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GEOPHYSICAL INVESTIGATION OF WESTERN PART OF FEDERAL UNIVERSITY OF TECHNOLOGY, GIDAN KWANO CAMPUS, MINNA, NIGER STATE, USING ELECTRICAL AND SEISMIC REFRACTION METHODS

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Abstract

A geophysical survey of western part of Federal University of Technology, Gidan Kwano Campus, Minna, was carried out using Electrical Resistivity (VES) and Seismic refraction methods. The aim of this survey was to determine the ground water potentials of the area and to also locate those areas that could be useful for civil engineering purposes. Careful interpretation of the seismic data obtained shows two geologic sections within the survey area. The first layer has an average seismic velocity value of 1237.86 ms^{-1}. The second layer is the refractor layer whose seismic velocity average is 4581.67 ms^{-1} and has an average depth of 4.74m. The results obtained from the electrical resistivity method also shows that the survey area consists of three geoelectric/geologic layers. The first layer has resistivity values between 20Ωm and 200Ωm, which represents topsoil the second layer has resistivity value ranging from 200Ωm to about 900Ωm and typifies weathered and fractured basement. The fresh basement forms the third layer with resistivity value above 1000Ωm. The results obtained from both methods shows that the area appropriate for ground water development were found in the north-east and north-central portion of the survey area with aquifer systems of 100m in width and depth between 3.8m and 25m. Similarly the site most appropriate for civil engineering purpose could be located at the southern part of the survey area where the fresh basement is shallow.

Keyword: Seismic refraction, Seismograph, Refractor Depth, Velocity, Lithology, Aquifer Geoelectric, Resistivity, Basement and Vertical Electrical Sounding (VES)

Introduction

The growth of any community is a function of availability of basic infrastructural needs like water, roads, electricity and industries among others. Groundwater is of significant importance to Northern Nigeria where the amount of rainfall is limited to very few months of the year with annual rainfall of 1000-1500mm [Eduvie, 1998]. Surface water sources are often inadequate or non existent [Baimba, 1978 and Perez and Barber, 1965]. There is then need for scientific identification of parameters governing ground water resources, assessment and management, particularly if satisfactory living conditions of the inhabitants are to be catered for. The University has relocated three schools out of her four schools or faculties from Bosso Campus to Gidan Kwano Campus. Consequently, there would be an increasing demand for portable water supply to complement the existing one on campus and the need to delineate the areas that would be suitable for civil-environmental development.

The Federal University of Technology (F.U.T), Gidan Kwano Campus, Minna, is located at Km 12 along Minna-Kateregi Bida road. The study area is located within the university campus and is about 1.8 km away from Minna-Kateregi Bida road, directly behind the student hostel, Figure 1. Federal University of Technology, Gidan Kwano Campus, Minna, is part of Minna NW sheet 42, on a scale of 1:250,000. It lies between latitude $9^{0}28'$N and $9^{0}37'$N and longitude $6^{0}23'$E to $6^{0}29'$E. The site covers an area of about 100,000 hectares with three defined sectors; North, Central and Southern sectors [Works Department, Federal University of Technology, Minna, 1983]. The study area is displaced from a minor road that passes besides girls' hostel block which is about 65m south of the road and covers 500m x 250m as shown in Figure 1.

The rock types found in the study area are believed to be part of the older granitic suite and are mostly exposed along the river channel where they appear in most cases weathered [Udensi et al, 1986]. The major rock types are porphyritic, medium to fine grained granite [Adesoye, 1986 and Adeniyi et al, 1988]. The results of the borehole log from the area show that the area has a good potential for ground water development [Jimoh, 1998].

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The VES method was chosen for electrical method of survey because it has proven to be an economic, quick and effective means of solving most ground water problems in different parts of the world [Brusse, 1963, Zohdy and Jackson, 1969 and Frohlich, 1974]. The method is also used to estimate the thickness of the overburden as it is presented in this work [Parasnis, 1987]. Similarly, seismic refraction method was also chosen as the second geophysical method so as to complement the results of the electrical method. Seismic method was chosen, because it is substantially less expensive compared to reflection, particularly when used as reconnaissance tool in newly explored area like the case of this survey. It is also the most important geophysical technique in terms of expenditure and number of geophysicists involved. The predominance of the seismic method over other geophysical methods is due to various factors, the most important of which are the high accuracy, high resolution and great penetration of which the method is capable. Furthermore, seismic refraction method is best suited for groundwater search and civil engineering work (Telford, et al, 1976).

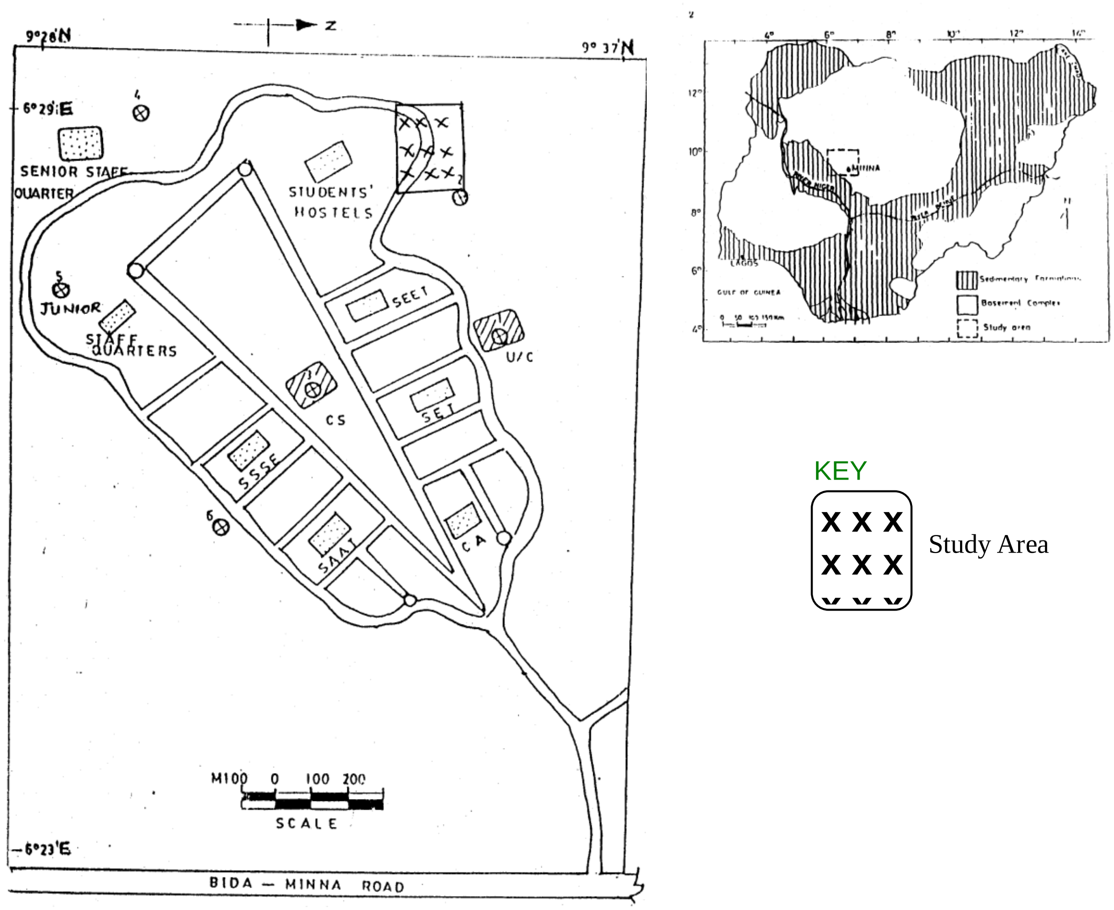

Fig. 1: Map of Federal University of Technology, Gidan Kwano Campus, Minna. Showing the Location And Accessibility of the Study Area and The Geologic Map of Nigeria

The main objective of this survey is to detect and delineate the geologic sections beneath the semi-consolidated and consolidated sediments through the appropriate interpretation of the measured physical properties (velocities and resistivity values of rock samples) of various lithologies from the field. These physical properties would also be used in conjunctions

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with already published work so as to justify the geologic information of the given rock. The results from these would then be used to draw conclusion to locate the possible sites within the study area where ground water development could be better sited and where civil engineering purposes could be better done.

Data Collection

The study area was gridded as shown in Figure 2, the survey area was covered by six profiles and each profile was 500m long. The inter grid spacing and that of inter-profile spacing were 50m apart respectively. Sixty-six (66) VES and SHOT points were covered. The Terrameter SAS 4000 was the instrument used to collect data for electrical resistivity method and Schlumberger array method was employed.

Similarly, the instrument used to collect seismic data was the three-channel enhancement seismograph. Eleven shot points and VES points were recorded on each profile for both methods. At each shot point the arrival times for each of the geophones were recorded. Successive shots were taken at uniform intervals along each line and successive detector spreads were shifted about the same distance as the corresponding shot points in order to keep the range of shot-detector distance approximately the same for all shots. This arrangement was chosen such that the first arrivals will be refracted from formations of interest such as basement.

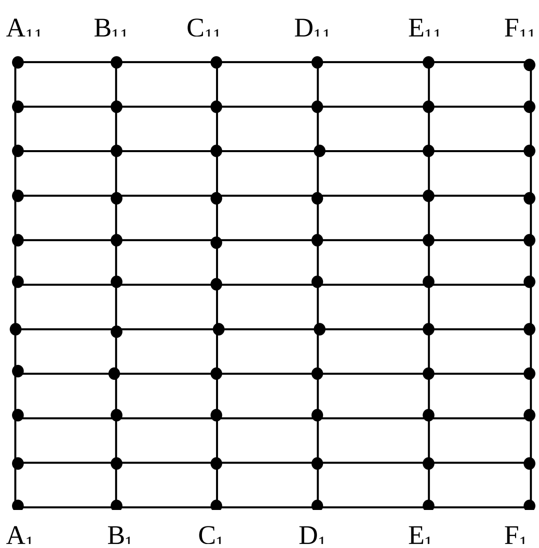
Since the seismograph used was three-channel, the three geophones were laid three times for each shot point with 5m interval, such that, at each shot point, a total distance of 45m was covered and nine geophones readings were recorded.

Data Analysis

The velocity of seismic wave in a homogeneous solid medium is a function of the elastic constants and the density of the materials making up the medium (Gardner, *et al,* 1974).

From Table1, seismic velocity information can be correlated with rock type and can therefore be used in identifying subsurface materials. Due to the overlapping of velocities for different rocks, it is not advisable to restrict the identification of rock type exclusively to velocity. It can however be used in a small area where range of velocity is small and therefore certain rocks can be identified based on velocity. Surfer8, a graphic computer package was then used to produce the contour maps of the first layer velocity, second layer velocity and the refractor depth.

The VES interpretation was done using an iterative computer program, called Zohdy software. This program performs automatic interpretation of the Schlumberger sounding curves. The curve gives the equivalent n-layered model from the apparent resistivity of each sounding point. Surfer8 was then used to produce the contour maps of data deduced from the Zoddy interpretation.



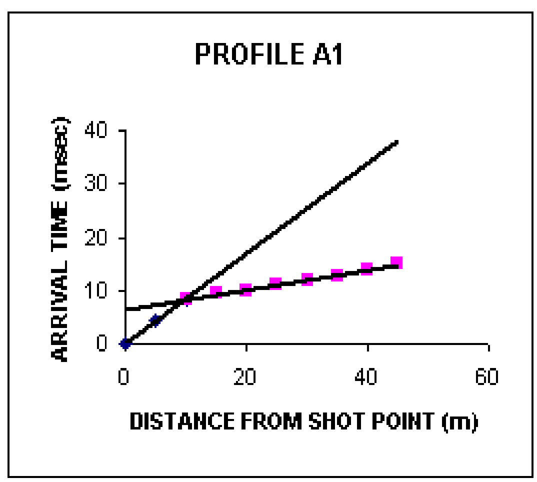


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Fig.ure 2: The survey Layout in a gridded format

Fig. 3a: A typical time-distance graph

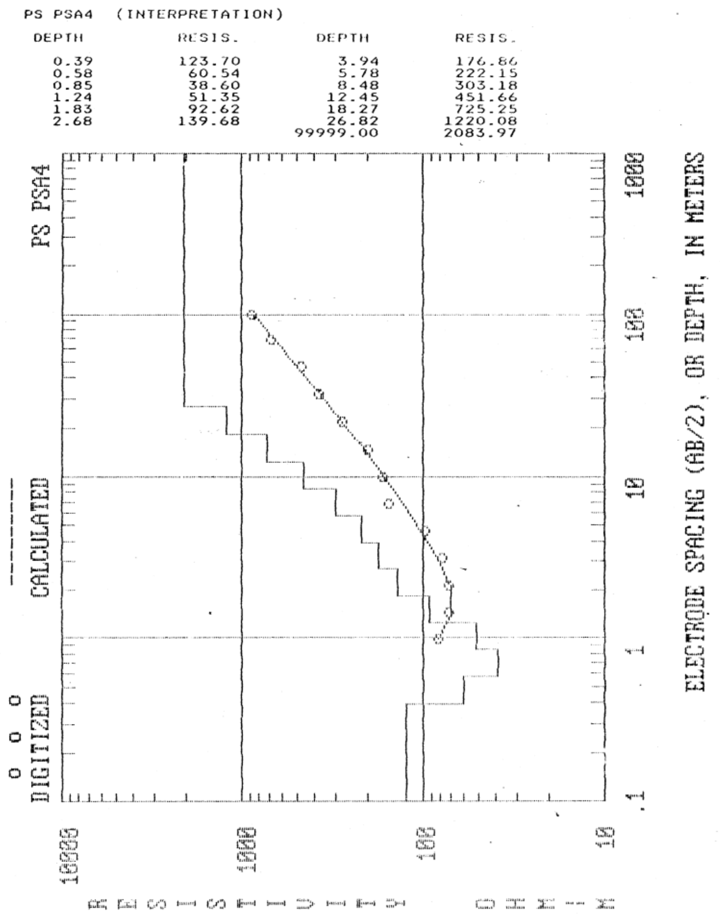

Fig. 3b: A typical Zohdy n-layered geoelectric curve of the sub-surface

The interpreted Zohdy model was used to construct the following maps, which enhanced a very detailed interpretation of the field data obtained:

(i) Contour map of geoelectric sections along profiles
(ii) The Iso-resistivity contour maps at different depth and
(iii) Depth to basement or overburden thickness contour map

For easy and accurate interpretation of the results of the VES, vertical electrical section of each profile was derived from the Zohdy curves and contoured. The geologic section of each of the profiles was derived from the geoelectric vertical-sections using the available resistivity values of rock types in basement area (Table 2).

Table 1: Measured seismic velocity in rocks (Telford et al, 1976)

Rock Type	VELOCITY (m/s^2)
Alluvium	350 – 2000
Clay	UP TO 2500
Dry Sand/Gravel	500 – 1000
Sandstone	1000 – 4300

Limestone	1700 – 4200
Shale	1000 – 4300
Granites	UP TO 7700
Metamorphic Rocks	3000 – 7700

Table 2: Resistivity values of Rock types in basement Area [Ajayi and Hassan, 1990]

Rock Type	**Resistivity (ohm-m)**
Fadama loam	30 – 90
Sandy	100 – 200
Sand and Gravel	100 – 180
Weathered Laterite	150 – 900
Fresh Laterite	900 – 3500
Weathered Basement	20 – 200
Fractured Basement	500 – 1000
Fresh Basement	>1000

The processing of seismic data on the other hand is often based on the first arrivals, since it permits accurate interpretation and easy recording of their travel times. The Wyrobek method (Telford, et al, 1976) was used to analyze the data. This uses graphic aids to facilitate the routine computations. Based on the Wyrobek approach and on the field data, a plot of the travel time (T) versus the detector position of all the receiving stations along each profile was obtained (The time distance graph was plotted (using Excel package), figure 3). The slopes of these graphs were then used to obtain the average velocities, V_1 and V_2 for both the first layer and the refractor. The intercept time was also determined from the graph. To obtain the depth to refractor at each shot point, the intercept time was divided by two to give the half-intercept time often called the delay time D. Values of the delay time D at each shot point were thus multiplied by an appropriate factor F to obtain the depth. For a homogeneous overburden as assumed for this survey:

$$\text{Slope} = \frac{\text{Change in time}}{\text{Change in distance}}$$

$$V = \frac{1}{slope}$$

This procedure is carried out for all the shot points to obtain V_1 and V_2, the velocities of the first layer and the refractor respectively. These two velocities along with the intercept time yield depth to refractor as given in the equation below

$$Z = \frac{T_i}{2} \cdot \frac{V_1 V_2}{\sqrt{\left(V_2^{\,2} - V_1^{\,2}\right)}} \qquad (1)$$

Data Interpretation

The subsurface vertical sections through profile A - F are shown in figure 4 to 9 respectively. These maps were contoured at an interval of 300Ωm.

From figures 4 to 9 indicate that C3, to C5 and C10; A4 to A6, A9 and A11; B2, B5 and B7; D4; E2 and E6; F1, F2 and possibly F9 to F11 are depressions (valley) that may likely be good potential for underground water. The following are the lithology layers and their thicknesses as obtained in this work with respect to Table 2 above:

(i) First layer consists of dry Lateritic topsoil, fadama loam, sandy-clay, and gravel and has resistivity values below 300Ωm with thickness between 0.39m to about 20.0m

(ii) The second layer consists of weathered and fractured basement with thickness between 3.8m to about 25m, its resistivity values ranges from 300Ωm and about 900Ωm. This constitutes the aquifer system of this area.

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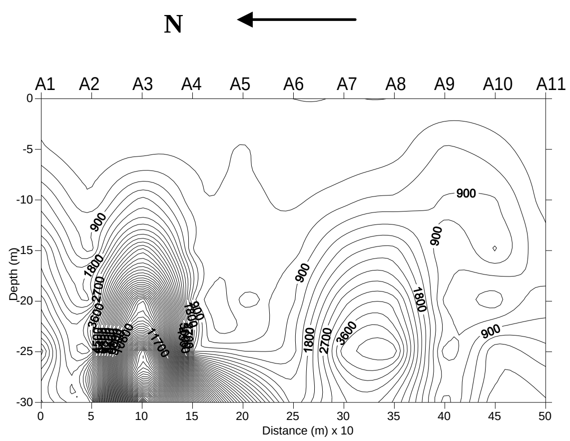
(iii) The third layer is the fresh crystalline basement, which constitutes the bedrock of the area and has infinite thickness.



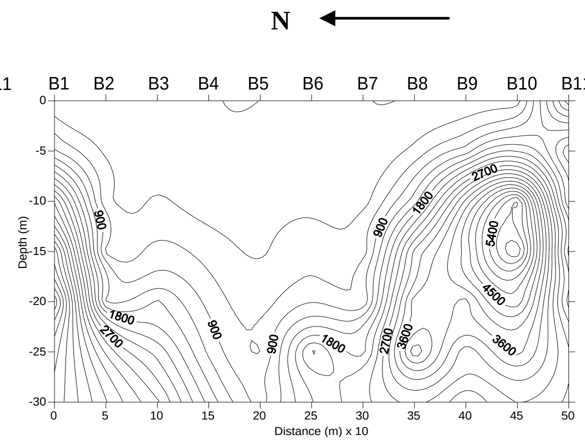


Fig.4: Geoelectric Vertical section along Profile A (Contour Interval is 300Ωm)

Fig. 5: Geoelectric Vertical section along Profile B (Contour Interval is 300Ωm)

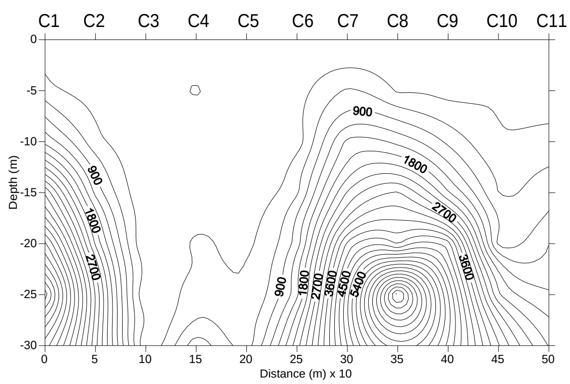


Figure6: Geoelectric Vertical section along Profile C (Contour Interval is 300Ωm)

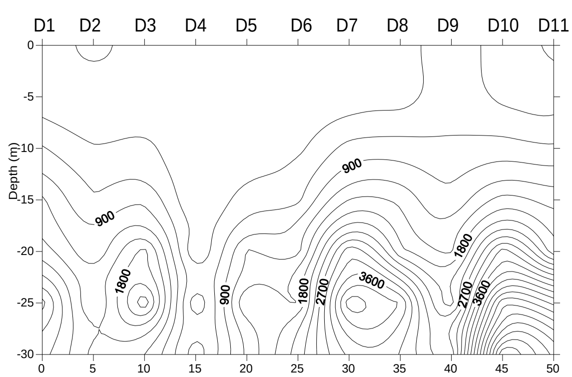
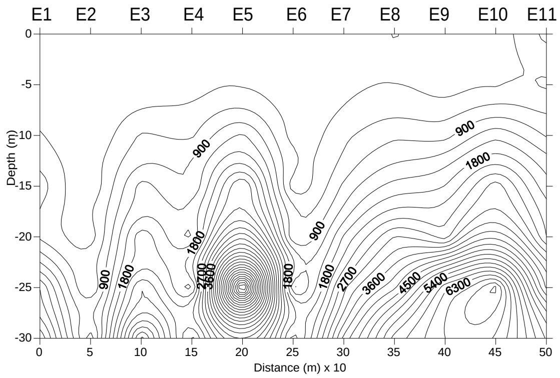


Figure7: Geoelectric Vertical section along Profile D (Contour Interval is 300Ωm)



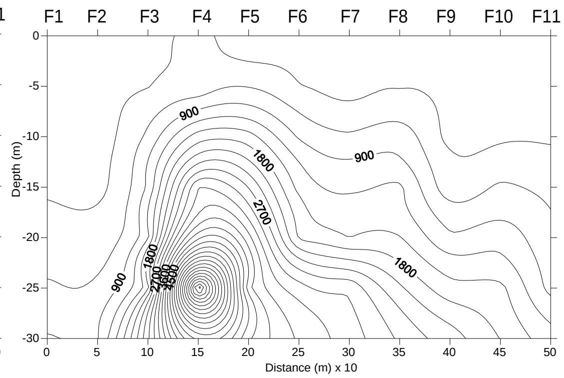


Fig.8: Geoelectric Vertical section along Profile E Profile F (Contour Interv al is 300Ωm)

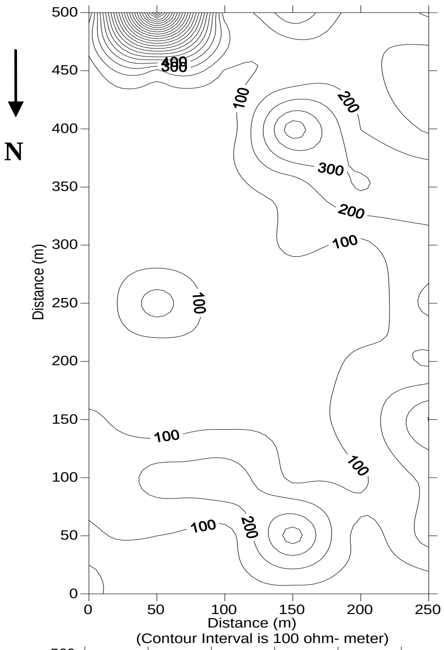
Fig. 9: Geoelectric Vertical section along (Contour Interval is 300Ωm)

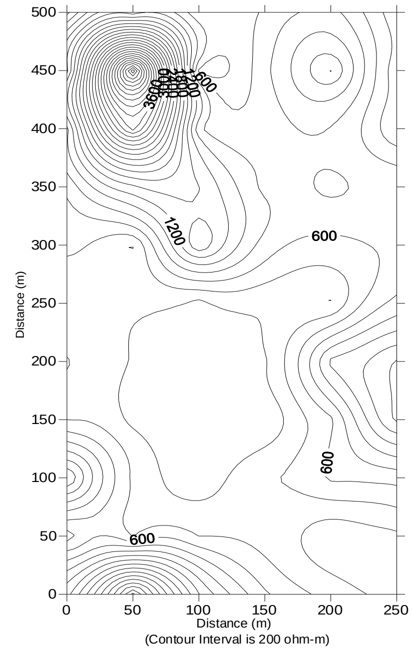
Interpretation of Iso-resistivity Contour Map at Various Depths

Iso-resistivity maps show the conductivity pattern with depth through slicing of the entire study area horizontally or through a cross-section. The cross-sectional maps were used to corroborate the results of the vertical sections. These maps include the resistivity map of the topmost layer and iso-resistivity maps at depth of 5m, 10m, 15m, 20m, 25m and at 30m. For illustrations, few of these maps were presented here. The deductions made from them are as discussed below.

Figure 10 shows the iso-resistivity contour map for topsoil. The map was drawn at contour interval of 100Ωm. The map shows a spatial variation of the resistivity of the topmost layer, which could be used to compare with the surface features like stream and exposed outcrops. The entire surface of the study area shows low resistivity values ranging between 100Ωm and 200Ωm, which covers most part of the area except at southeastern part, which show high resistivity value.

A B C D E F A B C D E F A B C D E F





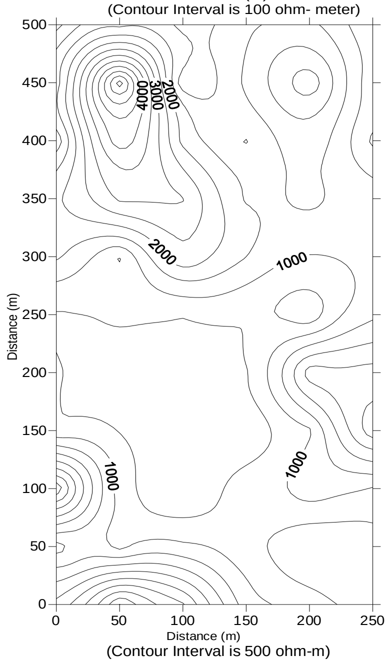


Fig.10, 11 and 12,: Iso-Resistivity Contour Map of topsoil, 10m Depth and 15m Depth respectively

The Iso-resistivity contour map at 10m depth was contoured at 200Ωm interval as shown in figure 11. The resistivity value of 200Ωm to 400Ωm could be observed at central, north eastern, south-western and north-western part, this zone may likely show saturated or nearly saturated (water) horizons. The fractured or fairly weathered basement could be found prominently at south-western part of the map (i.e. VES D8, D9, E8, E9, F8 and F9) with resistivity value ranging between 400Ωm and 600Ωm. Very high resistivity value of 1000Ωm was found prominent at south-eastern part and VES B1. They are fresh basement rock.

The Iso-resistivity contour map at 15m depth, figure 12, was contoured at 500Ωm

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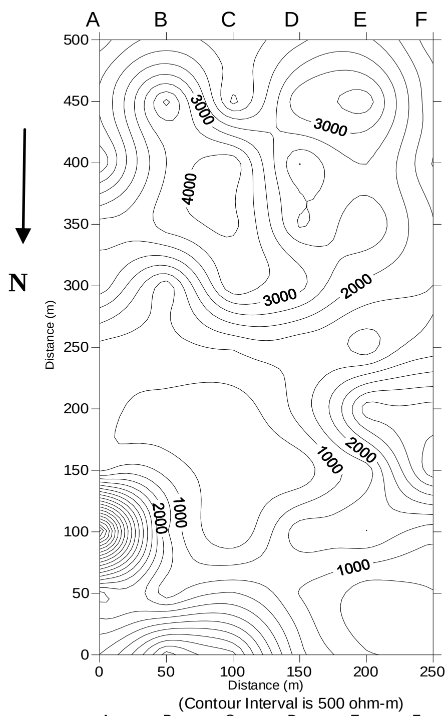
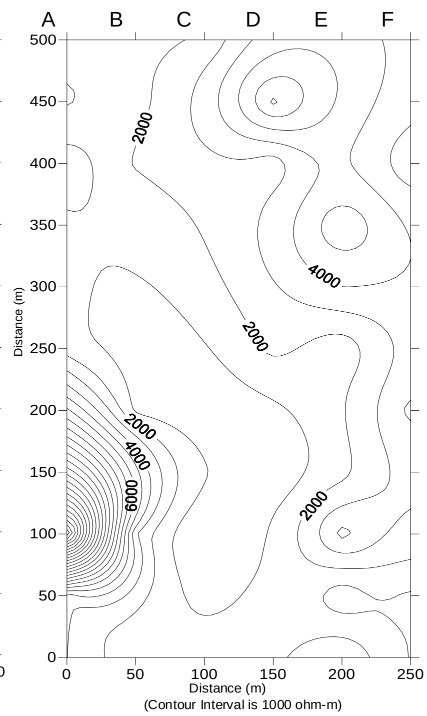
interval. This is very similar to map obtained at 10m depth only that those areas that are said to be fractured now have the resistivity value of 1000Ωm and above and this corresponds to the shaded part of figure 15.

The Iso-resistivity contour map at 20m-depth, figure 13, was contoured at 500Ωm interval. Areas delineated with less than 1000Ωm are likely to contain weathered and fractured basement rock. The Iso-resistivity contour map at 30m-depth, figure 14, was contoured at 1000Ωm interval. The area characterized with resistivity value within 1000Ωm corresponds to the shaded area of figure 15.





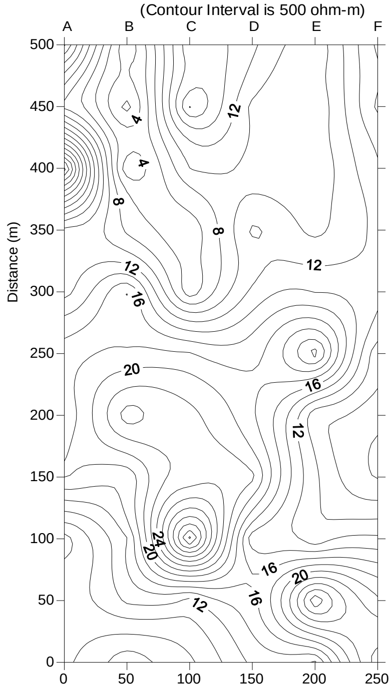


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Fig. 13, 14 and 15: Iso-resistivity contour Map at 20m Depth, 30m Depth and Depth to Basement contour Map Respectively

Map of Depth to Basement

Figure 15 is the depth to basement map contoured at 2m intervals. It shows that the basement varies between 4.0m and about 36.0m. The southeastern region of the survey area is characterized as having a shallow basement. This could be attributed to heavy outcrop of granite found at the surface. Thus the overburden is said to be thinnest at those area. The deepest basement (36.0m) is found at C3. The areas with overburden thickness or depth to basement between 16m to about 36m correspond to the shaded area of the figure 15. The results of the iso-resistivity and depth to basement maps corroborate the results from the vertical section maps. The sounding point C3 shown in figure 6 is well corroborated by figure 15.

Interpretation of Seismic Data

The most important parameter used in interpretation of seismic work is the velocity. This is the rate at which the acoustic energy propagates through the various units of the sub surface. This seismic velocity information within certain limits is converted into rock type in an attempt to identify the sub surface materials. The time distance graph was plotted (using Excel package). Figure 3 is a sample of the resulting time-distance graph plotted with data from shot A_1. The graphs show a two-layer case. The slopes of the two layers were calculated, and the inverse of the slopes gives the values for V_1 and V_2. The depth to refractor was also calculated using the relation in equation 1 above. This was done for all the shot points.

For example, table 3 shows a two-layer case (model) for profile A. The first layer velocity varies from 716.33 m/s to 1538.46 ms^{-1} with an average of 1149.70 ms^{-1}. The second layer velocity varies from 1935.36 ms^{-1} to 6666 ms^{-1} with an average of 4616.93 ms^{-1}.

Table 3: Interpreted Parameters along Profile A

Shot Point	First Layer Velocity V_1 (M/S)	Refractor Velocity V_2 (M/S)	Depth To Refractor Z(M)
A1	1190.48	5405.41	4.27
A2	1149.43	4906.77	4.73
A3	716.33	3145.64	6.62
A4	1204.82	6622.52	3.98
A5	1176.47	1935.36	3.70
A6	1111.11	4570.38	4.87
A7	1176.47	3236.25	5.05
A8	1538.46	6666.67	3.95
A9	1086.96	3571.43	4.91
A10	1315.79	5476.45	4.07
A11	980.39	5249.35	4.49

The depth to refractor varies from 3.7 m to about 6.62m with an average of 4.60m. This process was repeated for all other profiles, however, following this process, summary table; table 4, 5 and 6 were obtained.

Table 4, shows the summary of the first layer velocity for all the profiles. Based on the values on this table, the first layer velocity throughout the entire survey area varies between 716.33 ms^{-1} to 2024.29 $ms^{-1.}$ It is clear from Table 1 that the velocity values obtained for the first layer over the entire survey area can be easily correlated with the materials found in the superficial layers. It was also observed on the field that this superficial layer is composed of clay, dry sand and gravel according to Table 1.

The contour map of the first layer velocity V_1, figure 16 was produced by the use of surfer 8 contouring package.

Figure 16 show that there are closures around the fourth and sixth shot point on the third profile (i.e. around north, south and central portion of the survey area). We can also observe some closures at the boundaries of the entire area. The points marked H are the areas of high closures at the centre of which we obtain the highest velocity. Also the point's marked L are point of low closures.

Table 4: First Layer Velocity, V_1 (m/s)

Short Point	Profiles					
	A	**B**	**C**	**D**	**E**	**F**
0	1190.48	1666.67	1111.11	1582.28	1492.52	961.54
50	1149.43	1234.57	1190.48	1492.54	1219.51	1488.10
100	716.33	1369.86	909.09	1201.92	1388.89	862.07
50	1204.82	1052.63	2118.64	847.46	1412.43	1510.57
200	1176.47	1666.67	1366.12	877.19	1428.57	1201.92
250	1111.11	1190.48	2024.29	1333.33	847.46	1000
300	1176.47	869.57	1538.46	740.74	1392.76	1250
350	1538.46	1250	1052.63	1052	1084.60	1312.34
400	1086.96	1250	1187.65	1146.78	1666.67	1428.57
450	1315.79	1063.83	934.58	1250	1282.05	1250
500	980.39	1176.47	1000	847.46	1388.89	1587.30

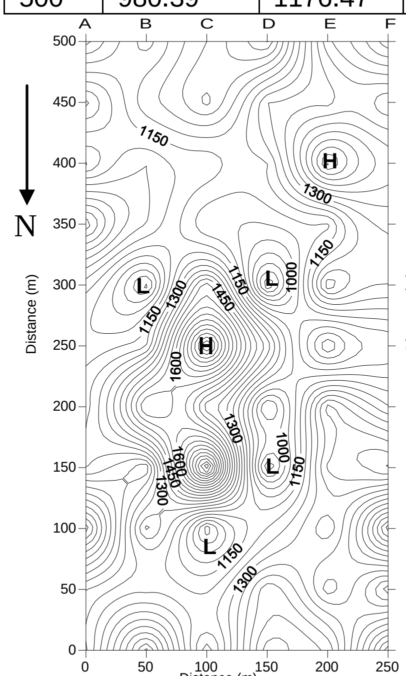

Fig. 16 contour map of first layer velocity (contour interval is 50m)

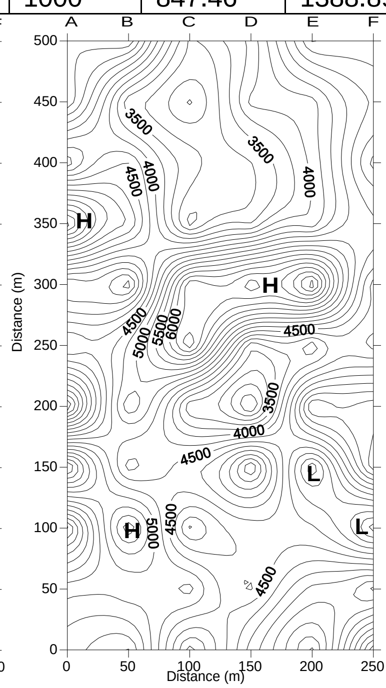

Fig. 17 contour map of second layer velocity (contour interval is 250m)

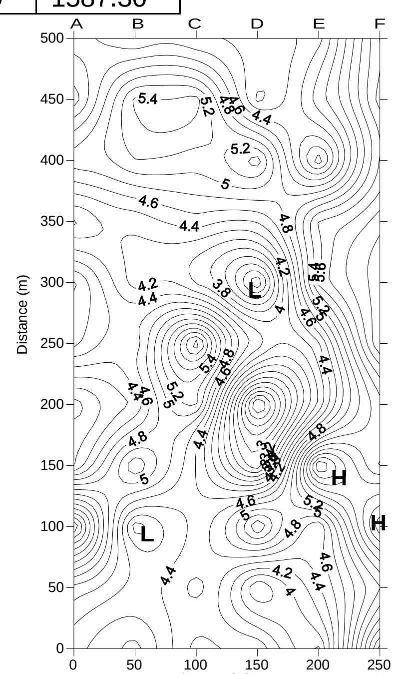

Fig. 18 contour map of Refractor Depth (z) (contour interval is 0.2m)

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The values in table 5 shows the velocity of the second layer throughout the survey area, it vary from 1935.36 ms^{-1} to 7485 .03 ms^{-1}. The contour map for V_2 (second layer) was obtained, as figure 17.

The points marked H on this contour map are the areas having high velocities. The points marked L are the areas of low velocities. High concentrations of closures were also observed around the eastern and western portion of the survey area.

Table 5: Second layer velocity V_2 (ms^{-1})

Short point	Profiles					
	A	B	C	D	E	F
0	5405.41	5770.34	3623.19	5109.86	6305.17	3544.84
50	4906.77	4837.93	5096.84	4217.63	5330.49	5834.31
100	3145.64	5973.72	3680.53	4374.45	4293.69	3076.92
150	6622.52	4130.52	4714.76	6049.61	3271.18	5931.20
200	1935.36	5216.48	3293.81	2431.32	5800.46	5668.93
250	4570.38	4784.69	6706.91	3541.08	3573.93	3906.25
300	3236.25	2828.05	6480.88	6666.18	7485.03	4116.92
350	6666.67	4995.00	2888.50	3468.61	4081.63	4965.24
400	3571.43	4516.71	3397.89	3240.44	4078.30	5599.10
450	5476.45	3317.85	2707.83	4078.30	4154.55	5030.18
500	5249.34	5476.45	3204.10	3810.98	5518.76	5405.41

The depth to refractor contour map figure 18 was obtained from table 6. The refractor depth varies from 1.88m to about 6.66m with an average of 4.72m over the entire survey area.

Table 6: Depth to the refractor (Z) in m.

Shot point	Profiles					
	A	B	C	D	E	F
0	4.27	3.92	4.67	3.40	3.76	6.50
50	4.73	4.34	4.28	3.59	4.38	5.38
100	6.62	3.87	4.46	3.53	4.40	6.58
150	3.98	5.40	4.36	3.00	6.66	5.36
200	3.7	4.22	5.25	1.88	4.05	5.53
250	4.87	4.48	3.80	4.32	5.85	6.42
300	5.05	5.6	3.96	2.79	3.60	6.30
350	3.95	4.26	4.52	4.42	5.63	6.12
400	4.91	5.20	5.07	5.52	5.70	5.62
450	4.07	5.45	5.48	3.94	4.72	5.9
500	4.49	4.20	4.21	4.13	4.31	5.81

The points marked H on it are indicating the areas with the high depth to the refractor. The points marked L are the areas where the low depths to the refractor were observed. High concentrations of closures were also observed around the western, portion of the survey area.

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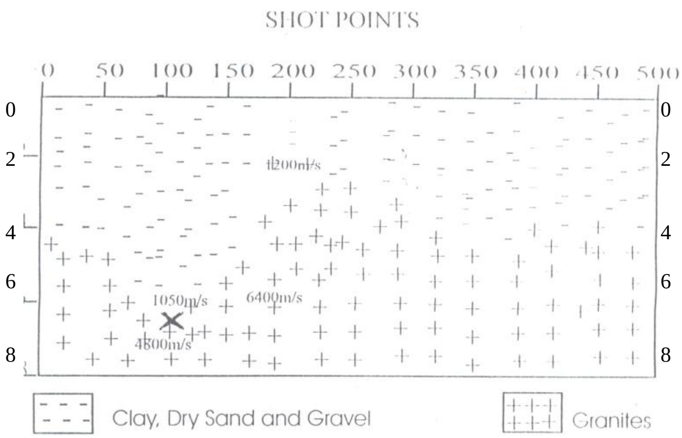

Fig. 19a Geologic Sections along Profile A

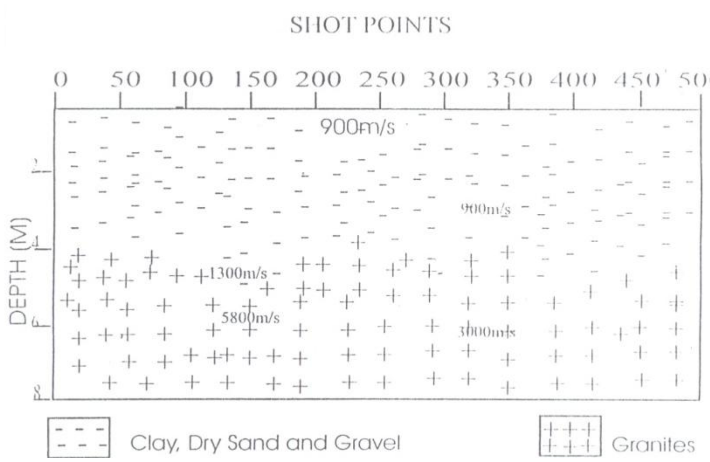

Fig. 19b Geologic Sections along Profile B

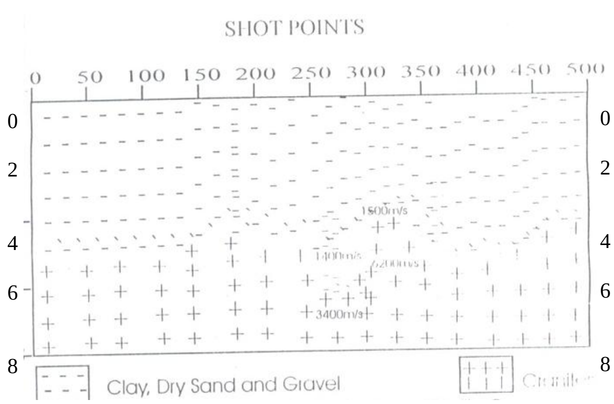

Fig. 19c Geologic Sections along Profile C

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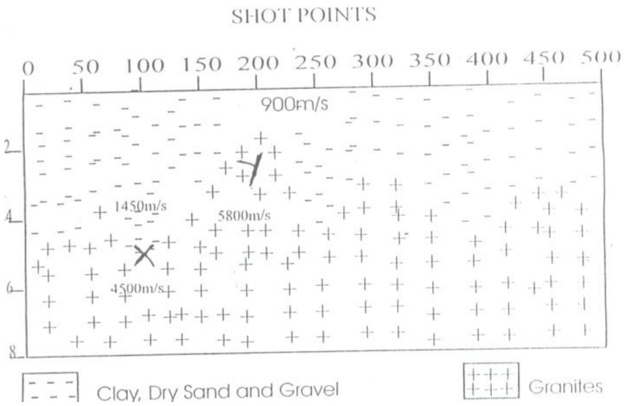

Fig. 19d Geologic Sections along Profile D

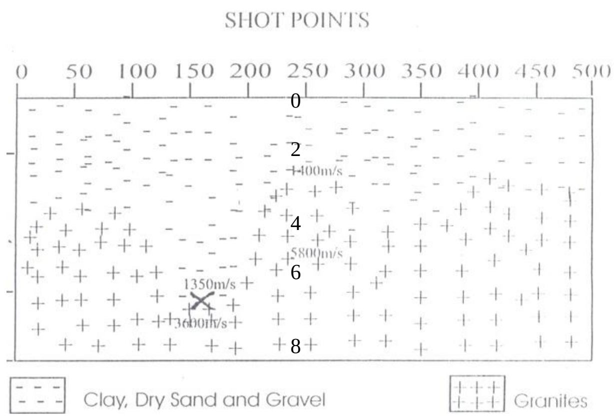

Fig. 19e Geologic Sections along Profile E

Figures 19a to 19e shows the geologic sections along profile A to E. These figures were obtained jointly from table 2 and table 6. These figures are very similar to figure 18. The deductions from those figures had been summarized with tables 4, 5 and 6, with adequate and appropriate referenced to table 2. The point marked X on profile A (figure 19a) has first layer velocity of 1050m/s, the second layer velocity is 4800m/s and the depth (overburden thickness) to the refractor is 6.6m.

Discussion

From the VES data, the thickness and the resistivity values of different layers were determined. There were three geologic units found beneath VES station, which revealed various lithological compositions of various layers delineated. The geologic sections formed revealed that the first layer consists of lateritic topsoil, fadama loam, sand-clay and gravel. The second layer suggests the presence of weathered and fractured basement, while the third layer constitutes the fresh basement of the area.

The map of depth to basement, figure 15 shows that, areas with outcrop of rocks are the areas that have their basement uplifted and therefore have thin overburden. This is prominent at southern part and northeastern part. The areas with basement depth between 18.0m and 32.0m are the areas characterized by lowland and fadama. This area corresponds to the shaded region of figure 15 and is

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therefore characterized with very thick overburden.

There are about three main factors that determine the areas suitable for ground water exploitation, these are: (i) the conductivity of the subsurface, [Aboh *et al*, 1996].

(ii) The presence of suitable aquifer and
(iii) The thickness of the aquifer

From the above factors, zones or areas that will be considered to be suitable for ground water exploitations are the weathered basement, which is the major component for aquifer system. Aquifer system in the basement areas was classified to consist of weathered and fractured basement [Ajayi, and Hassan, 1990, Dogara, 1995]. Thus, where the fractured zone is saturated, relatively high groundwater yield can be obtained from borehole penetrating such a sequence. Weathered and fractured basement (i.e. the second layer of the survey area) satisfies these three conditions. Similarly, areas of deep basement depressions of shallow basement probably serve as recharge points for underground water [Ajayi, and Hassan, 1990]. Figures 3-8 (vertical sections) show that, those areas with depression features (valley) are those areas delineated as good potential for underground water resources. This corroborates with the iso-resistivity contour maps at various depths including the depth to basement contour map. However, those areas with elevated basement could be better used for civil engineering works.

Similarly, the time-distance graphs from the seismic survey show two geologic sections throughout the entire survey area. The first layer velocity ranges from 716.33 ms^{-1} to 2024.29ms^{-1} (Table 3) and the refractor layer of seismic velocity ranges from 1935.36ms^{-1} to 7485.03 ms^{-1} (Table 4). The wide range of velocity variations can be attributed to the in-homogeneity of this region. The range of the first layer velocity indicates that the principal constituents of the rock found in the first layer are clay, dry sand and gravel. The proportions of these deposits vary at the various shot points within the survey area. The velocity variation is reflected in the contour map of figure 18. The existence of several closures both high and low is an indication of in-homogeneity of the first layer. The high velocity closures may be as a result of variation in consolidation rather than lithological differences. It is also confirmed from geologic point of view that the variations in the level of consolidation at the various shot points, may be responsible for the differences in the seismic velocities witnessed throughout the entire survey area.

Considering the contour map of the refractor velocity (figure 17), it is observed that at the south-west portion of the survey area we have high closures. It can also be observed at north – eastern part of the survey area. The positions marked H on the contour map (figure 17) indicates high closures. The points marked L on the north-west portions of the survey area, indicates the areas of low closures. The velocity variation is reflected in the contour map of figure 17. The existence of several closures both high and low is an indication of in homogeneity at the refractor layer. The high velocity closures may be as a result of variation in consolidation rather than lithological differences.

The contour map of the depth to refractor (figure 18) also shows closures indicating variations of depth to the bedrock. High concentrations of closures are observed along the eastern and western margin of the contour map. The positions marked H on the contour map corresponds to the area having the maximum depth to the refractor and the points marked L are the areas of lower depth to the refractor. The depth variation is reflected in the contour map of figure 18. The existence of several closures both high and low is an indication of in-homogeneity of the depth to refractor. The high depth closures may be as a result of variation in consolidation rather than lithological differences.

Conclusion

The result of the two methods (or investigations) shows that the study area is underlain with maximum of three geologic layers. The electrical (with three layers) method shows that the first layer consists of lateritic topsoil, fadama loam, sandy-clay and gravel. The second layer is characterized by weathered and fractured basement, while the third layer is the fresh basement rock. Seismic (with two layers) could be characterized with first layer velocity ranges from 716.33 ms^{-1} to 2024.29ms^{-1} while the second layer have velocity range from 1935.36 ms^{-1} to 7485.03ms^{-1}. However, the refractor depth within the survey area range between 2.79m to 6.66m with an average depth to refractor of 4.74m and is mainly composed of granites.

The results of the VES investigations shows that depth to basement rock in some areas were found to be in the range of 18m and 32m (shaded region of figure 15); while seismic refraction method only shows that the refractor depth was found to be in the range of 2.79 and 6.66m. Thus VES method has better penetrating power with respect to seismic refraction method as used in this work.

However, some areas with greater depth in seismic agreed largely with VES investigation. The areas identified for ground water exploitation from both methods are in the north-central and northeastern parts while the southern part of the study area where the basement is shallow, is however good for civil engineering works (figure 15 and 18).

Recommendation

The University is situated on a wide expanse of land most of which is yet to be developed. This calls for more geophysical surveys with a view to identifying suitable areas for various development projects on the campus. With such surveys, reliable geophysical information about sites will be known. This will save the management a substantial amount of money in terms of borehole construction and location of buildings of different capacities and also ensures their optimal performance. We also recommend that a well should be drilled and the water be tested for portability.

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