

Structural Analysis of Digitized Lineament from Satellite Imagery and Vertical Electrical Soundings (VES) Studies for Ground Water Exploration in Part of Nasarawa State.

Y.S. Agunleti, M.Sc.*; E.A. Arikawe, Ph.D. (in view); J.I.K. Okegye, Ph.D. (in view); and S.I. Fadele, Ph.D. (in view)

Department of Geology and Mining, Nasarawa State University, PMB 1022, Keffi, Nigeria.

E-mail: asylong@yahoo.com*

ABSTRACT

The study area is underlain by the migmatite, gneisses, Schist and Older Granites. LANDSAT 5-TM imagery of the area have been analyzed and interpreted in order to determine the lineament trends for groundwater recharge across the area. The drainage pattern is structurally controlled and drains down from high to low elevation i.e. generally from north–south flow directions in the area. Rose (azimuth-frequency) diagram of the lineaments digitized from the imagery shows trends in the NE-SW and WNW-ESE directions with NE-SW as the major trends. Lineament density calculation shows that the lineament density is high to low from Grid A- Grid B - Grid C and Grid D, respectively. Areas having high lineament density represent areas with relatively high groundwater potentials.

Vertical Electrical Sounding (VES) using Schlumberger array was carried out at eight (8) VES stations. ABEM terrameter (SAS 1000) was used for the data acquisition. The field data obtained have been analyzed using computer software (*IPI2win*) which gives an automatic interpretation of the apparent resistivity. The VES results revealed heterogeneous nature of the subsurface geological sequence. The geologic sequence beneath the study area is composed of hard pan top soil (clayey and sandy-lateritic), weathered layer, partly weathered or fractured basement and fresh basement. The resistivity value for the topsoil layer varies from $83\Omega\text{m}$ to $672\Omega\text{m}$ with thickness ranging from 0.38 to 3.38m. The weathered basement has resistivity values ranging from $35\Omega\text{m}$ to $871\Omega\text{m}$ and thickness of between 0.52 to 20.3m. The fractured basement has resistivity values ranging from $62\Omega\text{m}$ to $229\Omega\text{m}$ and thickness of between 12.3 to 28.1m. The fresh basement (bedrock) has resistivity values ranging from $133\Omega\text{m}$ to $760\Omega\text{m}$ with infinite depth. However, the depth from the

earth's surface to the bedrock surface varies between 14.9 to 29.51m.

(Keywords: LANDSAT 5-TM imagery, VES, GIS, DEM, lineament)

INTRODUCTION

Water is one if not the most valuable and vital natural resource to mankind for sustainable life and also for any other use. With the surface water sources dwindling to meet the various demands, groundwater has become the only reliable and safe resource. The indiscriminate use and scarcity of this vital natural resource often cause chaos in an area where the availability is a major problem and therefore the need to always search for aquiferous zone for sufficient groundwater.

An efficient planning and development of ground water development in the crystalline basement rocks which characterize the geology of study is largely due to the development of secondary porosity and permeability by fracturing and or weathering of these rocks. Fractured basement and superficial layer created by weathering processes with varying degree of porosity and permeability can be a good source of reliable aquifer. The structure and resistance of rock type are the principal governing factors for the variation patterns.

Groundwater exploration in the study area is aimed at delineating the lineament computed from the digitized from LANDSAT 5-TM imagery of Keffi sheet 208 NE. Remote sensing techniques and Geographic Information System (GIS) techniques are considered the most appropriate new alternative tools for groundwater exploration (Moore, 1982). The main advantages of using remote sensing for groundwater exploration is the reduction of cost and time

needed, the fast extraction of information on the occurrence of groundwater and the selection of promising areas for further groundwater exploration (Toleti et al., 2001). The objective of this research is identifying prospective areas for groundwater exploration in of the study area state based on the integration of satellite images, topographic, geological and structural data with vertical electrical sounding (VES).

STUDY AREA

The study area is located in Nasarawa State, North-central Nigeria between latitudes 8° 45' 00" and 9° 00' 00" 'N, and longitudes 7° 45' 00" – 8° 00' 00"E, covering an area of about 720km². Elevation ranges between 250meters to 520meters. It is bounded in the north by Kaduna state and in the east by Plateau and Taraba states. It is also bounded in the west by Federal

Capital Territory (FCT) and in the south by Kogi and Benue states (Figure 1).

GEOLOGY OF THE STUDY AREA

The study area falls within the north-central sector of the Nigerian basement complex. McCurry and Wright (1976); Fitches et al. (1985); Ajibade et al. (1987) have been able to describe the geology of central Nigeria in details. In summary, the study area is underlain by gneisses, migmatites, schist and older granites of the Nigerian basement complex which bears the imprints of thermo-tectonic events of the Archean to early Paleozoic times (Oyawoye, 1964; McCurry, 1976; Fitches et al., 1985; Ajibade et al., 1987). The pegmatite dykes associated with these Basement Complex rocks usually shows N-S, NNE-SSW, NE-SW and NNW-SSE trends.

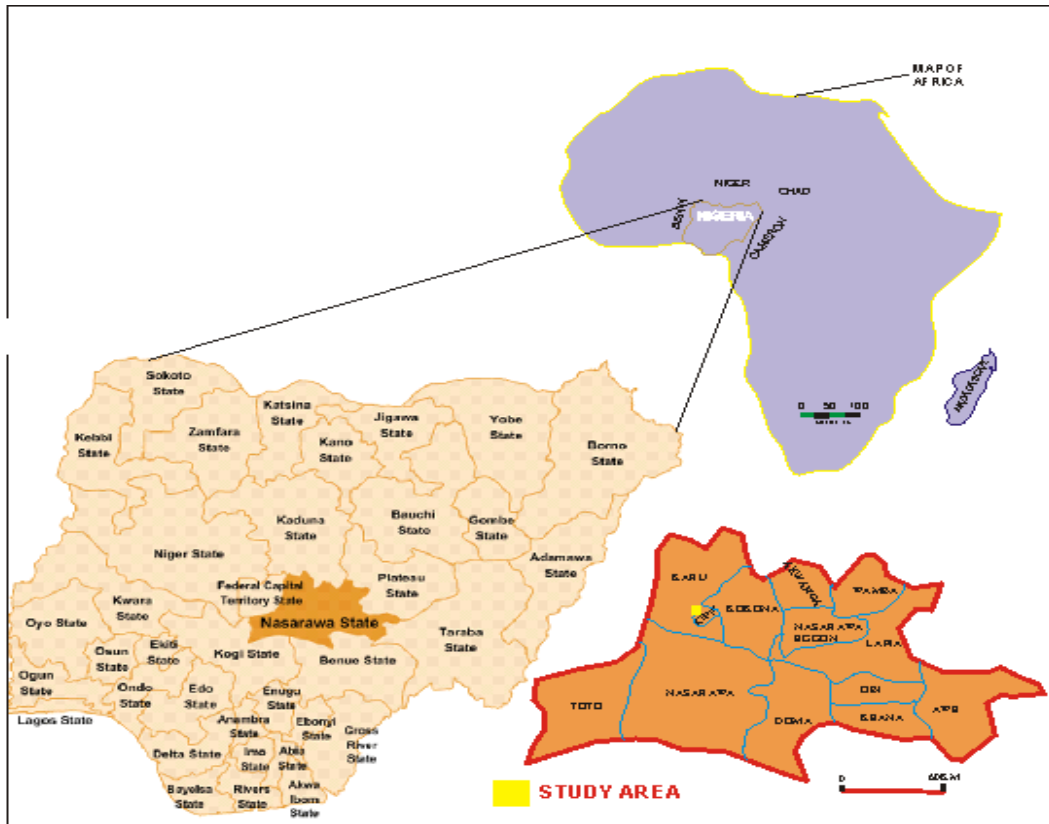


Figure 1: Map of Nigeria showing the Location of the Study Area in Nasarawa State.

CLIMATE AND VEGETATION

The study area falls within the hot climate region of north-central Nigeria. The temperature of Nasarawa State where the study area fall ranges between 25°C and 28°C, while the rainfall ranges from 131.75cm – 146cm. The study area falls largely within the Northern Guinea Savannah zones which consist mainly of short trees, grasses and the plateau type of mosaic vegetation.

MATERIALS AND METHODS

Vertical Electrical Sounding (VES)

Eight (8) Vertical Electrical Soundings (VES) using Schlumberger array were carried out in the study area at least two at each grid. Current electrode spacing AB used was 300m, that is, $1/2AB=150m$. The potential electrode separation MN was also increased accordingly but did not exceed 15m as suggested by (Dobrin and Savit, 1988) that potential difference should not exceed

one-fifth of the half-current electrode separation. The instrument used for this survey is the ABEM SAS 1000 Terrameter.

Landsat Imagery

The LANDSAT imagery of the study area (Figure 2) is part of the whole satellite map of Nigeria acquired by Geomatics International Inc., A 30 m spatial resolution LANDSAT 5-TM (Thematic Mapper) scene P188r054 covering the area. The RGB 521 was selected and used for the interpretation. The pre-processing and post image processing and analysis were carried out to enhance the quality of the images and the readability of the features using the spatial analysis tools of Integrated Land and Water Information System (ILWIS 3.3) and Arc GIS 9.3. The study area is divided in four (4) grids namely; Grid A, B, C, and D. Each of the grids with an approximate area of 191 square kilometers is studied for the best area for groundwater accumulation (Figure 3). Golden SURFER 10 was used to plot the digital elevation model (DEM).

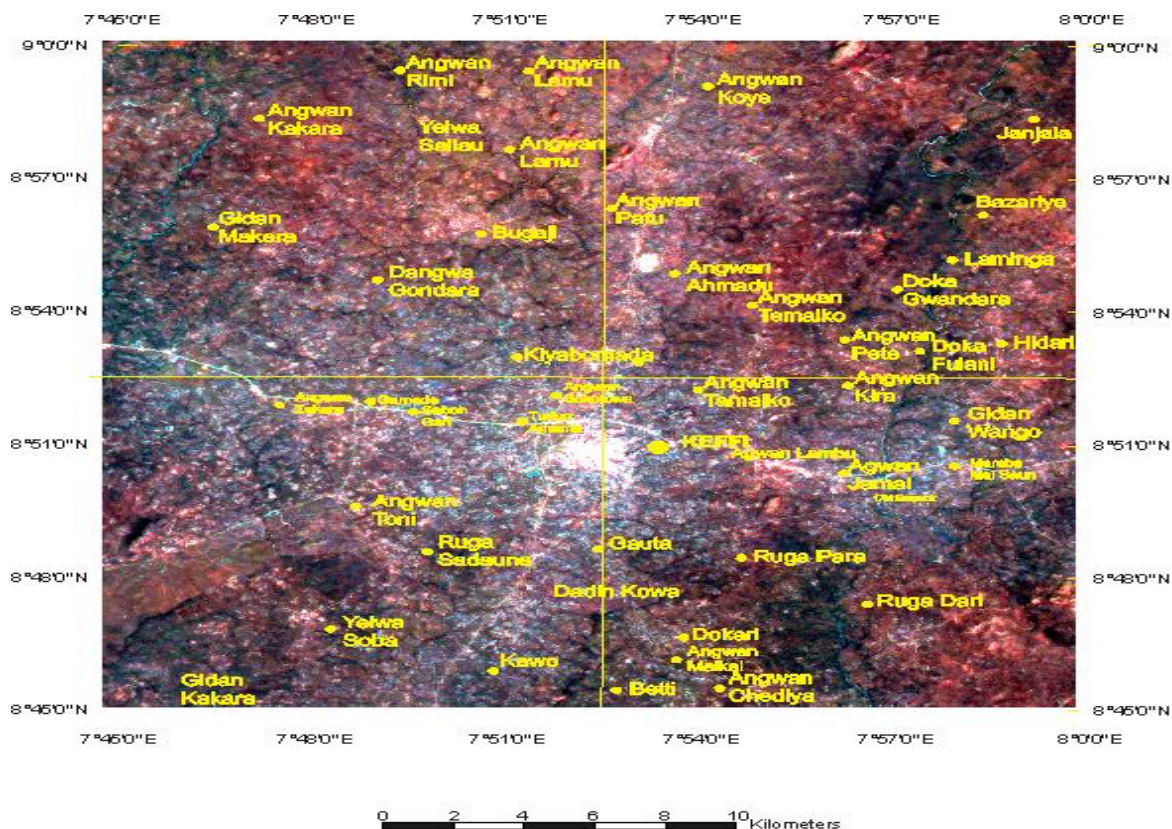


Figure 2: LANDSAT 5-TM Imagery of Keffi Sheet 208 NE Covering the Study Area.

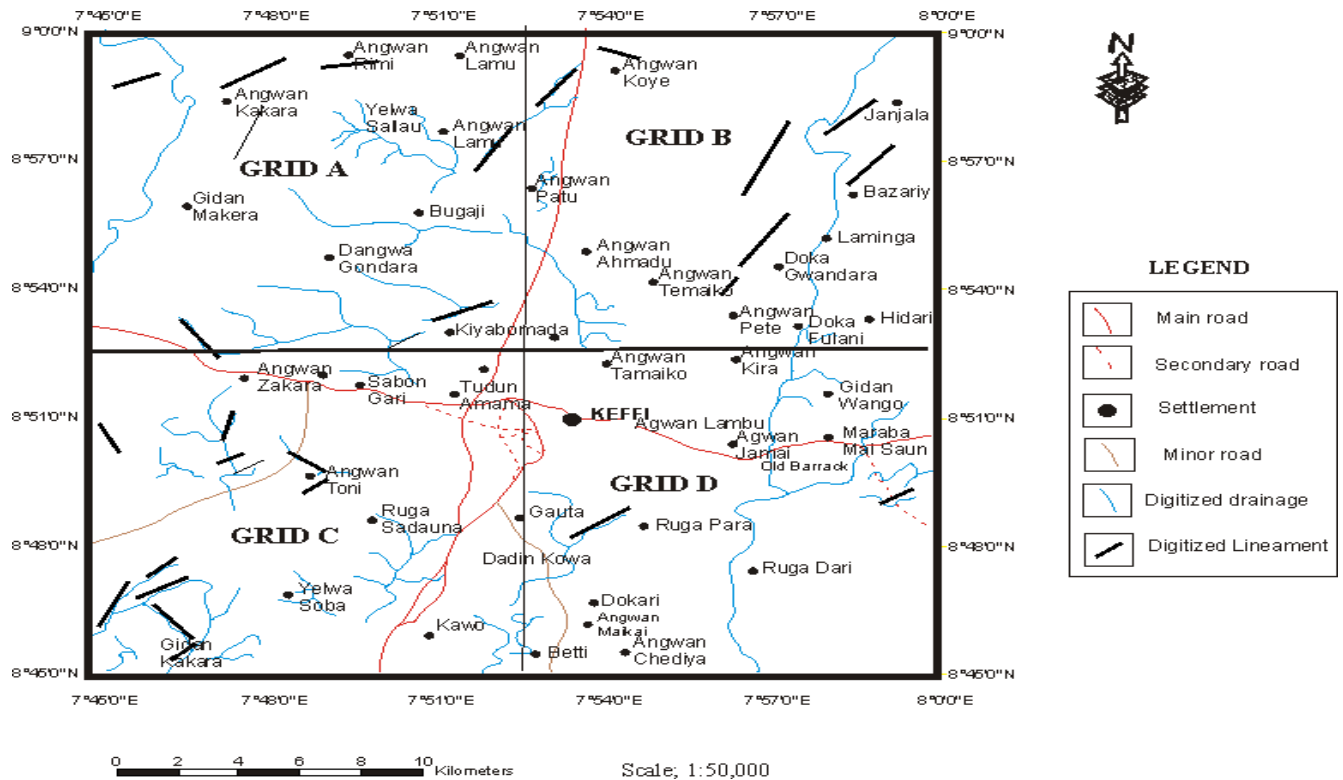


Figure 3: Lineament and Drainage Map of the Study Area derived from LANDSAT 5-TM.

RESULTS AND DISCUSSION

Topographic map of the study area on a scale of 1:50,000 were digitized and used to create a shaded relief, and grid vector. The digitized lineament and drainage pattern strictly from the satellite imagery is then superimposed on the contour shaded relief and grid vector map (Figure 4).

Figure 5 shows the rose azimuth plot of fractures (lineament) with a preferred NE-SW orientation. The commonest method used to calculate lineament density is based on the number of lineaments per unit area (number/km²), or the total length of lineaments per unit area (km/km²) or both. However for this study, rose (azimuth-frequency) diagram and lineaments per unit area (km/km²) was used and the results are shown on (Table 1). From the Lineament density calculation, the study area shows that the lineament density is high to low from Grid A- Grid B - Grid C and Grid D, respectively.

The geometric factor, K, was first calculated for all the electrode spacings using the formula; $K = \pi (L^2/2b - b/2)$, for Schlumberger array with $MN=2b$ and $1/2AB=L$. The values obtained, were then multiplied with the resistance values to obtain the apparent resistivity, ρ_a , values. Then the apparent resistivity, ρ_a , values were plotted against the electrode spacings (1/2AB) on a log-log scale to obtain the VES sounding curves using an appropriate computer software *IPI2win* in the present study.

Two resistivity sounding curve types were obtained from the studied area and these are the H ($\rho_1 > \rho_2 < \rho_3$) and KH ($\rho_1 > \rho_2 < \rho_3 > \rho_4$) type curves. The modeling of the VES measurements carried out at eight (8) stations has been used to derive the geoelectric sections for the various profiles. These have revealed that there are mostly four and three geologic layers beneath each VES station.

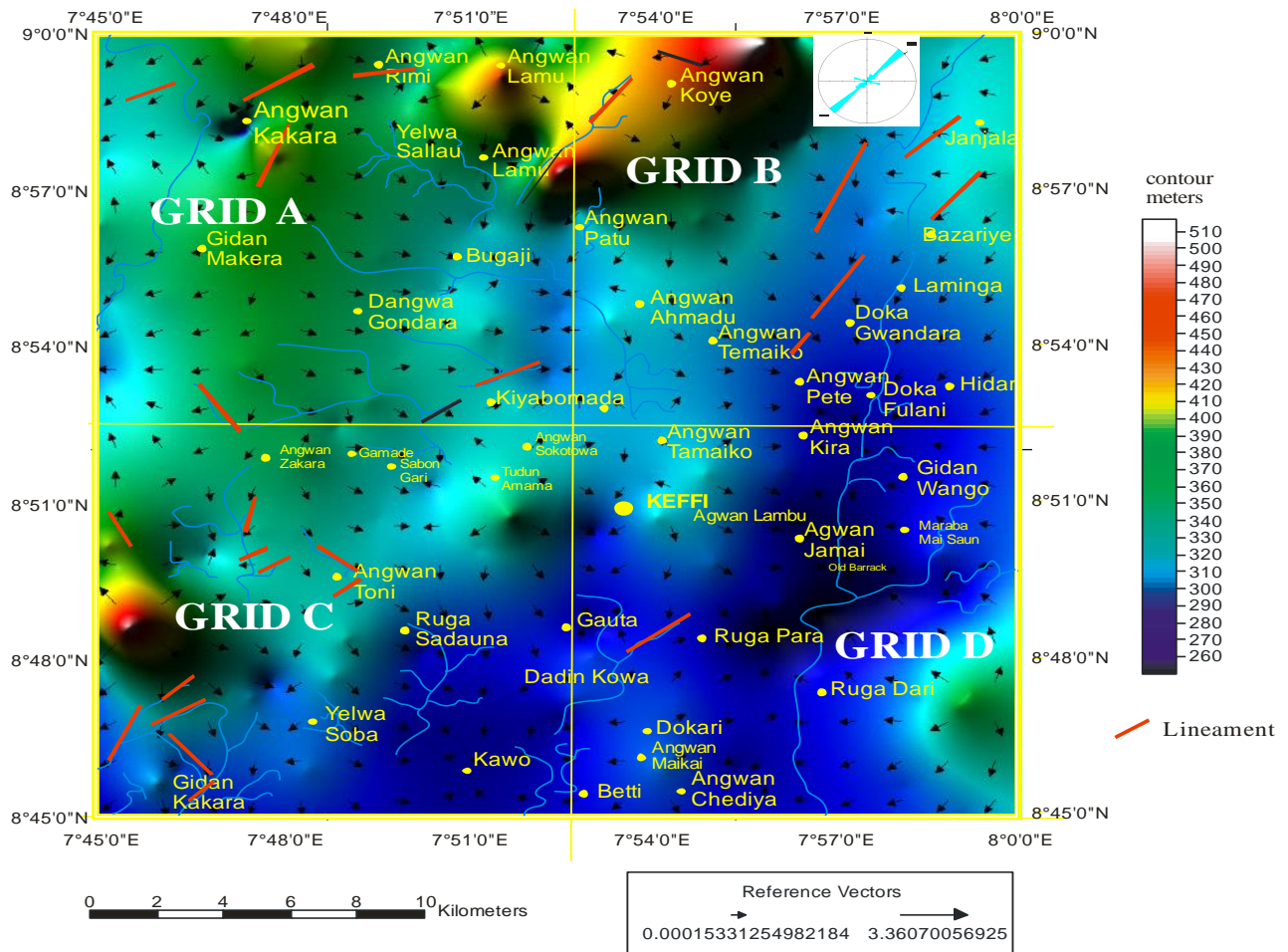


Figure 4: Lineaments Super-Imposed on Contour Shaded Relief and Grid Vector Layer.

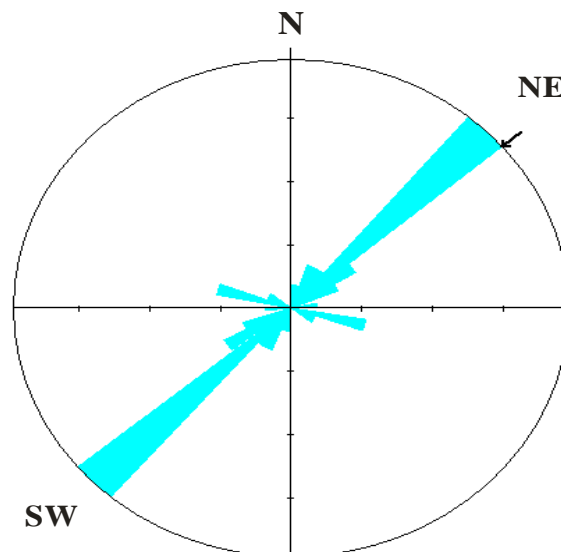


Figure 5: Rose Azimuth Plot of Digitized Lineament showing NE-SW Major Trend.

Table 1: Showing Lineament Density Calculations from the Study Area.

GRID	Area covered (Km ²)	Total lineament length (Km)	Lineament density
A	191.276	15.89	0.083
B	191.284	14.83	0.078
C	191.272	12.68	0.066
D	191.272	3.37	0.018

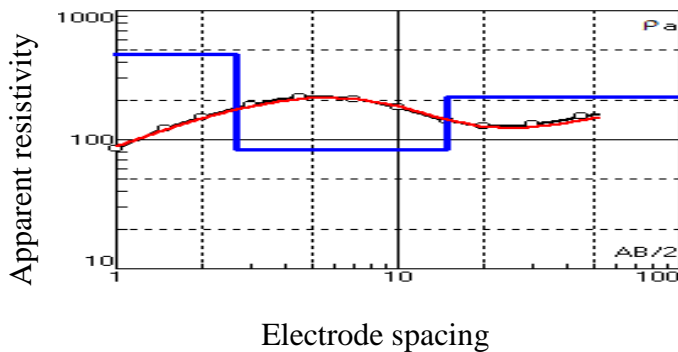
The geologic sequence beneath the study area is composed of top soil, weathered basement, partly weathered/fractured basement, and fresh basement. The topsoil is composed of clayey and sandy-lateritic hard pan with resistivity values ranging from 83Ωm to 672Ωm and thickness varying from 0.38 to 3.38m, thinnest at GRID A1 and thickest at GRID C1. It is however, observed from the geoelectric sections that GRID A1 & A2 and GRID B1 & B2 are characterized with low resistivity values varying between 83Ωm to 240Ωm suggesting the clayey nature of the topsoil in these areas are possibly high moisture content.

The second layer is the weathered basement with resistivity and thickness values varying between 35Ωm and 871Ωm and 0.52 to 20.3m respectively. This layer is thickest at GRID C1, suggesting this point for siting borehole but

thinnest at GRID C1. Other points with probable high water potentials suitable for siting borehole include: VES GRID A2, B1, C2, D1 and D2 respectively with appreciable thickness of weathered rock (i.e., aquiferous zone).

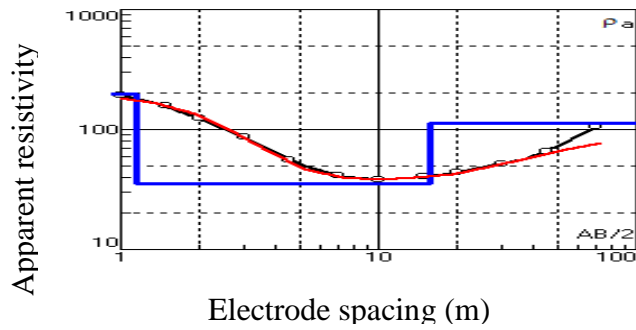
The third layer is the partly weathered and fractured basement with resistivity and thickness values varying between 62Ωm to 229Ωm and 12.3 to 28.1 m respectively. The layer is extensive and thickest at VES GRID B1 and thinnest at VES GRID A1.

The fourth layer is presumably fresh basement whose resistivity values vary from 133Ωm to 760Ωm with an infinite depth. However, the depth from the Earth's surface to the bedrock surface varies between 14.9 to 29.51m, deepest at VES GRID B1 and shallowest at VES GRID A1.



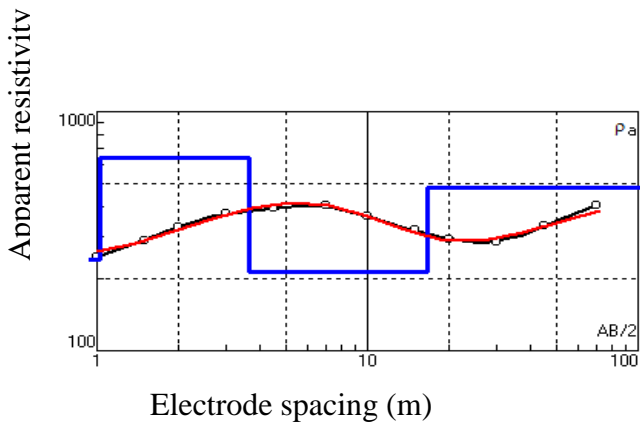
N	ρ	h	d
1	83	0.486	0.486
2	210	2.18	2.67
3	83	12.3	14.9
4	160		

Figure 6: VES Station at GRID A1 (TYPE KH CURVE).



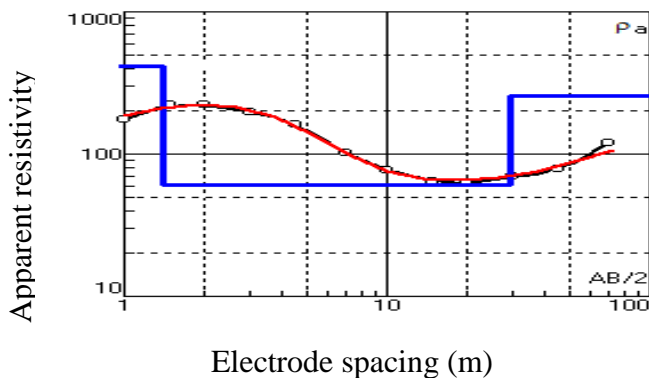
N	ρ	h	d
1	198	1.15	1.15
2	35	14.7	15.8
3	113		

Figure 7: VES Station at GRID A2 (TYPE H CURVE).



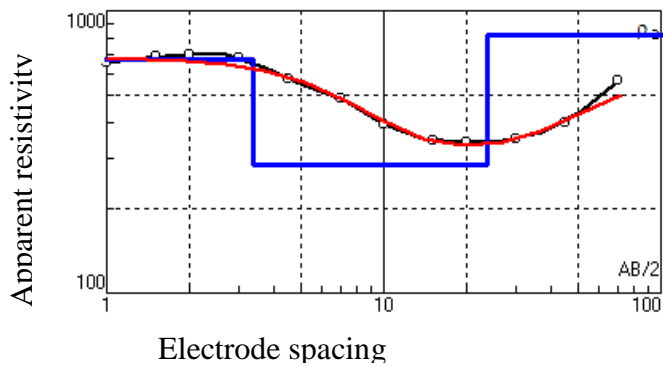
N	ρ	h	d
1	170	0.375	0.375
2	210	1.03	1.41
3	62	28.1	29.5
4	122		

Figure 8: VES Station at GRID B1 (TYPE KH CURVE).



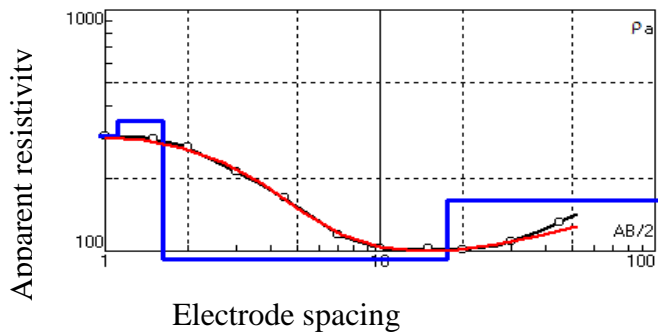
N	ρ	h	d
1	240	1.03	1.03
2	440	2.63	3.65
3	214	13	16.7
4	460		

Figure 9: VES Station at GRID B2 (TYPE KH CURVE).



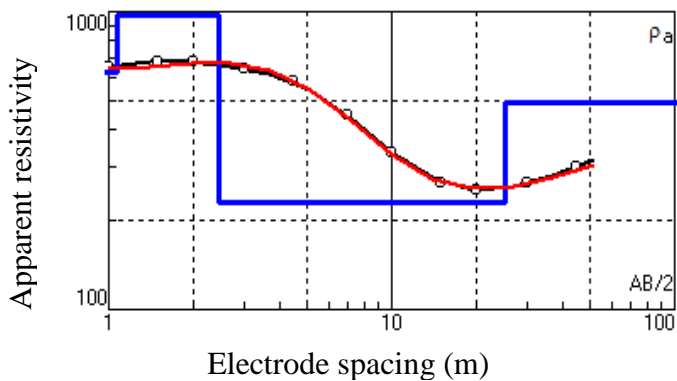
N	ρ	h	d
1	672	3.38	3.38
2	286	20.3	23.6
3	760		

Figure 10: VES Station at GRID C1 (TYPE H CURVE).



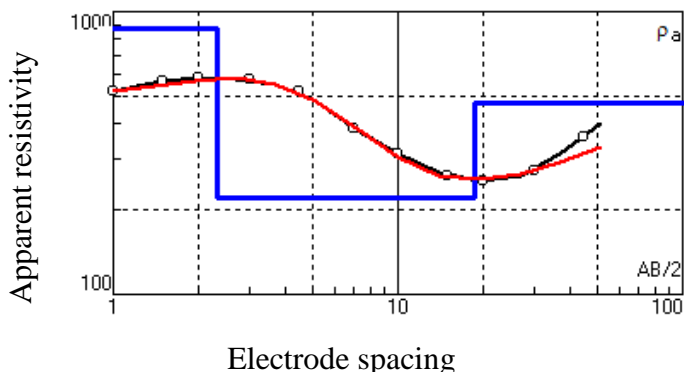
N	ρ	h	d
1	301	1.11	1.11
2	347	0.517	1.62
3	92	15.9	17.6
4	162		

Figure 11: VES Station at GRID C2 (TYPE KH CURVE).



N	ρ	h	d
1	626	1.07	1.07
2	973	1.38	2.45
3	229	22.7	25.2
4	495		

Figure 12: VES Station at GRID D1 (TYPE KH CURVE).



N	ρ	h	d
1	495	0.921	0.921
2	871	1.4	2.32
3	219	16.3	18.6
4	475		

Figure 13: VES Station at GRID D2 (TYPE KH CURVE).

CONCLUSION

Lineament density calculation, the study area shows that the lineament density is high to low from Grid A- Grid B - Grid C and Grid D, respectively, with a preferred NE-SW orientation. The geologic sequence beneath the study area is composed of top soil, weathered basement, partly weathered/fractured basement, and fresh basement. The topsoil is composed of clayey and sandy-lateritic hard pan with resistivity values ranging from 83 Ω m to 672 Ω m and thickness varying from 0.38 to 3.38m, thinnest at GRID A1 and thickest at GRID C1. It is however, observed from the geoelectric sections that GRID A1 & A2 and GRID B1 & B2 are characterized with low resistivity values varying between 83 Ω m to 240 Ω m suggesting the clayey nature of the topsoil in these areas are possibly high moisture content.

The second layer is the weathered basement with resistivity and thickness values varying between 35 Ω m and 871 Ω m and 0.52 to 20.3m respectively. This layer is thickest at GRID C1, suggesting this point for siting borehole but thinnest at GRID C1. Other points with probable high water potentials suitable for siting borehole include: VES GRID A2, B1, C2, D1 and D2 respectively with appreciable thickness of weathered rock (i.e., aquiferous zone).

The third layer is the partly weathered and fractured basement with resistivity and thickness values varying between 62 Ω m to 229 Ω m and 12.3 to 28.1 m, respectively. The layer is extensive and

thickest at VES GRID B1 and thinnest at VES GRID A1.

The fourth layer is presumably fresh basement whose resistivity values vary from 133 Ω m to 760 Ω m with an infinite depth. However, the depth from the earth's surface to the bedrock surface varies between 14.9 to 29.51m, deepest at VES GRID B1 and shallowest at VES GRID A1.

REFERENCES

1. Ajibade, A.C., M.A. Rahaman, and M. Woakes. 1987. "Proterozoic Crustal Development in the Pan-African Regime of Nigeria". ILP Working Group 3 Mid-term Report.
2. Dobrin, M.B. and C.H. Savit. 1988. *Introduction to Geophysical Prospecting. Fourth Edition.* McGraw- Hill Books: New York, NY.
3. Fitches, W.R., A.C. Ajibade, I.G. Egbuniwe, R.W. Holt, and J.B. Wright. 1985. "Late Proterozoic Schist Belts and Plutonism in NM Nigeria". *Journal of Geological Society of London.* 142:319–337.
4. McCurry, P. and J.B. Wright. 1976. "Geochemistry of Calc-Alkaline Volcanic in Northwestern Nigeria, and a Possible Pan-African Suture Zone". *Earth Planetary Science Letter.* 37:90-96.
5. Moore, G. 1982. "Groundwater Applications of Remote Sensing". Open file report 82 – 240. U.S. Department of Interior Geological Survey, EROS Data Center, Sioux Falls, South Dakota

6. Oyawoye, P.O. 1964. "Geology of Nigerian Basement Complex". *Journal of Mining and Geology*. 1:110-121.
7. Toleti, B., B. Chandhary, K. Kumar, G. Saroha, M. Yadar, A. Singh, M. Sharma, A. Pandey, and P. Singh. 2001. "Integrated Groundwater Resources Mapping in Gurgoan District (Haryana) India using Remote Sensing and GIS Techniques". Kurukshetra University, Department of Geophysics: Shahabad, India.

SUGGESTED CITATION

Agunleti, Y.S., E.A. Arikawe, J.I.K. Okegye, and S.I. Fadele. 2014. "Structural Analysis of Digitized Lineament from Satellite Imagery and Vertical Electrical Soundings (VES) Studies for Ground Water Exploration in part of Nasarawa State". *Pacific Journal of Science and Technology*. 15(1):345-354.



ABOUT THE AUTHORS

Y.S. Agunleti, M.Sc., is a graduate of geology in the Department of Geology and Mining, Faculty of Sciences, Nasarawa State University, Keffi, also graduated as a Mining Engineer from School of Mines and Metallurgy, Kogi State Polytechnic, Lokoja, both in Nigeria. He specializes in geochemistry and structural geology, also found worthy in application of remote sensing for mineral and groundwater explorations with practices not limiting to mining.

E.A. Arikawe, Ph.D. (in view) is an Assistant Chief Geologist with National Agency for Science and Engineering Infrastructure (NASENI), currently on his Ph.D. study in Mineral Exploration and Mining from Nasarawa State University, Keffi. He specializes in geochemistry and economic geology.

J.I.K. Okegye, Ph.D. (in view) is a Lecturer in Nasarawa State Polytechnic, Lafia. He holds a Masters degree in Mineral Exploration and currently is on his Ph.D. in Mineral Exploration and Mining with Nasarawa State University, Keffi. He specializes in economic geology and mineral processing.

S.I. Fadele, Ph.D. (in view), is currently undergoing his Ph.D. programme in Nasarawa State University. He earned his Masters in the Department of Physics (Applied Geophysics option), Faculty of Sciences, Ahmadu Bello, University, and Zaria, Nigeria. He specializes in application of geophysical methods in mineral, groundwater explorations and engineering and environmental studies.