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Application of Coefficient of Anisotropy to the Geophysical Prospecting of Campo—Ma'an Area of the Ntem Complex in Cameroon

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Abstract

Audiomagnetotelluric data were acquired for 10 sounding stations in open fields and roads along the main highways from Campo to Ma'an in Cameroon. An application of the coefficients of anisotropy was used to determine the tectonic settings and the nature of the contacts between the sedimentary formation of the Kribi-Campo basin and the cratonic Ntem Complex. The results of this study show that apart from the sedimentary formation, the metamorphic formation in this area comprises two metamorphic blocks: a regional metamorphic block which might be igneous or granitic in nature and composition and seem to be Precambrian and plutonic in origin and a contact or transitional metamorphic block, which might represent schist or gneiss rocks. The contact or transitional metamorphic block might be as a result of a long period of contact between regional metamorphic rocks and rocks of sedimentary formation. These contact/transitional metamorphic rocks which are found sandwiched between rocks of sedimentary formation and rocks of the regional metamorphic block and at varied depths confirm the existence of vertical and sub-vertical contacts between the Kribi-Campo basin and the cratonic Ntem complex. Two types of rock contacts have been identified: a sedimentary-schist contact which is found at the boundary between the sedimentary formation and the transitional metamorphic block and a schist-granite contact between the transitional and regional metamorphic blocks. Two main formations: a sedimentary formation, which is found in the Kribi-Campo sub-basin and the Ntem River bed and its flood plains and the metamorphic formation which includes both the transitional and regional metamorphic

rocks have also been identified in the area of study. Subsurface rocks and rock materials have been observed to be highly resistive and occupying almost the entire subsurface in the area of study confirming the high vertical tectonic stability of the Ntem Complex even at contact with the sedimentary Kribi-Campo basin.

Keywords

1. Introduction

According to [1], the geometrical arrangement of interstices in rocks has a pronounced effect on their electrical conductivity. This is as a result of the fact that due to the water contained in these interstices, the conduction of electric current tends to be electrolytic rather than electronic. As a result of this, the resistivity of rocks varies with the mobility, concentration and degree of dissociation of ions in the interstices. Rocks are usually deposited in layers such that the electrical conduction varies depending on the direction of deposition. In an isotropic medium, the propagation of telluric or electric current is in all directions [2]. In cases where the conductivity depends on the direction of the current, the medium is said to be anisotropic [3]. In general, sedimentary rock formations are considered to be isotropic, however according to [1], the anisotropy of rocks and rock materials is characteristic of their stratification. This is demonstrated in the field during Magnetotelluric prospection by the fact that for a homogeneous subsurface, telluric current tends to flow in the direction of strike of the bedding planes than in the more resistive perpendicular direction. And that is why in magnetotelluric data collection the transverse and perpendicular directions of apparent resistivity must first be determined by the method of rotation [4]. The assertion by [1] implies that the geometrical arrangement of the interstices in rocks also has a pronounced effect on their anisotropy. [3] also identifies the case of micro-anisotropy in which in laminated rocks, the laminas have different resistivity values. By employing the magnetotelluric method in the field, [5] came across rocks that they considered to be laterally isotropic. For this reason, the apparent resistivity values also vary with lateral directions. The following statements enable the coefficient of anisotropy of resistivity to find its place in magnetotelluric prospecting:

- According to [5], an on the spot calculation of coefficients of anisotropy can, in addition to the method of rotation by [4]; be a very useful tool in determining the direction of structural trend of the geologic features in a particular region of prospecting.
- Iso-anisotropy contour maps can provide a more effective and efficient representation of the variation of apparent resistivity with depth for a vertical

cross-section through a slice of Earth under consideration. Calculated values of coefficient of anisotropy can be used to determine in a vivid manner the types of rocks formations in the region of investigation [5].

- From a pseudo-section of anisotropy it is possible to distinguish completely isotropic from completely anisotropic zones [5]. These "pseudo-section of anisotropy could be an important tool for an initial modelling".

- For a 2-D model made up of two adjacent blocks with quite different apparent resistivity values (fault, contact, fracture, and intrusion) it can be deduced that telluric current circulates along the strike of the more resistive block. The coefficient of anisotropy can be used for such a 2-D structure to locate the boundary between conductive and resistive blocks, and to determine the direction chosen by telluric current near important discontinuities [6].

The revelations above show the importance of anisotropy coefficient in magneto-telluric prospecting and in the analysis and interpretation of the acquired data. The present work, which is based on these findings, has as main objective the application of the coefficients of anisotropy to determine the tectonic settings and the nature of the contacts between the sedimentary formation of the Kribi-Campo basin and the cratonic Ntem Complex in the Campo-Ma'an area of South Cameroon.

2. Geo-Tectonic and Geological Settings

The entire African continent underwent a major phase of basement re-activation in the Late Precambrian, which resulted in the structural differentiation of the continent into stable cratonic nuclei, surrounded by mobile belts [7] [8]. This event has controlled the subsequent tectonic history that has affected the whole continent with the most recent events being the East African rift that was initiated some 30 Ma to 40 Ma [9]. Studies of absolute plate motion show that at present, the African plate is almost stationary and this may be the reason why some of the most recent tectonic movements in the continent have been dominated by vertical and oscillatory motions which have led to either intrusions from the underlying substratum or subductions of near-surface materials into the architectural settings of subsurface formations [10] [11].

The Congo Craton of central Africa is composed of Archean crust, early to mid-Proterozoic fold belt and Proterozoic cover exposed in a ring of Archean terranes of diverse size and separated from one another by intervening Proterozoic belts or cover surrounding the Congo Basin [12]. Most of these terranes have been stable since the end of the Archean. This Craton being one of the cratonic nuclei is a large sub-circular mass of about 5.7×10^6 km^2 in area and has an approximate diameter of 2.5×10^3 km. The north western margin of the Archean Congo Craton which is found in the South of Cameroon is called the Ntem Complex [13] [14]. The Ntem Complex is divided into three main structural domains: to the north there is a major thrust that marks the contact with the Pan-African orogenic mobile belt called the Yaounde group, to the northwest end there are the Nyong and Ayina series and in the south-central area the Ntem

series [15]. The Ntem series is dominated by massive and banded plutonic rocks of the charnockite suite and by intrusive tonalites, trondhjemites and granodiorites [16]. The entire Ntem Complex in particular and the Congo Craton in general are involved in two of the three orogenic cycles that are known in Cameroon:

- The Liberian cycle which dates from the Archean era (about 2.5 Ma old) and is bounded by major thrusts that separate the Ntem series from the Nyong unit to the Northwest and the Pan-African Yaounde Group to the North of the Ntem Complex [17]. This era began with the intrusion of magmatic rocks from which the greenstone belts were derived. Greenstone belt formation was followed by diapiric intrusion of the Tonalite-Throngemite Granodiorite (TTG) between 2900 Ma and 2800 Ma, during the major tectono-metamorphic phase [16]. The structures formed are essentially vertically dipping and the metamorphism dominated by granulite facies rocks that ended with an important migmatisation event, resulting in the intrusion of anatectic potassic granitoids [18].

- The Eburnean or Transamazonian cycle that dates from the Palaeoproterozoic period (2.5 Ma to 1.8 Ma ago). This corresponds to the Nyong and Ayina series found to the north western border and to the east of the Ntem complex [19]. This Eburnean orogenic cycle is characterized by intrusion of doleritic dykes; which cycle ended with either a thermal or hydrothermal event at around 1800 Ma [16].

The present study area is found at the south-western edge of the Ntem Complex and cuts across the southern portion of the Nyong and Ayina series and the south-western portion of the Ntem series. It lies between latitude 2°22'N and 2°26'N and longitude 9°57'E and 10°41'N, stretching from Campo through Nyabessan to Ma'an, having a minimum altitude of 39 m at Campo and maximum of 554 m at Ma'an (Figure 1).

3. Material and Methods

3.1. Magnetotelluric Data

The magnetotelluric data used in this work was acquired during a field study that took place in March 2015 using an ECA 540 AMT resistivity meter which has a frequency range from 4.1 Hz to 2300 Hz giving a total number of twelve frequencies. Field data is acquired at points called sounding stations which are chosen as a function of the orientation of the geological features of interest such as faults and contacts that might have prompted the prospecting. For each station a Global Positioning System (GPS) is first used to determine the angular coordinates and the altitude. Then, using the resistivity meter, twelve series of measurements are made in two predetermined perpendicular directions for the component of electric field intensity, its mutually perpendicular component of magnetic field intensity and the values of the apparent resistivity. In the case of this data the principal directions were chosen in the North-South and East-West
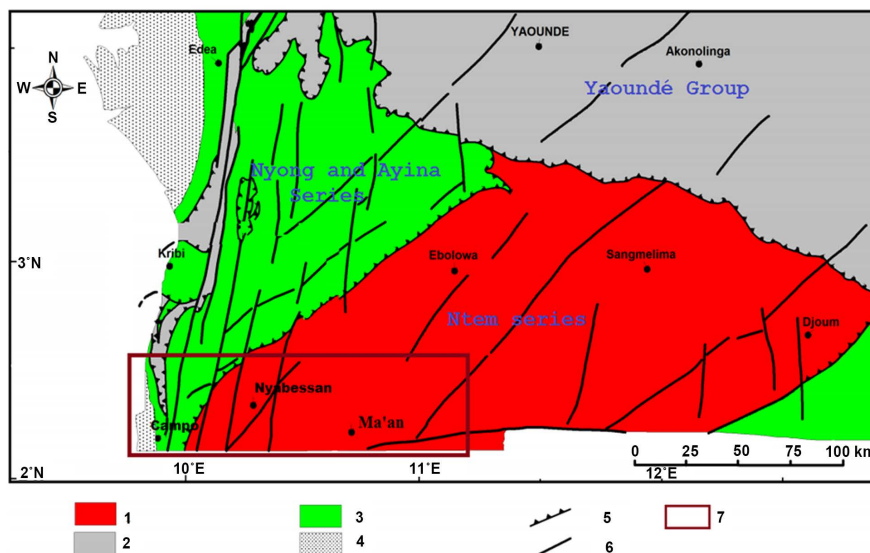
Figure 1. Simplified geological map of south Cameroon showing study area as modified from [20] 1: Archean Basement; 2: Neoproterozoic cover; 3: Neoarchaen-Paleo-proterozoic cover; 4: Post Pan African cover; 5: Thrust fault; 6: fault.

cardinal directions. For each frequency two average apparent resistivity values are got (one in each direction). The Audiomagnetotellurics data acquisition was conducted for 10 sounding stations along the main highways from Campo to Ma'an. In the field, sounding stations were chosen as a function of the existing geographical features, the knowledge on the subsurface geology and accessibility. The area of study is found in a dense equatorial forest into which access was difficult except for open fields and roads and also because of the presence of the Campo-Ma'an national park that covers a great portion of the area and the Ntem river flood plains which are very swampy, woody and extremely inaccessible by foot. Some of the identified geological and geographical features are the contact between the Kribi-Campo Basin and Ntem Complex, the Ntem River that flows in a NNE-SSW direction corresponding to the direction of major faults and the other streams that run in the area. The data for each sounding station is made of position (altitude, longitude and latitude) and the frequency of alternating telluric current, components of electric and magnetic fields and apparent resistivity of subsurface rocks. It is this data that have been used in the present study.

3.2. Coefficient of Anisotropy Equation

According to [5], related equations of resistivity coefficient of anisotropy are simple and easily derived when a medium is isotropic. They considered an anisotropic and tabular medium in which the values of apparent resistivity in a direction perpendicular to the structural discontinuity are higher than those parallel to it. These are called transverse apparent $\left(\rho_T \right)$ and longitudinal apparent $\left(\rho_L \right)$ resistivity respectively. Considering a block of earth of one square metre in cross-sectional area, cut out of a group of layers of infinite lateral extent of

specific resistivity ρ_i and of varying thickness of depth h_i, with the subscript i indicating the position of a layer of earth, the equation for the coefficient of anisotropy can easily be derived. This coefficient of anisotropy which depends on the resistivity and the flow of current is given according to [22] by the expression:

$$\lambda = \sqrt{\rho_T / \rho_L} = \sqrt{\frac{\left(\sum_i^n \rho_i h_i\right)\left(\sum_i^n \frac{h_i}{\rho_i}\right)}{\left(\sum_i^n h_i\right)^2}} \tag{1}$$

The equation above also represents the flattening coefficient for a homogeneous but anisotropic medium where the equipotential surfaces about a point source of current are flattened ellipsoids of revolution [22]. According to [5] the derivation of the formula for the coefficient of anisotropy as above, allows for a deduction of its dependence on the geo-electric section, which may in turn depend on the geologic section (stratigraphic or lithological) for rocks covering a long geological period [23].

3.3. Pseudo Depth of Penetration of Telluric Currents

According to the principle of the skin-effect upon which the magnetotelluric method is based, the depth of penetration of telluric current decreases with an increase in frequency until this current becomes completely attenuated [24]. This enables the pseudo-depth of penetration of the telluric current to be determined using the equation:

$$P = 0.503\sqrt{\bar{\rho}T} \tag{2}$$

where T is period, which the reciprocal of frequency measured in seconds (s).

For each station and as a function of the frequency and the geometric mean apparent resistivity value, the pseudo-depth of penetration of the telluric current is determined.

From the two values of apparent resistivity got in the two principal directions, the geometric mean value of apparent resistivity, $\bar{\rho}$, measured in Ωm is calculated using the formula:

$$\bar{\rho} = \sqrt{\rho_L \rho_T} \tag{3}$$

3.4. Geoelectric Sections

A geo-electric section is a 2D presentation of the earth's subsurface that is described by two fundamental parameters: the resistivity of the subsoil ρ_i and thickness of depth h_i [25]. The geo-electric section can also be described as a function of other parameters such as conductance, resistance and coefficient of anisotropy. It is thus employed to show how the electrical properties of rocks and rock materials can be averaged over a large volume of earth, which may not necessarily be homogeneous [25]. For a layered sequence of rocks, the

geo-electric section shows boundaries between layers represented by pronounced resistivity contrasts. In the geo-electric section, it is possible to recognize structures like folds, faults and intrusions. A fault is recognized in a geo-electric section by a break in the continuity of the normal geo-electric sectional sequence [25]. Some amount of geo-electric section is always repeated or missing at the fault contact [26]. From the geo-electric section, a measure of the fault magnitude is equal to the thickness of the missing or repeated section [27].

A geo-electric section differs from a geologic section when the boundaries between geologic layers do not coincide with the boundaries between layers characterized by different resistivity values. This is because, the electric boundaries separating layers of different resistivity values may or may not coincide with boundaries separating layers of different geologic age or different lithological composition. In some cases several geo-electric layers may be distinguished within a lithological homogeneous rock. The reverse can also occur when layers of different lithology or ages, or both, have the same resistivity and thus form a single geo-electric layer [21].

In this work, the geo-electric sections are all oriented in the same direction as the profiles and are derived from the iso-anisotropy contour maps. On the geo-electric sections, resistivity values and pseudo-depths change downward into the subsurface. The pseudo-depths and lateral distances have been extended beyond the profile dimensions. An extension of the pseudo-depth is used to determine the most probable origin of what might appear in the iso-anisotropy contour map as an intrusion, a fault, a facture or a fold. An extension of the lateral distance beyond the length of the profile is used to determine the extent of what might appear on the iso-anisotropy contour map as a subsidence zone.

3.5. Iso-Anisotropy Contour Maps

An iso-anisotropy contour map is a plot of the pseudo-depth of penetration of telluric current in vertical axis against the distance from a base station taken as origin on the horizontal axis. This plot gives a series of contour lines that represent the paths connecting points with the same coefficient of anisotropy values. These contour lines provide a two-dimensional representation of the variation of coefficient of anisotropy with depth for vertical cross-section through a slice of earth under consideration. They illustrate the shape of the structures within the sub-surface. According to [28], when the sub-surface is homogeneous and has uniformly varying apparent resistivity values, the contours are horizontal and parallel, uniformly spaced and unfolded. Abrupt changes in the values of apparent resistivity are indicated on the contour map by curved contour lines. These curved lines always close up around centers of low or high coefficient of anisotropy values, which might be representative of flattened ellipsoids of revolution, separated from each other by faults and/or fractures. Contour lines that are in faulted areas have very high gradient with the contours closely packed together along the line of high gradient.

3.6. Apparent Resistivity Profiles

Figure 2 shows a graphical representation of the sounding stations in terms of the angular coordinate system (longitudes and latitudes). Sounding stations grouped and aligned in a chosen direction constitute a profile. There is a maximum of four sounding stations per profile for a total of five profiles (P_1 to P_5). For each profile a particular sounding station has been chosen as base or control station with respect to which all other stations in the profile are referenced. Profiles 1, 2 and 3 have a common base station that is located in Campo at the edge of the Kribi-Campo sedimentary sub-basin. Profile 4 has a base station located at the entrance into the Campo-Ma'an national park from Campo. These four profiles are oriented transverse to a suspected contact between the sedimentary Campo Basin and the metamorphic Ntem Complex. Profile 5 has its base station at Ma'an and is oriented transverse to the flow direction of the Ntem River which is in the NNE-SSW direction in this area.

4. Results and Interpretation

4.1. Analysis and Interpretation of Iso-Anisotropy Contour Maps

Figure 3(a) to Figure 3(e) give a presentation of iso-anisotropy contour maps for the five profiles considered in this work. These maps have been obtained from the anisotropy coefficients using the MT2DInvMatlab computer program [29]. This is a two-dimensional modeling program for magneto-telluric data which works through a combination of two interactive algorithms in FORTRAN and Matlab. MT2DInvMatlab employs the finite element method to calculate magneto-telluric 2-D responses with an incorporated smoothness-constraint least-square inversion method.
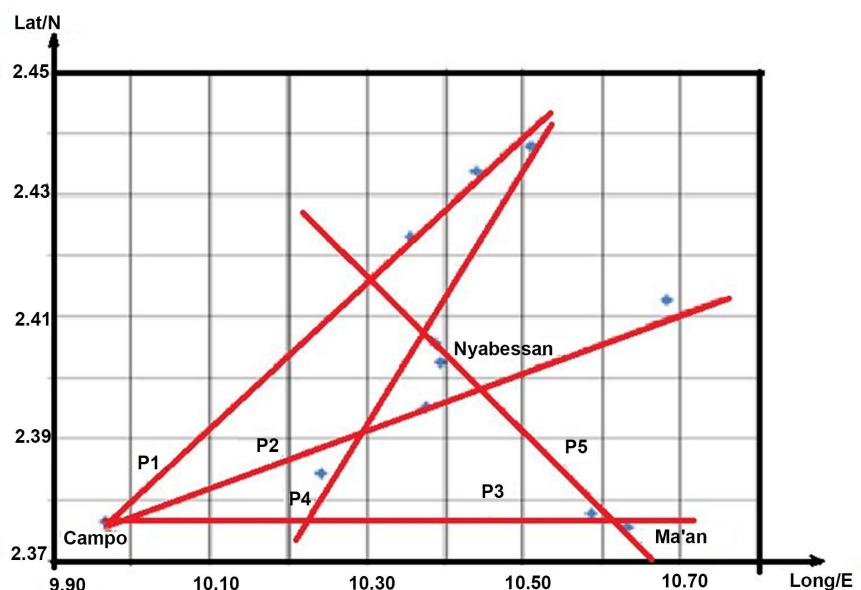

**Figure 2.** Graphical representation of the five profiles in the study area.

The colour codes vary from deep to light blue for values of coefficient of anisotropy ranging from $0.0 < \lambda \leq 1.1$, from deep to light green for values of coefficient of anisotropy ranging from $1.1 < \lambda \leq 1.4$ and finally from orange through red to deep pink for values of coefficient of anisotropy of $\lambda > 1.4$. The first range of values of coefficient of anisotropy corresponds to rocks of sedimentary formation or weathered and unconsolidated metamorphic rocks, which in this area of study might be made up principally of limestone and sandstones [28]. According to [30], this formation may also consists of conglomerates and arkosic sandstones interbedded with shales. The second range of values of coefficient of anisotropy corresponds to sedimentary rocks or weathered metamorphic materials that are undergoing (re-)transformation into metamorphic rocks through the process of contact metamorphism. These might generally be made up of schist and gneiss. The third range of values of coefficient of anisotropy corresponds to metamorphic rocks of plutonic origin which forms the Precambrian basement of the Ntem Complex. These might mostly be made up of intrusions of igneous, granite or granodiorite rocks.

Apart from the sedimentary formation, two types of metamorphism can be observed from the iso-anisotropy contour maps. There is regional metamorphism, which is depicted by the rocks with values of coefficient of anisotropy of $\lambda \geq 1.4$, which might be igneous or granitic in nature and composition and seem to be Precambrian and plutonic in origin. These rocks are found at the base in all the **Figure 3(a)** to **Figure 3(e)** and in some cases like in **Figures 3(a)-(e)** are uplifted to the surface. The second type of metamorphism is contact or transitional metamorphism which is depicted by rocks with values of coefficient of anisotropy in the interval $1.1 < \lambda \leq 1.4$, which might represent schist or gneiss rocks. This might be as a result of a long period of contact between regional metamorphic rocks and rocks of sedimentary formation. The resultant effect could be consolidation probably due to compaction under high petro-static pressure, high temperature and multidirectional tectonic forces. Such contact/transitional metamorphic rocks are found in the **Figures 3(a)-(e)** sandwiched between rocks of sedimentary formation and rocks of regional metamorphic formation and at varied depth in what seems to be due to a vertical and sub-vertical contacts. According to [31], such vertical motions as witness in **Figures 3(a)-(e)** are also associated with the development of intracratonic sedimentary basins, which is considered as one type of cratonic deformation that has occurred throughout geologic records. In **Figures 3(d)** rocks of the various formations are almost horizontally layered.

Two types of rock contacts can be identified in these figures. There is the sedimentary-schist contact which is found at the boundary between the sedimentary formation and the transitional metamorphic block. And there is the schist-granite contact between the transitional and regional metamorphic blocks. It can be seen that for **Figures 3(a)-(e)** the boundaries separating the three types of blocks are made of sub-vertical and vertical iso-anisotropy contour lines of high gradients, which may represent deep-seated fault systems of varied
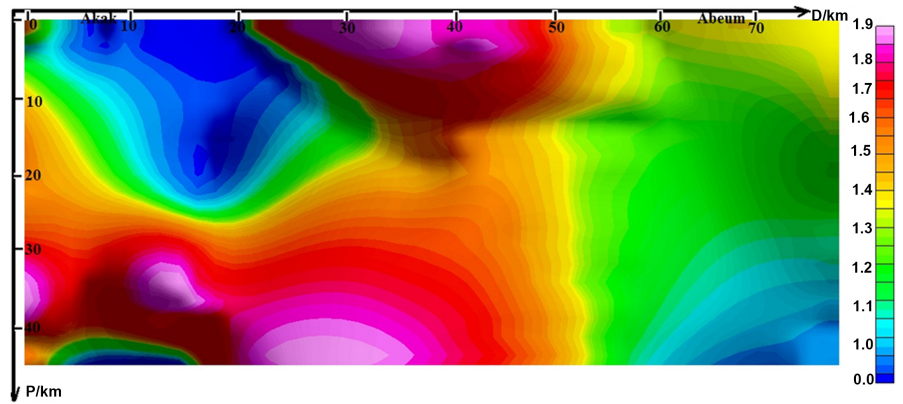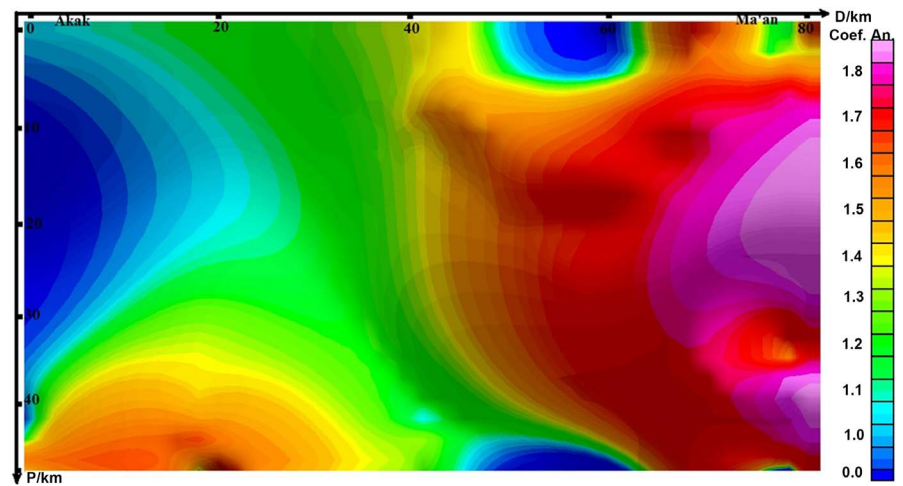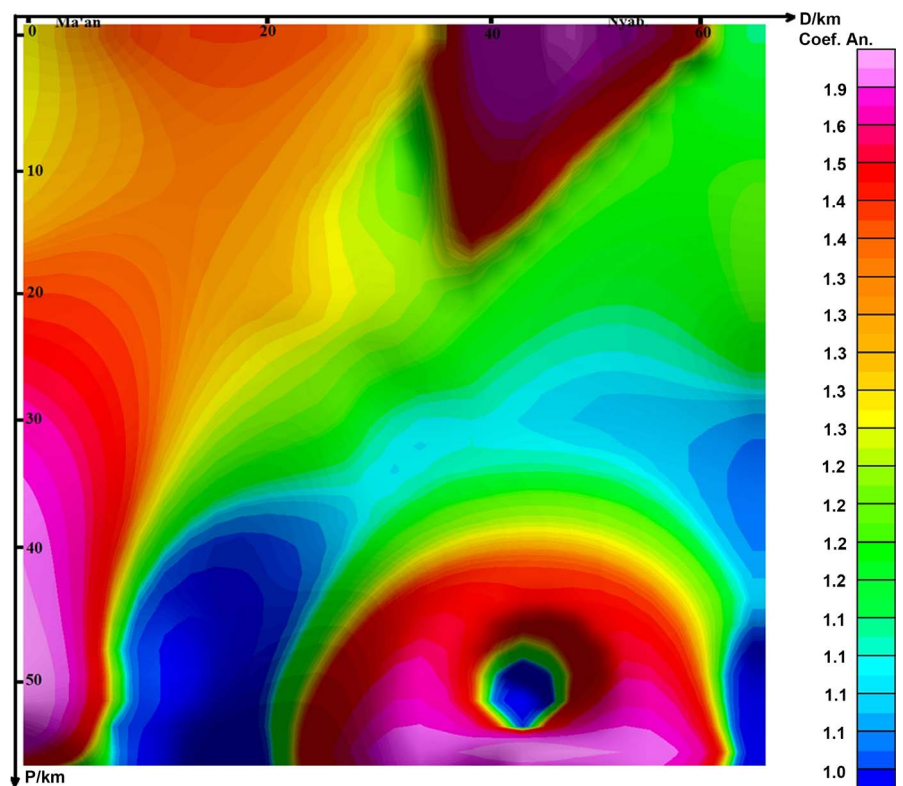
(a)
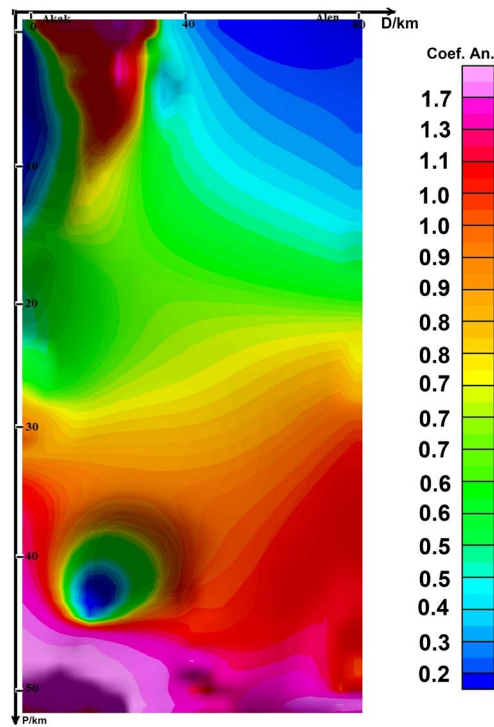
(b)
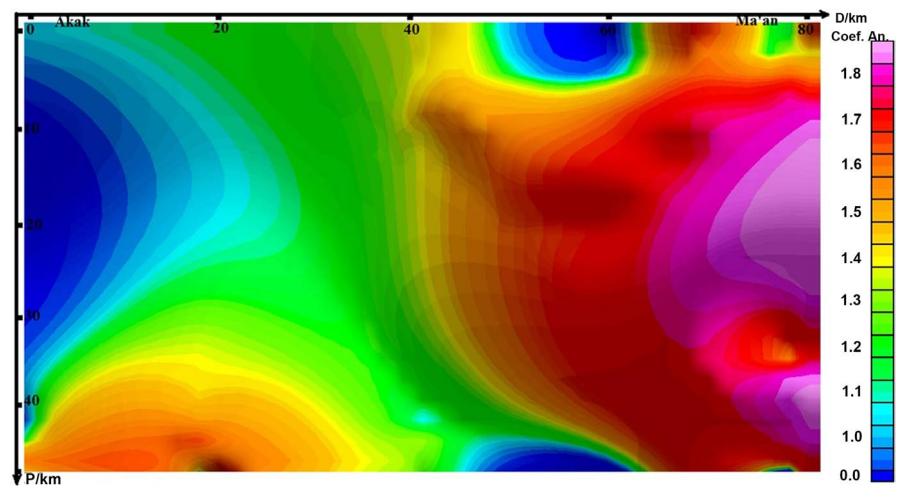
(c)

(d)

(e)

Figure 3. (a) Iso-anisotropy contour map for profile 1 (Bearing N84˚E); (b) Iso-anisotropy contour map for profile 2 (Bearing N85˚E); (c) Iso-anisotropy contour map for profile 3 (N90˚E); (d) Iso-anisotropy contour map for profile 4 (Bearing N79˚E); (e) Iso-anisotropy contour map for profile 5 (Bearing N97˚E).

magnitudes. From all the figures it can be observed that both the sedimentary and metamorphic blocks suffered from a lot of tectonic and oscillatory movements leading to conformed and unconformed layering. In general, the area under study has a complex and uneven tectonic structure which seems to have given rise to a vertical movement of the basement with subsidence of the sedimentary

formation and uplift of the metamorphic formation. These seem to confirm the assertions by [10] [11], according to which the Congo Craton is almost stationary, with the most recent tectonics dominated essentially by vertical motions.

The iso-anisotropy contour maps have clearly brought to light the two main formations that exist in the area of study. There is the sedimentary formation, which is found in the Kribi-Campo sub-basin and the Ntem River bed and its flood plains. This formation occupies areas with colour codes varying from deep to light blue for values of coefficient of anisotropy ranging from $0.0 < \lambda \leq 1.1$. The sedimentary formation of the Kribi-Campo sub-basin is well demarcated at the origins of **Figure 3(a)** to **Figure 3(c)** around the locality of Akak. As can be observed, this formation has a width of about 20 km on the surface with depth varying from 0 km to a maximum of 20 km on **Figure 3(a)** and over 50 km on **Figure 3(c)**. The sedimentary formation of the Ntem River bed and its flood plains is demarcated in figures 3.3 at around 60 km to the East of Akak and in **Figure 3(e)** at around 40 km to the Northwest of Ma'an. As can be observed in **Figure 3(c)** its width is about 10 km with a maximum depth of about 10 km. While in **Figure 3(e)** this width is about 20 km at the surface in Nyabessan decreases with increasing depth. The structure extends eastwards at depth in what seems to have been a faulted system with sedimentary infill, attaining a maximum of 20 km under the locality of Ma'an. The metamorphic formation of the Ntem Complex have colour codes ranging from green to orange, red and pink and for values of coefficient of anisotropy of $\lambda > 1.1$. This includes both the transitional and regional metamorphic rocks. As can be observed from all the iso-anisotropy contour maps the metamorphic formation of the Ntem Complex occupy a greater portion of the entire area with a complete absence of sedimentary cover in most of the localities.

4.2. Analysis and Interpretation of Geoelectric Sections

Figure 4(a) to **Figure 4(e)** give a presentation of the geo-electric sections for the five profiles in this work with respect to three parameters: the lateral spread of the stations from the base station, the pseudo-depth of penetration of the electromagnetic waves and the logarithm of geometric mean values of transverse apparent resistivity $\left(\rho_T \right)$. The transverse resistivity values which are acquired across a suspected geological feature (fault, fracture, fissure, lineament, contact etc.) are always higher than the longitudinal values which are acquired along the suspected feature. This is unlike in the iso-anisotropy contour maps above where both the transverse and longitudinal apparent resistivity values have been taken into consideration. The aim of these geo-electric sections representations is to show how the electrical properties of rocks and rock materials can be averaged over a large volume of earth, which may not necessarily be homogeneous.
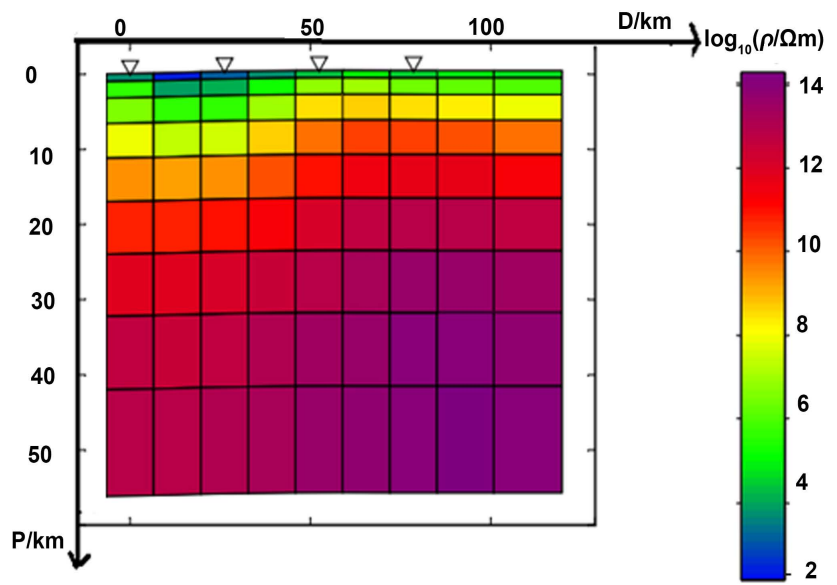
A general observation of all the geo-electric section figures reveals that: the low resistivity material $\left(2 \leq \log_{10} \left(\frac{\rho}{\Omega m} \right) < 4 \right)$, blue colour code, is of limited
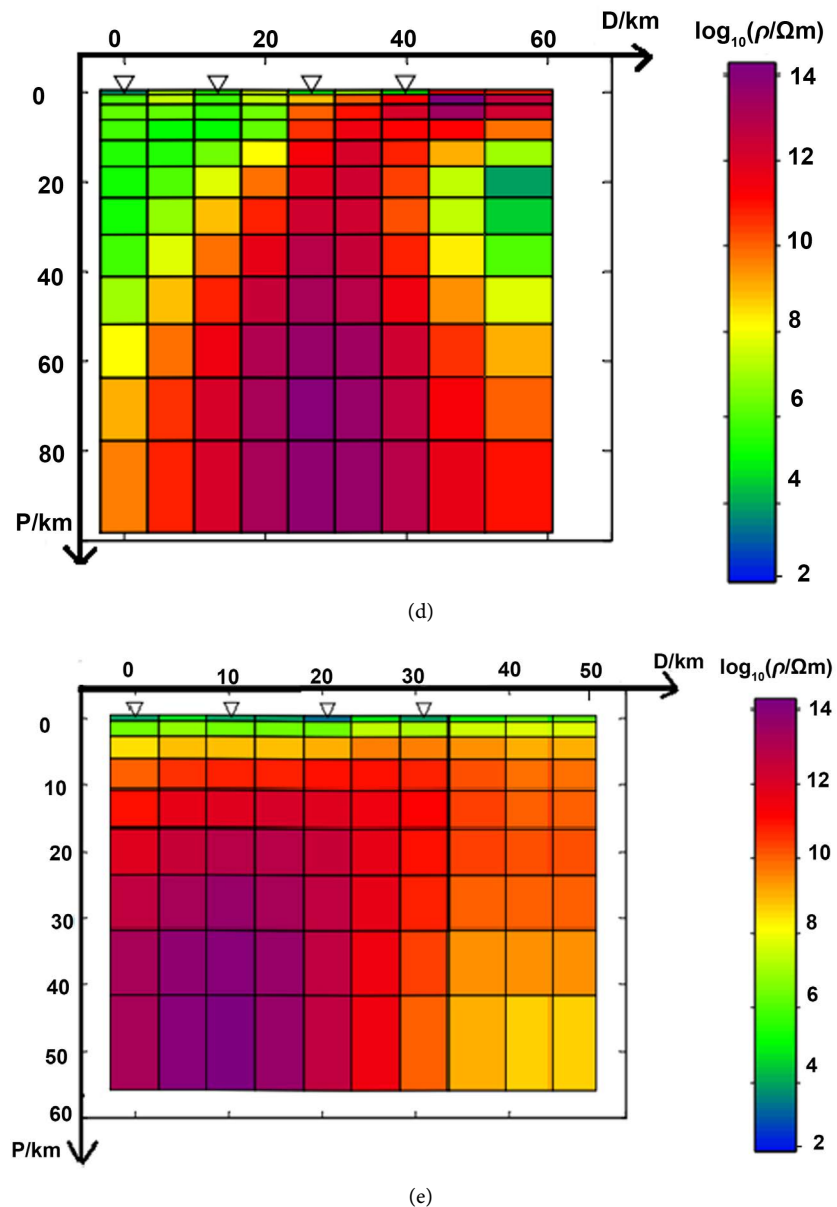
(a)

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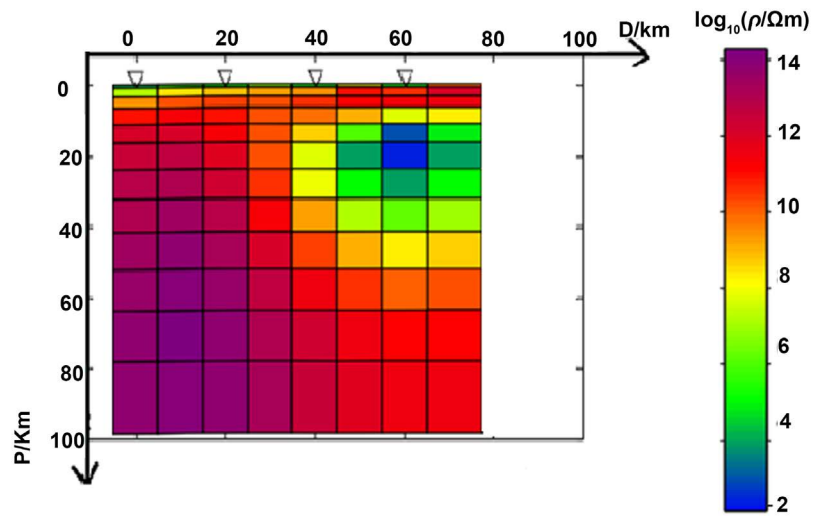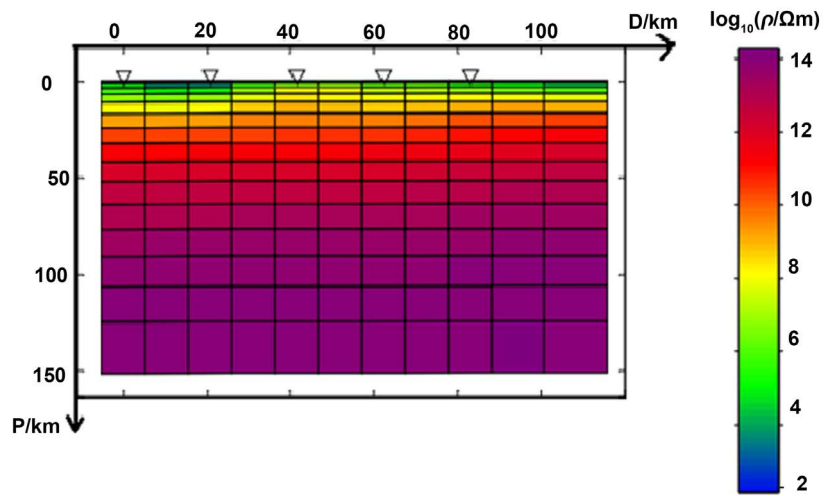
Figure 4. (a) Geo-electric section for profile 1 (Bearing N84˚E); (b) Geo-electric section for profile 2 (Bearing N85˚E); (c) Geo-electric section for profile 3 (N90˚E); (d) Geo-electric section for profile 4 (Bearing N79˚E); (e) Geo-electric section for profile 5 (Bearing N97˚E).

extend and is found mostly at near surface, hardly exceeding 1 km in depth, except in **Figure 4(a)** where this material is lodged inside the high resistivity material at an approximate pseudo-depth of 20 km. This low resistivity material found within the subsurface of **Figure 4(a)** seems to originate from a lateral embodiment of such material from a reverse faulting system to the far end of the geo-electric section. At near surface, these low resistivity materials are mostly concentrated to the western extremes of the profiles, which are close to the contact zone between the sedimentary Kribi-Campo basin and metamorphic Ntem Complex, and explains the sedimentary nature of the materials. The moderately

high resistivity material ($4 \leq \log_{10}\left(\dfrac{\rho}{\Omega m}\right) < 8$), from deep green to deep yellow colour, is generally not uniformly distributed for the various geo-electric sections as this is often interrupted by very high resistivity material, $\left(\log_{10}\left(\dfrac{\rho}{\Omega m}\right) \geq 8\right)$, of colour from red to deep purple. The missing or repeated green to deep yellow colours represent either faulted structures or lineaments. Such is the case with geo-electric sections of **Figure 4(a)**, **Figure 4(c)** and **Figure 4(d)**.

The geo-electric sections reveal that the entire area of study is mostly made up of materials of very high resistivity, $\left(\log_{10}\left(\dfrac{\rho}{\Omega m}\right) \geq 8\right)$, which seems to have originated from depths of $\left(P \geq 50\ \mathrm{km}\right)$ as can be observed in all the figures 4.1 to 4.5. This material is probably of plutonic Precambrian origin and should obviously be igneous or granitic in nature. Also, the remarkable presence of the moderately high resistivity materials of $\left(4 \leq \log_{10}\left(\dfrac{\rho}{\Omega m}\right) < 8\right)$ in all the figures from the surface to varying depths confirms the hypothesis of transitional metamorphism as explained under the iso-anisotropy contour maps above. These materials should probably be of schist/gneiss nature. It is observed that the moderately high and very high resistivity materials put together occupy almost the entire geo-electric section in each of the five, **Figure 4(a)** to **Figure 4(e)**. This confirms the high vertical tectonic stability of the area of study. Due to the limited presence of the low resistivity materials of sedimentary origin, it can be said that the geo-electric section representations have almost completely masked detailed structures that were revealed by the is o-anisotropy contour maps. This is not strength given that the geo-electric sections are constructed from transverse apparent resistivity values only.

5. Conclusions

This work had as main objective the application of the coefficients of anisotropy to determine the tectonic settings and the nature of the contacts between the sedimentary formation of the Kribi-Campo basin and the cratonic Ntem Complex in the Campo-Ma'an area of South Cameroon. The magnetotelluric data collected for 10 sounding stations and organized in 5 profiles have been used to draw 5 iso-anisotropy contour maps and construct 5 geo-electric sections.

From the iso-anisotropy contour maps, it has been deduced that apart from the sedimentary formation, the metamorphic formation comprises two metamorphic blocks: a regional metamorphic block which might be igneous or granitic in nature and composition, and seems to be Precambrian and plutonic in origin and a contact or transitional metamorphic block, which might represent schist or gneiss rocks. The contact or transitional metamorphic block might be as a result of a long period of contact between regional metamorphic rocks and

rocks of sedimentary formation. Due to this long period of contact, the resultant effect could be consolidation brought about by compaction under high petro-static pressure, high temperature and multidirectional tectonic forces. In most cases, the contact/transitional metamorphic rocks are found sandwiched between rocks of sedimentary formation and rocks of regional metamorphic block and at varied depth in what seems to be due to a vertical and sub-vertical contact. Two types of rock contacts have been identified: a sedimentary-schist contact which is found at the boundary between the sedimentary formation and the transitional metamorphic block and a schist-granite contact between the transitional and regional metamorphic blocks. Also, from the iso-anisotropy contour maps, two main formations have been identified in the area of study. There is the sedimentary formation, which is found in the Kribi-Campo sub-basin and the Ntem River bed and its flood plains and the metamorphic formation which includes both the transitional and regional metamorphic rocks. This metamorphic formation of the Ntem Complex occupies a greater portion of the entire area with a complete absence of sedimentary cover in most of the localities.

From the geo-electric sections which were constructed from transverse apparent resistivity values, it has been observed that the moderately high and very high resistivity materials put together occupy almost the entire subsurface in the area of study confirming its high vertical tectonic stability and by extension that of the entire Ntem Complex.

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