOUS OBSERVATIONS](#)).
5. If necessary, smooth the azimuth profile using the **Add azimuth control points** block of commands ([CORRECTING THE CALCULATED AZIMUTH VALUES](#)).
6. Use the **Export XYZ** command to create a geographically referenced file that can be imported by Potent.

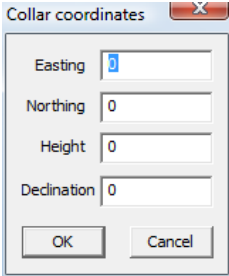
Using DecodeLAS

This program takes as input a “.LAS” file created by a Mt Sopris down-hole magnetic tool. The file format is along the following lines:

```
~VERSION INFORMATION
VERS .2.0 :CWLS LOG ASCII STANDARD-VERSION 2.0
WRAP .YES :MULTIPLE LINES PER DEPTH STEP
~WELL INFORMATION
STRT .M 1.695 :START DEPTH
STOP .M 154.245 :STOP DEPTH
STEP .M 0.05 :STEP
NULL . -999.25 :NULL VALUE
COMP . COMPANY XYZ :COMPANY
WELL . :WELL
FLD . :FIELD
LOC . :LOCATION
PROV . :PROVINCE
SRVC . BOREHOLE WIRELINE :SERVICE COMPANY
DATE . :LOG DATE
UWI . 0000 :UWI
~CURVE INFORMATION
DEPT .M :DEPTH
MAGX .GS :MagX
MAGY .GS :MagY
MAGZ .GS :MagZ
ACCX .G :AccX
ACCY .G :AccY
ACCZ .G :AccZ
~PARAMETER INFORMATION
:
TD D . :TD DRILL
TD L . :TD LOGGER
:
:
STRT . :STRTC
LOG . :LOG TYPE
LOGG . :LOGGER
~OTHER
~A
1.695
-0.41754 -0.17252 -0.20833 0.37128 0.18372 0.90607
1.745
-0.41749 -0.17223 -0.20832 0.37208 0.18307 0.9063
1.795
-0.41463 -0.17861 -0.21001 0.37079 0.18621 0.90583
1.845
-0.41396 -0.17993 -0.21007 0.36991 0.18783 0.90623
...
...
Etc.
```

After reading this file the **Collar coordinates** dialog box is displayed. If known, enter the grid coordinates of the collar of the drill hole. Also, if the local magnetic declination has not been allowed for previously, enter it here.

If these quantities are not known just leave them as zero. The positions subsequently calculated by Raw2XYZ will be relative to the collar of the drill hole.



The image shows a dialog box titled "Collar coordinates" with a close button (X) in the top right corner. It contains four input fields: "Easting" with a value of 0, "Northing" with a value of 0, "Height" with a value of 0, and "Declination" with a value of 0. At the bottom of the dialog are two buttons: "OK" and "Cancel".

Click **OK** to create the output file, which is located in the same folder as the LAS file. The name of the output file is the same as that of the LAS file with the “.las” extension replaced by “.txt”. Refer to [THE RAW2XYZ INPUT FILE](#) to see an example of a DecodeLAS output file.

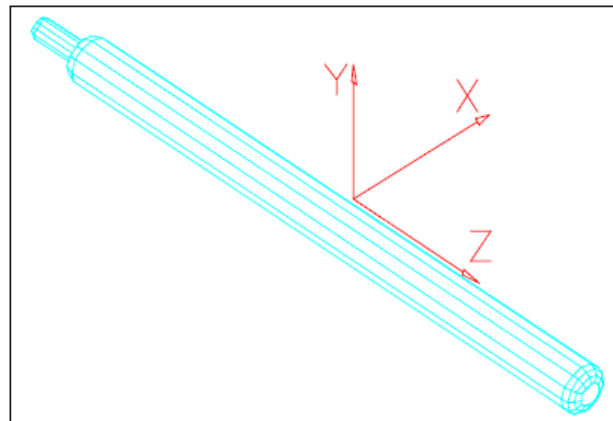
Using Raw2XYZ

Raw2XYZ allows you to interact graphically with down-hole magnetic survey data to ensure optimal recovery of all three geographic magnetic components.

The problem

Down-hole magnetometer probes such as the 2DVA-1000 produced by the Mt Sopris™ company (www.mountsopris.com) have sensors for recording three orthogonal components of acceleration and of magnetic field at specified intervals down the hole. The components are relative to the axes of the probe; the Z axis is conventionally directed along the length of the probe, while X and Y (the cross-components) are relative to a reference mark on the probe casing. This is described clearly in the manual for the 2DVA-1000 probe, of which the following is an extract:

The probe measures the magnetic field and acceleration in three different directions, that is, along three orthogonal axes. The probe has an index mark (a 'V') stamped on the lower part of the housing. This mark indicates the side of the probe from which the positive X axis extends. The Z axis is the longitudinal axis and points down. The Y axis is defined using a right hand coordinate system where the cross product of X and Y equal Z. The X and Y axis are in the horizontal plane when the probe is vertical.



(Copyright © Mt Sopris Instrument Company)

For the purpose of modelling 3-component magnetic data using Potent it is necessary to resolve the observed probe-referenced magnetic components into geographic (East, North, Up) components. This requires knowledge of the inclination and azimuth at each observation point down the hole.

Using the accelerometer components it is possible, at each observation point down the hole, to calculate two directional properties:

- The inclination of the tool (and hence of the hole) relative to the horizontal.
- The “roll” of the tool – its rotation about its length (Z axis) relative to its starting orientation.

Importantly, it is not possible to determine the azimuth (horizontal direction, or bearing) of the hole from the accelerometer data alone. The azimuth must be recovered from the magnetometer data (making due allowance for the local magnetic declination, or “variation”), assuming that the magnetic field is directed towards magnetic north. However, this is where the problem arises; in a

mineral exploration survey the target at which the hole is directed is often sufficiently magnetic to distort the local magnetic north direction, and therefore to cause the calculated azimuth to be incorrect. This can be seen in [FIGURE 1](#), which shows the magnetic components resolved along the three geographic axes. Notice that the East component is zero. This is a necessary effect of using the magnetic data to calculate the azimuth: the definition of magnetic north involves there being no East component to the magnetic field.

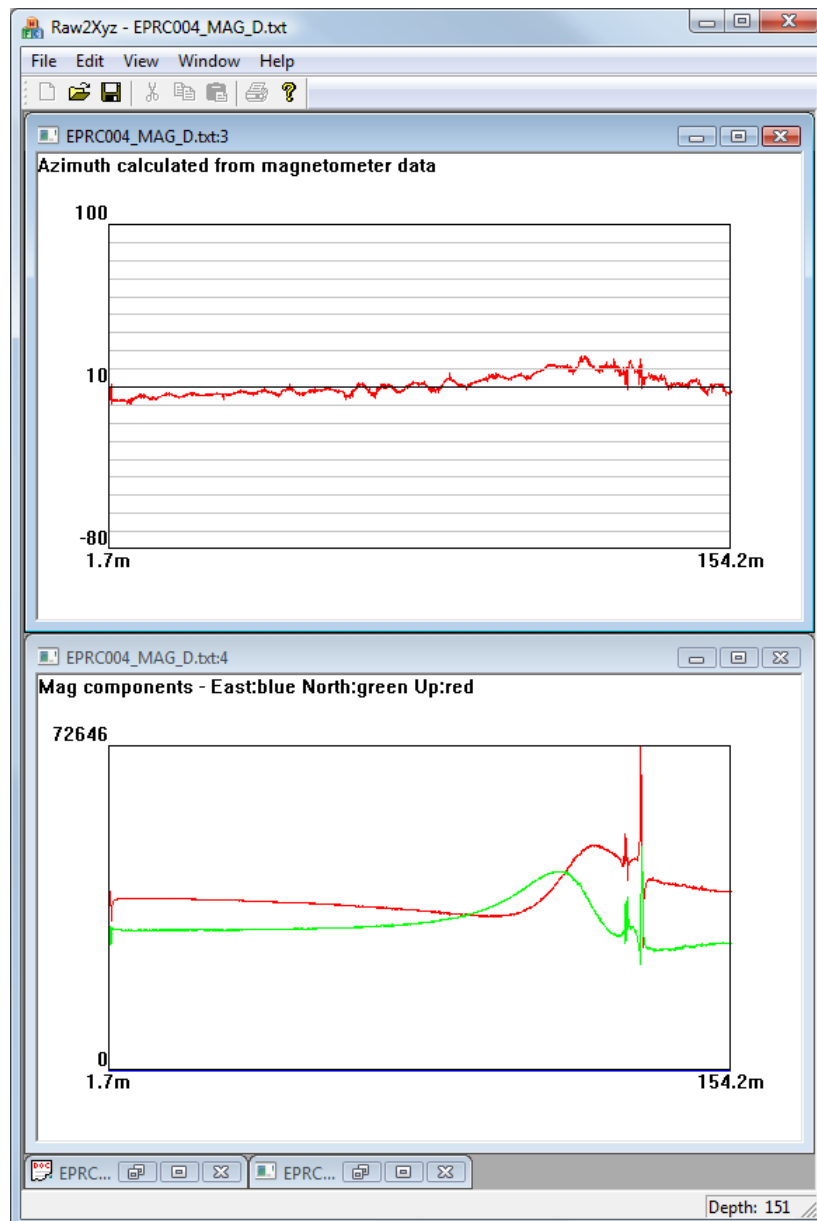


Figure 1 – Azimuth (top pane) distorted by magnetic anomaly (bottom pane)

In such situations the hole may be surveyed using a gyroscope probe. Such probes have three orthogonal gyroscopes, which allows determination of inclination and azimuth at specified intervals down the hole without recourse to magnetic observations. Raw2XYZ is aimed at the (usual) situation where gyroscope data is not available. It uses smooth interpolation to obtain an improved estimate of the azimuth derived from the magnetic data.

The Raw2XYZ input file

The input file used by Raw2XYZ must have exactly the following format (the number of spaces between columns is not significant):

```
Collar coordinates:
Easting  431180.00
Northing 7956700.00
Height   0.00
Declination 4.50
DEPTH    MagX      MagY      MagZ      AccX      AccY      AccZ
1.69500  -0.41754  -0.17252  -0.20833  0.37128   0.18372   0.90607
1.74500  -0.41749  -0.17223  -0.20832  0.37208   0.18307   0.90630
1.79500  -0.41463  -0.17861  -0.21001  0.37079   0.18621   0.90583
1.84500  -0.41396  -0.17993  -0.21007  0.36991   0.18783   0.90623
1.89500  -0.41104  -0.18577  -0.21097  0.36822   0.19152   0.90456
1.94500  -0.40682  -0.19293  -0.21245  0.36765   0.19314   0.90575
1.99500  -0.40253  -0.19797  -0.21739  0.36604   0.19701   0.90560
2.04500  -0.39825  -0.19717  -0.22896  0.36540   0.19836   0.90305
2.09500  -0.39497  -0.18199  -0.24297  0.36452   0.19886   0.90472
2.14500  -0.38924  -0.15789  -0.24628  0.36492   0.19862   0.90440
...
...
Etc.
```

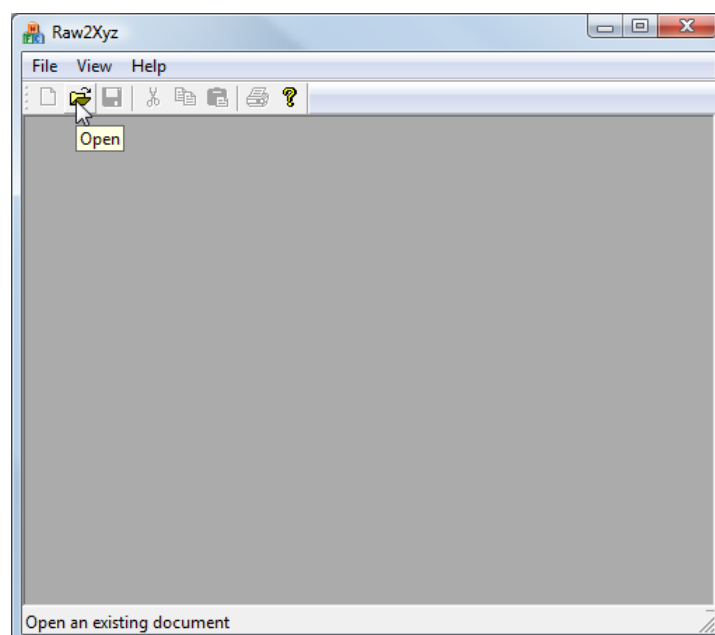
Such a file is generated by DecodeLAS.

The columns in the file have the following significance:

- DEPTH is the distance from the surface along the path of the hole, in metres.
- MagX, MagY and MagZ are the magnetic field components, in gauss (1 gauss = 10^5 nanotesla), along the tool axes.
- AccX, AccY, AccZ are the accelerometer components (units are not significant) along the tool axes.

Running Raw2XYZ

Run the program in any of the usual windows ways – desktop icon, Start menu, etc. (It's helpful to maximize the Raw2XYZ window before loading data.) Click **Open** and load an input file, such as one created by DecodeLAS.



Raw2XYZ reads the data, performs the calculations necessary to locate the data points and resolve the magnetic components along the East, North and Up directions, and displays the results in four windows:

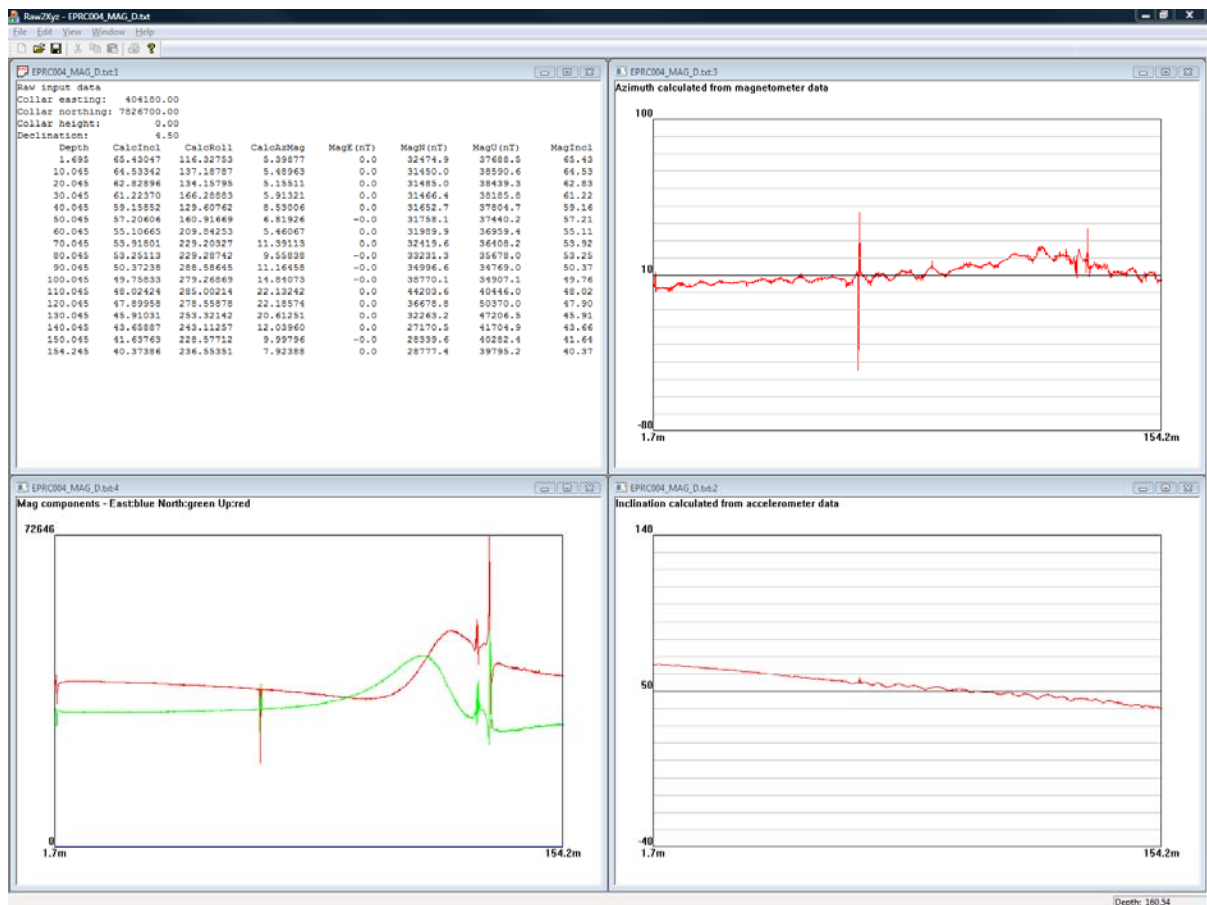


Figure 2 – Example down-hole magnetic data

- The text window displays the calculation results for a sample of the data points spread over the length of the hole. (It might be necessary to make the window wider to see all the columns.)

The **Depth** column is the same as that in the input file and so may be used to locate the corresponding line in the input file for checking.

All the other columns are calculated values.

- **CalcIncl** is the inclination (degrees down from the horizontal) derived from the accelerometer data.
- **CalcRoll** is the tool roll angle in degrees, also derived from the accelerometer data.
- **CalcAzMag** is the azimuth of the hole calculated from the magnetometer data. Check the value near the top of the hole for sanity; it should reflect the design bearing of the hole. If it does not then the tool might have been oriented wrongly. Refer to [ALLOWING FOR DIFFERENT TOOL ROLL REFERENCE](#).
- **MagE, MagN, MagU** are the geographically referenced magnetic components derived from the three angles just described. (Initially MagE is zero, as it was used to derive the azimuth of the hole.)
- **TVD** is the true vertical depth below the surface.

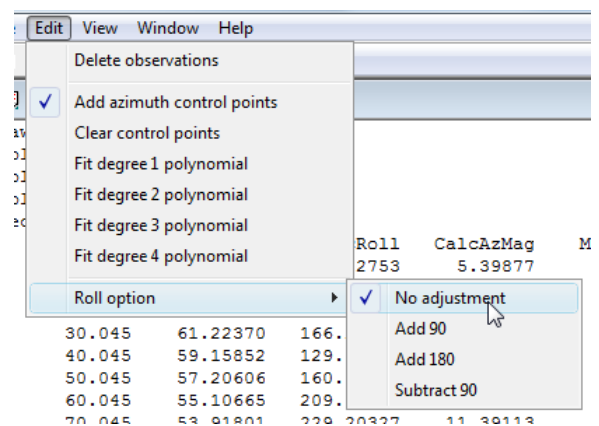
- **East, North, Height** are the geographical coordinates, incorporating collar easting, collar northing, collar height and local magnetic declination.
- The magnetic components window displays plots of the three magnetic field components. Initially the east component is zero. (If no field profiles are visible it is probably due to the presence of large noise spikes. The profiles will appear when these are removed, as described in [DELETING SPURIOUS OBSERVATIONS](#).)
- The inclination window shows a trace of the inclination of the hole. The Y axis extends 90° either side of the average value.
- The azimuth window shows a trace of the azimuth of the hole as derived from the magnetometer data. The Y axis extends 90° either side of the average value. Notice that the azimuth trace is distorted where the magnetic field traces show anomalies.

Any of the graphical windows can show spikes as in [FIGURE 2](#). These can be instrumental, or due to geological noise.


Allowing for different tool roll reference

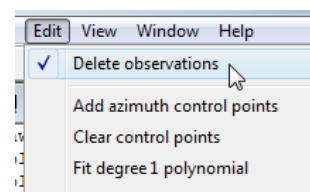
If the azimuth values (and consequently the magnetic components) do not appear sensible there could be a problem with the initial tool orientation (roll). This could be due to an operator error, or due to using a tool that uses a different convention for defining its X,Y directions.

To try different roll configurations click **Roll option** from the **Edit** menu and select one of the three alternatives. The angles and field components are recalculated immediately. It should be clear which option is appropriate.

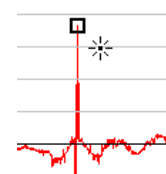


Deleting spurious observations

You may clean up spikes in the data using the **Delete observations** command from the **Edit** menu. On the graphical windows the cursor changes to the Delete observations cursor, .



When the cursor locks on to an observation point the cross changes to a small box, as shown here. Click on the point to delete it. (It is deleted only from memory, not from the input file.)



As you delete spikes from one window you will see them disappear from other windows also, as they are generally related.

Correcting the calculated azimuth values

After deleting spikes, the Azimuth and Magnetic windows of [FIGURE 2](#) look as in Figure 3:

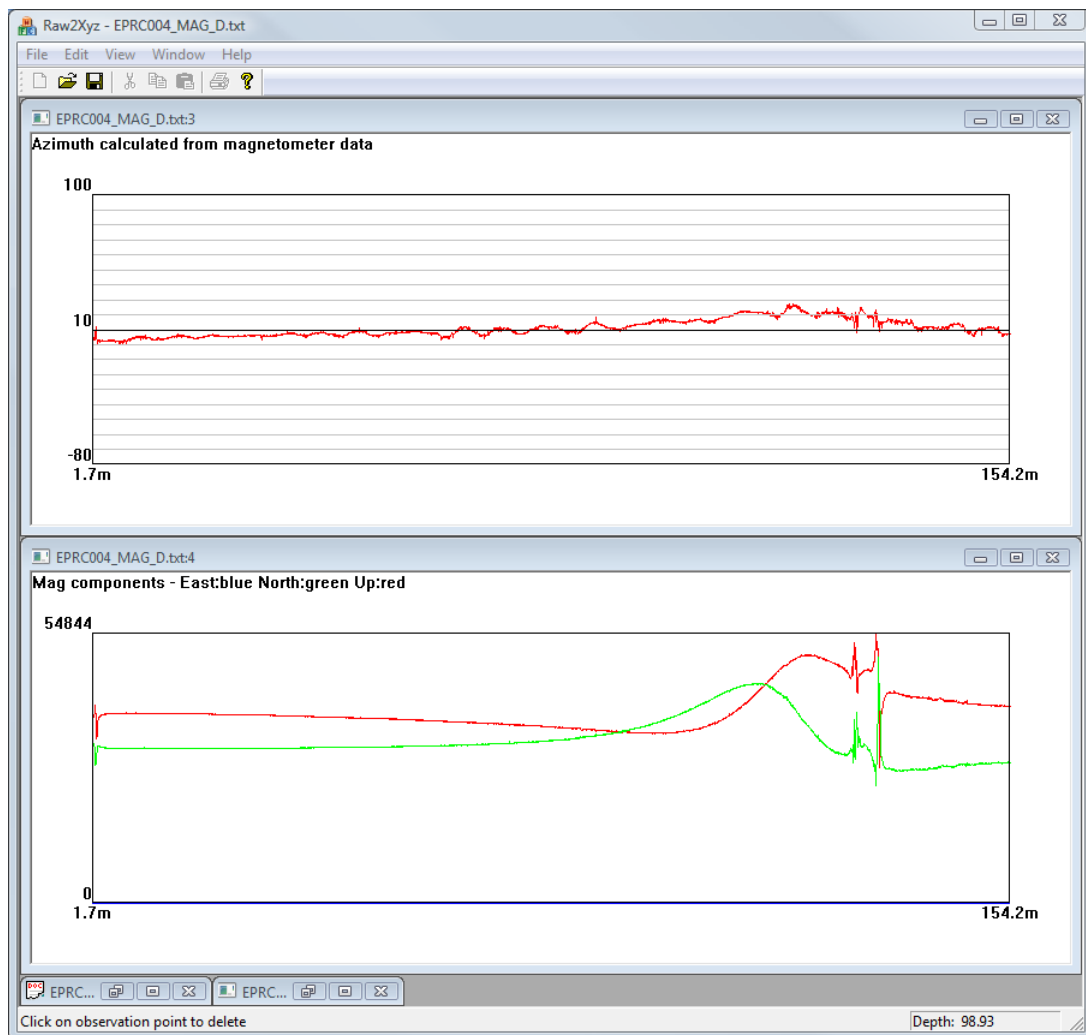
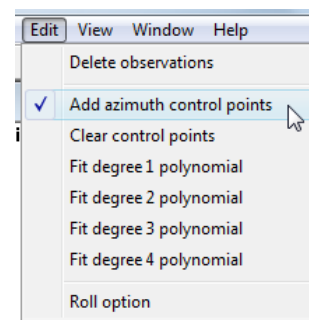


Figure 3 – Azimuth and Magnetic profiles after spikes have been removed.

Consider the azimuth profile. It is apparent that the distortion in the profile in the bottom third of the hole is related to the magnetic field anomaly. Also we know that the track of the hole must be reasonably smooth, given the length of the drill rods and the relatively small hole diameter. Therefore we propose that a smoothed version of the azimuth profile would be a better representation of the true azimuth.

Raw2XYZ provides a set of menu commands that allow you to fit a smooth curve to the azimuth profile. The smoothed version of the azimuth is then used for calculating the geographical locations of the observation points and the East, North, Up magnetic field components.



The procedure is as follows (all commands are in the **Edit** menu):

1. Check the **Add azimuth control points** command. When over the Azimuth window the cursor becomes a cross.
2. Click on the azimuth profile to mark a set of points that represent the curve that you believe best represents the true azimuth profile. The points (“control points”) are marked by blue crosses, as in [FIGURE 4](#), where five points have been marked:

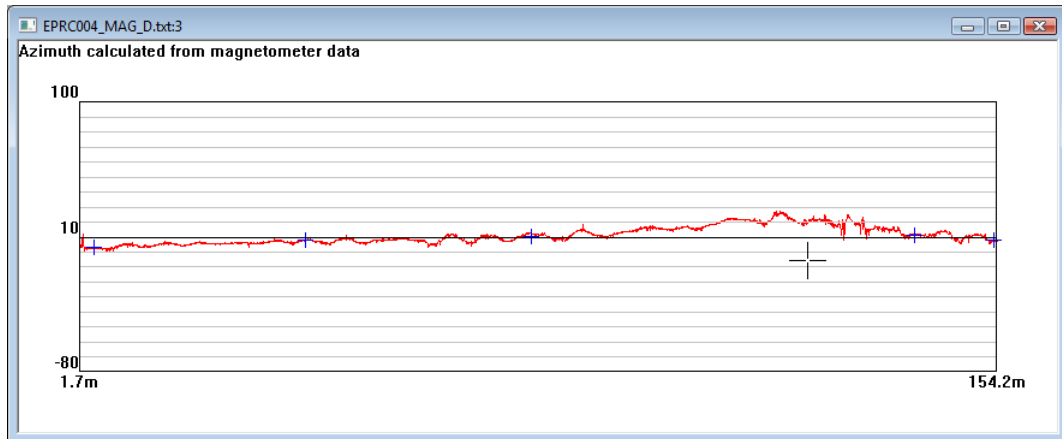
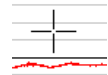


Figure 4 – Marking azimuth control points (blue crosses)

3. Fit a polynomial of appropriate degree to the control points, as in [FIGURE 5](#). Raw2XYZ then uses the polynomial curve as the true azimuth. Notice that the East magnetic field component is no longer zero as it is not being used to calculate the azimuth – this is now done by the polynomial.

Of course using this technique, and in particular positioning the control points and choosing the degree of the polynomial, is a judgement that the interpreting geophysicist must make on a case by case basis. That is why the program has not been made fully automatic.

4. If you put a point in an inappropriate place, click **Clear control points** and start again.

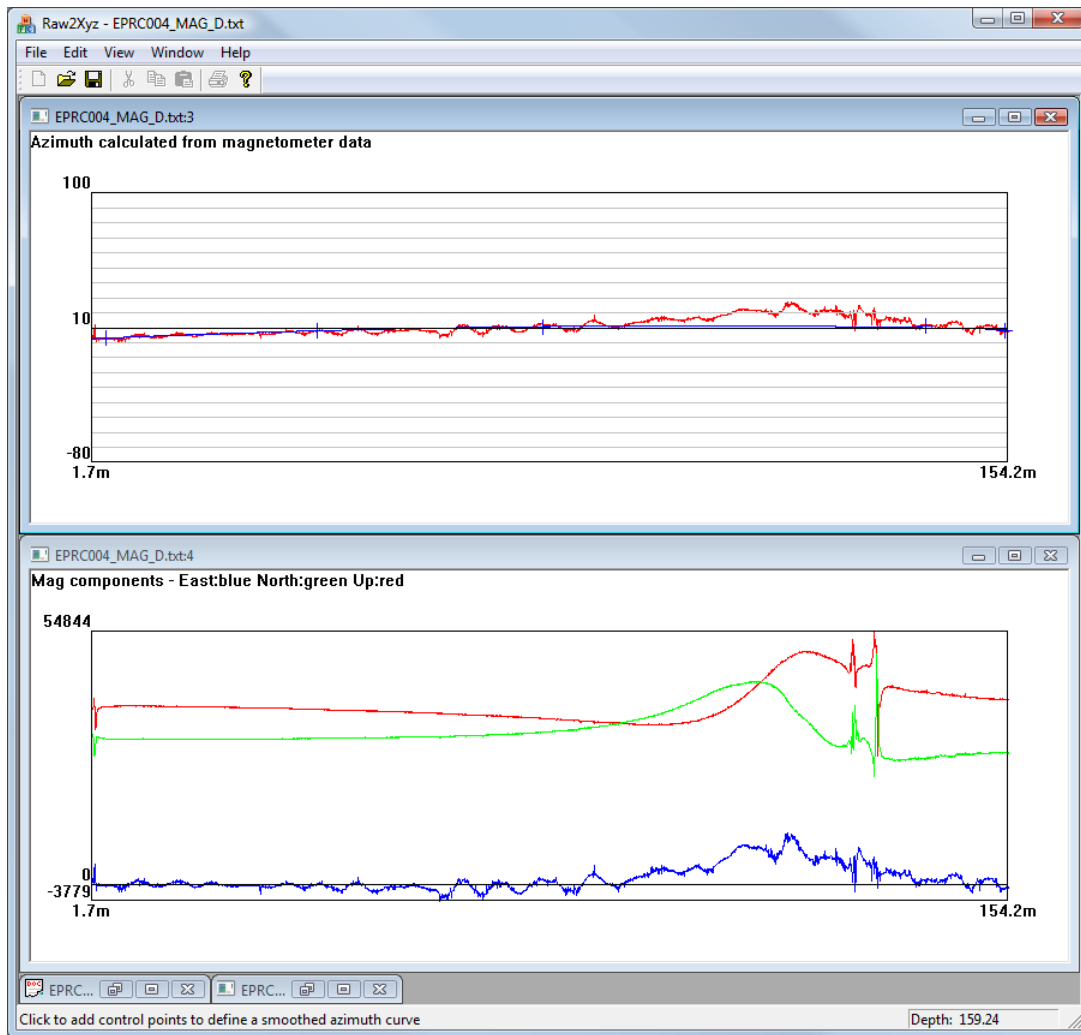


Figure 5 – Degree 2 polynomial fitted to control points

Exporting to Potent

Once you have (optionally) cleaned up the observations and smoothed the azimuth profile simply click the **Export XYZ** command (**File** menu) to export the transformed data into an XYZ file that is easily imported into Potent.

The channels exported are Easting, Northing, Height, TMI, MagEast, MagNorth and MagUp, as in this example:

```
/East North Height TMI magE, magN, magZ
Li EPRC004_MAG_D
2425079.95 46960204.23 -9.25 49749.79 1869.65 32421.04 37688.49
2425079.95 46960204.25 -9.29 49735.13 1788.33 32398.12 37692.79
2425079.95 46960204.27 -9.34 49791.94 1456.79 32304.57 37861.99
2425079.94 46960204.29 -9.39 49786.25 1505.05 32301.35 37855.36
...
...
Etc.
```

The Li line is used by Potent to recognise the name of the hole.