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Research Paper

Ground Gravity Survey of 1:250,000 Sheet 61 (Akure), Southwestern Nigeria.

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ABSTRACT
Ground gravity survey was carried in part of southwestern Nigeria underlain mainly by the Basement Complex rocks to establish second order gravity base stations and produce the bouguer anomaly map of the area. Sixty (60) evenly distributed gravity base stations were established in the study area and were tied to IGSN 71 through the PGNN Base station at Akure. The processed data were presented as 2D maps with both contour and colour shaded maps. The Bouguer anomaly field values range from about -21.471 to 14.357mGal, the free-air anomaly values range from 3.428 to 68.813mGal/m while the residual Bouguer Anomaly values range from about -11.853 to 12.153mGal. There is mostly a general NE/SW and few N/S trends in all the anomaly fields. Four major bouguer anomalies with unique characteristic features were identified which maybe related to the contrasting lithological and structural features. These are: (1) Akure-Ikere-Igbaraoke High (2) Ikare-Ogbagi-Ajowa High (3) Ute-Uzebba High and (4) IjeshaIsu-Ikole-Ponyan Low. The relatively high oval shape bouguer anomaly "Ikare–Ogbagi-Ajowa high" at the NE part of the study area can be a new frontier for mineral exploration.

KEYWORDS: *Gravity survey, Basement Complex, Base stations, Bouguer anomaly, mineral exploration*

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I. INTRODUCTION

Gravity data have consistently been valuable tools in geological mapping (both structural and lithological features), mineral exploration, mapping underlying basement topography in sedimentary areas, delineation of crustal weakness and mass imbalances within the lithosphere and in the preliminary stages of oil and gas exploration (Basin Analyses). Despite the usefulness of gravity data, paucity of such gravity data in part of southwestern Nigeria has made such research and mineral exploration difficult (Only one gravity stations/base stations in an area of over 12,100km^2), hence there is urgent need for this research in this part of southwestern Nigeria.

The present study is aimed at generating the gravity database of the study area through the densification of the existing sole gravity base station in the area and establishment of easily accessible base stations in the study area that are properly tied to International gravity Standardization Net, 1971 (IGSN '71). Also, production of reduced height map, Absolute Gravity value map, Free Air anomaly map and Bouguer anomaly map of the area.

The study area is in Southwestern part of Nigeria and lies between latitudes 7^{o}00'N and 8^{o}00'N and longitudes 5^{o}00'E and 6^{o}00'E with an approximate area extent of 12,100km^2. It covers Ekiti state, parts of Ondo, Kogi and Edo states (Figure 1). The area is accessible through network of major road, minor roads, footpaths and waterways. Elevation in the study area varies from 112m from the southern part to about 626m in the north-central part (Figure 2).

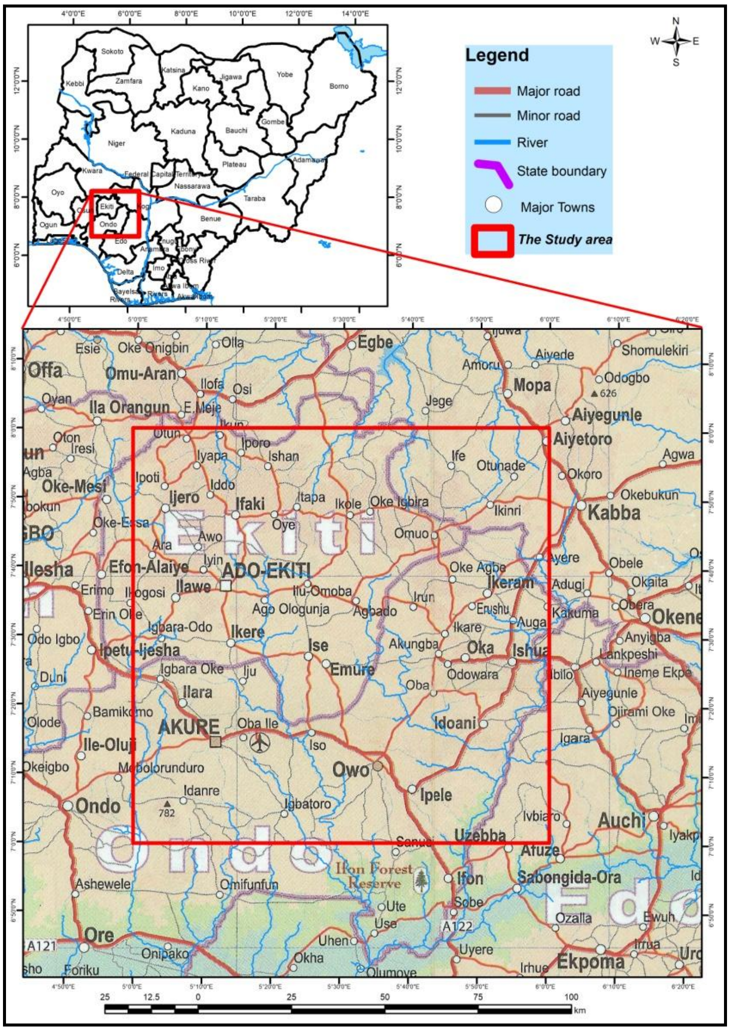

Figure 1: Location Map of the study area

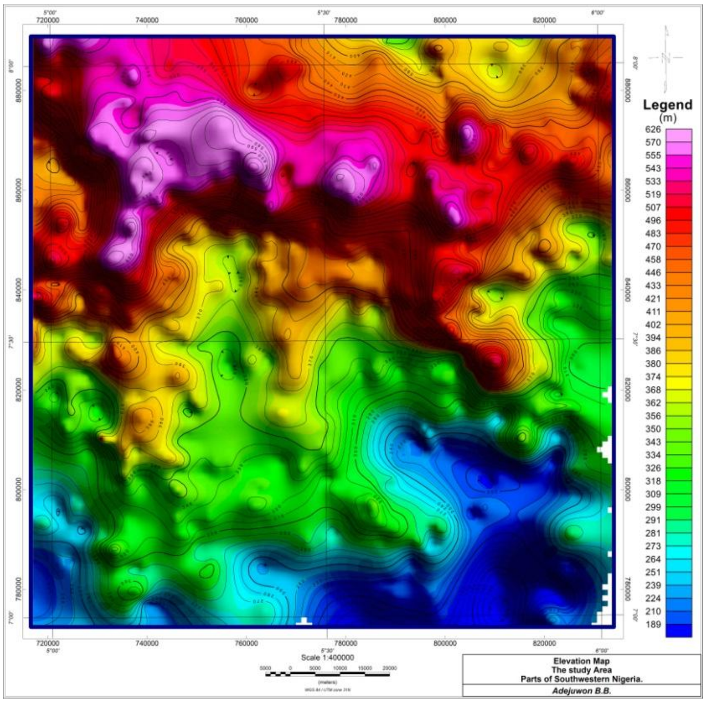

Figure 2: Elevation Map of the study area

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 cover the extreme southeastern part (Figure 3).
According to Rahaman (1978) and Olarewaju (1982), about six lithologies are known in this region: -

- The migmatite – gneiss complex
- The slightly migmatised to unmigmatised paraschists and meta-igneous rocks
- The charnockitic rocks
- The older granites
- The un-metamorphosed granitic rocks composed mainly of microcline and quartz
- The dolerite dykes which are composed of mainly mafic minerals.

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). The Benin basin (Dahomey Embayment) is bounded in the west by the Ghana Ridge which is an extension of the Romanche Fracture Zone and the east by the Benin Hinge line, a basin escarpment which separates the Okitipupa structure from the Niger delta basin and marks the continental extension of the Chain Fracture Zone (Opara *et al.*,2012). 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.

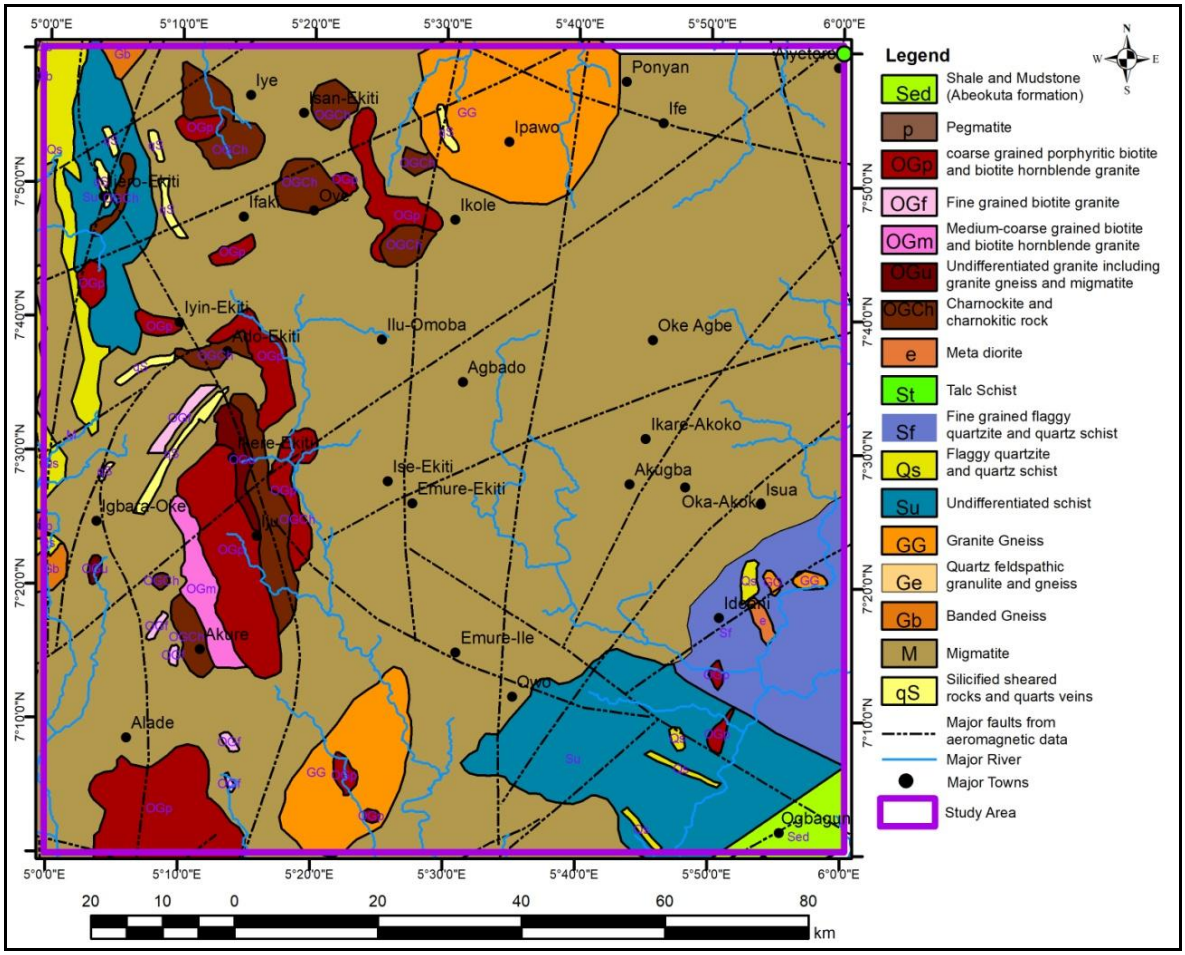

Figure 3: Regional Geological Map of study area (Modified after NGSA, 2006)

II. MATERIALS AND METHODS

The gravity data acquisition in the study area started at an existing gravity base station established by Osazuwa (1985) at St Peters' College, Akure (Figure 4) with absolute gravity values of 978055.275mGal. A Lacoste and Romberg gravimeter (G-512) licensed to Nigerian Geological Survey Agency was used for this gravity data acquisition in the study area (Plate 1). Its temperature controlled and the heater circuit powered by a 12V battery with a reading line of 2.4 operating at a temperature of 52.4^{o}C. Heights of the gravity stations were measured with Two Wallace and Tiernan altimeters (Plate 1). The Psychro-Dyne thermometer was used to measure the wet and dry temperatures from which the relative humidity was derived using the psychrometric chart.

Gravity measurements were taken at 2.0 km intervals along motorable roads and footpaths through-out the study area. The pattern of movement adopted for this survey is the looping (closed loop) sequence in which all the loops for a particular day were either chained or looped into one another in a kind of cascade and the first reading for the day always started from a base station (Osazuwa, 1985, 1988 & 1992). This kind of sequence is compatible with most gravity data processing software such as Geotools (GravMaster), Geosoft (Oasis Montaj) etc. Gravity differences due to instrumental drift and tidal effects was monitored together by a repeated reading taken at the base station every two hours. Several base stations were established at chosen locations throughout the study area. The choice of these base stations depend largely on the distribution of the detail stations.. Schools, churches, post offices and major road junctions were used as base stations. The common corrections carried out in a gravity survey include: latitude, tidal, altitude, free air, Bouguer, terrain and drift corrections. This has been explained in details by Adejuwon *et al* (2013 and 2018).

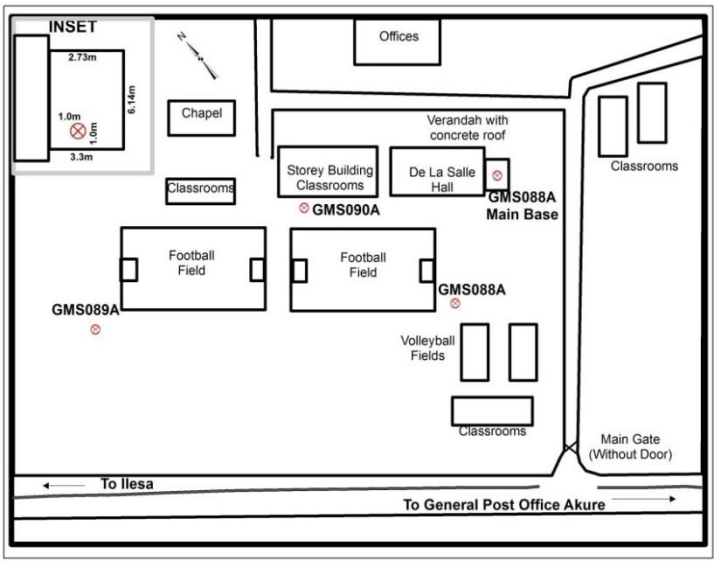

Figure 4: Synopsis of PGNN Base Station.

Plate 1: Data acquisition with G512

III. RESULT AND DISCUSSION

A total of eight hundred and three (803) detail stations given a gravity data density of 1/15km^2 i.e. an approximate of one detail gravity station in 2km radius. This is a considerable improvement on the existing station density of 1/12,100km^2 and recommendation of 1/25km^2 by Osazuwa et al (1994). Sixty (60) base stations were established in the study area (Figure 5) giving a base station density of 1/200km^2 which is a positive improvement on the existing base station density of 1/12,100km^2. These base stations were evenly distributed in the study area and are tied to IGSN'71 (Morelli et al, 1974) through the PGNN of Osazuwa (1985). The base stations were carefully established for preservation purposes at Post office, Local Government secretariats, customary courts, orthodox churches and important road junctions.

The absolute gravity value of the study area ranges from 977996.665mGal to 978088.938mGal i.e. from the northcentral part to the southeastern part with an average value of 978043.088 ±19.21mGal. The very low absolute gravity value was recorded in the northcentral part of the Ekiti state around Igede, Ido, Oye, Ikole etc (Figure 6). This corresponds to the area with high elevation, thereby confirming the relationship between elevation and gravity i.e. they are inversely proportional to each other (figures 2 and 6). Other areas show a little variation in gravity. The highest absolute gravity values were recorded in the southeastern part (sedimentary basin) with corresponding low elevation values around.

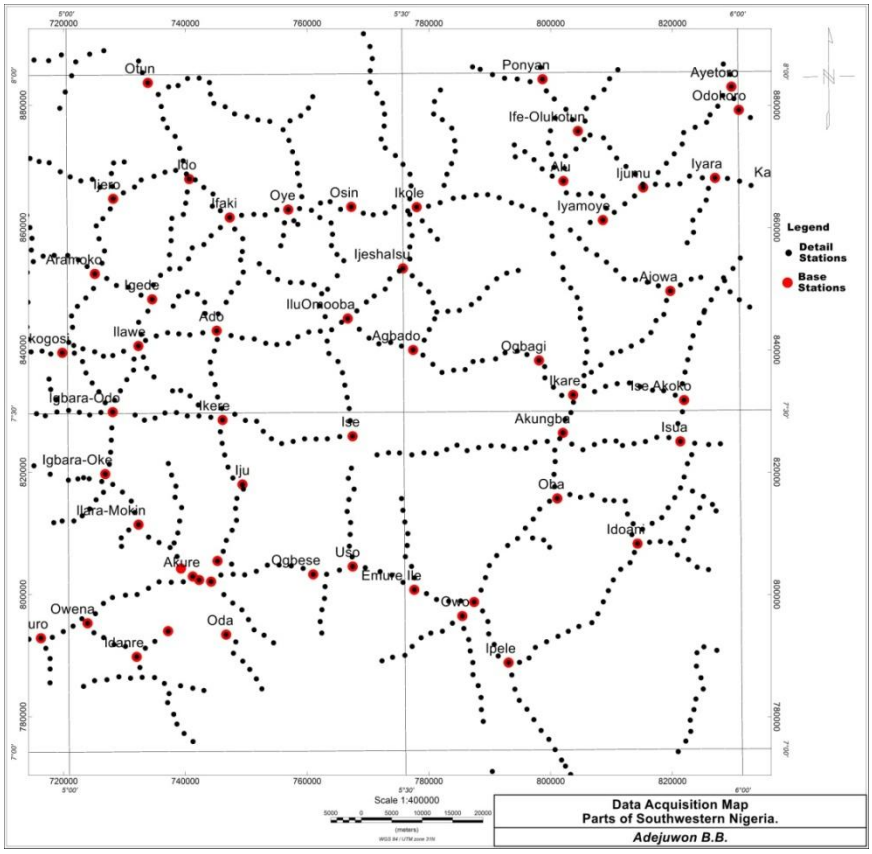

Figure 5: Data Acquisition Map

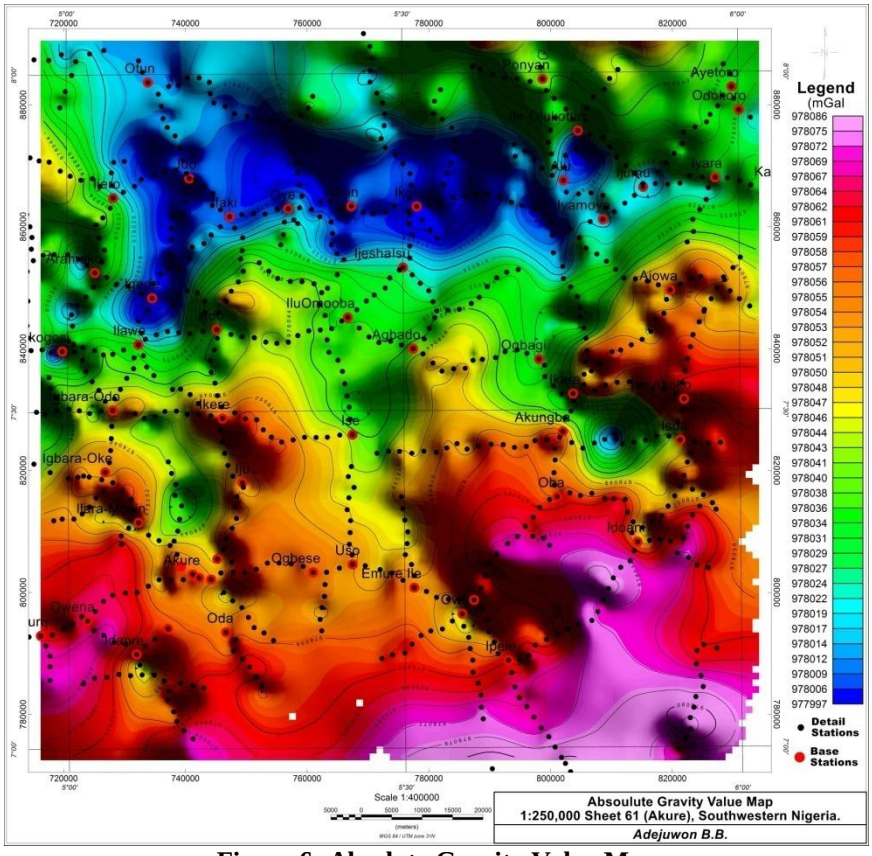

Figure 6: Absolute Gravity Value Map

The observed gravity values were reduced to bouguer anomaly. Bouguer anomaly field is devoid from the effect of geological materials lying between the observation point and the datum. The Bouguer anomaly values range from about -21.471 to 14.357mGal with mean value of -2.916 ±6.914 mGal (Figure 7). 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 southern parts of the study area (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 northwest, the charnockite of Oye, Ado, Akure and Idanre area and the Akoko high.

The residual Bouguer Anomaly values range from about -11.853 to 12.153mGal with a mean value 0.439 ± 4.716mGal (Figure 8). 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 (Akure, Ikere, Ifon area) map show positive gravity values. 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.

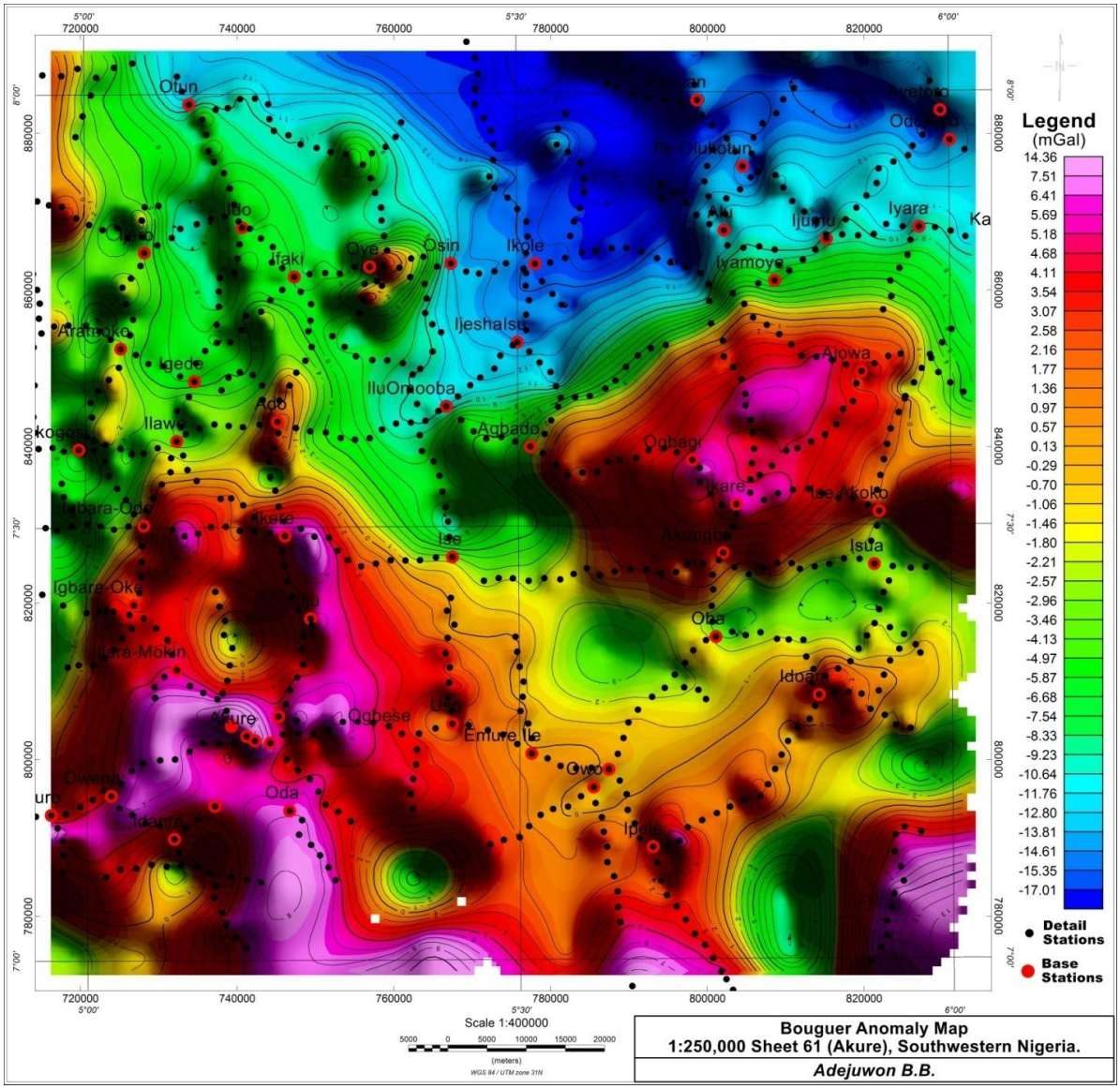

Figure 7: Bouguer Anomaly Map

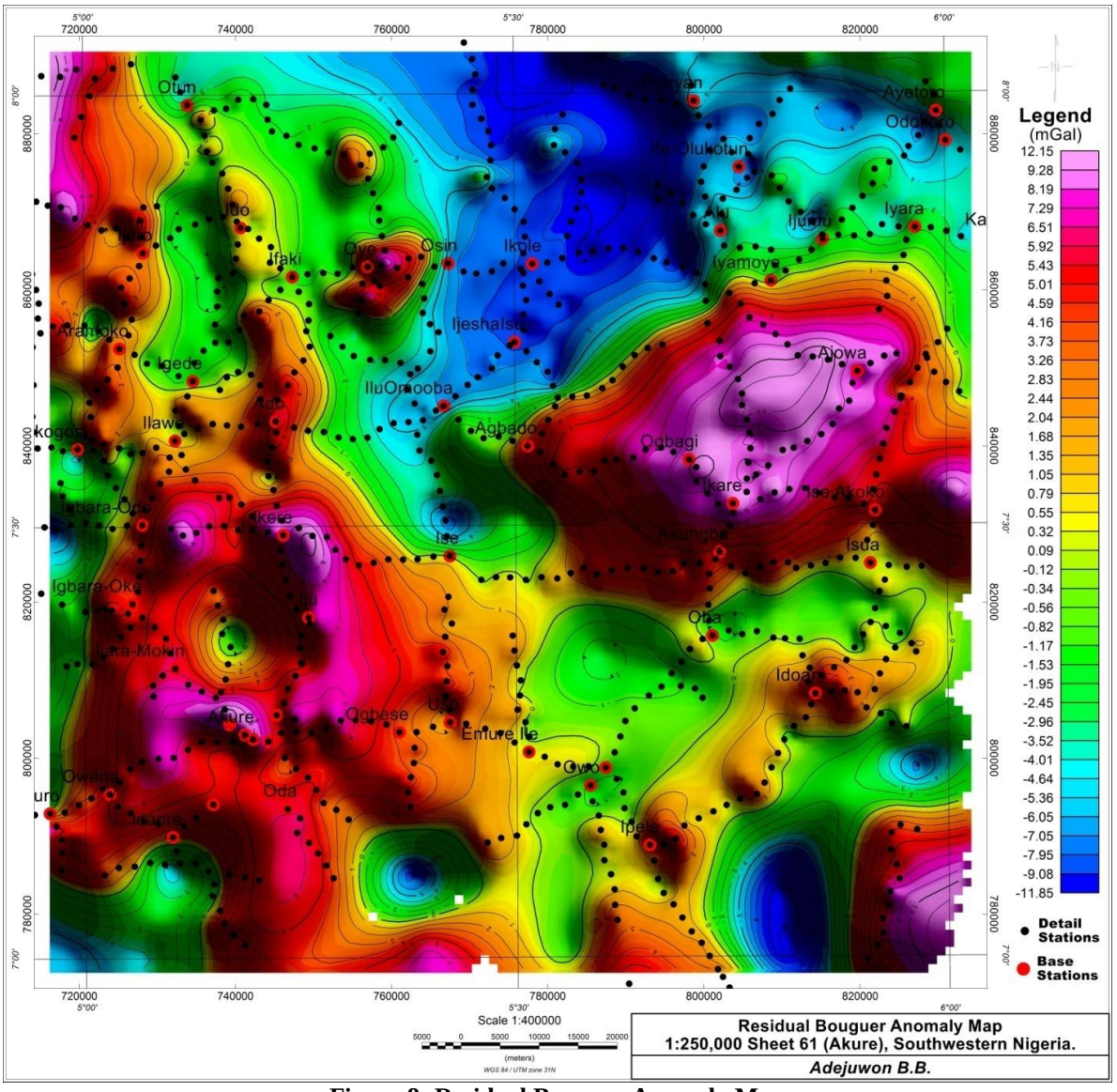

Figure 8: Residual Bouguer Anomaly Map

The Free-Air anomaly values range from 3.428mGal/m to 68.813mGal/m with mean value 39.359 ± 9.9mGal/m (Figure 9). It shows the highest value around the north-eastern part (around Omuo, Ikare and Ajowa Akoko area) and northcentral part (Otun-Igede-Ifaki-Ido-Oye area) of the study area. The lowest free-air anomaly value is recorded around the southeastern and southwestern part of the study area. Geologically, the southeastern section of the study area falls within the sedimentary formation. There is seemingly direct relationship between the Free Air Anomaly map and the Elevation in some parts of the study area. The positive high free Air Anomaly values area correspond to the high elevation areas.

The Free-Air anomaly map (Figure 9) shows a general NE-SW and N/S trends which are consistent with the general structural setting of the area. It mirrors the Elevation map to some extent. This seemingly partial agreement between the Free-Air anomaly and the Elevation suggest that study area is not too from the Coast. Except in few places, the correlation between the Free-Air anomaly map and the Bouguer anomaly map are not perfect. This suggests isostatic in-equilibrium typical of a basement complex.

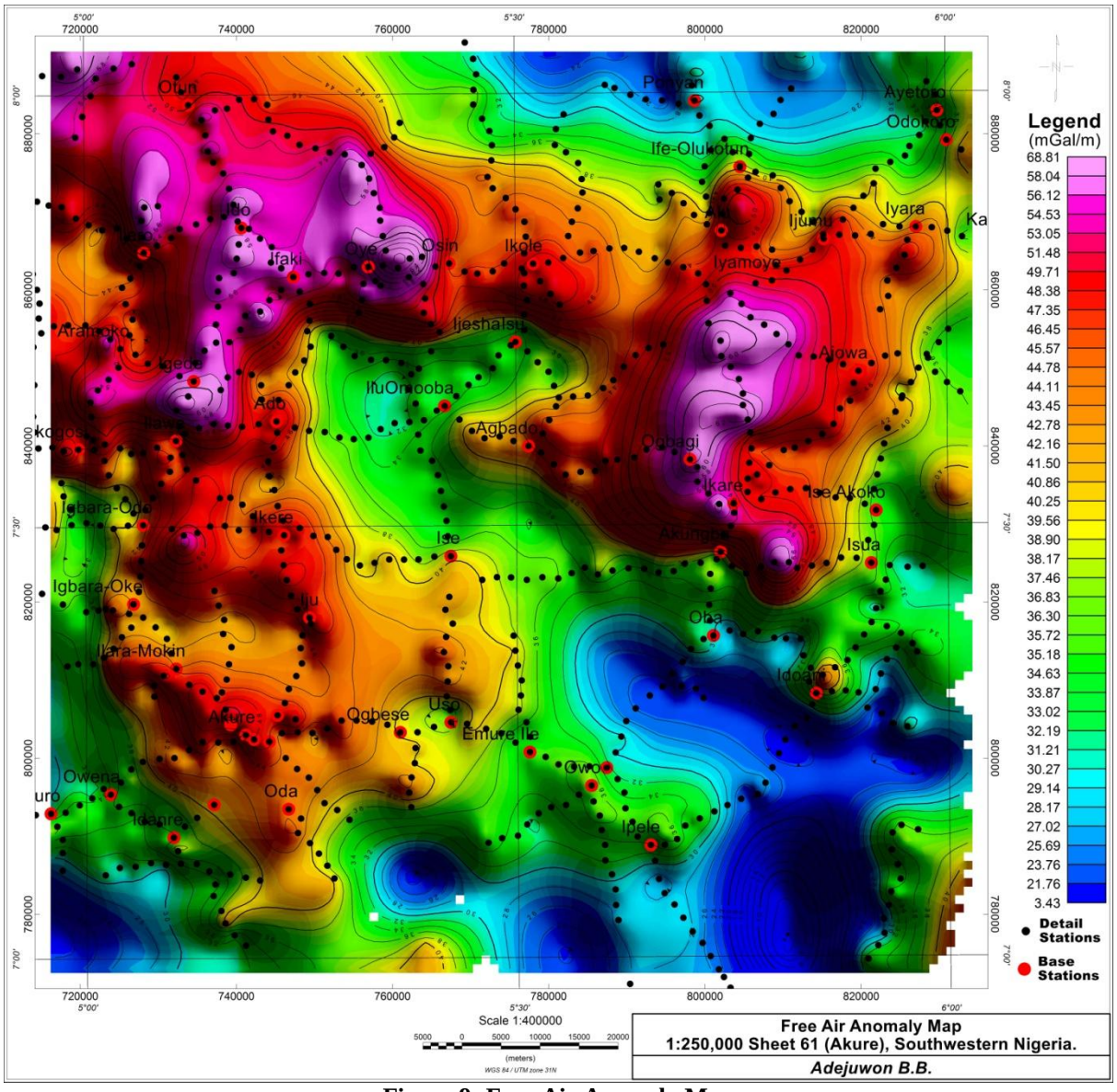

Figure 9: Free-Air Anomaly Map

Qualitative interpretation

The gravity field is characterized by low amplitude anomaly of varied lateral extent and closures. The trend of the Bouguer anomaly map is generally NE/SW to N/S around the western-half of the study area. Correlation of the Geology and Bouguer anomaly maps indicates that high Bouguer anomaly running NE/SW corresponds to the sedimentary part in the southeastern end of the study area is characterized by high Positive Bouguer anomaly running approximately N/S around Uzebba, Uroe, Ute etc. termed "Ute-Uzebba High" (Figure 10).

A relatively high oval shape bouguer anomaly (between 0 to 6mGal) termed "Ikare–Ogbagi-Ajowa high" running linearly ENE/SWS was observed at the NE part of the study area (figure 10). The area is underlain by migmatite, Charnockitic rocks and granite gneiss around Ikare, Ogbagi Ajowa, Ise-Akoko area. From the mineral map of the area, semi precious minerals e.g. Corumdum and metallic mineral e.g. iron ore are documented, hence these dense ferromagnesian minerals and rocks maybe responsible for the positive bouguer in the area.

Another interesting observation is seemingly higher bouguer value of charnockite (hypersthene bearing granite) area compared with the pure granitic rock area as observed around Idanre, Akure, Ikere, Ado, Oye etc. This positive bouguer anomaly around Akure is termed "Akure-Ikere-Igbaraoke High".

The lowest Bouguer anomaly of -19.5mGal occurs at northern part of the study area within the older granite suite of Ijesha-Isu, Ikole, Ponyan, Ayetoro and Iyara area. This broad and laterally extensive negative gravity closure almost elliptical but irregular in shape in value between -6 and -19.5 mGal is termed "IjeshaIsu-

Ikole-Ponyan low". This closure is mainly underlain by granite gneiss and biotite granite (compare Figures 3 and 7).

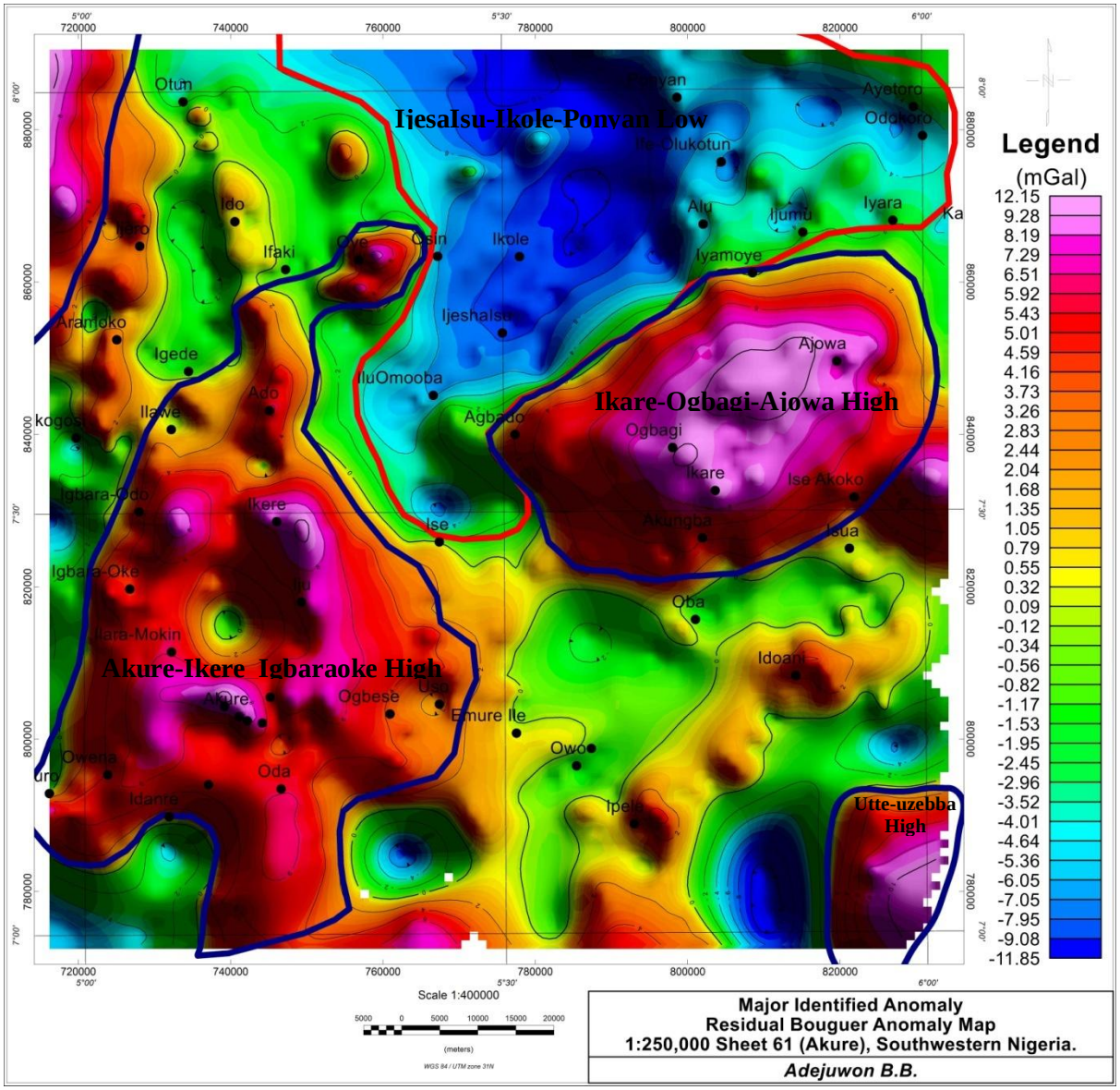

Figure 10: Major Anomalies of Interest

IV. CONCLUSION

The study area lies within the southwestern part of Nigeria and is underlain mainly by the Basement Complex rocks and the Cretaceous/Tertiary to recent sediments in the southeastern. The Basement Complex rocks comprise of charnokites, Migmatites, gneisses, schists, quartzites, amphibolites, granites, granodiorite and diorite assemblages. Structural trends in the crystalline basement complex rocks are dominantly ENE/WSW with significant associated NE/SW and N/S trends.

Four major bouguer anomalies with unique characteristics features which may be related to the contrasting lithological and structural features were identified. These are: (1) Akure-Ikere-Igbaraoke High (2) Ikare-Ogbagi-Ajowa High (3) Ute-Uzebba High and (4) IjeshaIsu-Ikole-Ponyan Low.

For mineral exploration, a common feature of mineralized veins in Nigeria is their proximity to major and subsidiary fault structures which can be delineated and mapped with such gravity data. The relatively high oval shape bouguer anomaly (between 0 to 6mGal) termed "Ikare–Ogbagi-Ajowa high" running linearly ENE/SWS is observed at the NE part of the study area can be a new frontier for mineral exploration. Hence, the mining industry will find this research work as valuable tools for exploration.

With the recent treat and possible menace of geo-hazard in the country such as earth tremor whose frequency of occurrence has been on annual increase in several parts of the basement complex region of Nigeria

(the study area inclusive); continuous monitoring of the deformed areas with gravimeter and seismometers for their geo-hazard potentials is recommended.

Establishment of sixty (60) easily accessible and fairly distributed base stations in the study area would facilitate easy access to gravity base stations leading to more and improved gravimetric research in the study area. More Gravimetery research at more detailed scale should be carried out around most of the identified major anomalies for further mineral potential, geodesy and crustal studies. Production of Bouguer Anomaly maps, Free-air anomaly maps and Absolute gravity value map (previously not existing) in this part of southwestern Nigeria would be a future referral data, map and documents for further gravity study.

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