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Preliminary interpretation of gravity mapping over the Njaba sub-basin of southeastern Nigeria: An implication to petroleum potential

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Gravity data were acquired along two profiles in some parts of the Njaba River sub-basin. Profile A-A' and B-B' run for about 30 and 12 km respectively with the end of the two profiles meeting at Oguta Lake. The Bouguer gravity anomaly along Profile A-A' revealed initial positive gravity values to a wavelength of about 21 km and then followed by a sudden drop of the observed gravity showing a significant gravity minimum. Profile B-B' showed an alternating gravity high and low which was followed by a sudden extremely low value in the observed gravity. Further investigation showed that the structure modeled is graben and horsts bounded by two normal faults. The high gravity observed is due to the lesser density contrasts between the sediments and the basement which had resulted from the up-warping of the crust. The area showing low gravity revealed thick sedimentary accumulation of recently deposited alluvium deposits deposited in the subsided area bounded by these two faults. The structural framework of the parts of the sub-basin studied suggested an environment favorable for large scale entrapment of hydrocarbons. This is justified by the ongoing exploration and exploitation of petroleum resources in the study area.

Key words: Gravity profiles, gravity anomaly, density contrasts, sub-basin, graben and horst, Oguta Lake.

INTRODUCTION

Gravity studies were carried out in the study area – some parts of Njaba River sub-basin which is in the Northern (oldest) depobelt of Niger Delta in Nigeria along two profiles (A-A' and B-B') in the area stretching a distance of more than 42 km altogether as shown in Figure 1. The study area is geographically located in the Southeastern part of Nigeria, and covers an aerial extent of about 50 km^2.

It lies between latitudes 5°30'N to 5°45'N and longitudes 6°45'E to 7°00'E in the northwestern part of Imo State. The important localities or towns within the study area are Ogbaku, Izombe, Mgbidi, Oguta, Uba-Agwa, Egwe, Orsu-Obodo, Ezzi-Orsu, and Eziama. The objectives of the gravity measurements made in the study area – Njaba River sub-basin, were to determine:

(a) The thickness (depth) of the sedimentary basin that is, depth to the basement.
(b) The lateral thickness of the sedimentary basin in the study area.

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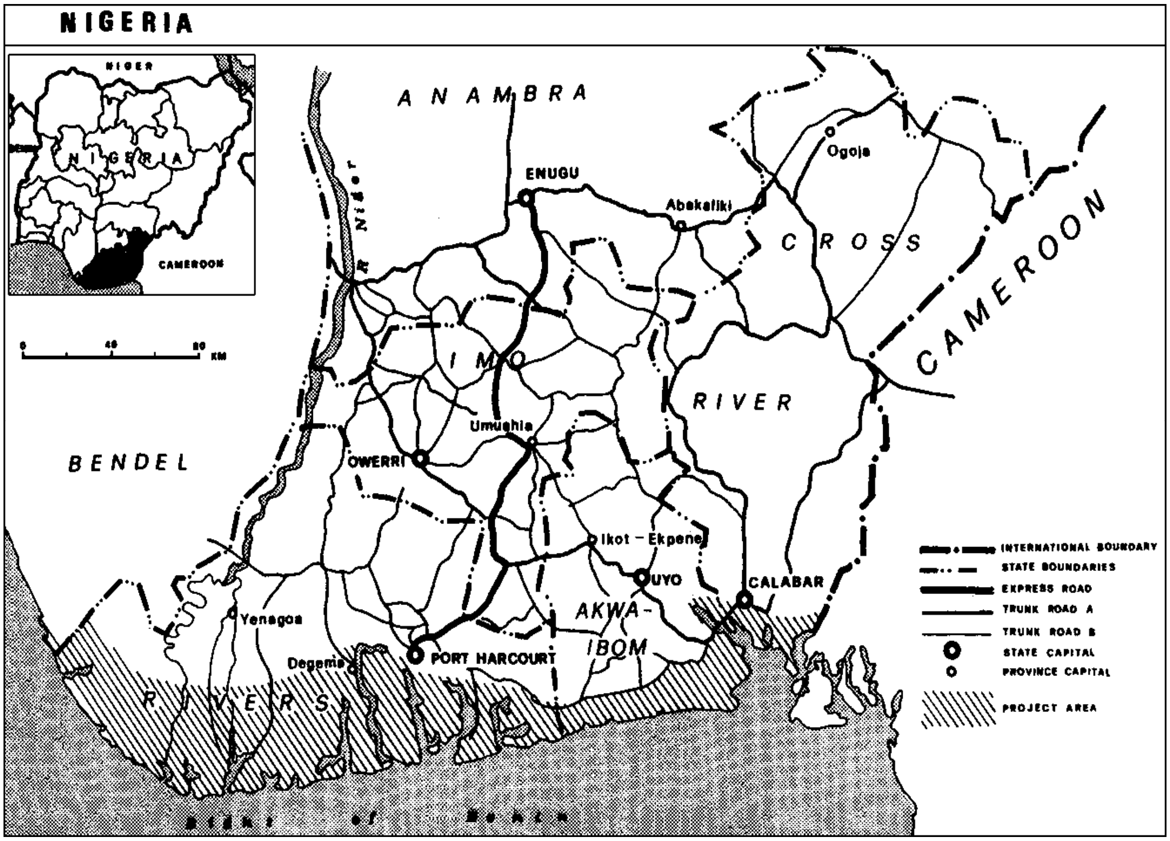


Figure 1. Location of Southeastern Nigeria

(c) To establish the basement topography
(d) The variation in density of the various formations present in the study area.
(e) Produce of a geologic model that clearly shows the general subsurface geological structures of the given field, thus providing information about the subsurface structures (large sediment thickness, and other geological structures which aid in the generation, migration and accumulation of petroleum) of the area and its favorable implications, for natural resources evaluation (that is, petroleum exploration/exploitation).

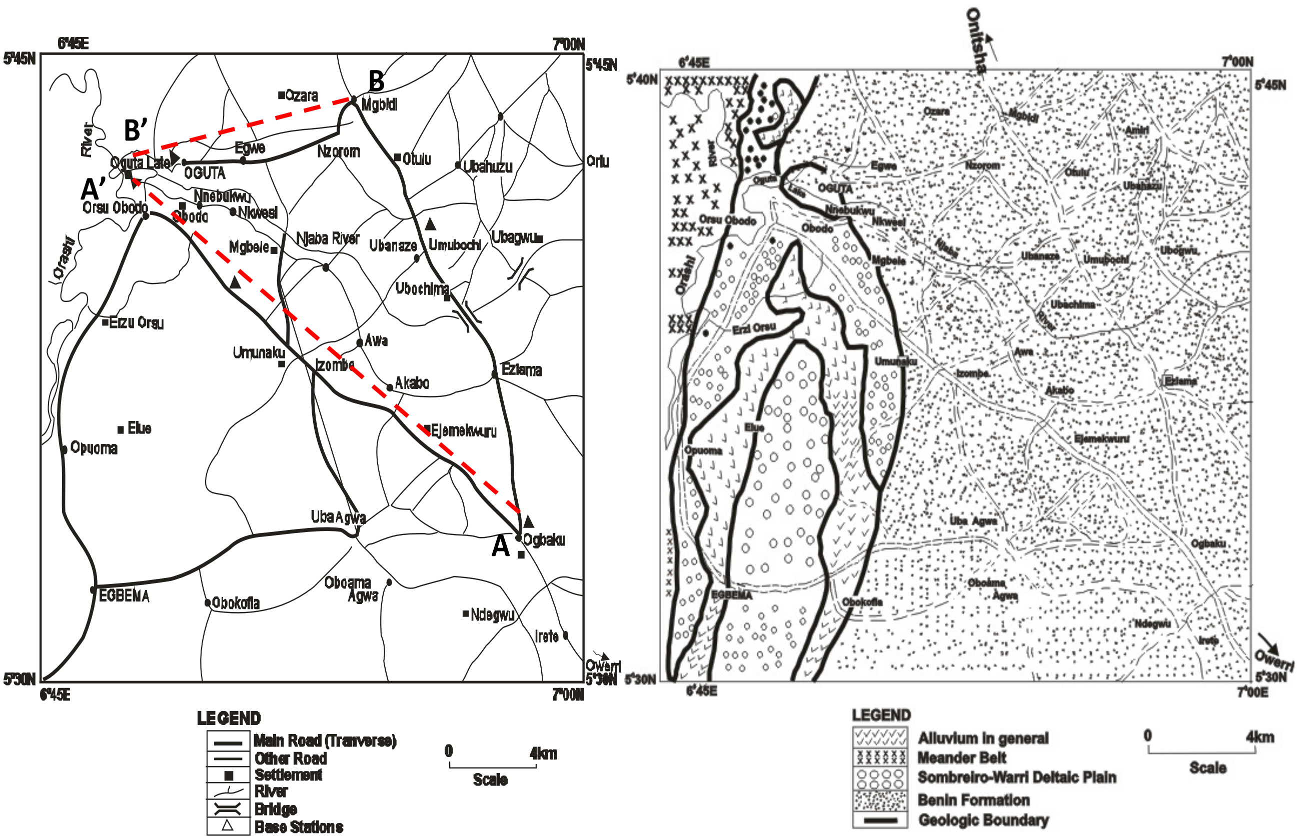
Hospers (1965) observed the gravity field of Niger Delta and showed negative values of low magnitude, called the 'Niger Delta Minimum' which is a gentle gravity minimum reaching -40 mgal that covers most of the sub-aerial part of Niger Delta. Four main types of oil field structures have been recognized in the area by Weber and Daukoru (1975). These are the simple rollover structures, multiple growth fault structures with antithetic faults and collapsed crestal structures. Hydrocarbon traps, which are not controlled by faults are described as stratigraphy and unconformity traps (Avbovbo, 1978).

The northern delta province (the Njaba River sub-basin is situated in this depobelt), which overlies relatively shallow basement, has the oldest growth faults that are generally rotational, evenly spaced, and increase their steepness seaward (Doust and Omatsola, 1990).

LOCATION OF THE STUDY AREA

The study area is located in the northern and oldest depobelt of the Niger Delta region which is on the Gulf of Guinea on the West Coast of Central Africa and geographically located in the Southeastern part of Nigeria, and covers an aerial extent of about 50 km^2. It lies between latitudes 5°30'N to 5°45'N and longitudes 6°45'E to 7°00'E in the northwestern part of Imo State. The important localities or towns within the study area are Ogbaku, Izombe, Mgbidi, Oguta, Uba-Agwa, Egwe, Orsu-Obodo, Ezzi-Orsu, and Eziama (Geological Survey of Nigeria, 1984). In general, Southeastern Nigeria lies roughly between latitudes 4°25'N and 7°00'N of the equator, and longitudes 6°30'E and 9°30'E of the Greenwich meridian (Figure 1). It is therefore dominantly situated within the tropical rain forest belt.

The study area is one of the most important districts in Southeastern Nigeria due to the presence of abundant economic and mineral resources. It has witnessed an increase in population over the years and is fast becoming an industrial area with lots of socio-economic



Location map of the study area

Geologic map of the study area

Figure 2. Location and Geologic maps of the study area.

activities due to rural-urban migration and discovery in the area of mineral oil resources. Access roads to the study area e.g. the Owerri - Onitsha Express road that connects the East to other parts of Nigeria, have been greatly improved because of the tourism potential for this site – the Oguta Lake. The study area is also accessible through the Ogbaku – Oguta 2, Ogbaku – Mgbidi, Mgbigi – Oguta 1 and other minor roads that link other small villages to these areas. These major roads served as the traverses for the field work on the study area. Figure 2 shows the location and geologic map of the study area.

DATA COLLECTION AND REDUCTION

The survey was referred to as base station at Alvan Ikoku College of Education (Owerri) with a base gravity reading of 9780629.04 g.u which is the standard benchmark (SBM) that had been earlier established as part of the National Gravity Network System. A secondary base station was created at Ogbaku junction (Lat. 5° 33’N, Long. 6°58’E) with a gravity value of 9780628.37 g.u. This was used to tie the different survey stations together.

Intermediate base stations were established at 10 km intervals by a technique of looping usually in the form ABABCBC. Detailed gravity readings were taken at 1 km intervals along the highways. Field equipment used includes a Lacoste and Romberg gravimeter Model no. G466, a compass, sample bags and marking tape, geologic hammer, camera, base-map (scale 1:100000), Global Positioning System (GPS), map 76CS (30 channels), GPS etrex 12, field notebook, shovel, core samples, ropes, stationeries, etc.

Field investigation was undertaken in three phases. The first phase involved a reconnaissance survey, which involved acquainting and liaising with the people living in the study area because the work required digging the ground up to 1 m and collecting undisturbed soil samples (for density analysis); so the people had to be informed and enlightened on the planned activities. The next phase involved gravity data collection using the gravimeter, and also the collection of undisturbed soil samples at about 1 m below the earth surface. At every station, the following important measurements were taken and recorded (because gravity values depend on these factors): the gravity reading using the gravimeter, height above sea level, latitude and longitudes (that is, the position coordinates of the stations) by using the GPS; measurements were made in loops after a certain time interval usually metric. Topographic maps at scales 1:100000 were used to locate the stations within an accuracy of 100 m. This field work was carried out in June, 2008.

Laboratory analysis involved bulk and dry densities analysis of the soil/rock samples to determine the density contrast between the sediments and the crustal density in the area of study. Data reduction was accompanied by the conventional methods. The latitude effects were corrected to obtain the theoretical gravity effect by using the 1967 international gravity formula (Wollard, 1979) given as follows:

Table 1. Corrected gravity data for profile A-A' and B-B'.

Town	Station (Km)	gth (g.u.)	FAC (g.u)	BC (g.u)	FAA (g.u)	B.A (g.u)	REG. (g.u.)	RES (g.u.)
					(A) Profile A-A'			
Ogbaku	0	9780803.265	241.7965	13.467	66.9013	53.4345	58	-4.56555
	1	9780804.207	238.0331	13.581	62.2490	48.6685	54.4758	-5.8073
	2	9780805.034	245.5599	13.343	67.9067	54.5639	50.9516	3.612252
	3	9780806.806	223.9205	10.038	44.6654	34.6277	47.4274	-12.7997
	4	9780808.12	220.1571	7.178	39.5241	32.3466	43.9032	-11.5566
	5	9780808.868	233.3289	10.143	51.4379	41.2953	40.379	0.91627
Ejemekuru	6	9780809.592	224.8613	11.913	41.5552	29.6425	36.8548	-7.21234
	7	9780810.476	219.2163	8.636	32.7067	24.0709	33.3306	-9.25966
	8	9780811.347	219.2163	7.742	30.8572	23.1148	29.8064	-6.69161
	9	9780812.214	231.4472	16.034	40.8386	24.8042	26.2822	-1.47797
	10	9780813.102	210.7487	16.032	18.1894	2.1575	22.758	-20.6005
	11	9780813.609	237.0923	12.239	42.7175	30.4789	19.2338	11.24507
	12	9780814.014	211.6895	8.052	16.4736	8.4219	15.7096	-7.28771
Izombe	13	9780814.917	219.2163	10.422	22.1822	11.7598	12.1854	-0.42564
	14	9780815.773	222.9796	13.025	24.0267	11.0021	8.6612	2.340916
	15	9780816.864	230.5064	11.899	28.5480	16.6494	5.137	11.5124
	16	9780817.677	204.1628	10.539	1.5192	-9.0196	1.6128	-10.6324
ICSS	17	9780818.721	208.8670	10.782	5.0092	-5.7725	-1.9114	-3.86107
	18	9780819.648	205.1036	10.866	-0.5536	-11.4196	-5.4356	-5.98401
	19	9780820.557	197.5769	10.736	-9.6589	-20.3945	-8.9598	-11.4347
Nkwesi	20	9780821.707	210.7487	11.451	1.4266	-10.0247	-12.484	2.459316
	21	9780822.873	180.6417	8.343	-28.2195	-36.5626	-16.0082	-20.5544
	22	9780824.159	89.3800	3.278	-113.1203	-116.3985	-19.5324	-96.8661
	23	9780825.106	92.2026	5.135	-111.7767	-116.9119	-23.0566	-93.8553
	24	9780825.862	85.6167	6.397	-119.8624	-126.2590	-26.5808	-99.6782
OrsuObodo	25	9780826.455	80.9124	4.287	-125.6274	-129.9139	-30.105	-99.8089

Table 1 Contd.

Oguta II	26	9780827.953	72.4449	2.460	-135.6997	-138.1599	-33.6292	-104.531
	27	9780828.166	72.4449	1.968	-134.7426	-136.7108	-43.153	-99.5574
				(B) Profile B-B'				
Mgbidi	0	9780831.41	-212.705	10.777	43.208	32.431	22	10.431
	1	9780831.41	-212.705	10.288	3.691	-6.597	17.769	-24.366
	2	9780831.23	-213.734	12.906	65.7	52.796	13.538	39.258
	3	9780830.45	-213.226	15.337	12.58	-2.757	9.307	-12.064
	4	9780829.83	-212.957	10.333	4.381	-5.952	5.076	-11.028
	5	9780829.82	-213.399	15.273	11.465	-3.808	0.845	-4.653
Egwe	6	9780829.58	-214.086	19.794	13.599	-6.195	-3.386	-2.809
	7	9780829.69	-214.652	19.414	16.423	-3.171	-7.617	4.446
	8	9780829.59	-214.628	13.251	-11.403	-24.654	-11.848	-12.806
Oguta	9	9780829.38	-206.576	2.657	-113.431	-116.088	-16.079	-100.009
	10	9780829.64	-207.552	1.955	-127.578	-129.533	-20.31	-109.223
	11	9780829.092	-206.295	2.326	-120.677	-123.003	-24.541	-98.462

g_{lat} = 9780318.46 (1 + 0.005278895 sin2φ + 0.000023462 $\sin^4φ$) g.u.

Where φ is the latitude of the station.

The above formula has a maximum error of 0.04 g.u (Lowrie, 2002). The formula reproduces the actual measured absolute values of gravity at sea level within 1 g.u. Free-air correction was applied using the relation

$$g_{fc} = 3.080\ h\ g.u.$$

where g_{fc} is the free air correction and h is the height of station above sea level.

The Bouguer corrections were applied by using the calculated densities of the *in-situ* soil samples collected at each station ranging from 2.08 × 10^3 – 2.44 × 10^3 kg/m^3 which is a reasonable approximation for the mean surface density of sedimentary rocks (Blakely, 1996). When these densities were subtracted from the mean crustal density of 2.67×10^3 kg/m^3, we obtained the density contrast that was used in the Bouguer correction, giving a density contrast of the range of 0.20 – 0.60 kg/m^3 for the mean density of surface rocks. The Bouguer correction g_{BC} was therefore given as:

g_{BC} = 0.419 ρh g.u.

Where ρ = density contrast; h = station elevation (m).

In order to obtain Bouguer anomaly at each station, the value g_B was calculated by the following formula (Telford et al., 1976).

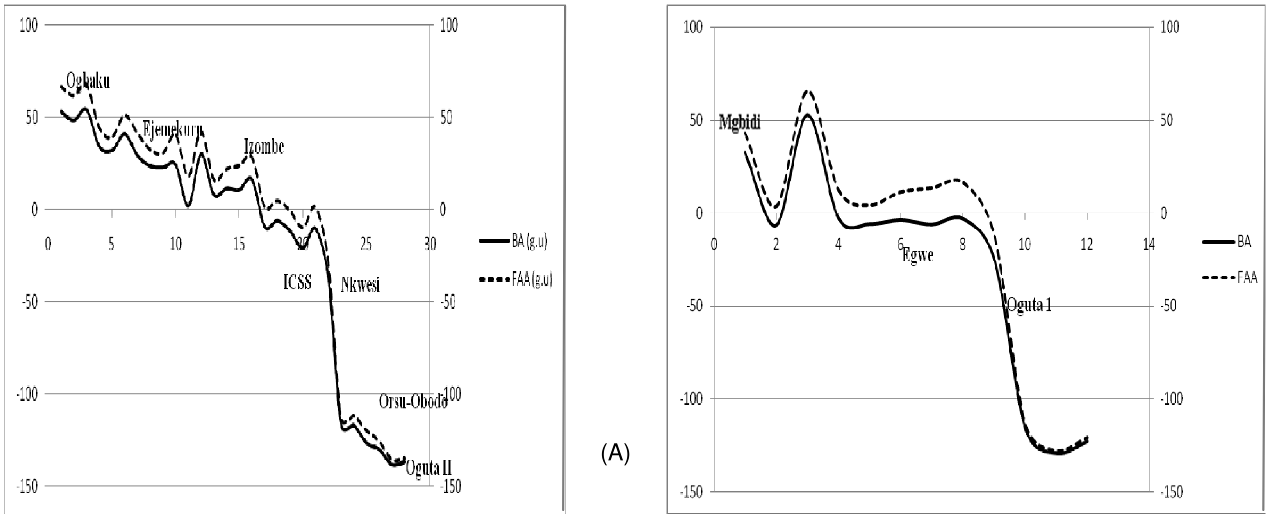
$g_B = g – g_{lat}$ + 3.080 h – 0.419 ρh g.u.

Where g is the measured gravity reading gotten in the field (g.u.) at height h (m), theoretical gravity effect g_{lat} (g.u.) and ρ is Bouguer density contrast.

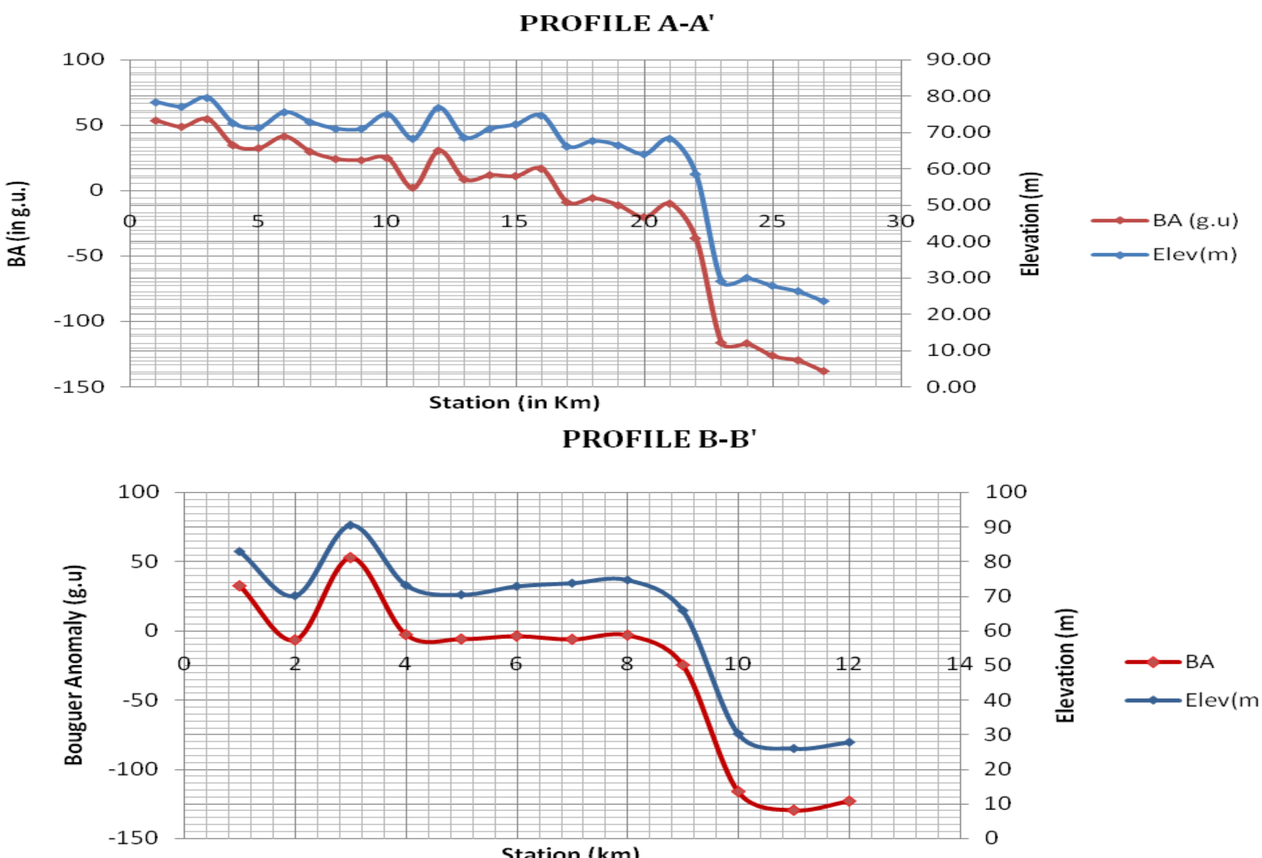
In this study, terrain correction was omitted because the terrain in the study area is sufficiently flat for the elevation correction to provide adequate compensation for topographic effects. Table 1 shows the corrected (reduced) gravity data from the field data (in Appendix Table 1). The resultant free-air anomalies, Bouguer anomalies and the topography along the two profiles are shown in Figures 3a and b.

ROCK DENSITY DETERMINATION

Undisturbed fresh soil samples were taken from deep depth (> 1 m) at all station points along all the traverses during the field work. The true densities of the rock samples were found using the famous Archimedes



(A)



(B)

Figures 3. (a) Bouguer anomaly and free-air anomaly for profiles A-A' and B-B', (b) Relationship between the Bouguer and elevation of the Profile A-A'and B-B' (Note: The marked relationship in the trend between the elevation and the bouguer anomaly observed in profile AA' and BB').

principle. The densities obtained were used in the computation of the Bouguer anomalies with respect to each station. The results of the densities for the various rock types and deduced density contrast as identified in the area were summarized in a graph showing the variation in densities determined for the different stations as shown in Figure 4.

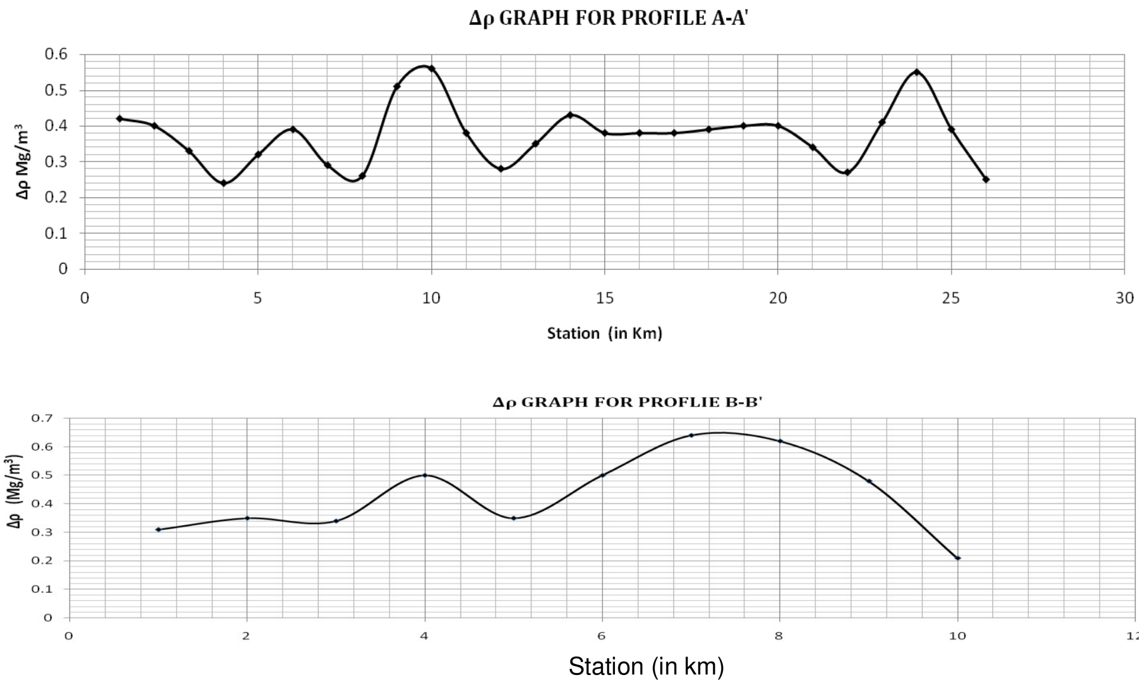


Figure 4. Density contrast graph for Profiles A-A’ and B-B’.

REGIONAL – RESIDUAL SEPARATION

Visual smoothening or graphical method was used to fit the regional trend on the Bouguer anomalies data for Profiles AA’ and BB’ refer to (Figure 5a) to produce residual anomalies shown in Figure 4b. The regional curve along the two profiles have been represented by a first degree polynomial (linear) fitted visually through the points considered to be least affected by local disturbances (Parasnis, 1998). This line slopes gently from the inland area – Ogbaku to Oguta lake end of Profile A-A’ and from Mgbidi to the Oguta lake end of Profile B-B’ with a gradient of about -3.524 and -4.231 g.u./km for A-A’ and B-B’ respectively. This exercise was carried out in excel program of windows office for the two Profiles A-A’ and B-B’ and is shown in Figure 5a and the residual anomalies obtained is shown in Figure 4b.

BOUGUER/RESIDUAL ANOMALY MAPS AND THEIR INTERPRETATIONS

The Bouguer gravity anomaly data were displayed on a map covering the study area by using the coordinates of the stations where the gravity data was obtained and generally the bounding coordinates of the study area (Latitude 5° 30’ to 5° 45’N; Longitude 6° 45 to 7° 00’). The study area was arranged on a 15 × 11 grid covering the whole area. About 95 gravity values (one value per station) collected in the whole study area were contoured using Winsurfer® Program. The result gave a computer-based Bouguer anomaly map of the area shown in Figure 6a. This was carried out to enhance the use of computer program for the regional-residual separation and modeling of the residual anomaly.

The gravity map is a two-dimensional display of the Bouguer anomalies over parts of Njaba River sub-basin and it consists of series of anomaly closure trending northeast – southwest of the study area. The beginning sections of Profiles A-A’ and B-B’ (Ogbaku to a few kilometers after Izombe for A-A’ and some kilometers after Mgbidi for B-B’) show a high positive anomalies. There is a sharp drop in the observed gravity in the distal part of Profile A-A’, some kilometers (about 7 km) before the lake and 2 km after Mgbidi of Profile B-B’ which indicates the presence of sediments density (deduced to be recent sedimentation of alluvium deposits as confirmed in the geologic map of the area in Figure 2) which led to the subsidence and subsequent faulting noticed in the profiles at the points where the gravity minima started in both profiles. The high anomalies may be due to a block of high density basement occurring at a depth which can be determined to be shallow and the gravity minima can be said to be as a result of the density contrast which occurred between the sediments and basement, and/or a downwarp of the sediment.

THE GEOLOGIC MODEL AND ITS INTERPRETATION

The modeling program used for the interpretation is GM SYS® software, and the output model redesigned in AutoCAD for better presentation. The observed gravity (using the residual anomaly data) gotten from the regional-residue separation across the profiles was modeled using a 2-Dimensional model and the models with the best fit and the least error results are shown in Figure 7A-C. Due to the regional (coarse scale) nature of the investigation (seen in some of the observed gravity), some of the models are approximated.

Ambiguities in gravity anomaly modeling were reduced to the least minimum with the help of geologic information of the study area. The methodology involves adjusting the parameters which gravity depends on that is, depth, area and density contrast, in order to achieve the possible best fit model this was done with the help of a conceptual model and knowledge and information extracted from the geologic map of the study area. The geologic model built using GM SYS for the profiles A-A’ and B-B’ showed

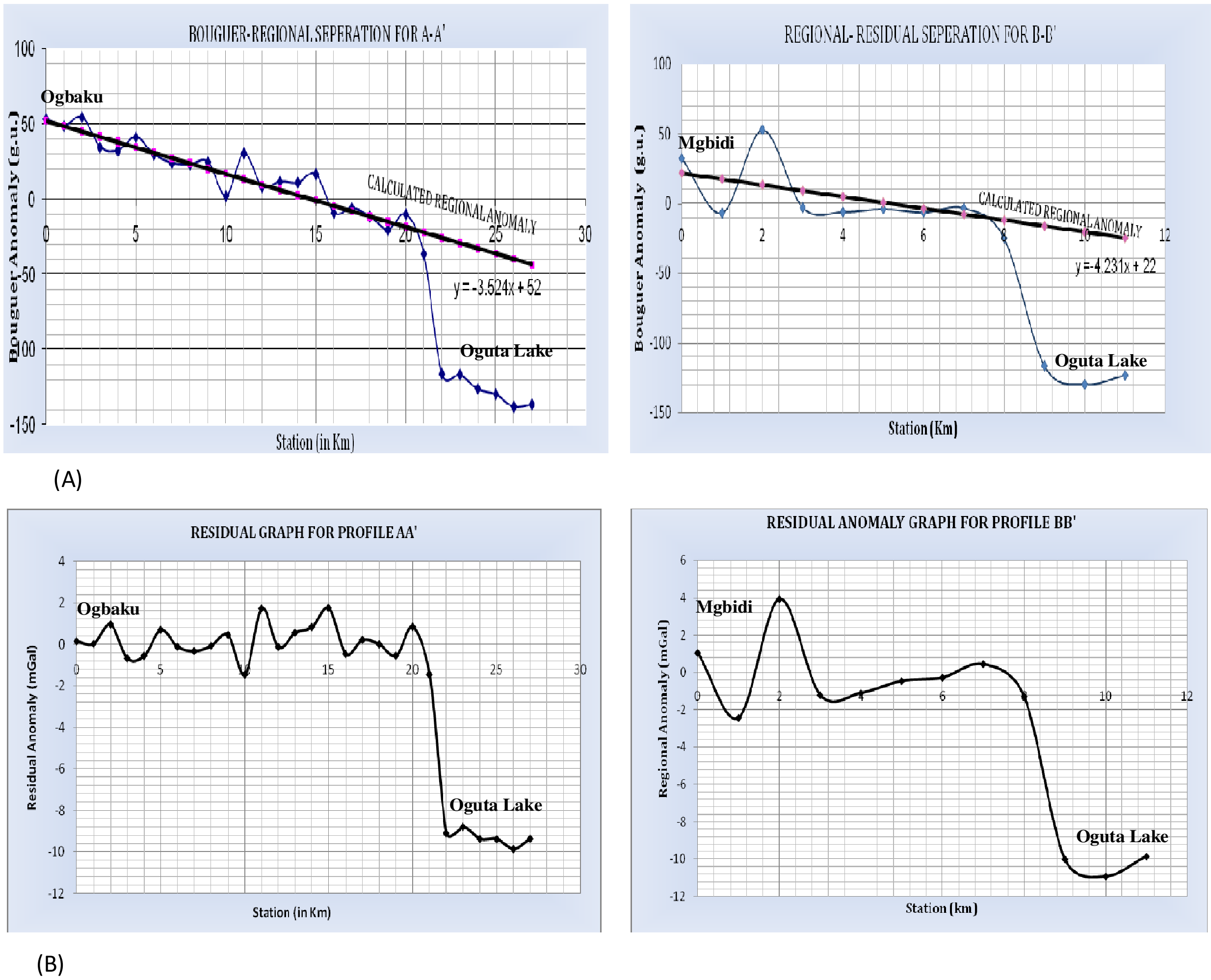


Figure 5. (a) Regional – residual separation graphs for profiles A-A' and B-B', (b) Residual anomalies for Profiles A-A' and B-B'.

clearly the fault, the throw of the fault and the depths of the sedimentary bodies seen in the area. Also the densities of the formations were deduced (which in fact acted as the controlling factor used in modeling the observed gravity) and were indicated in the model.

In Profile A-A' the density contrast between the sedimentary body and the basement is in the range 0.2-0.45 Mg/m^3 and the density contrast between that of the recent sedimentary deposit (alluvium deposit) and the basement are in the range of 0.30-0.60 Mg/m^3 showing that it is of a lesser density when compared to the basement and the other formations seen along the profile. The summarized version of the model is shown in Table 2A and B.

Profile B-B' (Figure 7B) showed almost similar type of observed gravity and model as that of Profile A-A' when moving from Mgbidi through Egwe to Oguta lake (Oguta l) and confirms that the two areas of the same geologic episode (that is, geologically, the area are the same) and the same tectonic structures and stratigraphy was evident in the two profiles when they were modeled together end-to-end (Figure 7C). The structural fault throw was seen from the model to occur from about the 3 km from Oguta Lake. Using the geologic models (that gave the best fit to the gravity anomaly), it is seen that the depths estimates of the formations to the basement rock ranges from 1.6 to 5.2 km for Profile A-A' and 1.2 to 3.6 km for Profile B-B'.

DISCUSSIONS

From Figure 7C which shows a combined model structure of Profile A-A' and Profile B'-B (reversed B-B') such that the two ends of the profiles A' and B' meet at a point (Oguta lake), a structural basin was mapped out (using the model of the observed gravity) which has a very large thick deposit of alluvium (recent) sediments of the geological age – Quaternary and are bounded by two large normal faults. The rivers (Njaba and Ossu rivers) flowing in the area could be said to be the transporting medium of the sediments into the mapped basin.

The antithetic (counter-regional) faulting in the Niger-Delta are said to trend northwest to southeast (NW-SE) which is evident of fault F_1-F_2 in Profile B-B' and are said

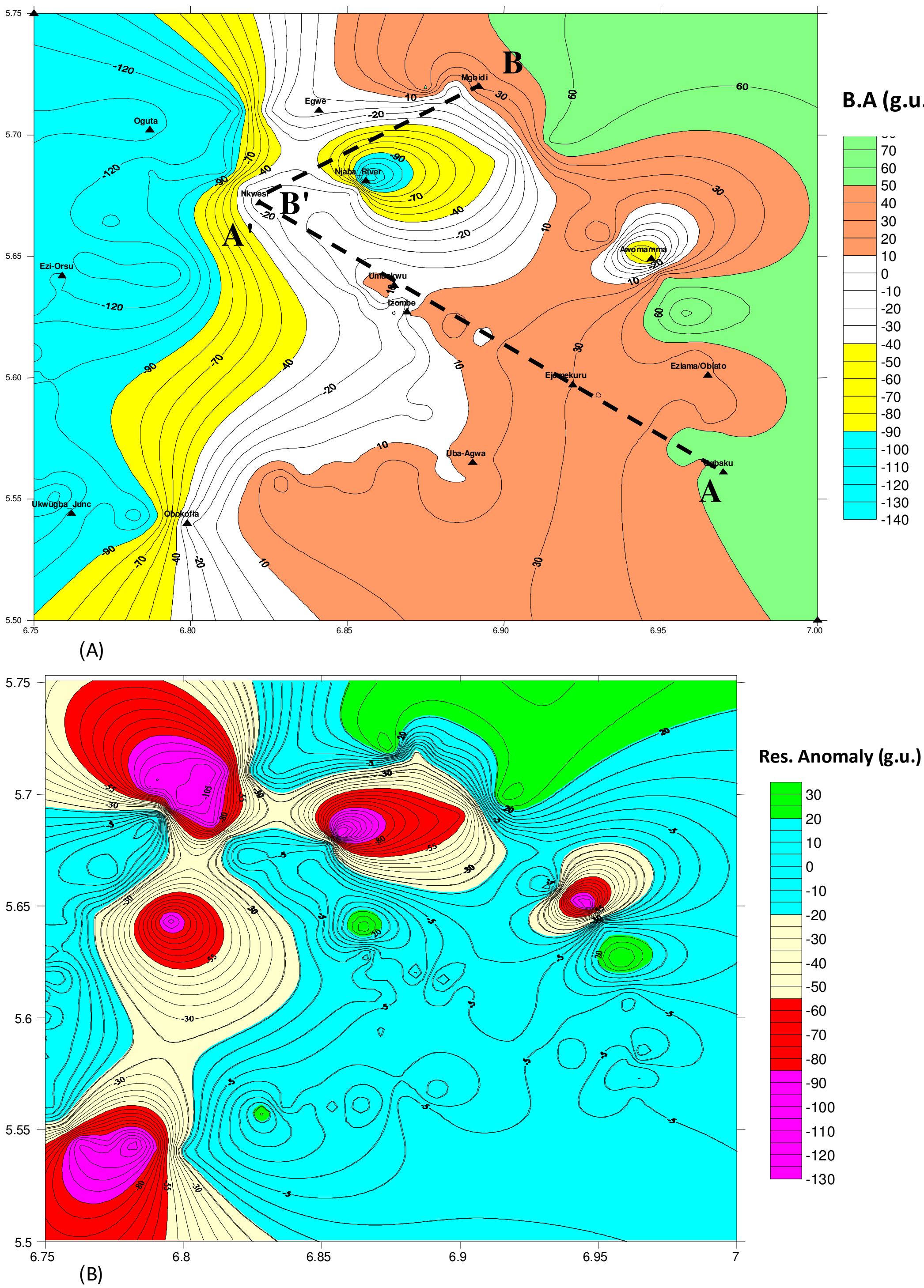


Figure 6. (a) The Bouguer anomaly map of the study area showing the two profiles of major interest A-A' and B-B', (b) Residual contour map of the area.

to be formed by gravitational slumping due to the mobility of the deep buried sediments, which most times are shale, moving from below to top owing to the isostatic process of the action (effect) of the sedimentation process going on the other side (which produces the regional/synthetic fault). From recent 3D-seismic interpretation with integrated well log interpretation done from wells drilled in some fields in some parts of the area

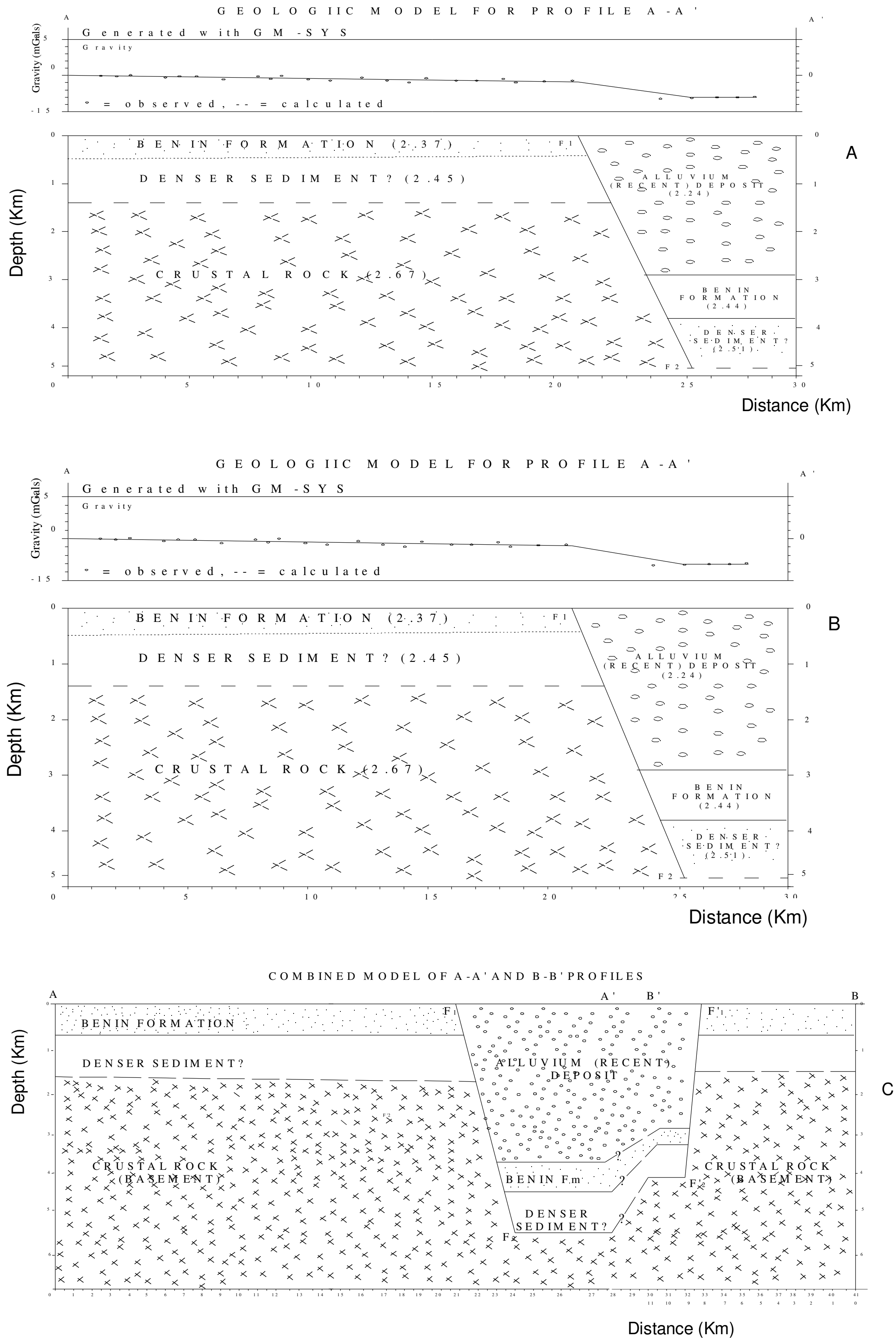


Figure 7A, B and C. A separate and combined geologic model of observed gravity of Profiles A-A’ and B-B’.

Table 2. The formations deduced, density and calculated from the model of profile A-A’ and B-B’.

Formations	Modeled density (density contrast) Mg/m^3	Calculated depth (m)
	Profile A-A’	
A. SHALLOW Fm		
- Benin Fm	2.37(0.30)	600
- Denser Sediments$^?$	2.45 (0.22)	1600
B. DEEPER Fm		
- Benin Fm	2.44 (0.23)	4100
- Denser Sediments$^?$	2.51 (0.16)	5200
Alluvium (Recent) Deposit	2.24 (0.43)	3400
Crust	2.67	1600 - 5200
	Profile B-B’	
A. SHALLOW Fm		
- Benin Fm	2.36 (0.31)	600
- Denser Sediments?	2.40 (0.27)	1200
B. DEEPER Fm		
- Benin Fm	2.42 (0.25)	2800
- Denser Sediments?	2.49 (0.16)	3600
Alluvium (Recent) Deposit	2.23 (0.44)	2100
Crust	2.67	1200 - 3600

(e.g. Izombe and Ossu fields), the area was found to consist of several complex structures (such as graben structures, synthetic (regional) and antithetic faults (counter-regional) faults, shale diapers, etc) which are in line with the structural styles found in Niger Delta (Evamy et al., 1978) and it was concluded that since the area is in the oldest depobelt of Niger-that is, the Northern depobelt. This school of thought from the seismic-end confirms our result on the presence of the structures located or found in the basin (Ekweozor and Daukoru 1994).

In reference to hydrocarbon exploration in the area, considerations should first be made to the implications of the structural features (faults and anticlines maybe) which abound in the basin. The depths interpreted (Table 2A and B) for the anomalies suggest that the area under study is thick enough, sediment-wise for hydrocarbon accumulation potentials. Also the existence of regional structural features is of major interest since deep faulting are targets for hydrocarbon accumulations.

Another interesting observation in this study was the possibility of the presence of large water reservoirs. The presence of a comparable thickness of continental sandstone of Eocene age (e.g. Benin sandstone) could serve as a very good underground water reservoir and serve as target for groundwater exploration to solve the problem of water supply, if there be, of the people living in the area (Uma, 1989). Thus the availability of thick continental sandstone formations (porous and permeable) in the basin serve as target for groundwater exploration to solve the problem of water supply, if there be, of the people living in the area.

Conclusion

Intelligent estimates of the depth of the different density-varying formations were made and it was concluded that there was a subsidence or down warping of the basement (resulting in the formation of large bounding faults) in the distal parts of the two profiles considered to be at a depth ranging from 3.6 to 5.6 km and when the profiles were joined end-to-end, it showed the existence of a basin in the Northwestern parts of the Figure 7C. Earlier studies (Merki, 1970) showed that the maximum thickness to the basement of the Niger delta is about 12.2 km (40,000ft). Since sedimentary thickness are expected to increase as we move southwards towards the Atlantic ocean and the sub-basin is known to be situated far into the northern part of the Niger Delta, the depth values obtained in the present study appears logical. Any error associated with such depth will be consistent with the ambiguity associated with gravity interpretation.

The interpretation of the observed gravity shows an estimated sedimentary thickness of about 7 km in the mapped basin and the observed structural features such as faults may have serious implications for hydrocarbon accumulation. This justifies the current exploitation of petroleum resources in some parts of the Njaba River sub-basin which are very close to the interpreted profile (the producing fields in the area include Izombe and Ossu fields).

RECOMMENDATION

Detailed geological and geophysical (deep 3D-seismic) studies should be carried out in the study area to accurately map and get more information on the subsurface geological structures as this would guide in providing more detailed and in-depth information of the subsurface geology and economic geology of the study area.

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APPENDIX: DATA PRESENTATION

Table 1. Gravity data for (A) Profile A-A' (Ogbaku – Oguta II) and (B) Profile B-B' (Mgbidi to Oguta 1).

Town	Station (km)	Time	Elevation (m)	Latitude (N)	Longitude (E)	Meter reading	g abs (g.u.)
	(A) Profile A-A' (Ogbaku – Oguta II)						
Ogbaku	0	9:30	78.35	5.561	6.97	1760.6	9780628.37
	1	9:40	77.13	5.566	6.963	1760.65	9780628.423
	2	9:56	79.57	5.571	6.956	1759.67	9780627.381
	3	10:04	72.56	5.581	6.942	1759.83	9780627.551
	4	10:13	71.34	5.589	6.937	1759.77	9780627.487
	5	10:23	75.61	5.593	6.93	1759.29	9780626.977
Ejemekuru	6	10:30	72.87	5.597	6.922	1758.64	9780626.285
	7	10:37	71.04	5.602	6.914	1756.46	9780623.967
	8	10:42	71.04	5.607	6.907	1755.54	9780622.988
	9	10:47	75.00	5.612	6.9	1754.24	9780621.606
	10	10:53	68.29	5.617	6.893	1753.24	9780620.542
	11	10:59	76.83	5.620	6.884	1752.01	9780619.234
	12	11:05	68.60	5.622	6.876	1751.6	9780618.798
Izombe	13	11:10	71.04	5.627	6.869	1750.74	9780617.883
	14	11:16	72.26	5.632	6.862	1749.74	9780616.82
	15	11:23	74.70	5.638	6.856	1747.94	9780614.905
	16	11:30	66.16	5.643	6.849	1748.06	9780615.033
ICSS	17	11:51	67.68	5.654	6.849	1747.9	9780614.863
	18	12:13	66.46	5.659	6.835	1747.08	9780613.991
	19	12:28	64.02	5.666	6.828	1746.45	9780613.321
Nkwesi	20	12:40	68.29	5.672	6.822	1745.57	9780612.385
	21	12:44	58.54	5.680	6.816	1747.1	9780614.012
	22	12:50	28.96	5.685	6.811	1754.29	9780621.659
	23	13:05	29.88	5.689	6.804	1753.79	9780621.127
	24	13:12	27.74	5.693	6.796	1753.09	9780620.383
Orsu-Obodo	25	13:24	26.22	5.701	6.788	1752.65	9780619.915
Oguta II	26	13:32	23.48	5.702	6.787	1752.55	9780619.808
	27	13:40	23.48	5.643	6.795	1753.65	9780620.978
	(B) Profile B-B' (Mgbidi to Oguta 1)						
Mgbidi	0	14:55	82.927	5.72	6.892	1751.52	9780618.71
	1	15:03	70.122	5.72	6.884	1751.28	9780618.45
	2	15:10	90.549	5.719	6.875	1750.38	9780617.5
	3	15:22	73.171	5.715	6.875	1750.12	9780617.2
	4	15:31	70.427	5.712	6.859	1749.79	9780616.87
	5	15:36	72.866	5.712	6.85	1749.37	9780616.4
Egwe	6	15:42	73.78	5.71	6.841	1748.5	9780615.5
	7	15:49	74.695	5.711	6.833	1748.07	9780615.04
	8	15:54	65.854	5.71	6.824	1748	9780614.969
Oguta	9	16:05	30.183	5.71	6.815	1755.37	9780622.808
	10	16:15	25.915	5.711	6.807	1754.7	9780622.095
	11	16:22	27.744	5.707	6.799	1755.36	9780622.79