*International Research Journal of Environment Sciences*________________________________ ISSN 2319–1414
Vol. **4(2),** 1-6, February **(2015)** *Int. Res. J. Environment Sci.*

Geophysical Delineation of Subsurface Fracture Associated with Okposi-Uburu Salt Lake Southeastern, Nigeria

Okoyeh E.I.[1], Akpan A.E.[2], Egboka B.C.E.[1]*, Okolo M.C.[1] and Okeke H.C.[1]
[1]Department of Geological Sciences, Nnamdi Azikiwe University Awka, NIGERIA
[2]Physics Department University of Calabar, NIGERIA

Available online at: www.isca.in, www.isca.me
Received 21th October 2014, revised 5th December 2014, accepted 8th January 2015

Abstract

10 vertical electrical sounding (VES) and 2 electrical resistivity tomography (ERT) were conducted around the vicinity of Okposi and Uburu salt lakes to delineate the depth of salty groundwater and the fracture zone that serve as conduit through which the salt lakes are recharged. 4 to 5 geoelectric layers were delineated from the computer interpreted VES data. The resistivity of the first to the fifth layer range from 82.3 to 397.3 Ωm, 1.7 to 97.9 Ωm, 17.3 to 244.1 Ωm, 5.9 to 71.9 Ωm, 42.7 to 95.8 Ωm and were interpreted as shalely sand, fractured shale, shalestone, fracture shale, shalestone respectively. The thickness of the first layer is approximately 3m while the second layer ranges from 5 m to 25 m. An anomalous low resistivity region was observed from the ERT image at a depth of 5 m confirming the VES results. The low resistivity unit interpreted as fractured shale is an indication of salt water reservoir. The fractured shale also forms significant conduits at the base of the lakes for recharge.

Keywords: salt Lake, VES, ERT, geoelectric layers, groundwater.

Introduction

Water is vital for sustainable development and plays a major role in the improvement of standard of living of people. Water although abundant in the some areas remains a scare commodity in terms of quality. Evaluation of the physicochemical parameters of the salt lakes (Okposi and Uburu) revealed high level salinity with Na^+ as the dominant cation and Cl^- as the dominant anion[1]. The study area is located within the lower Benue trough of southeastern, Nigeria between latitude $6^0$00'N to $6^0$10'N and longitude $7^0$42' E to $7^0$51'E figure-1. The occurrence of the brines in this region is associated with the fracture system within the bedrock[2]. Application of geoelectrial resistivity method in structural investigation and aquifer delineation has been extensively discussed in literatures[3-6]. Electrical resistivity tomography (ERT) technique a comparatively recent field procedure in electrical resistivity technique has been found to be a useful technique in high resolution lithological mapping and characterisation[7-9], hydrological monitoring and characterisation[10,11] and environmental and engineering investigations[12-17]. Geophysical method involving (Vertical Electrical Sounding (VES) and Electrical Resistivity Tomography (ERT)) was integrated in this study with geological information to delineate the depth to groundwater and depth to fracture that serve as conduit for the salt lake recharge.

General geology and Hydrogeology: The study area is situated in the Benue trough of the early cretaceous. Earlier authors contributed significantly to the details of the evolution and stratigraphic setting of the Benue trough[18-22]. The well-develop folds and fractures of the lower Benue trough form host to lead-zinc mineralization predominant in the area and also serve as channel/conduit for the salt groundwater[23].

Topographically, the area consists of irregular ridges and slopes which are controlled by bedrock geology[24]. While the general geology of the ridges and hills consist of indurated argillaceous sandstone, the lowlands are underlain by shales. Earlier literature also established the existence of a southwest moderately dipping fault associated with a linear oriented fissure zones along which Okposi salt lake upfluxes. The current study tends to determine the depth of occurrence of these fracture/fissure zone beneath the base of the salt lake.

The study area is within the tropical rainforest belt of southeastern, Nigeria with an average rainfall of about 2000mm. It is characterized by two seasons, the dry seasons (November – March) and the wet season (April – October) with pronounced changes in rainfall pattern attributed to climate change. The flood plains of the ephemeral rivers/streams and the salt lakes are flooded during the wet season encouraging subsistence cultivation of crops.

The bedrock lithology and the structural trend of the study area control to a large extent the hydrogeology of the area. The rock are well compacted by the series of tectonic events that took place in the area. Weathering and fracturing positively impact on the permeability of the bedrock thereby enhancing their groundwater potentials.

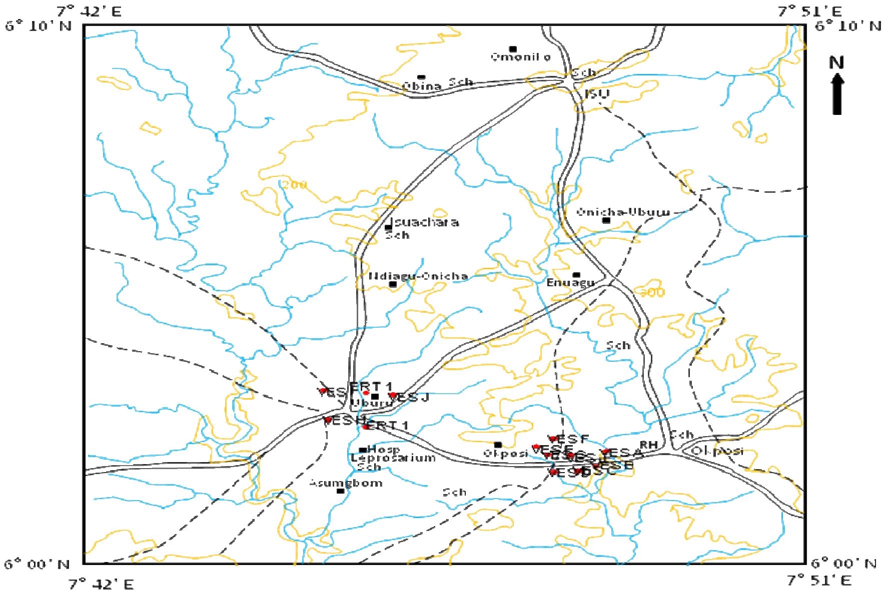

Figure-1
Location map of the area showing sampling points

Material and Methods

Geophysical investigations involving electrical resistivity measurement were carried out in the accessible parts of the study area. The investigation engaged both the Schlumberger array and the Electrical Resistivity Tomography (ERT) using SSR-MP-ATS model of IGIS resistivity meter and ABEM SAS 1000 terrameter respectively. The Schlumberger electrode configuration was adopted for the vertical electrical sounding (VES). Where the current electrode spread is restricted by inaccessibility especially at Uburu, electrical resistivity tomography (ERT) was carried out at a distance of about 5m from the salt lake and at a minimum current electrode spread of 5m with the aim of intercepting as much as possible all subsurface features (lithology and structure) associated with the salt lake.

Data acquisition: 10 VES data was acquired using the SSR-MP-ATS model of IGIS resistivity meter and its accessories. The current electrode spread for the VES ranges between 300m to 500m. In view of the relatively low gradient of the area, the VES data were not corrected for topographic effects. The minimum current electrode spacing (AB) was 2 m while the corresponding potential electrode spacing (MN) was varied from 0.5 m at AB = 2 m to a maximum value of 40 m at maximum AB. The measured apparent resistances were converted to apparent resistivity domain using equation-1.

$$\rho_a = \pi . R_a . \frac{\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{MN} \qquad (1)$$

The Wenner array was used in acquiring high quality ERT data suitable for proper mapping of vertical contacts with a minimum electrode spacing (a) of 5 m and a maximum electrode spacing was 80 m. The reciprocal error (RPE) was computed using equation 2 with 5% set as the maximum accepted value.

$$RPE = 100 \frac{|\rho_f - \rho_r|}{\rho_f + \rho_r} \qquad 2$$

Where ρ_f and ρ_r are the forward and reverse resistivity values respectively.

Data analyses: The apparent resistivities obtained were manually plotted against half current electrode separation on a bilogarithmic graph to obtain curves figure-2. Data (distances and apparent resistivities) generated from the smoothened curves were analysed using WINRESIST computer program to obtain depths and resistivities.

The RES2DINV code was used in modelling the ERT data. The extent of fit was also quantified using the RMSE. The 2-D subsurface image is shown in figure-4.

Interpretation of results: 4-5-layered shallow subsurface electro-stratigraphic sequences were interpreted. A summary of the resistivity characteristics and the basic statistics of the various geoelectric layers are shown in table-1.

The dominant materials in the first, third and fifth layers in all the sites are characterized by moderately high resistivity values that varying from 82.3 Ωm to 397.3 Ωm for layer 1, 17.3 Ωm to 244.1 Ωm for layer 3 and 42.7 Ωm to 95.8 Ωm for layer 5. These layers were interpreted to be silty sand, mudstone and shalestone respectively with maximum thickness of 3 m and 25 m. The thickness of the fifth layer could not be determined from the data acquired in the field.

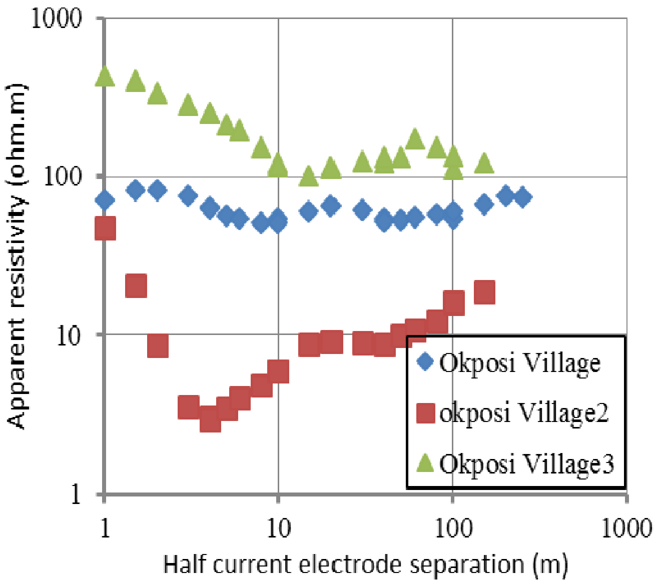

Figure-2
Samples of smoothened VES curves

The second and fourth layers were observed to be characterized by low resistivity values. Resistivity variation of the second and the fourth layers varied between 1.7 Ωm to 97.9 Ωm and between 5.9 Ωm to 71.9 Ωm respectively. These layers interpreted as fractured shale were observed at depths of 5 m and 25 m.

The 2-D ERT subsurface image captures the area as being dominated by an alternating sequence of low resistivity (< 15 Ωm) materials that are sandwiched by high resistivity (> 15 Ωm) materials. Three major anomalous resistivity zones are prominent in the resistivity image. The over lying low resistivity, the middle high resistivity and the bottom lying low resistivity materials that could not be properly mapped.

The overlying and the bottom-lying low resistivity materials were interpreted to be fractured shale similar to the second and fourth layers observed in the VES result. The prominently high resistivity anomaly that occupies the central portion of the image was interpreted to be shalestone. The anomalous low resistivity zones were interpreted to be indication of salt water reservoirs. Between 45- 60 m and 90- 100 m along the profile where the depth to bottom of the anomalously low resistivity regions is ~ 5 m, salt water accumulates. These regions could be the zones where salt water can be mined economically.

Conclusion

The VES data revealed 4 to 5 layered shallow subsurface electro-stratigraphic sequence while the ERT image showed three anomalous resistivity zones. The dominant material in the first, third and fifth layers is characterized by moderately high resistivity values ranging from 82.3 Ωm to 397.3 Ωm. The base of the fifth layer was not reached by the electrode spread. The thicknesses of the first and third layers were ~ 3m and ~ 50m respectively. The second and fourth layers were observed to be characterized by low resistivity values ranging from 1.7 to 97.9 Ωm and 5.9 to 71.9 Ωm respectively. These layers were interpreted as fractured shales with thickness of about 5 m and 25 m.

Three major anomalous resistivity zones were prominent in the resistivity image obtained from the ERT data. The low resistivity anomalous fractured shale observed from the ERT image confirmed the interpretation of the VES results and is indicative of salt water reservoirs. The fractured shale at a depth of about 5m may serve as the conduit through which the salt water recharges the lakes. It is inferred that beyond the depth of 25 m, groundwater of good quality could be mined economically.

Acknowledgement

The lead author acknowledges the International Foundation for Sciences (IFS) whose grant support made this research a success. She is also grateful to Geological Sciences Department Nnamdi Azikiwe University for their assistance during the field work.

References

1. Okoyeh E.I. and Egboka B.C.E., Evaluation of Hydrochemical Parameters of Okposi and Uburu Salt Lakes, Nigeria, IJSER, **4(6),** 2882-2889 (2013) http://www.ijser.org, **(2013)**

2. Tijani M.N. and Uma K.O., Geological, Geophysical and Hydrochemical studies of the Okpoma Brine field, Lower Benue Trough, South-eastern Nigeria, *Jour of Min and Geol.*, **34(1),** 55- 68 **(1998)**

3. Majumdar R.K. and Das D., Geoelectric and Geochemical studies for hydrological Characterization of Sagar Island regoin, South 24 Parganas, West Bengal, India, *IAHS-AISH Publ.,* **(312),** 50-59 **(2007)**

4. Stewart M., Layton M and Lizanec T., Application of resistivity surveys to regional hydrologic reconnaissance, *Ground Water,* **21,** 42-48 **(1983)**

5. Niwas S. and Singhal D.C., Estimation of aquifer transmissivity from Dar-Zarrouk parameters in porous media, *J. Hydrol.,* **50,** 393-399 **(1981)**

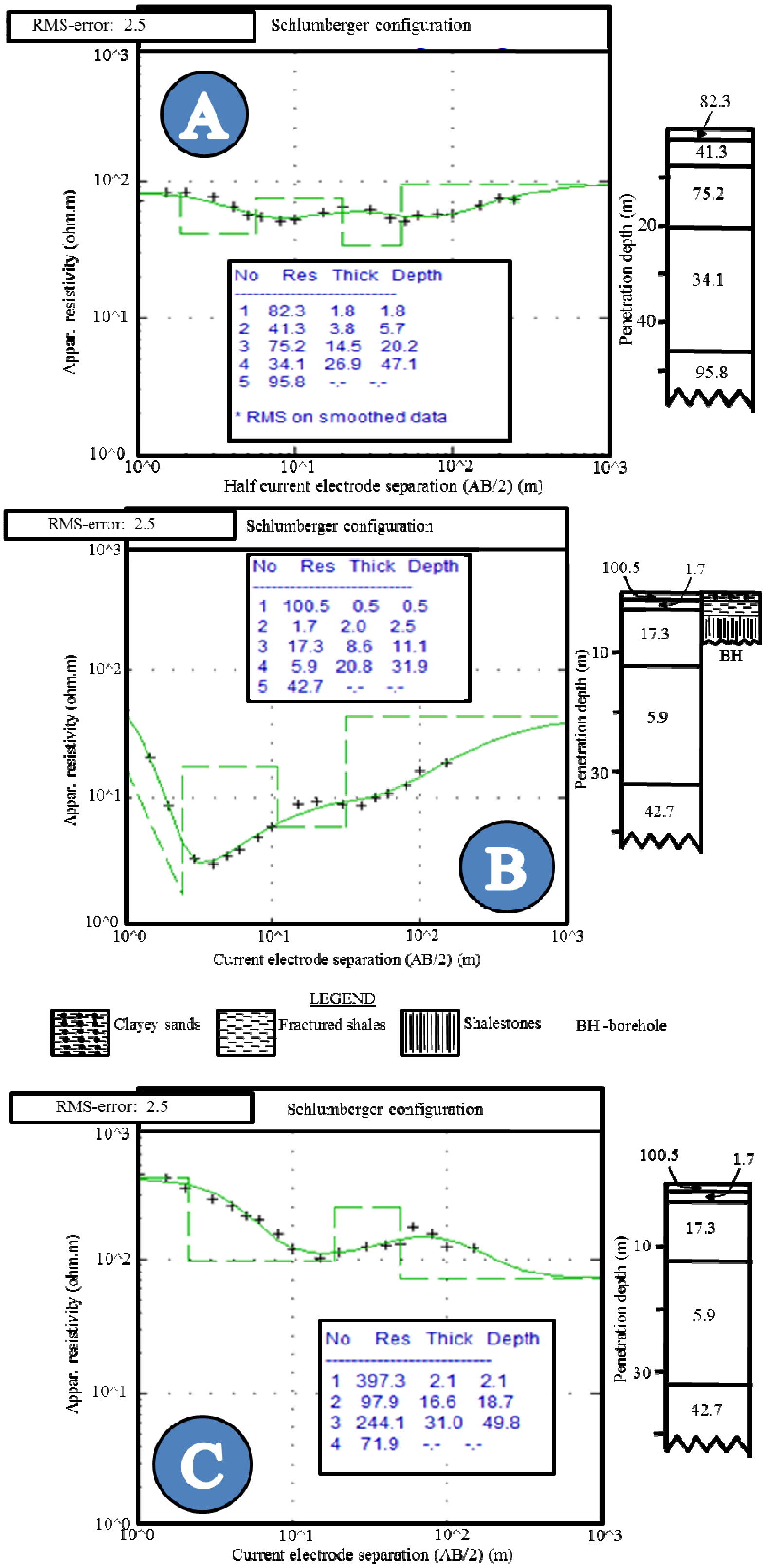

Figure-3
Samples of the modelled VES curves represented as A, B, and C

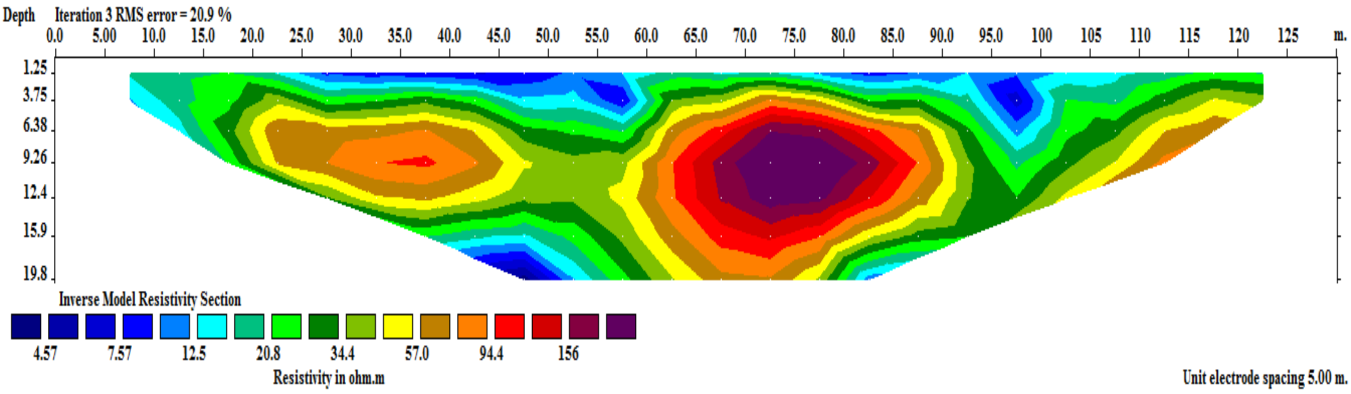

Figure-4
2-D subsurface image of the study area obtained from the ERT data

Table-1
Summary of layer parameters generated from the computer inversion exercise

VES Station Code	Geoelectric layer number	Mean Layer Resistivity (Ω.m)	Approximate depth range From the surface (m)	Approximate Thickness (m)	Suspected Lithologic Deduction
A	Layer 1	82.3 41.3 75.2 34.1 95.6	0.0 – 2.0 2.0 – 10.0 10.0 – 25.0 25.0 - 50.0 50.0 - ∞	2.0 8.0 15.0 25.0 ∞	Shaly/Silty sand Fractured shales Shalestone/mudstone Fractured shales Shalestones
B	Layer 1	100.5 1.7 17.3 5.9 42.7	0.0 – 1.0 1.0 – 5.0 5.0 – 15.0 15.0 – 40.0 40.0- ∞	1.0 4.0 10.0 25.0 ∞	Shaly/Silty sand Fractured shales Shalestone/mudstone Fractured shales Shalestones
C	Layer1	397.3 97.9 244.1 71.9	0.0 – 3.0 3.0 – 25.0 25.0 – 50.0 50.0 - ∞	3.0 22.0 25.0 ∞	Shaly/Silty sand Fractured shales Shalestone/mudstone Fractured shales
	Layer 1 Min Max Mean STD	82.3 397.3 193.4 176.8		1.0 3.0 2.0 1.0	
	Layer 2Min Max Mean STD	1.7 97.9 47.0 48.3		4.0 22.0 11.3 9.5	
	Layer 3Min Max Mean STD	17.3 244.1 112.2 117.8		10.0 25.0 16.7 7.6	
	Layer 4Min Max Mean STD	5.9 71.9 37.3 39.1		25.0 25.0 25.0 7.1	
	Layer 5Min Max Mean STD	42.7 95.8 69.3 37.5		- - - -	

6. Ekwe A.C., Onu N.N and Onuoha K.M., Estimation of aquifer hydraulic characteristics from electrical sounding data : The case of middle imo river basin aquifers, south-eastern Nigeria, *J. Spatial Hydrol.,* **6,** 121-131 **(2006)**

7. Kneisel C., Assessment of subsurface lithology in mountain environments using 2D resistivity imaging, *Geomorphology,* **80(1-2),** 32-44 **(2006)**

8. Casas A., Himi M., Diaz Y., Pinto V., Font X. and Tapias J.C., Assessing aquifer vulnerability to pollutants by electrical resistivity tomography (ERT) at a nitrate vulnerable zone in NE Spain, *Enviro. Geo.,* **54,** 515–520 **(2008)**

9. Sudha K., Israil M., Mittal S. and Rai J., Soil characterization using electrical resistivity tomography and geotechnical investigations, *Applied Geophy,* **67, 74-79 (2009)**

10. Giocoli A., Quadrio B., Bellanova J., Lapenna V. and Piscitelli S., Electrical resistivity tomography for studying liquefaction induced by the May 2012 Emilia-Romagna earthquake (Mw = 6.1, North Italy), *Nat. Haz. and Earth Sys. Sci. Discussions*, **1,** 5545–5560 **(2013)**

11. Wallin E.L., Johnson T.C., Greenwood W.J. and Zachara J.M., Imaging high stage river-water intrusion into a contaminated aquifer along a major river corridor using 2-D time-lapse surface electrical resistivity tomography, *Water Res. Res.*, **49(3),** 1693-1708 **(2013)**

12. Ingham M., High resolution electrical imaging of fault zones. Phy. of the Earth and Plan, *Interiors,* **150,** 93-105 **(2005)**

13. Schuett H., Kiessling D., Schoebel B., Krueger K., Schmidt-Hattenberger C. and Schiling F., Monitoring of geological CO_2 storage with electrical resistivity tomography (ERT) : Results from a field experiment near Ketzin/Germany, American Geophy, Union, Fall Meeting Abstract, **S54A-03**, **(2008)**

14. Akpan A.E., George N.J. and George A.M., Geophysical investigation of some prominent gully erosion sites in Calabar, southeastern Nigeria and its implications to hazard prevention, *Disaster Adv.,* **2(3),** 46-50 **(2009)**

15. Akpan A.E., Ukwang E.E. and Esu E.O., Investigating the state of some engineering materials in parts of Akamkpa area of the Precambrian Oban Massif, southeastern Nigeria, *Jour. of Min. and Geo.,* **40(2),** 113-119 **(2011)**

16. Chambers J.E., Wilkinson P.B., Wealthall, G.P., Loke, M.H., Dearden, R., Wilson R., Allen D. and Ogilvy, R.D. Hydrogeophysical imaging of deposit heterogeneity and groundwater chemistry changes during DNAPL source zone bioremediation, *Jour. of Cont. Hydrol.,* **118(1-2),** 43–61 **(2010)**

17. Rosales R.M., Martínez-Pagan P., Faz A. and Moreno-Cornejo J., Environmental Monitoring using electrical resistivity tomography (ERT) in the subsoil of three Former Petrol Stations in SE Spain, *Water, Air and Pollution, doi,* **10,** 1007/s11270-012-1146-0 **(2012)**

18. Reyment R.A., Aspect of the Geology of Nigeria, Ibadan Univ, Press, Ibadan, 145 **(1965)**

19. Nwachukwu S.O., The tectonic evolution o the southern portion of the Benur Trough, Nigeria, *Geol. Mag.*, 109, 411- 419 **(1972)**

20. Wright J.B., Origin of the Benue Trough : A critical review in Geology of Nigeria. (ed. C.O. Kogbe), Elizabethan publ. Co. Lagos, 187-205 **(1976)**

21. Offodile M.E., Hydrogeochemical interpretation of the middle Benue and Abakaliki brine Fields, *Jour of Min. and geo.*, **13(2)** 79 **(1976)**

22. Ofoegbu C.O., A tectonic model for the evolution of the Benue Trough of Nigeria, Geol. Rundschau, **73, 1007-1018 (1984)**

23. Akande S.O., Hoffknecht A. and Erdtmann B.D., Environment of ore formation and anchizonal metamorphism in Pb-Zn-flourite-barite deposits of the Benue trough, Nigeria, *Geol. en Mijnbouw*, **74,** 131-144 **(1992)**

24. Agarwal M., Jain S. and Shandilya A.K., Hydro-Chemical Evaluation of Ground Water of Area Around Raisar, Bikaner District, Rajasthan, India, *Int. Res. J. Environment Sci.*, **2(5),** 72-78 **(2013)**