ABSTRACT
Migori greenstone belt is one of the major mineral prospects in Kenya, major mining activities are currently conducted by the local artisans using open cast methods. In order to subject the prospect to industrial use, a good understanding of the geophysical features in the subsurface which are likely to control the distribution of minerals is necessary. In this study, a 2-D litho-prediction model of Nyabisawa-Bugumbe area was developed from geologically constrained inversion of gravity field data. The measured gravity field data were subjected to cleaning process to remove perturbations which were not of geophysical interest, and later enhanced by removing long wavelength anomalies which are as a result of regional trend. The density variations were then inverted for the geometrical parameters of the model. Gravity high trending NW-SE around Nyabisawa, Kirengo towards Nyambeche was delineated. The gravity high is bounded by two major faults along rivers Migori and Munyu. Integrating the 2-D inversion of gravity data and the geology of the area, the gravity field perturbation is associated with banded iron formations.

Keywords: Gravity, Anomalies, Migori Greenstone belt, Inversion, Minerals

Introduction
Geological and tectonic setting
Migori greenstone belt runs west-northwest to east-southeast between Lake Victoria and the Great Rift Valley. The geology of the area consists of Archean greenstone belt that surrounds Lake Victoria.
In this case an ability to define host structures or units as well as vein location and orientations, coupled with the facility to discriminate mineralized from unmineralized terrain is required.

Gravity technique
Gravity data is acquired with the goal of determining distributions of density. This physical property can be interpreted in terms of lithology and/or geological processes and their geometric distributions can help delineate geological structures and used as an aid to determine mineralization and subsequent drilling target (Philips et al., 2010). Because gold, which is one of the suspected mineral, is typically associated with small scale structural features, dense, good-quality data and sharp positioning are important when searching an ore body (Airo and Mertanen, 2007)

Once data is obtained from gravity survey, variations in the earth’s gravitational field which did not result from the differences of density in the underlying rocks were corrected. Drift correction
is done by having a base station which should be preoccupied periodically in the day. A drift curve is plotted and readings made in other stations assumed to have a linear drift as fitted base readings. Using the drift rate each reading is corrected to what it would have read if there were no drift.

Gravity varies with latitude because of the non-spherical shape of the earth, with polar radius shorter than equatorial radius. The theoretical value of gravity (\(g\phi\)) at given latitude (\(\phi\)) is calculated using gravity formula

\[
g_\phi = 9.78032677141 + 0.00193185138639sin^2\phi/\sqrt{1 - 0.00669437999013sin^2\phi} \text{ ms}^{-2}
\]

and it is subtracted from or added to the measured value to isolate latitude effect. As one moves away from the center of the earth, gravity decreases, the rate of decrease can be deduced by assuming spherical earth. From

\[
g = GM/r^2
\]

\[
\frac{\Delta g}{\Delta r} = -2g/r = -0.3086\Delta h
\]

Where \(g\) is gravity, \(G\) is the universal gravity constant, \(r\) is the distance from Centre of the earth, \(M\) is the mass of the earth and \(h\) is the altitude. If the site is above the reference point, free air correction is added to the observed gravity value. If the site is below the reference point, free air correction is subtracted from the observed gravity value. Bouguer correction (\(g=2\pi G\rho\Delta hg\)) where \(\rho\) is the average crustal density, is done to remove the effect of attraction of a slab of rock present between the observation point and the datum. Terrain correction is also done to remove the effect of a hill or a valley at the vicinity of a station, which ultimately reduces the gravity value.
Figure 1.1: Local geology of Migori greenstone belt (Shackleton, 1946)

For gravity model, we shall consider an infinite long linear mass distribution with mass m per unit length extending horizontally along the y-axis at depth z (Telford, et al., 1976). The contribution $d(\Delta g_z)$ to the vertical gravity anomaly $\Delta g_z$ at a point on the x-axis due to a small element of length $dy$ is

$$d(\Delta g_z) = Gmdy \sin \theta / r^2 = Gmzdy / r^3$$

$$\Delta g_z = Gmz \int_{-\infty}^{\infty} dy / r^3 = Gmz \int_{-\infty}^{\infty} dy / (u^2 + y^2)^{3/2}$$

Where $u^2 = x^2 + z^2$ the integration is simplified by changing variables so that $y = utan \varphi$.

$$dy = usec^2 \varphi d\varphi$$

and $(u^2 + y^2)^{3/2} = u^3 sec^3 \varphi$
This gives
\[ \Delta g_z = \frac{Gmz}{u^2} \int_{-\pi/2}^{\pi/2} \cos \varphi d\varphi \]

which, after evaluation gives
\[ \Delta g_z = \frac{2Gmz}{(u^2 + x^2)} \]

Methodology
Gravity data acquisition
Gravity data was collected from 200 stations established over an area of 100 km² bounded by the latitudes 34°25′E-34°30′E and longitudes 1°04′S-1°10′S in Nyabisawa-Bugumbe area of Migori Greenstone belt in Kenya (Fig. 2.1), with station and profile spacing of 300 m and 1 km respectively. Relative gravity measurements were taken using Worden gravity meter model prospect 410. the complete Bouger anomaly contains information about the subsurface density alone. A contour map of the Bouger anomaly Figure 2.2 gives a good impression of subsurface density. The interpretation of gravity data involved identifying the anomalies from the Bouger anomaly map, selecting profiles across the anomalies and subjecting the profiles to both Euler deconvolution and Forward modeling.

Euler Deconvolution theory
Euler Deconvolution aids the interpretation of gravity field. It involves determination of the position of the causative body based on an analysis of the gravity field and the gradients of that field and some constraint on the geometry of the body Zhang et al. (2000). The quality of the depth estimation depends mostly on the choice of the proper structural index which is a function of the geometry of the causative bodies and adequate sampling of the data Williams et al. (2005).

It is based on the Euler equation of homogeneity,

\[
(x - x_o)T_{xz} + (y - y_o)T_{zy} + (z - z_o)T_{zz} = n(B_z - T_z)
\]

...............3.1

for the gravity anomaly vertical component \( T_z \) of a body having a homogeneous gravity field, \((x_o, y_o, z_o)\) are the unknown co-ordinates of the source body centre to be estimated. The values \( T_{xz}, T_{zy}, T_{zz} \) are the measured gradients along the \( x-, y- \) and \( z- \)directions, \( n \) is the structural index and \( B_z \) is the regional value of the gravity to be estimated. In 2-D this equation reduces to;

\[
(x - x_o)T_{xz} + (z - z_o)T_{zz} = n(B_z - T_z)
\]

...............3.2

There are three unknown parameters \((x_o, z_o \) and \( B_z \) With selected window, there are \( n \) data points available to solve the three unknown parameters. When \( n \geq 3 \) these parameters can easily be estimated (Zhang and Sideris, 1996).

![Figure 2.2: Gravity profile and colour shaded map of Migori Greenstone belt](image-url)
Figures 2.3: Power spectral analysis of magnetic data of Migori Greenstone belt

**Forward modelling**

This interpretation technique is applied where the shapes and depths of anomaly sources are important. It involves preparation of gravity field models of a subsurface using all available geological information, and it is then compared with the field actually observed (Parasnis, 1986). This process was done using the grav2DC software developed by Taiwan et al (1964).

**Results and Discussion**

**Interpretation of Euler solutions**

Figures 3.1 and 3.2 below shows the vertical and horizontal gradients of the gravity field and 2-D Euler solutions for profiles AA’ and BB’. The solutions cluster well at a shallow depth estimated to be between 20 m to 1000 m. The depth of these high gravity causative bodies under profiles AA’ and BB’ coincide well with the geology of the study area which reveals stripes of banded iron formation suspected to host minerals.
D Forward modelling interpretations
Profile AA’ is used to model the gravity high anomaly centered at grid co-ordinates (665000, 9905000). The result of the forward modeling shows a dense structure with the maximum depth
to the top as 100 m, density contrast $0.1832 \text{ g/cm}^3$ and a width of 3.321 km. Figure 3.3 shows the fit between the computed gravity anomaly curve and the observed anomaly along profile AA’.

Similarly, Profiles BB’ (Fig. 3.4) is used to model gravity high anomaly centered at grid coordinates (680000, 9902500). The best fit is obtained at a depth of about 150 m, density contrast $0.3908 \text{ g/cm}^3$ and a width of 850 m.

Figure 3.3: Observed, calculated anomaly and forward model for 2-D body along profile AA’.

Figure 3.4: Observed, calculated anomaly and forward model for 2-D body along profile BB’.
Conclusion

The result of this study shows that the Northern part of Nyabisawa-Bugumbe area of Migori Greenstone belt consist of gravity highs which can be associated with relatively high density bodies compared to the surrounding rocks. An integration of this study with the geological report of the study area shows the possibility of the banded iron formations which occasionally act as a host to other minerals being the cause of the high density. These dense structures have been modelled to be at a depth of about 50-1000 m from the surface on the northern part of the study area. This also correlates well with the power spectral analysis in figure 2.3 and the Werner solutions in figure 3.5.

Acknowledgement

I wish to acknowledge Chuka University and Jomo Kenyatta University, Physics departments for availing the geophysical survey instruments. I also acknowledge the department of Mines and Geology for availing the geological report of Migori Greenstone belt.

References


