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Research Paper

Use Of Potential Methods in Investigating Faults And Fractures in Kiamunyi Area South West of Menengai in The Kenya Rift

Physics

KEYWORDS : Gravity, Magnetics, Iso-map, Fault line, anomaly

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ABSTRACT

The rapidly growing Nakuru town needs expansion to accommodate the increasing population. This vast expansion can only be done at the outskirts of the town. However, no single research has been done with the aim of checking the geological stability of the regions around Nakuru town; either by mapping new fault lines or by confirming using geophysical methods the presence of fault-lines shown on geological maps. Kiamunyi estate being in the outskirts of the town was therefore chosen for this research; to evaluate the stability of the area for development. The potential methods were employed for this study. Gravity and magnetic data were contoured and interpreted. From the gravity contour map, a gravity low was observed between two gravity highs. A low magnetic intensity zone that occurred between two high magnetic intensity regions was also evident. The location of these anomalies from both the gravity and magnetic contour maps coincides. It is therefore concluded that the observed anomalies indicate the presence of a fault that strikes Northwest-Southeast.

1.0 Introduction

Kiamunyi is located in the southern part of the Kenya Rift Valley which lies within the East African Rift Valley (figure 1). It is one of the environs of Nakuru town to the west and lies at the foot of the Menengai volcano to the south west. Numerous geophysical studies have been done around the Menengai volcano focusing on geothermal exploration (Simiyu and Keller, 2001; Mariita, 2007; Simiyu, 2009; Wamalwa et al., 2013). The main focus has however been in the volcano, though some studies have focused on Nakuru town and its environs (Ngecu and Nyambok, 2000). Studies have shown that Nakuru town and its environs; including Kiamunyi have experienced subsidence in the past leading to damage of property in addition to landscape and environmental degradation (Ngecu and Nyambok, 2000). They suggested that the underlying cause of this subsidence could be buried faults covered by volcanic deposits. These subsidences are mainly collapse of unconsolidated sediments occurring along fault zones due to heavy rains.

However, studies around the Menengai volcano have not focused on the use of geophysical methods to guide the developers of the growing town. In this study therefore, the potential methods of geophysical exploration were used to map faults around the Kiamunyi estate southwest of the Menengai volcano with the aim of determining the stability of the subsurface rocks.

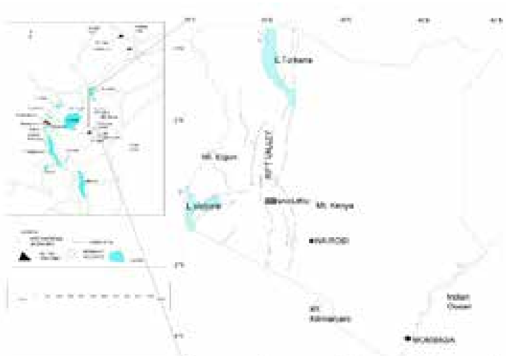

Figure 1: Map of the Kenyan Rift in relation to the East African Rift showing the location of Nakuru town (grey box).

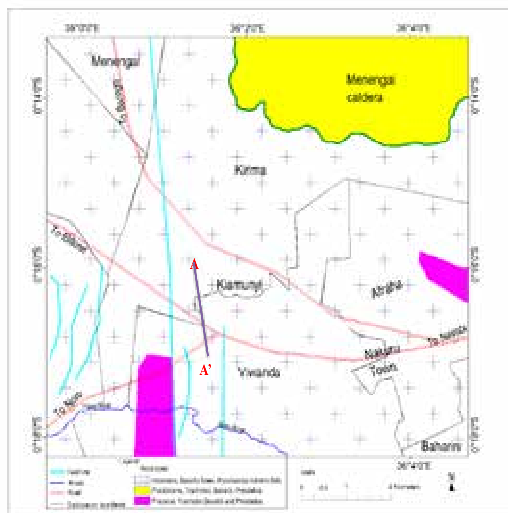

Figure 2: Geological map of Nakuru area.

2.0 Previous studies

Seismic studies have been done in the area around Menengai volcano in exploration for geothermal resources (Young et al., 1991; Simiyu and Keller, 2001). Their findings showed that Menengai region is served with a dense network of faults trending N-S which helps in recharging the geothermal reservoirs. A case study of Nakuru region has also been done which shows that the likely cause of ground subsidence observed in Nakuru and its environs is the dense network of fault lines found in the area (Ngecu and Nyambok, 2000).

3.0 Potential methods

The gravity and magnetic methods of geophysical exploration are collectively referred to as potential methods. This is because they both involve measurements of potential fields. The gravity and magnetic methods employ measurement of earth's gravitational field and magnetic field respectively (Telford et al., 1990).

The variations in gravity are due to lateral change in the density of the subsurface rocks in the vicinity of the measuring point.

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The subsurface geology is usually investigated on the basis of variations in the Earth's gravitational field arising from differences of density between subsurface rocks (Philip et al., 2002). An underlying concept is the idea of a causative body, which is a rock unit or region of different density or different magnetic susceptility from its surrounding. Buried features on a bedrock surface, such as a buried valley or fault, can give rise to measurable anomalies. Magnetic exploration involves mapping variations in the magnetic field to determine the location, size, and shape of such bodies (Telford et al., 1990; Sharma, 2002). Detection depends on the amount of magnetic material present and its distance from the sensor.

3.1.1 Gravity data acquisition
The La Coste and Romberg gravimeter was used for this study. Stations were located at least 100 m from known sources of vibrations such as the busy Nakuru-Eldoret and Nakuru-Baringo roads to minimize the effects of vibrations caused by moving vehicles.

Gravity measurements were taken at random stations with inter-station separations of between 20 m and 100 m. A local base station was established where readings were taken after every one hour of the data collection exercise. This would help in correcting for the instrumental drift as well as the tidal correction. Station coordinates and elevations were determined using the GPS and recorded alongside the meter readings. Hammer's method was employed to obtain the terrain corrections. This was done by dividing the region around each station into three concentric rings of radius 2 m, 20 m and 50 m. The mean difference in elevation between the station and each segment was then determined at angular intervals of about 90º, 45º, and 22.5º from the inner segment to the outer segment respectively (Sharma, 2002). The Hammer Chart was then used to deduce the terrain correction for each station.

3.1.2 Data processing
First, the instrumental drift as well as the tidal correction was done to the raw data. The Bouguer correction was obtained using the formula:

$$g_B\ (\text{mGal}) = 0.4192 \times h \times \frac{2670}{10{,}000}$$

A constant rock density of 2.67 g/cm^3 was assumed. Where "gB" is the bouguer correction in mGal, h is elevation in meters, 0.4192 = 2πG and

G = 6.67×10-11 m^{3}kg^{-1}s^{-2} referred to as the gravitational constant (Telford et al., 1990; Sharma, 2002). The Bouguer correction was added to the observed gravity value.

The free air correction was calculated using a constant elevation multiplication factor of 0.3086 mGal per metre;

$$g_{fa}\ (\text{mGal}) = 0.3086 \times h$$

Where "gfa" is the free air correction in mGal and h is the elevation in metres. Since all the stations were above the datum, the free air correction was added to the observed gravity values (Telford et al., 1990; Sharma, 2002).

The terrain correction as calculated using the equation below was subtracted from the observed gravity (Sharma, 2002).

$$g_T = G\rho\varphi\left\{(r_2 - r_1) + \sqrt{r_1^2 + (\Delta h)^2} - \sqrt{r_2^2 + (\Delta h)^2}\right\}$$

Where "gT" is terrain correction, is the angular intervals, is the mean elevation between each segment and the gravity station, is the density of the terrain material; taken to be 2.67 g/cm^3 and and are the radii of the inner and outer rings bounding the segments respectively.

3.2.1 Magnetic data acquisition
Establishing and positioning of magnetic stations including the base station was done using a global positioning system (GPS). Two Geometrics 856 Proton Precession Magnetometers were used for this study. A base station, far from power lines and metallic objects was chosen.

The base magnetometer was set to take and store readings at the base station for the whole day during a data collection exercise. This was to be used in correcting for diurnal variations (Parasnis, 1986; Rivas 2009).

Stations were randomly selected at inter-station spacing of about 20 to 100 m. The total magnetic field intensity was measured at each station. However the fact that the study area is already occupied posed a major problem of magnetic noise in the region, therefore magnetic data collection from some of the areas was impossible. For instance the dense network of power lines was a hindrance to continuous data collection. Possible sources of magnetic noise were therefore avoided by locating the stations at least 50 m away from them (Philip et al., 2002). The magnetometer was set to take three readings at each station and display the average value. A total of three hundred and sixty five (365) stations were occupied in a period of four days. Coordinates of the stations were taken using the GPS. The time when a specific reading was taken, was recorded alongside the average field reading and coordinates of the station. This was to be used for the diurnal corrections.

3.2.1 Magnetic data processing
Diurnal corrections were done to the magnetic data using the base station readings. A low pass filter was also applied to eliminate the low wavelengths due to cultural noise (Glen et al., 2013).

3.3 Results and discussion
The gravity data was gridded to produce a simple bouguer anomaly map of the study area with a constant contour interval of 10 mGal as in figure 3 below.

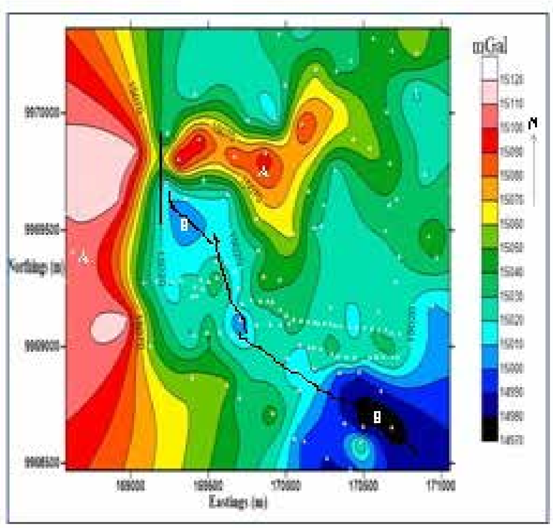

Figure 3: Complete Bouguer-anomaly contour map of the study area.

The data stations are represented with white triangles. The different colour shades represents the gravity values in mGal with the highest and lowest gravity values in this area being 15120 mGal and 14970 mGal, marked with letters A and B respectively.

Gravity highs are evident on the west as well as the central regions of the map. This is the region marked A on the map while a gravity low marked B is observed on the south eastern side but stretches to the central parts of the study area. This gravity low occurs between gravity highs and can be associated with a fault or fracture or low density volcanic materials.

The magnetic data was also gridded and contoured to produce total magnetic field intensity iso-contour map. A constant contour interval of 20 nT was used as shown in figure 4 below;

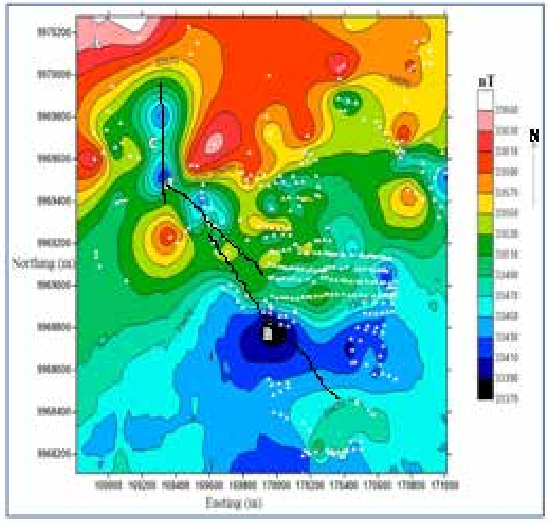

Figure 4: Total magnetic intensity contour map

The highest magnetic intensity observed is around 33650 nT while the lowest magnetic intensity is 33370 nT. These are the regions marked A and B on the total magnetic intensity contour map respectively.

On the western side of the magnetic contour map, a low magnetic intensity region; labeled C is observed which stretches towards B. This low magnetic intensity region occurs between two high magnetic intensity regions This region can be related to a linear structure such as a fault line or a region of low magnetic materials.

3.4 Conclusion and recommendation

The contour map in figure 3 and figure 4 above shows anomalies that can be correlated with the geological map of the area. High gravity regions represent relatively denser rocks as compared to the adjacent rocks. On the other hand, low gravity regions show possible areas with less dense or unconsolidated rocks as compared to the surrounding. This might also be an indication of a deepening basement or a fractured or faulted zone. However, since the low gravity zones occur between high gravity zones, then this is likely to be caused by a fault line where the low gravity region can be said to have subsided with respect to the surrounding high gravity regions. This faulted region is shown by the solid black line and runs Northwest-Southeast.

As observed in figure 4, the magnetic field in the study area varies from one data point to the other. Thus, a lateral variation in magnetic intensity is evident. A low magnetic intensity region occurring between high intensity zones is a possible indication of a fault line; which is a distinct signature of fault structures within a geological unit. The low intensity is likely as a result of rocks that subsided during the formation of the fault line.

The anomalies observed in both figure 3 and 4 runs Northwest-Southeast which agrees well with the studies done around the region which show that the faults in this area run north-south as seen in the geological maps of the study area (figure.2) (Ngecu and Nyambok, 2000). This is the region cutting through point labeled A and A' in the geological map; figure 2. The two data sets show similar trends whereby the anomaly seems to cut Northwest-Southeast hence the general trend of the fault line mapped in this study. Thus it is concluded that a fault line exists in the study region as shown in black solid line in both figures 3 and 4. The fault line runs Northwest-Southeast and seems to originate from the Menengai volcano and terminate in Lake Nakuru.

Construction around the faulted zone should be discouraged to avoid loss of lives and property in case of more subsidence around the fault line which could result to collapse of infrastructure.

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