Processing Vertical Component Magnetic Survey Data

GOPH 547

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Contents

Abstract

Anomalous bodies in the subsurface produce strong magnetic fields that are detectable via geophysical instruments. These magnetic fields vary with the predicted theoretical values and as such, these magnetic fields can provide information within that local regions subsurface geology composition. The investigation explores raw supplied magnetic data and applying typical corrections to it. Corrections include removing the regional variation on the raw magnetic data's vertical component. Upward and downward continuation concepts were also explored, with figures illustrating their effects on the processed data.

Background and Theory

Magnetic fields on the Earth can be represented by a 3D vector. The overall magnitude of the magnetic fields tends to be at maximum near the poles while weaker at the equator. Radial component of the magnetic field are stronger at the poles while the tangential are stronger at the equators. The component of the 3D vector that is of most interest in geophysical surveys is the Fz or vertical component represented by;

$$F_z = \left(\frac{\mu M}{G\rho}\right) U_{zz} = \left(\frac{\mu M}{G\rho}\right)\frac{\partial g_z}{\partial z} \tag{1}$$

whose use is in making plots of pseudo gravity that are useful for interpretation of the data.

Magnetic data usually comes in the form of derivatives of magnetic potential in the z direction which is used to highlight edges of anomalies and enhance local shallow features. Once raw magnetic data is collected, corrections need to be applied like gravity data. The investigation required us to perform residual removal at first, eliminating the regional variation with respect to x and y directions. To explain what residual removal really is, it is the result of leftover material which can affect and change the magnetic field. Removal of this residual variation improves resolution.

Upward continuation is an extrapolation method in order to process magnetic data so that, in some cases, it can be made more significant. It is an inversion problem. The method involves using measurements at a lower elevation and then extrapolating upward while making a key assumption of continuity of subsurface strata. It tends to lessen noise as it is an averaging process and omits effect of shallower, irrelevant material. The following theoretical equation;

$$F_z(x',y',-h)=\frac{h}{2\pi}\int_y\int_x\left[\frac{F_z(x,y,0)}{R^3}\right]dxdy=\frac{h}{2\pi}\int_y\int_x\left[\frac{F_z(x,y,0)}{\left\{(x-x')^2+(y-y')^2+h^2\right\}^{\frac{3}{2}}}\right]dxdy \quad (2)$$

was used to perform upward continuation of raw data, after residual regional variation effects were removed.

Downward continuation is a forward problem. It is a method used to estimate magnetic field at a surface below the which where data was observed and measured. Continuity of field is also assumed in this method. It amplifies noise since noise are high frequency, low wavelength. However this method gave us much more detailed results since its magnetic field is being calculated closer to the surface. The following recursion equation;

$$\begin{aligned}F_z(x',y',+h)\approx 6F_z(x',y',0)-\cdots\\ \cdots-\{F_z(x'-h,y',0)+F_z(x'+h,y',0)+\cdots\\ \cdots+F_z(x',y'-h,0)+F_z(x',y'+h,0)+\cdots\\ \cdots+F_z(x',y',-h)\}\end{aligned} \quad (3)$$

was used to perform downward continuation, again after residual regional vacation effects were removed previously.

Method and Algorithm

Beginning the lab dealt with mostly plotting the raw magnetic data. Using built in Matlab functions to create figures, first the contour function was employed to plot the 2D raw data. The raw Fz data was then plotted against x and y coordinates. This allowed us to have a visual context of the regional variation in the Fz data which was later removed in the following questions.

The next question had us create a linear fit to the data using polyfit function and storing that as a variable. This variable was then subtracted from the Fz component of the raw magnetic data with respect to x and y so that the regional variations in x and y were eliminated. A first order polynomial was then fitted to the data using the matlab function **polyfit()**, which was also used to attain the coefficients of the polynomial. Then the linear components of the regional variations in the y direction was removed by subtracting it from Fz. This was then repeated for regional variations in the x direction.

Finally, upward and downward continuation was performed to the data to examine how the anomalies respond in the resulting figures. The algorithm employed the equations used in the background theory (2 and 3) to perform the processing. Nested for loops were used in the implementation to survey through all grid points and then apply said equations. The step size or h value used for the upward and downward continuation was, for both, 30. Once the figures were finally plotted after the implementation of the upward/downward continuation, clear distinctions could be made to see how the data was enhanced to provide more relevant detail of the subsurface anomalies, which can be proved to be helpful in interpretation.

Results and Discussion

To begin, the first figure shows a 2D contour plot of raw magnetic data in the local region. The magnetic field seems to be strongest in the north of survey area, along Y axis. As this is raw data, it suffers from non-zero constant component (residual) and linear components of regional variations have yet not been removed from the data and further processing is needed.

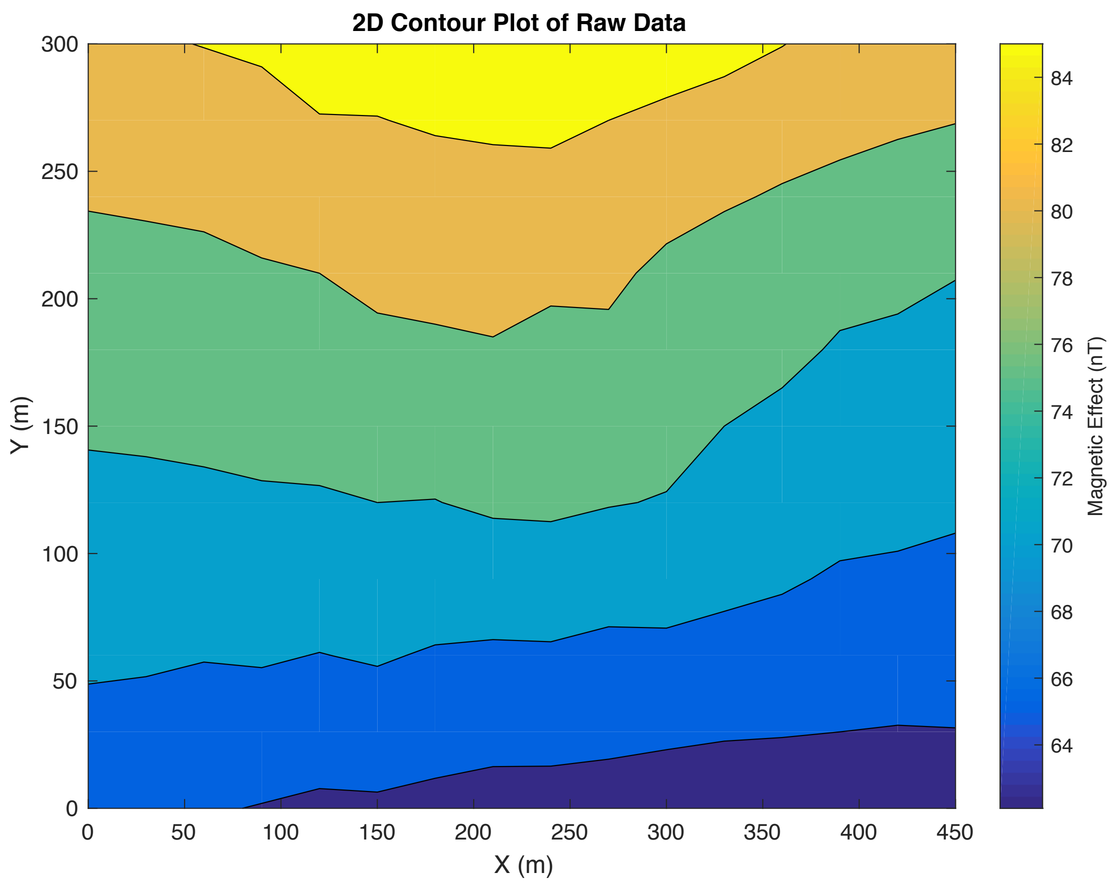

Figure 1: 2D contour plot, raw magnetic data

The bottom figure 2 illustrates the raw data in a slightly different manner; with respect to x and y directions separately. To note, it is evident there is greater variation in the Y direction whereas the X direction is a lot less variant in magnitude.

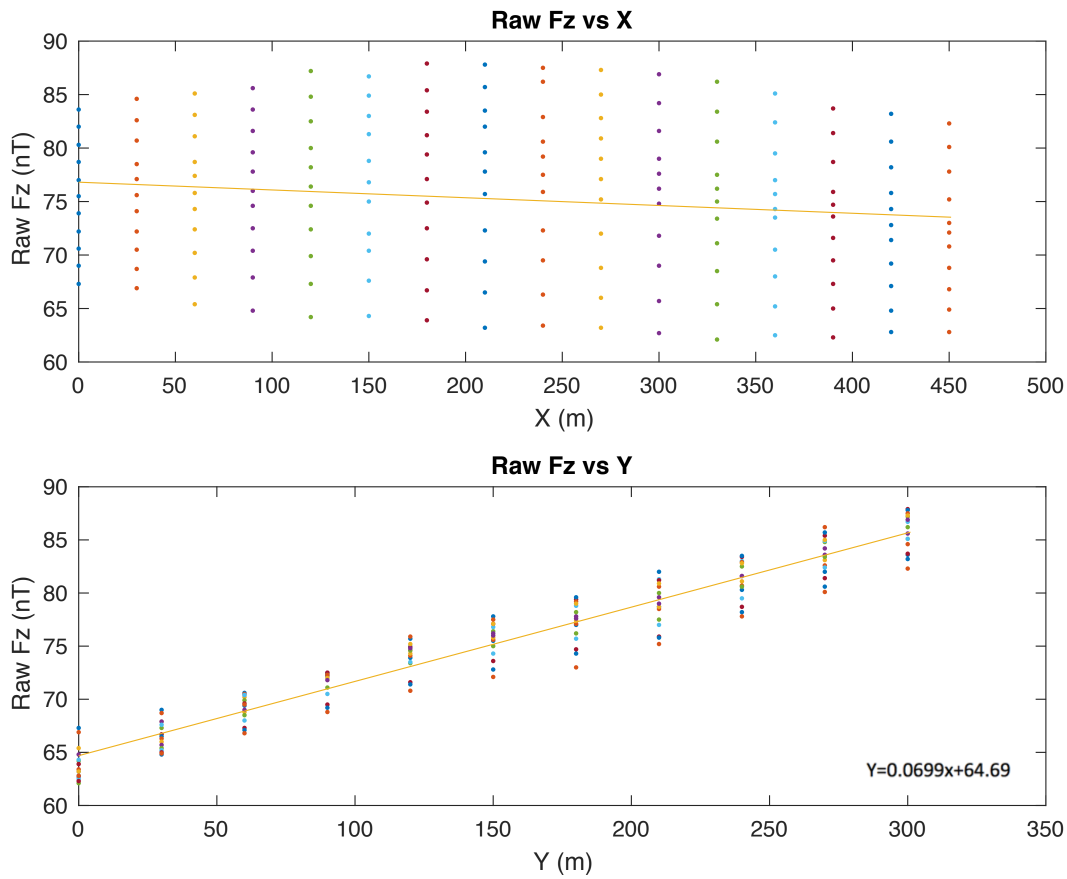

Figure 2: raw magnetic data Fz plotted with respect to X and Y

Figure 3 is produced after applying regional corrections. The y component of the variation was removed and plotted. There seems to be magnetic high in centre of plot and magnetic field strength decreases with respect to distance as you move away from centre in the x direction. However, strong magnetic fields are still found in the Y direction as you move away from the centre in Y direction.

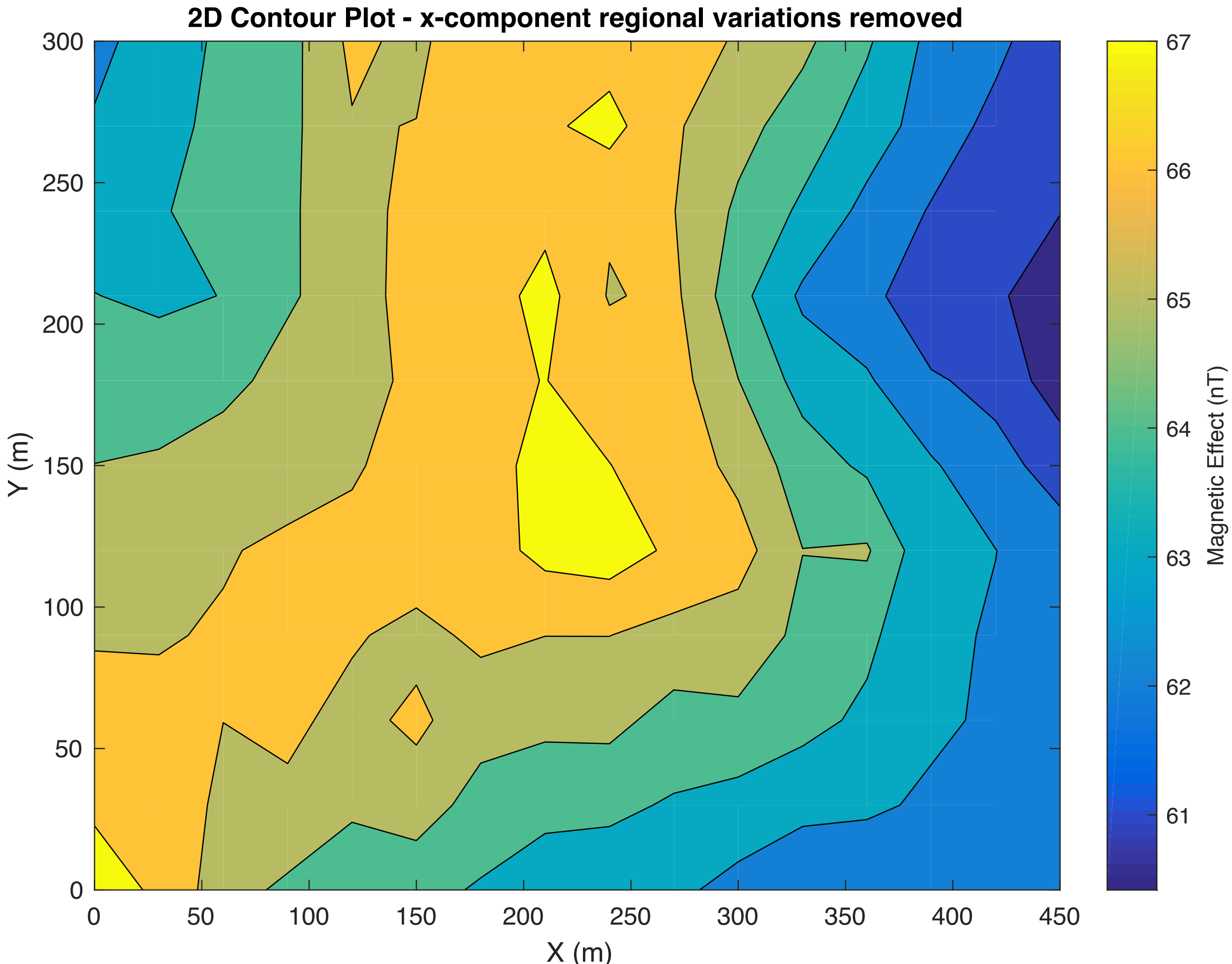

Figure 3: 2D contour plot after y component regional variation removed

The following plots show the effects of regional variations being removed. We can see in the top two figures that the X component was removed, which is reflected n the linear plot. Once both x and y components are removed, in figure 7 we can see the linear plots are constant since they are both horizontal. The second 2D contour plot (figure 6) shows all residual and regional variations removed by removing minimums of Fz. It is important to note the scale change in the colorbar. We can clearly note the change in the contour plots that can aid in interpretation of the figures, seeing how the anomolous body is more pronounced in figure 6, compared to figure 4.

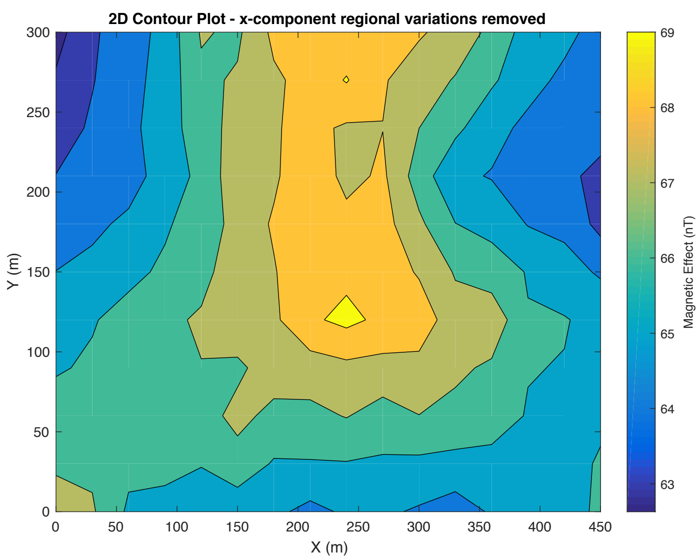

Figure 4

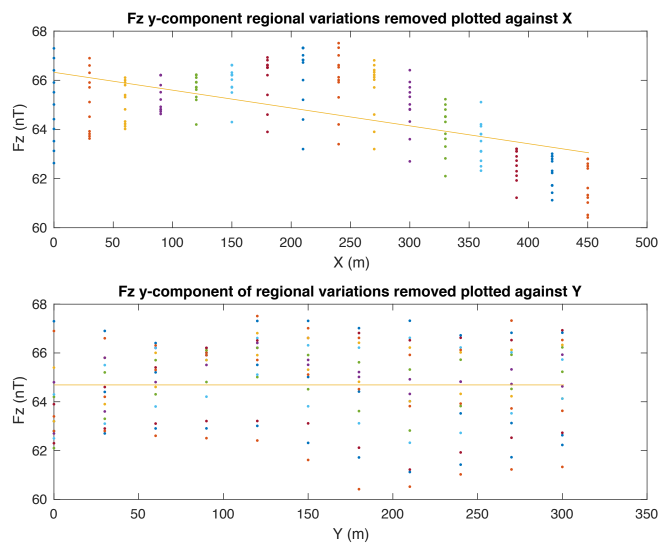

Figure 5

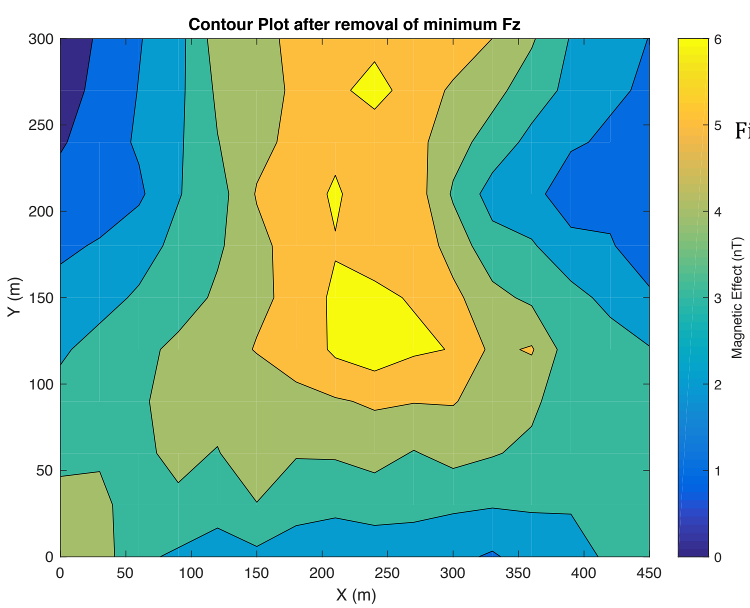

Figure 4

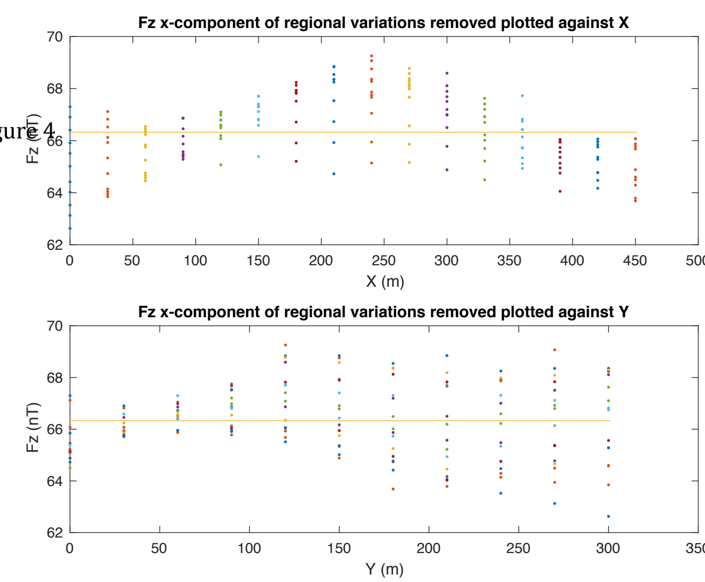

Figure 6

Figure 7

The final part of the laboratory involved performing upward and downward continuation. Using the integral finite-difference method (equation 2), figure 8 was generated which essentially shows a more 'zoomed out' view of the region, by step size 30m. It is also important to note the scale changes, getting less intensive as we are zooming out. This general area of the anomalous body is still the same yet we can now see the edges at the bottom. This plot also is much smoother as it tends to remove noise.

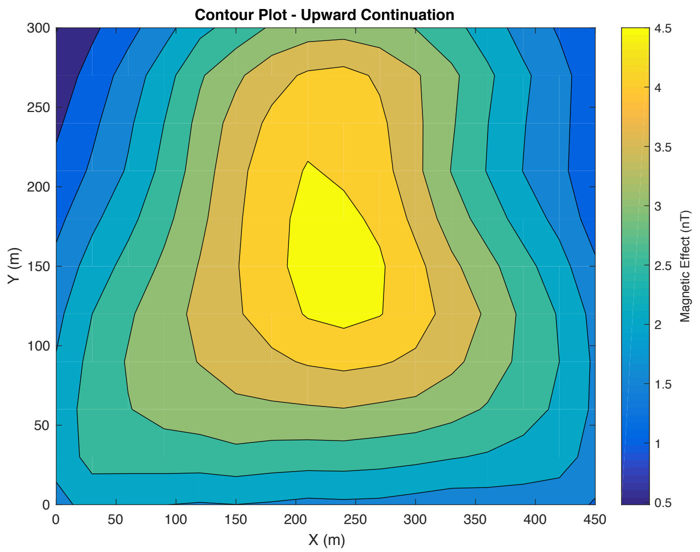

Figure 8: applying upward continuation in local area

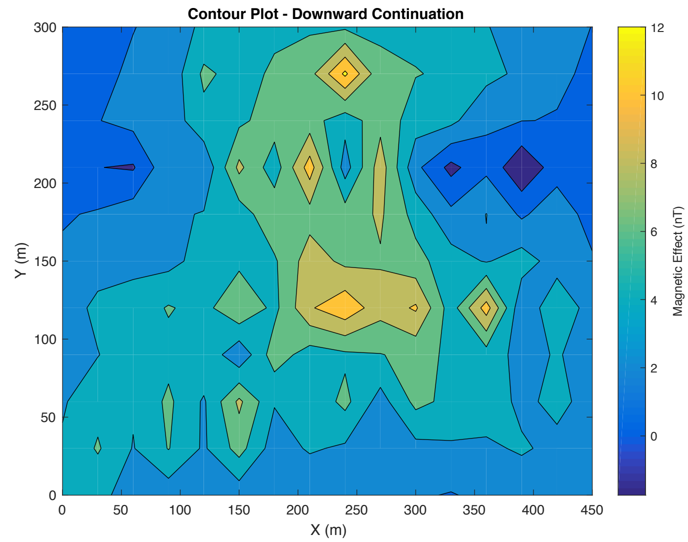

Figure 9: applying downward continuation in local area

Figure 9 shows the effects of downward continuation. The figure seems a lot more noisy which is understandable as downward continuation tends to amplify noise. We are essentially 'zooming in' into the area, which might help us pinpoint locations where the anomaly signature is coming from, instead of just being a seen as a large body in figure 8. Also to note is the scale becomes higher in intensity showing that we are more 'closer' to anomalies. Downward continuation seems to illustrate that, rather than just one large anomalous body, there may possibly be smaller separate bodies in the subsurface, which again aids our interpretation of the data.

Conclusions

The investigation explored raw magnetic data and how to process. As like gravity data, it is important to perform corrections before doing any interpretations. Regional variations needed to have been removed from the X and Y directions, affecting the Fz component of the raw data. If you compare the final figure to the raw data in figure 1, one can observe the necessity of these corrections. While looking simply at the 2D contour plot in the beginning, it was hard to pinpoint where exactly the anomalous region is. After applying corrections, we can see it is in the centre of the survey area. Later on, upward and downward continuation to the data was applied. Upward continuation essentially zoomed out of the survey area, which highlighted where the edge of the anomaly may be. It also smoothed out the data, since the upward continuation process tends to remove noise. While downward continuation 'zoomed' into the survey area. It provided insight that instead of there being a large anomalous body in the centre, there may be instead three smaller bodies that may be contributing to the effect. Having a higher resolution image of the subsurface increases the chances significantly at correctly locating the anomaly. Which is very important to the industry since misplacing an anomaly can be an extremely pricey mistake to make.

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References

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