Geoelectrical Prospection of Aquifers in Eseka Region, Center-Cameroon

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Abstract
This geophysical study was carried out in the city of Eseka, the head quarter of Nyong and Kelle Division, Center Region of Cameroon. It had as aims to prospect aquifers and to propose models of geophysical structures of the underground basement in the city. To this effect, the geophysical method of electrical resistivity was chosen, due to the local geologic context, and its easy application. With the aid of a resistivimeter of mark TERRAMETER ABEM SAS 300, twenty (20) electrical soundings were effectuated in different points in the city. The treatment of data was done through several interpretation softwares, such as Geo-Elect. Mod and surfer 8.0. Qualitative and quantitative interpretations, coupled with field and laboratory observations, permitted: the characterization of the lateritic crust constituted of the model of the terrain, into four and five layers of distinct terrain by their resistivity and thicknesses; the definition of the average depth of the upper aquifer from about three (03) meter in the loose clayey level, and the lower aquifer at about thirty (30) meter in the weathering and fractured gneiss level; the localization of the zone of conduction and resistant anomaly, at chosen depths in the study area. These results are important in future modeling process of the aquifers in this area.

Keywords: Eseka, aquifer, electrical sounding, electrical resistivity, geo-electrical cross section.

INTRODUCTION
In most places within the basement terrain of Eseka town (Figure 1 and 2), Central Region of Cameroon, there is a major problem of potable water for domestic and industrial uses. The sources of water in this town are through shallow wells in the urban areas and mostly through streams and springs in the rural communities. Despite these sources, there is shortage of portable water in the city of Eseka. This shortage was partly aggravated by the collapse of SNEC (National Society of Cameroon waters). Most boreholes drilled in Eseka have high spate of failure rate which could be attributed to the underlying complex geology and inadequate geophysical information prior to sitting and development of boreholes in the area. Beside, borehole yield is frequently low in the basement complex area during the dry season, and during these periods, water supplies from borehole do not have long-term sustainability, so it is imperative to locate borehole on aquiferous zone: a lithological formation that is characterized by fracture, shear, joint, fissure and/or faulted basement rocks. This is because the differing properties of various rock types by nature of their origin, lithology and structure influence the geoelectric parameters of a particular site. An aquifer is any mass of permeable rock material from which a significant amount of water can be recovered. Aquifers differ in properties, because these properties are in function of the rock types which constitutes them. Different lithologic materials constitute the basement complex and sedimentary aquifers. In hard rock terrain, aquifers are fractured rocks and weathered in situ materials, while the sedimentary aquifers consist of sands and sandstones. The existence of fracture zones in a geologic medium aid in groundwater accumulation (Hazell et al., 1988).

Groundwater distribution in basement complex areas varies from place to place due to the localized nature of basement aquifers (Dan-Hassan and Olorunfemi., 1999, Meli’i et al., 2011, 2012; Teikeu et al. 2012; Ekoro et al., 2012). The spacial variation of the aquifer parameters such as porosity, permeability, transmissivity and conductivity can be attributed to, among other causes, tectonic set-up and degree of weathering of near-surface rocks (Baker et al., 2001). Therefore, electrical resistivity method is the major geophysical application in hydrogeologic investigation which is directed towards aquifer characterisation and groundwater quality study (Asfahani, 2006; Bello and Makinde, 2007). High resistivity contrasts usually occur between solid rocks and saturated fracture zones (Leroux et al., 2007). This study aims to localize the different types of aquifers and to propose the models of underground
geophysical structures enclosing these aquifers through geo-electrical cross sections, obtained from data of Vertical electrical sounding (VES).

Figure 1: Location map of the study area, VES stations and its environs.

GEOLGY OF STUDY AREA
The study area (Figure 2) is part of the Lower Nyong unit, in this unit, several petrographic and structural studies have been carried out. In the petrographic viewpoint, Champetier De Ribes and Aubaque (1956), for the first time described the gneiss of Eseka in which they qualified them as migmatites. Lasserre and Soba (1976) using the Rb-Sr dating method on micas gave these gneiss an age of 528 Ma. Jourde (1978) described a belt of ferriferous formation from the Mamelles up to Eseka through Mewongo and Ngovayang. Thouvenin and Edimo (1980, 1981) in Bokally (1991), signaled the presence of granites, tonalits and alkaline syenites at the North, East and West of Eseka. According to Minyem and Nedelec (1990) most Eseka gneiss show the same geochemical characteristics (major and trace elements) as those of the Ntem archean TTG (Tonalite-Trondhjemite-Granodiorites) which are considered as their protoliths. More recent works on the new Eseka-Ngwate railway fragment show that the dominant petrographic type is a slightly migmatised grey gneiss. These gneiss are associated to quartzites and at times boudins of basic and ultrabasic rocks (Nédélec and Minyem, 1991).

However, the studied and appreciated tectonic event in the Lower Nyong unit was the overlapping of the Yaoundé nape on the Lower Nyong unit (Ball et al., 1984). The structuration of the Lower Nyong unit is marked probably by a post-liberian and anti-panafrican D2 deformation, but clearly posterior to D1 phase defined in the Ntem unit. It divides this major tectono-metamorphic event into three episodes as follow D2a, D2b and D2c. The D2a episode is the most important, it is at the origin of the essential structuration of the Lower Nyong unit while the D2b and D2c episodes discretely manifests by sinistral blastomylonitic strike-slip faults which also affects the Ntem unit. The works of Minyem and Nédélec, (1990), indicate a D1 phase of liberian age, identifiable in the Ntem unit characterized by a subvertical (S1) foliation in a N090E direction; a D2 phase whose age is presumably Eburnian, responsible for a (S2) foliation in a N040E direction, generally dipping towards the SE; a D3 phase of panafrican age responsible for the overlapping of the Yaounde group...
micaschists towards the South. According to the same author, the D2 deformation phase was the highest deformation to allow marks in the Lower Nyong unit in the Eséka region. In Eséka region, the association of the NE-SW foliation and the sinistral strike-slip fault contributed to an Eburian orogenesis (Toteu et al., 1994).

The pedologic covers of South Cameroon were developed on stable continental surface by the isostatic readjustment and the replay of ancient alignments Ségalen (1967). In Eséka, reddish ferrallitic soils are developed on hill slopes and tops, and hydromorphic soils in the low areas of valleys where several streams proliferates, thus characterizing the drainage network of the region. The latter results from ferrallitisation processes which prevail in the hot and humid climate. The Eséka gneiss have undergone intense weathering by complete hydrolysis of minerals, followed by the individualization of clays and metallic oxyhydroxides (Fe, Al) in the form of more or less harden residual products (Cady, 1962 in Schellmann, 1981). These soils have been affected by climatic variation and intense pedologic processes thus their polycyclic character. They are characterised by very thick pedologic profiles that can exceed 30 m. The study of their genesis, evolution (Bitom, 1988; Yongué-Fouateu, 1986) and the organization of these soils (Bekoa, 1994; Bilong, 1988; Nyeck, 1988) present very varied soils and generally differentiated into three large sets on the parent rock: a weathering set with conserved original structures of the parent rock; an intermediate set characterized by the accumulation of metallic oxyhydroxides and clay with totally or partially transformed lithorelictual organization; a loose upper set constituted of resistant residual minerals (quartz) and secondary minerals (kaolinite, hematite, goethite, gibbsite, boehmite).

GEOPHYSICAL DATA ACQUISITION
In the framework of this study, the geophysical method used is that of electrical resistivity. It is the most used method in hydrogeological prospection of crystalline formations due to their appropriate local geological context and its ease to put to work. The data obtained in this study, results from Schlumberger sounding carried out in the course of several geophysical field trips (Figures 3, 4 and 5 and table 1). A total of 20 electrical sounding were executed on a surface area of about 10 km², in different neighbourhoods of Eséka town where the population urgently need supply in portable water (Fig. 1). Measurements were taken with minimal length line \( AB/2 = 1.5 \) m and maximal \( AB/2 = 250 \) m, these values were dependent on the localization of the structure being searched, because the larger the length of line \( AB/2 \) the deeper the targeted structure.

The results of resistivity measurements were effectuated on an electrical drill report sheet with a bi-logarithmic scale of a Géo.Elect.Mod. data inversion software (which on the x-axis, contained the different electrode \( AB/2 \) (in m) spacing values and on the y-axis, the different values of corresponding apparent resistivity \( \rho_a \) measured on the field in ohm.m. The set constitutes an “electrical sounding diagram”). It’s a one dimensional (1D) interpretation software of Schlumberger vertical Sounding (VES) data by Gosh linear filters. In the input, it introduce the values of \( AB/2 \) (in m) and the apparent resistivity \( \rho_a \) measured on the field and at the output, it restitutes automatically calculated values of apparent resistivities \( \rho_{ac} \) and a curve \( f(\rho_{ac}) = AB/2 \). This method supposes homogenous layers and horizontal interface with respect to the sounding line.

One-Dimensional Interpretation
In the study area, the data collected revealed two types of curves and field models.

Type 1 Sounding curves or field model 1
They are obtained after the treatment of data at different sounding points (SE1, SE2, SE3, SE4, SE5, SE6, SE7, SE8, SE9, SE10, SE11, SE12, SE13, SE14, SE15, SE16), and characterizes field models with five layers (Fig. 3). for each sounding, it materializes the succession of layers from top to bottom: less conductors, clayey, compacts, of resistivity between 100 ohm.m and 170 ohm.m and an average thickness of 1 m. They are identified from the first points of curves and corresponds to the organo-mineral lateritic cover; conductors, clayey sand, porous, with resistivity between 35 ohm.m and 50 ohm.m and an average thickness of 3 m. They constitutes upper
accumulation aquifers of surface water and are identified by the first extremum of curves; a resistant clayey layer, compacts, with resistivity between 250 ohm.m and 350 ohm.m and an average thickness of 5 m. They corresponds to the nodular lateritic and cuirassed levels, characteristic of tropical regions and are identified by the second extremum of curves; a very conductive layer, clayey sand, porous, with resistivity between 10 ohm.m and 30 ohm.m and an average thickness of 30 m. They are identified by the third extremum of curves and contains the weathered and fissured lower aquifer lower which supplies the drainage network of the sector; a very resistant layer, with resistivity superior to 3500 ohm.m. They are identified by the climbing branches of curves and corresponds to the gneissic crystalline basements, on which lies the other layers.

Type 2 Sounding Curves or Field Model 2
They are obtained by the treatment of data at different sounding points (SE17, SE18, SE19, SE20) and are characteristic of a four layered field model (Fig. 4), as such, this type of sounding presents from top to bottom: a conductive layer, clayey, compact, with resistivity between 70 ohm.m and 120 ohm.m and an average thickness of 1 m. This layer is identified by the first point of the curves and corresponds to the organo-mineral lateritic cover; a resistant layer, clayey, compact, with resistivity between 275 ohm.m and 300 ohm.m and an average thickness of 13 m, it is identified by the first extremum of the curves and corresponds to the nodular lateritic and cuirassed levels which are characteristic to the humid and dry tropical regions; a very conductive layer, clayey sand, porous with resistivity between 10 ohm.m and 35 ohm.m, and an average thickness of 15 m. This layer is identified by the second extremum of the curves. It contains the weathered and fissured lower aquifer; a very resistant layer with resistivity superior to 3500 ohm.m. This layer is identified by the climbing branches of curves and corresponds to the gneissic crystalline basements, on which lies the other layers.

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PT (Pedolith thickness) = organo-mineral lateritic cover + nodular lateritic cover
ST (Saprolith thickness) = weathered and fissured layer + saprolite
DBR (Depth to bedrock or Regolith) = PT + ST
Aquifers located in boreholes in the Eseka region present average flow of order 887 l.h\(^{-1}\) this is as result of the numerous stream and lakes found in the locality, principal recharge sources and of the thick layer of the lateritic mantle, porous at the top and impermeable in its intermediate part, issued from the weathering of gneiss and multiple paleoclimatic episodes characteristics of hot and humid tropical region which have been successively put in place in the locality.

Although the deduced information from the 1D interpretation was correlated with the geologic studies and surface thermal manifestation, it is still not fully understood for the 3D geologic structure. To get a realistic solution, we have applied 2D inversion for the same data set, as discussed in the following section.

**Two-dimensional Interpretation**

In the framework of this study, it is done with the aid of graphic software, Surfer 9.0 data inversion and constitutes one of the most appropriate data representations for a continuous and horizontal underground exploration at a determined depth and which depends on the length of the chain (wire) AB/2 (Figures 6 and 7).

The maps represented here were wedged at two different depths. The spacing of chain (wire) AB/2 equal to 6.3m (Fig. 6) and 58m (Fig. 7), values whose terrains presents very strong resistivity. It is a 2-D representation of curves with equal apparent resistivity. On which the longitudes are placed on the x-axis while the latitudes of each station are plotted on the y-axis. The iso-resistivities are griged and the corresponding resistivities distributed on all the surface of the study area can be visualized. The map established to a length of chain (wire) AB/2 = 6.3 m, presents resistivities from 50 ohm.m to more than 190 ohm.m, divided into three (03) domains (Fig. 7):

- **First domain** which is very conductive and whose iso-values curves presents the forms of spaced and dissymmetric ovoids, with resistivities between 50 ohm.m and 90 ohm.m, covering all the eastern half of the map, which indicates the presence of an aquifer of about 2 m in the zone; a second domain (green) which is conductive, presenting in a meandering vertical band which crosses the map from North to South with iso-value curves between 100 ohm.m and 140 ohm.m, which can be considered here as a transition zone between the very conductive zone and the resistant one; a third domain (red) which is resistant, situated at the SW and NW of the map, with the iso-value curves presenting an elliptic dissymmetry at the SW and symmetric parallelism at the NW, with resistivities from 150 ohm.m and 190 ohm.m, which can be explain by the fact that this zone can either be situated at a higher topographic position and by the lack of water in the formations of the zone at this depth.
CONCLUSION

This geophysical study was carried out in the town of Eséka, head quarter of the Nyong and Kéllé Division, Center Region of Cameroon. It has as aim to experiment a methodology with objective to localize the different types of aquifers in the region and to propose the models of the underground geophysical structures containing these aquifers through geoelectrical cross sections and iso-resistivity maps obtained from vertical electrical sounding (VES) data realized in the town of Eséka. To do this, the electrical resistivity method by sloping of Schlumberger drills was chosen due to its ease to put to work and the favorable local geologic context. As such, this study through obtained drill curves and realized iso-resistivity maps, permitted: to consider the weathering crust as constituted of five layers of terrain distinct by their resistivity and their thicknesses; to define the average depths of the upper aquifer at about 3 m in the loss clayey level and the lower aquifer at about 30 m in the weathering set; to localize the zones of conductive and resistant anomalies at chosen depths in the study area. As a result of this study, several perspectives have been sited to ameliorate its results in the geophysical as well as in the hydro-geological viewpoints; densify drill points in the town in order to close the prospection mesh.

REFERENCES


