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MAGNETOTELLURIC METHOD FOR GROUNDWATER EXPLORATION IN CRYSTALLINE BASEMENT COMPLEX, CAMEROON

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Magnetotelluric (MT) stations were set up to locate potential groundwater resources in the crystalline basement complex in southern Cameroon. The results have revealed the presence of two aquifers units. The first unit is the shallow or phreatic aquifer located in the sandy weathered layer. It has a mean resistivity value of 100 ohm.m and a mean thickness of 8 m. It is not present in all stations and its thickness and depth of occurrence vary within the site under the lateritic crust layer. The second unit is a deep aquifer, located in the fractured bedrock and has a mean resistivity value of 900 ohm.m and a mean thickness of 30 m. Correlation with data of existing water points (boreholes and hand-dug wells) demonstrates that, in the study area, the first unit is erratic and can be easily contaminated by human activities. So, at some sites, it is not possible to improve traditional hand-dug wells. Generally, only drilling is suitable.

INTRODUCTION

Water is essential for sustenance of life. The knowledge of the occurrence, replenishment and recovery of potable groundwater assumes special significance in quality-deteriorated regions, because of scarce presence of surface water (Todd, 1980; Fouepe Takounjou, A. et al., 2009). During recent years, increasing pollution, agricultural activities and losing of water sources have modified exploitation and water policies. The present study area is located in the equatorial rain forest with average altitude of 700 m. Though, the region has many rivers, it is difficult for the population to access potable water. This area is underlain by crystalline basement complex, where the occurrence of groundwater is due largely to the development of porosity and permeability by weathering and fracturing the rocks. Experience throughout the world has shown that the rate of failure of boreholes is usually highest in the basement complex terrain. This is mainly due to an inadequate knowledge of basement aquifers, which results from in-situ weathering and/or denudation of basement rocks. Geophysical surveys of the subsurface for aquifers can be very important in the basement complex where groundwater occurrence is erratic (Nur and Kujir, 2006; Buchanan and Triantafilis, 2009; Janssen and Valstar, 2010). The results from this study are a contribution to better understanding and management of the aquifer systems in the area.

GEOLOGY AND HYDROGEOLOGY

The area is located in the northern part of the Congo Craton, principally in the region of Sagmelima Cameroon, between the meridian lines 11°56' to 12°07', and the parallels 2°54' to 2°59' (Figure 1). It is covered with various Precambrian rocks (Manguelle-Dicoum and al. 1992; Vicat and Bilong, 1998). The plutonic formations consist of granitoid belonging to two lines installation at successive episodes: charnockites (towards 2900 Ma), and more potassic and leucocratic granites (2700-2600 Ma). Within these rocks, frequent intrusions in relation to various tectonic events can be found: gneiss, shales, dolerite, gabbro and peridotites. This region is in the equatorial rainforest with average altitude of 700m and its climate classification is based on the annual and monthly means of temperature and rainfall. This area is drained by numerous rivers such as the Nyong, Dja, Lobo, So'o; Ndou and Libi.

DATA COLLECTION AND METHOD

The electromagnetic methods measure mainly the apparent resistivity of the physical environments studied starting from the relation:

$$\rho_a = 0.2T(|E/H|)^2 \quad (1)$$

ρ_a represents the apparent resistivity of the grounds in Ωm; T the period of the wave in s; E the electric field in mV/km and H the magnetic field in gamma (Cagniard, 1953). Electromagnetic methods induce small electrical current in the ground. These currents flow more readily in conductive earth materials than in resistive strata. By studying the behaviour of the electrical currents in the ground, we can deduce the location of conductive strata. The depth of penetration, p (km), of the telluric wave is that depth at which its amplitude decreases by a factor of *e* of its surface value, and given by:

$$p(km) = 0.503(\rho_a T)^{1/2} \quad (2)$$

Groundwater, through the various dissolved salts it contains, is ionically conductive and enables electric currents to flow into the ground. Consequently, measuring the ground resistivity gives the possibility to identify the presence of aquifers El-Qady (2006).

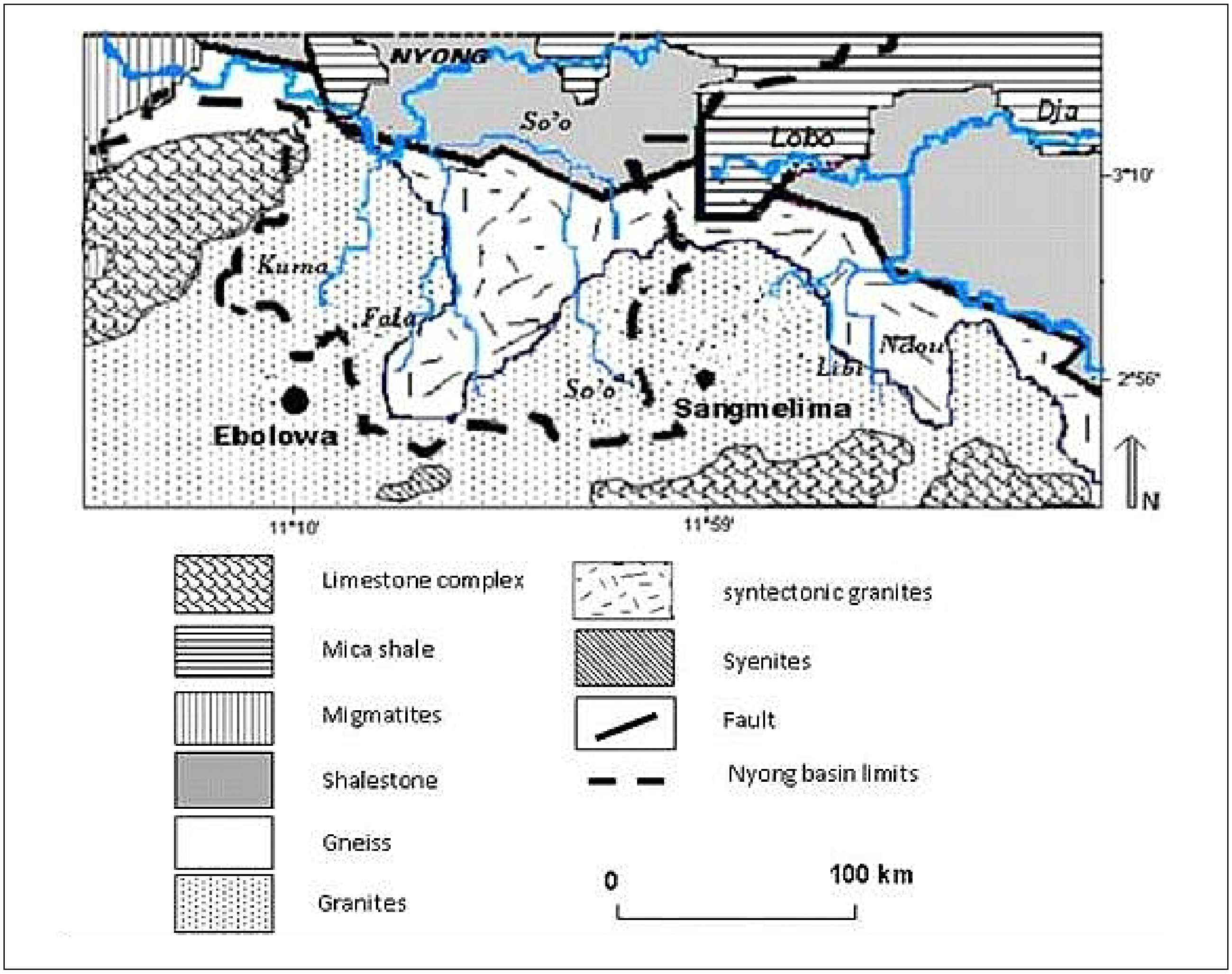

Figure 1. Hydrogeological map of Nyong basin Vicat and Bilong (1998) modified.

The instrument used was the scalar AMT resistivity meter ECA 540-0, consisting of a detector to measure one component, E, of the electric field and another detector to measure simultaneously the component H of the magnetic field at the same frequency of the natural telluric field.

The MT measurements sites (Figure 2) were mainly established in the vicinity of the water drillings carried out by the community, along the tracks and in the plantations for which the access authorization was obtained on an approximate 1km grid in dryland areas. Moreover, the limits of the city and the presence of the marshes conditioned this establishment.

RESULTS AND DISCUSSION

The interpretation of the MT soundings shows that there are three types of curves (Figure 3, 4 and 5). The interpretation at station S_2 (Figure 3) gives the following succession: the first layer with 3.5 meters thickness and 236 Ω.m of resistivity followed by 16.8 meters of resisting rock of 2700 Ω.m, the third layer with 978 Ω.m of resistivity and a thickness of 27.4 meters, the fourth layer with 137 meters and 2762 Ω.m of resistivity, and the three last layers constitute the substratum.

The results of the S_8 station (Figure 4), shows eight layers. The first one with a mean resistivity of 228 Ù.m and 8 meters thickness, the second layer with 6 meters thickness and 100 Ω.m of resistivity, the third layer with 25 meters thickness and 2683 Ω.m of resistivity, the fourth layer

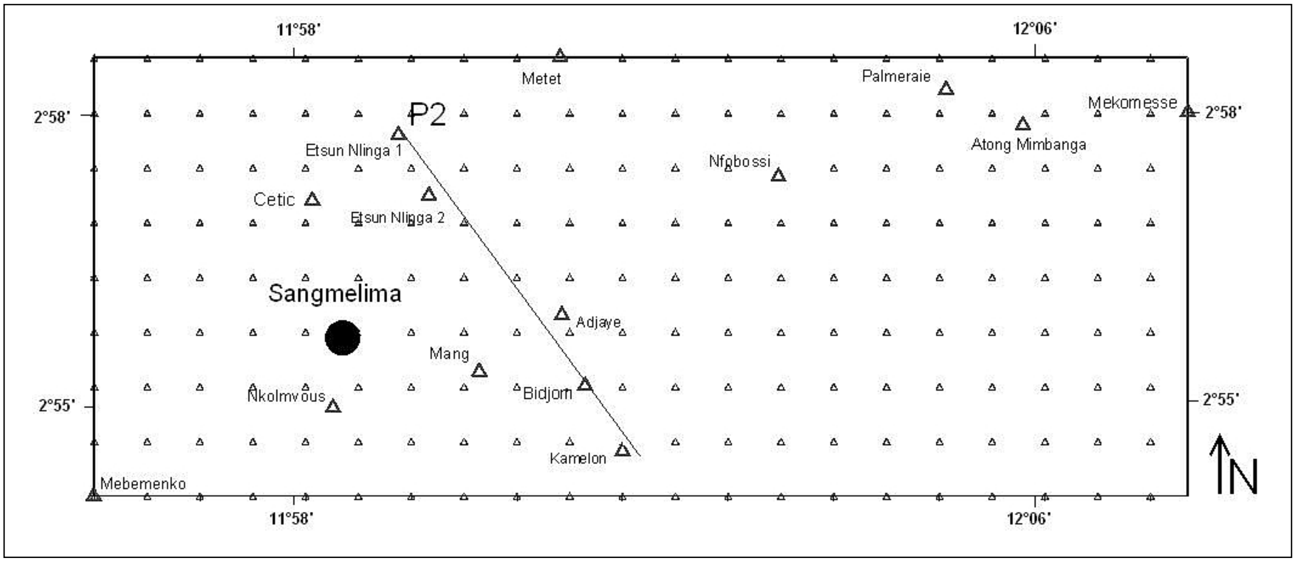

Figure 2. MT stations map.

with 978 Ω.m and 25 meters thickness, the fifth layer with 2834 Ω.m of resistivity and 18 meters thickness, the sixth layer with 1468 Ω.m of resistivity and 438 meters, and the two last layers represent the substratum. The curve of Figure 5 (station S_{13}) gives from the surface the following succession: 7 meters of the first layer with 238 Ω.m of resistivity followed by 21 meters of resisting rock of 2725 Ω.m, the third layer, conductive with 978 Ω.m of resistivity and a thickness of 28 meters, a 186 meters layer with 2799 Ω.m of resistivity, and the three last layers constitute the substratum.

The Tables 1, 2 and 3 summarise the results obtained by the interpretation of MT soundings and show that, the layer of 100 Ω.m is not always present in the study area. But the layer with 978 Ù.m of mean resistivity is always present.

A geoelectrical cross section is obtained starting from the extension of the 1-D model, carried out by juxtaposition along the profile of survey, of the geoelectrical columns coming from the interpretation of the MT soundings. It is thus about a horizontal distribution of the grounds according to the profile. It can make it possible to detect the variations of resistivity caused by the presence of water in the ground Vozoft (1972) and El-Qady (2006). In general, the geoelectrical cross section (Figure 6) watch succession of five different grounds: a topsoil, of (230±40) Ω.m of resistivity and (10±4) m thickness, a layer of (100±40) Ω.m of resistivity and (8±2) m thickness, a resistant layer of resistivity ranging between 2000 and 3000 Ω.m and of (30±5) m thickness, a conducting level of mean resistivity (900±80) Ω.m and thickness ranging between 10 and 50 meters resting on one boxing of resistivity > 3000Ω.m.

To identify the geological causative structures of this electrical anomalies, some boreholes were made at S_2, S_8 and S_{13} stations and the obtained results were present in Figure 7. Correlated with the previous MT data existing close to these stations (Figure 7), the first layer corresponds to the lateritic cover, the third and the fifth with the dry granites, while the second and fourth grounds are recognised as the relative thick aquifers around the stations S_6, S_7, S_8 and S_9, and correspond to the weathered layer and fractured granite. The first unit aquifer located in the weathered layer correlated to the MT layer with a resistive mean value of 100 Ω.m and mean thickness value of 8 meters. This unit is erratic and can be easily be contaminated by human

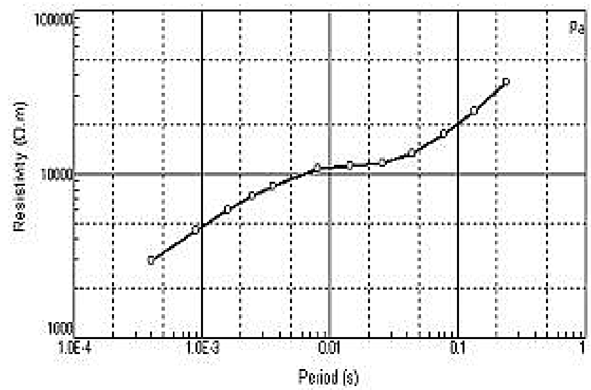

Figure 3. Sounding of Nkolmvous station (S_2)

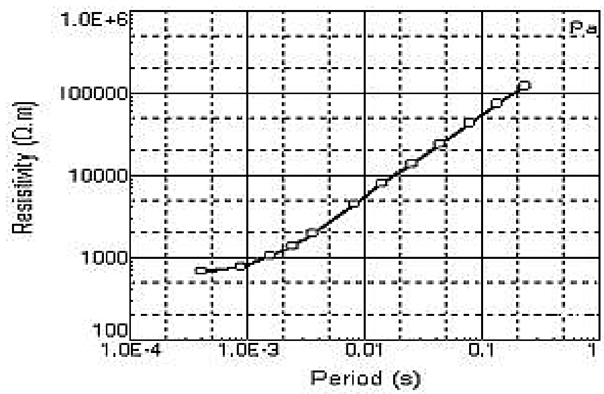

Figure 4. Sounding of Bidjom station (S_8)

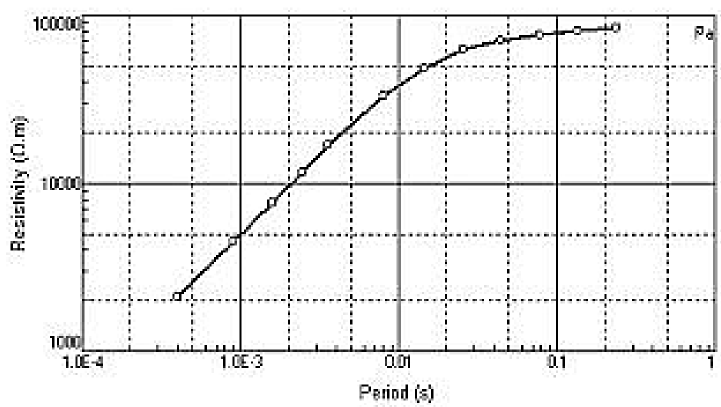

Figure 5. Sounding of Atong Mimbanga station (S_{13})

Table 1. Parameters obtained from interpretation of S_2 sounding.

Number	Resistivity (Ω.m)	Thickness (m)	Depth (m)
1	236	3.5	3.5
2	2700	16.8	20.3
3	978	27.4	47.7
4	2762	137.3	185.0
5	7801	128.0	313.0
6	19245	12600	12913
7	2.7 E + 5		

Table 2. Parameters obtained from interpretation of S_8 sounding.

Number	Resistivity (Ω.m)	Thickness (m)	Depth (m)
1	228	7.9	7.9
2	100	6.3	14.2
3	2683	25.0	39.2
4	978	65.0	104.2
5	2834	17.6	121.8
6	1468	438.2	560.0
7	14678	45.5	605.5
8	6.8 E + 7		

Table 3. Parameters obtained from interpretation of S_{13} sounding.

Number	Resistivity (Ω.m)	Thickness (m)	Depth (m)
1	238	7.4	7.4
2	2725	20.6	28.0
3	978	27.9	55.9
4	2799	186.1	242.0
5	16284	391.0	633.0
6	82729	14100	14700
7	3.1 E + 6		

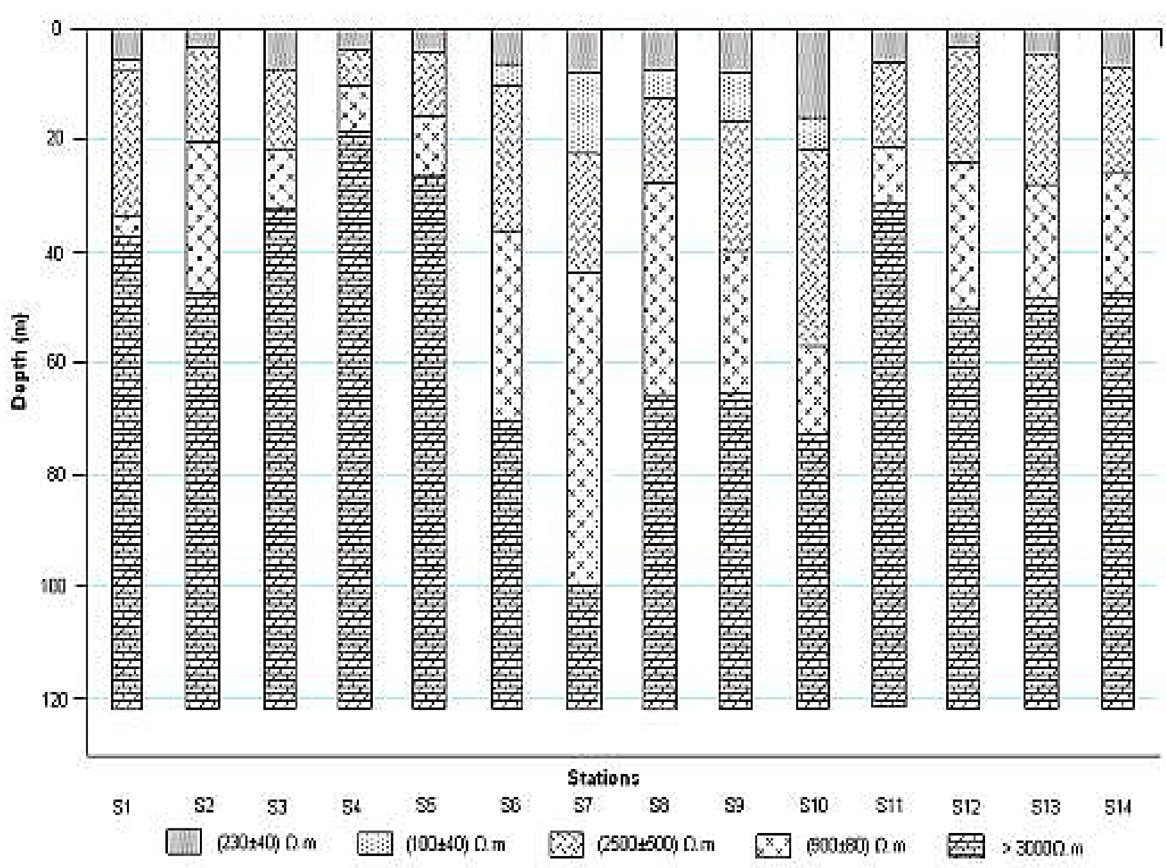

Figure 6. Geoelectrical cross section.

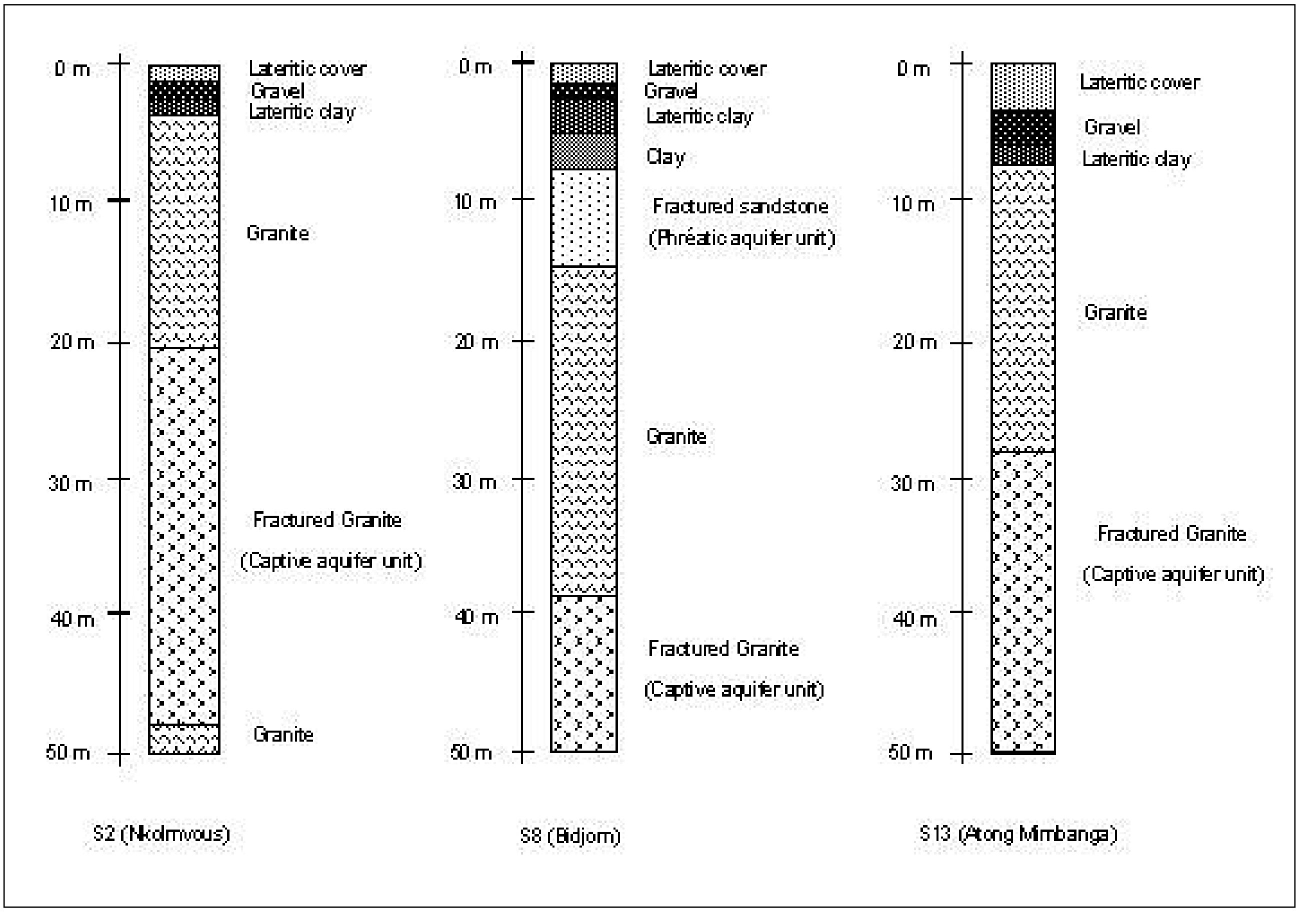

Figure 7. Lithological section from boreholes of S2, S8 and S13 stations.

activities. The second unit aquifer is located in fractured granite and corresponds to the MT layer with 978 Ω.m and mean thickness value of 30 meters.

CONCLUSIONS AND RECOMMENDATIONS

Geophysical investigation in the Nyong basin near Sangmelima area using magnetotelluric methods has revealed the presence of two aquifers units. Its interpretation has led us to identify the first unit which is the shallow or phreatic aquifer in the sandy weathered layer. It is not present in all stations and its thickness and depth of occurrence vary within the site under the lateritic crust layer. The second unit is the fractured bedrock. This demonstrates that at some sites it is not possible to improve traditional hand-dug wells, only drilling of boreholes are possible. By this method, results of the electrical resistivity survey are in correlation with data of existing water points (boreholes, hand-dug wells and springs). The magnetotelluric method is revealed to be very useful for the prospection of groundwater and so can be essential to choose the best drilling sites.

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