DEPTH ESTIMATION OF MBEU IRON ORE DEPOSIT USING MELLIN TRANSFORM

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ABSTRACT

Mellin transform is a mathematical tool which has been vastly used in solving potential field (gravity and magnetic) problems, in order to locate the depth to the target such as fault, intrusive, ore deposit, outcrop in geophysical survey for mineral exploration. This study focused on the determination of the depth extent of iron ore deposit (anomalous body) in Mbeu, Meru County, Kenya using Mellin transform as a device and compare the obtained result with that carried out by using integrated gravity techniques. From the four (4) different traverse VV, XX, YY and ZZ obtained using Gravimeter, their residual gravity anomalous profile were digitized and the values obtained were used in the computation of the depth to the ore deposit of each anomalous profile using Matlab program. With the Mellin transform as a tool, a spherical model was develop having the range of arbitrary values $0 \leq s \leq 3$. With the aid of discreet and theoretical Mellin transform, two arbitrary point s_1 and s_2 were reached where the Mellin transform value at those point, $M(s_1)$ and $M(s_2)$ are used in the depth estimation. From the computation, the discreet Mellin transform values which gives the approximate depth values with that of already existing value were obtained at $M(0.6)$ and $M(0.9)$ for VV, $M(2.75)$ and $M(2.95)$ for XX, $M(0.75)$ and $M(0.9)$ for YY, $M(2.0)$ and $M(2.5)$ for ZZ. It was observed that the depth obtained with the aid of mathematical tool fall within the range of the values obtained from the previous research, thereby making Mellin transform an inevitable and valid tool for potential field survey analysis.

Keywords: Mellin transform, Gravity, Depth, Matlab.

INTRODUCTION

Integral transforms are recognized as useful tools for quantitative studies of geophysical anomalies. In contrast to Fourier and Laplace transform that were introduced to solve physical problem, Mellin transform arose in a mathematical context. Besides its use in mathematics, Mellin transform has been applied in many different areas of physics and engineering. With the increasing use of modern digital computer, this has facilitated the direct interpretation of geophysical data employing the Mellin transform. Mellin transform being an integral transform has been considered as a generalized form of the gamma function of the form

$$\Gamma(x) = \int x^{s-1} e^{-x} dx \qquad (1)$$

Mellin transform is an improper integral of the third kind which gives a large place to the theory of analytic function and relies essentially on Cauchy's theorem and the method of residue.

The effects of the sampling interval Δx and length of the data (profile) on the accuracy of the discrete Mellin transform and hence on the accuracy of the estimated source parameters have been studied separately by the authors (Mohan et al., 1985). The advantages of the Mellin transformation method over graphical techniques are that (1) all the observed values are used, (2) only a few transformed values are required for computation, and (3) the interpretation procedure can be computerized. Gravity has been used in mineral exploration since the early 1900's due to its ability to delineate highly dense geologic features from the surrounding host rock. Application of gravity to mineral deposition environmental considerations includes identification of lithologies, structures and at times ore bodies themselves (Wright, 1981). Historically, gravity has been used in oil exploration in any places involving salt because of the large density contrast of salt, at almost all depths, with surrounding sediments; positive when shallow, negative when deep (Greene and Bresnahan, 1998).The gravity survey for the whole of Kenya has been done by Khan and Swain (1977). The duo examined the nature of the axial gravity high. They noted its association with the prominent volcanoes similar to those in the southern part of the rift and showed that the lift axis is associated with the intermittent narrow positive anomaly (gravity high). Elsewhere the gravity method has found a frequent application in mapping bedrock topography in glacial environments (Ibrahim and Hinze, 1972; Carmichael and Henry, 1977). Pal *et al*. (2006) used geological interpretation to determine the cause of gravity highs and lows. The gravity highs are associated with iron ore group and metamorphic group of rocks. The iron ore group rocks overlie the basement rocks and are exposed over vast areas in the east. The gravity lows are associated with anticline structures of granitic masses which clearly indicate the intrusive natures of the granitic masses. The earlier studies carried out in the area indicated the presence of granitic intrusion. This suggests the possibility of the occurrence of valuable minerals (Mason, 1953). However, the study was of an exploratory kind and was not adequately detailed; Many authors like Nettleton(1976), Radhakrishan Murthy(1973), Mohan et al (1986) , Olowofela and Ozebo (2002) , Sunmonu and Olowofela,(2003), Ozebo et al (2013) have adopted this similar approach relating potential problem (gravity and magnetic) to Mellin transform thereby resulting into a reasonable outcome.

In this study, Mellin transform will be used as a tool to determine the depth to the center of iron ore deposit and then compare the result obtained with those previous work over the study area. With this approach, the strength of Mellin transform on that of field samples can be tested and therefore validated as an indispensable tool in solving potential problems.

GEOLOGICAL AND HYDROGEOLOGICAL DESCRIPTION

The regional geological setting of Mbeu (Figure 1) is dominated by the Archaean or Basement System rocks and comparatively young Tertiary, Pleistocene and Recent extrusive rocks and subordinate sediments (Mason, 1952). The Mbeu area is largely covered by the Mt. Kenya volcanic rocks (Schoeman, 1948). The plains consist of mafic rocks and rest on the Sub-Miocene.

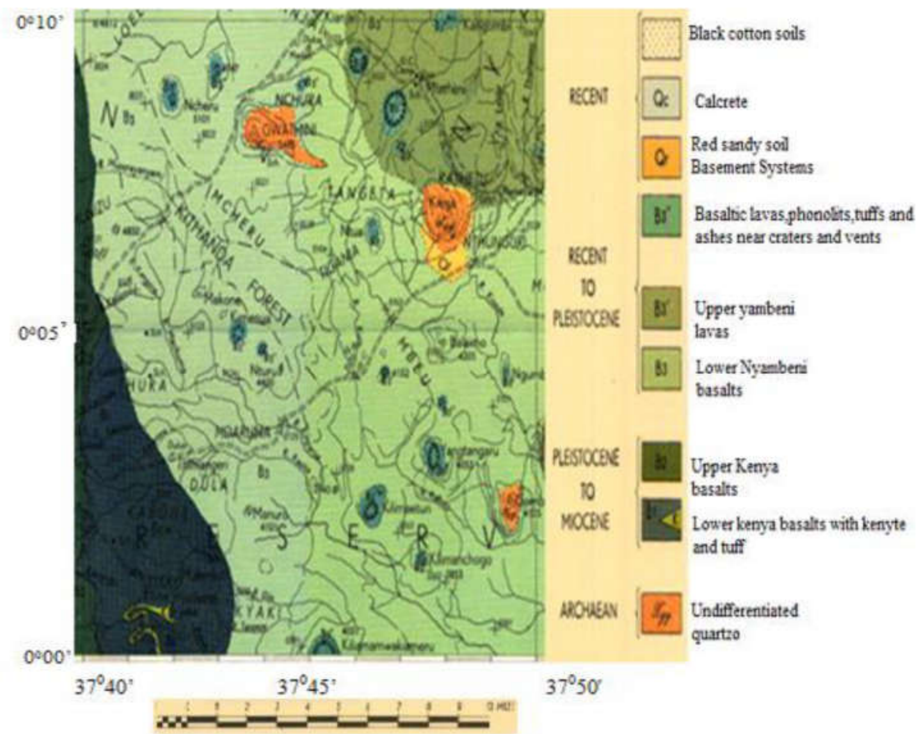

Figure 1: The geological map of the study area (Mason, 1952)

The Basement System of Mbeu forms the floor upon which all the remaining rocks of the area rest, and consists of schist, granulites and heterogeneous gneisses of varying composition. The rocks are monotonous, consisting essentially of quartzo- feldspathic gneisses containing varying proportions of biotite content. The rocks are frequently intensely veined by stringers of quartz and feldspar, while some layers and lenses are typically pegmatitic in texture.

METHODOLOGY

From the gravity survey over the study area extract from Abuga (2013), four traverse VV,XX ,YY and ZZ were drawn as shown in contour plot in figure 3 obtained using gravimeter, which result into anomalous profile for each traverse after processing. The profile line VV, XX, YY and ZZ of the gravity map of the Mbeu iron ore depopsit were analyzed using the residual gravity curve shown in figure 4, 5, 6 and 7. The anomalous profile were digitized with the aid of Tech dig software. Using these digitized values, the discrete Mellin transform were calculated for each of the profile using MATLAB program code. . Because the asymptotic regions are not considered for parametric evaluation, the depth to the center of the sphere is evaluated from the values of the discrete Mellin transform of the residual gravity effect $M(n\Delta s)$ obtained at two arbitrary point $n\Delta s_1$ and $n\Delta s_2$ and using equation (4), the depth to the center of the ore deposit for different anomalous profiles can then be calculated and compare with that obtained by Abuga (2013).

SIMULATED MODEL

The gravity effect of the spherical structure is given by equation (2) by Dobrin (1976) as

$$g(x) = m\frac{z}{\left(x^2 + z^2\right)^q} \tag{2}$$

$$q = 3/2 \quad \text{and} \quad m = \frac{4}{3}\pi\rho G R^3$$

Where ρ is the density contrast, G is the universal gravitational constant, R is the radius,

and z

is the depth to the center.

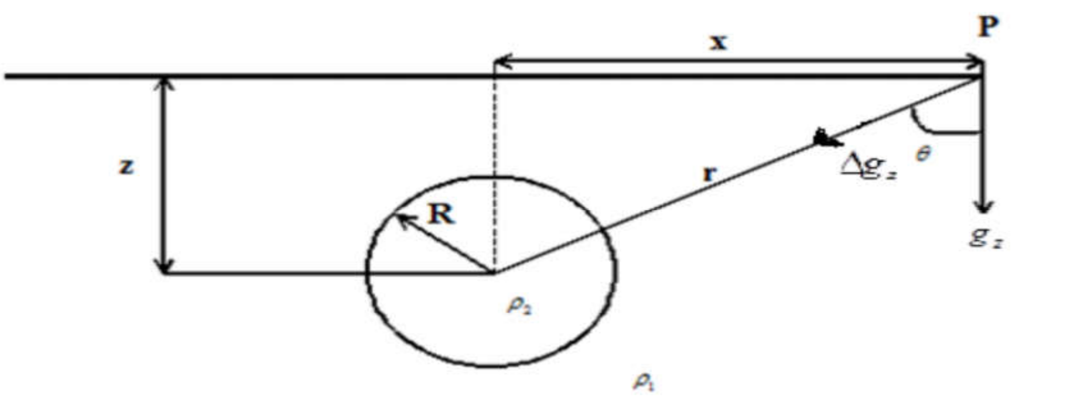

Figure 2 : Shows the model description of spherical structure to the centre of ore deposit.

The Mellin transform of a function $g(x)$ is defined by Sneddon (1979) as

$$M(s) = \int_0^\infty x^{s-1} g(x)dx \tag{3}$$

Where s is a positive integer or fractional number.

Using equation (3),the Mellin transform of the gravity effect of a sphere, is reduced to

$$M(s) = \beta Z^{s-\alpha+1}\Gamma\frac{s}{2}\Gamma\frac{\alpha - s}{2} \qquad (4)$$

where for a sphere

$\alpha = 3$ and $\beta = \frac{4}{3}\sqrt{\pi}\rho G R^3$

The theoretical Mellin transform of the gravity effect is a continuous function in the interval (0, 3) in the case of a sphere . Because there would not be absolute symmetry in the case of field data, the symmetry is strengthened by the computation

$$g(x) = \frac{g(x) + g(-x)}{2} \qquad (4)$$

Gravity field data are collected in discrete form; thus, to facilitate extraction of parameters as formulated above, the discrete Mellin transform is defined as

$$M(n\Delta s) = \sum_{\lambda=1}^{N} (\lambda \Delta x)^{n\Delta s - 1} g(\lambda \Delta x) \qquad (5)$$

Where

N = total number of the observed values,

Δx = station interval of the observed values,

and

Δs = interval of the discrete Mellin transform.

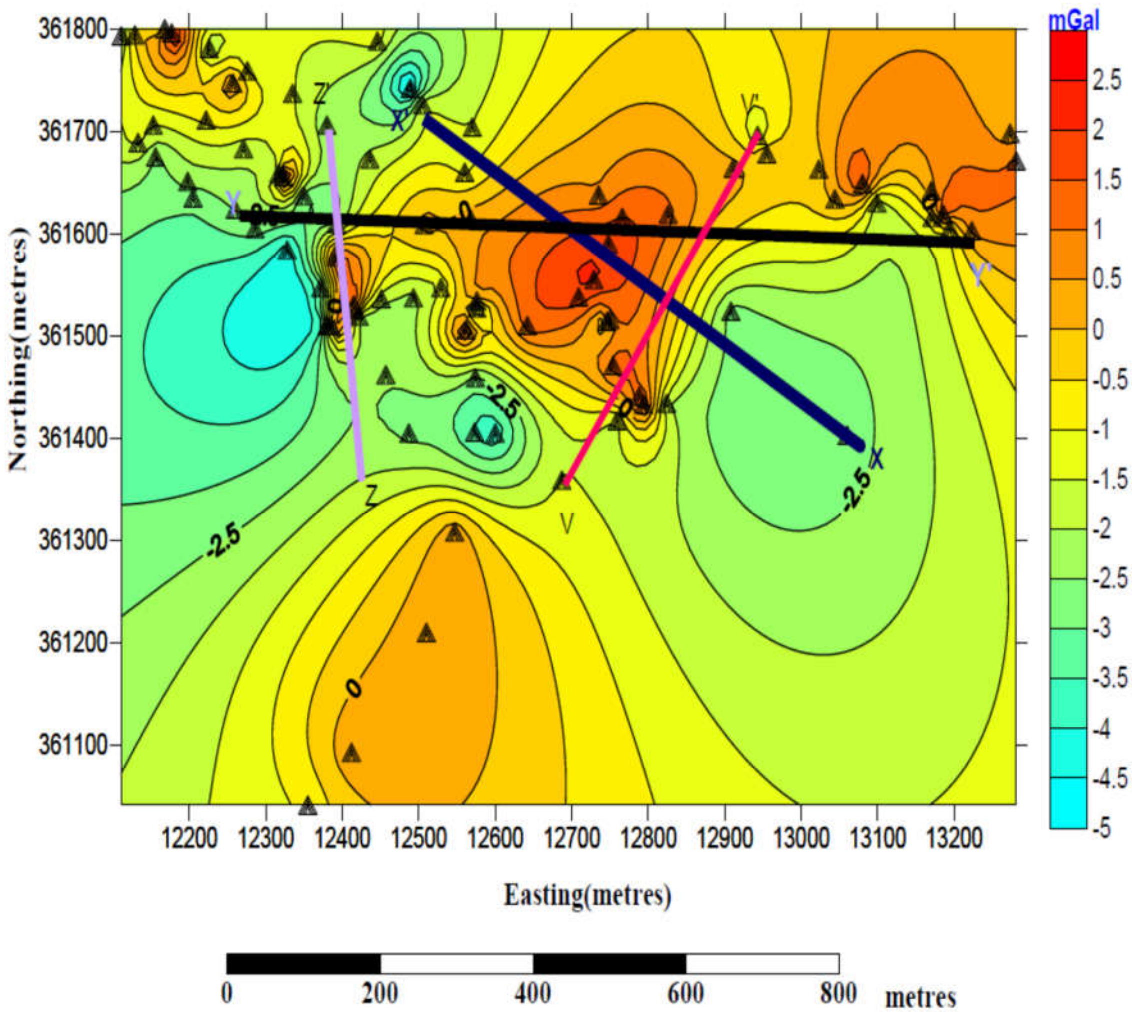

Figure 3: Contour map showing gravity measured stations.

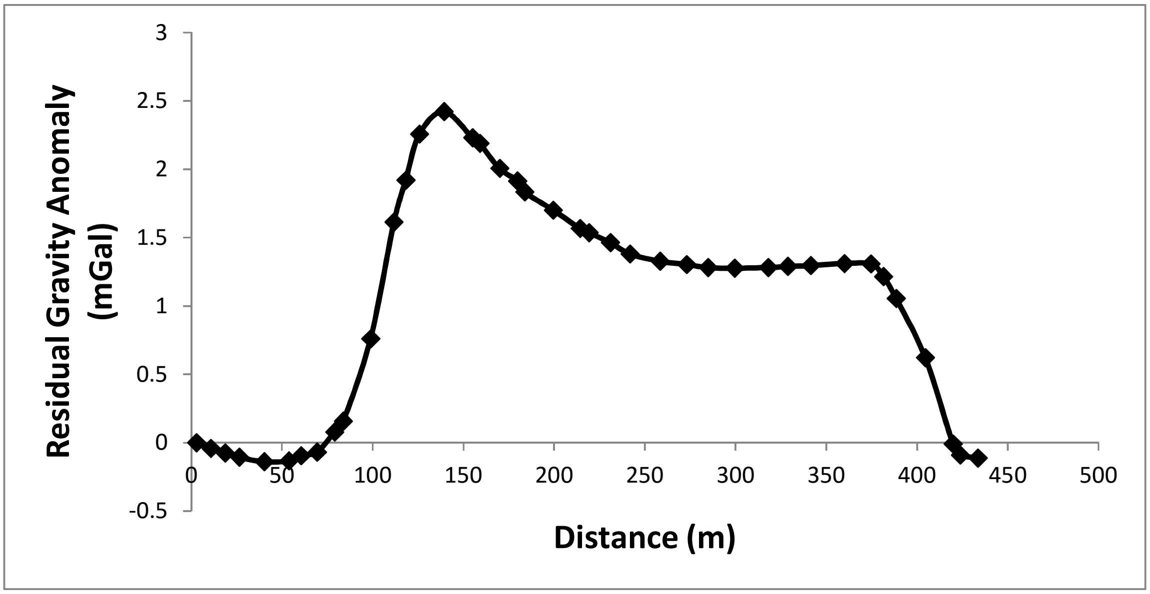

Figure 4: Shows the gravity anomaly profile for traverse VV

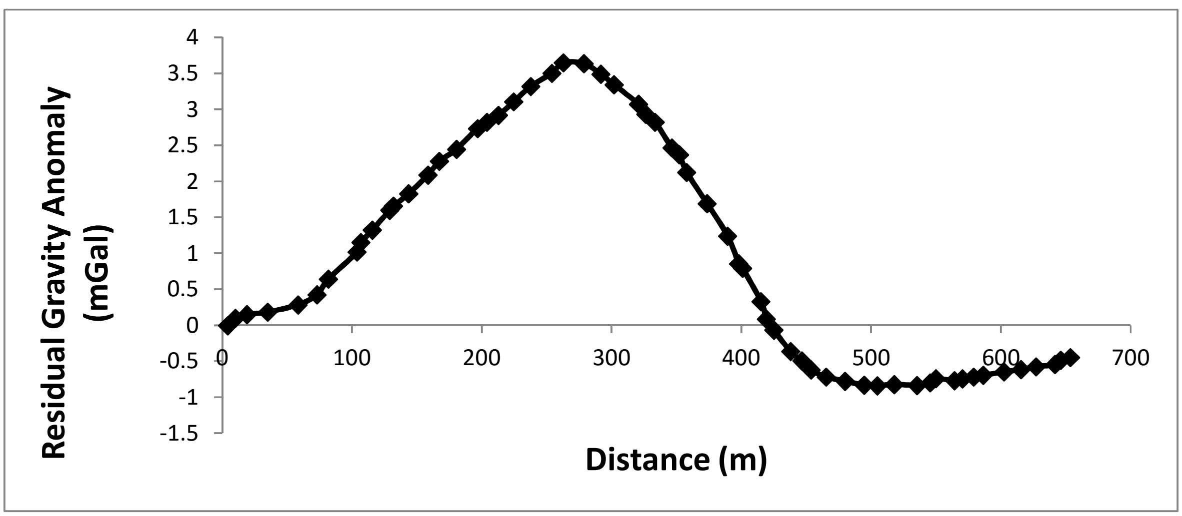

Figure 5: **Shows the gravity anomaly profile for traverse XX**

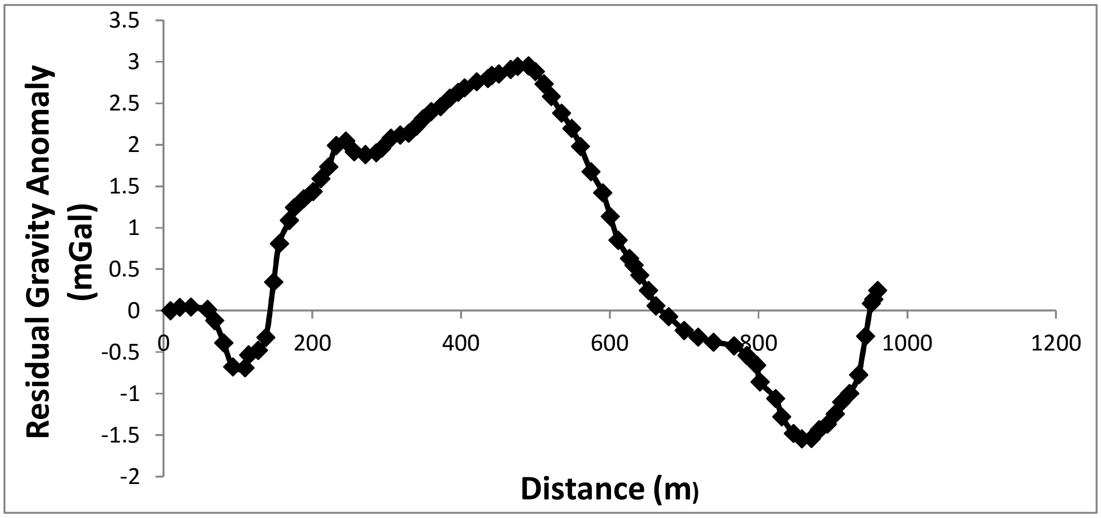

Figure 6: **Shows the gravity anomaly profile for traverse YY**

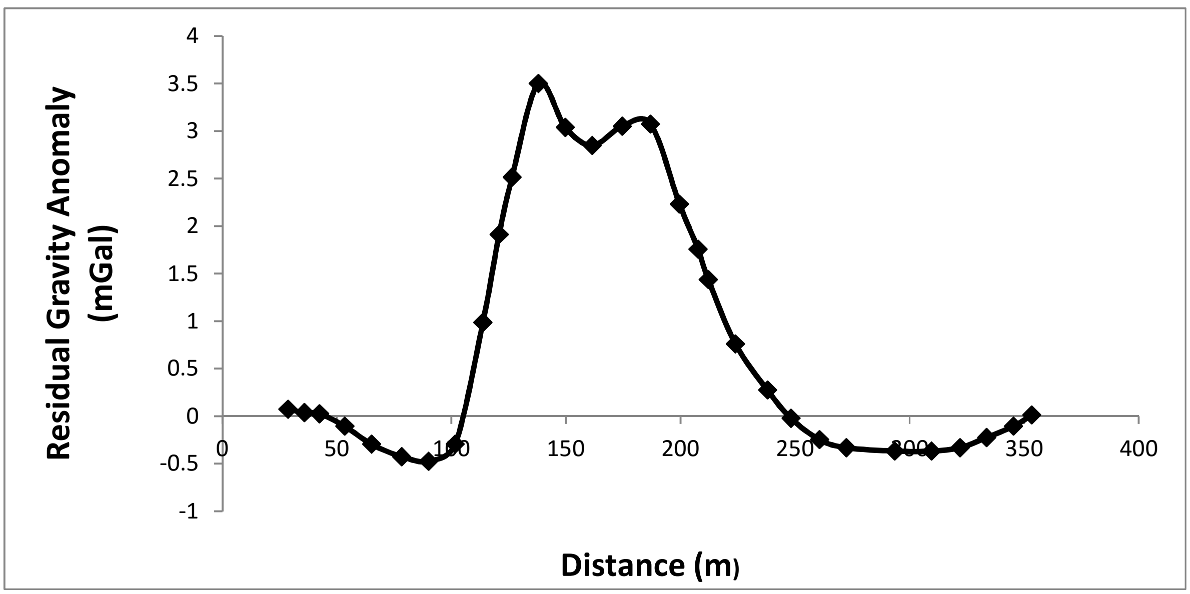

Figure 7: **Shows the gravity anomaly profile for traverse ZZ**

RESULTS AND DISCUSSION

The result obtained from the digitised value from each of the anomalous profiles (Figure 4, 5, 6 and 7) represent the gravity value g(x) in mGal and horizontal distance (x) respectively. This value were then used in equation (4) in conjuction with that of equation (5). In solving, two arbitrary point s_1 and s_2 were reached in which the Mellin transform were computed at those point. The two arbitrary points were 0.6 and 0.9, 2.75 and 2.95, 0.75 and 0.9, 2.0 and 2.5 for VV, XX,YY and ZZ respectively, all within the specified range of s i.e $0 \le s \le 3$.Computing the Mellin transform, we have for XX as shown.

$$M(2.75) = \beta Z^{0..95}\Gamma(1.375)\Gamma(0.125)$$

and

$$M(2.95) = \beta Z^{0.75}\Gamma(1.475)\Gamma(0.025)$$

By solving, we have

$$\frac{M(2.95)}{M(2.75)} = \frac{Z^{-0.2}\Gamma(1.475)\Gamma(0.025)}{\Gamma(1.375)\Gamma(0.125)}$$

Using equation (5),

$$M(2.95) = -147344$$
$$M(2.75) = -47501$$
$$\Gamma(1.475) = 0.885679$$
$$\Gamma(0.025) = 39.44696$$
$$\Gamma(1.375) = 7.533942$$
$$\Gamma(0.125) = 0.888914$$

where Γ = Gamma function.

Therefore the value of Z (depth to the ore deposit) for XX was obtained as 13.4m
Similarly using the same procedure the Z value for profile VV, YY and ZZ was also obtained as shown in table 1.
Most iron formation is said to associated with positive, high-amplitude gravity anomalies because it contains elevated abundances of high-density iron minerals, including magnetite and hematite. The magnetic signature of iron-formation is usually one to two orders of magnitude greater than that of its host rock. With this assertion, it can be observed in the figure 8, 9, 10, 11 around the region of arbitrary value of s = 2.5 and above, there exist a

sharp anomaly of high amplitude indicating that the iron ore is well deposited in those region, This study therefore support the fact that the area is well endowed with iron ore deposits Also, from the Mellin transform curve obtained, it show that the trend of the curve appear to be like that of gamma function curve, which is in agreement with the fact that Mellin transform is a generalised form of gamma function, which is said to be asymptotic in nature.

Table1: The comparism of the depth to the ore deposit

Authors	Depth estimate for the profiles			
	VV	XX	YY	ZZ
Abuga (2013)	114 .48	12.98	120.10	2.89
Present study	116.20	13.40	119.80	2.56

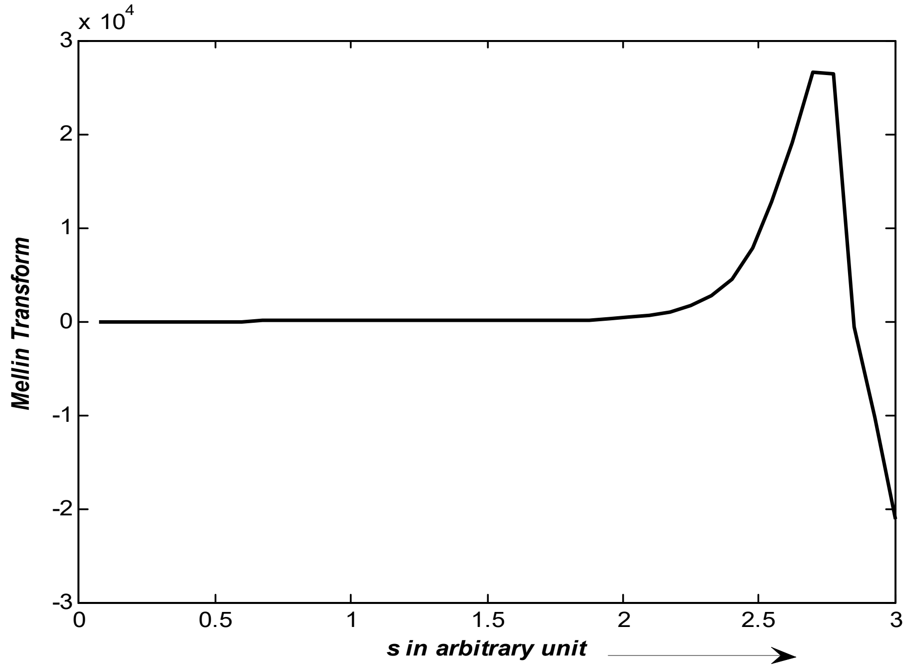

Figure 8: Mellin Transform graph for traverse VV

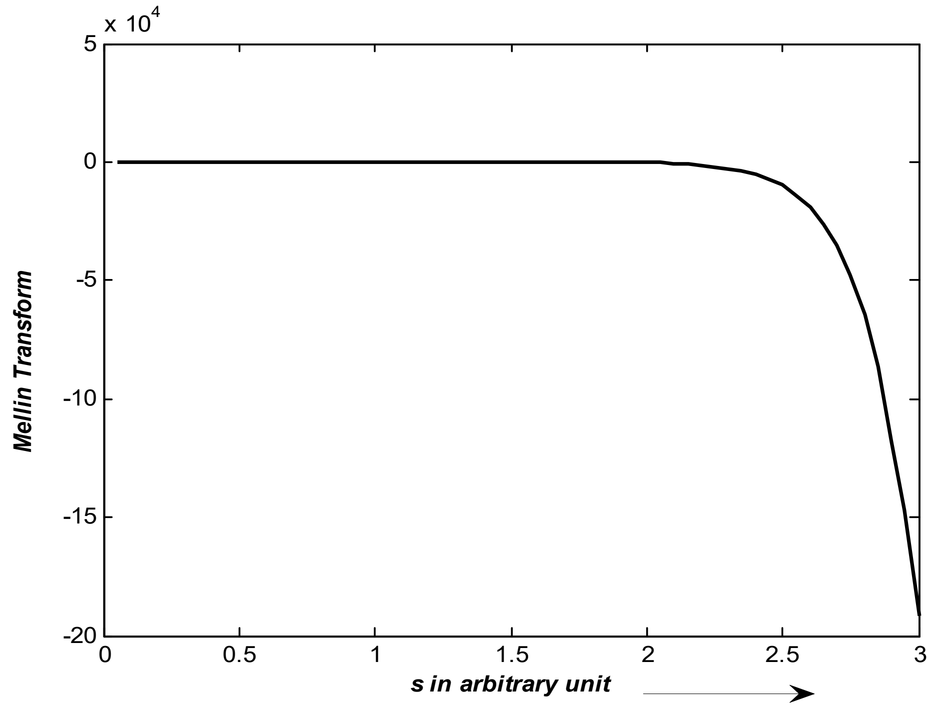

Figure 9: Mellin Transform graph for traverse XX

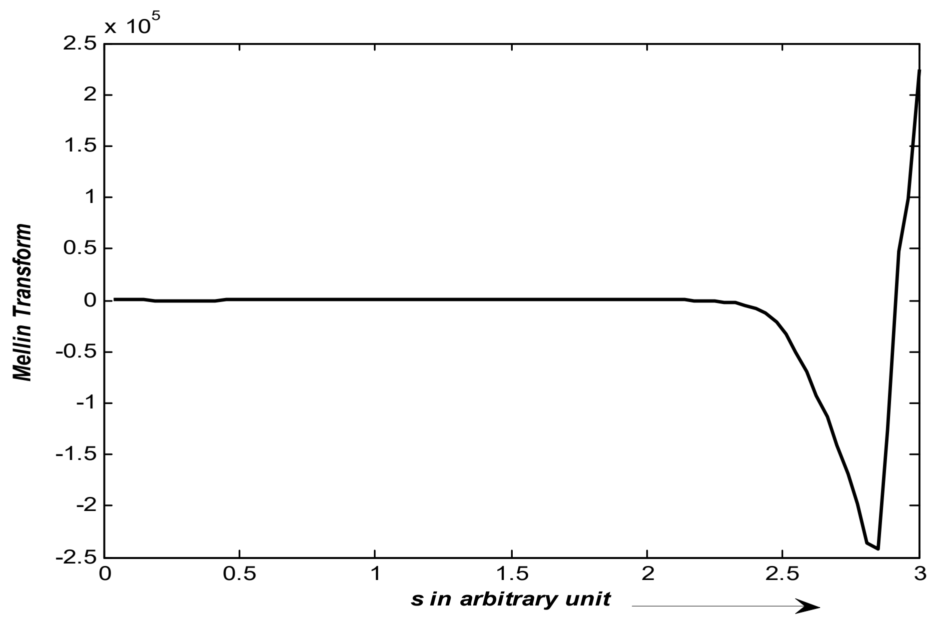

Figure 10: Mellin Transform graph for traverse YY

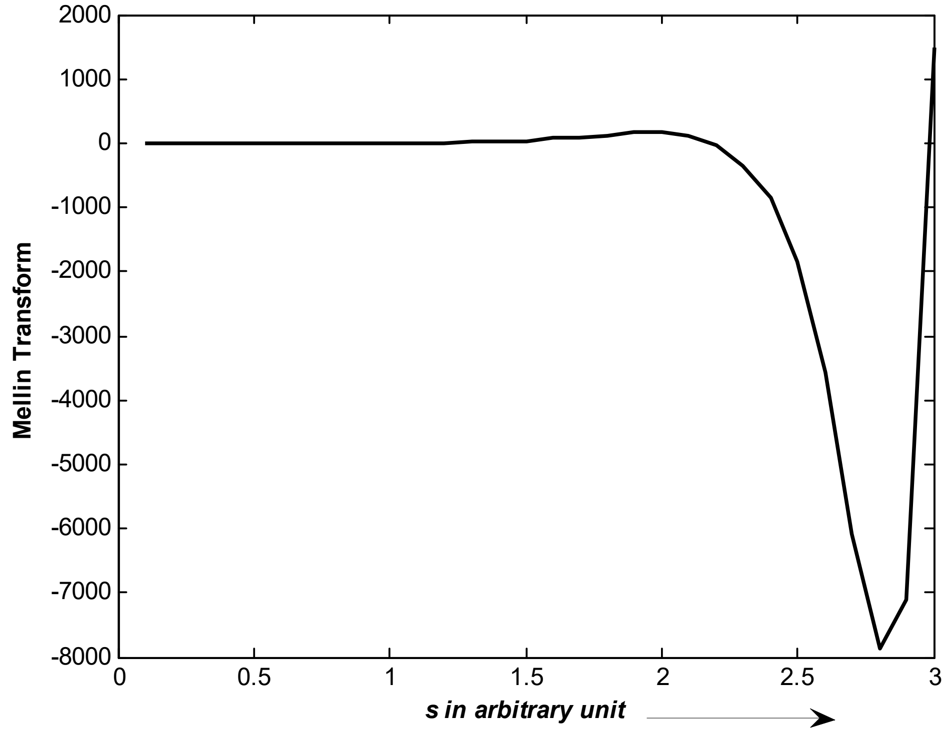

Figure 11: Mellin Transform graph for traverse ZZ

CONCLUSION

This study has reveal, with the aid of Mellin transform as a tool, that there exist anomaly over a particular range indicating the presence of mineral deposit in the study area. The similarity of the curves of the transformed anomalies as shown in Fig.8 -11 and the gamma function curves is observed. This may be attributed to the fact that Mellin transform is a generalized form of a gamma function. Conclusively, the validity of Mellin transform has been tested and results obtained are in conformity with the previous research over the area.

RECOMMENDATION

Geophysical survey do make use of either gravity and magnetic method to investigate the potential related problem in order to reveal the geological formation and mineral deposit in a particular area, in the subsequent work over the area, it will be advisable to use magnetic method and compare the deposition depth result with that of the gravity .

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