Subsurface stratigraphic mapping using geoelectric method and its impact on development in Federal College of Education (technical) Gusau, Zamfara State, Nigeria

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REVIEW

A resistivity survey has been carried out in order to determine the subsurface stratigraphic mapping of Federal College of Education (Technical), Gusau, Zamfara State. Twenty - four Vertical Electrical Soundings (VES) have been conducted with maximum current electrode separations of 200 m. Schlumberger array has been used. WinGlink software has been used in interpreting the results. Two and three subsurface layers exist in the study area. The first layer has resistivity values ranging from 1 to 522 Ωm and thickness 0.40 to 2.29 m, the topsoil is predominantly clay. The second geoelectric layer has resistivity values that varies from 5.0 to 4 000 Ωm with thickness 0.37 to 17 m, lithology of the second layer varies from sandy clay to weathered/fractured sandstone while the third layer resistivity ranges from 50.0 to 9 900 Ωm, the rock type in this layer vary from weathered/fractured basement to fresh basement. The topsoil thickness ranges from 0.40 to 4.0 m while the overburden thickness of the surveyed area ranges from 0.40 to 18.0 m. The results show that the area can support low to giant engineering structure.

Key words: stratigraphic mapping, lithological beds, geoelectric sections, resistivity sounding

1. Introduction

Gusau, the capital of Zamfara State, has witnessed an upsurge in infrastructural development and an increase in human population in recent years. On the basis of increasing economic activities and booming construction works coupled with the incidence of collapsed building and structures in the country, this investigation was carried out to provide detailed information on the characteristics of the subsurface lithology and ground conditions prior to the commencement of construction works. Since every civil engineering structure - building, bridge, tunnel, highway, tower, wall, canal, and dam - must be founded on the surface of the earth[4,2] it is appropriate that detailed information on the strength and fitness of the host earth materials must be ascertained through investigation of the subsurface at the proposed site.

Generally, geophysics provides some of the required information to delineate those materials in the subsurface of the earth. Many geophysical techniques are available which can be used to map and delineate the subsurface. Geophysical

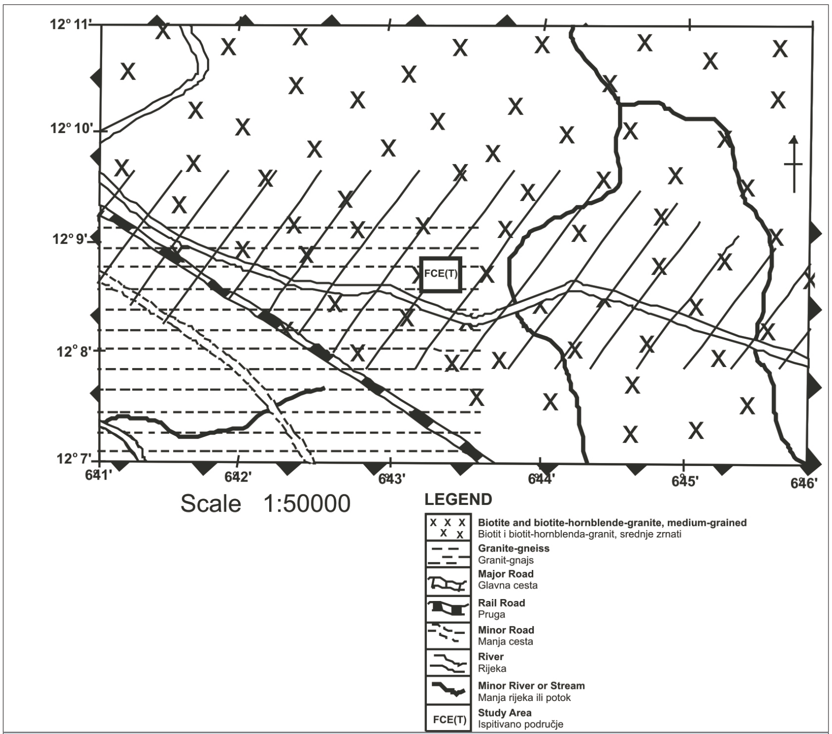

Fig. 1. Geological map of part of Gusau showing the study area (adapted from GSN,1965)

Sl. 1. Geološka karta dijela grada Gusau prikazuje proučavano područje (prerađeno prema GSN, 1965.)

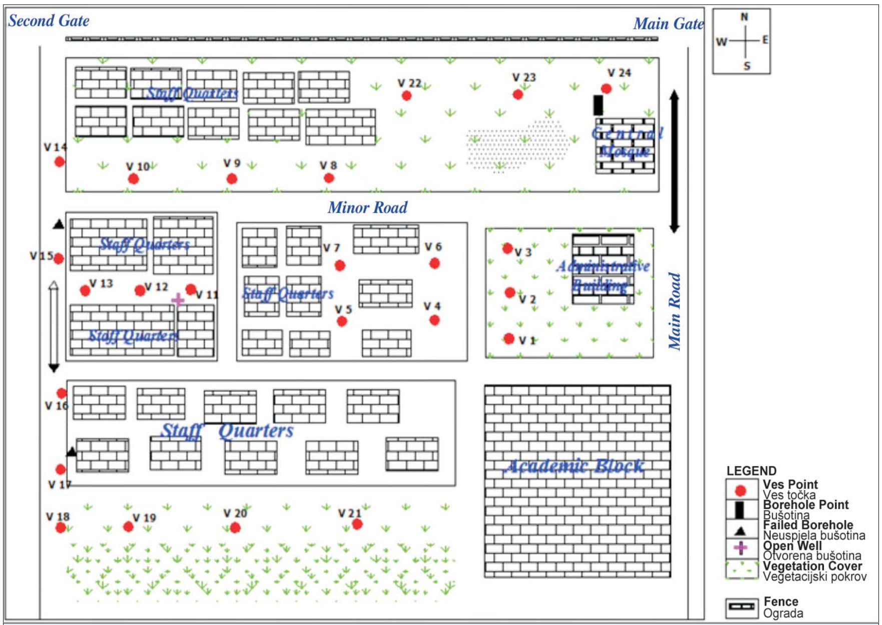

Fig. 2. Base map of the study area showing the VES points
Sl. 2. Osnovna karta proučavanog područja prikazuje točke vertikalnog električnog sondiranja (VES)

tools that are routinely used to image the subsurface of the earth in support of mining related geotechnical investigations include seismic methods, ground penetrating radar (GPR), electrical resistivity, electromagnetic (EM), induced polarization (IP) and magnetic methods.[2,7] In this work, resistivity method using Schlumberger array was employed to delineate the subsurface stratigraphy of Federal College of Education (Technical), Gusau, Zamfara state, as an aid to civil engineering or construction works.

2. Geomorphology, Vegetation and geology of the area

The study area is gently undulating without outcrop. The elevation varies between 476 and 487 m. The area experiences two distinct seasons: the dry season (November - April) and rainy season (May - October).

The vegetation of the area consists of desert of bread leaved savannah with some scattered trees. The surveyed area is entirely underlain by rocks of the Nigerian-basement complex. The main rock types of the area are the biotite and biotite-hornblende-granite (medium grained). The migmatites and granite of the area are dominantly banded tonallitic gneisses with minor granite gneisses (figure 1).

The topography of the study area consists of low-lying terrains and is fairly flat.

3. Equipment and Field Procedure

Electrical resistivity measurements were carried out using ABEM Terrameter SAS 300 system.

This is a resistivity meter with a reasonably high sensitivity. The equipment is rugged, user's friendly and powerful for deep penetration.[3]

The resistivity survey involved 24 sounding stations. The vertical electric soundings (VES) were conducted by using the symmetrical Schlumberger array with a maximum current electrode spacing (AB) of 200 m. The end result of the field measurement is the computation of the apparent resistivity (ρ_a).

$$\rho_a = K\frac{\Delta V}{I} \tag{1}$$

where K is the geometrical factor which depends on the array used, ΔV is the potential difference and I is the current.

For the Schlumberger arrays in symmetrical form, the geometrical factor is given as:

$$K = \pi\left\{\frac{a^2}{b} - \frac{b}{4}\right\} \tag{2}$$

where a is distance from the centre of the array to the current electrode and b is the distance between the potential electrodes.

4. Data Processing and Presentation

To minimize erroneous interpretation due to human error, the WinGlink software was utilized for processing

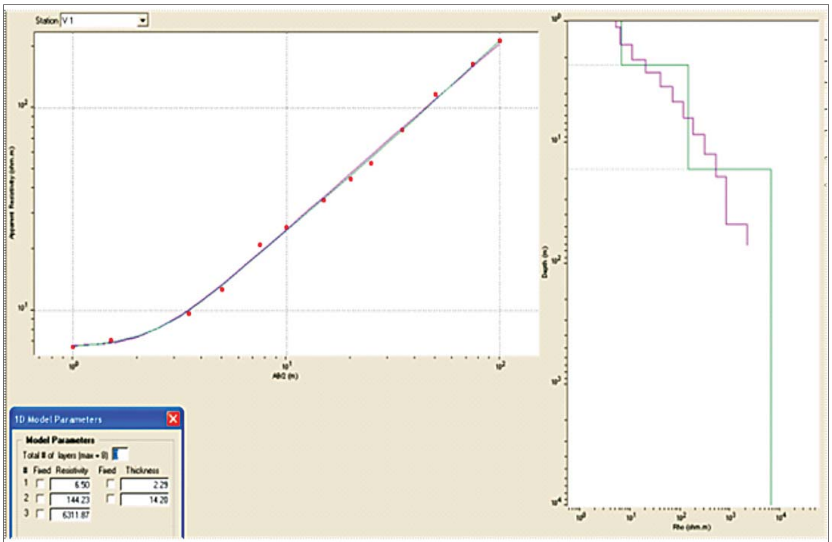

Fig. 3a. Vertical Electrical Sounding curve for station 1
Sl. 3a. Krivulja vertikalnog električnog sondiranja na stanici 1

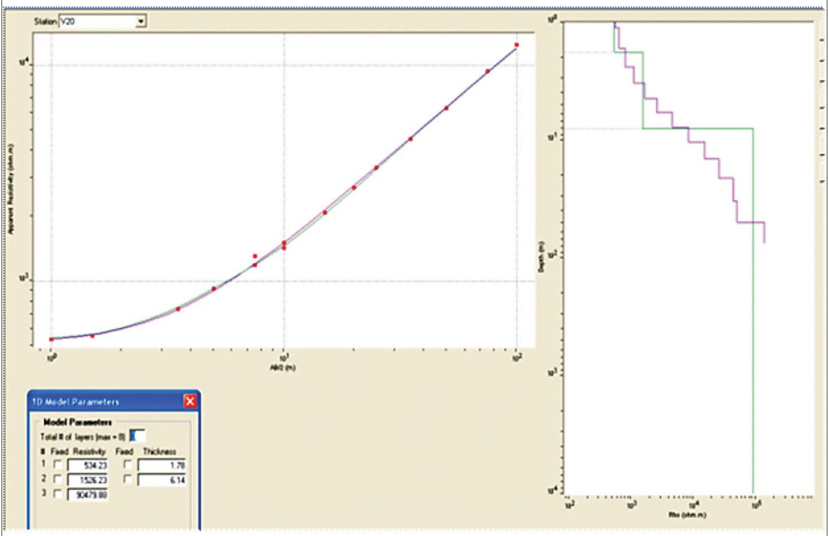

Fig. 3b. Vertical Electrical Sounding curve for station 20
Sl. 3b. Krivulja vertikalnog električnog sondiranja na stanici 20

the acquired data. The processed data were presented in the form of 1-D model resistivity curves and geoelectric sections and maps.

5. Results and Discussion

The results of the data processing and interpretation are briefly discussed as follows.

5.1 1-D Model Resistivity Curves

The apparent resistivity values have been plotted against half the current electrode separation (AB/2) in meters on a computer based log-log graph using the WinGlink software. Computer iterated interpretations of the apparent resistivity data have been carried out using the software. These iterations are presented as 1-D iteration models. Figure 3 (a and b) shows the representative samples of these curves.

5.2 Contoured Maps

Several maps have been produced (using WinGlink software) to monitor the trend of lithological variations with a view to assessing the subsurface stratum suitable for low, medium and giant engineering structure.

Figure 4a shows the topsoil map which indicates a variation of 0.4 m to 4.0 m in thickness. The lithology of the top soil is majorly clay soil with the exception of few stations where weathering has taken place.

Figure 4b shows isopach thickness of the clay layer and it varies from about 0.47 m to 8.70 m. The map shows that North- West position of the surveyed area have high clay thickness which is an indication that such places cannot support a high-rise building.

Figure 4c is an overburden thickness map showing the soil layers over the bedrock of the surveyed area. The overburden thickness ranges from 0.40 m to about 18.11 m.

5.3 Geoelectric and Geologic Sections

At each VES station, 1-D model has been produced using the WinGlink software. The models have been used to produce geoelectric and geologic sections for the various profiles which are discussed as follows:

Profile AA

The geoelectric and geologic sections across A to A have used data from VES 1, 2 and 3. Three subsurface layers are shown (5a). The first geoelectric layer has resistivity values ranging from 3 to 6 Ωm with thickness that varies from 0.65 to 2.29 m and is composed of clay.

The second geoelectric layer has resistivity values that vary from 6 to 144 Ωm and thickness values that range from 0.84 to 14.20 m. Beneath VES 1 at this layer is weathered sandstone which constitutes aquifer unit. This area can support engineering structures because of the nature of the rock type but if giant engineering structure is to be built around VES 3, the foundation must go deep beyond clay materials (more than 4 m deep because clay cannot support giant engineering structure).

The third geoelectric layer has resistivity values that vary from 197 to 6 003 Ωm. The lithology of this layer is weathered basement except beneath VES 1 which has encountered fresh basement.

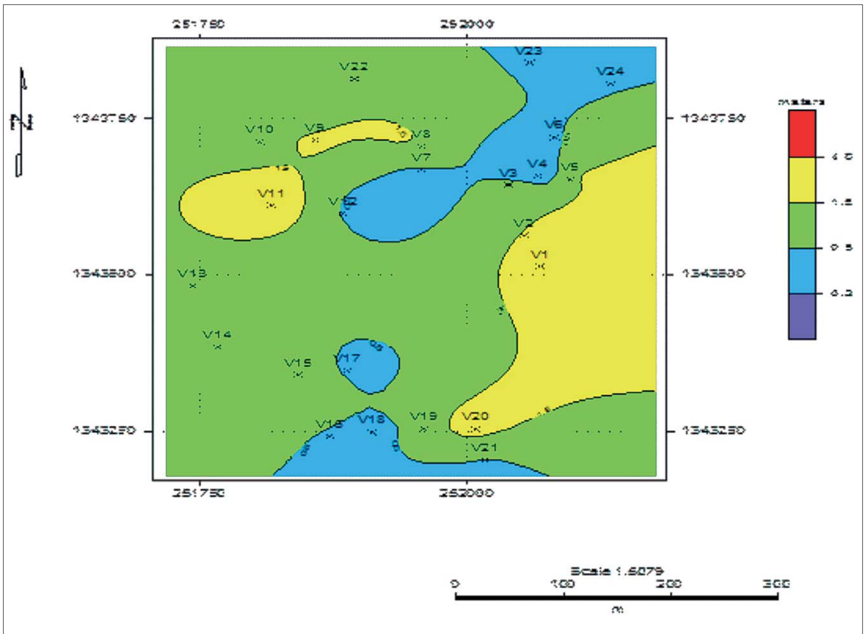

Fig. 4 a. Topsoil map.
Sl. 4a. Karta površinskog sloja

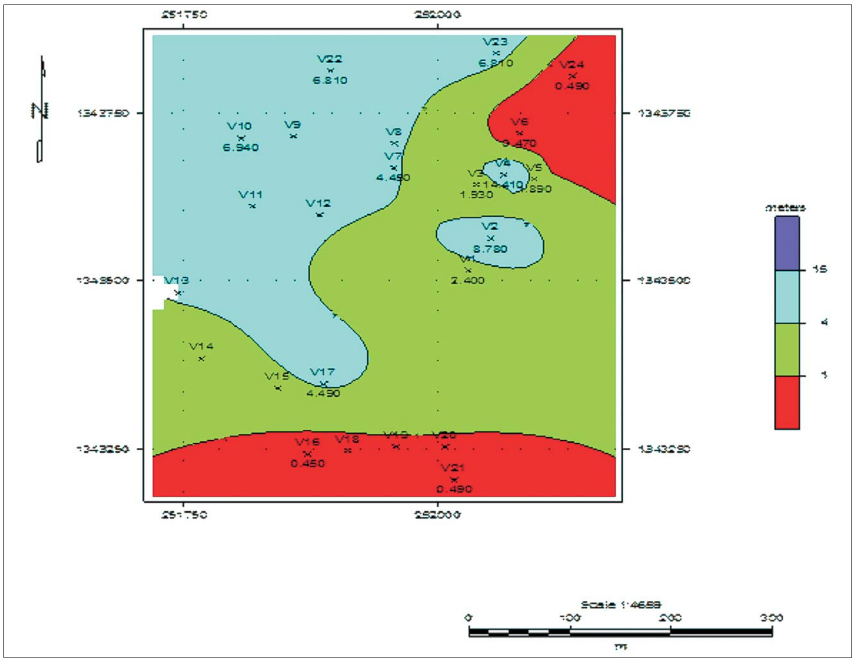

Fig. 4b. Isopach thickness of clay layer
Sl. 4b. Izolinije debljina sloja gline

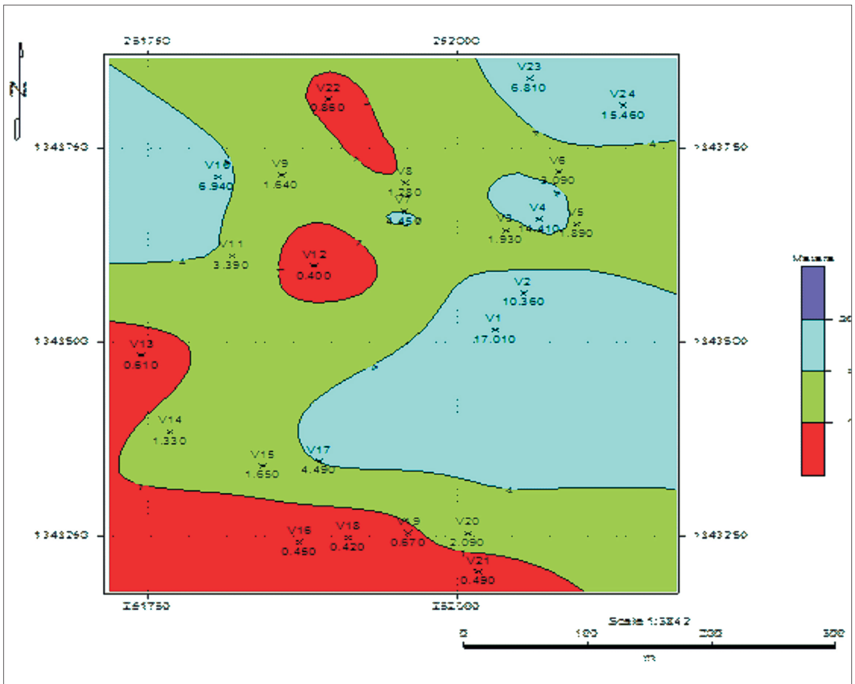

Fig. 4c. Overburden thickness map
Sl. 4c. Karta debljina pokrovne stijene

Profile BB

This is a short profile with only VES 4 and 5. There are three subsurface layers (figure 5b). The first layer is the topsoil, which has resistivity values of 1 to 7 Ωm and thickness of 0.63 to 0.74 m, clay predominates in this layer.

The second geoelectric layer has resistivity values between 5 to 20 Ωm and thickness 0.79 to 7.92 m. This layer composed of clay materials.

The third geoelectric layer has resistivity values that vary from 50 to 95 Ωm with no thickness because the current terminates in this zone. This layer contains sandy clay with no potential for groundwater because sandy-clay has poor retention for water. The area can support only low building because of predominance of clay materials in this area.

Profile CC

The geoelectric and geologic sections across CC consists of VES 3, 6 and 7. It is made up of three subsurface layers (figure 5c). The top soil is an indicative of clay with resistivity values between 3 and 6 Ωm and thickness values between 0.45 and 0.63 m.

In the second geoelectric and geologic sections, clay material still dominates except underneath VES 6 which composes of weathered basement. The resistivity values in this layer range from 6 to 130 Ωm with thickness ranging from 0.84 to 2.62 m

Fresh basement is encountered in third layer underneath VES 7 while VES 3 and 7 consists of weathered and fractured basements with resistivity values of 200 and 586 Ωm respectively. There is potential for groundwater development in this area and any form of structures can be built here.

Profile DD

The geoelectric and geologic sections across D to D are made up of data from VES 8,9,10 and 14 (figure 5d). The section reveals three subsurface layers.

The top layer has resistivity values ranging from 18 to 545 Ωm with thickness 0.8 to 1.64 m.

The fresh basement is encountered right from the second layer underneath VES 8 and 14. Beneath station 9, the fractured basement with resistivity of 733 Ωm forms the aquier unit with thickness 16.47 m while clayey sand with resistivity 44 Ωm and thickness 6.14 m is underneath VES 10.

The third layer is composed of fresh bedrock except underneath VES 10 which contains weathered bedrock with resistivity of 292 Ωm, this constitute an aquifer unit and can be drilled for productive borehole. Low to giant structures can be sited in this area also.

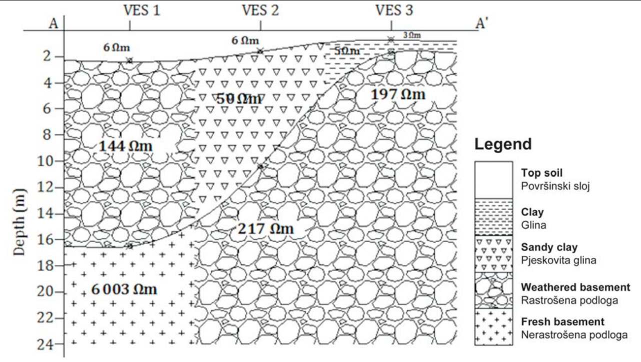

Fig.5 a. Geoelectric and geologic sections beneath VES 1- 3
Sl. 5a. Geoelektrične i geološke sekcije ispod VES 1 -3

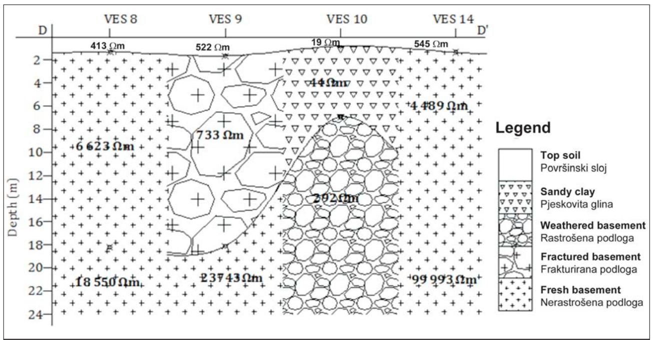

Fig. 5 d. Geoelectric and geologic sections beneath VES 8, 9, 10 and 14
Sl. 5 d. Geoelektrične i geološke sekcije ispod VES 8, 9, 10 i 14

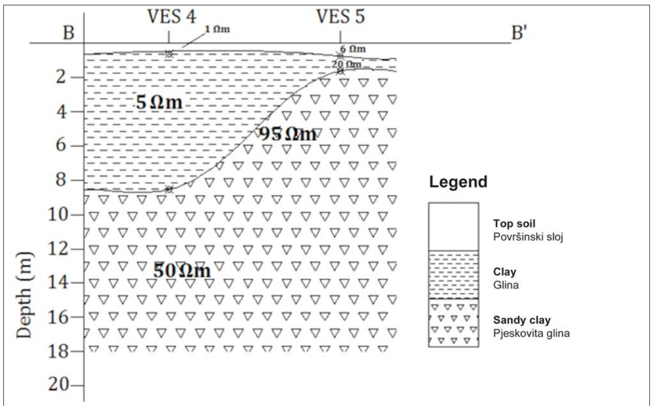

Fig. 5b. Geoelectric and geologic sections beneath VES 4 and 5
Sl. 5 b Geoelektrične i geološke sekcije ispod VES 4 i 5

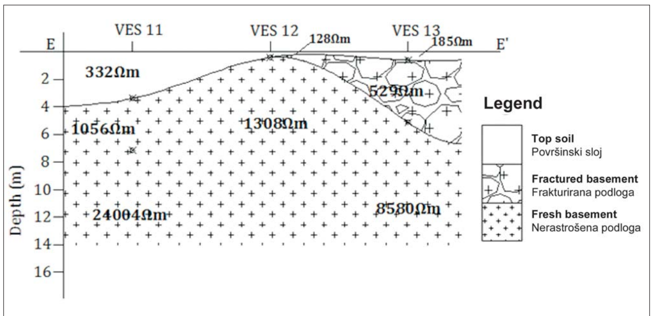

Fig. 5e. Geoelectric and geologic sections beneath VES 11 - 13
Sl. 5e. Geoelektrične i geološke sekcije ispod VES 11 - 13

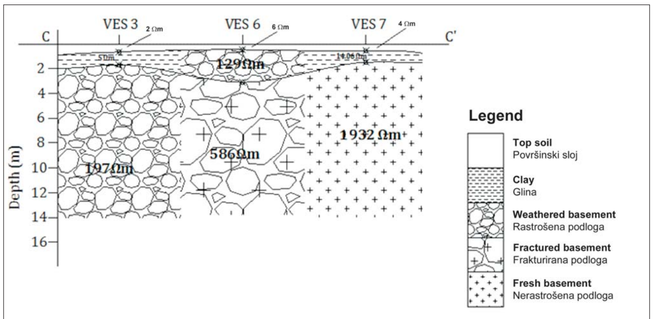

Fig. 5c. Geoelectric and geologic sections beneath VES 3, 6 and 7
Sl. 5 c. Geoelektrične i geološke sekcije ispod VES 3, 6 i 7

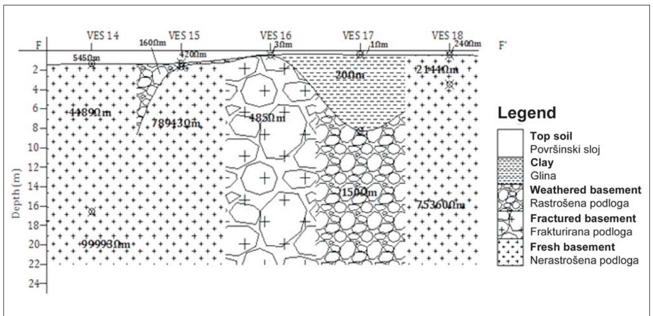

Fig. 5f. Geoelectric and geologic sections beneath VES 14 -18.
Sl. 5f. Geoelektrične i geološke sekcije ispod VES 14 - 18

Profile EE

The VES 11, 12 and 13 constitute this profile. The geoelectric and geologic sections reveals two and three subsurface layers (figure 5 e).

The lithology of the topsoil contain weathered and fractured basement with resistivity values between 128 to 332 Ωm and thickness values of 0.4 to 3.39 m.

Fresh basement has been encountered in the second layer with the exception of VES 13 which consists of fractured basement with resistivity value of 528 Ωm and thickness 1.33 m. Although, fractured basement constitute aquifer unit, it is not so thick to retain enough water.

The third layer composed of fresh basement with resistivity values of above 8 000 Ωm. The area can support any forms of structures.

Profile FF

This is the longest profile consisting of VES points 14, 15, 16, 17 and 18 (figure 5f). The geoelectric and geologic sections revealed two and three subsurface layers.

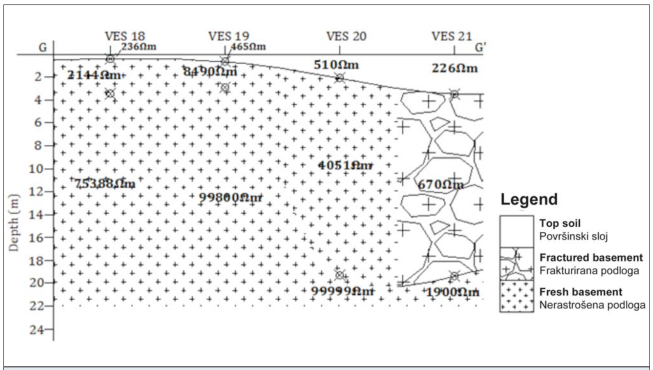

Fig. 5g. Geoelectric and geologic sections beneath VES 18-21
Sl. 5g. Geoelektrične i geološke sekcije ispod VES 18 - 21

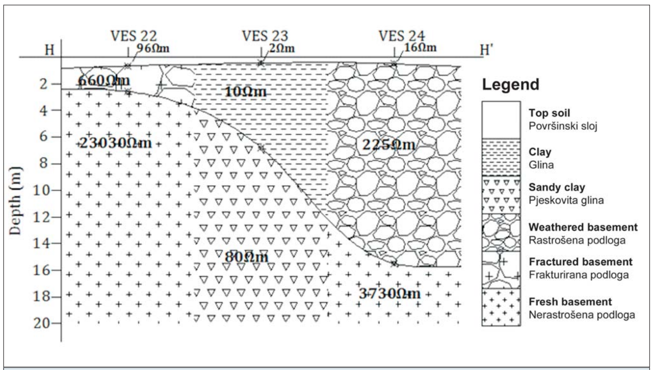

Fig. 5h. Geoelectric and geologic sections beneath VES 22-23
Sl. 5h. Geoelektrične i geološke sekcije ispod VES 22 - 23

The topsoil lithology ranges from clay to fractured bedrock with resistivity values ranging from 1 to 545 Ωm and thickness between 0.45 and 1.33 m.

In the second geoelectric layer, fresh basement is being encountered beneath VES 14 and 18. Fractured bedrock with resistivity value 484 Ωm is encountered beneath VES 16 with no thickness because the current terminates in the zone. Beneath VES 15 is the weathered basement having resistivity value of 158 Ωm and thickness 0.37 m while clay predominates underneath VES 17 with resistivity value of 18 Ωm and thickness 7.71 m.

The third layer has resistivity which ranges from 148 to 99 990 Ωm. Low to giant structures can be sited here.

Profile GG

The geoelectric and geologic sections across G to G consists of data from VES 18, 19, 20 and 21. Three subsurface layers are revealed across this profile (figure 5g).

The first layer reveal weathered and fractured basement with resistivity values ranging from 226 to 509 Ωm and thickness between 0.47 and 3.5 m.

In the second layer high values of resistivity is an indication of fresh basement especially beneath VES 18, 19 and 20. However, beneath station 21, the fractured bedrock with resistivity of 670 Ωm forms the aquifer unit with thickness 15.88 m and constitutes a favourable location for groundwater development. The area can support any form of structure.

The third layer is fresh basement having resistivity values of above 1 900 Ωm.

Profile HH

The geoelectric and geologic sections across H to H are made up of data from VES 22, 23 and 24 (figure 5h). It reveals three subsurface layers. The topsoil lithology ranges from clay to sandy clay with resistivity values ranging from 2 to 96 Ωm and thickness values 0.44 to 0.66 m.

Beneath VES 23 in the second layer, low resistivity value of 10 Ωm is an indication of clay. It has thickness of 6.37 m. The layer is composed of weathered / fractured basement beneath VES 22 and 24 with resistivity value in the range of 225 to 657 Ωm and thickness of between 2.58 to 14.99 m. This constitutes good aquifer for groundwater exploitation along this traverse. Giant engineering structures should be avoided around VES 23 because of predominance of clay materials as shown by low resistivity value.

The lithology of the third layer ranges from sandy clay to fresh basement with resistivity variation from 78 to 23 034 Ωm.

6. Implication for Engineering structures

The results of the geophysical investigation carried out showed that the study area can accommodate probably low to high engineering structures. The result shows that areas around VES 4, 5 and 23 can only support low structures because clay materials predominate there, high engineering structures should not be built in those areas. Olorunfemi and Fatobi[5] have shown that floating a building on clay led to foundation failure.

7. Conclusion

The subsurface investigation using vertical electrical sounding at Federal College of Education (Technical) Gusau, Zamfara State revealed that the stratigraphy consists basically of two to three layers. Based on the results of the interpreted resistivity measurements and the 2-D sections (geoelectric and geologic sections), it can be deduced that the area can support low to giant engineering structures.

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