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Regional Geoelectrical Survey Across Some Parts of Anambra and Niger Delta Basins, South-Eastern Nigeria.

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ABSTRACT

A regional geoelectrical study was embarked upon covering some major towns within the Niger Delta and Anambra basin. Some of the towns include; Owerri, Umuahia, Ohafia, Aba, Umuosu, Ngwa, Mbaise, Okigwe, Lekwesi, etc. About 100 Vertical Electrical Sounding points were established along two long profiles running perpendicularly to each other at North-South and East-West directions covering a distance of about 110km in each traverse. The maximum electrode spread was 500metres, AB/2. The schlumberger array was adopted on the field. The ABEM Terrameter SAS 4000 was used for the data acquisition. The purpose of the study is to examine the variability in lithological units both vertically and horizontally from the North to South and East to West along these profiles because there have been reported cases about land degradation like; gully erosion, landslide, minor subsidence, road failure, etc within the study area. The field data were processed with computer softwares. Iso-resistivity values at AB/2 equals 1m, 4m, 8m, 15m, 50m, 150m, 250m and 350m at surface electrode spacings were plotted and processed for each VES point in order to reveal the variation in resistivity with depth and variability changes in lithological units with depth. This procedure was repeated for all the VES stations on the East-West profile and North-South profile. Results show that the top soil contour has resistivities between 200Ωm and 9000Ωm while at AB/2 = 4m, resistivities are 500 - 1000Ωm (Aba), 1000 - 5000Ωm (Owerri), 2000 - 2500Ωm (Afikpo). Results were also obtained for AB/2 = 8m, 15m, 50m up to 250m. These resistivity values were interpreted as clay, shale, sand, etc, accordingly. From the correlation of the VES points, other geologic structures like faults, boundaries, flood plains, landsides are identified. Other environmental implications are highlighted.

1.0 Introduction

The solid earth is the base on which every other structure, be it houses, roads, bridges or even agricultural practices stand on. Though the solid earth is divided into three major regions but the aspect most concerned is the crust which is the earth's hard outer layer. The crust is classified into continental (under the ground0 and oceanic (under the ocean) [1],[2]. Greater number of human activities rests on the continental crust. The continental crust comprises of various rock units and the distribution may be related to the geological basins they filled [3]. The natural distributions of geologic Formations across the basins have trends which may be widespread within certain geographic locations [4]. The content and characteristics of rocks units make them suitable for certain activities or usage. Hard rocks and other rocks such as sand, sandstone form suitable stable landmass or base for road construction while clay and shale rock units are suitable for agricultural practices. Eventually some of these structures may be built on sub surfaces which do not have the bearing capacity to withstand the load and thereby result in road failures, collapse of buildings and on the other hand, some areas may be highly prone to erosion and small scale subsidence sometimes occur. Most parts of south eastern Nigeria have reported cases of either erosion menace or road failures and even collapse of buildings. This is attributed to the variability in the lithological units (composition or type of rock units) [5]. The northwestern parts of the study area are erosion prone. The towns include Akokwa, Urualla, Isiekenesi, Orlu, Umuchu, Umuaka, Isuochi, etc, have established erosion sites which have eroded some major roads connecting the towns. For instance erosion has cut off Isiekenesi from Okwelle, Umuaka from Orlu, while there are remarkable road failures between Umuahia and Okigwe along Portharcourt – Enugu express road. Also there are reported cases of road failures along Umuahia – Bende road, etc. Even when some of these roads have been reconstructed they still do not last or serve the purpose for which they were built.

These occurrences suggest a detailed study of the sub surface rock units in order to proffer solution to these challenges. The readily and reliable geophysical method to approach these challenges is the resistivity method, [6], [7],[8].The advantage of this method is that it is less cumbersome in the instrumentation and also less expensive [8]. The iso-resistivity of the area will be taken and contoured at different depths to identify locations with low resistivity which is associated with road failures and collapse

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of buildings. Profiles of the true resistivities of the geoelectric layers and their corresponding depths will be drawn from the centre in the East – West and North – South directions to serve as guide to the design and construction works as well as management of these sites. Other geological implication such as faulting, flood plains an the likes will be highlighted.

2.0 Location and geology of the Study Area

The study area is located in the South East of Nigeria between Latitudes 5o00′N and 6o00′N and Longitudes 7o00′E and 8o00′E. The major towns within the study area are: Okigwe, Afikpo, Umuahia, Aba, Ohafia, Oweri, Abiriba, Arochukwu, Ikot Ekpene, Uyo, Abak etc. Fig. 1.

Fig.1. Geological Map of Nigeria showing the basement and sedimentary basins.

The study area is situated within a sedimentary terrain of South Eastern Nigeria. Eleven geologic formations are identifiable; Alluvium , Benin Formation, Ogwashi-Asaba Formation, Ameki Formation, Imo Shale, Nsukka Formation, Ajalli Formation, Mamu Formation, Nkporo Shale Group, Ezeaku Shale Group, and Asu River Group, Fig.2

The age is of Cretaceous to Tertiary. The cretaceous stratigraphic succession of southern Nigeria comprises strata of three marine depositional sequences. The mid-Albain to cenomanian phase represented by the Asu River Group and Odukpani Formation. This is succeeded by the Turonian-Coniacian succession consisting of the Eze-Aku and Awgu Formations.

The Turonian-Coniacian marine depositional cycle in the Benue trough was terminated by the santonian tectonism. The deformation was characterized by compressional stresses which paralleled or occurred simultaneously with the establishment of NE-SW trend of the trough [9]. The Pre-santonian incompetent beds were folded, faulted, intruded and uplifted to give rise to the Abakiliki anticlinorium. They contemporaneously subsided along the flanks of the uplift which resulted in the formation of the major Anambra and minor Afikpo basin to the south-west and south-east respectively. These new structural depression became depocentres for the remaining cretaceous and early Tertiary Periods. The compano-maastrichtian deposits constitute the proto-Niger Delta and represent the third and terminal cretaceous marine depositional phase in the trough. At the base of succession and unconformable Turonian-coniacian beds, is the marine Nkporo shale. These are succeeded by the paralic coal bearing Mamu Formation followed by the Ajali sandstone and terminate with the paralicNsukka Formation. The Paleocene transgression terminated by the southerly advance of the proto-Niger Delta.

The tertiary period began with the Paleocene transgression which saw the deposition of Imo Formation. The marine Paleocene bed is mostly overlain by continental strata which suggest that the Paleocene trans-Saharan Epeiric Sea later formed a series of narrow, long and disconnected basin were filled with sediments during the uppermost Paleocene to earliest Eocene. Regression began in the Eocene with the deposition of the Bende formation. The deposition of the Miocene Ogwashi-Asaba Formation and post Miocene Benin Formation completes the depositional history in the basin [9].

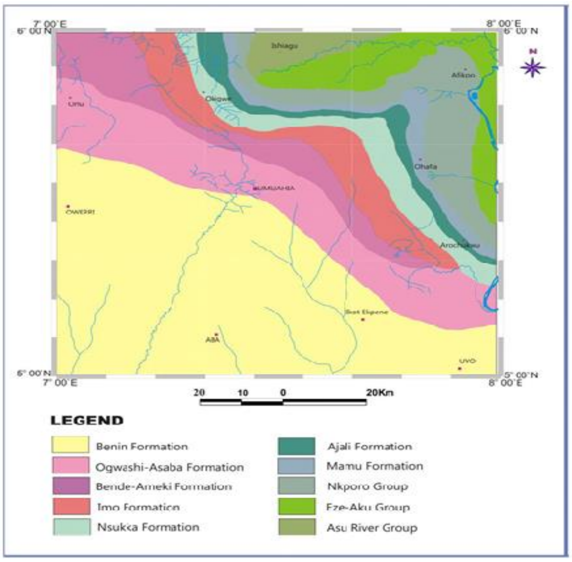


Fig2. Geological Map of the Study Area after Geological Survey of Nigeria (1974).

3.0 Materials and Method

3.1 Theory of Resistivity Method

Data from resistivity surveys are customarily presented and interpreted in the form of values of apparent resistivity,ρa. Apparent resistivity is defined as the resistivity of an electrically homogeneous and isotropic half space that would yield the measurement relationship between the applied current and the potential difference for a particular arrangement and spacing of electrodes. An equation giving the apparent resistivity in terms of applied current distribution of potential and arrangement of electrodes can be arrived at through an examination of the potential distribution due to a single current electrode. The effect of an electrode pair (or any other combination) can be found by superposition. Consider a single point electrode located on the boundary of a semi – infinite electrically homogeneous medium which represents a fictitious homogeneous earth. If the electrode carries a current I, measured in amperes (A), the potential at any point in the medium or on the boundary is given by;

$U = \ell(1/2\pi r)$ (1)

Where U = potential in volts, V;

ρ = resistivity of medium, Ωm;

r = distance from the electrode (Keller, 1977)

For an electrode pair with current at electrode A and electrode B, the potential at a point is given by the algebraic sum of the individual contributions.

$U = \rho L(1/2\pi r_A) - \rho L(1/2\pi r_B) = \rho L/2\pi(1/r_A - 1/r_B)$ (2)

Where r_A and r_B = distances from the point toelectrodes A and B.

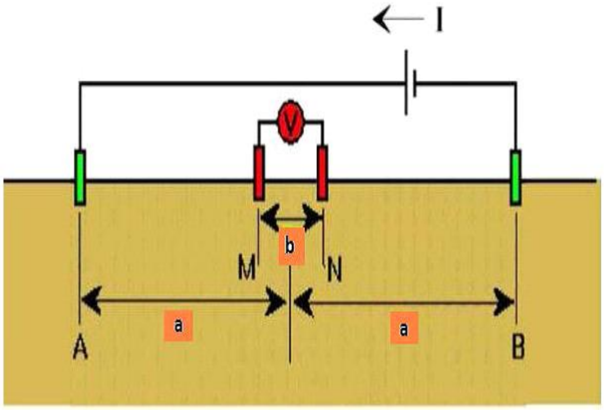


Figure 3. Vertical electrical sounding array (Schlumberger array).

Figure 3 illustrates the electric field around the two electrodes in terms of equipotentials and currents lines. The equipotentials represent imagery shells, or bowls, surrounding the current electrodes, and on any one of which the electrical potential is everywhere equal. The current lines represent a sampling of the infinitely many paths followed by the current, paths that are defined by the condition that they must be everywhere normal to the equipotential surfaces.

In addition to current electrodes A and B, figure 3 shows a pair of electrodes M and N, which carry no current, but between which the potential difference V may be measured. Following the previous equation, the potential difference V may be written;

$V = U_M - U_N = \boldsymbol{\rho}_{L/}2\pi(1AM-1/BN-1/AN)$ (3)

Where UM and UN = potentials at M and N;

AM = distance between electrodes A and M, etc.

These distances are always the actual distances between the respective electrodes, whether or not they lie on a line. The quantity inside the brackets is a function only of the various electrode spacing. The quantity denoted 1/k, which allows rewriting the equation as;

$V = \boldsymbol{\rho}L/2\pi K$ (4)

Where K = array geometric factor

The equation can be solved for ℓ to obtain;

$\boldsymbol{\rho} = 2\pi KV/I$ (5)

The resistivity of the medium can be found from measured values of V, I. The ratio of V/I equals R, the resistance of the material or rock unit. The geometric factor K is a function only of the geometry of the electrode arrangement.

For this array, in the limit as 'a' which is the distance between A and the midpoint or the distance between B and the midpoint, approaches zero, the quantity v/a approaches the value of the potential gradient at the midpoint of the array. In practice, the sensitivity of the instruments limits the ratio, of ‘b’ to ‘a’ and usually keeps it within the limits of about 3 to 30

Therefore it is typical practice to use a finite electrode spacing and equation (6) to compute the geometric factor (Keller & Frischnecht, 1966; Kearey,et al., 2002). The apparent resistivity ρ a is;

$\boldsymbol{\rho}_{a\,=}\ \pi\,(a^2/b - b/4)\ R = \boldsymbol{\pi}\left[\frac{(AB/2)2}{MN} - \frac{MN}{4}\right] = KR$ (6)

In usual field operations, the inner (potential) electrodes remain fixed, while the outer (current) electrodes are adjusted to vary the distance a. The spacing b, is adjusted when it is needed because of decreasing sensitivity of measurement. The spacing must never be larger than 0.45 or the potential gradient assumption is no longer valid. Also, the spacing b, may sometimes be adjusted with ‘a’or AB/2 held constant in order to defect the presence of local inhomogeneities or lateral changes in the neighborhood of the potential electrodes.

3.2 Research Methodology

The resistivity method was used to delineate and describe the shallow sedimentary lithology of the area. The instruments used for the operation include: ABEM Terrameter SAS1000, Etrex GPS, Compass, Two 500m Current Cable reels, Two 70m Potential cable reels, Electrodes, four hammers, two measuring tapes. The materials used for processing were Log-log graph sheets, Computer modeling using resistivity software by Henker (1985), Sufer 10 software. The procedure engaged for data acquisition involved the schlumberger array for vertical electrical soundings (VES). Soundings were carried out with non-polarizable stainless steel current and potential electrodes with their reels and switching units (clips and plugs). Reading for resistance were taken at half electrode separations, determined by the choice of b (P1 P2) and obeying the relation a ≤ 4b ie (C1C2 ≤ 4 P1P2). The maximum current electrode separation was 500m.

The field set up of the schlumberger electrode configuration shows the movement of the current electrodes, C1C2 that move outwards symmetrically with P1P2, all connected to the ABEM SAS 1000 Terrameter placed in the centre, figure 3.

A compass and an etrex Geographic positioning system (GPS) were used to measure the bearing and coordinates (Latitude and Longitudes) of the sounding spots.

The resistivity measurements were made with the signal averaging system ABEM SAS 1000 Terrameter. This portable microprocessor controlled integrated receiver and transmitter operate by taking automatic consecutive readings and averaging them to provide direct digital resistance readout. Its power supply is by means of rechargeable batteries with current amplitude switch selected from 0.2 to 20 milliamperes and output in the form of a squre wave. Current amplitudes could be increased to 500 milliamperes.

The SAS 1000 Terrameter could be operated in two mode: the resistance and voltage modes. In the resistivity surveying mode, it comprises of a battery powered deep penetration resistance meter with enough current electrode separation of 2km under good surveying conditions. Discriminations circuitory and programming separate direct current (DC) voltages, self potentials and noise from the incoming signals and is calculated automatically and displayed in digital form in kilohms or milliohms. The overall range is from 0.5 milliohms to 1999 kilohms.

A total of 300 soundings were carried out in the study area, figure 4 The major towns covered are Owerri, Okigwe, Orlu, Arochukwu,Ohafia, Abiriba, Item, Mbaise, Afikpo, Uga,Nnewi etc. The iso-resistivity maps show possible variations in resistivity for half current electrode separation of AB/2= 1m, 4m, 15m, 30m, 50m, 80m, 150m, 250m, 300m, see Appendix II (a) to (d). This was obtained by taking the resistivity values of various stations at a particular depth of AB/2(m). Then Appendix II was used to produce maps for each depth as shown in Figure 4.10(a), to Figure 4.10(k). An iso-resistivity map is a qualitative interpretation tool which shows possible variations in resistivity at the given electrode spacing and does not give the true resistivity of a definite geo-electric layer (Mbonu et al., 1991).

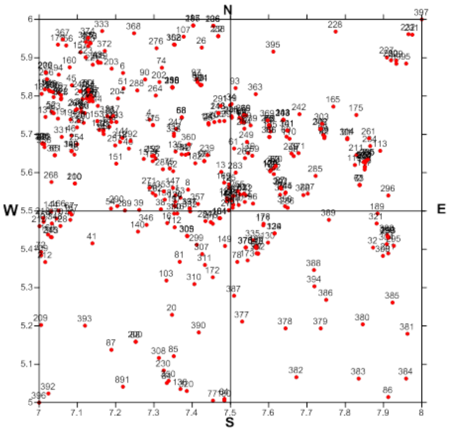


Figure 4. Location of VES Spots within the study area.

4.0 Results and Discussions

The VES data obtained from a total of 397 VES spots within the study area, Figure 4.were analyzed, computer modeled and interpreted to ascertain the nature of the lithologies and their compositions, Table 1 to Table 9. Also the environmental implications as benefits and demerits on the environment are highlighted.

4.1 Results of Iso-Resistivity Measurements across the Study Area at various depths At AB/2 = 1m.

At this depth, the resistivity values range from 20.0Ωm to about 9000 Ωm. The results at AB/2=1m describes the surface of the topsoil resistivity. The areas of high resistivity values include Umuchu, Akowa, and some parts of Orlu, Afikpo are sandy, while some places like lekwesi and some parts of Okigwe, Otampa, Uturu, Item, Umuahia, Bende, Itu, Nkporo, Ohafia, Arochukwu, etc, have low resistivity in the range of 10Ωm to 450Ωm, and they are interpreted as shaly topsoil, Figure 5,

Table 1. Table 1. Result of Isoresistivity of the study area at AB/2 = 1m.

Location	Resistivity Range(Ωm)	color	lithology
Eddah,Akokwa	5000-10,000	Deep Blue	sand
Abak	2000-5000	Green	sand
IKot-Ekpene, Uyo, Afikpo,Nbawsi, Arochukwu,Odukpani,Ohafia	1000-2000	Light blue	Silty sand
Okigwe, Umuahia,Itu,Bende, Otampa,Item,	0-500	Purple	Clay/shale

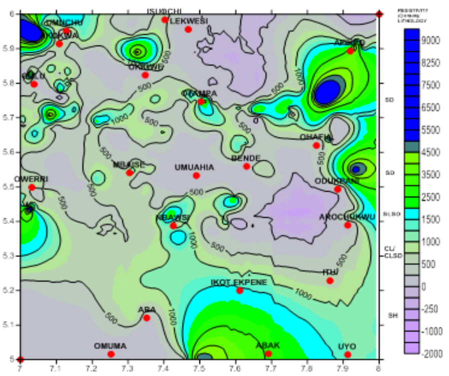


Figure 5. Downward continuations of the study area AB/2=1m.

At AB/2=4m

The horizon of resistivity increased Figure 6. The resistivity values increased from the value at AB/2=1m as observed from the contours spreading 15Ωm to 1500Ωm to larger spread from the initial spots at 1m, Table 2.

Table 2. Result of Isoresistivity of the study Area at AB/2 = 4m.

Location	Resistivity Range(Ωm)	color	lithology
Eddah,	5000-10,000	Deep Blue	sand
Abak,Afikpo,Otampa	2000-5000	Green	sand
IKot-Ekpene,Isuochi,Mbaise,Uyo	1500-200	Light blue	Silty sand
Owerri,odukpsni,Aba,	500-1000	V.Light Blue	Clayey Sand
Arochukwu,Odukpani, Umuahia,Lekwesi, Okigwe, Umuahia, Itu, Bende, Otampa, Item,	10-500	Purple	Clay/shale

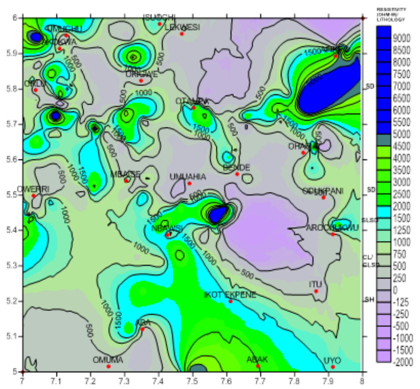


Figure 6. Downward continuations of the study area AB/2=4m.

At AB/2=15m

The trend of increase in resistivity has been established. From the Northwest, it shows a diagonal or a divide extending to Southeast Figure 7. Within the south, a uniform resistivity exist in the range of 500 Ωm at places like Aba, Omuma in southern part, Owerri in the far west, Orlu, Akokwa in the Northwest to 1500 Ωm in places like Umuchu, Mbaise, Ikot-ekpene and Uyo. Abak and some parts of Owerri, Orlu, and Akokwa have values as high as 2500 Ωm to 4500 Ωm. The upper diagonal has fewer places of high resistivities in patches. These places are upper parts of Okigwe, lower parts of Otampa, Arochukwu, Ohafia, Isuochi and Afikpo. The trend of the high resistivity areas in the north is not well defined. It seems to be trending from NW to SE around Isuochi through Okigwe towards Otampa and turns toward the East and then flows through Ohafia. Other places in the Northern area have low resistivities, 10Ωm to 1000Ωm and they are interpreted as Shales and sandyshales. In the central region there is a belt of resistivity in the range of 500Ωm running from Akokwa, Okigwe, through Umuahia trending towards Itu. This may suggest a geologic Formation boundary.

Table 3. Result of Isoresistivity of the study area at AB/2 = 15m

Location	Resistivity Range(Ωm)	color	lithology
Eddah,	5000-10,000	Blue	sand
Abak,Afikpo,	2000-5000	Green	sand
Isuochi, Ikot-Ekpene, Uyo, Umuchu	1500-2000	Light purple	Silty sand
Aba, Owerri, Akokwa	1000-1500	V.Light Blue	Clayey Sand
Itu, Arochukwu, Okigwe ,Lekwesi,Umuahia	10-500	Purple	Clay/shale

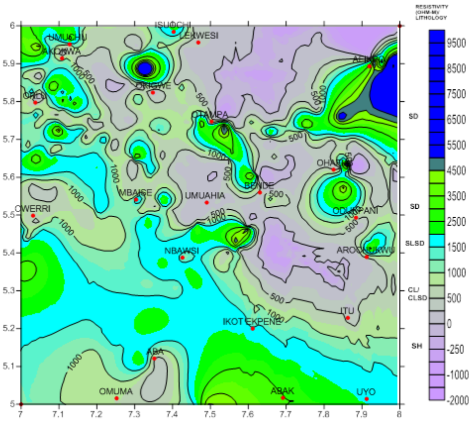


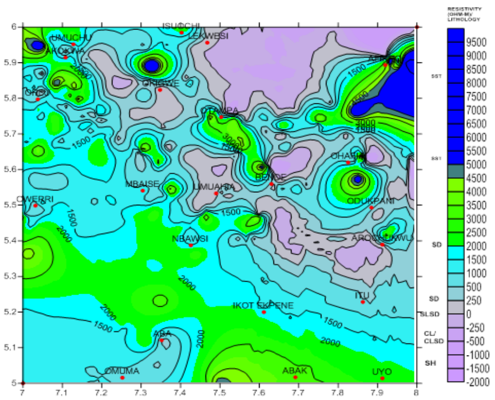
Figure 7. Downward Continuation of the Study Area at AB/2=15m.

At AB/2=30m.

The increase in resistivities is consistent, Table 4. Most parts of the lower divide have high resistivity values in the range of 500 Ωm around Aba, Omuma, Owerri, Orlu to 1500 Ωm at Nbawsi, Owerri, Itu, Mbaise, etc. to 4500 Ωm in the environs of Abak, Owerri, Akokwa, Umuchu, Isuochi, Okigwe, Uyo, etc. In the NE part, Afikpo has high resistivity values, while lekwesi in the North central has low resistivity values, though there are pockets of average values between them. This can be explained with the blue and Green shades of colours in the contour map, Figure 8.

Table 4. Result of Isoresistivity of the study area at AB/2 = 30m.

Location	Resistivity Range(Ωm)	color	lithology
Eddah, Above Okigwe	5000-10,000	Blue	Sand/Sandstone
Abak, Uyo	2000-45000	Green	sand
Ikot-Ekpene, Arochukwu, Nbawsi Mbaise, Afikpo, Abak Aba, Omuma Owerri, Orlu, Otampa, Isuochi, etc	1o00-2000	Light purple	Silty Sand
Arochukwu, Lekwesi, Okigwe Umuahia, Bende.	10-250	Light Blue	Clay/shale



At AB/2=50m.

The high resistivity values in the range of 5000Ωm to 27000Ωm occurred Abak and Omuma, Mbaise and Owerri have a range of resistivities of 1500Ωm to 5000Ωm, Figure 9, Umuchu and Akokwa. These are interpreted as Sands and Sandstone. Uyo, 5. These are Table around interpreted as SiltySands and Sands. While the environs of Umuahia, Arochukwu, Odukpani have resistivities in the range of 200Ωm to 750Ωm. Places like These are described as Shale, Clay, and SiltyClay. Similar resistivities occur at lekwesi, Otampa in the North. Central part.

Table 5. Result of Isoresistivity of the study area at AB/2 = 50m.

Location	**Resistivity Range(Ωm)**	**color**	**lithology**
Umuchu, Akokwa	5000-27,000	Blue	Sand/Sandstone
Uyo, Abak , Omuma, Mbaise and Owerri	1500-405000	Green	SiltySand, Sand
Umuahia, Arochukwu, Odukpani	200-750	Light Blue	Silty/sand,sand
Lekwesi, Otampa	10-250	purple	Clay/shale

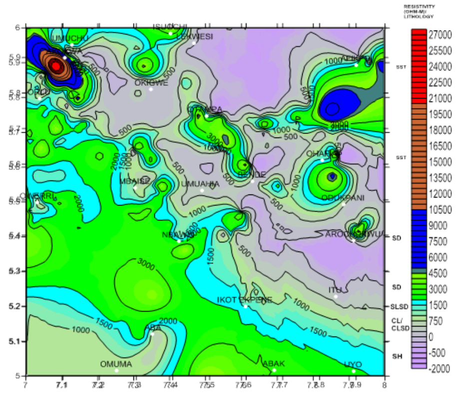


Fig 9. Downward Continuation of the Study Area at AB/2=50m.

At AB/2=80m.

The resistivity range is of 10Ωm to 8000Ωm as shown in Table 6. The thickness of sand units increases with depth, Figure10.

Table 6. Result of isoresistivity of the study area at AB/2 = 80m.

Location	**Resistivity Range(Ωm)**	**color**	**lithology**
Edah, Ikwunano	5000-8000	Blue	Sand/Sandstone
Afikpo	2000-4500	Green	Sand
Aba, Abak, Ikot-Ekpene Nbawsi, Mbaise	1500-2000	Light Blue	Silty sand,
Akokwa, Owerri, Orlu Ohafia	500-1000	Light purple	Sandy clay clayey sand
Arochukwu, Odukpani, Lekwesi	10-500	Purple	Clay/Shale

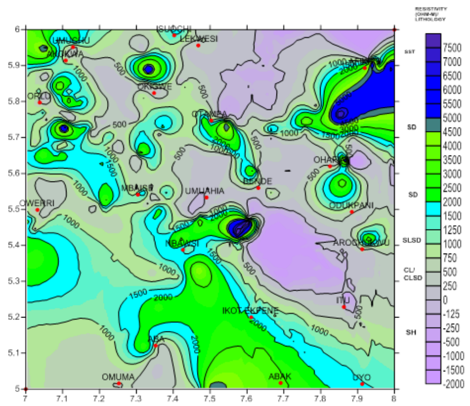


Figure 10. Downward Continuation of the Study Area at AB/2=80m.

At AB/2=150m.

The delineation is very distinct. High resistivities in the range of 1500 Ωm to 10000 Ωm continues at this horizon in the NW and southern areas such as Umuchu, Owerri, Aba, Ohafia and disappears at Okigwe, Lekwesi, Afikpo, Bende, and Arochukwu, Table 7, Figure 11.

Table 7. Result of Isoresistivity of the study area at AB/2 = 150m.

Location	**Resistivity Range(Ωm)**	**color**	**lithology**
Akokwa, Umuchu, Ohafia	8500-10,00	Red	Sand
Ohafia, Isuochi, Umuaka, Etche	5000-8500	Deep blue	Sand
Uyo, Mbaise, Nbawsi	2000-4500	Green	Sand
Aba, Owerri, Ikot-Ekpene	1500-2000	Light blue	Silty sand
Lekwesi, Arochukwu, Afikpo, Okigwe, Bende	5 -250	Purple	Clay/Shale

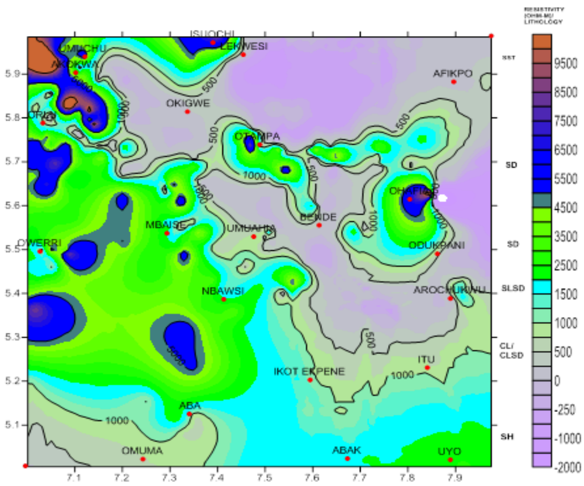


Figure 11. Downward Continuation of the Study Area at AB/2=150m.

At AB/2=300m

The trend becomes more distinct at greater depth and the boundaries clearly delineated Table 8, Figure 12. The resistivities below the NW – SE diagonal are all high ranging from 1500Ωm to >9500Ωm denoting sands The sandstone units are prominent and clearly observed especially around Afikpo, between Aba and Nbawsi, Isuochi, below Owerri.

High resistivities are prominent in the NW-SE direction. Few places have higher resistivity values manifest in some locations at shallower depths. The resistivity ranges from 5000Ωm to 10500Ωm occur mostly in Umuchu and Akokwa Area in the NW, locations below Orlu-Njaba, between Owerri (Ikeduru) and Mbaise in the E-W direction and two locations before Aba. The higher resistivity clusters indicate consolidation of the dominant rock units deposited in these areas. This may be sandstones or coarse sands like gravels. Other places of very high resistivities at greater depth include Ohafia, Ikwuano, Abiriba/Igbere, Afikpo, Ohafia and Isuochi.

Table 8. Result of Isoresistivity of the study area at AB/2 = 300m.

Location	Resistivity Range(Ωm)	color	lithology
Umuchu, AKokwa, Ngwa, Afikpo	8500-9500	Red	Sand/Sandstone
Isuochi, Umuchu Ngwa, Umuaka	5000-8500	Blue	Sand
Aba, Abak, Mbaise, Afikpo, Ohafia	2000-4500	Green	Sand
Ikot-Ekpene, Nbawsi, Aba, Owerri, Uyo	1500-2000	Light blue	Silty sand
Arochukwu, Bende, Odukpani,Okigwe,			

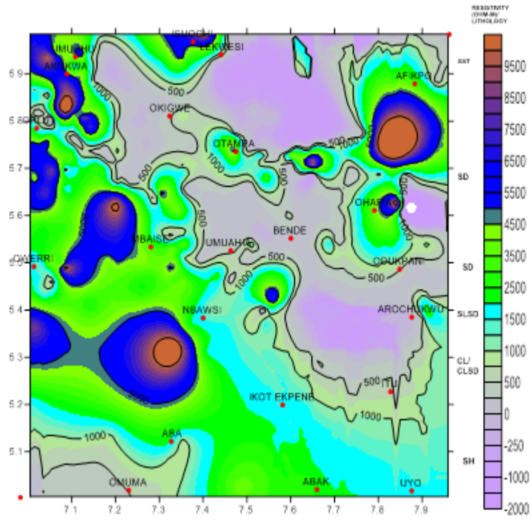


Figure 12. Downward Continuation of the Study Area at AB/2=300m.

Table 9 shows results of isoresistivity of some selected locations within the study area. The values increased from surface to deep horizons around Umuchu/Akokwa, Aba, Owerri, Mbaise, Afikpo and Ohafia. The range of resistivity is 1000Ωm at 1m to 10,000Ωm at 300m. The high subsurface resistivity agrees with the characteristics of Benin Formation. Otampa, Okigwe and Umuahia lie in the boundaries of Mamu, Nsukka, Ajalli, Ameki and Benin Formations. The range of resistivity values in this area is wide, 10Ωm - 500Ωm. The resistivity range around Umuahia is showing that the lithology is mixed up between clay/shale and clay/sand. Umuahia is located within Ogwashi-Asaba Formation which is between the costal plian sands and Ameki Formation. This Formation is characterized by clay, shale and clayey sand units. At Arochukwu the highest resistivity occurred at depths 15-30m with resistivity range of 500Ωm to 1000Ωm and decreased with increase in depth. This shows that Arochukwu is underlain by shale. This conforms to the disappearance of the Ajalli and Nsukka Formations after Arochukwu.

Table 9. Summary of isoresistivity values of some locations at AB/2 = 1m to AB/2 = 300m.

AB/2(m)	Umuchu/Akok	Okigwe	Afikpo	Otampa	Umuahia	Ohafia	Owerri	Mbaise	Aba	Arochukwu
1	1000-2000	10-50	1000-2000	200 - 5500	10-500	0-500	0-500	1000-2000	0-500	0-500
4	500-1000	10- 15	2000-4500	290 – 4000	10-500	10-500	500-1000	500-1000	500-1000	500
15	1500-2000	15 – 45	2000-4500	16 – 170	10-500	500	500	1500-2000	500-1000	500-1000
30	1500-2000	40 – 60	2000-4500	50 – 300	500	1500-2000	500-1000	2000	500-1000	500
50	600 – 1000	50 - 150	2000 - 4000	18 – 400	400 - 50(	1000 - 1500	1100	1500	1200	300
80	500-1000	10-500	2000-4500	13 – 370	250-500	500-1000	500-1000	1000-1500	1000-1500	500
150	2000-8000	100 - 150	250-500	13 – 300	500-100(	5000-9000	1000-1500	1500-4000	1000-1500	250
300	5000-10,000	10 0- 500	200-400	15 – 50	500-100(	5000-10000	1000-2000	2000-4500	1500-4000	10-250

Profile along the North - South direction (Longitude 7.5^{0}E)

Figure13 is a profile that runs through the centre, longitude7.5^{0}E from South to North of the study area. The results of the ten layer interpretation models from each VES location were used for the modeling of the profile. The towns and VES spots located within this profile include: VES 64 at Ukwa, Aba to the centre at VES 149, Umuosu in Ngwa, Umuahia, and Isuikwuato. The description of the lithology can be divided into three segments viz; Ukwa to Ngwa, Umuahia to Nkpa in Bende and Ovim to Amibo in Isuikwuato. In the first segment, from the surface to depth of about 100m the resistivity range is 3000Ωm to 6000Ωm while from120m to 300m the resistivities range from 10,500Ωm to 27,000Ωm. The resistivity of the area is high, increasing from the ground surface to a depth of about 300m, Fig 4.10(a). The lithology is interpreted as sand, coarse or gravely sand to sandstones. The resistivity values between Ngwa and Umuahia varied from 500Ωm to 1500Ωm which reduced with depth. Also, from VES 149 (Umuahia) to VES 351, the resistivity range decreased to between 0.0Ωm to 750Ωm around Nkpa in Bende. These are interpreted as clay/shale to sandyshale. Another set of high resistivity values were observed to have increased again from VES 25 (Ovim), 1500Ωm to VES 208, at Eluama in Isuikwuato, from 3000Ωm to 10500Ωm. This range of resistivity extends to 120m where another range of resistivity, 1000Ωm to 500Ωm extends upto 250m are sands and sandyclays. The Northern part of Otampa is predominantly composed of low resistivity values in the range of 0.01Ωm to 200Ωm. They are interpreted as shales and which are extensive beyond 300m.

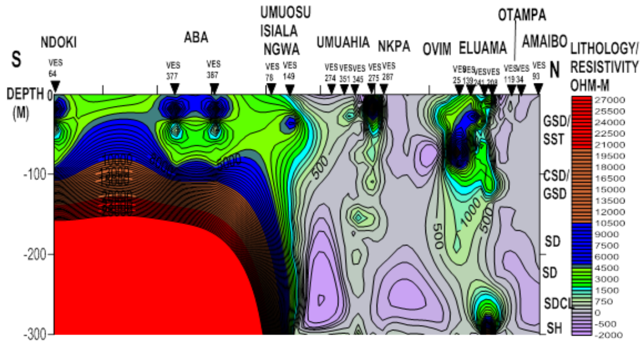


Figure 13. North – South Profile along Longitude 7.5^0 E.

This profile runs from Owerri through Umuahia to Odukpani, Figure 14. It contains about 18 VES spots. Owerri to Umuahia is located in the Western part of the study area while Umuahia to Odukpani is in the Eastern part. Umuahia can be said to be centrally located. The resistivity values in the Eastern part are generally low, in the range of 0.10Ωm to 750Ωm. The areas with very low resistivities less than 5Ωm are around Ubibia Bende. These values occurred especially from 100m to beyond 300m. The resistivity values around Umuahia ranges from 500Ωm to 1500Ωm. The values observed around Umunwanwa dropped to less than 10Ωm from about 65m which continues to great depth of about 200m with resistivity values of about 750Ωm which seems to increase gradually. In Odukpani area, the seemingly high resistivity of 500Ωm to 750Ωm occurred at shallow depth that is less than 50m and beyond this depth, the resistivies are very low. These values are interpreted as sandy clay, sandy shale and shale respectively. The resistivity values in the Western part range from1500 Ω m to 27000 Ω m. The highest resistivity values occurred between Owerri, and Mbaise, and Ikeduru at VES 166, VES 167 and VES 54 locations with resistivity values of 10500Ωm to 27000Ωm at depths of 100m to 200m. They are denoted by brown and red colours, (10500 Ω m, 2100Ωm, 21000 Ω m to 27000 Ω m) as shown in Figure 15 and the next high value is denoted by the blue colour in the range of 4500 Ω m to 10500 Ω m. At greater depths of 200m to 300m the values are denoted by green (1500 Ω m to 4500 Ω m) and light blue or sky-blue colour in the range of 750 Ω m to 1500 Ω m. The geologic interpretations of this range of colours are sands and sandstones, coarse to gravely sands to coarse sands, sands and Sandy clays respectively. The resistivity values decreased with depth from Umuahia towards Bende,. High resistivity values occurred in the shallow depths from surface to less than 100m.

The sand thickness is greatest in the southern and northern areas. Within the limits of investigation, the south has sand thickness of 150m -350m while it is 5m-25m in the North. Sand is good aquifer because its high resistivity is proportional to permeability while clay and shale that have very low resistivities are bad aquifers**.**

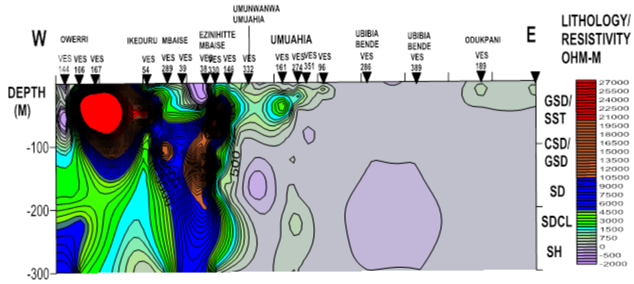


Figure 14. Profile East to West Direction on Latitude 5.5^0 N.

4.2 Discussion

The lithology of the southern and Northwestern and some parts of the Northeast such as Afikpo and Ohafia consist mainly of sands and this is good for civil engineering constructions and prone to erosion. Such places are Ndoki, Aba, Owerri, Etche, Uyo, Ikot-Ekpene, Mbaise, Orlu, Akokwa, Ohafia, Isuochi, Eluama, and Afikpo Figure 4.10(a) to Figure 4.10(i).

The subsurface lithology of Umuahia which is the mid way is mixed with clay/shale and sand rock units with varying low to high resistivities while the resistivity values around Bende are low and interpreted as shale and sandy shale. The environmental implications are that the rock units are mainly shales that are fertile for crop production. Also the drainage pattern is dendritic in which small branches of stream channels branch off to many places and the topography is undulating.

The third portion is from Ovim to Eluama in Isuikwuato Figure 4.10(h), where the resistivity values are high and are interpreted as sands and sandstones respectively. The implications are that this area is prone to Erosion and soil degradation but groundwater is viable. The last part is Amaibo towards Ishiagu. The resistivity values are low and are interpreted as shale. They have similar drainage pattern with the Bende area.

The lithology of the Southern parts consists mainly of sand units while in the Northern parts, especially the Northeastern area where the dominant rock unit is shale. Some places like Acha, Ugwuezi, Item, etc, do not have sand units, except the lateritic topsoils that range from 0.1m to 2.0m.

The profiles of the lithologies showed a stable soil that is viable for groundwater from Ndoki to Ngwa while ground water exploration is difficult from Umuahia to Bende, and Amibo in the East and North respectively, Figure 14 and Figure 15.

The two profiles drawn in the N-S and E-W directions differentiated the lithologies to sand, sandstone, clayey sand, clays and shales. The profiles revealed sand, sandstone units in the Western and southern suggesting areas of good water exploitation but prone to erosion and landslides while the eastern and NE flank is predominately clay and shale which cause road failures but is good for agricultural purpose.

5.0 Conclusion and Recommendations

5.1 Conclusion

The topography in the NE area has low lands except Afikpo. The landforms sediments consist mainly of sands with high resistivities (1000Ωm-27000Ωm) in the NW to SW which extend to SE; all the southern area while NE is made up of low Resistive rock units (0.2Ωm -500Ωm) of clays and shales. The interpreted resistivity values revealed thick sand deposits in the NW, SW, SE and some places such as Ohafia, Afikpo, Alayi in the NE. The ridges from Isuochi through Okigwe, Isuikwuato, Alayi, Ohafia and Arochukwu formed an inverted 'S' shaped cuesta. This cuesta tappers from N-S and disappears after Arochukwu. The drainage pattern is dendritic and no River flows across the cuesta. The other highland runs from Umuchu to Orlu and disappears around Okwelle. This high lands form a divide that is being drained by the major Rivers in the Area, such as Imo River and Njaba River. A geological Formation boundary is established at the central region passing through Akokwa, Okigwe, Umuahia, and Itu at a spread of AB/2 =15m, which is at true depth of 10m in the NW – SE direction, at resistivity, ρ = 500Ωm along these towns. The trend of elevation reduces from north to south. The highest points of the topography are located in the northern part specifically Akokwa and Isuochi while the southern parts are low, slightly few metres above sea level. A good lithological description of the subsurface has been presented which can serve as a guide to hydrogeophysical and hydrogeological information for groundwater in this area. The NW and SW parts are prone to erosions and landslides than the NE region because of the sandy rock units that make up the land forms. The NE regions have low resistivity value and contain fine grained rock units of clays and shale. The geoelectric layers revealed that the subsurface comprises mainly of thick columns of sand, sandy clay, clayey sand, sandstone, silt, from ground surface in the north western area while the rock units in the northeastern area are sandy shale, shaly sand and shales. The implications of these are that there may be cases of road failures and collapse of high rise buildings and structures. Also, this indicates high vulnerability of the rock units to pollution in the NW to SW than in the NE.

5.2 Recommendations

The erosion and landslide prone areas of NW and SW should be checked and monitored constantly in order to avoid the degradation and destruction of the landforms. The northeastern and some central regions comprising Lokpanta, Lokpaukwu, Afikpo, Item, Edda, Arochukwu , Bende and Umuahia are underlain predominantly by shale should have well designed regional water scheme from the areas that have reasonable thick sand columns in order to provide portable water for the settlers Also, large scale agricultural cultivation projects should be established in the areas with low resistivity values corresponding to clays and shale from the surface. Groundwater exploitation in the NW and especially the SW to Southern parts should be controlled to check groundwater pollution because of the high permeability of the rock units.

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