Determination of Earth's Crust Movement at Kwoi, Kaduna State Using Gravity Method

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ABSTRACT

The earth's crust is deforming due to plate tectonic which causes earth tremor. Monitoring of this deformation is essential for the preservation of life and property. Gravity Survey plays an important role in crustal deformation monitoring which means a change in geometric configuration whose monitoring problem is to determine the spatial relationship of a set of object point relative to a number of reference points. The aim of this study is to determine the movement of the Earth's crust at Kwoi, Kaduna State and its environs, using Gravimetric method in other to monitor the effect of Earth tremor that occurs within the study area and the above aim were achieved through the following objectives: acquisition of GNSS and gravity data of the study area, the reductions of the observed gravity data, determination and analyses of the GNSS and gravity data using Trimble business center and Gravsoft and conducting some test using necessary statistics. The gravity data acquisition was done using LaCoste and Romberg (G664) gravimeter while The GNSS field data acquisition (Observation) was done on a Static mode for minimum of thirty minutes per session using Trimble R8 Model 3 dual frequency GNSS receiver. Trimble Business Centre (TBC) software with its accessories were used for the processing of the coordinate data to obtain the adjusted latitude, longitude and ellipsoidal height of the study area, Gravsoft works with Notepad to process raw gravity data, to correct for errors and to also obtain the gravity value of the study area, Microsoft Excel were used to average the gravity data before using Gravsoft to process. The results of this work shows the adjusted coordinates of all the stations, the gravity value, gravity anomaly, free air anomaly and bouguer anomaly of the stations which were observed in three different epoch. The comparative analyses of the three epochs were done and represented using a graph though there exist a minimal change between the epochs which needs constant monitoring or observation to avoid future ocurance of natural disaster on life and properties.

Keyword: Tremor, Gravity, Earth Tremor, Gravsoft, Global Navigation Satellite System, GNSS, Geoid Model, Ellipsoidal earth.

1.0 INTRODUCTION

Gravity is a potential field; it is a force that acts at a distance (Mariita 2007). The gravity method is a non-destructive geophysical technique that measures differences in the earth's gravitational field at specific locations. It has found numerous applications in engineering, environmental and geothermal studies including locating voids, faults, buried stream valleys, water table levels and geothermal heat sources. The success of the gravity method depends on the different earth materials having different bulk densities (mass) that produce variations in the measured gravitational field. These variations can then be interpreted by a variety of analytical and computers methods to determine the depth, geometry and density that causes the gravity field variations. For better definition of the bodies causing the perturbations in the gravity field, the gravity data should be collected with small stations spacing, such as 1 km. For engineering investigations this may be as low as 5 meters or less. In addition, gravity station elevations must be determined to within 0.2 meters. Using the highly precise locations and elevations plus all other quantifiable disturbing effects, the data are processed to remove all these predictable effects. The most commonly used processed data are known as Bouguer gravity anomalies, measured in mGal. The interpretation of Bouguer gravity anomalies ranges from just manually inspecting the grid or profiles for variations in the gravitational field to more complex methods that involves separating the gravity anomaly due to an object of interest from some sort of regional gravity field.

From this, bodies and structures can be inferred which may be of geothermal interest. Volcanic centres, where geothermal activity is found, are indicators of cooling magma or hot rock beneath these areas as shown by the recent volcanic flows, ashes, volcanic domes and abundant hydrothermal activities in the hot springs. Gravity studies in volcanic areas have effectively demonstrated that this method provides good evidence of shallow subsurface density variations, associated with the structural and magmatic history of a volcano.

The earth's terrain is not at rest but moves slowly due probably to the nature of the earth itself and the underground man-made conditions of the earth's crust. It is, therefore, very important to be sure of the movements of earth that serve human life. Hence, a lot of studies for determining and analyzing the earth movement are often implemented. During these studies, the used measurement techniques and systems, which could be geodetic or non-geodetic, are determined considering the movement of the earth, its environmental conditions, and the expected accuracy from the measurements. A few causes of such movements are volcanic eruption which moves downwards on a sloping rock formation, ultimately causing a landslide; change of ground water level, which may result in compression (compaction or consolidation) of the interceded layers of clay and silt the aquifer system; drainage and oxidation of organization soils; dissolution and collapse of susceptible rocks; tidal phenomena; tectonic phenomena; etc. Some serious effects of crustal deformation include loss of level free board and subsequent reduction in flood protection, change in gradient along water conveyance canals, and collapse of engineering structures (Richardus, 1977). Monitoring and analyzing deformations of engineering structures (such as dams, bridges, viaducts, high-rise buildings, etc.) constitutes a special task for geodesists. There are several techniques for measuring the deformations. Geodetic techniques, through a network of points interconnected by angle and/or distance measurements, usually supply a sufficient redundancy of observations for the statistical evaluation of their quality and for detection of errors. They give global information on the behaviour of the deformable structure, while the non-geodetic techniques give localized and locally disturbed information without any check unless compared with some other independent measurements.

It is against this background that the determination of earth movement within Kwoi, Kaduna state using gravity data became necessary to give more clear view about the geodynamics of the study area and take into account, the relation between gravity changes and seismic activity. The occurrence of the natural disaster (earth tremor) in some part of the country(Kwoi, Ibadan, Abuja and Ijebu-ode) which is the quivering or vibration movement on ground due to plates tectonics possess a demand for gravity survey for effective monitoring and controlling of crustal movement within the study area and also for the protection of life and property.

2.0 LITERATURE REVIEW

2.1 THEORETICAL FRAMEWORK

2.1.1 Brief Overview of Gravity

Gravity is most accurately described by the general theory of relativity (proposed by Albert Einstein in 1915) which describes gravity not as a force, but as a consequence of the curvature of space-time caused by the uneven distribution of mass. The most extreme example of this curvature of space-time is a black hole, from which nothing—not even light—can escape once past the black hole's event horizon. However, for most applications, gravity is well approximated by Newton's law of universal gravitation, which describes gravity as a force which causes any two bodies to be attracted to each other, with the force proportional to the product of their masses and inversely proportional to the square of the distance between them. Gravity surveying uses gravity meters to measure very small variations in the earth's gravity field. Observations are corrected for instrument drift, earth tide, latitude, station height and the effect of surrounding terrain. Other lesser impacts on gravity observations include atmospheric pressure, ocean loading, polar motion, the height of the water table and the amount of soil moisture. As appropriate to the objectives, precision and accuracy of a survey, all of these effects may be removed using rigorous observational procedures, standardized models and computations. Once the various corrections have been applied to gravity observations, the reduced data is essentially a reflection of variations in the gravity field directly related to changes in rock density and structural architecture.

2.1.2 Theory of Gravity

The theory of gravity surveying is directly dependent on Newton's law of gravity: According to Newton, gravitational attraction was caused by an unexplained magnetic force that acted across space and caused mutual attraction between two bodies. Einstein rejected the ideas of Newton. According to the interpretation of the gravitational field which prevailed in the 20th century, gravity was a 'physical phenomenon' in that it was generated by 'masses of matter'. What was supposed to have happened was that matter 'curved and warped space-time' and when physical masses of this matter were 'falling' or were in orbit, they were actually following a straight line in this curved space time which created stretched holes in the 'fabric of space-time'. Thus we must infer that somehow space must be composed of a 'fabric' of some sort, although no one has ever defined what properties it must possess. There is an unresolved inconsistency in Einstein's interpretation of gravity, in that like Newton, Einstein would also need to explain the falling of an apple. It is that point that General Relativity must deviate from a purely physical explanation of gravity and resort to an energy field of some sort. Now according to one interpretation of how this is supposed to work, when an apple is raised up to a height, it takes 'potential energy away from the gravity field'. This is shown in the second panel where the apple now has more 'potential energy' (symbolized by the addition of the yellow to the bar on the right) while the 'gravitational field' has lost that much energy, as shown by the green section in the bar on the left. When the apple begins to fall, as shown in the third panel, the apple must give back the energy that it took from the gravitational field when it was lifted up, and once the gravitational field gets back its lost energy, both apple and field are back in equilibrium. If an object is moving and has a certain momentum, and then encounters the curved space-time, it is easy to imagine that object following the curves of space time, because the object is already moving.

2.2 Gravity anomalies

A gravity anomaly is the difference between a gravity measurement that has been reduced to sea level and normal gravity. Normal gravity, used to compute gravity anomalies, is a theoretical value representing the acceleration of gravity that would be generated by a uniform ellipsoidal earth. By assuming the earth to be a regular surface without mountains or oceans, having no variations in rock densities or in the thickness of the crust, a theoretical value of gravity can be computed for any point by a simple mathematical formula. The theoretical value of gravity at a point on the ellipsoid's surface depends both on the size and shape of the ellipsoid and on a value, computed from observational data, which is accepted as the theoretical value of gravity at the equator. It varies only with the latitude of the observation point if the figure of the earth is taken as an ellipsoid of revolution. While there are several formulas for computing Theoretical Gravity, the one most commonly used is the Gravity Formula 1967 which is based on the Reference Ellipsoid 1967, the parameters of which correspond to the Geodetic Reference System 1967. A simple formula will convert 1967 theoretical (or normal) gravity to the newer more accurate 1980 system, GRS 80 (Chapter II). A number of different procedures can be used to reduce a gravity measurement from the physical surface to sea level and, depending upon which procedure is used, different types of gravity anomalies result. The most common type of gravity anomaly used for geodetic applications is the so-called free-air gravity anomaly..

The word, anomaly, as used in geodesy refers to a deviation from the normal and can be used either for a single point or to describe a regional or area effect. To represent an area of the earth's surface, the gravity measurements (anomalies) within the area are averaged by some specialized technique to produce a mean value. This may be done for areas of different size such as the one degree by one degree square. To make use of the anomalies, the observed gravity must be reduced to a common frame of reference, the geoid-mean sea level. The reductions may take into account the elevation above (or below) sea level and can account for the mass between the point and sea level, the surrounding terrain, and the assumed structure of the earth's crust.

1. Normal gravity

The normal or theoretical gravity value at a geographic location is calculated using the assumption that the Earth is a regular homogeneous ellipsoid of rotation (the reference ellipsoid). The following equation gives a closed form approximation to the normal gravity based on the 1967 geodetic reference system:

$$gN = 9780318.5\ [1.0 + 0.005278895 \sin^2 \phi + 0.000023462 \sin^2 \phi]\ \mu ms^{-2}$$

Where: ϕ is the geographic latitude of the point A rough rule of thumb is that normal gravity decreases or increases by about one milligal per mile (1 μms^{-2} per 160 metres) at 30° latitude in a north or south direction.

2. Free-air anomaly

The simple free-air gravity anomaly is calculated using the following formula:

$$FA=gObs-gN+3.086H\mu ms^{-2}$$

Where: gObs is the observed gravity

gN is the normal gravity on the ellipsoid at that latitude H is the height of the meter above the geoid (AHD)

3. Bouguer anomaly

The simple Bouguer gravity anomaly is calculated using the following formula: BA= FA- 0.419pEμms^{-2}

Where: FA is the free-air gravity anomaly in μms^{-2}

P is the density assumed for the crustal mass around the geoid

E is the elevation of the ground surface above the geoid (AHD)

More complex anomalies may be calculated with extra corrections and for various environments (eg at the bottom of a mountain lake) as set out in the International Gravimetric Bureau (BGI) Bulletin. Several examples are shown in Figure 6.

4. Terrain corrections

Definition Gravity anomalies are calculated on the assumption that the gravity station is sitting on a horizontal plane. If the topography differs from a plane this assumption is incorrect and a terrain correction must be applied to compensate. Any ground above the observation point (hills) tends to attract a mass upwards and any lack of ground below the observation point (valley) reduces the downward attraction. In both cases a positive terrain correction needs to be added to the observed anomaly to normalise its value. The correction is an integral of the gravitational effect of the mass above or the mass deficit below. The correction depends on the density of the surface strata (Leaman 1998).

2.3 Factors affecting gravity

Gravitational acceleration measured at any point depends on five factors, all related to either *M* or *r* or both. The affects are as follows, and corrections for these effects must be applied to data sets. The section on data reduction explains further.

a. **Latitude**: From equator to pole, gravity varies by roughly 5000 mGal (greater at poles). The gradient (i.e. rate of change with respect to latitude) is maximum at 45° latitude, where it is about 0.8 mGal/km.
b. **Elevation**: The effect of changing the elevation of a measurement is quite significant. For modern instruments, a change of only a few centimetres can be detected, and between sea level and the top of Mt. Everest, the difference is roughly 2000 mGal.
c. **Slab effect:** Going up in elevation rarely means up into air (except for airborne surveys). If we are "up," there are rocks and soils between us and where we were. The attraction of these materials counteracts the effect of going up in elevation. Therefore, the elevation correction is counteracted by subtracting a factor of $0.0419 \times h \times d$ mGal, where h is elevation in metres, d is density of intervening materials in g/cc. This is called the **Bouguer correction**.
d. **Topography**: Effects due to nearby topographic relief (hills or valleys) may be significant, but are rarely more than 1.0 mGal. These effects are rather tedious to apply, but are important when there is steep topography near the measurement locations.
e. **Earth tides**: Tidal effects are as much as 0.3 mGal, and these are usually accounted for by recording several measurements at a single station (a base station) throughout the course of a survey.

3.0 METHODOLOGY

The methodology was divided into data acquisition, data processing and results presentation and analysis. Figure 2 shows the flow chart of the adopted methodology.

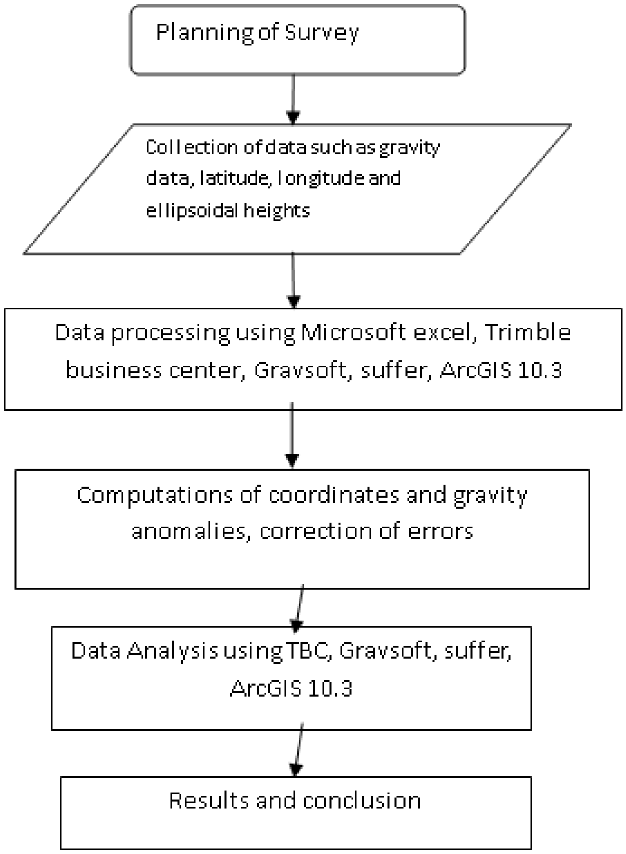

Fig 1: Flow Chart of the Adopted Methodology

3.1 Data Requirement

3.1.1`Data Type

GNSS data gotten from the field using Trimble instrument on a static mode for the determination of the positions and ellipsoidal heights of the study points, Gravity values of the study point acquired from the field using A Lacoste and Romberg (G- 512) gravimeter, the DEM data which were acquired from the office of the surveyor general of the federation. The above data serves as the input parameters for the determination of earth's crust movement of Kwoi for the monitoring of the effect of earth tremor.

3.1.2 Data Source

The data required for determination of earth's crust movement at Kwoi Kaduna state were sourced from the Office of the Surveyor General of the Federation, Abuja.

3.3 Data Preparation and Models

This phase includes determining the mean gravity data from the field work using Microsoft excel.

3.4 Data Acquisition

The GNSS field data acquisition (Observation) in this project was done on a Static mode for minimum of thirty minutes per session by one team while the other two teams served as Reference points (Base Stations). This was designed in such a way that for each session, a loop network was formed with one rover (gravity point) and two base stations (Monitoring Control Pillars). Trimble R8 Model 3 dual frequency GNSS receiver was used by each team for the observation. The GNSS R8 Receiver antenna was set up, cantered and levelled on the station marker. The power source and memory requirements were assessed to ensure complete data acquisition; antenna heights measurements and photograph at the start and end of each session of the observation were taken. The

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antenna height measurement was made to the centre of bumper. Likewise, the panoramic view of the points (survey points), surrounding view and horizon from the four Cardinal points (North, East, South and West) were photographed. Adequate and proper records of all the field observation were made on the OSGOF GNSS Field sheet. OSGOF Station description (reconnaissance) sheets, obstruction (visibility) diagram sheets and GNSS observation sheets were used for this exercise. See In accordance to the technical specification, all the receivers were configured to acquire data using logging rate 5 seconds, elevation mask angle; 15˚, Position Dilution of Precision (PDOP) <4, The number of satellites in view during observation ranged from 10 to 18 satellites.

The gravity field data acquisition of this project was done by the use of LaCoste and Romberg (G664) Gravimeter. At each gravity point, the LaCoste and Romberg (G664) Gravimeter was levelled. The internal temperature and voltage of the Gravimeter were checked, then voltmeter was connected to the gravimeter and the graduation adjusted from positive direction till the gravity pointer is 0 and the voltmeter reading is almost 0.00, then the readings were recorded from the LaCoste Gravimeter, voltmeter and time of reading. The height of the gravimeter above the ground point was also measured and recorded. This was repeated in all the station where the gravity readings were taken. The readings were booked in OSGOF gravity field sheet. See samples of the field sheets and the pictures of the gravimeter below.

Plate 1. (a, b and c) shows the sample of the gravity data field sheet and the pictorial view of the gravimeter when the observation at Kwoi was in progress.

3.5 Data Processing

The data processing was carried out using the Trimble Business Center (TBC) software version 2.5. The processing was done using the established controls (YSJ29/MCP2, YSJ30/MCP3 and YSJ31/MCP4) as references. The Gravity data acquired were averaged using MS-excel and then processed using Gravsoft software

4.0 Results Analysis

4.1 Reduction of Data

The goal of data reduction is to remove the known effects caused by predictable features that are not part of the "target." The remaining anomaly is then interpreted in terms of sub-surface variations in density. Each known effect is removed from observed data. First the various "corrections" were described, and then the presentation options were listed. After the field observations the data acquired was reduced in other to correct for errors by taking the mean of the gravity data. This phase helps in the removal of the "known" effects from observed gravity values: Temporal corrections, tides, instrument drift, Latitude correction, Elevation corrections Free air, Bouguer, terrain correction (if needed) and the step taken involves: Remove tidal effects (use tide model or base station readings), Correct for instrument drift using base station readings, Calculate absolute gravity, Subtract GRS67 gravity value (theoretical gravity) – latitude correction. After the derivation of gravity, this formula (gobs +0.3086 *ellipsoidal height –the average height) for determining the free air and (gobs + 0.1967 * ellipsoidal height – the average height) for bouguer anomaly was used to determine the anomalies respectively.

Table 4.0 shows the g(mGal) value after all the corrections were done and the free air and anomaly were also derived.

gN = 9780318.5 [1.0 + 0.005278895 $\sin^2 \phi$ + 0.000023462 $\sin^2 \phi$] μms^{-2} Where: ϕ is the geographic latitude

FA=gObs-gN+3.086Hμms^{-2}
where: gObs is the observed gravity

gN is the normal gravity on the ellipsoid at that latitude H is the height of the meter above the geoid (AHD)

BA= FA- 0.419pEμms^{-2}

Where: FA is the free-air gravity anomaly in μms^{-2}

P is the density assumed for the crustal mass around the geoid

E is the elevation of the ground surface above the geoid (AHD)

Table 4.0 Reduction of gravity data (first epoch)

Index	Longitude	Latitude	ellipsoidal height (m)	g (mGal)	Free air (mGal)	Bouguer anomaly (mGal)
4	8.00666	9.45941	793.344	1.594	0.6509184	0.9928848
5	8.00742	9.45598	797.957	0.093	0.5734902	0.3992619
20	8.03186	9.4519	791.211	1.822	0.2206746	0.8013237
31	7.99891	9.45737	780.942	5.923	1.1526612	2.8824114
49	8.00855	9.44221	803.507	1.585	3.7782202	2.9829469
52	7.99332	9.43304	826.994	1.094	10.535308	7.1118398
57	8.00205	9.44444	806.555	0.504	3.637833	2.5014885
59	8.00072	9.44938	787.097	3.753	0.8820942	1.9230999
62	8.01251	9.45829	928.122	-30.122	10.527409	-4.212283
200	7.99521	9.43708	816.857	1.967	8.2800302	5.9908919
300	8.01357	9.45282	804.345	0	2.451827	1.5627815
400	8.00251	9.46729	774.828	6.515	-0.142119	2.2717876
			796.4024			

Table 4.1 Reduction of gravity data (second epoch)

Index	Longitude	Latitude	ellipsoidal height (m)	g(mGal)	Free air (mGal)	Bouguer anomaly (mGal)
4	8.00666	9.45941	793.344	1.602	0.658918	1.000885
5	8.00742	9.45598	797.957	0.107	0.58749	0.413262
20	8.03186	9.4519	791.211	1.832	0.230675	0.811324
31	7.99891	9.45737	780.942	5.925	1.154661	2.884411
49	8.00855	9.44221	803.507	1.589	3.78222	2.986947
52	7.99332	9.43304	826.994	1.102	10.54331	7.11984
57	8.00205	9.44444	806.555	0.512	3.645833	2.509488
59	8.00072	9.44938	787.097	3.757	0.886094	1.9271
62	8.01251	9.45829	928.122	-30.13	10.51941	-4.22028
200	7.99521	9.43708	816.857	1.972	8.28503	5.995892
300	8.01357	9.45282	804.345	0.002	2.453827	1.564782
400	8.00251	9.46729	774.828	6.52	-0.13712	2.276788

Table 4.2 Reduction of gravity data (third epoch)

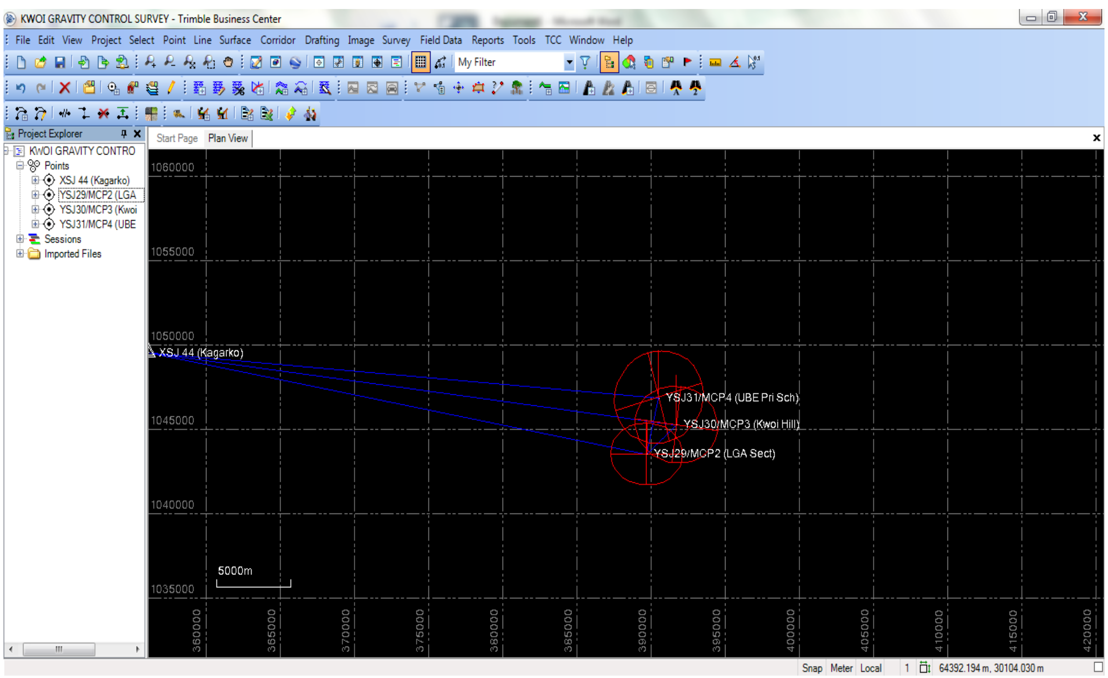
Index	Longitude	Latitude	ellipsoidal height (m)	g(mGal)	Free air (mGal)	Bouguer anomaly (mGal)
4	8.00666	9.45941	793.344	1.603	0.659918	2.968885
5	8.00742	9.45598	797.957	0.108	0.58849	2.381262
20	8.03186	9.4519	791.211	1.833	0.231675	2.779324
31	7.99891	9.45737	780.942	5.926	1.155661	4.852411
49	8.00855	9.44221	803.507	1.5893	3.78252	4.954247
52	7.99332	9.43304	826.994	1.103	10.54431	9.08784
57	8.00205	9.44444	806.555	0.513	3.646833	4.477489
59	8.00072	9.44938	787.097	3.758	0.887094	3.8951
62	8.01251	9.45829	928.122	-30.131	10.51841	-2.25428

200	7.99521	9.43708	816.857	1.973	8.28603	7.963892
300	8.01357	9.45282	804.345	0.0041	2.455927	3.533882
400	8.00251	9.46729	774.828	6.53	-0.12712	4.253788
			796.4024			

4.2 Proccessing GNSS and gravity Data

GNSS data were processed using trimble business center where the obtained raw coordinate in RINEX format were processed to produce the adjusted coordinate of all the stations observed. Table 4.3 shows the adjustment report of the stations, the errors that were corrected using least square adjustment method which are already programmed in the Trimble business center software. The processing of the nine other stations was done using the established controls (YSJ29/MCP2, YSJ30/MCP3 and YSJ31/MCP4) as references.

Plate 2.0: this shows the network diagram of the monumented beacons and its referenced point used for its adjustment.



4.3 To determine the nature of earth crust movement at the study area.

This is done to check the effect of earth tremor within the study area using the results of free air and bouger anomaly for the three epoch to ascertain if the earth crust is moving or not.

Fig 1 the graph shows the relationship between g(mGal), free air anomally(mGal) and Bouguer anomaly (mGal) for the first epoch.

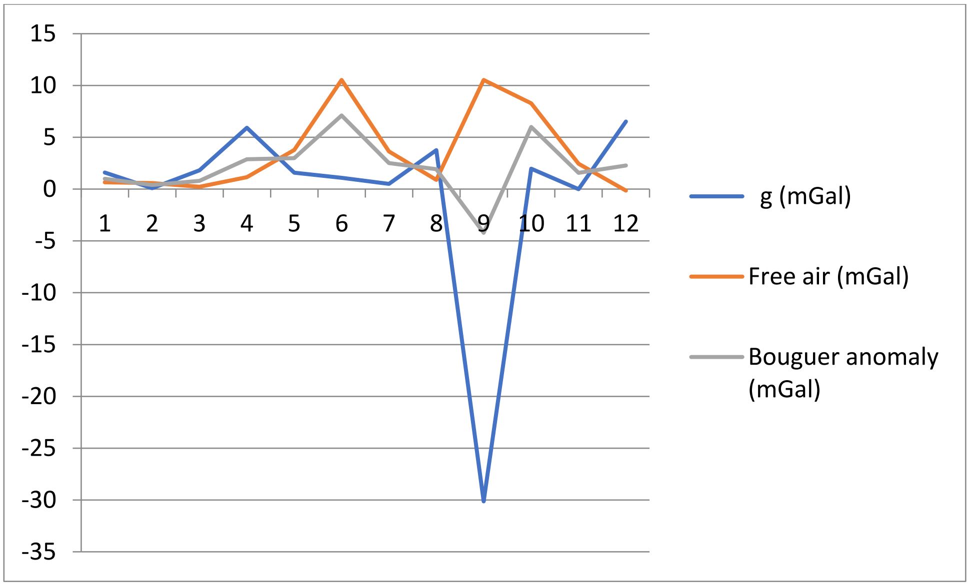


Fig 1 shows the profile of the study of the first epoch to ascertain the nature of earth's crust movement using the baseline observations. The g(mGal) were derived using the Gravsoft software where the gravity raw data and the adjusted coordinates of the stations were used in the PreprocessGrav Extension after correcting the anomalies. The g(mGal) is one of the parameters used for the derivation of free air and bouguer anomalies. Fig 4.0 shows how the terrain is profiled though the movement of the earth's crust won't be ascertained here because it is the baseline observations.

Fig 2 the graph shows the relationship between g(mGal), free air(mGal) and Bouguer anomaly(mGal) for the second epoch.

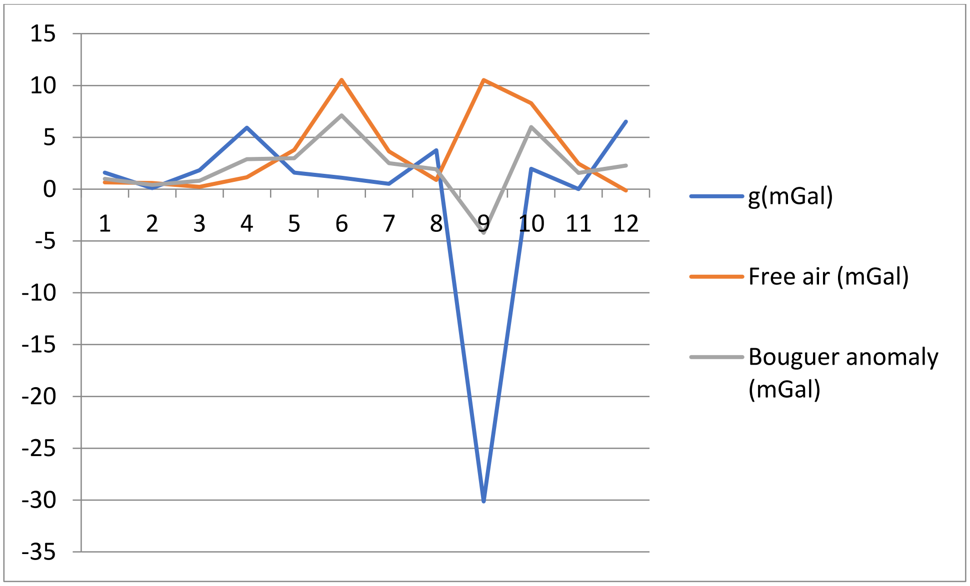


Fig 2 shows the profile of the study of the second epoch to asertain the nature of earth's crust movement. The stations were observed after six months and all the corrections carryout to determine the gravity anomaly. The g(mGal) were derived using the Gravsoft software where the gravity raw data and the adjusted co ordinates of the stations were used in the PreprocessGrav Extention after correcting the abnomalies. The g(mGal) is one of the parameters used for the derivation of free air and bouguer anomalies. This graph shows how the terrain is profiled which when compared with the first epoch graph shows the movement of the earth's crust within the study area for a period of 6months .

Fig 3 the graph shows the relationship between g(mGal), free air (mGal) and Bouguer anomaly(mGal) for the third epoch.

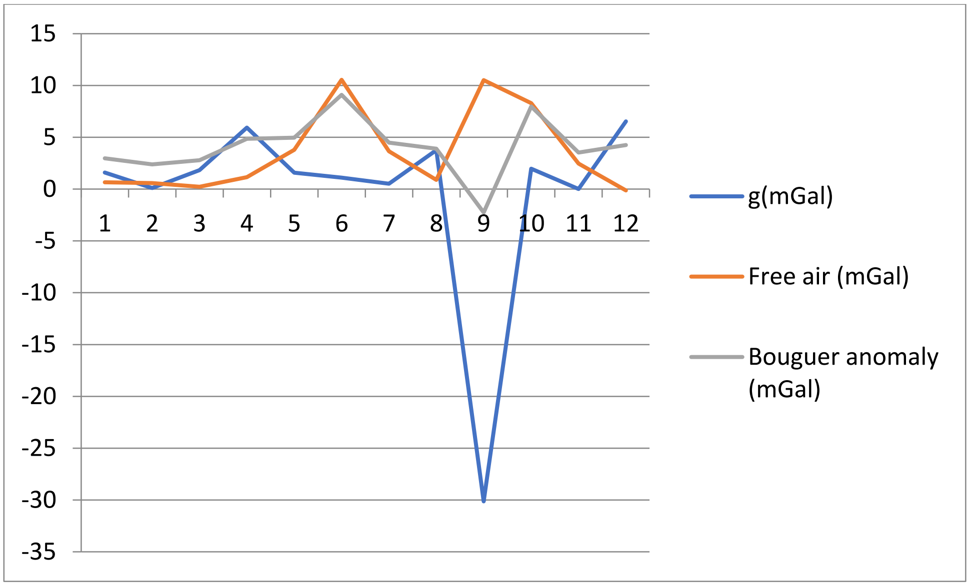


Fig 3 shows the profile of the study of the Third epoch to asertain the nature of earth's crust movement. The stations were observed after one year of the baseline observation and all the corrections carryout to determined the gravity anomaly. The g(mGal) were derived using the Gravsoft software where the gravity raw data and the adjusted co ordinates of the stations were used in the PreprocessGrav Extention after correcting the abnomalies. The g(mGal) is one of the parameters used for the derivation of free air and bouguer anomalies. This graph shows how the terrain is profiled which when compared with the second epoch shows the movement of the earth's crust within the study area for a period of 6 months .

Fig.4 the graph shows the relationship between the first and second epoch.

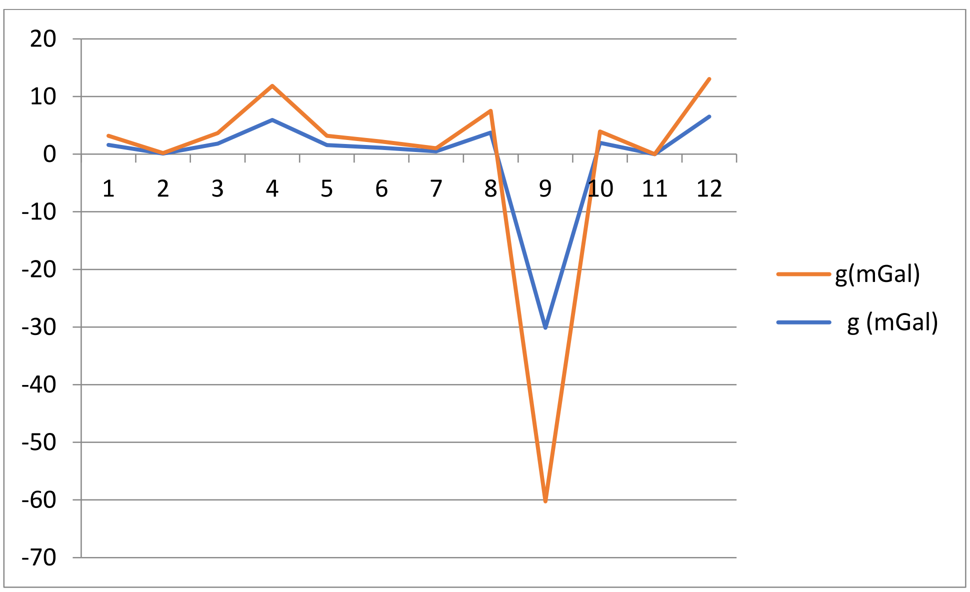


Fig 4. shows the relationship between the first and second epoch of observation to astertain the nature of the crust movement within the study within six months interval though there is a change between the two epoch but it is minimal and should be taken into consideration to avoid future damages when not properly managed.

Fig 5 the graph shows the relationship between the second and third epoch.

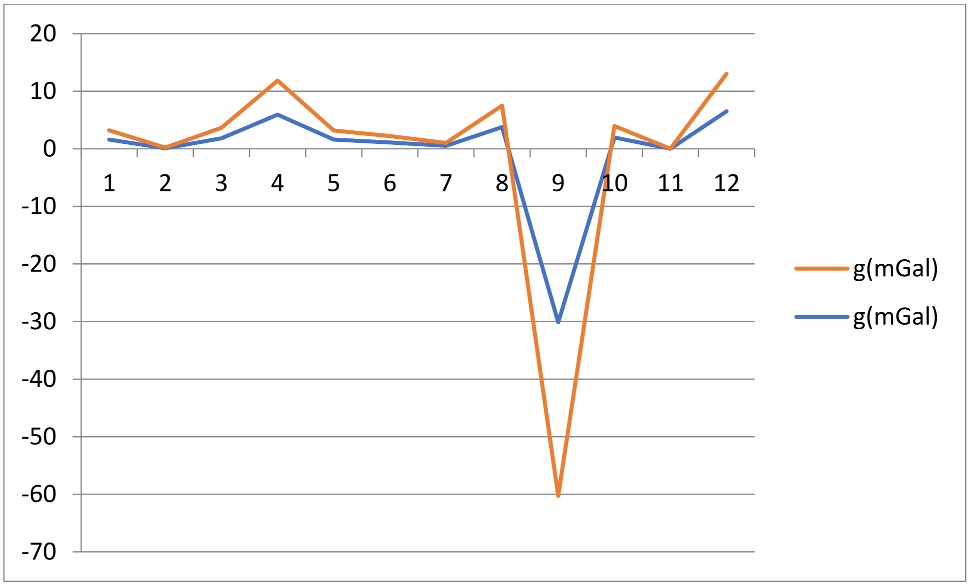


Fig 5 shows the relationship between the second and third epoch of observation to ascertain the nature of the crust movement within the study within six months interval though there is a slight change between the two epoch but it is minimal and should be taken into consideration to avoid future damages when not properly managed. The profiling used the g(mGal) which was derived using the station coordinates and the gravity raw data with volt reading, date, time and year of observation while free air and bouguer anomalies were derived using the formula (g(mGal) +0.3086 *(height – the average heights) and g(mgal) + 0.1967 *(height – the average height) respectively. This will help in showing the movement of the earth's crust within the study by profiling the parameters (g(mGal), free air and Bouguer anomaly) to ascertain the effect or rate of change within the study area.

5.0 CONCLUSION

The Gravity Survey for the determination of earth's crust movement at Kwoi, Kaduna state was successfully carried out using Trimble GNSS equipment on static mode for minimum of 30 minutes and LaCoste and Romberg (G664) Gravimeter to acquire the RINEX data and gravity data respectively. First three beacons were monumented and observed to serve as the referenced station and they are YSJ 29, 30 and 31 respectively while the remaining nine were casted on a nail along the places that were affected by the earth tremor, the first order control point XSJ 44 at Kargako were used to execute the project. A base (R8 GNSS) was set up on the pillar, all the necessary adjustment was carried out i.e. levelling and centering and the base was powered on. A well condition triangular network was designed with XSJ 44 as the base and Monitoring Pillars (YSJ29/MCP2, YSJ30/MCP3 and YSJ31/MCP4) as the rovers. Static observation of two hours minimum duration was carried out to coordinate the rovers with horizontal accuracy of 0.050m + 1.000ppm and vertical accuracy of 0.100m + 1.000ppm. The Base gravity point at old post office in Suleja, Niger state was transferred to MCP 3 located on Kwoi hill, in Jaba LGA, Kaduna state for the execution of this project. The LaCoste and Romberg (G664) Gravimeter was placed on the gravity Base point at Suleja and all necessary adjustment were taken i.e. levelling, checking the internal temperature and voltage, a voltmeter was connected to the gravity meter and the graduation was then adjusted from positive direction till the pointer is 0 and the voltmeter reading is almost 0.00, then the reading taken on the LaCoste Gravimeter that of the voltmeter and time of reading was taken. After the opening of the Loop at Suleja, the Gravimeter was taken to pillar YSJ 30/MCP3 on Kwoi hill where same procedure was repeated. The Gravimeter was brought back to Suleja same procedure was again repeated, then the final closing of the loop was at YSJ 30/MCP3.

The data were acquired in three different epochs and its analysis done accordingly with the required accuracy. A total number of twelve (12) points were coordinated and their Gravity readings were taking during the execution of the project. This project was successfully carried out, the aim and objective for which the study was based and the expected results shows that there exist a change in the earth's crust movement following the comparative analysis perform on the epochs of observation and this results will serve as a basis for monitoring the earth's crust movement which will aid in decision making and saving future damages of life and properties

6.0 RECOMMENDATIONS

The following recommendation is hereby made for further research: The data acquired during this project are to be useful for effective monitoring of the effect of the earth's crust movement within the study area. Owing to the fact that it is established that there is an existence of natural disaster (earth tremor) within the study area and the graphs shows that there is actually a slight change between the first second and third epoch which is minimal and subsequently, GNSS and Gravity Observations can be repeated on these Gravity Stations at a chosen time interval for future monitoring of the earth tremor effect to avoid future damage and its prediction at Kwoi, Kaduna State Nigeria to save life and properties.

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