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Research Paper

Structural Interpretation of Ground Gravity and Aeromagnetic data of parts of Southwestern Nigeria.

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ABSTRACT
Ground gravity and aeromagnetic data of parts of southwestern Nigeria underlain mainly by the Basement Complex rocks was interpreted in order to delineate structural trends and fault systems of the area. The processed data were presented as 2D maps with both contour and colour shaded maps. There is mostly a general NE/SW and few N/S trends in all the anomaly fields. Six major bouguer anomalies with unique characteristic features were identified which maybe related to the contrasting lithological and structural features. These are: (1) Ilefara-Ilesha-Ilaorogun High (2) Akure-Ikere-Igbaraoke High (3) Ikare-Ogbagi-Ajowa High (4) Ute-Uzebba High (5) Ondo -Bagbe Low and (6) IjeshaIsu-Ikole-Ponyan Low.
The elongated NE/SW trending bouguer anomaly at the western part of the study area termed the Ifewara-Ilesha-Ilaorogun High coincide with the geologically established shear zone associated with Ifewara-Zungeru fault system in orientation and location. Hence, the gravity data have confirmed the existence of the mega fault system which is related to gold mineralization within the Ilesha Schist belt. The Ifewara fault system is a typical tectonic setting where there is a relative movement causing shearing trending NNE/SSW. This shear zone produces mylonitised rock. This mylonitization creates a density contrast with the surrounding rocks. Also, the high bouguer anomaly value can be attributed to the fault zone acting as pathway for upward movement of mineralising fluid with the emplacement of gold among other minerals.
KEYWORDS: *Ground Gravity, Aeromagnetic data, Basement Complex, structural trend, Bouguer anomaly, mineralization, shear zone.*

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I. INTRODUCTION

Gravity and Magnetic data are power tools in structural mapping. Most rocks have unique physical properties which give different responses to geophysical measurements; hence obscure structural and lithological features from the traditional surface geological mapping are better resolved with the aid of geophysical data such as gravity and magnetic (Adejuwon, 2021). A well interpreted geophysical dataset can provide the third dimension to surface mapping and sampling, it maps rocks, structure, alteration, etc. under a surface cover of overburden or water, it aid to detect changes in mineralogy, alteration, etc. that are not readily observable visually.

The study area is in Southwestern part of Nigeria and lies between latitudes 7°00'N and 8°00'N and longitudes 4°30'E and 6°00'E with an approximate area extent of 18,150km^2. It covers Ekiti state, parts of Ondo, Osun, Kogi and Edo states (Figure 1). Elevation in the study area varies from 93m from the southern part to about 1037m in the north-central part (Figure 2). The northern part is generally an upland zone, with elevations being generally above 450m. The landscape is dotted with rugged hills.

Geologic setting

The study area is underlain mainly by the Precambrian Basement rocks. From the regional geological map of the area, the basement rocks which are mainly migmatites, schists, charnokites, and granites cover over 95% of the study area while the sedimentary rocks covers the extreme southeastern part (Figure 3).

According to Rahaman (1978) and Olarewaju (1982), about six lithologies are known in this region which area: (a) The migmatite – gneiss complex (b) The slightly migmatised to unmigmatised paraschists and meta-igneous rocks (c) The charnockitic rocks (d) The older granites (e) The un-metamorphosed granitic rocks composed mainly of microcline and quartz (f) The dolerite dykes which are composed of mainly mafic minerals.

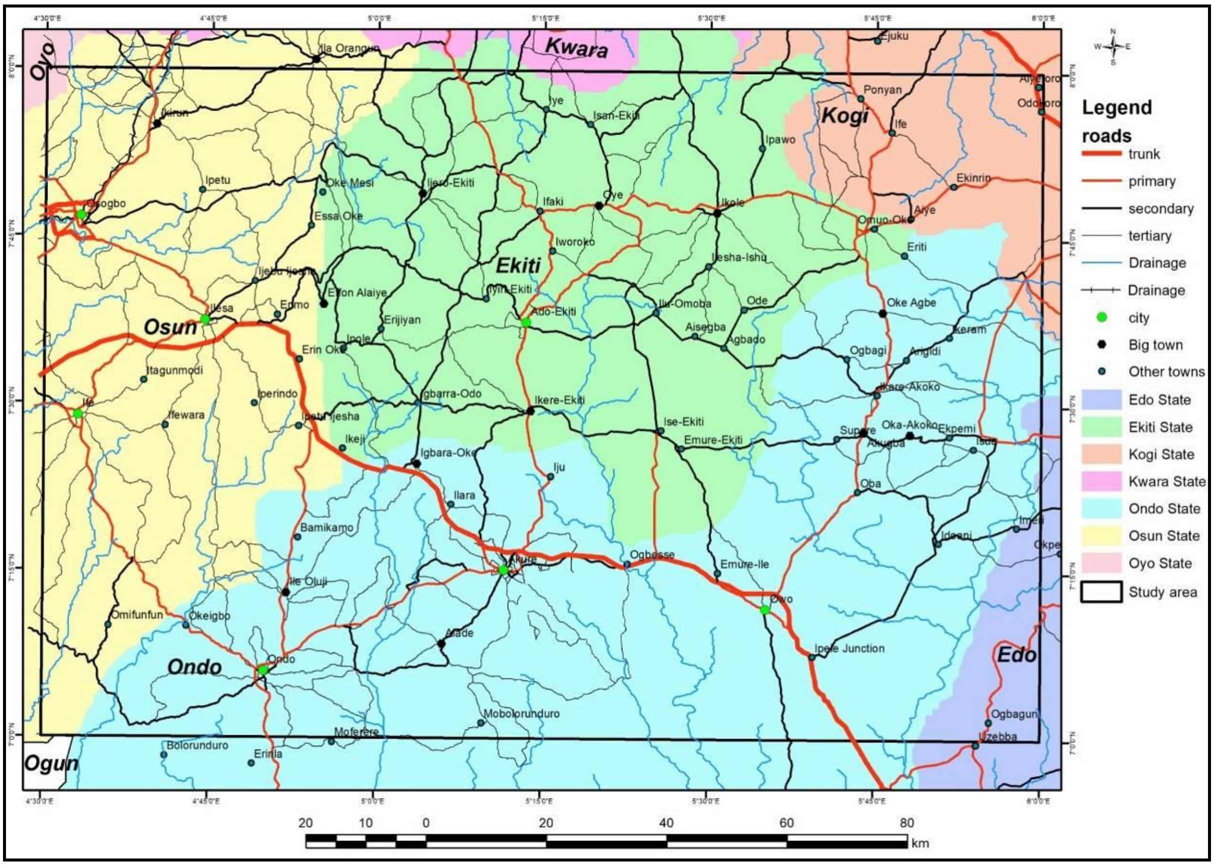

Figure 1: Location and Accessibilty Map of the study area

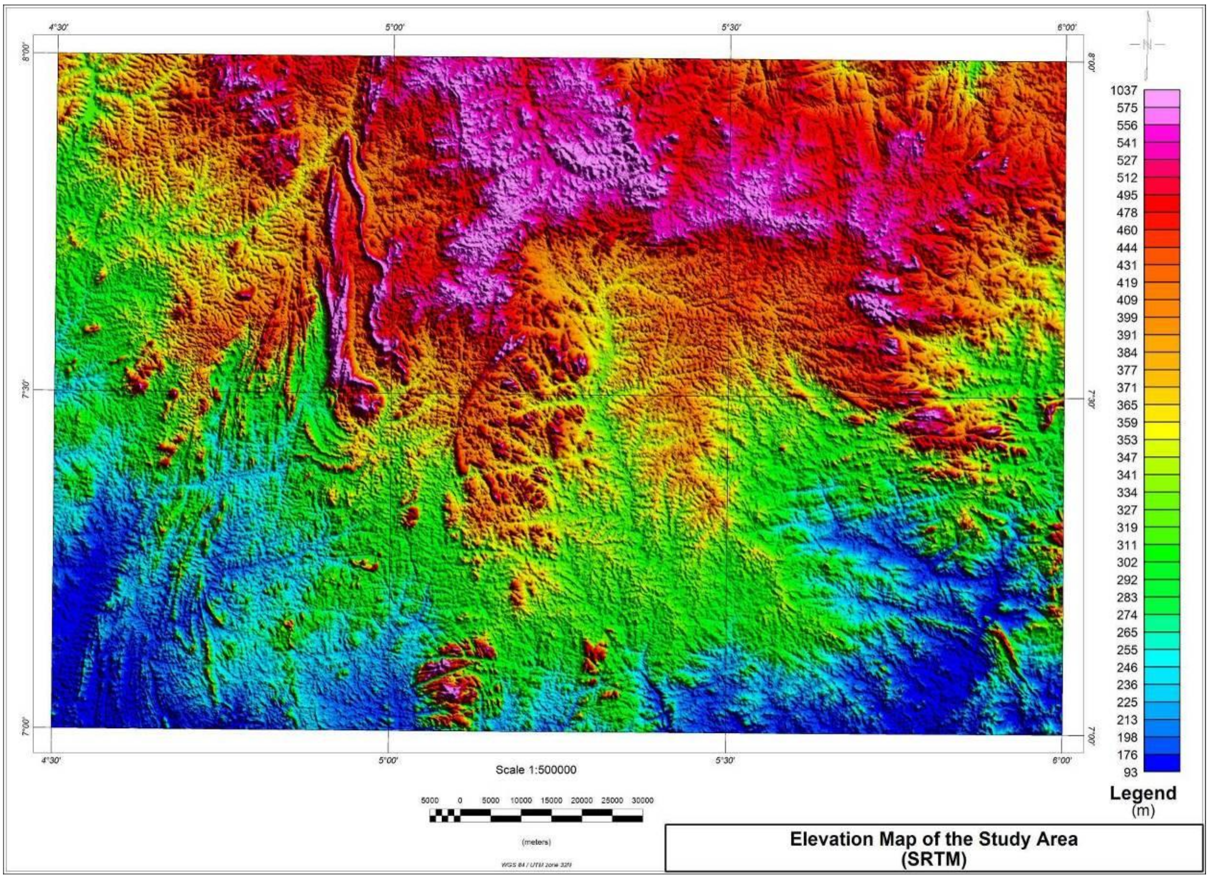

Figure 2: Elevation Map of the study area

The geological setting of the area involves a suite of Pan-African (600±150 Ma) orogenic granitoids, known as the 'Older Granites'. The granitoids were emplaced into migmatites, gneisses and schists of ages varying from Liberian (2,700 Ma), Eburnean (2,000 – 2,700 Ma) and Kibaran (1,100 Ma; Holt *et al.*, 1978; Ogezi, 1977) or the Pan-African time (Ajibade *et al.*, 1986) but are now reduced to synclinorial remnants by subsequent erosion (Russ, 1957). The sedimentary part at the southern region falls within the Dahomey basin. Dahomeybasin is generally long with a total length of about 800 km, narrow and parallel to the coastline (Adejato *et al.*, 2018). This part of Dahomey basin that outcropped in the study area consists of Cretaceous Abeokuta formation, Tertiary Ewekoro formation, followed by Ilaro formation and Quaternary Benin formation.

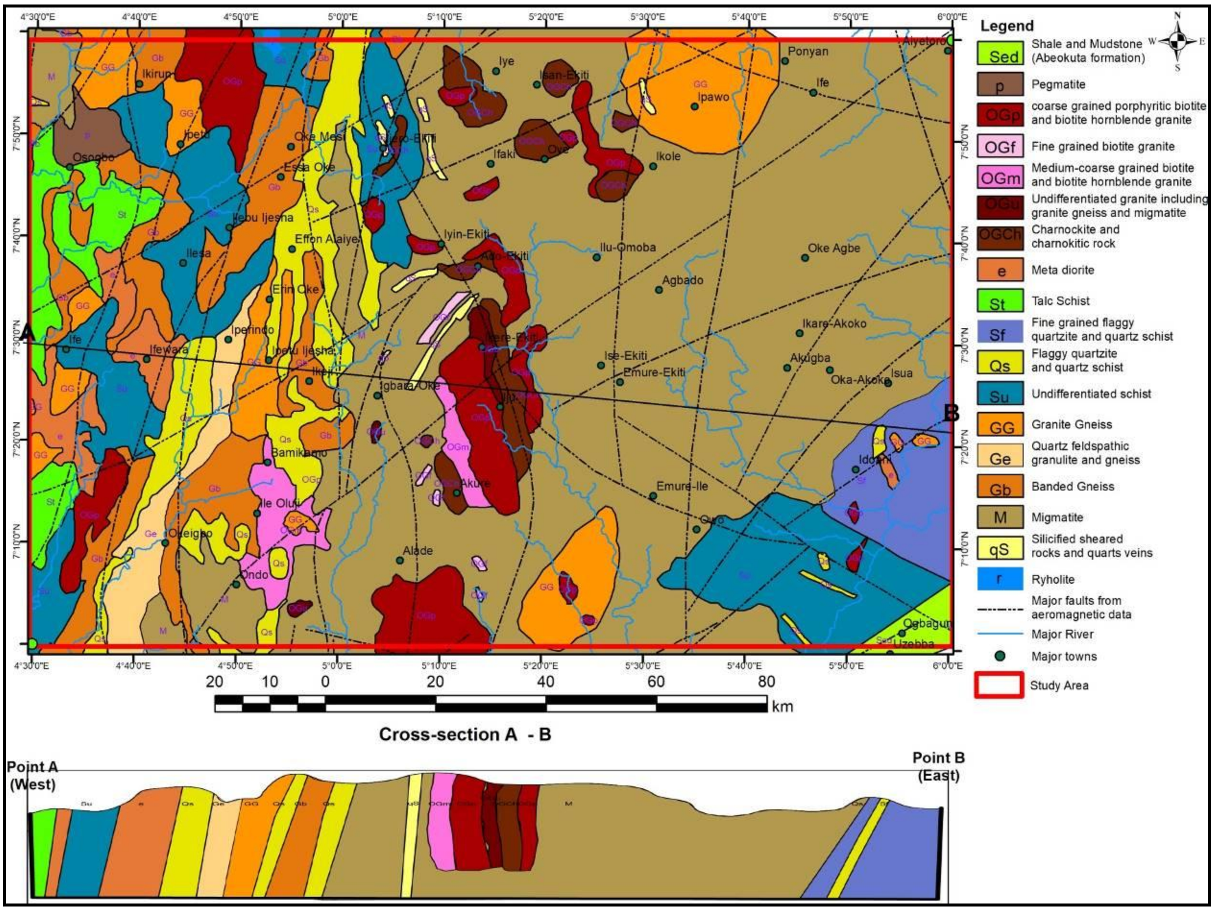

Figure 3: Regional Geological Map of study area (Modified after NGSA, 2006)

II. MATERIALS AND METHODS

A Lacoste and Romberg gravimeter (G-512) was used for this gravity data. The gravity data acquisition in the study area started at an existing gravity base station established by Osazuwa (1985). Gravity measurements were taken at 2.0 km intervals along motorable roads and footpaths through-out the study area. Gravity differences due to instrumental drift and tidal effects were monitored together by a repeated reading taken at the base station every two hours.

About one hundred and twenty-five (125) loops were carried out during the survey while seventy-five base stations were established at chosen locations throughout the study area (Figure 4). Heights of the gravity stations were measured with Three Wallace and Tiernan altimeters with Psychro-Dyne thermometer to measure the wet and dry temperatures from which the relative humidity was derived using the psychrometric chart. Bench marks of known heights obtained from the Office of Surveyor General of Ondo state were used as controls in the determination of elevations.

A high-resolution Aeromagnetic data fron Nigerian Geological Survey Agency was used for the interpretation. The survey parameters of the aeromagnetic data are: Flight line spacing (500m), Tie line spacing (2km), Terrain clearance (80m), Flight direction is NW-SE while the Tie line direction NE-SW. The acquired airborne geophysical data was processed and interpreted for likely structural signatures. In order to delineate lateral boundaries due to the main sources of magnetic responses, edge enhancement techniques based on magnetic signal derivatives –vertical gradients, analytical signal were used.

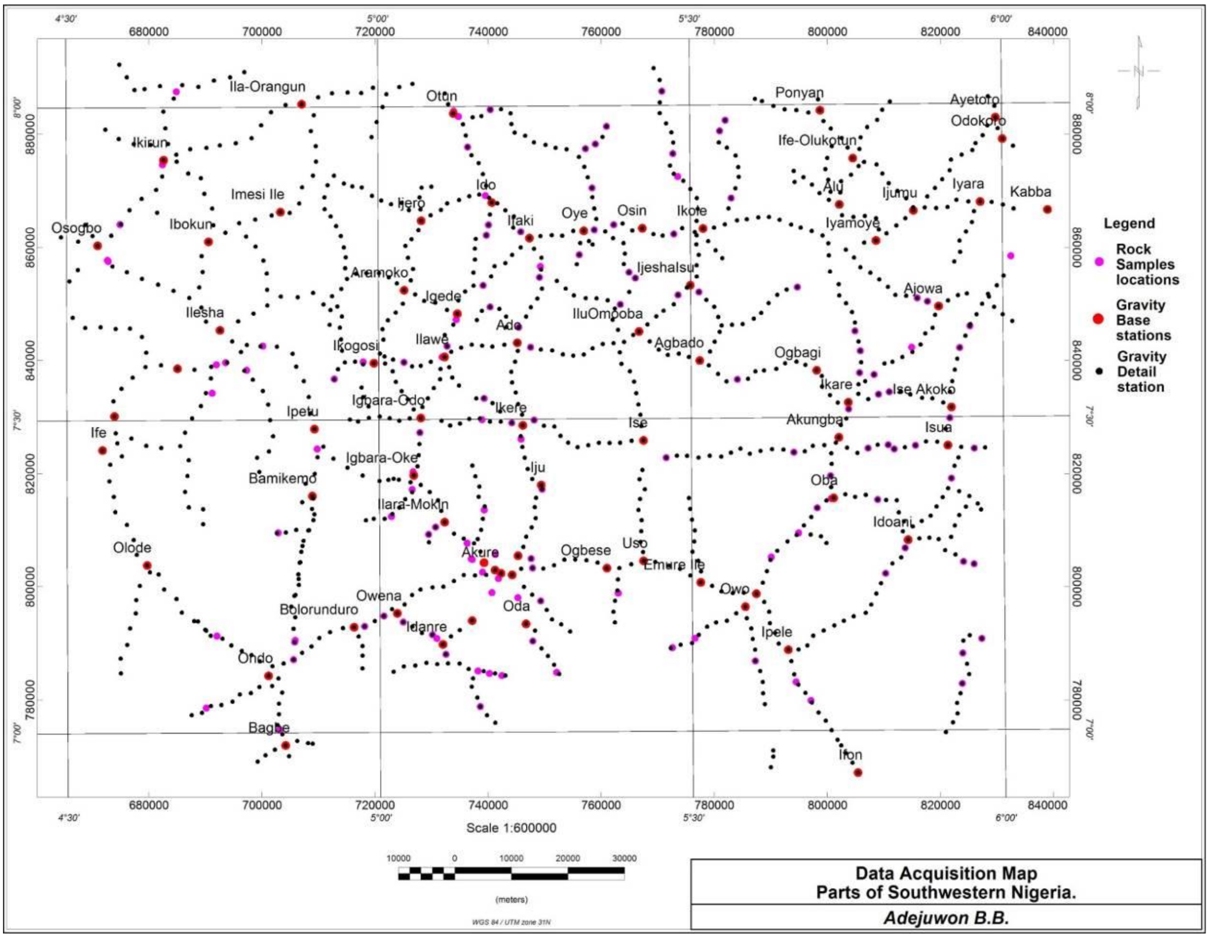

Figure 4: Gravity Data Acquistion Map

III. RESULT AND DISCUSSION

From this study, a total of one thousand and ninety-three (1,093) detail stations from about one hundred and twenty-five (125) closed loops. The loops were kept at an average of 2hours with the summary in Table 1 below. From the analysis, the time for the loops varied between 34mins to 153min with an average of 114 ± 22mins. The close repeatability of data at the close of every loop due to the low drift rate of the gravimeter used is worthy of mentioning. It ranges from 0.01 to maximum of 0.38meter reading with an average of 0.0792 ± 0.0744.

The one thousand and ninety-three (1,093) detail stations give a gravity data density of 1/16.6km^2 i.e. an approximate of one detail gravity station in 2.3km radius. This is a considerable improvement on the existing station density of 1/4538km^2.

Seventy-five (75) base stations were established in the study area (Figure 4) giving a base station density of 1/242km^2 i.e. an approximate of one gravity base station in 8.7km radius. This is a considerable improvement on the existing base station density of 1/9,075km^2.

Table1: Summary of the Error Analysis

	Change in value at Base	Time interval (minutes)
Minimum	0.01	34
Maximum	0.38	153
Mean	0.0792	114
Standard deviation	0.0744	22

Bouguer anomaly field is devoid from the effect of geological materials lying between the observation point and the datum. The observed gravity values were reduced to Bouguer Anomaly map (Figure 5). The Bouguer anomaly values range from about -19.087 to 16.914mGal with mean value of -2.01 ±6.713 mGal. The northcentral/northeastern parts of the study area (Ijesa-isu, Ikole, Ipao, Itapaji, Iye, Ponyan, Ijumu, ayetoro area) map show negative gravity values probably indicating low-density bodies. The western and southern parts of the study area (Ilesha, Ife, Akure, Ikere, Ifon area) map show positive gravity values probably indicating high-density bodies. It is noteworthy that positive gravity anomalies are associated with shallow high-density bodies whereas gravity lows are associated with shallow low-density bodies (Wright, 1981).

High bouguer values are associated with Ilesha schist belt to the west of the study area, the charnockite of Oye, Ado, Akure and Idanre area and the Akoko high. The bouguer anomaly map is characterized by several closures with varied amplitudes and gradients. This may be related to the litho-structural features of the underline rocks in the study area which varied widely both in composition, mineralogy, orientation, depth of emplacement and density (Adejuwon, 2021).

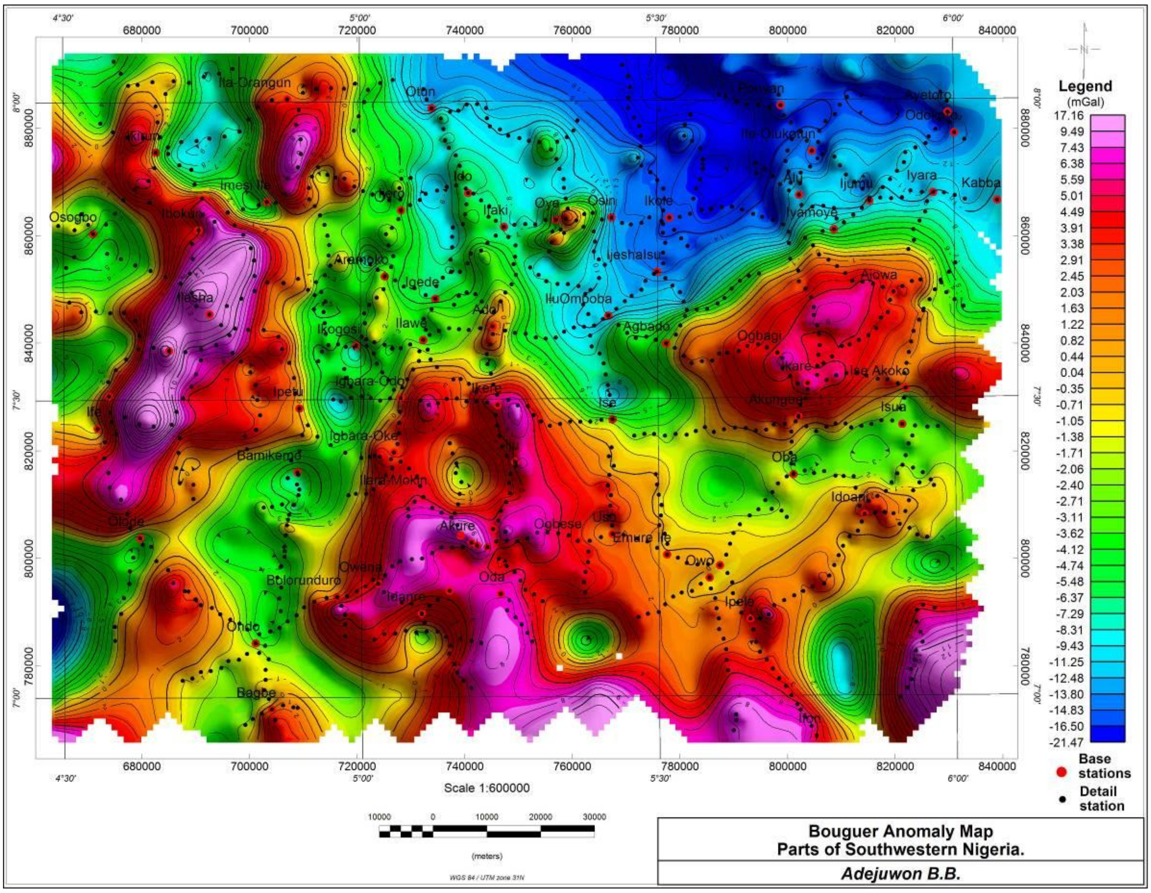

Figure 5: Bouguer Anomaly Map

For meaningful geological inferences and deductions from the gravity data, it is imperative to separate the effects which are associated with geologic features of interest from the total gravity field. The computed regional anomaly (Figure 6) was subtracted from the Bouguer anomaly map (Figure 5) to obtain the field due to local geological events i.e. residual bouguer map (Figure 7). The residual bouguer anomaly map is characterized by several closures with varied amplitude and gradient similar to the bouguer anomaly map but the anomaly here are more distinct.

This regional field varies from -10.628mGal in the north to 3.841mGal in the south and dipping slightly to the east. The residual Bouguer Anomaly values range from about -10.577 to 19.805mGal with a mean value 1.479 ± 5.319 mGal. The northcentral/northeastern parts of the study area (Ijesa-isu, Ikole, Ipao, Itapaji, Iye, Ponyan, Ijumu, ayetoro area) map show negative gravity values probably indicating low-density bodies. The western and southern parts of the study area (Ilesha, Ife, Akure, Ikere, Ifon area) map show positive gravity values probably indicating high-density bodies.

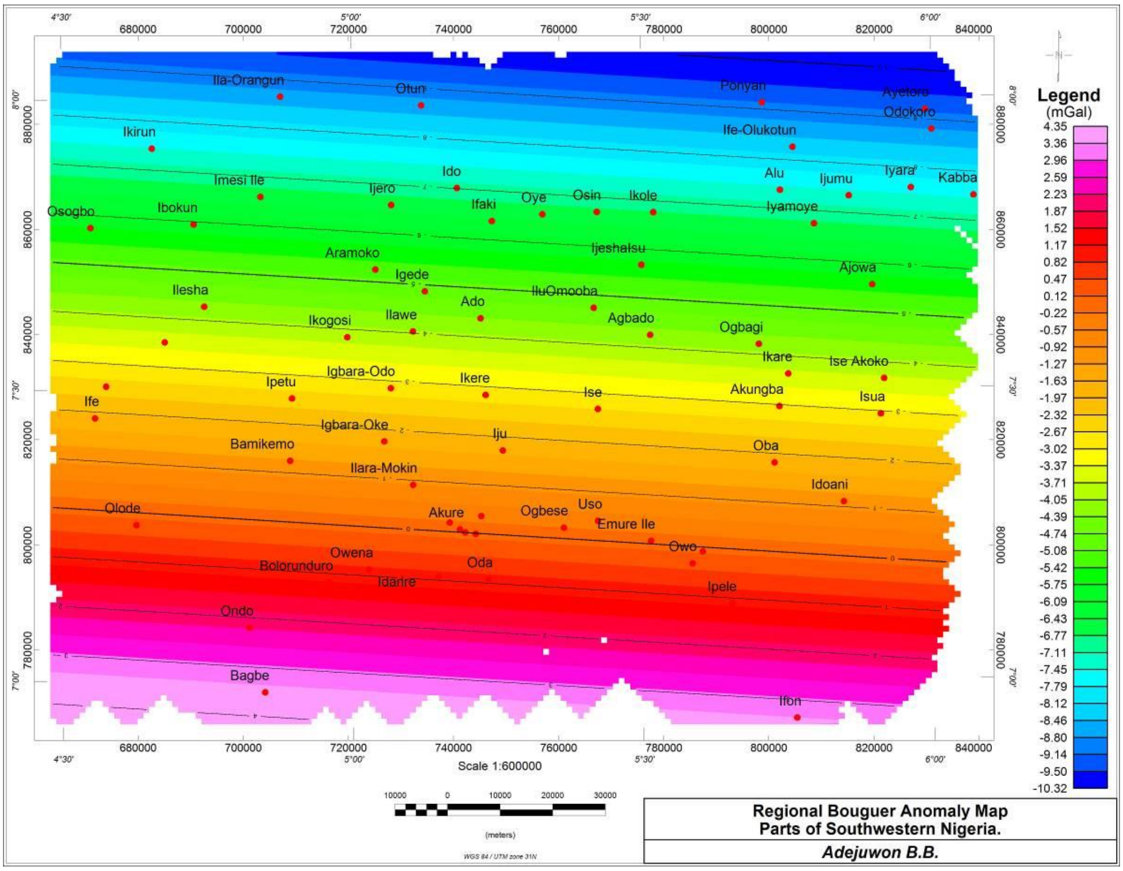

Figure 6: Regional Bouguer Map

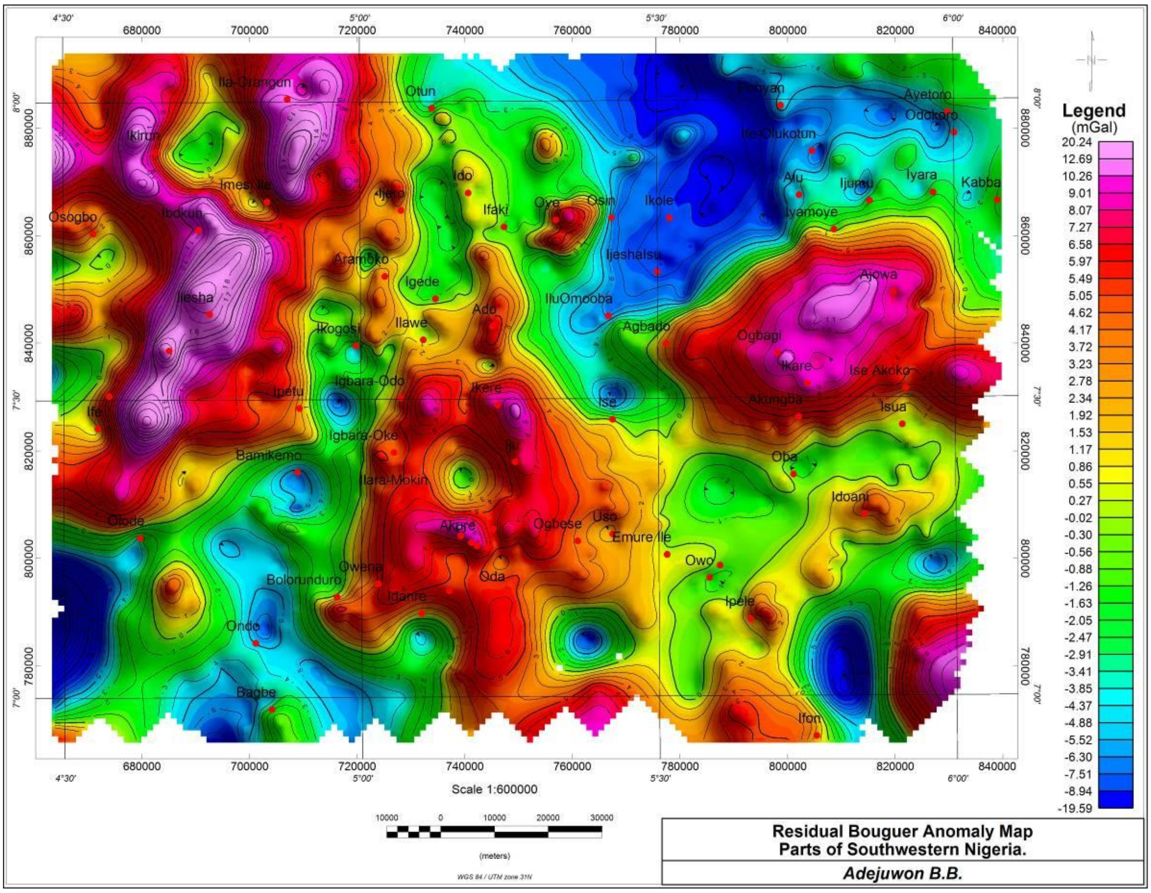

Figure 7: Residual Bouguer Anomaly Map

The bouguer anomaly map were compared with the existing aeromagnetic data from the study area. The total Magnetic Field Intensity map (Figure 8) with its several derivatives such as analytic signal (Figure 9) and first vertical derivative (Figure 10) provides value-added products for delineation of the structural features in the area. Analytic signal map is useful in locating the edges of magnetic source bodies, particularly where remanence and/or low magnetic latitude complicates interpretation. The analytic signal map from the aeromagnetic data compares well in parts with the bouguer anomalies especially the Ikare-Ajowa-Ogbagi high, Akure-Ikere-Igbaraoke High, Ikole-Ponyan low and parts of Ifewara-Ilesha-Ilaorangun High (Figures 5, 7 and 9) which is an indication that most of the bouguer anomaly were equally magnetic.

The identified structures from the aeromagnetic data were overlain on the Bouguer anomaly maps to produce the structural map for the study area (Figure 11) with the rose diagram of the structures from the two data set shown in figure 12. From the structural map, there are conjugate faults i.e. two intersecting sets of fault with opposite shear sense (Davatzes and Aydin, 2003). Most of the identified structures from the gravity anomaly map coincide with structures from the aeromagnetic data in term of position and orientation. From this map, the delineated Ifewara-Ilesha-Ilaorangun High coincides with the already known NNE/SSW Ifewara fault which is an integral part of the Ifewara-Zungeru fault. This shear zone is marked by major fault trending in same direction from both the magnetic data as well as the gravity data. Fault zones are often associated with enhanced, focused, repeated fluid circulations in the earth's crust (Micklethwaite et al (2010) and Grara et al 2018). These fluids may have different origins and possibly transport minerals to a favorable area of deposition; that will ultimately allow for the formation of potential economic ore deposits.

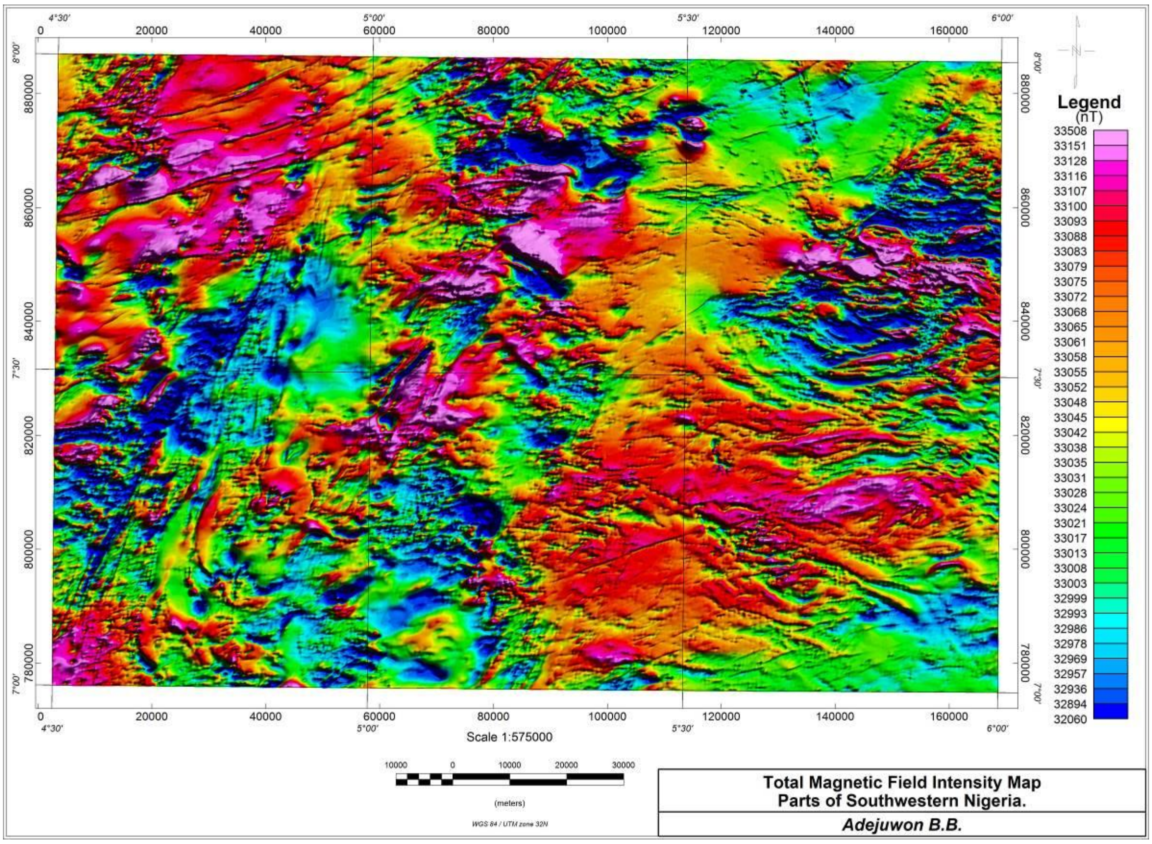

Figure 8: Total Magnetic Field Intensity Map

The high bouguer value observed at this western part of the study area is attributed to the Ifewara shear zone. The Ifewara fault system is a typical tectonic setting where there is a relative movement cuasing shearing trending NNE/SSW. This shear zone produces mylonitised rock. This mylonitization creates a density contrast with the surrounding rocks. Also, the high bouguer anomaly value can be attributed to the fault zone acting as pathway for upward movement of mineralising fluid with the emplacement of gold among other minerals. This is in agreement with the findings of previous geochemical research in the area such as Bolarinwa & Adepoju (2017) that "the observed shearing of the amphibolites is not unconnected with the Ifewara fault which provided the pathway for the magma. The fault could have been responsible for magma upwelling from the mantle and subsequent contamination and emplacement of the magma in a Within-plate tectonic setting".

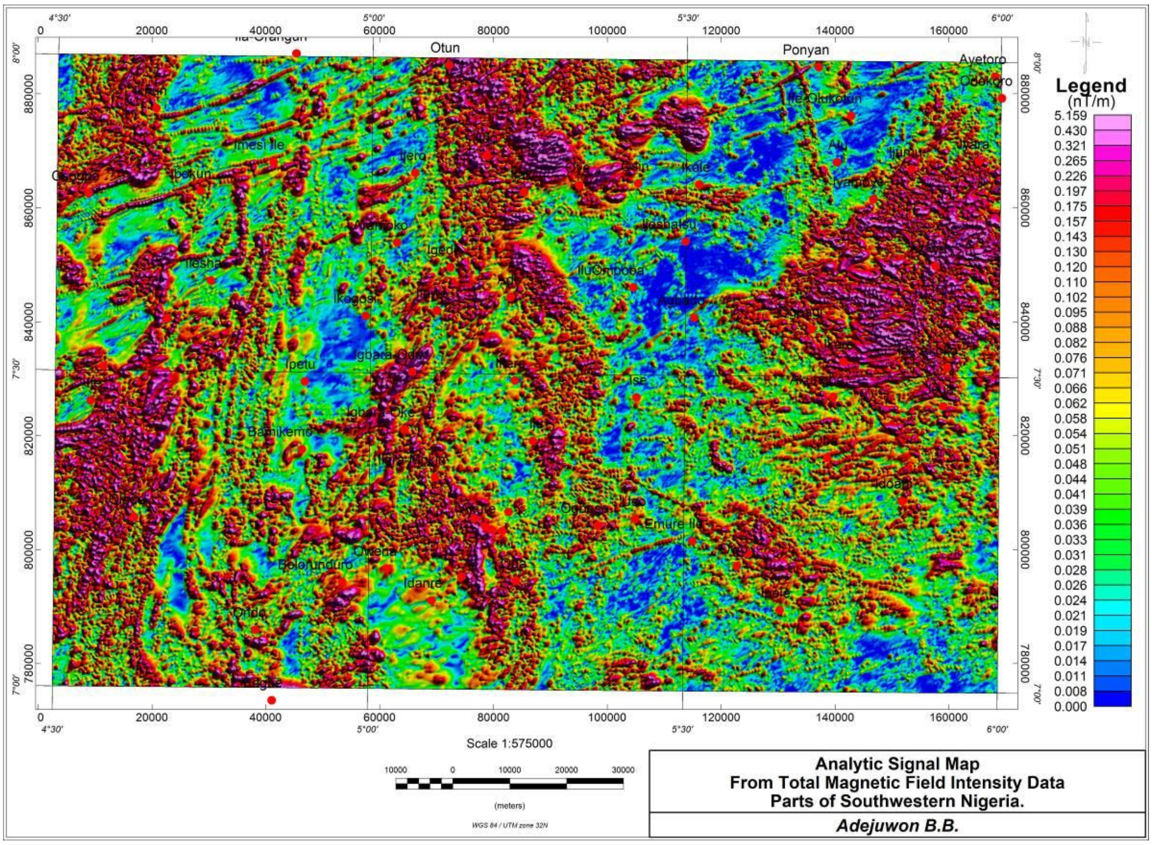

Figure 9: Analytic Signal Map

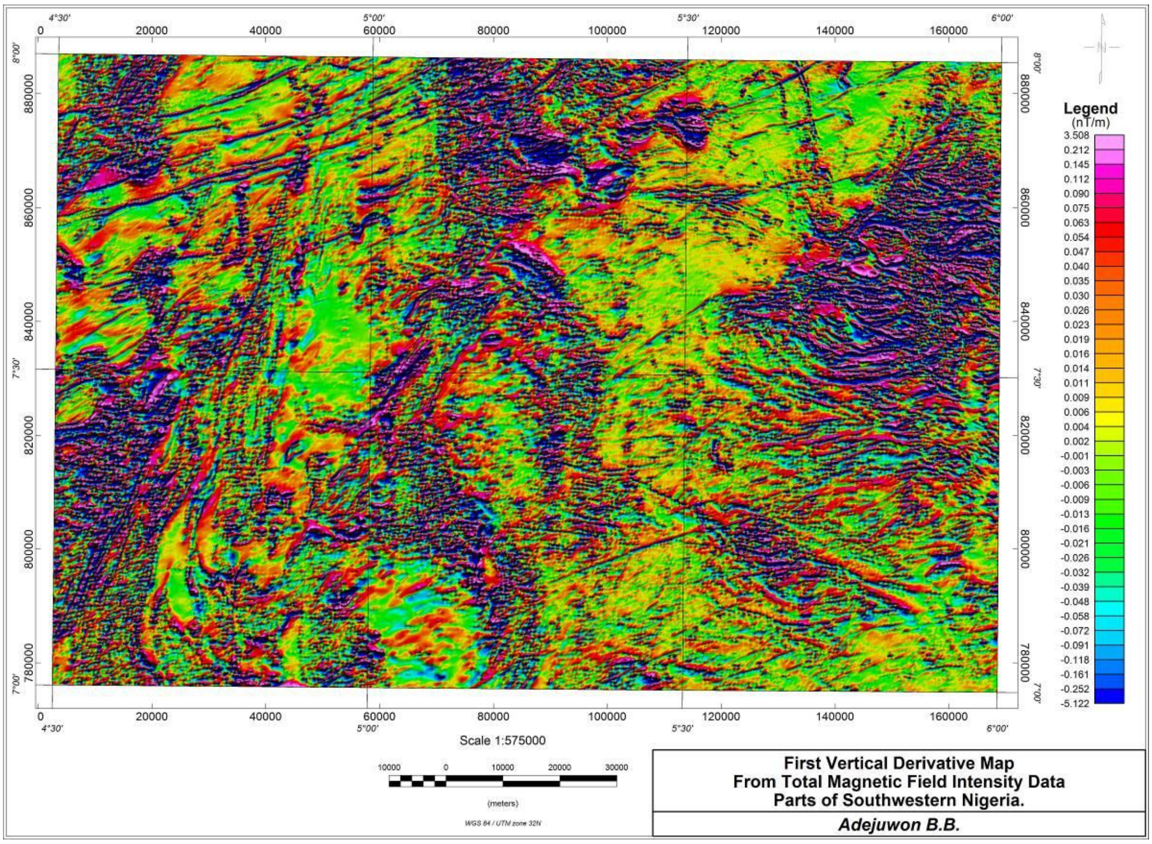

Figure 10: First Vertical Derivative Map

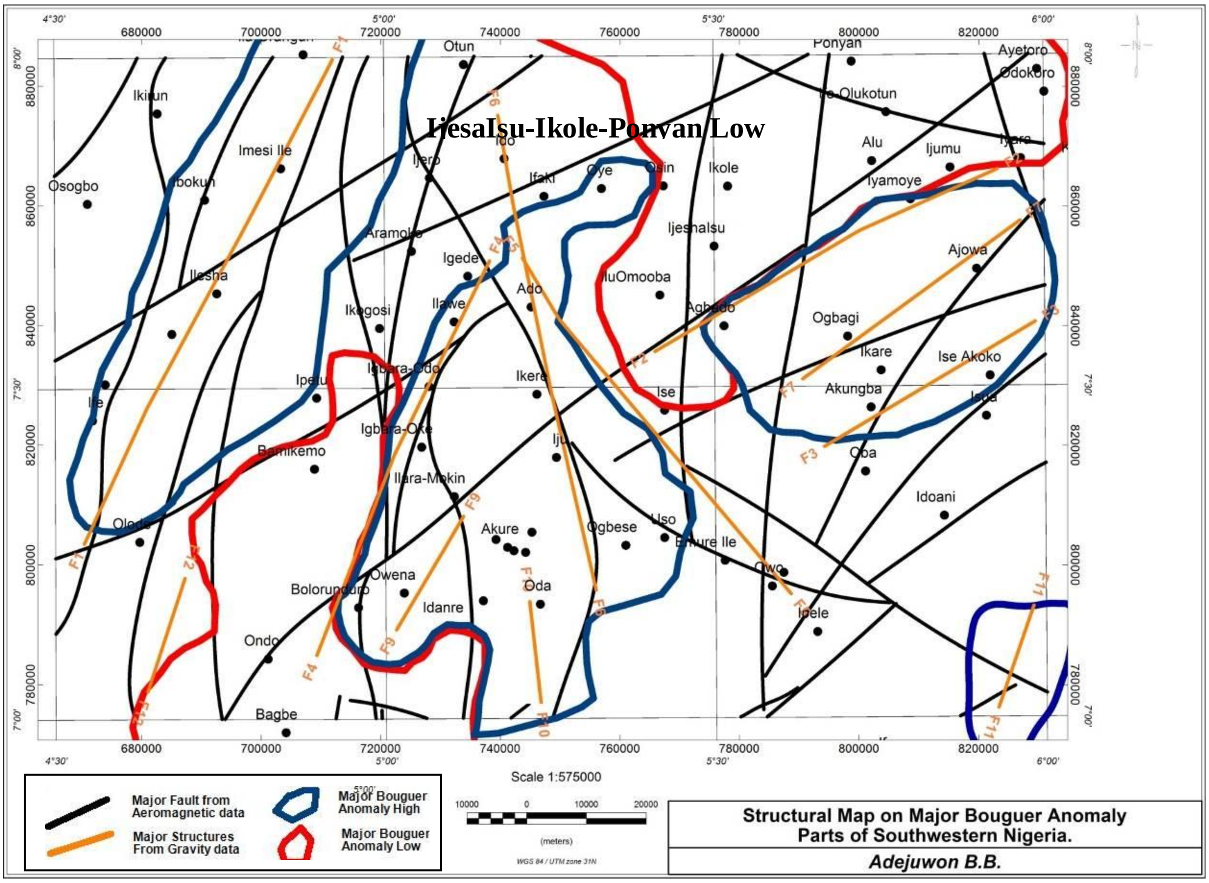

Figure 11: Major structural Map of the study area on Gravity Anomalies of Interest

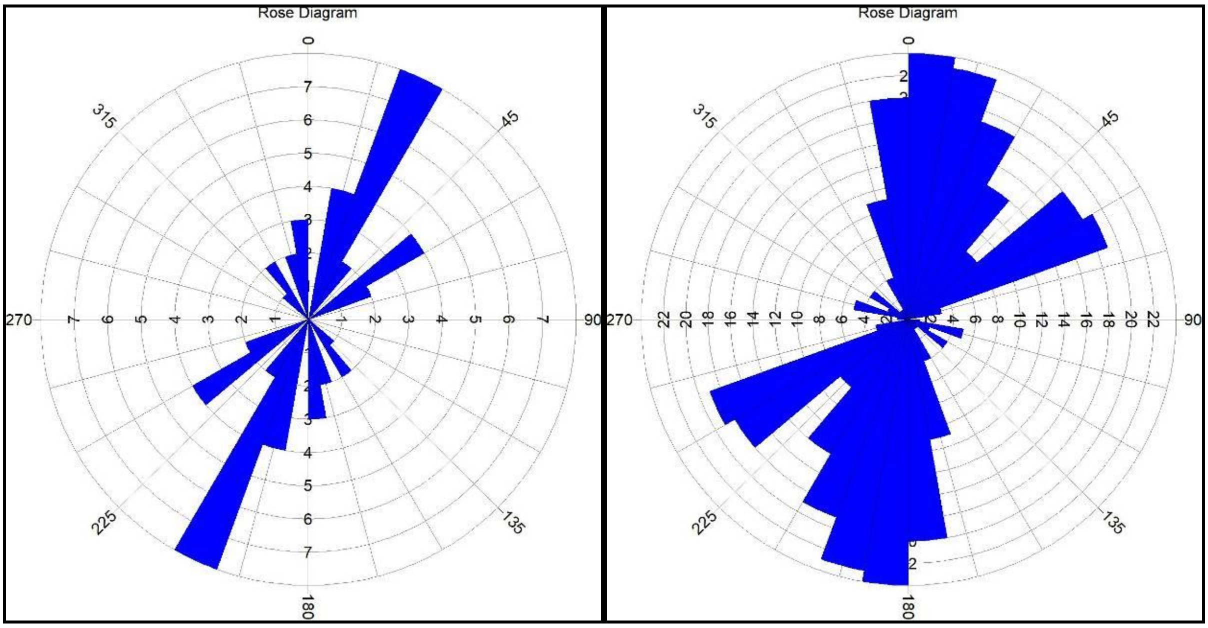

Figure 12: Rose Diagram from the structures delineated from (a) Gravity data (b) Aeromagnetic data

IV. CONCLUSION

From the analysis of the various data sets and maps from this research work clearly show the gravity distribution within the study area which is vital tool for researchers, structrural interpretation and mineral exploration. Researchers carrying out gravity survey in any part of the study area will find the data useful since they can tie their surveys to IGSN (1971) through any of the established Base Stations. The identification of six dictinct bouguer anomalous zones will serve as referral points to open up futher investigation on the densel nature of the basement complex.

Northern and southern continuity of the identified Ifewara system outside the study area i.e. into parts of Kwara state and Ogun state should be investigated. More Gravimetery research at more detailed scale or microgravity should be carried out around most of the identified major anomalies for further mineral potential, geodesy and crustal studies.

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