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ORGINAL ARTICLE

Geological models derived from 1D and 2D audiomagnetotelluric (AMT) modeling using Bostick approach in the Messamena / Abong-Mbang area (East-Cameroon)

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ABSTRACT
An Audio-Magneto telluric (A.M.T) study has been done in Cameroon in the Messamena/Abong-Mbang area. It consists of two profiles of measurements roughly S-N. The A.M.T data sets are collected using a resistivimeter with frequencies ranging from 4.1 Hz to 2300 Hz. The frequency range used has permitted to reach some important depths because of high resistivity values due to the metamorphic rocks. A 1D linearized inversion and 2D modeling of data led to attain the granitic basement at 9km in one hand, and to put in evidence an important buried fault structure at Abong-Mbang in another hand. From a 2D modeling of pseudo-sections of resistivity and phase, a system of folds has been discovered at Messamena. The tectonic structures put in evidence in the Messamena/Abong-Mbang area are perfectly linked to the collision between the Pan-African Chain and the Congo Craton. The pseudo sections of phase for the two profiles permitted to propose two geological models of rock layers distribution.
KEYWORDS: *AMT soundings, resistivity mean value, Bostick resistivity, phase, pseudo-section, fold, fault.*

INTRODUCTION

A recent interpretation of audio-magneto telluric [1] covering the east adjacent area Akonolinga/Ayos has permitted to put in evidence a buried fault oriented W-E in Ayos, and a system of crushing structures.

In addition the using of 1D and 2D modelling of magnetotelluric (MT) data for geological prospecting based on the study of the behaviour of the electrical conductivity in the subsurface in many areas around the world [2-5] has been for the authors a motivation base of the actual study. The combination of the resistivity mean value principle[3,6,7] and the Hilbert transformation [4,8] from which we obtained phase values has led to propose 2D geological models of the subsurface in the Messamena/Abong-Mbang area, based on the interpretation of audiomagnetotellurics (AMT) data collected using an apparatus which is measuring simultaneously the electric and magnetic fields [1, 4, 9-11].

GEOLOGY OF THE STUDY AREA

The area under study is situated between the latitudes 3°30'N and 4°30'N and the longitudes12°30'E and 13°30'E (figures1a & 1b), and covers approximately a surface of 70 km (W-E) x 50 km (S-N). It appertains to the Central African fold belt (CAFB) [12-14].

The Messamena/Abong-Mbang area which is adjacent to the Akonolinga-Ayos's, is situated at the northern edge of the Congo Craton [15, 16]. This area is also bounded, at the northern part by the Cameroon faulting zone (CFZ) linked to the Cameroon volcanic line (CVL). According to geological investigations [13, 14, 17, 18], the area is included in the Yaoundé series and it's constituted (figure 1b) of garnetiferous gneiss and migmatite embrechites, and of migmatite garnetiferous and micachists [19]. The basement appears by some granite outcrops in the northerneast (figure 1b). The observed granites are calco-alcaline with biotite or monzanite. Many quartz veins are observed above the parallel 4°. These veins can be source of gold bearing indices [19].

According to the tectonic point of view, the area of study is characterized by four phases of deformations D_1-D_4 [1, 13, 18]. The observed tectonic lines are directed SW-NE below and turned to be SE-NW above the parallel 4°N (figure 1b). Geophysical studies along the parallel 4° in the west adjacent areas [1, 20, 21] have led to put in evidence some buried faults directed W-E and have confirmed tectonics napes with a southern vergency.

The geological observations and tectonic facts show the complexity of the Messamena/Abong-Mbang area.

MATERIAL AND METHOD

The Magneto telluric (MT) method has been introduced[9], developed [10, 22] and applied in geophysical and structural geology prospecting [1, 2, 4, 6, 8, 23-25] consists on the simultaneous measurements of orthogonal electric and magnetic natural fields at any point on the surface of the Earth, in order to deduce the resistivity of rocks of the homogeneous subsurface. But in the real case the subsurface is inhomogeneous and the determination of the apparent resistivity is governed by the law given below by:

$\rho_a=0.2\ T\ (E_x/H_y)^2$ where T is the period of the wave in seconds, E_x the electrical field in the OX direction, H_y the magnetic field in the perpendicular direction OY.

In this work, we have used data collected from the AMT soundings experiments during dry seasons from 1993 to 1996 in the Messamena/Abong-Mbang area, with the help of an ECA 540 resistivity meter, which operates in the frequency range of 4.1-2300 Hz. During the field campaign, the measurements have been made far away of the circuit of distribution of electricity network to avoid the superposition of other electrical field generated by the presence of the H.T electrical reseau to the natural.

By interpretation, we can therefore determine the succession of the layers of the Earth supposed to be inhomogeneous but contrasted by their different thicknesses and their corresponding resistivities.

Two profiles (figures 1a and 1b) including a total of 15 stations of AMT soundings have been realized along some roads, by taking into account the fact that they are transverse to the W-E direction which is suspected to be the structures one. Each station is identified by its geographic coordinates determined by GPS Garmin.

The exploitation of data has been done as follow:

(1) We used the mean apparent resistivity given by the formula below:
$\rho_m= (\rho_t.\rho_{//})^{1/2}$, where ρ is the mean apparent resistivity, ρ_t is the resistivity perpendicular to the principal direction of the structure and $\rho_{//}$ is the resistivity parallel to the principal direction [3,7].

(2) The ρ_m calculated above has been used to determine the Bostick resistivities for each profile and the Hilbert's transformation [8, 23] has permitted us to obtain the phase values from which the pseudo-sections of rsesistivities and phases have been drawn. From the pseudo-sections of the phases, geological models of the subsoil have been sketched.

RESULTS

Description of profiles

Profile A (figures1a and1b) is entirely located in the south of / /4°N and includes 7 stations of measurement noted MS1 to MS7. According to the geological map [19], they are situated respectively on garnetiferous micaschists (MS1), embrechite Gneiss (MS2 to MS6) and garnetiferous gneiss (MS7). This profile is running across two metamorphic contacts which are founded between embrechite gneiss (MS2) and micashists (MS1) directed NW, and between embrechits gneiss (MS6) and garnetiferous gneiss (MS7) with SSW-NNE orientation.

Profile B is directed approximately S-N and on horseback on the / /4°N. It's has of 8 stations, identified by AB1 to AB8 (figures 1a and 1b). From AB1 to AB3, stations of measurement are situated into the south of //4°N, and AB4 is the north of the Nyong stream bank. From a geological point of view, AB1 to AB7 are situated on the garnetiferous gneiss with 2 micas, while AB8 is located on embrechite gneiss. This profile crosses therefore a metamorphic contact between AB7 and AB8.

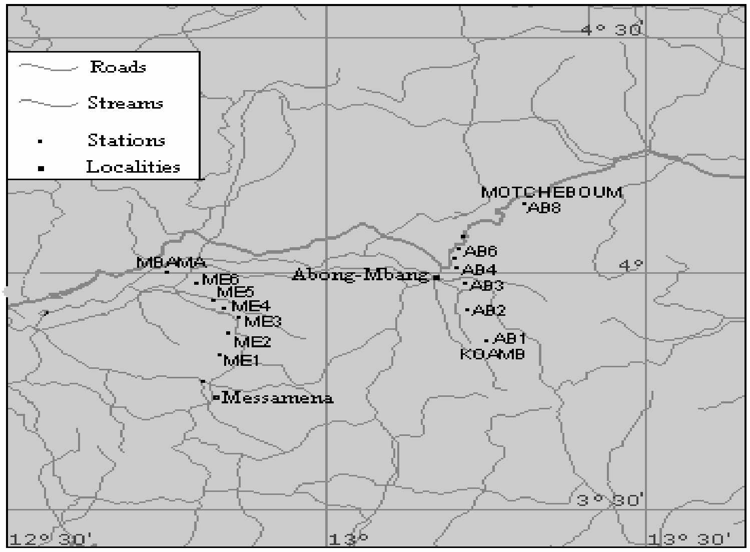
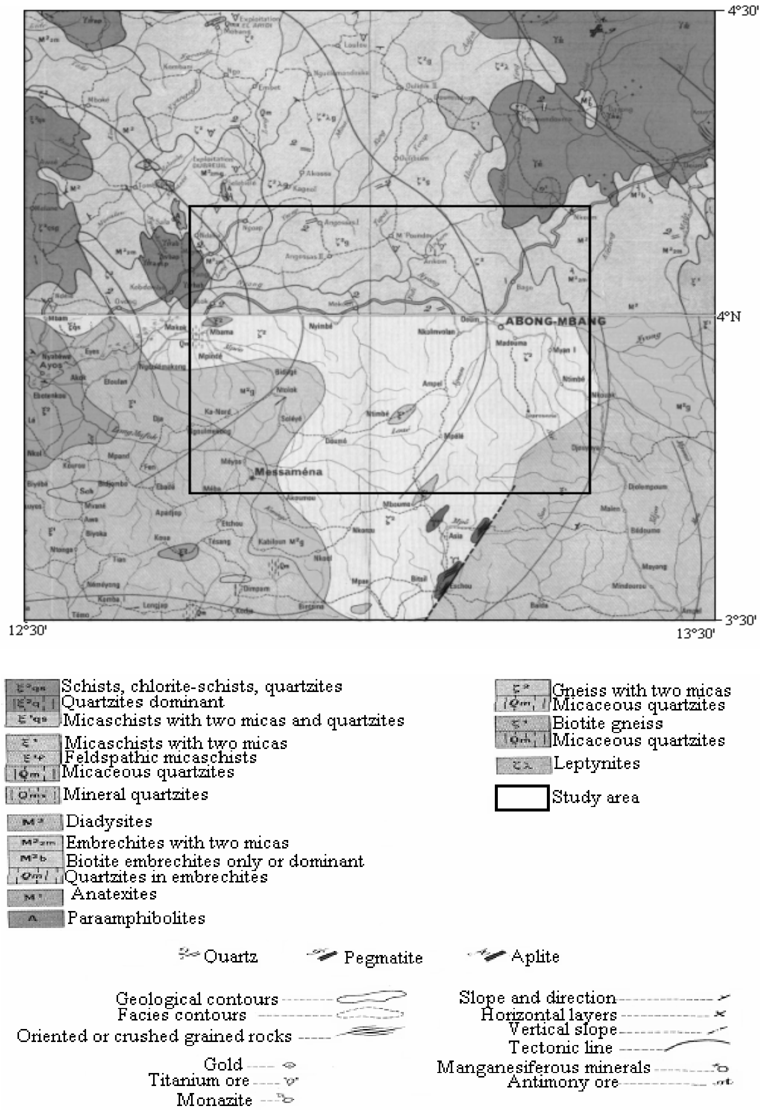


Figure 1a: Sounding stations map



LEGENDS

Figure 1b: Geological map of the study area (modified from Gazel & Giraudie, 1965)

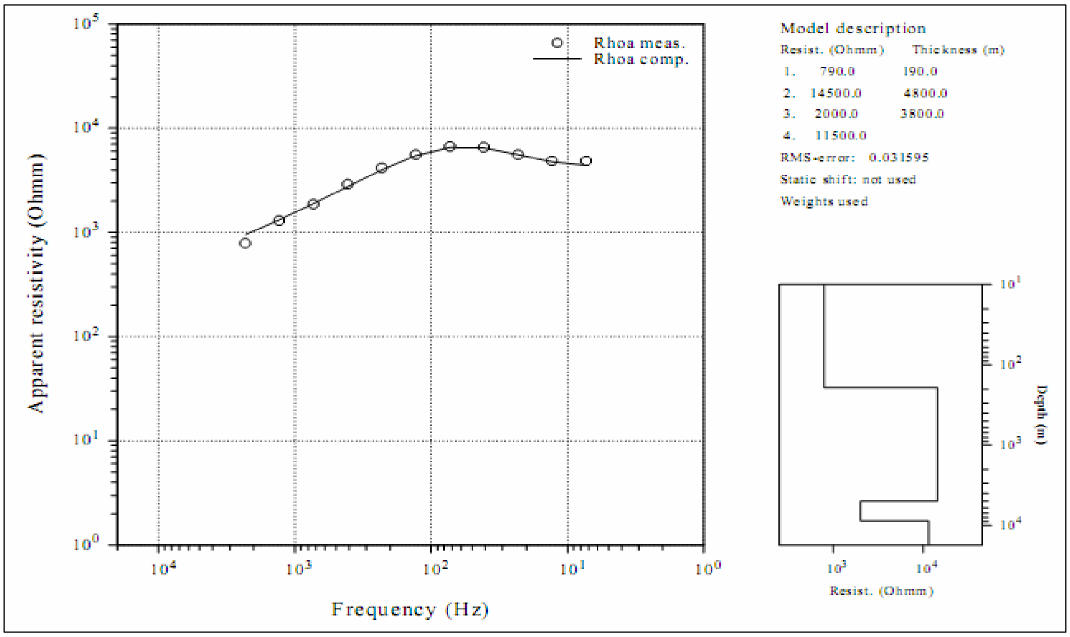


Figure 2a: Sounding curve illustrating a model of 4 layers (AB3 station)

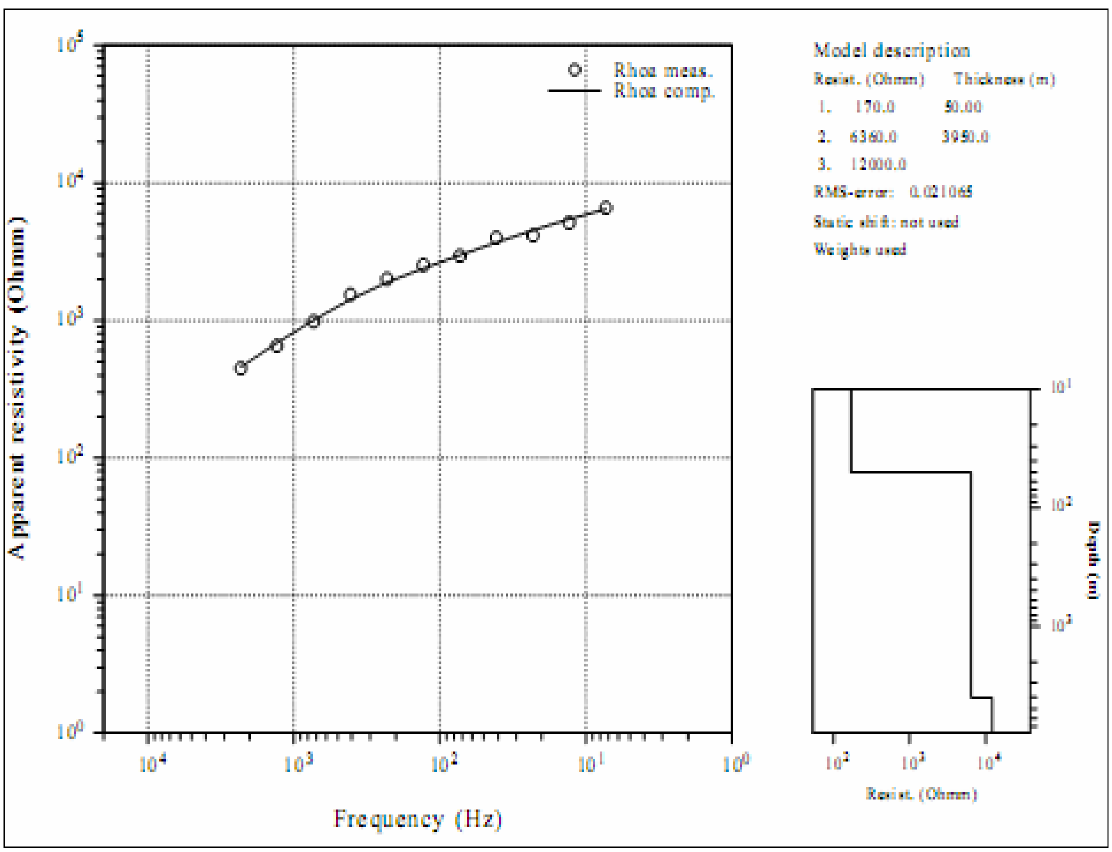


Figure 2b: Sounding curve illustrating a model of 3 layers (ME2 station)

Sounding curves

The interpretation sounding curves has been done by using the AMTINV program [26] for the 2 profiles. It has lead to identify 3 and 4 layers (figures 2a and 2b).The resistivity and the thickness of the concern layers are summarized in table 1.

Table 1: Layers and thicknesses for each station for the two profiles from 1D modelling.

Profile A			Profile B		
Station	Resistivity (0hm-m)	Thickness (m)	Station	Resistivity (0hm-m)	Thickness (m)
ME1	88	32	AB1	360	192
	1295	820		1900	1300
	480	695		250	400
	3500	infinite		7800	Infinite
ME2	170	50	AB2	600	210
	6460	3950		14000	4500
	12000	infinite		500	700
ME3	380	190		11000	Infinite
	3500	800	AB3	790	190
	1060	2100		14500	4800
	5500	infinite		2000	3800
ME4	850	190		11500	Infinite
	8850	2650	AB4	610	300
	1200	3100		2150	6500
	5000	infinite		6000	Infinite
ME5	215	128	AB5	180	74
	2300	1060		1500	1310
	225	850		5400	Infinite
	2500	infinite	AB6	150	114
ME6	810	210		2040	4750
	7700	1025		7800	Infinite
	1225	2200	AB7	150	59
	3500	infinite		2490	4070
ME7	300	108		11000	Infinite
	5300	3950	AB8	540	190
	13000	infinite		3300	3500
				13000	Infinite

The analysis of this table has drawn our attention on these facts which are followed:

- The resistivity value of the third layer for the four layers model is lower than the value of the second one layer;
- The value of the resistivity is increasing with the depth.
- The comparison of the values of resistivity obtained with dose from standard literature [27, 28] has lead to sketch a lithostratigraphic column which is constituted from the bottom to the top with: granite, schist, micaschist, gneiss and those rocks of cover formations.

Resistivity profiling curves

From the data collected on profile A we have got profiling curves (figures 3a and 3b). These resistivity profiling curves of profile A show a discontinuity between ME3 and ME5 characterized by a high resistivity value from the superficial layers toward the deep layers with a maximum in ME4. A second discontinuity is observed between ME5 and ME7 and it is characterized by a relative elevated resistivity values in ME6 which are decreasing to the surface toward the depth. These two discontinuities are separated by a drop of resistivity in ME5. In general, the resistivity variations along the profile are pseudo sinusoidal.

The resistivity profiling curves obtained from profile B (figures 4a and 4b) reveal a remarkable discontinuity between AB2 and AB4 for the near surface, which is prorogated to AB5 in deep structures. This discontinuity is a characteristic of a resistivity passageway that covers the AB2 to AB5. It has a maximum of a resistivity values in AB3 and seem to announce fractures. This curve present an important drop which is followed by a low increasing of the resistivity values from AB6 to AB8.

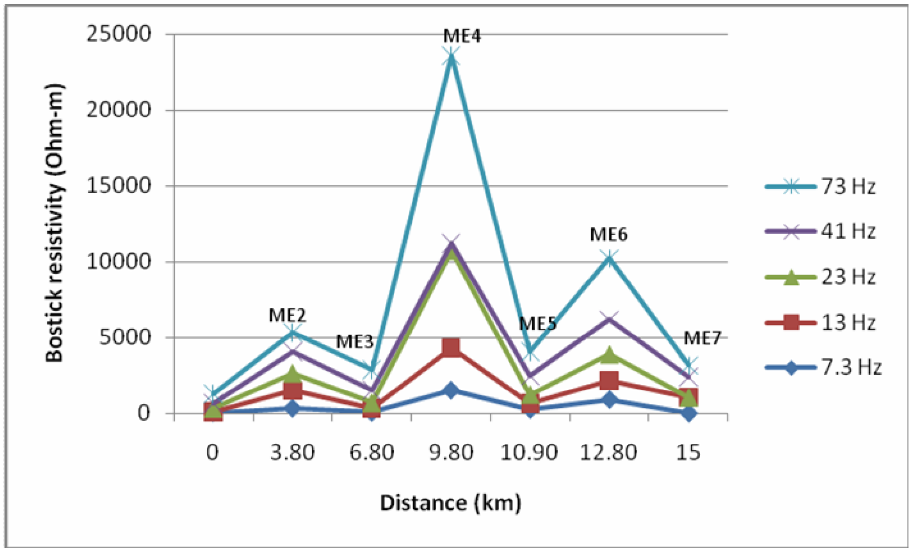


Figure 3a: Resistivity profiling curves for profile A (low frequencies)

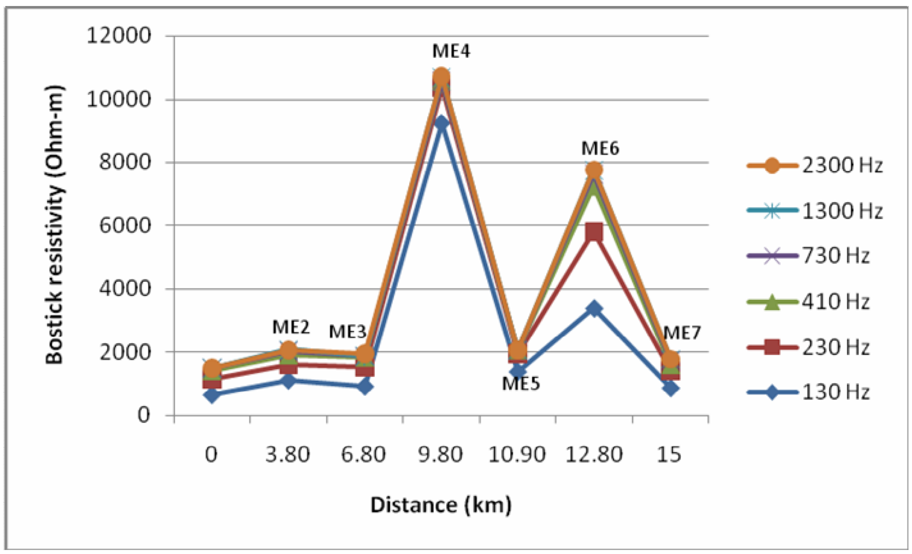


Figure 3b: Resistivity profiling curves for profile A (high frequencies)

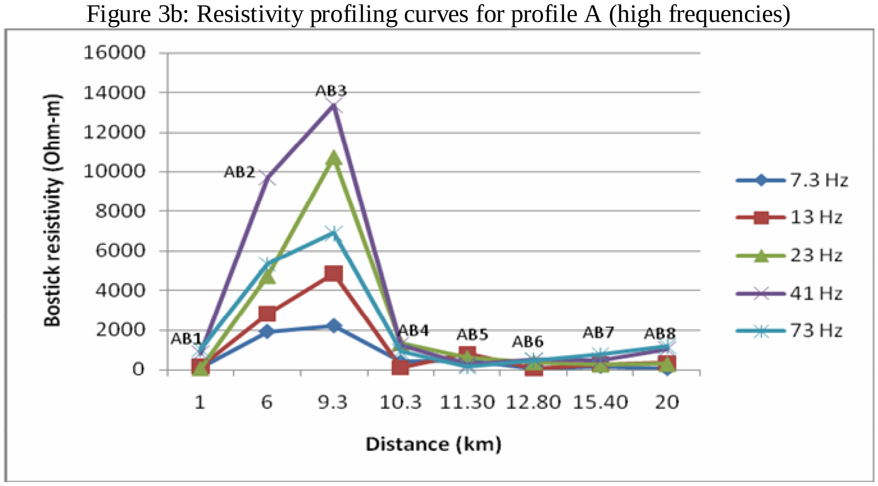


Figure 4a: Resistivity profiling curves for profile B (low frequencies)

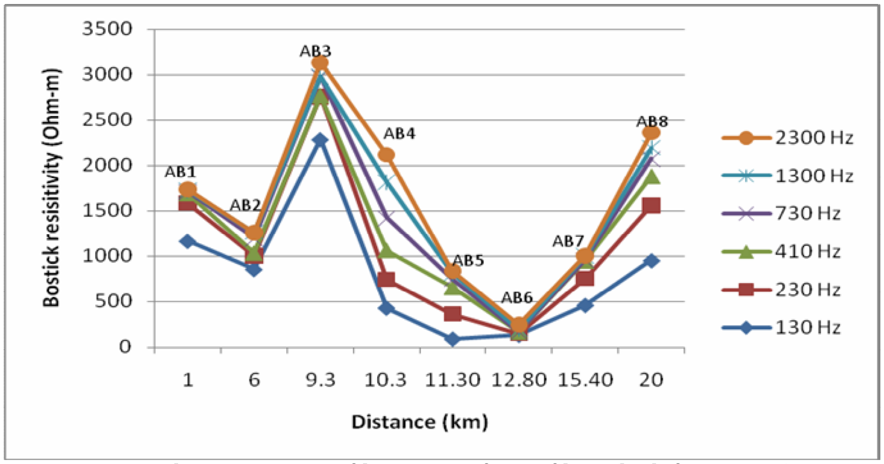


Figure 4b: Resistivity profiling curves for profile B (high frequencies)

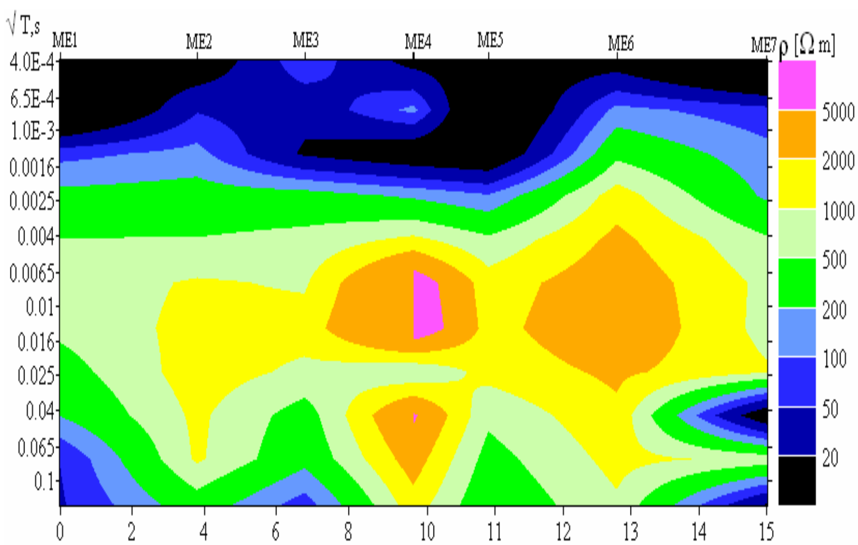
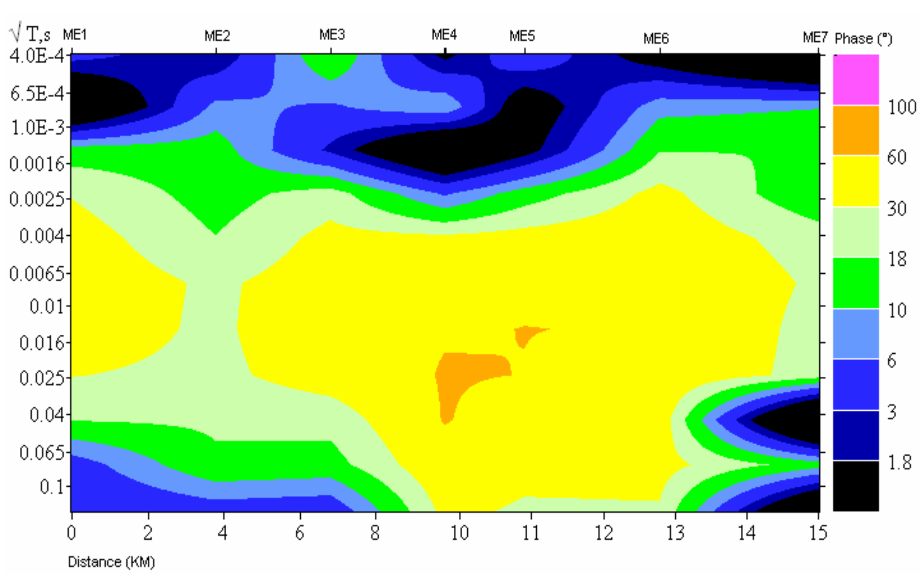


Figure 5a: Bostick resistivity pseudo-section of profile A

Figure 5a: Phase pseudo-section of profile A



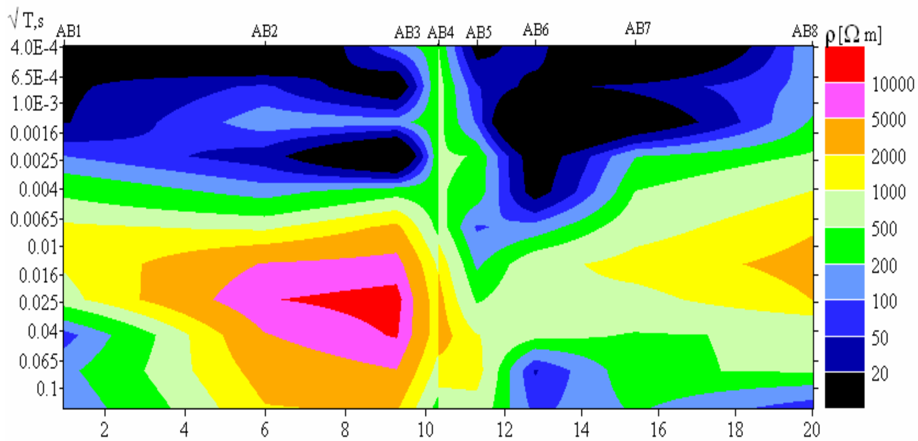


Figure 6a: Bostick resistivity pseudo-section of profile B

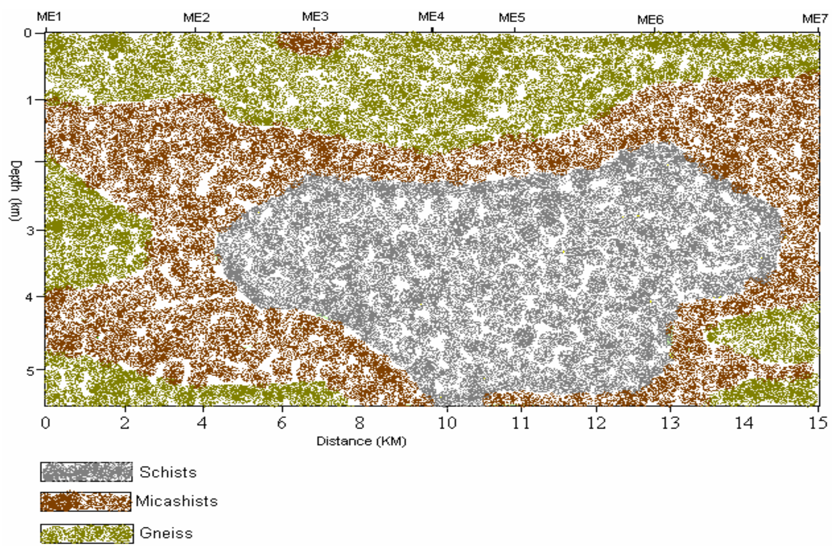


Figure 7: Geological model of profile A

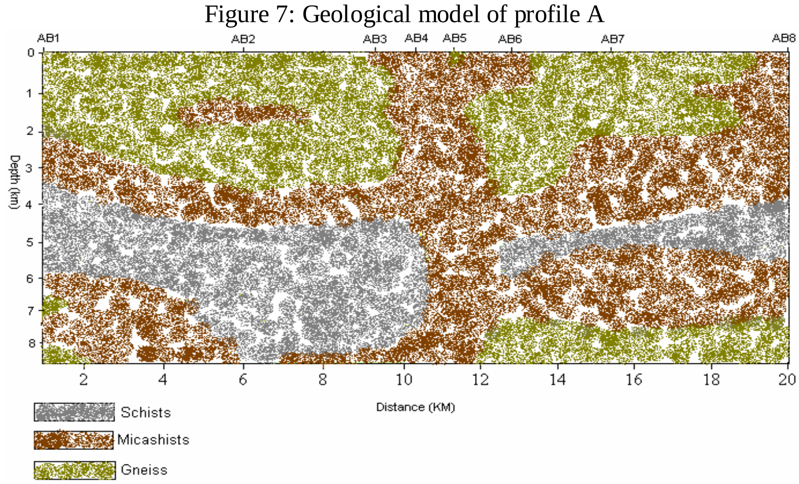


Figure 8: Geological model of profile B

Pseudo-sections

A general analysis of the two types of the pseudo-sections (resistivity and phase) has enabled to observe a presence of folds and fractures which are witnessed that, the area has been a theatre of collision between the Pan-African belt and the Congo Craton formations.

The resistivity and phase pseudo sections of profile A (figures 5a and 5b) show a deep layer ascent toward the surface that is embedded in some others. This ascent has opened a passageway in average depth to a block of rocks presenting low resistivity values. This block of rocks is enveloped by a layer having a mean resistivity and phase values respectively 750 ohm and 24°.
The resistivity and phase pseudo sections obtain from profile B (figures 6a and 6b) has put in evidence a fracture of almost vertical dip in the near surface until depth in the AB4 station. This fracturation is characterized by a passageway of which its mean resistivity value is about 500 ohms. This passageway separates two blocs having identical characteristics.

DISCUSSION

The analysis of the AMT data of profile A shows a fault between ME3 and ME5 to dip lower than 90°, and another in ME6 with a strong dip in depth, follow-up by folds in near surface. However, geology signals simple contacts between embrechite gneiss and micashists, and between embrechite gneiss and garnetiferous gneiss respectively. On profile B, geology signals a tectonic line, directed NNE to the south of Abong-Mbang and NNW to the north. This line is parallel to contact garnetiferous gneiss/micashists, to the south, and to contact garnetiferous gneiss / embrechite gneiss, to the north. No one geological indication doesn't not seem to suggest, the existence of a major E-W tectonic accident on the profile between AB3 to AB5. On the other hand, our survey reveals a model perfects structure fault type. The fault identified on ME6 station, seems to correspond to the one which has been identified respectively in Akonolinga (AK6) and Ayos (AY6) [1]. These observations show that the area was subjected to a very intense tectonic movement. It is the proof that, in this area, there was an intensive shock between the Pan-African Chain and the Congo Craton. of everything that proceeds and with the help of the phase pseudo sections, we proposed 2D geological models for each profile (figures 7 and 8). The results obtain from the AMT analyses are similar to those from a gravity study [29], in which a deep seated fold and fault systems oriented W-E have been identified using a 2D1/2 modeling [30].

CONCLUSION

We have developed the Bostick approach for de 1D and 2D modeling of the AMT data of the Messamena/Abong-Mbang area. This study permitted a better knowledge of internal structure of this area. Indeed, they observed a presence of a major accident, the fault oriented sensibly E-W that spread of AB4 until AK6 [1] passing by ME6 and AY6. In the profile A, the interpretation and 1D and 2D modeling of data have led to put in evidence an intense folds system. The results obtained are in agreement with the one derived from a gravity study [29] which revealed a deep folds and fault system oriented E-W.

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