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# Using Ground Magnetics to Detect Limestone in Masvingo, Zimbabwe

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**Abstract:** ***Ground magnetic geophysical survey techniques were successfully applied to detect near-surface limestone deposits in karstic terrain of the Nyanda Mountains in Masvingo, Zimbabwe. The broad aim was to establish the geomagnetic total field anomaly maps that reveal the metamorphic and sedimentary units in the study area thereby identifying limestone reserves crucially required for mostly cement production. The results from the mountain range surveyed confirmed that buried limestone units existed within an undulating karstic topography which correlated perfectly well the reconnaissance and geological mapping in exposed areas. Limestone, being non-magnetic was characterized by low values in the surveyed area. Ground magnetic survey was preferred not only because of its cost effectiveness but also that compared to alternative ground penetrating radar and resistivity methods often used in limestone exploration; it is very convenient in the otherwise difficult terrain. The results produced very encouraging and usable clearly delineated maps.***

**Keywords:** geophysical survey; limestone; geomagnetic field; non-magnetic; anomaly

## 1. Introduction

Although limestone is also often explored using the ground penetrating radar and resistivity, the magnetic method was seen to be more convenient given its cost effectiveness and suitability in the difficult mostly almost vertical terrain. The study has beneficial implications to the cement making industry as it could then easily exploit the precisely located limestone reserves. The study sought to test whether ground magnetic method can be useful in uniquely mapping and confirming the presence or absence of limestone reserves in a complex subsurface geology having varying magnetic nature.

The study area, Nyanda Mountains are located within the Masvingo Greenstone Belt (MGB). The structure and subsurface configuration of the Belt (MGB) which lie in the Zimbabwe Craton (ZC), were previously investigated using aeromagnetic and gravity data. Magnetic maps compiled from the Zimbabwe Geological Survey national aeromagnetic data set show the bulk of the greenstone belt to have low magnetic anomaly values associated with limestone, but with high magnetic anomaly values along its northern and western margins over ultramafic units and banded iron formations. The younger granites generally show higher magnetic anomaly values compared to both the greenstone belt and the older gneisses. A pronounced east-northeast-trending broad magnetic high is observed over the Charumbirapluton, and its edges mark the boundaries with the greenstone belt to the north, and the Limpopo belt to the south; with the latter characterized by low magnetic values. Several linear, small amplitude magnetic lows, which are mostly due to faults, trend northwest to southeast and north to south, with some revealing an apparent dextral movement. The information obtained from modeling, derivative maps and depth slicing suggest a trough-shaped configuration for the MGB, which is consistent with other known greenstone belts on the ZC and elsewhere. This information is consistent with an intra-cratonic, extensional rift environment for emplacement of the greenstone belt (Hoover etal 1992).

## 2. Theory

### Ground magnetics

The magnetic method is a passive method, relying on no controlled source but seek to delineate naturally occurring variations in magnetic field. Anomalies arise due to variations in some specific physical property of rocks which are a function of the rocks' entire history and their present state. Lateral variations in rock magnetization give rise to magnetic anomalies. The aim of a magnetic survey is to investigate subsurface geology on the basis of anomalies in the Earth's magnetic field resulting from the magnetic properties of the underlying rocks. According to Kearey, P (1984), although most rock-forming minerals are effectively non-magnetic, certain rock types contain sufficient magnetic minerals to produce significant magnetic anomalies. Similarly, man-made ferrous objects also generate magnetic anomalies [12]. Magnetic surveys can be performed on land, at sea and in the air.

The magnetic field **B** due to a pole of strength m at a distance r from the pole is defined as the force exerted on a unit positive pole at that point

$$\mathbf{B} = \frac{\mu_o m}{4\pi\mu_R r^2}$$

The anomaly can have a horizontal component (**ΔH)** and vertical component **(ΔZ),** so if I is the inclination,

$$\Delta\mathbf{B} = \Delta\mathbf{Z}\sin\mathbf{I} + \Delta\mathbf{H}\cos\mathbf{I}\cos\alpha$$

To remove regional gradients, the single dipole approximations of the earth's field may be used. The equations are given as:

$$\mathbf{Z} = \frac{\mu_o}{4\pi}\frac{2M}{R^3}\cos\theta,\ \mathbf{H} = \frac{\mu_o}{4\pi}\frac{M}{R^3}\sin\theta,$$

$$\frac{\partial Z}{\partial\theta} = -2\mathbf{H},\ \frac{\partial H}{\partial\theta} = \frac{Z}{2}$$

**Z** and **H** are vertical and horizontal field components and θ is the colatitude angle in radians, R the radius of the earth, M the magnetic moment of the earth and $\frac{\partial Z}{\partial \theta}$ and $\frac{\partial H}{\partial \theta}$ are rates of change of **Z** and **H** with colatitude respectively.

Magnetic anomalies caused by rocks are localized effects superimposed on the normal magnetic field of the Earth (geomagnetic field). All magnetic anomalies caused by rocks are superimposed on the geomagnetic field in the same way that gravity anomalies are superimposed on the Earth's gravitational field. The geomagnetic field is geometrically more complex than the gravity field of the Earth and exhibits irregular variation in both orientation and magnitude with latitude, longitude and time. This is generally at an angle to both the vertical and geographic north. The dip of magnetic fieldis the *inclination* of the field and the horizontal angle between geographic and magnetic north is the *declination D*. In the southern hemisphere the dip is generally upwards towards the north. The line of zero inclination approximates the geographic equator, and is known as the magnetic equator. About 90% of the Earth's field can be represented by the field of a theoretical magnetic dipole at the center of the Earth inclined at about 11.5° to the axis of rotation. The magnetic moment of this fictitious *geocentric dipole* can be calculated from the observed field.

## 3. Study Area

The Nyanda mountain range is about 15km south east of Masvingo town, along the Masvingo-Beitbridge Highway. The survey site is bounded by 7772600N 260800E; 7772600N 262200E; 7772000N 262200E; 7772000N 260800E in local coordinates, ARC1960 UTM zone36S.

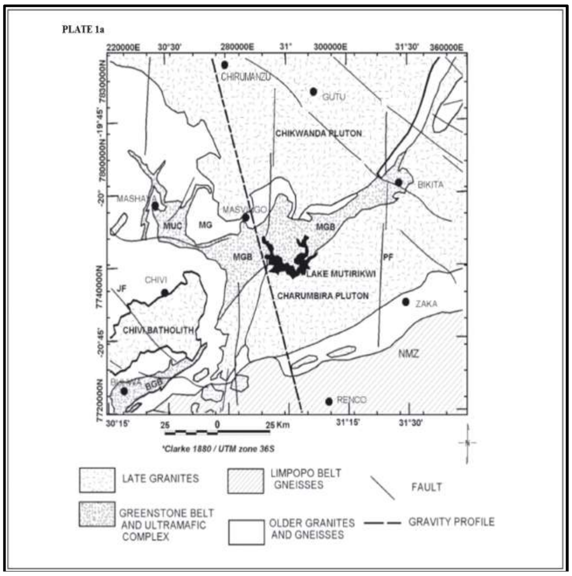


**Figure 1a:** shows the MGB and surrounding geologies

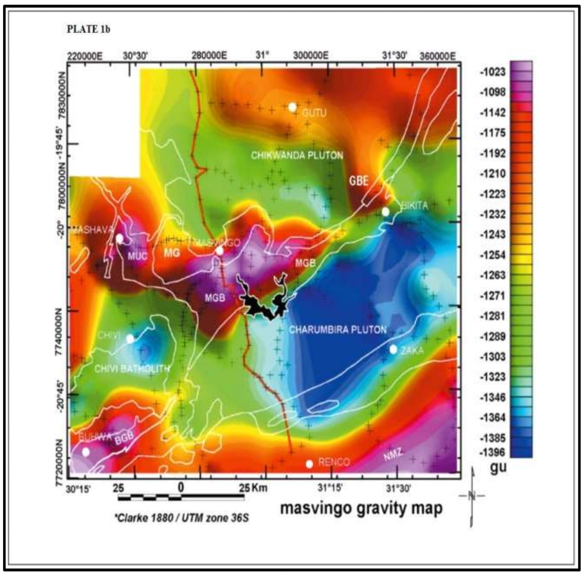


**Figure 1b**: Shows the MGB gravity map

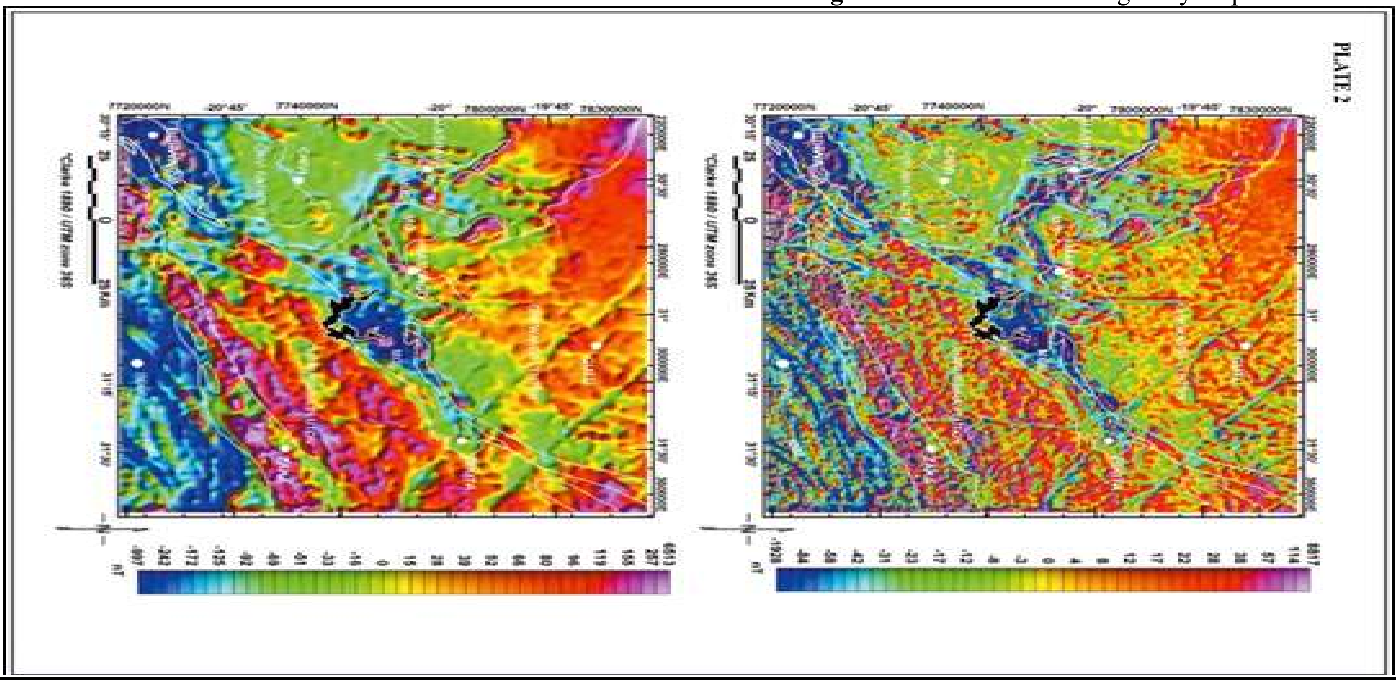

**Figure 2:** showing the magnetic anomaly maps of the MGB and surrounding geologies

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## 4. Methodology

The magnetometer used was the proton precession magnetometer. During the survey, all sources of artificial noise must be eliminated. Such include metallic gadgets carried by the operator or vehicles. Diurnal corrections are essential in most field work, unless only gradient data are to be used. If only a single instrument is available, corrections have to rely on repeated visits to a base or sub-base, ideally at intervals of less than one hour. At the start of each survey day the diurnal magnetometer must be set up. Data reduction was carried out using GEMlinkW 3.0 software and presented as Excel (*.xls) for MapInfo, and GEOSOFT grid files.

## 5. Results and Discussions

Below are a series of maps and plates of the grids and filtered grids which resulted from the magnetic survey for limestone detection. The image displayed first, Figure 3 is a grey scale raster image for the magnetic data as processed by Oasis Montaj. The darker regions are those with very low magnetic readings as compared to the regions with brighter shades. The Minimum curvature gridding method (RANGRID GX) fits a minimum curvature surface to the data points using a method similar to that described by Swain (1976) and Briggs (1974). This minimum curvature surface is the smoothest possible surface that could fit the data values.

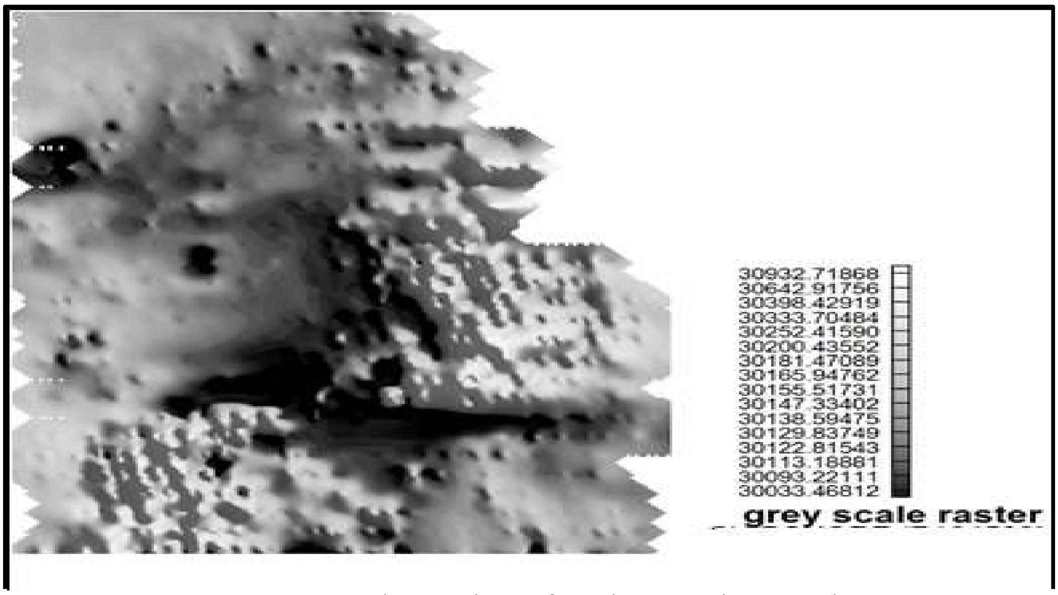


**Figure 3**: Grey scale raster image from the magnetic survey data

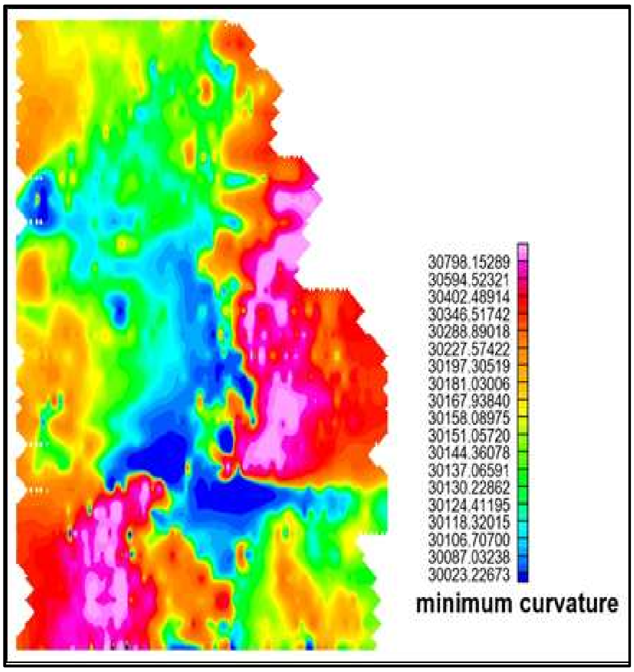


**Figure 4:** A minimum curvature grid

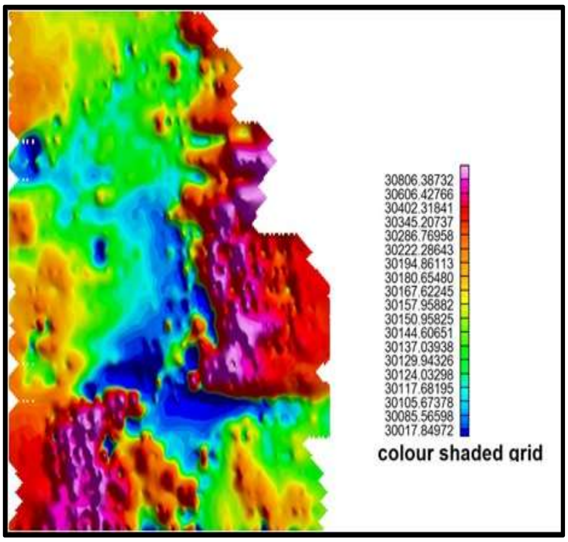


**Figure 4**: bcolour shaded grid

Minimum curvature first estimates grid values at the nodes of a coarse grid. This estimate is based upon the inverse distance average of the actual data within a specified search radius. If there is no data within that radius, the average of all data points in the grid is used. By using the scale to the right of the grid, the deep blue regions are of the lowest magnetic values and the bright pink are of the highest magnetic field values recorded. After gridding, several filters were applied to the minimum curvature grid so as to remove noise, remove regional trends and enhance geological features. The objective, according to Reeves C,(2005) is to select a filter and parameters that did not introduce additional noise into the data (Kearey, 1984). 1D filter were applied to the nT channel in the database, while 2D filters were applied to gridded data used during image processing.

The filters applied to the data were the 3X3 convolution, 5X5 symmetric convolution, 9X9 symmetric convolution, a grid math application, analytic signal, automatic gain correction, horizontal gradient filters, trend surface removal and vertical derivative convolution. After applying all the different gridding methods, the colour methods and the filtering methods, a final colour shaded grid (figure 4b) was produced. This was the one placed on the fore during the magnetic data interpretation and the anomalies were mapped on this grid. All the other geological integrations such as sheer zones, faults, throw backs and cuts that were noted from the various grids and filters were also overlain on this grid during interpretation.

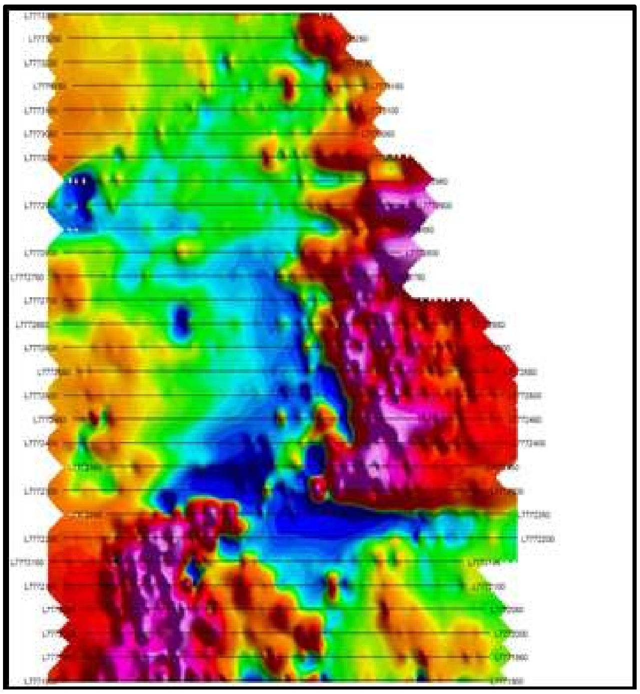

**Figure 5:** showing the line path on the colour shaded grid

## 6. Interpretation

All the maps, grids and plates discussed in sections above were scrutinised to come up with the qualitative interpretation. The areas with intermediate low magnetic values and close to with those with high magnetic values so can be considered as geologically ambiguous and hence need to be mapped out of the target areas which has low magnetic values. Looking at figure 4b, the areas with very low magnetic values can be seen to occupy mainly the middle most areas of the grid, bounded by northings 7772000N and 7772750N and eastings 262500E and 263000E. The low value anomaly is broken by a fault at 7772250N.

Figure 4a and figure4b are the main final maps showing the low magnetic value sites which are likely to contain the limestone, the target.

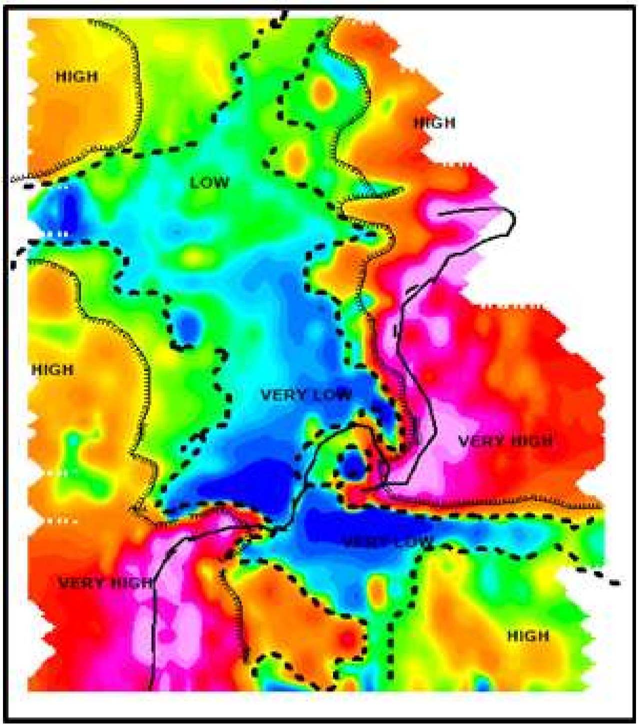


**Figure 6:** filtered grid showing the interpreted survey area

In figure 5, figure 6, figure 7 and figure 8 lines are added to grids to show anomaly demarcations. The fault line which is also the line with highest magnetic values is shown over the fault and it cuts the magnetic low region which is bounded by the broken lines. The target site can be seen to fill the centre of the grid, while the areas with magnetic high values area edged out by the teeth lines. The words HIGH, VERY HIGH, LOW, and VERY LOW are embedded in the grid to indicate areas with high, very high, low and very low magnetic values respectively.

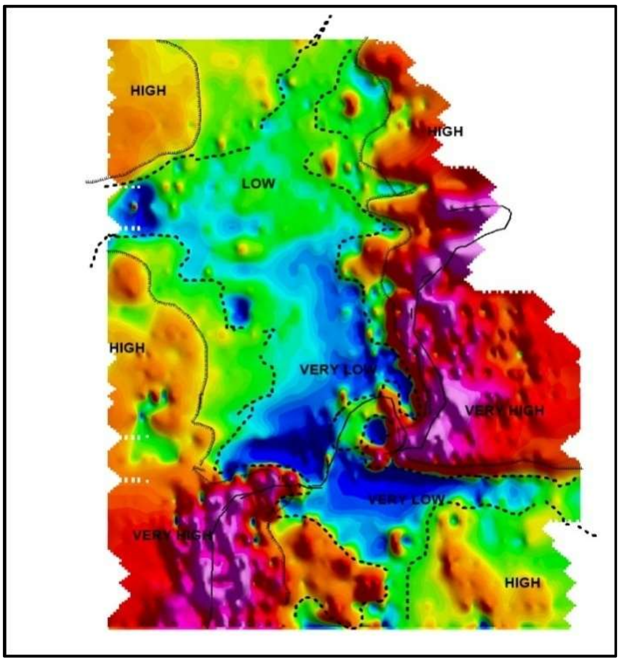


**Figure 7:** showing interpreted colour shaded grid

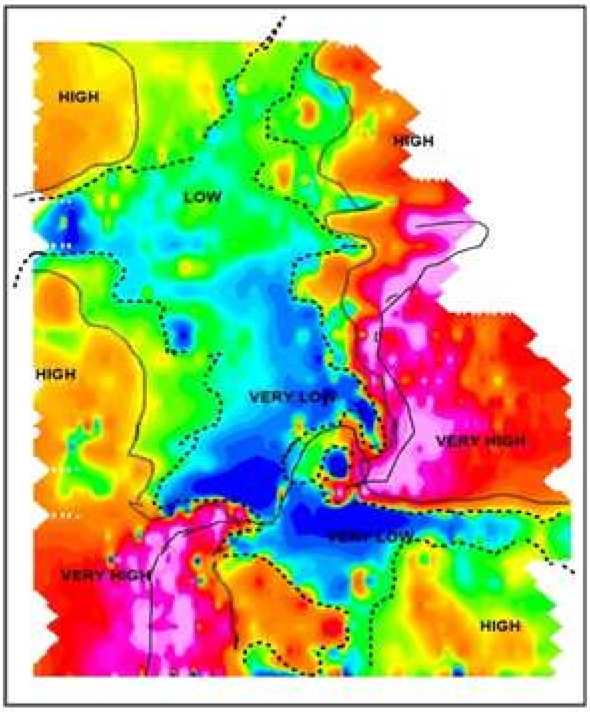


**Figure 8:** Showing interpreted minimum curvature grid

## 7. Conclusions

From this study and based on the interpretations outlined above, it can indeed be firmly established that limestone can be explored using its anomalously low magnetic property. The results of the magnetic study tallied very well with the geological mapping and outcrop field observations were the limestone was exposed and very closely exposed to the surface. As can be seen from the aeromagnetic map of the area, there is a general trend of magnetic low in this region which can possibly be attributed to the presence of limestone. These positions gave the least values of the magnetic signatures. Although the limestone reserves are clearly spread over a large region, were they are mostly concentrated and closest to the surface is very visible from virtually all the maps. The geo-database can be further upgraded for the whole of the Nyanda Mountain area and other surrounding areas with this new magnetic survey data.

A new set of data with the z element (elevation) still need to be taken in a new survey so as to carry out the third dimension interpretation which maps out the ore body and show the dip and strike of the anomalous body (source modelling). This study provides usable information as it is. It also forms a firm reference point for future studies involving the z element which is necessary for reserve quantity estimation as the lateral extent was well established.

## References

[1] **Hoover, D.B., Heran, W.D. and Hill, P.L.,** 1992,*The Geophysical Expression of Selected Mineral Deposit Models*, United States Department of the Interior, Geological Survey Open File Report 92-557, p. 128
[2] **Mussett, A.E. and Khan, M.A., 2000**, *Looking into the Earth: An Introduction to Geological Geophysics*, Cambridge University Press, Cambridge, p.470.
[3] **Parasnis, D.S.,** 1996, *Principles of Applied Geophysics* (Fifth Edition), Chapman & Hall, London, p.456.
[4] **Telford, W.M., Geldart, L.P., Sheriff, R.E. and Keys, D.A.,** 1990, *Applied Geophysics* (Second Edition), Cambridge University Press, Cambridge, p.770.
[5] **Van Blaricom, R.,** 1992, *Practical Geophysics II*, Northwest Mining Association, Spokane, p. 570.
[6] **Milsom, J.,** 2002, *Field Geophysics* (Third Edition), University College London.
[7] **AshwalD.,** 1997, *Greenstone Belts, Oxford Monograph on Geology and Geophysics*, Clarendon Press, Oxford, p. 567-580.
[8] **Reeves C,** 2005, *Aeromagnetic Surveys Principles, Practice & Interpretation,* Geosoft, Canada.
[9] **Kearey, P. and Brooks, V.**, 1984, *Introduction to Geophysical Exploration*, Chapter 2, p 10-26.
[10] **William J., et al, 2013,** *Exercises Overview for Gravity and Magnetic Exploration: Principles, Practices, and Applications* Cambridge University Press, p.512.

## Author Profile

**Bernard Siachingoma** has done Masters in Geophysics. Presently he is serving as Lecturer at Midlands State University, Zimbabwe. His research interests include Geophysics. He is also a PhD Scholar.