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Lithological Deformation And Its Effect On Mineralization In Migori Greenstone Belt, Kenya

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Abstract
Migori Greenstone Belt, located on the western part of Kenya is considered as one of the major gold fields in Kenya. It's mineralization is believed to occur a long a system of veins. With the continuous extraction of minerals in this belt, exploration is currently evolving from surface based exploration to subsurface exploration. This necessitates a better understanding of the geophysical features in the subsurface which are likely to have a direct bearing on the distribution of minerals. The host lithosphere is suspected to be under compression forces given that it is located between the western and eastern branches of the east African rift system, which are divergent zones. The resultant lithological deformation is expected to directly affect the mineralization within the prospect. This study was conducted to map the structural deformations and their contribution to mineralization within the belt. 2D forward modeling of gravity data using Geosoft computer program was carried out along four profiles. This was done in an attempt to detect any lithological deformation and presence of anomalous structures by attaining the best fit between the observed gravity anomalies and the calculated responses. Forward modeling reveal a series of folding and dike like structures which probably occurred as a result of the deformation of the lithosphere of which Migori greenstone belt forms part. This must have occurred from Permian times to the Miocene. From the forward models, the mineral rich layer is brought closer to the surface at a depth of approximately between 0-500 m, majorly at the crests of the folds as a result of the lithological deformation. This explains the discontinuous shallow existence and outcropping of minerals along the belt.

Key words: *Lithosphere, Gravity, Anomalies, Migori greenstone belt, Modeling*

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I. Introduction

The success story of gold mining in Migori Greenstone belt, (especially the history of Macalder mine, situated to the north-west of Migori town, in the south western Kenya) is a clear indication of the potential of this prospect in terms of mineral production. The continuous exploration of minerals within this belt has led to depletion of the mineral outcrops which initially could be worked on by the local artisans. This has resulted in evolution of mining methods from surface to sub-surface based, hence the necessity for a better understanding of the nature of distribution of the minerals.

Migori greenstone belt is squeezed between the diapiric Migori granite batholith to the south and a felsic volcanic succession to the north. The structure of the Migori greenstone belt appears to reflect diapiric movements of the Migori Granite batholiths. The geology of the area consists of Archean greenstone belt that surrounds Lake Victoria. The Archean rocks in this area are principally of the Nyanzian system, the Kavirondian system and the post-Kavirondian granites (Shackleton, 1946).

Gravity and magnetic methods have evolved from their sole use for mapping basement structures to include a wide range of applications, such as locating intra-sedimentary faults, defining subtle lithological contacts, mapping salt domes in weakly magnetic sediments and better defining targets through 3D inversion (Nabighian *et al*., 2005). These physical properties can be interpreted in terms of lithology and/or geological processes and their geometric distributions can help delineate geological structures and can be used as an aid to determine mineralization and subsequent drilling target (Philips *et al*., 2010).

Where the shapes and depths of anomaly sources are important, gravity and magnetic data are usually interpreted by the method of forward modeling. The gravity field of a subsurface model is prepared using all available geological information and compared with the field actually observed. The model is then modified, within the limits set by the geological constraints, until a satisfactory level of agreement is reached between calculation and observation.

II. Materials

Ground Gravity data from 425 gravity stations was collected within Migori greenstone belt bounded by the latitudes $34^0$15' E, -$34^0$40' E and longitudes $0^0$55' S, $1^0$12' S using Worden gravity meter model Prospector 410. This was done from the month of June to August 2018. Gravity meters require calibration and even then measure only differences in gravity field between two points rather than absolute field values. This survey was therefore based on a network of readings ultimately linking back to one point of known absolute gravity. The position co-ordinates were obtained using a hand held GPS.

III. Methods

Gravimeter measure relative gravity values, in order to convert relative gravity readings to absolute gravity readings, an absolute gravity station were identified at a point within the study area, with UTM co-ordinates (664111E, 9864090N) and absolute value of gravity of 9775484 mgals. While in the field, other base stations were established and periodically revisited during each day for the instrumental drift correction. A base line was then staked parallel to the geological strike; profiles laid perpendicular to the base at a spacing ranging from 300 m to 1000 m apart intersecting the regional structures normally. The gravity stations were laid approximately 200 m apart along each profile except for regions with poor terrain.

IV. Data presentation and Analysis

Before the data obtained from gravity survey was interpreted, correction for all variations which do not result from the differences in density of the underlying rocks was conducted using Geosoft Oasis Montaj application software. The Montaj gravity and terrain correction extension is designed to process gravity data from conventional ground surveys, with the final goal of producing a map of a gravity field showing the locations of the readings (Figure 1).

Four gravity profiles were then taken on the complete bouguer anomaly contour map of Migori greenstone belt. Profiles AA', BB' and CC' were taken perpendicular to the belt, while profile DD' targeted the potential variations along the belt (Figure 1). The observed curve and the calculated curve obtained by building a model under the profile using the available geological information were obtained.

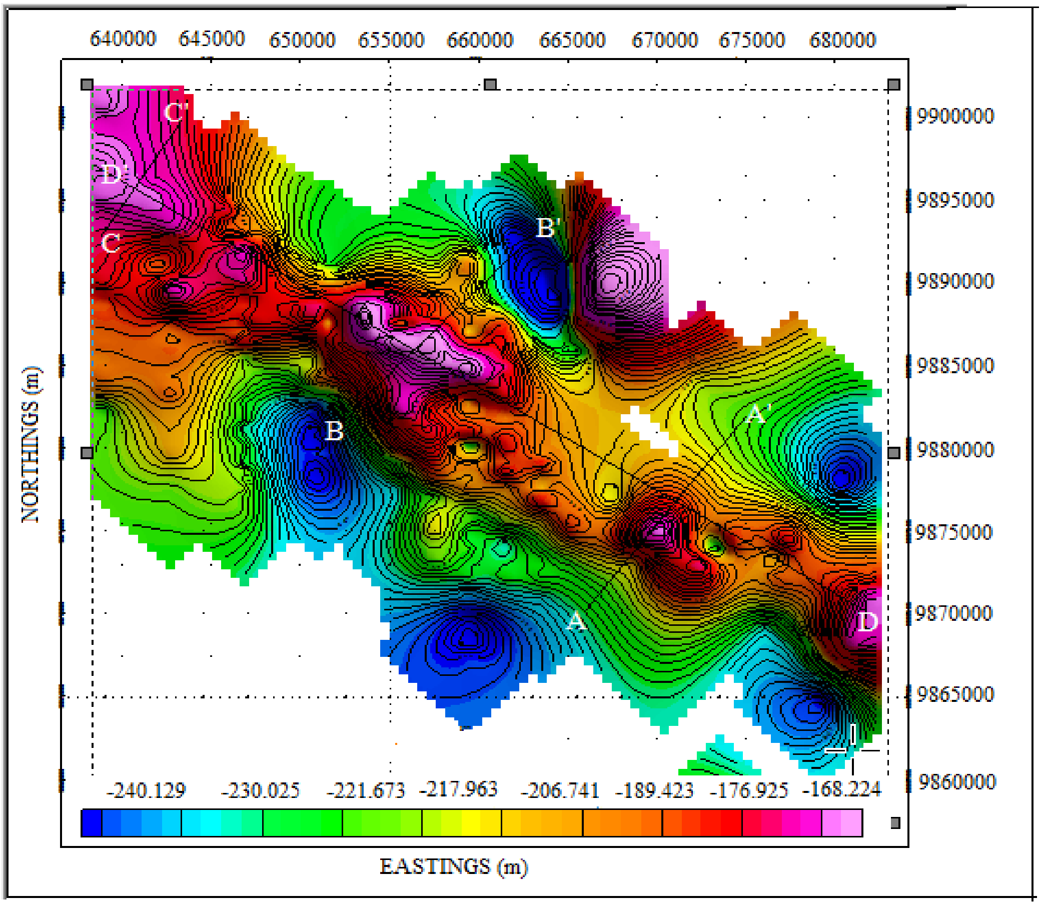


Figure 1: Selected profiles on the complete Buguer anomaly signature

The modifications to the models were performed interactively on a computer screen which shows both the model and the gravity data. Two-dimensional (2-D) approximations were used in which the geology was assumed not to vary at right angles to the line of profile and section. The 2-D approximation is generally adequate provided that the strike length of the anomaly is at least three times as great as the cross-strike width (Parasnis, 1986).

In this study, the startup model average depth of 500 m was obtained from the direct interpretations in spectral power analysis (Figure 2) and Werner deconvolution of the magnetic data (Figure 3) (Odek *et al*, 2018). Different horizontal layers of rock were taken with the targeted mineral rich layer at a start up depth of approximately 500 m. Crustal densities of 2.38 g/cm^3 and 2.63 g/cm^3 were measured using instantaneous water immersion method from rock samples obtained at depths of approximately 20 m and 100 m respectively from an existing mine. The model shape, depth and density were modified within the limits set by the geological constraints to obtain a fit between the observed and the calculated. The mathematical background of the calculated curve is based on the Talwani dike model procedures (Keary *et al*, 2002); this was done using Geosoft Oasis montaj application software. The models obtained correlated well with the available geological report which documents presence of shallow dikes and mineral outcrops.

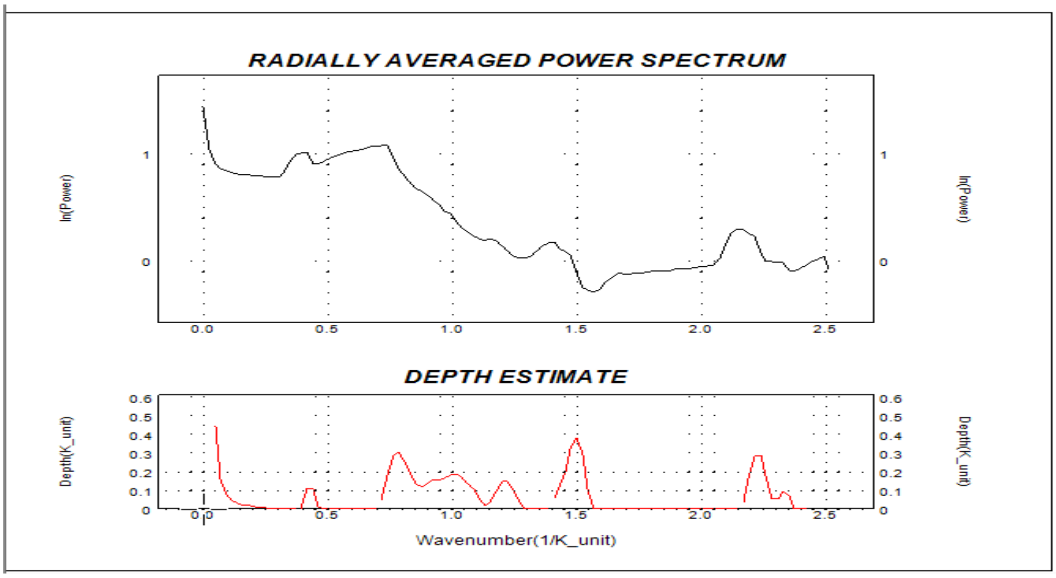
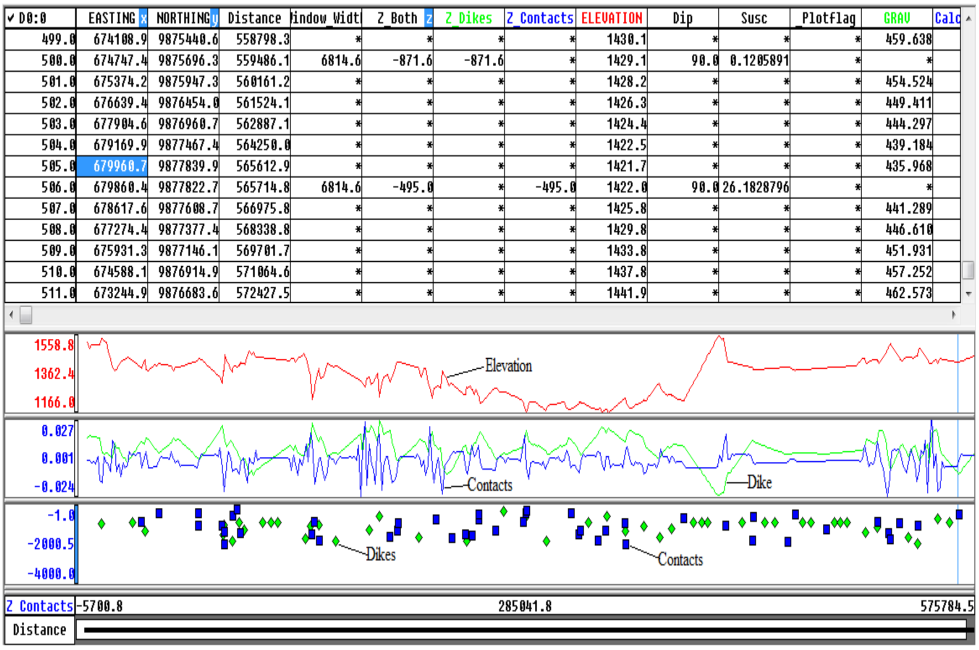


Figure 2: Computed power spectrum of the magnetic anomaly (Odek *et al*, 2018)



D0:0	EASTING	NORTHING	Distance	Window_Widt	Z_Both	Z_Dikes	Z_Contacts	ELEVATION	Dip	Susc	_Plotflag	GRAV	Calc
499.0	674108.9	9875440.6	558798.3	*	*	*	*	1430.1	*	*	*	459.638	
500.0	674747.4	9875696.3	559486.1	6814.6	-871.6	-871.6	*	1429.1	90.0	0.1205891	*	*	
501.0	675374.2	9875947.3	560161.2	*	*	*	*	1428.2	*	*	*	454.524	
502.0	676639.4	9876454.0	561524.1	*	*	*	*	1426.3	*	*	*	449.411	
503.0	677904.6	9876960.7	562887.1	*	*	*	*	1424.4	*	*	*	444.297	
504.0	679169.9	9877467.4	564250.0	*	*	*	*	1422.5	*	*	*	439.184	
505.0	679960.7	9877839.9	565612.9	*	*	*	*	1421.7	*	*	*	435.968	
506.0	679860.4	9877822.7	565714.8	6814.6	-495.0	*	-495.0	1422.0	90.0	26.1828796	*	*	
507.0	678617.6	9877608.7	566975.8	*	*	*	*	1425.8	*	*	*	441.289	
508.0	677274.4	9877377.4	568338.8	*	*	*	*	1429.8	*	*	*	446.610	
509.0	675931.3	9877146.1	569701.7	*	*	*	*	1433.8	*	*	*	451.931	
510.0	674588.1	9876914.9	571064.6	*	*	*	*	1437.8	*	*	*	457.252	
511.0	673244.9	9876683.6	572427.5	*	*	*	*	1441.9	*	*	*	462.573	

Figure 3: Werner solutions along profile DD' (Odek *et al*, 2018)

V. Data Interpretation

The qualitative interpretation of gravity data involved identification of the anomalies from the complete Bouguer anomaly contour map. The anomalies are interpreted based on the fact that, low values of complete Bouguer anomaly of the gravity data indicate low density material beneath the measurement point and high values of complete Bouguer anomaly of gravity data indicate higher density material beneath the measurement point.

Forward models were constructed by selecting profiles across the anomalies and guessing a body of suitable form, calculating its field and comparing with measured values for different profiles. The quantitatively interpreted result was later used in the determination of depth, density and extent of the causative body.

VI. Discussions

The complete gravity anomaly over Migori delineates high values trending ESE-WNW from Kenya-Tanzania border through Kehancha, Masaba, Nyanchabo, Migori, Mukuro, Masara, all through to Macalder (Figure 1). The anomalies peaks are at Kehancha, Masara and Macalder, regions that have witnessed a lot of artisan mining using opencast method. The gravity highs are indicative of high density materials in the subsurface.

Profiles AA' (Figure 4), BB' (Figure 5) and CC' (Figure 6) are modeled as dikes. Profile DD' (Figure 7) which was taken along the gravity anomaly was modeled as a series of folds. The crests of the fold model coincide with high mineral potential areas of Kehancha, Nyanchabo, Migori, Mukuro, Masara and Macalder. This is supported by the fact that Migori greenstone belt is located between the western and eastern branches of the east African rift system (Figure 8), due to the divergent nature of these branches; the lithosphere between the two is subjected to compression forces leading to folding.

VII. Conclusions

Quantitative interpretation done using forward modelling reveals dyke like structures along profiles AA', BB' and CC' with a series of folds along the anomaly profile DD'. The fold exposes the mineral rich layer at the crests. These causative structures are associated with granitic intrusive characterised by banded iron formations that also act as a host for other minerals.

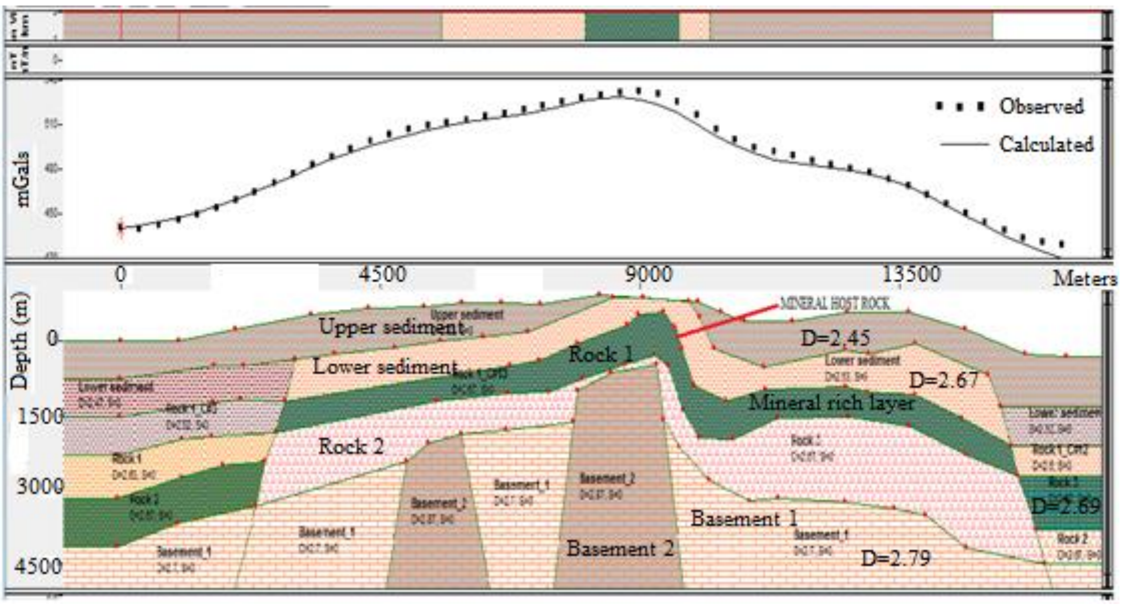


Figure 5: Forward model a long profile BB'

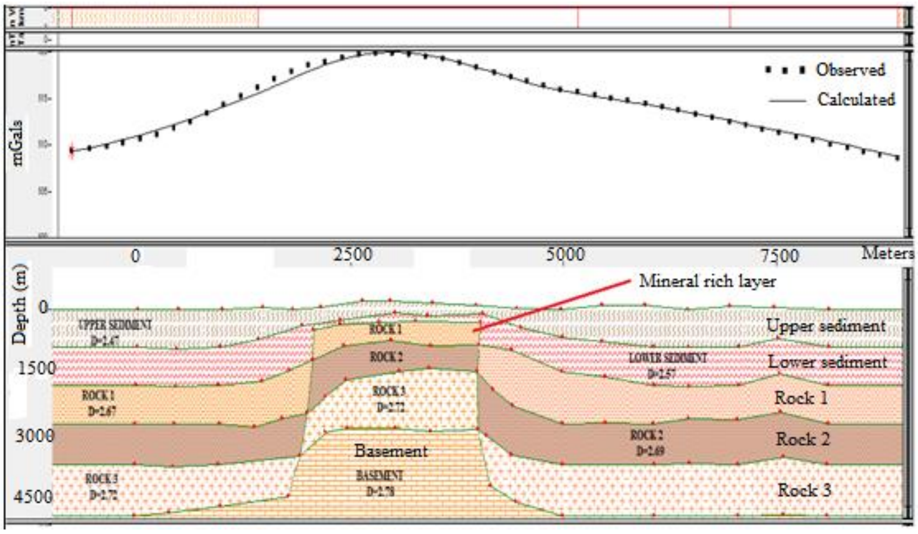


Figure 6: Forward model a long profile CC'

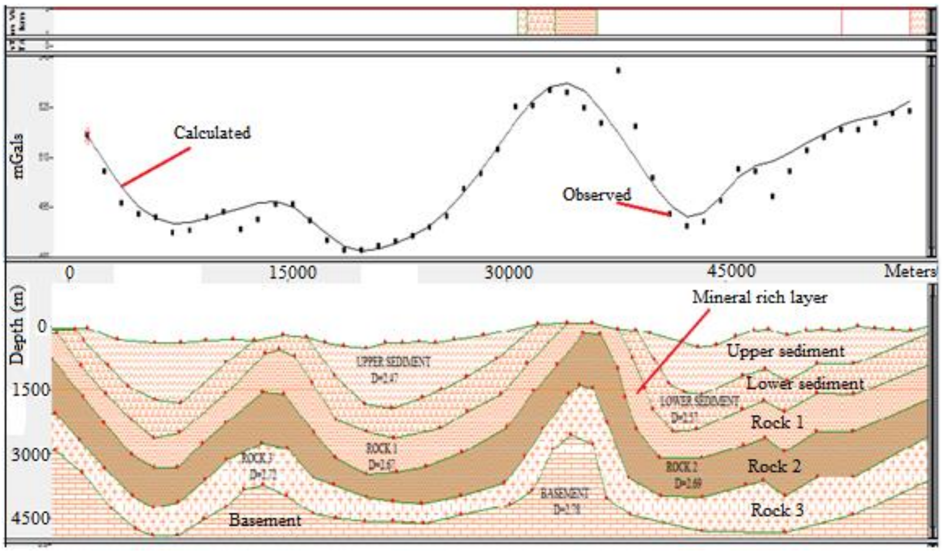


Figure 7: Forward model of gravity data a long profile DD'

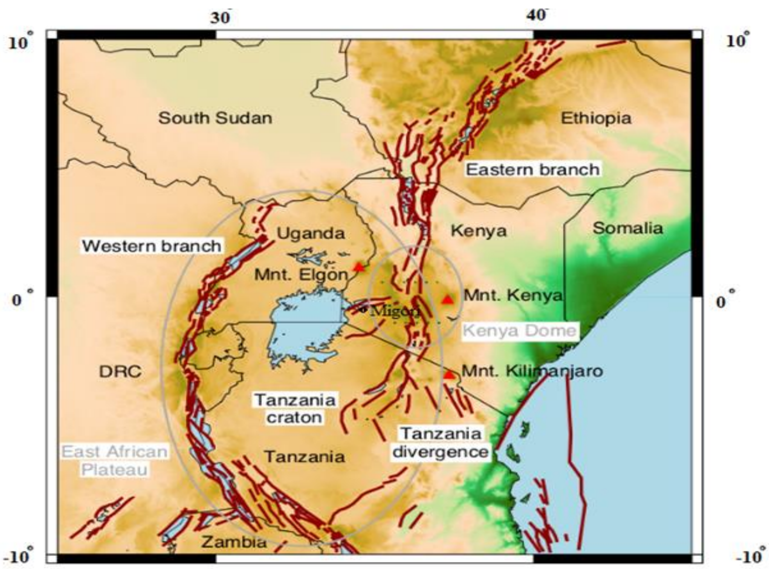


Figure 8: Topography (Amante & Eakins, 2009) and fault traces (GEM) of the central EARS

VIII. Recommendation

My gratitude to National Research Fund (NRF) and Chuka University for their financial support. I am also grateful to both Jomo Kenyatta University of Agriculture and Technology and Kenyatta University for the research equipment and technical support.

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