Geoelectrical Prospecting for fractured Basement Aquifer in Northern Portion of FUT-Minna Bosso Campus, Minna, North-central Nigeria

Article · December 2017

Christopher Unuevho
Federal University of Technology Minna

K.M. Onuoha
University of Nigeria

Amadi Akobundu Nwanosike
Federal University of Technology Minna

Alabi A. A.
Federal University of Technology Minna

GEOELECTRICAL PROSPECTING FOR FRACTURED BASEMENT AQUIFER IN NORTHERN PORTION OF FUTMINNA'S BOSSO CAMPUS, MINNA, NORTH-CENTRAL NIGERIA

[1?]C. I. Unuevho, [2a]K. M. Onuoha, [1b]A. N. Amadi, [3c]A. A. Alabi, [4d]J. A. Aderogbin, [4e]E. E. Udensi, [3f]Oshin, O.

1: Department of Geology, Federal University of Technology, Minna

2: Department of Geology, University of Nigeria, Nsukka

3: Department of Earth Sciences, Ajayi Crowther University, Oyo

4: Department of Physics, Federal University of Technology, Minna

?unuevho@gmail.com, a: mosto.onuoha@gmail.com, b: geoamaa76@gmail.com, c: alabiadekola@futminna.edu.ng

d:aaderogbin@gmail.com, e:eeudensi@gmail.com, f:o.oshin@acu.edu.ng

ABSTRACT

Only one out of three boreholes in the northern portion of FUTMINNA's Bosso Campus is productive. Values of hydrogeophysical parameters characterising fracture column at the productive borehole site were captured from vertical electrical resistivity and spontaneous potential (SP) sounding data. The values were employed to identify other sites with potential for groundwater production in the area. Sounding locations L1, L8, L14, L19 and L20 contain fracture column characterised by 200- 400?m resistivity, -10 to 20mV SP, 1200 - 2400?m^2 transverse unit resistance and 0.05 - 0.1?$^{-1}$ longitudinal unit conductance. Boreholes sited at these locations would be productive because the fracture column therein has identical values of hydrogeophysical parameters with the fracture column at the productive borehole site. Sounding locations14 and 20 were found to be groundwater convergence zones respectively within north-western and eastern portions of the investigated area. The fracture column in the vicinity of sounding location 20 is thickest and more spatially extensive, thereby making the eastern sector the most suitable for drilling productive borehole.

Keywords: *Fracture column, Groundwater convergence zone.*

Introduction:

Bosso campus of the Federal University of Technology, Minna (FUTMINNA) is sited within the basement complex of north-central Nigeria. A sketch map of the investigated northern portion of the campus is Fig.1. The investigated portion hosts the FUT Model College, Staff School, Catholic Church, and Interdenominational Chapel.

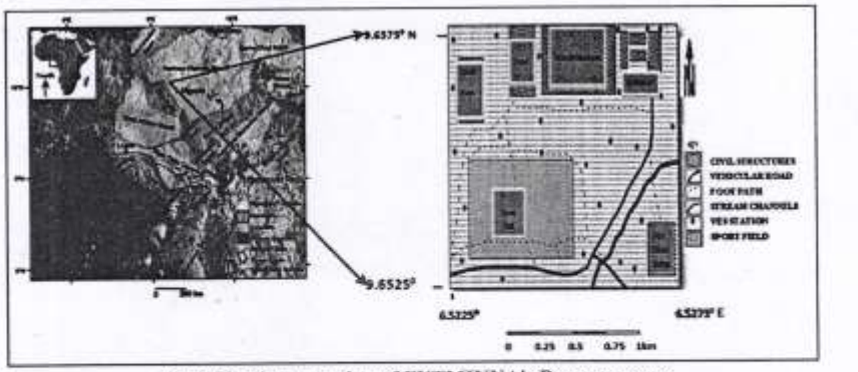


Fig.1: Northern portion of FUTMINNA's Bosso campus

Outcrops of fractured granitic rocks litter the area, and this suggests a very thin regolith. This leaves fractured basement aquifer as the only hope for steady groundwater supply source in the area. The length of the fractures ranges from 1.0-5.5m, while their width ranges from 0.01-0.1m (Fig.2). The surface fracture density ranges from 0.9-2.0m^{-1}.

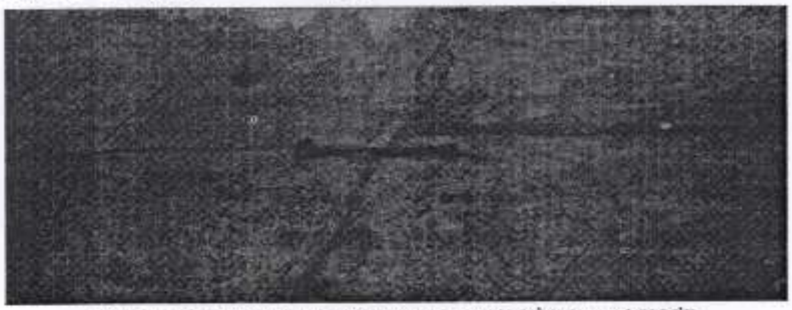


Fig.2: A fractured granitic outcrop at Lat. 9.6540'N; Long.6.5235'E

These fracture parameters suggest the existence of fractured bedrock within the subsurface. Two boreholes in the area have failed to produce water. However, one productive borehole exists in the eastern outskirts of the investigated area. This study attempts to employ the hydrogeophysical parameters of the successful borehole site to identify other sites with potential for groundwater production within the area. The productive borehole utilises hand operated pump to produce water. This implies it produces water from fractured basement that are shallower than 60m subsurface depth.

During oral discussions, Site –Geologists often reported encountering talc schist in the subsurface while drilling within the vicinity of the area. Outcrops of migmatite-schist complex exist NNE while schist outcrops SE of the area (Fig.3).

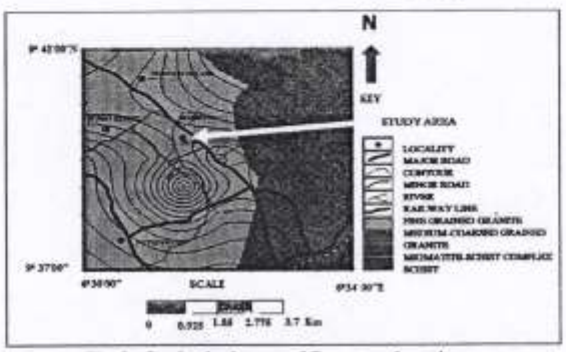


Fig.3: Geological map of Bosso and environs

Materials and Methods:

Campus Omega resistivity meter, *WinResist* forward modelling software and Suffer 11 contouring software constitute the materials employed in this study. Vertical electrical resistivity sounding (VES) was carried out with Campus Omega resistivity meter, using the Schlumberger array and maximum current electrode spacing (AB) of 140m. This maximum current electrode spacing is adequate to enable electrical current penetrate the fresh basement revealed to be shallow by numerous granitic outcrops, and any existing fractured basement revealed to be shallower than 60m depth by the hand-pumped productive borehole. VES was first conducted very close to the productive borehole to ascertain that the resistivity meter is appropriately responsive to subsurface geological conditions. Cumulative resistivity plotting method of Raghunath(2006) was combined with changes from concave to convex curve segments (and vice versa) method of Musset & Khan(2009) to identify approximate number of geoelectric layers, apparent depth to top of each layer and apparent resistivity of each layer. These parameters were used as input data for geoelectric layer modelling performed with *WinResist* forward modelling software. The geoelectric parameters characterising the modelled geoelectric layers constitute true depth to top and base of each layer, layer thickness and layer's true resistivity value. The modelled geoelectric layers constitute geoelectric section at each VES station, which were interpreted in terms of geological section for the VES stations. Dar Zarrouk parameters (transverse unit resistance,T; and longitudinal unit conductance, S) were computed for the fractured basement column, using its geoelectric parameters obtained from the geoelectric section as follows(Parasnis 1986; Oladapo *et al.*2004; Okiongbo & Odubo,2012):

$$T = \rho_i h_i \text{ ---------Equation 1}$$

$$S = \frac{h_i}{\rho_i} \text{ ---------Equation 2}$$

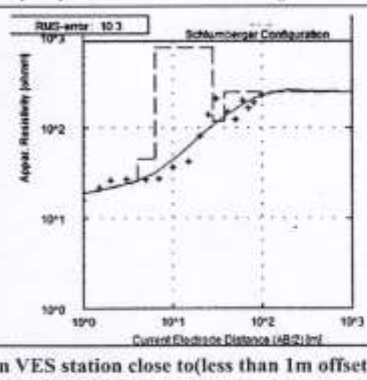
where ρ_i and h_i are respectively the resistivity and thickness of the fractured column obtained from the modelled geoelectric section.

Suffer 11 contouring software was employed to contour depth to base of fractured basement column, thickness of fractured column, resistivity values as well as S and T values of the fractured column. Campus Omega resistivity meter was also employed to measure SP at the AB spacing employed in the resistivity sounding. The SP values were also contoured for the fractured basement.

Results:

The VES curve in close vicinity(less than a metre offset distance) of the hand-pumped productive borehole is figure 4.

Distance	Resistivity
1.00	15.8780
1.50	21.3150
2.00	26.2410
3.00	26.5420
5.00	26.7910
7.00	27.2330
10.00	36.2450
15.00	42.2570
20.00	81.2310
25.00	138.7600
30.00	208.2130
40.00	151.9700
50.00	125.1400
60.00	198.4300
70.00	166.3100
80.00	192.3800
100.00	233.5100



No	Res	Thick	Depth
1	17.6	0.7	0.7
2	25.5	3.3	4.0
3	45.7	2.4	6.4
4	767.8	21.4	27.8
5	117.8	9.6	37.5
6	249.3	---	---

Fig.4: Modelled curve from VES station close to(less than 1m offset distance from) producing hand-pumped borehole

The curve revealed that the first fresh basement surface is about 6m deep. This agrees with the expected implications of observed numerous fresh granitic outcrops. It also revealed the presence of fractured basement between 37 and 50m depth. This also agrees with the expected significance of observed fractured granitic outcrops. Hand pump drives water production from the borehole, and this indicates it produces water from fractured basement between 37 and 50m depth, which is captured in its geoelectric section (figure 4). The curve also reveals that the resistivity of the productive interval is less than 300?m.

The VES curves in the area include A, H, K, KH, HKH, QQH curve types. Of these, the HKH curve type is dominant. Figures 5, 6,7,8,9 and 10 are respective representatives of the A, H, K, KH, HKH,and QQH curve types in the area. The combinations of K with H, and Q with H curve types indicate there exists more than one fresh basement unit in the subsurface. Drilling has verified this subsurface geological situation in Minna region of North Central Nigerian Basement Complex, where regolith and fresh basement units are drilled through before penetrating fractured basement aquifer unit. The first fresh basement unit is expected to be very shallow in K, KH, and HKH curve types, as indicated by the numerous fresh granitic and fractured granitic outcrops observed in the area. The fractured basement sought for is below the first fresh basement unit, and shallower than 60m depth. Hence maximum electrode spacing of 140m will reveal their presence where they exist.

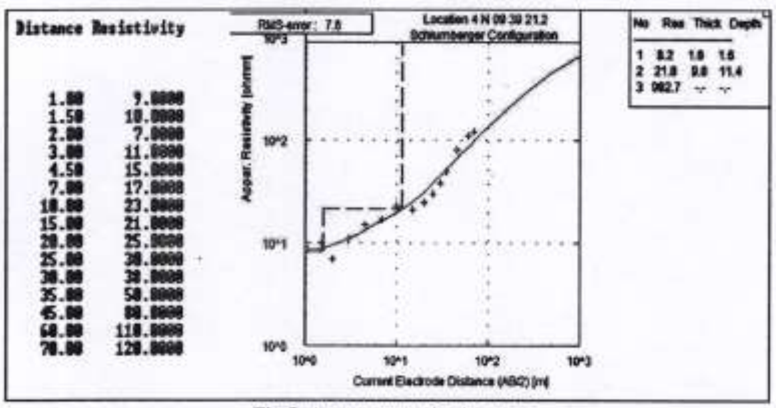


Fig.5: A-type curve in the area

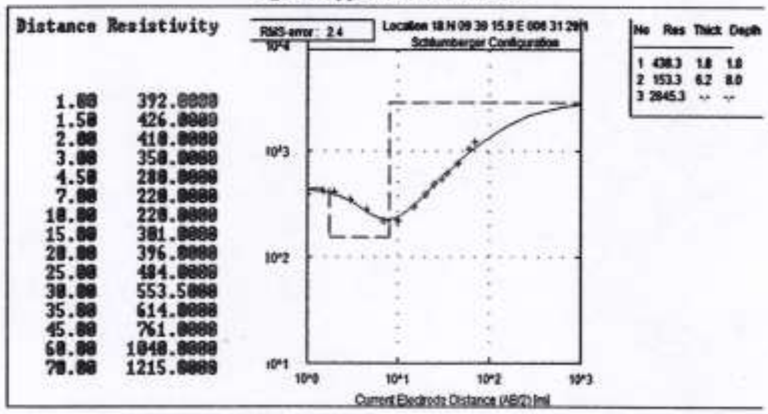


Fig.6: H-type curve in the area

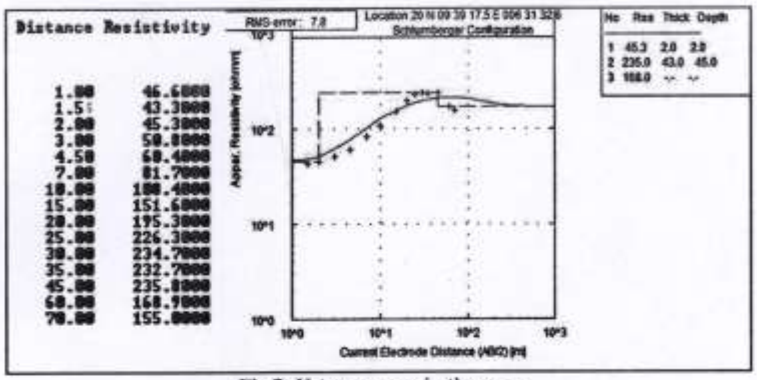


Fig.7: K-type curve in the area

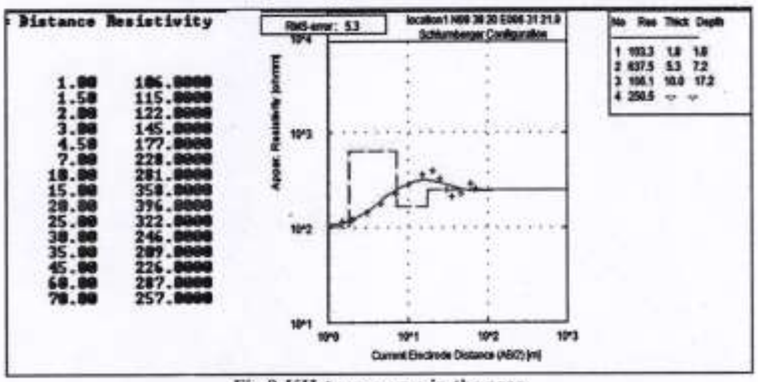


Fig.8:KH-type curve in the area

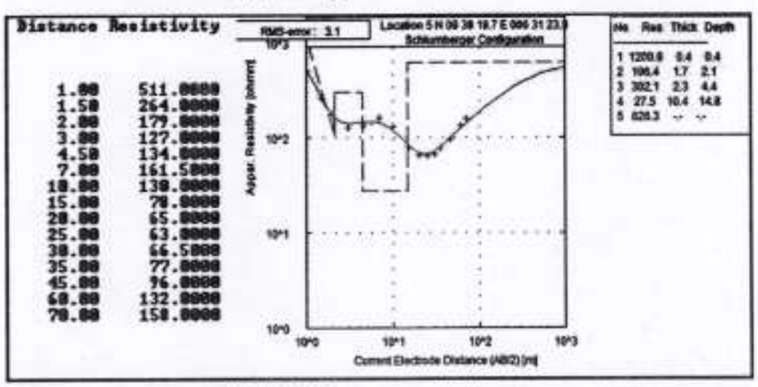


Fig.9: HKH-type curve in the area

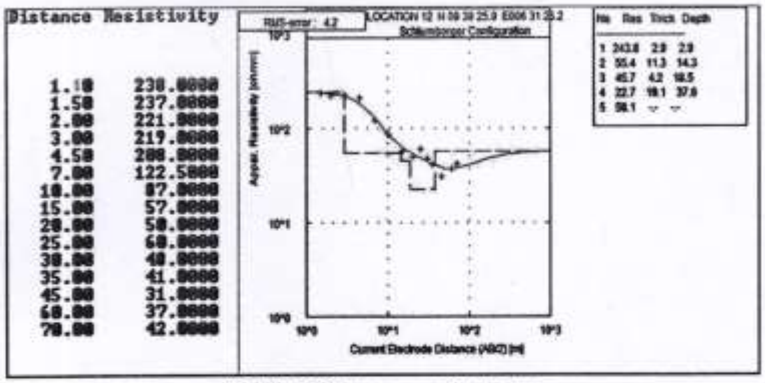


Fig.10: QQH-type curve in the area

Discusions:

Location 20 (Fig.7) is apparently the site with highest groundwater potential in the area. Its pattern of resistivity values indicates water-saturated fractures at depth in neighbourhood of 45m. Figure 11 is the modelled VES curve for VES data for location 14, which also appears to possess high groundwater potential because it indicates water bearing fractures between 9 and 14m, and between 18 and 34m depth.

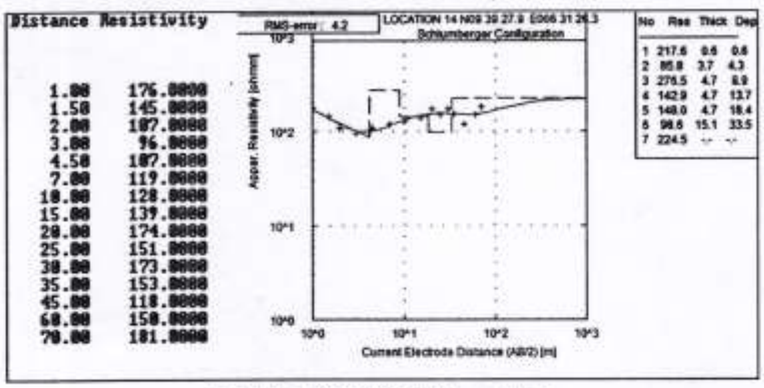


Fig.11: L 14(HKHKH VES curve type)

Figures 12 and 13 are respectively depth to the base map and resistivity map for the fractured basement unit. Fracture bottom at location 20 is deepest (between 28 and 52m) on the eastern portion of the investigated area (Fig.12). This implies that groundwater within fracture zone would flow and converge in the vicinity of location 20, in response to gravity. The resistivity within the groundwater convergence zone around location 20 is between 200 and 250?m. The depth range and resistivity value for this location are similar to those of the producing borehole. Locations 1, 8, 12 and 14(figures 12 and 13) are other locations that are characterised by the attributes of the productive borehole.

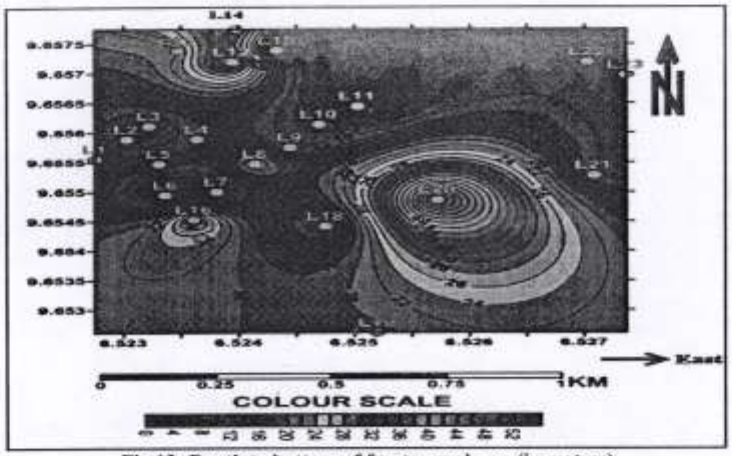


Fig.12: Depth to bottom of fracture column (in metres)

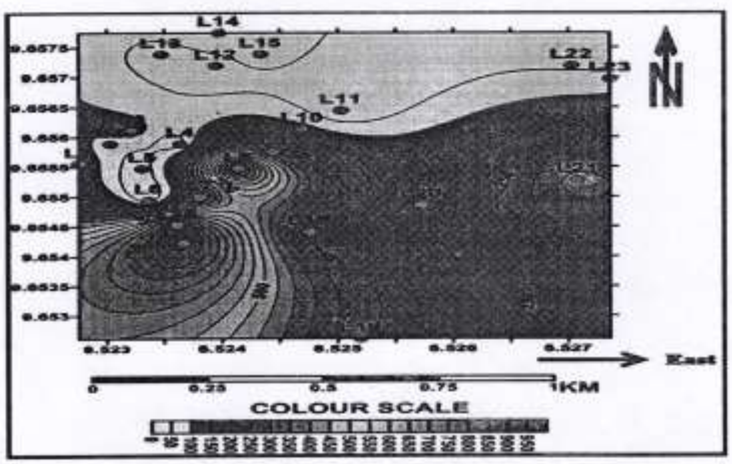


Fig.13: Resistivity variation in fracture column (in ?m)

Figures 14, 15, 16 and 17 are respectively the thickness, SP, T and S maps for the fractured basement interval. Fracture thickness around L20 varies between 6 and 9m (Fig.14) and the SP values vary between -19 and 20mV (Fig.15). T varies from 1200 to 2400 ?m^2 (Fig.16) and S varies between 0.05 and 0.1 ?$^{-1}$ (Fig.17). These geoelectrical parameters of L20 and its immediate vicinity are identical with those of the productive borehole site , which is characterised by 9.7m fracture thickness, SP values of -7 to 2mV, T value of 1143 ?m^2 and S value of 0.8 ?$^{-1}$.

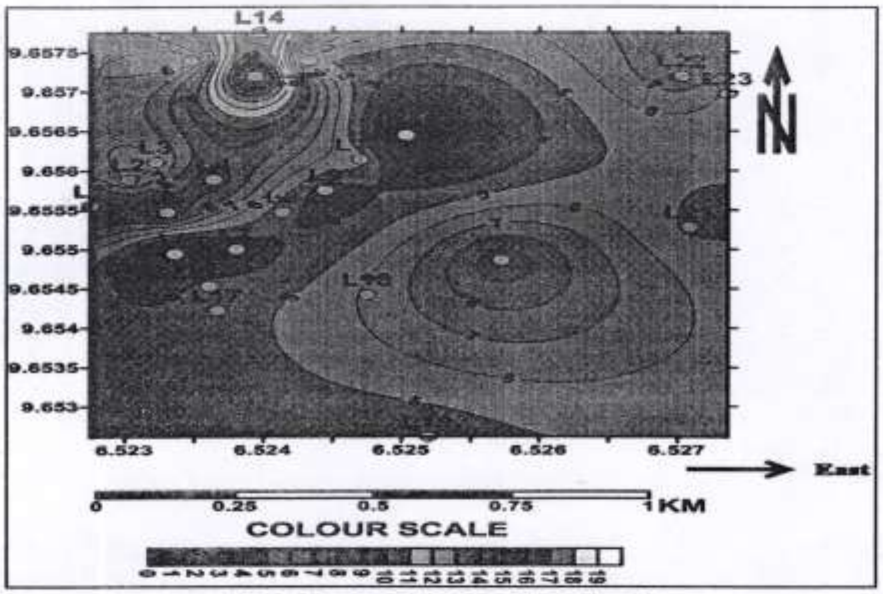


Fig.15: SP values of fracture column (in mV)

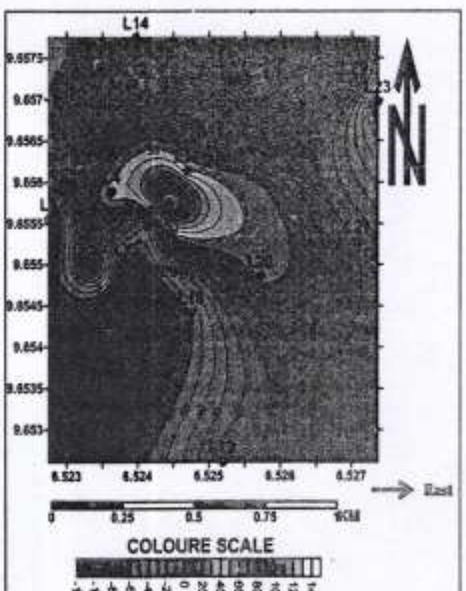


Fig.15: SP values of fracture column (in mV)

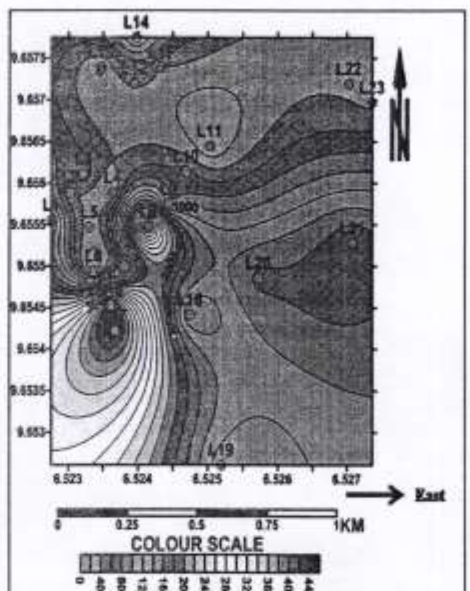


Fig.16: T values of fracture column (in ?m²)

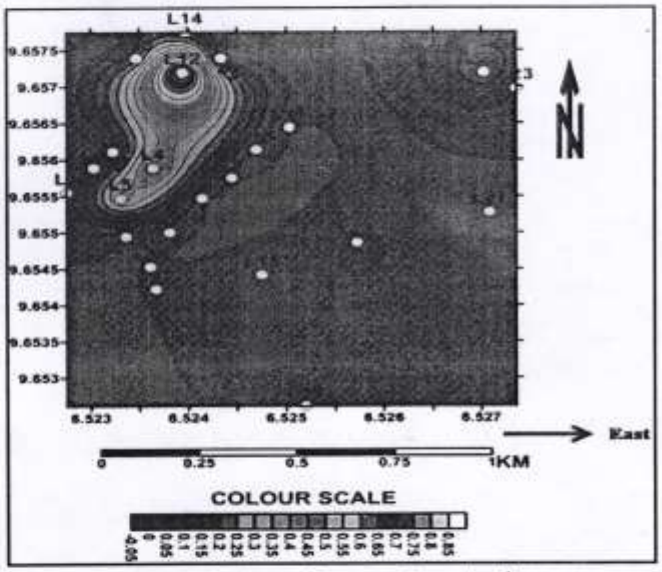


Fig.17: S values of fracture column (in ?$^{-1}$)

Gravity- induced groundwater convergence zone is expected in the NW portion of the area around L12 and L14, where depth to fracture bottom is between 26 and 34m (Fig.12), fracture thickness is between 11 and 18m (Fig.14) and SP values are between 0 and -10mV (Fig.15). Locations 12, 14 and 19 (like L20) have geoelectrical and Dar Zarrouk parameters that are identical with those of the productive borehole at Latitude 9.656°N and Longitude 6.527°E, about 0.23km north of VES L21.

These locations are markedly different from the location of the failed borehole at latitude 9.6568°N and longitude 6.527°E (about 0.187km NW of L11) in terms of depth to bottom of fracture column, fracture thickness, and fracture column resistivity (except at L12 and L14 where very low resistivity appears attributable to water-filled thick fracture column. The 140m maximum electrode employed in this study is in conformity with Kumar *et al.* (2015), who employed VES with maximum electrode spacing of 150m to capture water bearing fractures at 46m depth within basement terrain of Osmania University campus at Hyderabad in India. The resistivity values associated with the inferred water-filled fractures in this study are similar to values (between 100 and 300?m) reported by White *et al.* (1988) to characterise water-filled fractures in Victoria Province of Australia. Dan-Hassan and Olorunfemi (1999) established that all boreholes within groundwater convergence zone are productive within Kaduna town in North Central Nigeria Basement Complex. Ajiroba (2018) found that boreholes in Kadna region of North Central Nigeria Basement Complex produce water from fractures within groundwater convergence zone, which are characterised by SP values of -10 to + 30mv.

The failed borehole is located at a site where fracture thickness is 2m and the depth to bottom of fracture zone is about 4m (Figs. 12, 14, 13). This shallow depth of fracture bottom indicates the failed borehole is located within a divergence zone, from where groundwater flows to the convergence zones in its NW and SE. Groundwater convergence zones are commonly sites for productive boreholes, whereas the divergence zones are sites where boreholes are often unproductive (Olorunfemi & Okhue 1992; Olorunfemi 2009).

Concluding Remarks:

Vertical electrical sounding and spontaneous data have revealed the presence of subsurface fractured bedrock in the study area. Spatial variation in depth to bottom of the fracture column have revealed a groundwater convergence zone in the eastern sector around L20 and another convergence zone in the NW sector eastern sector around L14. Fracture column in the vicinity of L20 is thickest and most extensive, making the eastern sector most suitable for drilling water wells in the investigated area. Locations 12 and 19 are other sites with good potential for groundwater production. Borehole drilling can now be embarked upon on the basis of the revealed information to produce water for drinking and sanitary purposes at the Model College, Staff School, Catholic Church, and Interdenominational Church.

References:

Ajiroba, O.J. 2018. Integrated geological, hydrogeological and geo-electrical exploration for aquifers within kadna region, Minna sheet 164 SW, North Central Nigeria .B.Tech. Thesis, Federral University of Technology, Minna 127 pp.

Dan-Hassan, M.A. and Olorunfemi, M.O. 1999. Hydrogeophysical investigation of a basement terrain in the North Central part of Kaduna State, Nigeria. *Journal of mining and geology*, 36(2):189-206.

Kumar, D.V, Ramadan, G and Jagadish, S.V. 2015. Delinetion of groundwater potential zones through electrical resistivity parameter in hard rock terrains, Osmania University campus, Hyderabad, Jelagana State, India. *IOSR journal of applied geology and geophysics*, 11:01-10.

Musset, A.E. and Khan, M.A. 2009. *Looking into the earth: An introduction to geological geophysics*, 1st ed. Cambridge; Cambridge university press.

Okiongbo, K.S and Odubo, E. 2012. Geoelectric sounding for the determination of aquifer transmissivity in parts of Bayelsa State, South-South Nigeria. *Journal of Water Resource and Protection*, 4: 346-353.

Oladapo, M.I., Mohammed, M.Z., Adeoye, O.O., and Adetola, B.A. 2004. Geoelectrical investigation of the Ondo State Housing Corporation, Ijapo, Akure, Southwestern Nigeria. *Journal of Mining and Geology*, 40(1): 41-48.

Olayinka, A.I, Obere, F.O. and David, Jr, L.M 2000. Estimation of longitudinal resistivity from Schlumberger sounding curves. *Journal of Mining and Geology*, 36 (2): 221-229.

Olorunfemi, M.O. and Okhue, E.T. 1992. Hydrogeologic and geologic significance of a geolectric survey at Ile-Ife, Nigeria. *Journal of Mining and Geology*, 28 :2

Olorunfemi, M.O. 2009. Groundwater exploration, borehole site selection and optimum drill depth in basement complex terrain. *Water Resources* Special Publications Series 1: 20.

Paranis, D.S. 1986. *Principles of Applied Geophysics*, 4th ed. New York; Chapman and Hall.

Raghunath, H.M. 2006. *Groundwater*, 3rd ed. New Delhi; New Age.

White, C.C., Houston, J.F.T. and Barker, K.D. 1988. The Victoria Province drought relief project, 1, Geophysical siting of boreholes. *Ground Water*, 26: 309-316