International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Vertical Electrical Soundings for Subsurface Layers and Groundwater Investigations in the Mayo Kani Area in Cameroon

Janvier Domra Kana[1], Noël Djongyang[2], Abdouramani Dadjé[3], Danwé Raïdandi[3]

[1] Department of Renewable Energy, The Higher Institute of the Sahel, University of Maroua, PO Box 46 Maroua, Cameroon

[2] Department of Renewable Energy, The Higher Institute of the Sahel, University of Maroua, PO Box 46 Maroua, Cameroon

[3] School of Geology and Mining Engineering, University of Ngaoundere, PO Box 454 Ngaoundere, Cameroon

[4] Department of Mechanical Engineering, National Advanced Polytechnic School, University of Yaounde I, PO Box 8390 Yaounde, Cameroon

Abstract: ***This paper presents an investigation of sub-surface layered and ground water characteristics using Vertical Electrical Sounding (VES). The study was conducted in the Mayo Kani area in Cameroon. One hundred VES were carried out using the Schlumberger array in order to determine the nature, characteristics and spatial extend of the components of subsurface layers. The data were analyzed by the software IP2WIN while the isoapparent resistivity maps were plot by the help of the software SURFER. The results gave H, K, A, HK, HA, QH, KH, HKH, HAA, and HKHK types associated to three, four, five and six layers. The geological sequence beneath the study area is composed of topsoil (clayey sandy, sandy-lateritic, gravel, and dry alluvium), weathered layer, unsaturated layer, saturated formation and bedrock. Aquifer is located either in the alterations, sand, or fractured rocks. The resistivity value for the topsoil layer varies from 4.32 Ω.m to 9756 Ω.m with thickness ranging from 0.5 to 13.1 m, while the fresh basement (bedrock) has resistivity values ranging from 1058 Ω.m to 46961 Ω.m with infinite depth. However, the depth from the earth's surface to the bedrock surface varies between 9 to 80 m.***

Keywords: Vertical Electrical Sounding, Schlumberger array, subsurface layers, Resistivity, Ground water investigation.

1. Introduction

The use of geophysics for subsurface layers and groundwater explorations increased over the last few years due to the rapid advances in computer science associated to numerical modeling solutions. The Vertical Electrical Sounding (VES) has proved very popular with groundwater prospecting due to its simplicity [1]. Direct current resistivity method using Schlumberger array has been used by many researchers [2-7] and has been proven successful on depth estimation, ground water potential and hydrogeological estimation. A Schlumberger array sounding involves more detailed measurement at a location to obtain a layered model of the vertical resistivity structure. The advantages and disadvantages of the different arrays are discussed in various papers [8-11].

Many of the interpretation problems associated with traversing anomalies can be resolved by a program of soundings. These rely on an assumption of uniform 1-dimensional layering, so the arrays should be carefully located to avoid crossing resistivity contrasts (especially near surface) or excessive changes in topography. Soundings can be interpreted, while in the field, using curve matching procedures, and a programmable calculator. By assuming a hydrological gradient from high to low elevation, the flow groundwater direction can be determined.

Ten percent of the world's population is affected by chronic water scarcity and this is likely to rise to one-third by about 2025[12]. The water scarcity experienced by the people, led to the search for surface water supply which mostly occurs as rivers are subjected to pollution. The progressive population growth in Cameroon has led to severe shortage of potable water which poses a great challenge to both the citizens and the government. However, groundwater exploration is gaining more and more importance in Cameroon owning to the ever increasing demand for water supplies, especially in areas with inadequate surface water supplies (Far North region of Cameroon). Consequently, the main goal of our study is to investigate the subsurface of mayo Kani area in order to detect aquifer zone using VES method. The current study area belongs to the geomorphology in the inselberg of Kaele in Cameroon. This morphological unit is in the form of a vast dome, whose center is approximately at an altitude of 400 m. A total of hundred VES were carried out using the Schlumberger array in order to determine the nature, characteristics and spatial extent of the components of subsurface layers of this region.

2. Location and Geology of the Study Area

2.1 Site Description

The Mayo Kani division; located in the far north region of Cameroon is bounded approximately by longitude of 14, 16° E to 14, 94° E, latitude of 10, 14° N to 10, 94° (Fig. 1). The climate is of the Sudano-Sahelian type with two seasons of unequal lengths. The continental Saharan air mass high pressure covers the entire area from November to April or

May. This period corresponds to the dry season characterized by a total absence of precipitation. Sometimes, the potential evaporation reaches 7 mm of water per day with a relative humidity of 20 %. The average annual surface temperature of 28 °C makes this region one of the hottest in Africa.

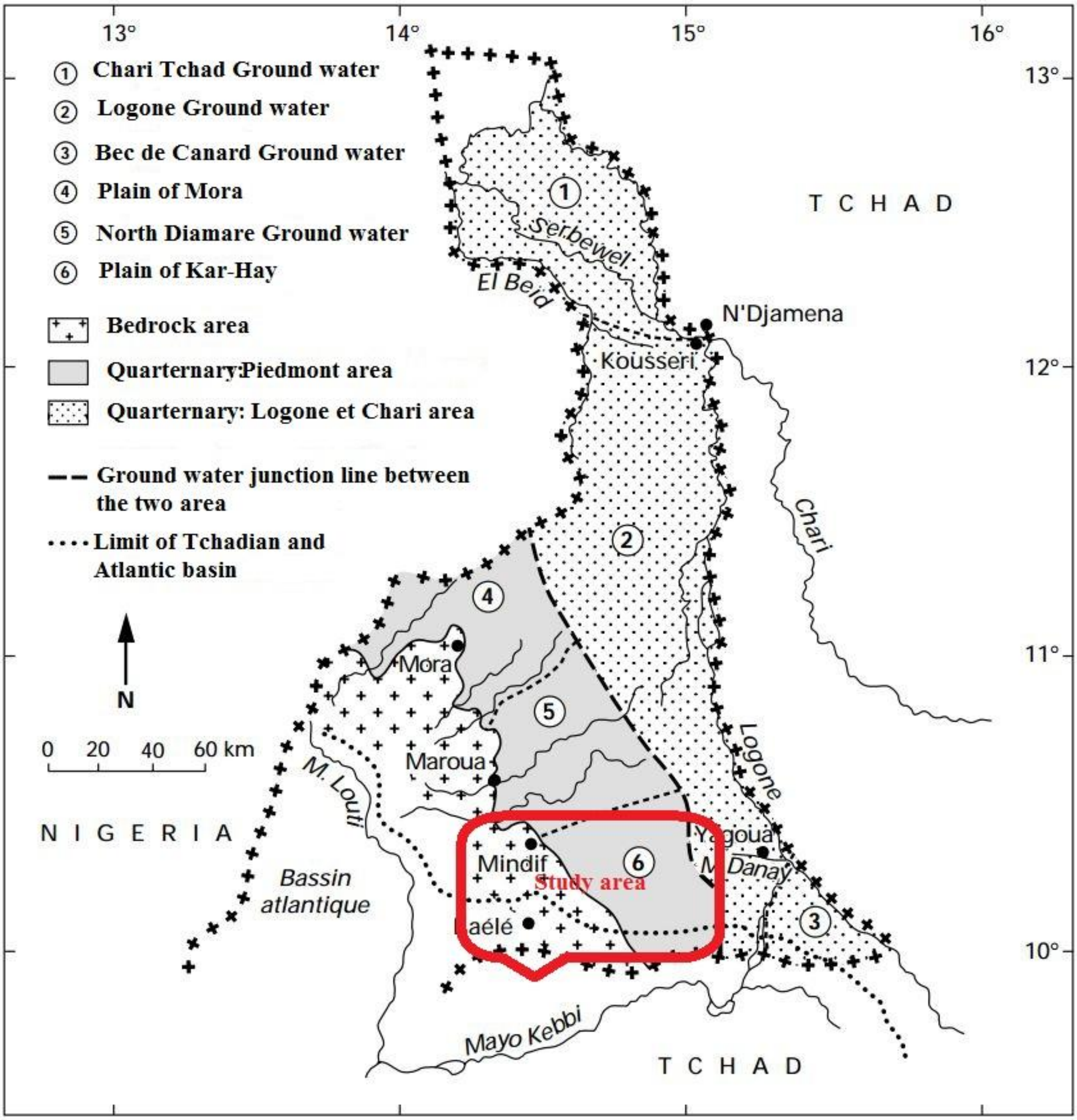

Figure 1: Hydrogeological unit of quaternary basin, Far North region of Cameroon (modified from Detay, 1987[13])

2.2 Geological Setting

Central Africa is formed of a Precambrian basement on which stand in discordance, Mesozoic and Cenozoic subhorizontal sedimentary formations. The Paleozoic is less expanded. Deep accidental relief affects the fresh basement and the sedimentary formation [14]. The bedrock formations and complex metamorphic base are generally migmatized and granitized. The complex base is an assemblage of various geological features that are common to have been taken by the Pan-African orogeny [15].

The Quaternary geologic history of northern Cameroon is closely linked to that of the central basin of Lake Chad (Fig. 1**)**. Deposits are under the control of series of regressions and transgressions caused by alternating dry and storm periods.

3. Material and Methods

The Geoelectrical survey presented in this paper involved 100 vertical electrical sounding localized in (Fig. 2) by Schlumberger array and 40 profiles. The field curves were interpreted by the well-known method of curve matching with the aid of the software IP2WIN. The VES data were acquired using ABEM terrameter (SAS1000) with current electrode separation (AB) varying from 1.5 m up to 240 m in successive steps. The VES sites of study area were chosen according to the accessibility and applicability of the Schlumberger method. The increase of potential electrode spacing MN is often marked by a discontinuity in the field curve. Then, the sounding curves were interpreted to determine the true resistivities and thicknesses of the subsurface layers.

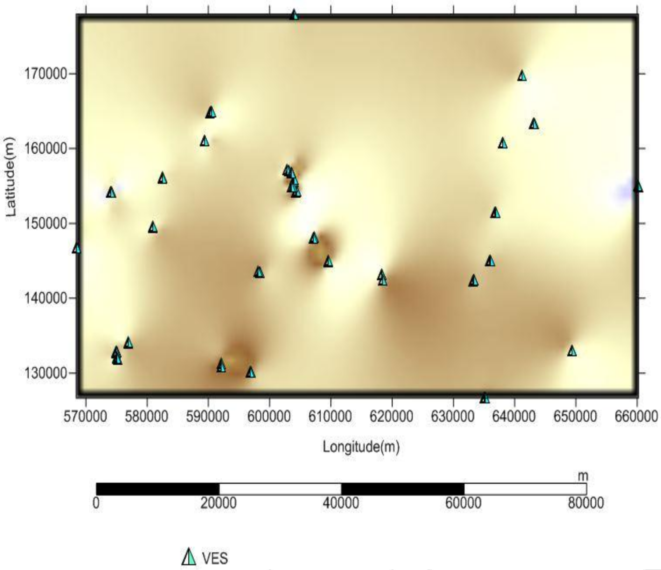

Figure 2: VES location and topographic elevation of study area

The relationship between the electrical resistivity, current and the electrical potential is governed by Ohm's law. To calculate the potential in a continuous medium, the form of Ohm's Law, combined with the conservation of current, as given by Poisson's equation is normally used. The potential due to a point current source located at x_d is given by:

$$\nabla.\left[\frac{1}{\rho(x,y,z)}\nabla\Phi(x,y,z)\right] = -\frac{\partial j_c}{\partial t}\delta(x_d) \qquad (1)$$

where ρ is the resistivity, Φ is the potential and j_c is the charge density. The potential at any point on the surface or within the medium can be calculated if the resistivity distribution is known.

The purpose of the resistivity method is to calculate the electrical resistivity of the subsurface, which is an unknown quantity. The measurements for the resistivity survey are made by passing a current into the ground through two current electrodes (usually metal stakes), and measuring the difference in the resulting voltage at two potential electrodes. In its most basic form, the resistivity meter has a current source and voltage measuring circuitry that are connected by cables to a minimum of four electrodes. The basic data from a resistivity survey are the positions of the current and potential electrodes, the current (I) injected into the ground and the resulting voltage difference (ΔV) between the potential electrodes (Fig. 3).

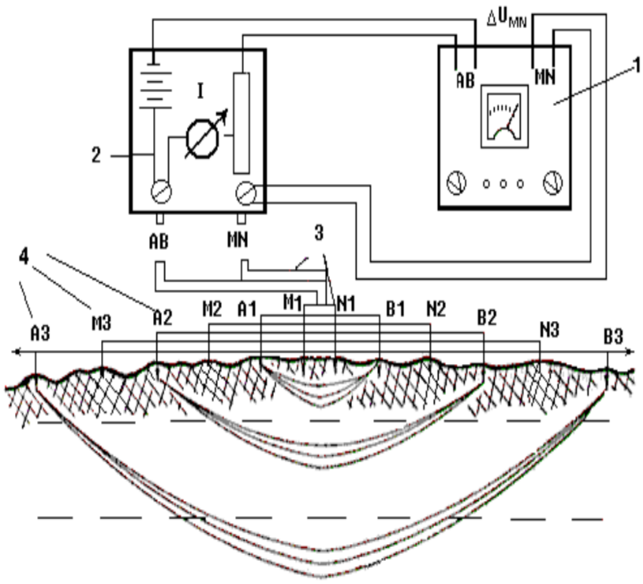

Figure 3: Scheme of the vertical electrical sounding (VES) device: (1) autocanceller, (2) commutator for electrodes AB and MN, (3) netted wires for different distances among electrodes AB and MN, and (4) electrodes [16].

The current and voltage measurements are then converted into an apparent resistivity (ρ_a) value by using the following formula:

$$\rho_a = k\frac{\nabla V}{I} \qquad (2)$$

Where k is the geometric factor that depends on the configuration of the current and potential electrodes [16]. Eq. (2) represents the simplest form of the inverse problem and assumes that the earth is homogeneous for each combination of current and potential measurements. The Root Mean Square (RMS) value of the apparent resistivity is obtained through the relation:

$$RMS = \sqrt{\sum_{i=1}^{n}\frac{(\rho_i)^2}{n}} \qquad (3)$$

where n is the total number of measurement points.

4. Results and Discussion

4.1 Vertical electrical sounding curves interpretation

The field curves at studied stations have been inverted one-dimensionally as explained in the following section. Ten different curve types have been observed; namely: H, A, K, HK, KH, HA, QH, HKH, HAA, HKHK types.

The geoelectrical layers of H, K, A curves types could be interpreted as three subsurface layers: topsoil/ lateritic layer / fractured layer and bedrock for H curve; topsoil/fractured layer and bedrock alteration/very fractured bedrock for K curve (Fig.4); and topsoil /fresh basement/weathered basement for A curve type. The true apparent resistivity ρ values for the three subsurface layers vary from 0.75 to 46961 Ohm.m. The different subsurface layer thickness h varies from 0.75 to 71.9 m while the deep of investigation d reaches up to 80 m.

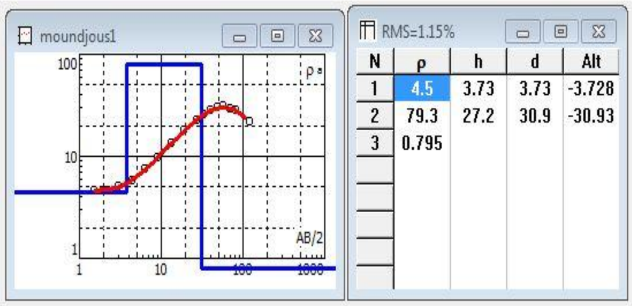

Figure 4: Typical model of Schlumberger array representing (K) curve at MOUNDJOUS's location

QH, HK, HA (Fig.5), and KH curve types could be being interpreted as four subsurface layers: topsoil/ clayey sand/ water sutured sand horizon/ bedrock; topsoil/sand/clayey sand/porous or fractured formation; topsoil, clayed sand/ aquifer/ bedrock intrusion, topsoil/ clayey sand/ sand/ altered granite. The apparent resistivity varies from 0.49 to 9756 Ohm-m while the thickness ranges from 0.75 to 80 m.

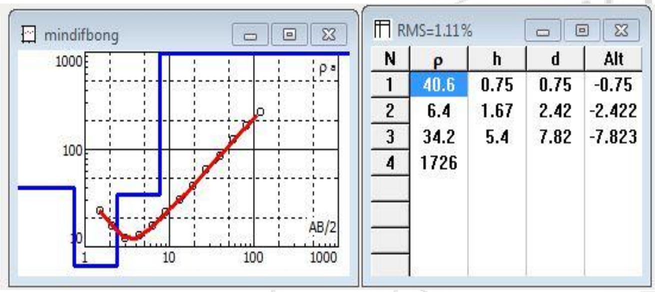

Figure 5: Typical model of Schlumberger array representing (HA) curve at MINDIFBONG's location

The five layers HKH (Fig.6) and HAA curves were observed at Djondjong (SEV1) and Mindif (SEV1). The first has a resistivity range between 15.8 and 378 Ohm.m, the top of bedrock is 17.4 m. It could be interpreted as topsoil/sand/clayey sand/sand/altered bedrock. The second could be interpreted as topsoil (clay mixed to gravel)/sand/clay/clayed sand/ hard rock. The resistivity of bedrock reaches 8758 Ω.m. This area is characterized by old volcanic activity.

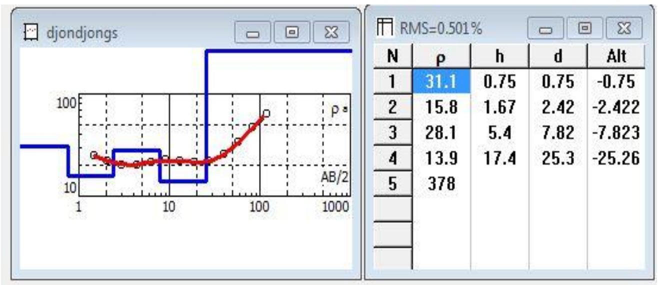

Figure 6: Typical model of Schlumberger array representing (HKH) curve at DJONDJONG's location

The six layers HKHK curves types (Fig.7) could be interpreted as topsoil/clayey sand/clay/sand/clayey sand/ aquifer. The thickness varies from 0.75 to 31.1 m. The deep approximates 35 m. Based on the result analysis above; one could infer that the lithology of the study area is predominantly sandy, clay and granite. These results are in conformity with those predicted in the literature. Groundwater is located either in the alterations, sand, and either in fractures rocks. The best targets for research and the exploitation of groundwater is directly above the fracture-alteration couples. The top of bedrock ranges between 9 and 80 m depending on area. This can be due to volcanic zone.

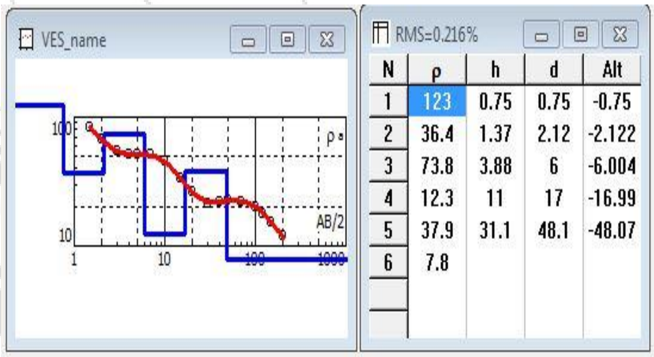

Figure 7: Typical model of Schlumberger array representing (HKHK) curve at SAMKESE's location

Table 1: The results of the interpreted VES curves

VES Location	$\rho_1/\rho_2/\rho_3/\rho_4/\rho_5$ Resistivities in Ω.m	$h_1/h_2/h_3/h_4$ Thichnesses in m	$d_1/d_2/d_3$ Depths in m	Curve type
BOULIWOLS1	34.9/14.5/38.2/14.7	0.816/5.38/4.56	0.816/6.19/10.8	HK
BOURLEOS1	19.2/8.62/5959	1.51/17.3	1.51/18.8	H
MINDIFS5	9.42/31.4/12736	2.34/9.8	2.34/12.1	A
DJONDJONGS2	31.1/15.8/28.1/13.9/378	0.75/1.67/5.4/17.4	0.75/2.42/7.82/25.3	HKH
MINDIFBS3	40.6/6 .4/34.2/1726	0.75/1.67/5.4	0.75/2.42/7.82	HA
MOUNDJOUS1	4.5/79.3/0.795	3.73/27.2	3.73/30.9	K
BADJAVAS2	9756/529/34.1/6770	0.808/10.8/33.3	0.808/11.6/45	QH
SAMKESES1	123/36.4/73.8/12.3/37.9/7.8	0.75/1.37/3.88/11/31.1	0.75/2.12/6/17/48.1	HKHK
MINDIFS1	79.4/3.98/17.7/78.8/8758	0.75/1.56/4.83/14.9	0.75/2.31/7.14/22	HAA
HARDEOS1	6.34/31.1/21/159	0.75/7.09/74.1	0.75/7.84/81.9	KH

3.1 Apparent Resistivity Map Interpretation

The isoapparent resistivity maps reflect lateral variation of apparent resistivity at a certain depth. In other words, these maps indicate distribution of apparent resistivity in the area against distance of current electrodes. In the case study, isoapparent electric resistivity maps were constructed at AB= 3, 4, 6, 8, 12, 18, 26, 54, 80, 116, 166, 200, and 240 m. The isoapparent electric resistivity map for AB= 3 m showed the apparent resistivity values in the northwestern. Center, and northeastern parts of the study area were lower than elsewhere (Fig.8).

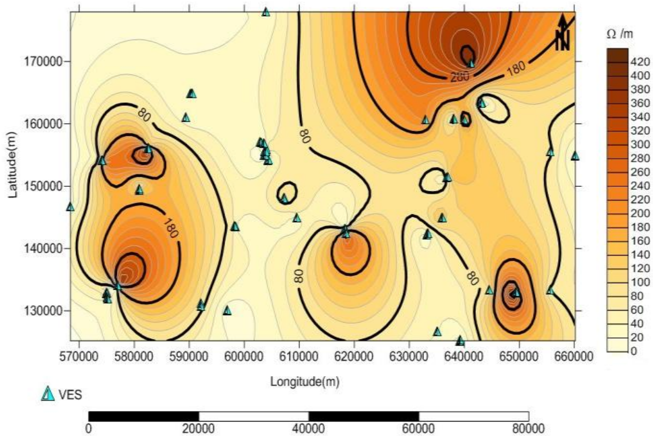

Figure 8: Isoapparent resistivity map for AB= 3 m

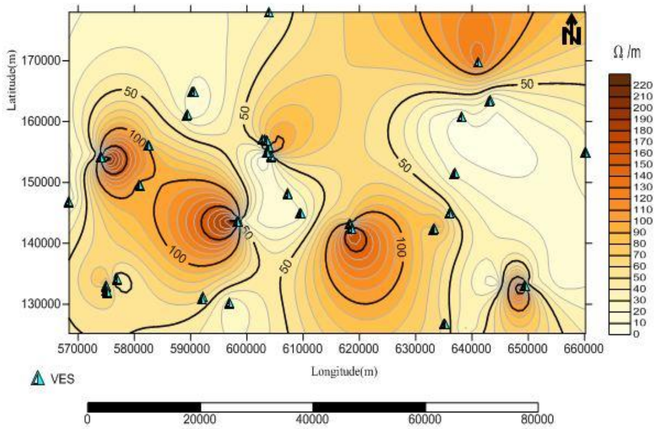

Figure 9: Isoapparent resistivity map for AB= 54 m

The low values of apparent resistivity could be attributed to the presence of a saturated layer and the high values of apparent resistivity to the presence of gravel. The isoapparent electric resistivity map for AB=54 m indicates the presence of saturated layer in the northwestern, center, eastern parts and unconsolidated and dry layer elsewhere (Fig. 9). The isoapparent electric resistivity map for AB= 166 m indicates the presence of an aquifer in the northwestern part of the study area and the presence of bedrock elsewhere. It showed that the apparent resistivity values in center parts of area were lower than the northeastern and western because sediments grain size decreases towards the center (Fig.10).

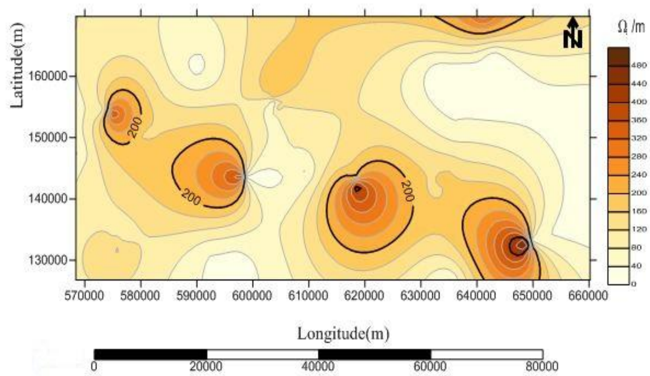

Figure 10: Isoapparent resistivity map for AB= 166 m

The isoapparent electric resistivity map for AB= 240 m reflects the lateral variation over a horizontal plane at a depth of about approximately 70 to 80 meters that indicated the presence of bed rock in the study area (Fig. 11).

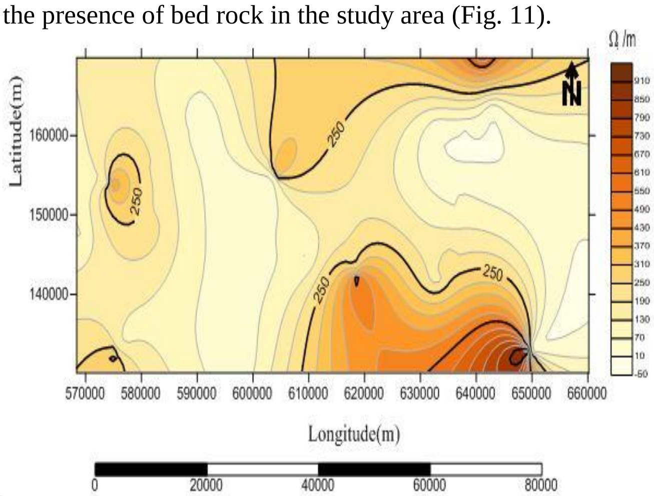

Figure 11: Isoapparent resistivity map for AB= 240 m

The apparent resistivity values of bed rock ranged from 100 to 500 ohm-m. Maximum values were recorded in the north western, center and southeastern part. The bedrock was different from part to another. Lower apparent resistivity values in the eastern part is associated to an aquifer.

5. Conclusion

Geoelectrical investigation using the Vertical Electrical Sounding (VES) method in the Mayo Kani area, Cameroon was presented in this paper. Main results revealed two, three, four and five geological layers composed of topsoil, clay, sand, sweathered basement, partly weathered or fractured basement, and fresh basement. Based on the qualitative interpretation of the VES data, it was deduced that several VES Stations like BourleoS1 and others are potential positions for siting boreholes. The isoapparent electric resistivity maps showed the apparent resistivity values in the center, northwestern and eastern parts of the study area were lower than elsewhere. This could be due to the presence of an aquifer. Southern and southwestern parts are characterized by bedrock formation. Nevertheless, further investigations should be made to quantify the potential of the study area.

6. Acknowledgements

Authors would like to express their deepest and sincere thanks to the Regional Delegation of Water and Energy of the Far north Cameroon for the facilities given during the data acquisition. Sincere thanks to the anonymous reviewers for the valuable comments that enhanced the manuscript to the present form.

References

[1] K.J. Domra, N. Djongyang, R. Danwé, P.N. Njandjock, A. Dadjé, ''A review of geophysical methods for geothermal exploration,'' Renewable and Sustainable Energy Reviews, 44, pp. 87–95, 2015.

ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

[2] J. Ahilan, K.G.R. Senthil, ''Identification of aquifer zones by VES method: A case study from Mangalore block, Tamil Nadu, S. India'', Arch Appl Sci Res, 3, pp. 414-21, 2011.
[3] J.J. Breusse, J.P. Mathiez, ''Application of electrical prospecting methods to tectonics in the search for natural steam at Larderello, Italy''. In P.L Lyons (Editor), Geophysical Case Histories, Vol.2. SEG, Tulsa, pp. 623-630, 1956.
[4] R.K. Frohlich, C.D. Parke, ''The electrical resistivity of vadose zone field survey'', Groundwater 27, 524-30, 1989.
[5] S.S. Gowd, ''Electrical Resistivity Surveys to delineate Groundwater Potential Aquifers in Peddavanka Watershed, Anantapur District, Andhra Pradesh, India'', J. Envir. Geol, 46, 118-131, 2004.
[6] I.N. Levi, ''2D Resistivity survey for groundwater exploration in A hard rock terrain: a case study of Magdas observatory, Unilorin, Nigeria'', Asian J EarthSci, 4, 46-53, 2011
[7] C. Thanassoulass, ''Geoelectric study of Lagadas Hot Spring area'', Int. Rep. No. 3995, IGME Greece, 10 pp, 1983.
[8] T. Dahlin, B. Zhou, ''A numerical comparison of 2D resistivity imaging with ten electrode arrays'', Geophysical Prospecting, 52 (5), 379–398, 2004.
[9] A.S. Saydam, K.. Duckworth, ''Comparison of some electrode arrays for their IP and apparent resistivity responses over a sheet like target'', Geoexploration, 16(4), 267–289, 1978.
[10] S. Szalai, L. Szarka, ''On the classification of surface geoelectric arrays'', Geophysical Prospecting, 56 (2), 159–175, 2008
[11] W. Zhou, B.F. Beck, A.L. Adams, ''Effective electrode array in mapping karst hazards in electrical resistivity tomography'', Environmental Geology, 42 (8), 922–928, 2002.
[12] WHO (World Health Organization), Guidelines for drinking water, Vol. 1, Recommendation. Geneva Switzerland, 1996.
[13] M. Detay, ''Prospection et identification des aquifères: Reconnaissances préliminaires et méthode d'implantation des ouvrages par étude de terrain et photointerprétation'', Session internationale de formation au Cefigre : Exploitation et gestion des ressources en eau souterraine, 1987
[14] M. Cornacchia, R. Dars, ''Un trait structural majeur du continent africain. Les linéaments centrafricains du Cameroun au golfe d'Aden'', Bull. Soc. Géol 1, 101-109, 1983.
[15] B. Bessoles, R. Trompette, La chaîne panafricaine, zone mobile d'Afrique centrale et mobile soudanaise. Yaoundé, BRGM, Mémoire n° 92, 1980.
[16] O. Koefoed, ''Geosounding Principles 1: Resistivity Sounding Measurements'', Elsevier Science Publishing Company, Amsterdam, 1979.

Author Profile

Janvier Domra Kana received the Bachelor Degree in Physics at the University of Ngaoundere and Master Degree in Geophysics at the University of Yaounde I in 2010 and 2012, respectively. He also got a Certificate in oil and gas exploration from the ''Institut Direct Service Management'' in Cameroon in 2012. He is now preparing a PhD Degree in Geothermal exploration and Systems at the University of Maroua in Cameroon.

Noël Djongyang received a PhD Degree in Energy systems from the University of Yaounde I in 2010. From 2007 to 2013, he was a senior lecturer at the Faculty of Science of the University of Ngaoundere. He is since 2013, the Head of Department of Renewable Energy at the Higher Institute of the Sahel of the University of Maroua in Cameroon

Abdouramani Dadjé received a Msc Degree in Electronics, Electrotechnics and Automatics from the University of Douala in 2011. He is now preparing a PhD Degree in Energy Systems and the Environment at the University of Maroua in Cameroon.

Danwe Raïdandi received a PhD Degree in Mechanical Engineering. He is now the Director of the Higher Institute of the Sahel of the University of Maroua in Cameroon