Integration of Electrical Resistivity and Induced Polarization for Subsurface Imaging around Ihe Pond, Nsukka, Anambra Basin, Nigeria.

Philip Ighovoyinvwin Oduduru, M.Sc.[1] and Luke I. Mamah, Ph.D.[2]

[1]Material and Energy Technology Department, Projects Development Institute (PRODA), Emene, Enugu, Nigeria.
[2]Geology Department, University of Nigeria, Nsukka, Enugu State, Nigeria.

E-mail: Oduduru@yahoo.com*
Telephone: +2348054744866

ABSTRACT

Electrical Resistivity (ER) and Induced Polarization (IP) were used to study the subsurface geology and structures around Ihe Pond, Nsukka in Anambra basin, Nigeria. Three profiles of max spread lengths of 500, 400, and 500m were conducted around the pond. The data were acquired simultaneously for both methods. Four faults designated Apo 1, 2, 3, and 4 with color code blue, red, green and black and their zones were mapped. The faults were located at points 180, 224, 265, and 320m on ER line one and two. Three litho units of sandstone and little limestone were observed on the ER and IP models. The ER values from the three profiles ranged from 136 - 21559Ωm and the IP values from the three profiles ranging from -81.0 to 240Ms. The faults zone acts as water pathway to the pond, from the hill top. Inverse chargeability models established the faults zones, as large gradients of chargeability. Correlation of strata to known formation depicts the presence of consolidated coarse to medium sandstones, while known fault was correlated to Apo 3 using coordinates readings. Analyzed samples of water from the pond showed low salinity and sulfides. Soil samples were also analyzed to compliment the geology, and the result shows that Al_2O, SiO_2, Fe_2O_3, ZnO and Na_2O_3 are relatively low and are in conformity with characteristics of laterite.

(Keywords: electrical resistivity, induced polarization, subsurface imaging, pond)

INTRODUCTION

Water is very important for domestic and industrial usage. While fresh water is renewable resource, the world supply of clean fresh water is steadily decreasing because of the high cost of geophysical prospecting and sinking of bore-holes. Many communities especially in rural settlements suffer from lack of water, to this effect the search for source of water led to the discovering of Ihe Pond, Nsukka, Nsukka Local Government Area of Enugu State, in Anambra Basin, Nigeria.

Ihe pond retains water even at the peak of the dry season; hence the main objective of this research is to decipher the subsurface imaging, by delineating the geologic structures and strata responsible for the water in the pond; identify strata on the basis of resistivity/chargeability; map out faults around the pond; correlate strata to known formations and faults to known faults; and to determine the origin of the pond.

Electrical Resistivity (ER) and Induced Polarization (IP) surveys were conducted simultaneously around Ihe Pond, Nsukka, in Nsukka Local Government Area of Enugu State (Figure 1), to study the subsurface imaging of the prospective area. ER survey was used to determine the subsurface resistivity distribution, by introducing artificial generated current DC through the rock layers mainly by the passage of ions in pore waters of the rocks (electrolytic process) (Kenrey and Brooks, 1991).

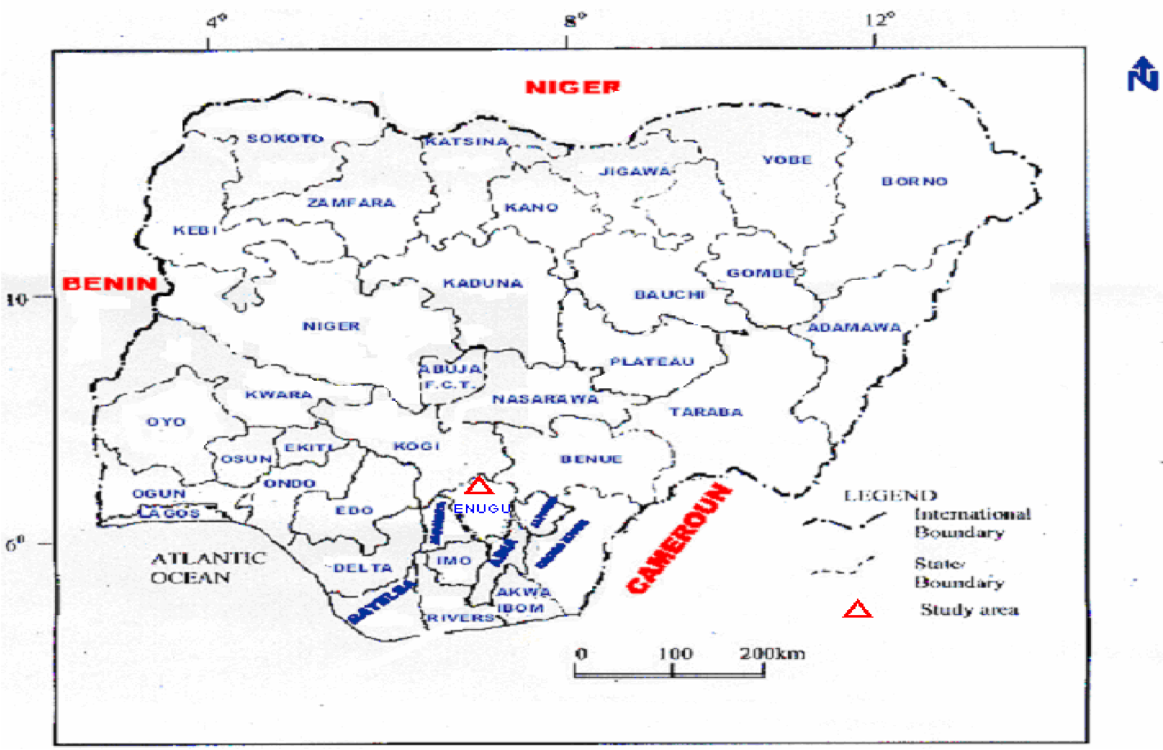

Figure 1: Map of Nigeria Showing the Location of Study Area.

Over the past 30 years it has been demonstrated through field applications that the IP technique has the potential to distinguish between sediments of different lithological composition (Slater and Lesmes, 2002a; Kemna et al., 2004) and of different groundwater salinity (Seara and Granda, 1987).

More recently, it has been used for environmental surveys and mapping of geological faults. The distribution of potential can be related to ground resistivities and their distribution for a horizontally stratified ground and homogeneous masses separated by vertical planes (e.g., a vertical fault with a large throw or a vertical dike).

Resistivity surveys are useful in detecting depths of bedrock surfaces. In coarse, granular soils, the groundwater surface is generally marked by an abrupt change in water saturation and thus by a change of resistivity. In fine-grained soils, however, there may be no such resistivity change coinciding with a piezometric surface.

IP finds application in the study of clay minerals. It has been used, in the fields of hydrogeology (Vacquier et al., 1957; Marshall and Madden, 1959), oil and gas field exploration (Sternberg and Oehler, 1990), and in environmental studies, such as mapping of polluted land areas (Towel et al., 1985). The dependency of polarizability of rocks/soils upon their lithological composition and hydrogeological properties favors the application of the IP method for hydrogeological (groundwater) and engineering geologic investigations.

Water naturally accumulates a variety of dissolved solids or salts as it passes through soils and rocks units way to the reservoir/sea. Since the pond is a source of water to the community during the dry season. A sample of water from the Ihe pond was analyzed to ascertain the degree of salinity, total dissolved solids, (TDS) and sulfides concentration for the safety of the consumers.

MATERIALS AND METHODS

Study Location

The study area around **Ihe pond**, Nsukka Town, in Nsukka Local Government Area of Enugu State, Anambra Basin, Nigeria, is bounded by latitudes 6^0 49^I 50.1^{II} N - , 6^0 51^I 20.4^{II} N and longitutdes 7^0 21^I 55^{II} E, - 70 22^I 33.9^{II} E, it has an area coverage of about $1.4km^2$. It is accessible by motorable roads and foot-path, especially those created by the villagers to fetch water from the pond. The base map of the study area, showing the accessibility to the study location is shown in Figure 2.

Geology

The study area is made up of three major geologic formations; the Mamu, Ajali and Nsukka formations, respectively. The Mamu formation consists of fine-medium grained, white to grey sandstones, shaly sandstones, sandy shales, grey mudstones, shales, and coal seams. The thickness is about 450m and it conformably underlies the Ajali formation.

The Ajali formation, consist of thick friable, poorly sorted sandstones, typically white in color but sometimes iron-stained. The thickness averages 300 m and is often overlain by considerable thickness of red earth, which consists of red, earthy sands, formed by the weathering and ferruginisation of the formation.

The Nsukka formation, previously known as the upper coal measures (Reyment, 1965), lies conformably on the Ajali sandstone. It consists of an alternating succession of sandstone, dark shale and sandy shale, with thin coal seams at various horizons. Eroded remnants of this formation constitute outliers and its thickness averages 250 m (Chukwudi et al, 2010).

Figure 2: Base Map of the Study Area, showing Accessibility and the three Profiles.

Methods

The geophysical survey around Ihe Pond has been studied based on the use of Electrical Resistivity (ER) and Induced Polarization (IP). Three ER/IP measurements were conducted around the Pond in order to identify strata and to delineate geologic structures responsible for the origin of the Pond. Geophysical data were acquired using SAS/1000 DC Terrameter. The Terrameter SAS/1000 was employed to conduct resistivity survey. SAS stands for Signal Averaging Systems, a method whereby consecutive readings are taken automatically and the results are averaged continuously. The SAS/1000 can operate in different modes (resistivity, self-potential, and induced polarization). A useful facility of the SAS/1000 is its ability to measure in four channels simultaneously. This implies that it can performed measurement up to four times faster.

Horizontal profiling using Wenner Array configuration survey, which is the simplest in terms of geometry of electrodes placement was employed. Apparent resistivity and chargeability measurements were inverted using 2-D computer software (RESDINV). We used an inversion method applying 2D inversion routine by Loke and Barker (1996), which is a Gause-Newton least square method based on the finite-difference model of the subsurface.

Three profiles of 500, 400, and 500m spread lengths were conducted around the Pond. The processed resistivity and chargeability data were interpreted visually from the automatically generated results by mapping out the correlated visible fault and strata. This was guided by the principles of fault and resistivity/chargeability of the rock units. Strata were correlated to known formation based on lithology and ER/IP values. Fault was correlated to known fault using co-ordinates readings.

In order to assured the safety of the water for the consumers, a sample of water from the Pond was analyzed for salinity (TDS) and sulfides concentration. Soil samples around the Pond were also analyzed for oxides composition to compliment the geology. The water and oxides composition analysis results are presented in Table 4.

Table 1: Chargeability of Different Minerals (Telford et al., 1990)

Mineral	Chargeability (ms)
Pyrite	13.4
Chalcocite	13.2
Copper	12.3
Graphite	11.2
Chalcopyrite	9.4
Bornite	6.3
Galena	3.7
Magnetite	2.2
Malachite	0.2
Hematite	0.0

Table 2: Chargeability of Minerals and Rocks (Telford et al., 1990)

Material	Chargeability (ms)
20% sulfides	2,000 – 3,000
8 – 20% sulfides	1,000 – 2,000
2 – 8% sulfides	500 – 1,000
Volcanic tuffs	300 – 800
Sandstone, siltstone	100 – 500
Dense volcanic rocks	100 – 500
Shale	50 – 100
Granite, grandodiorite	10 – 50
Limestone, dolomite	10 – 20

Table 3: Chargeability of Various Materials (after Telford et al., 1990)

Material	Chargeability (ms)
Ground water	0
Alluvium	1 – 4
Gravels	3 – 9
Precambrian volcanics	8 – 20
Precambrian gneisses	6 – 30
Schists	5 – 20
Sandstones	3 – 12
Argillites	3 – 10
Quartzites	5 – 12

Table 4: Water and Soil Analysis Results.

PARAMETER	VALUES
Al_2O_3 (%)	15.49
SiO_2 (%)	35.85
ZnO (%)	0.16
Fe_2O_3 (%)	27.34
Na_2O_3 (%)	2.01
Loss on ignition (%)	15.11
Salinity (TDS) (mg/L)	60.0
Sulfides (mg/L)	0.54

RESULTS AND DISCUSSION

Faults, Fault Zones and Strata

Inverse resistivity model of Profile 1: Figure 4 shows that three faults were delineated as Apo 1, 2 and 3 with color codes blue, red, and green, respectively. Apo 1, 2, and 3 are located at points 224, 265, and 330m on profile one. The orientation of the three faults are northwest to southeast, Figure 3. The blue colored area is dominated with saturated laterites, which is the fault zone, with low resistivity, ranging from 54 - 273Ωm. A stratum that is saturated with water is a good indicator of hydrogeological characteristics. The light green with resistivity range between 273 - 613Ωm is fine grain sandstone. The dark green, light yellow, solid yellow and brown colors with resistivity values ranging from 613 - 3091Ωm are medium grain sandstone. While the orange and the brick red colors with resistivity values o between 6943 - 15595Ωm are consolidated coarse sandstone.

Inverse Chargeability Model of Profile 1: Figure 5, four faults zones were delineated as Apo 1, 2, 3, and 4 fault zones. Apo 4 fault zone was not visible in Figure 4, but is visible in Figure 5 and named as Apo 4 with black color code. The dark and pale blue colored strata with chargeability values ranging from 3–12Ms are sandstone materials, according to Telford et al. (1990) Table 3. The faults zones that have light green, dark green to reddish brown colors with the chargeability values between 100 – 500Ms, are sandstone and siltstone (Telford et al., 1990, Table 2). Although the chargeability did not increase to 500Ms is due to low salinity, according to (Barker, 1990) chargeability will increase as salinity of the groundwater increases up to 500mg/L.

Inverse Resistivity Model of Line 2: Figure 6, captured all the four faults as Apo 1, 2, 3, and 4, with their respective fault locations at points 170, 205, 275, and 300m on Profile 2. Apo 1, 2, and 3 extended from Profile 1, while Apo 4 cuts across Profile 2 only with no extension to either Profile 3 or Profile 1.

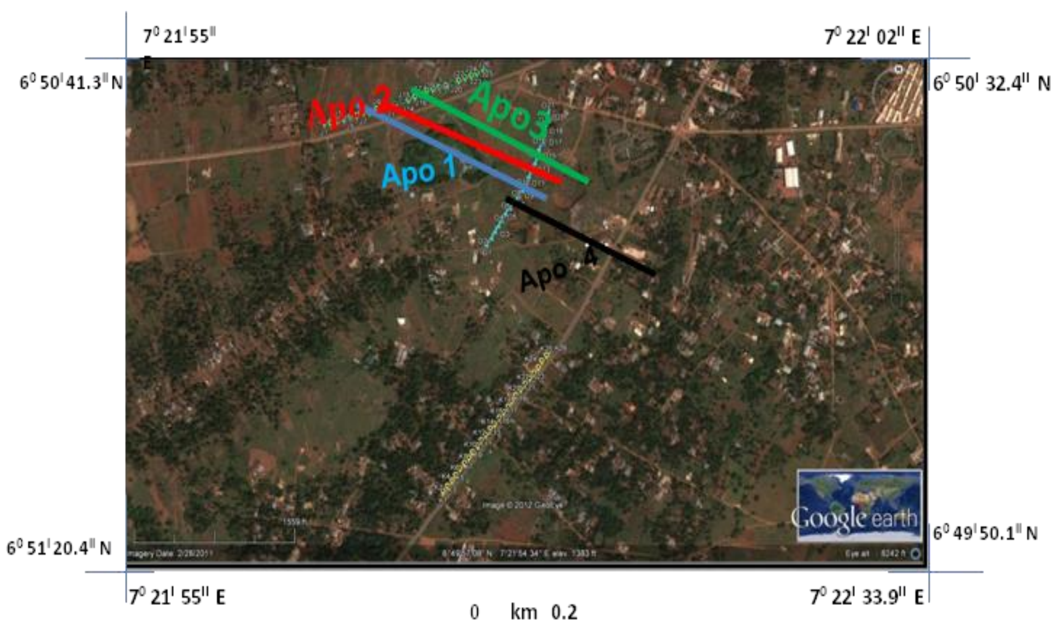

Figure 3: Base–Map showing the Interpreted Faults across the Two Profiles.

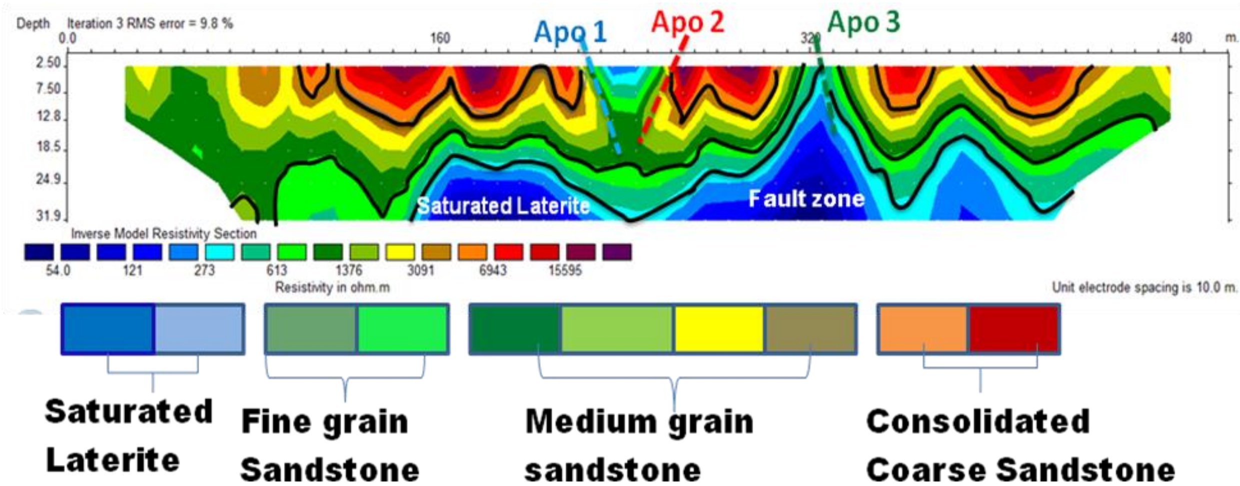

Figure 4: Inverse Resistivity Model of Line 1.

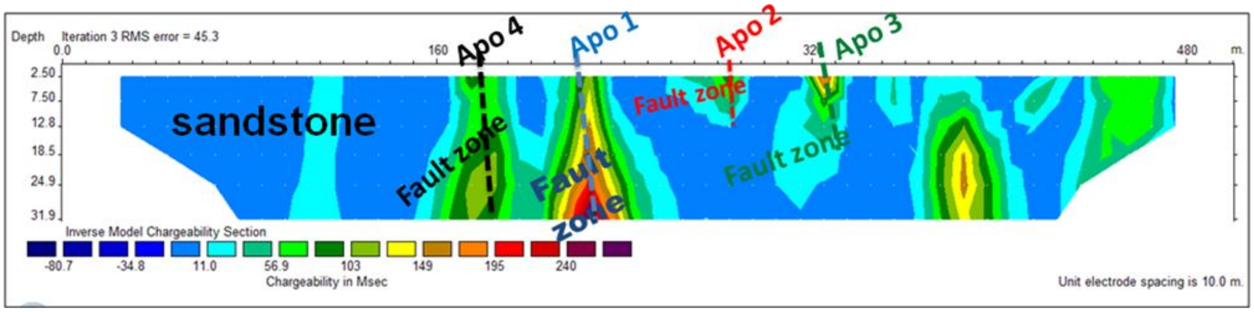

Figure 5: Inverse Chargeability Model of Line 1.

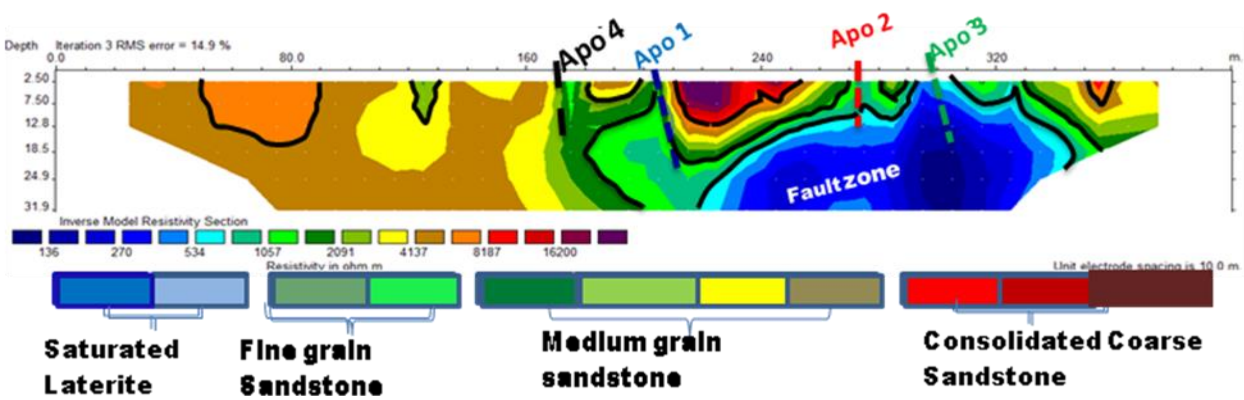

Figure 6: Inverse Resistivity Model of Line 2.

The orientation of the faults are northwest to southeast (Figure 3). A big fault zone with low resistivity values ranging from 136 - 534Ωm was delineated at the based of Apo 2 and Apo 3. The identified strata are saturated laterite, fine grain sandstone, medium grain sandstone and consolidated coarse sandstone, respectively. Saturated laterite, which is the fault zones, has resistivity values ranges from 136 - 534Ωm, fine grain sandstone has resistivity values ranging from 534 - 1057Ωm, medium grain sandstone has 1057 - 4137Ωm while the consolidated coarse sandstone has the resistivity values ranging from 4137 - 16200Ωm.

Inverse Chargeability Model of Line 2: Figure 7, the only fault zone mapped out is Apo 2 fault zone. The area covered by this profile is dominated by sandstone (light green color) with chargeability values of 3 – 12Ms, table 3. There are some clay intercalations; according to (Arstedemou et al, 2000) clay has chargeability value of less than 10Ms. The dark green color with chargeability value ranging from 10 – 20Ms is limestone (Table 2) on chargeability of different minerals.

Inverse Resistivity Model of Line 3: Figure 8 shows a good picture and indicating the layers strata as resistivity increases with depth. In this profile, no fault is visible, as there was no discontinuity in the geological unit. The strata were mapped out with regard to their resistivity values. The first two grouped layers (dark blue to light blue) between the depths of 5 – 17m with resistivity values ranging from 1043 - 2478Ωm is fine grain sandstone. The four grouped layers between the depths of 17 – 35m with resistivity values ranging from 2478 - 9075Ωm is medium grain sandstone. The three grouped layers between 35 – 37m depth, with resistivity values ranging from 9075 - 21559Ωm is consolidated coarse sandstone.

Inverse Chargeability Model of Profile 3: Figure 9 is dominated with alluvium, sand deposited by running water, with chargeability values ranging from 1 – 4Ms (Table 3).

Correlation of Strata to Known Formation

Figure 11, shows a correlation of subsurface strata to known formation to enhance the knowledge of the Formation layers and to compliment the interpretation works. The study outcrop Figure 10 is 3m deep.

Coarse sandstone and medium grain sandstone of the known formation were depicted in the resistivity model (Figure 4). The fault plane is filled with sandstone, that ease percolation.

Correlation of Fault to Known Fault

Amongst the delineated faults, the known fault with co-ordinates reading of Latitude 6^0 50^I 14.2^{II}(N), Longitude 7^0 21^I 43.3^{II}(E) and 463m Elevation is correlated to Apo 3 fault, having the same co-ordinates readings at point 320m, Figure 11.

The upthrown and downthrown thickness are 0.4 and 0.46m, respectively, and are made up of large size laterites. Overburden thickness comprises of coarse to medium size laterite of 0.43 overlain upthrown and 2.04m overburden thickness overlain the downthrown of the fault. The fault is known as normal fault.

Water Sampling

The result shows that Salinity (TDS) of the water from the Ihe Pond, is 60mg/L. This result is very much lower, compare to drinking water which has a recommended maximum TDS concentration of 500mg/L (US Geological survey, 1985), indicating that the water is fresh. The water from Ihe Pond is fresh because TDS value is less than 1,500mg/L, (Techobanogious and Schroeder. 1985).

Since the salinity was low, the chargeability values in all the inverse chargeability model were also lower than 250Ms Figures 5, 7, and 9, which according to (Barker, 1990) chargeability will increase as salinity of the groundwater increases up to 500mg/L. The result also shows that, the value of sulfides is 0.54mg/L. That is 0.00054%, is an indication that the percentage of sulfides presence is very low or negligible, according to Telford et al. (1990, Table 2) (2 - 8%) of sulfides produces chargeability value ranging from 500 – 1,000Ms, 8 – 20% of sulfides produces chargeability values ranging from 1,000 – 2,000Ms and 20% of sulfides and above, have chargeability value ranging from 2,000 – 3,000Ms.

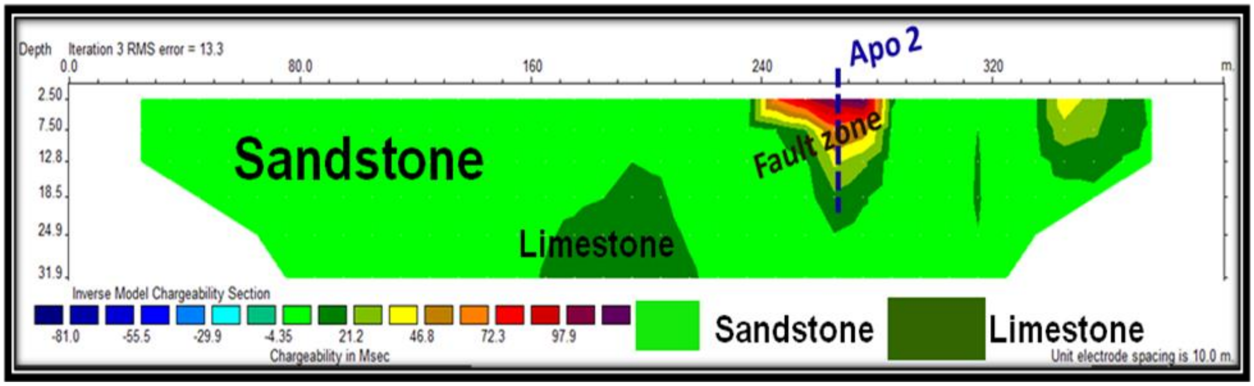

Figure 7: Inverse Chargeability Model of Line 2.

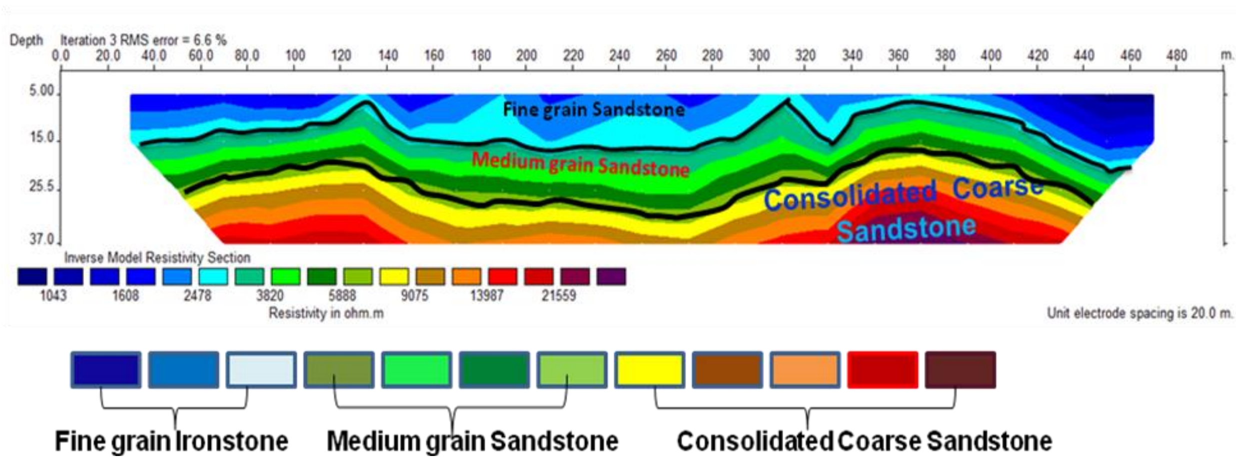

Figure 8: Inverse Resistivity Model of Line 3.

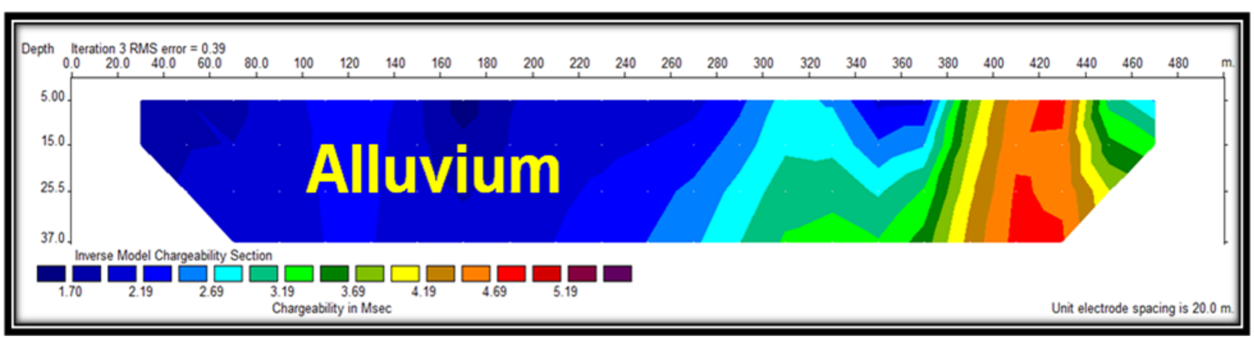

Figure 9: Inverse Chargeability Model of Line 3.

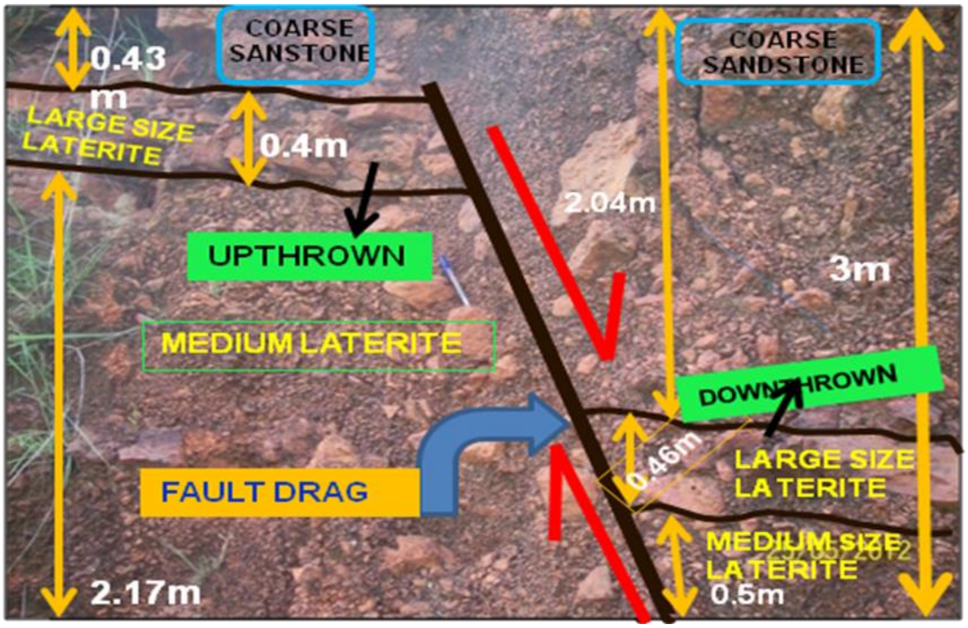

Figure 10: Study Outcrop Around Ihe Pond in Nsukka Formation.

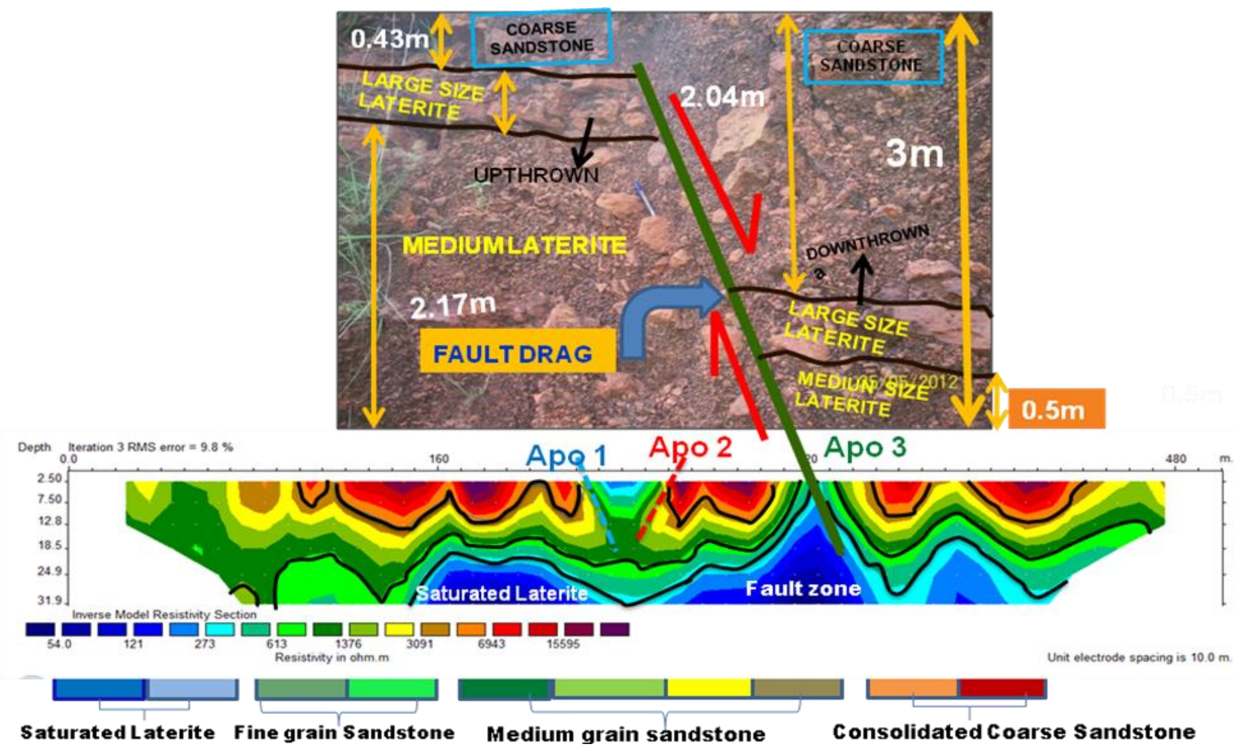

Figure 11: Correlation of Strata to known Formation.

The result is in conformity with the low chargeability values in all the three inverse chargeability models

Soil Sampling

The soil sample collected from the prospect area was taken to Projects Development Institute (PRODA), Enugu, Nigeria, for laboratory analysis to ascertain the percentage of oxides present. The oxides results are tabulated in Table 4. The result shows that Al_2O_3, SiO_2, Fe_2O_3, ZnO, and Na_2O_3 are relatively low and are in conformity with characteristics of laterite.

CONCLUSION

Three profiles were used to evaluate the subsurface imaging around Ihe pond. The survey conducted penetrated the formation to a depth of 37m. Four faults and their faults zones were identified and mapped out as Apo 1, 2, 3, and 4, with color codes blue, red, green, and black and their respective fault zones. The faults were located at points 224, 265, 330,170, 205, 275, and 295m (Figures 4 and 6). Apo 1, 2, and 3 extends from line 1 to 2, while Apo 4 cuts across line 2 only. The orientation of the faults are Northwest to Southeast (Figure 3). The faults act as water pathways from the hill top to the pond and the sandstone within the fault zone ease water percolation, which is the origin of the pond.

Three major strata were identified as fine grain sandstone, medium grain sandstone and consolidated coarse sandstone, according to their ER/IP values. Saturated stratum and limestone mineral were also delineated (Figures 4, 6, and 7). Correlation of strata to known formation establishes the true Nsukka Formation, which revealed exactly the true subsurface imaging of the studied outcrop (Figures 10 and 11). Known fault was correlated to Apo 3 fault.

The 60mg/L (TDS), water-sampling result shows that Ihe pond water is fresh. Soil sampling results shows that Al_2O_3, SiO_2, Fe_2O_3, ZnO, and Na_2O_3 are relatively low and are in conformity with characteristics of laterite.

The Integration of Electrical Resistivity and Induced Polarization Geophysical methods removes some of the ambiguities and uncertainties present with the individual use of the methods and have helped in the precise description of the subsurface and enhanced the models interpretation. It has also shown that integration of ER and IP methods are powerful and effective diagnosis tool to delineate geologic structures and for identification of strata.

REFERENCES

1. Abdullah, N.K., I.B. Osazuwa, and P.O. Sule. 2011. "Application of Integrated Geophysical Techniques in the Investigation of Groundwater Contaminated: A Case Study of Municipal Solid Waste Leachate". *Ozean Journal of Applied Sciences*. 4(1):11 – 29.

2. Adeleye, D.R. 1975. "Nigeria Late Cretaceous Stratigraphy and Paleogeography". *A A P G Bnll*. 59:2302 – 2313.

3. Agagu, K.O., E.A. Fayose, and S.W. Petters. 1985. " Stratigraphy and Sedimentation in the Santonian Anambra basin of Eastern Nigeria". *Journal African Earth Sci*. 5(2):177 – 185.

4. Akudinobi, B.E.B. and B.C.E. Egboka. 1996. "Aspects of Hydrogeological Studies of the Escarpment Regions of Southeastern Nigeria". *Water Resources J. NAH.* 7(1-2):12-25.

5. Amajor, L.C.198."Sedimentary Facies Analysis of the Ajali Sandstone (Upper Cretaceous) Southern Bennue Trough, Nigeria". *J. Min. Geol.* 21(1- 2): 71 – 77.

6. Amogu, D.K. and A.C. Ekwe. 2010. "Kinematics of Faults and Joints at Enugu Area of the Anambra Basin". *Journal of Geology and Mining Research.* 2(5):101-113.

7. Aristedemuo, E. and A.Thomas-Betts. 2000. "DC Resistivity and Induced Polarization Investigations at a Waste Disposal Site and its Environments". *J. Applied Geophysics*. 44: 275 – 302.

8. Barker, R.D. 1990. "Investigation of Ground Water Salinity by Geophysical Methods". In: Ward, S.H. (ed.). *Geotechnical and Environmental Geophysics*. Society of Exploration Geophysicists: Tulsa, OK. 2:201 – 211.

9. Chukwudi, C.E. and Z.U. Gabriel. 2010. "Geoelectrical Sounding for Estimating Groundwater Potential in Nsukka LGA, Enugu State, Nigeria". *Int'l. Journal of Physical Sciences*. 5(5):415 – 420.

10. Kearey, P. and M. Brooks. 1991. *An Introduction to Geophysical Exploration*. Blackwell Scientific Publications: New York, NY.

11. Keller, G.V., and F.C. Frischknecht. 1966. *Electrical Methods in Geophysical Prospecting*. Pergamon Press: Oxford, UK.

12. Kisa, M., S. Lee, N. Dimitrios, B. Andrew., D. Frederick, and W. Andy. 2011. "Use of Time-Domain Induced Polarization for Lithology Identification: A Case Study from the Hanford 300-Area". Symposium on the Application of Geophysics to Engineering and Environmental Problem. 24: 142

13. Knipe, R.J.,Q. J. Fisher, G. Jones., M.R. Clennell, A.B. Farmer, A. Harrison, and E.A. White. 1997. "Fault Seal Analysis Successful Methodologies, Application and Future Directions". In: P. Moller-Pederson and A.G. Koesther (eds.). *Hydrocarbon Seals*. NPF Special publication. 7:15-38.

14. Loke, M.H., and R.D. Barker. 1996. "Rapid Least-Squares Inversion of Apparent Resistivity Pseudosections using a Quasi-Newton Method". *Geophysical Prospecting*. 44:131 – 152.

15. Marshall, D.J. and T.R. Madden. 1959. "Induced Polarisation, A Study of its Causes". *Geophysics*. 24:790–816.

16. Reyment, R.A. 1965. In: *Aspect of the Geology of Nigeria*. University of Ibadan Press: Ibadan, Nigeria. 145.

17. Seara, J.L., and A. Granda. 1987." Interpretation of IP Time-Domain/Resistivity Sounding for Delineating Sea-Water Intrusions in Some Coastal Areas of the Northeast of Spain". *Geoexploration*. 24:153-161.

18. Seigel, H.O. 1959a. "A Theory of Induced Polarization Effects for Step-Function Excitation". In: J.R. Wait (ed.) *Overvoltage Research and Geophysical Applications*. 4 – 21. Pergamon Press: London, UK.

19. Scott, W.J. 1971. "Phase Angle Measurements in the IP Method of Geophysical Prospecting". Ph.D. Thesis. McGill University: Montreal, Canada.

20. Slater, L.D., and D. Lesmes. 2002a. "IP Interpretation in Environmental Investigations". *Geophysics*. 67: 77 – 68

21. Sternberg, B.K. and D.Z. Oehler. 1990. "Induced Polarisation in Hydrocarbon Surveys: Arkoma Basin Case Histories". In: Ward, S.H. (ed.) *Induced Polarisation: Applications and Case Histories*. Society of Exploration Geophysicists: Tulsa, OK. 4.

22. Tattam, C.M. 1944. "A Review of Nigeria Stratigraphy. Report of Geological Society of Nigeria (1943)". 24 – 46.

23. Techobanogious, G. and E.D. Schroeder. 1985. *Water Quality*. Addison – Wesley: Reading. MA.

24. Telford, W.M., L.P. Geldert, R.E. Sheriff, and D.A. Keys. 1990. *Applied Geophysics*. Cambridge University Press: Cambridge, UK.

25. Telford, W.M., L.P. Geldert, R.E. Sheriff. and D.A. Keys. 1976. *Applied Geophysics*. Cambridge University Press: Cambridge, UK.

26. Towel, J.N., R.G. Anderson, W.H. Pelton, G.R. Olhoeft, and D. LaBrecque. 1985. "Direct Detection of Hydrocarbon Contaminants using Induced Polarisation Method". SEG Meeting. 145-147.

27. Uma, K.O. 2003." Hydrogeology of the Perched Aquifer Systems in the Hilly Terrains of Nsukka Town, Enugu State, Nigeria". *Water Resources J. NAH*. 14:85 - 92.

28. United States Geological Survey (USGS). 1985. USGS: Washington, DC.

29. Vacquier, V., C.R. Holmes, P.R. Kintzinger. and M. Lavergne. 1957. "Prospecting for Groundwater by Induced Electrical Polarisation". *Geophysics*. 23:660–687.

30. Zonge, K.L. 1972. "Electrical Properties of Rocks as Applied to Geophysical Prospecting". Ph.D. Dissertation. University of Arizona: Tucson, AZ.

31. Zonge, K.L. and J.C. Wynn. 1975. "Recent Advances and Applications in Complex Resistivity Measurements". *Geophysics*. 40: 851.

ABOUT THE AUTHORS

Philip Ighovoyinvwin Oduduru, attended Federal University of Technology, Akure, Ondo State, Nigeria, where he obtained a Bachelor of Technology degree in Applied Geophysics. He obtained his Masters of Science Degree in Applied Geophysics from the University of Nigeria, Nsukka, Enugu State Nigeria. He works with the Projects Development Institute (PRODA), Enugu State, Nigeria as a research Officer. His areas of interest include seismic interpretation and well log evaluation, materials and energy research (coal carbonization), and resistivity and induced polarization evaluations.

Dr. Luke I. Mamah, is a graduate in Geology from the University of Nigeria (1975) and subsequently a graduate of Geophysical Engineering from Colorado School of Mines in

Golden, CO (1979). He also obtained a Ph.D. in Geophysics from the same school in in 1981. He has been teaching at the University of Nigeria since 1982 with research interests in applied geophysics and structural geology. He is a member of American Geophysical Union and Nigeria Mining and Geosciences Society.

SUGGESTED CITATION

Oduduru, P.I. and L.I. Mamah. 2014. "Integration of Electrical Resistivity and Induced Polarization for Subsurface Imaging around Ihe Pond, Nsukka, Anambra Basin, Nigeria". *Pacific Journal of Science and Technology*. 15(1):306-317.

Pacific Journal of Science and Technology