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Lithostructural Mapping by Geophysical Imagery of a Granite Deposit at Gbamakro in the Department Of Bouaké (Central Côte d'Ivoire)

YAPO Assi Martial[1], SOMBO Abé Parfait[2*] and TANO Kouakou Faustin[2]
[1]*Laboratory of Buildings and Public Works (LBTP) of Côte d'Ivoire*
[2]*Laboratory of Environmental Sciences and Technologies, Jean Lorougnon Guédé University of Daloa, Côte d'Ivoire*
Corresponding Author: SOMBO Abé Parfait

Abstract: *The research of massive rock extraction site (granite) to Gbamakro (Central Côte d'Ivoire) requires a good knowledge of the subsoil. This requires the implementation of geophysical methods of resistivity (profiling, sounding and electrical tomography). The aim is to determine the lithological and structural characteristics of the study area subsoil. The results show a resistant granite massif with fractures oriented N70 to N120. At north of the site, the fractures are associated with an altered massif. The roof of the massif is located under an altered horizon less than 5 m thick. Except north of the site, where it is at a greater depth (16 m).*

Keywords: *electrical profiling, electrical sounding, electrical tomography, geophysical.*

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I. Introduction

The granite is an earth's crust material, much used, as granulate in the construction of civil engineering works. In nature, granite does not always appear as a healthy massif that is outcropping. It can be weathered or localized under weathered horizons of varying thicknesses. The research for healthy granite extraction site requires the determination of the lithostructural characteristics of the subsoil. Geophysical methods of resistivity (profiling, sounding and electricals tomography) are used for that. These techniques are used for the lithostructural mapping of a granite deposit to Gbamakro in the department of Bouaké (Central Côte d'Ivoire). In practice, the electricals profiling allow to identify the lateral variation of the resistivity of the subsoil and the electricals soundings, the vertical variation. Electrical tomography allows 2D imaging of the deposit. The aim of this study is to determine the lithostructural characteristics of granite deposit to Gbamakro

II. Geographical and geological context

The study area is located in the district of the "Vallée du Bandama", in the Central of Côte d'Ivoire. Gbamakro deposit is 54 km north-east of the Bouaké town. Exactly, it is at longitude 4 ° 35 '0.7 " West and at latitude 7 ° 52' 35.1" North. Geologically, the study area corresponds to the Paleoproterozoic domain whose formations were structured during the eburnean orogeny (Fig. 1). Geological formations are essentially granitic.

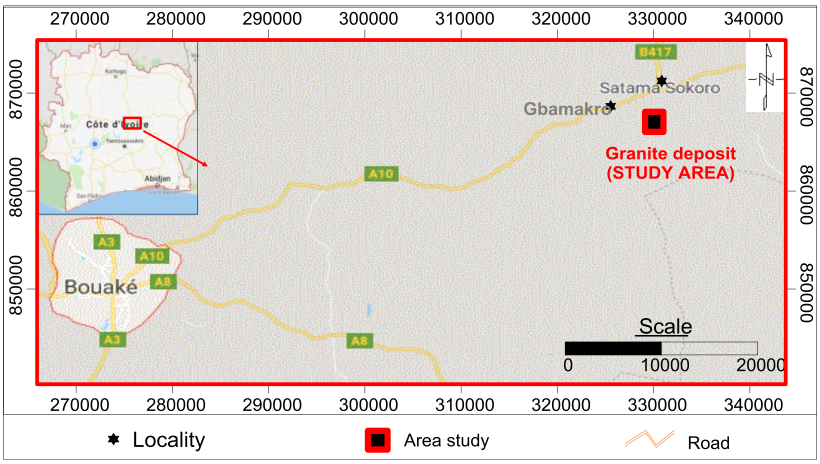

Figure 1: Location of the study area

III. Material and methods

The geophysical methods of resistivity (profiling, sounding and electrical tomography) are implemented in this study. They are based on sending in the subsoil of continuous electric current, from of injection electrodes A and B and the measure of a potential difference ΔV, from the electrodes M and N [1], [2], [3] and [4]**.** Resistivity's measures are made, from Syscal Pro resistivity meter. Five (05) parallel electrical profiling (L0, L50E, L100E, L50W and L100W), spaced of 50 m, are made according N-S orientation. The configuration of rectangle gradient is use. M and N electrodes spaced to 10 m are moved, according to the alignment of A and B electrodes, separated to 1200 m. A and B stay fixed to the extremity of the profiling. In practice, the measures are made each 10 m. From Microsoft Excel TM, electrical profiling data are represented in form of resistivity profiles, in a semi-logarithmic scale. The apparent resistivity values are on the ordinate, in a logarithmic scale. An apparent resistivity map is also made, from Surfer software.

Electrical soundings are made according to the Schlumberger configuration. AB / 2 is between 1.5 and 350 m and MN / 2 between 0.5 and 2 m. A total, five (05) electrical soundings are made, gradually increasing the distance between electrodes A and B. Soundings results of are processed, from WinSev 6 software. It allows the realization of electric sounding curves and their interpretation (inversion). Indeed, the apparent resistivity values are in a logarithmic scale and AB / 2 in arithmetic scale. The interpretation, by WinSev 6 software, uses inversion algorithms. The inversion is based on the comparison of theoretical curves with the curves obtained with the geoelectricals data (Fig. 2). This operation uses the gradient method which minimizes the sum of the quadratic relative deviations between the two curves. It is an iterative calculation technique that allows the research of the minimums or maximums of a function [3]. Interpretation is good only when the calculated curve for the model coincides with the measures. In this case, the model is a possible approximation of the reality of the subsoil because it generates data similar to those measured [3]. The different interpretations are made on the base of ground observation.

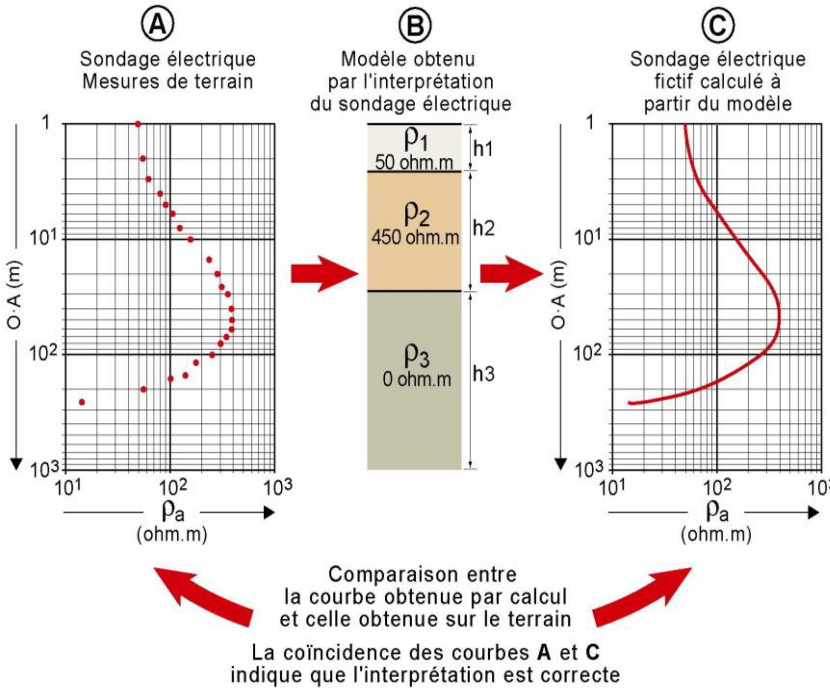

Figure 2: Electrical sounding curve inversion techniques [5].

The electrical tomography are executed, according to the asymmetrical pole-dipole configuration. This asymmetry can influence the model obtained after results inversion. A symmetrical geological structure will appear in the form of asymmetric apparent resistivity anomaly on the pseudo section. To remove this effect, the measurements are made in "forward" and "reverse" pole-dipole devices (Fig. 3). In practice, the electric current injection electrode B is placed at 600 m (5 times AM distance) perpendicular to the profile. This allows better intersect the geological structures. All this makes it possible to reach 10 levels of acquisition. Five (05) electrical tomography are made, three (03) on the profiles L0, L100E and L100W of the electric profiling and two others (LB and LB +10N) perpendicular to the previous ones (Fig. 4). Figure 4 shows the measures points of the profiling, sounding and tomography electrical made in this study.

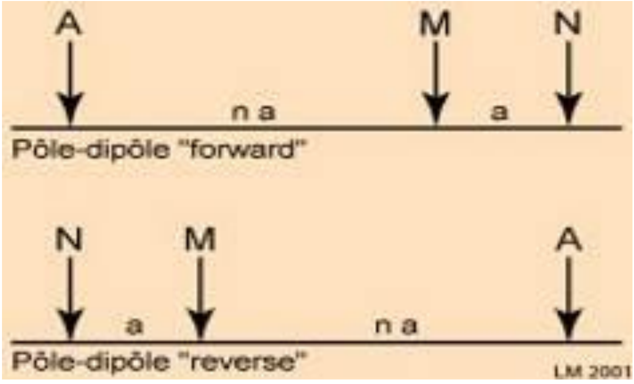

Figure 3: "Forward" and "reverse" acquisition for pole-dipole configuration

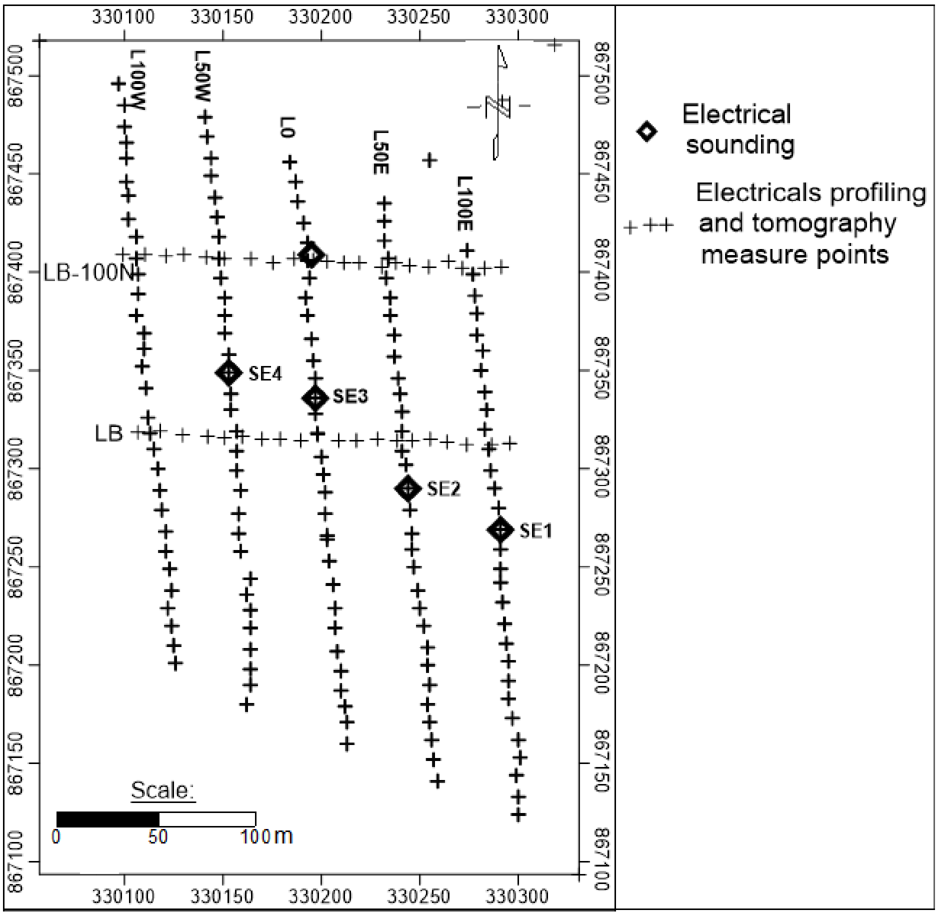

Figure 4: Different electrical profiles made on the site.

Res2Dinv software [6] is used for the interpretation of electrical tomography results. It allows iteratively to calculate a model corresponding to geoelectric data. In practice, the measured data is inserted into a program. This program establishes a model of apparent resistivity "A" (Fig. 5). The software, from "A" creates a "C" model. From "C", the software recalculates the apparent resistivity values corresponding to a model "B". It compares the apparent resistivity values recalculated with those obtained (comparison between A and B). If the difference is too large, the program modifies the model "C" as many times so that the difference between "A" and "B" is as small as possible.

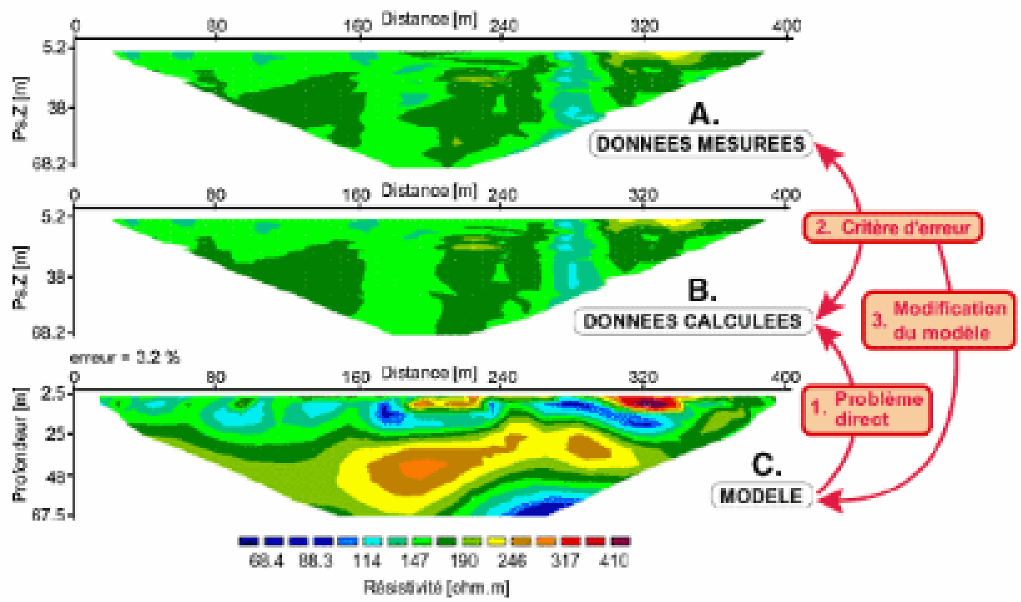

Figure 5: Iterative inversion in 2D tomography [7]

IV. Results

4.1 Analysis and interpretation electric profiling results

The figure 6 presents the results of the apparent resistivity profiles obtained on the granite deposit of Gbamakro. The resistivity values vary between 975 and 29000 Ohm.m. They are relatively very high and correspond to those of a resistant basement. These profiles show a significant variation in apparent resistivity north of the studied site. In this part of the site, we observe geoelectric anomalies characterized by resistivity drops. These conductive anomalies correspond to fractures in the granitic basement. The analysis of the alignments of these anomalies shows that these fractures follow orientations between N70 and N120. In the south, the profiles show a granitic substratum less affected by fractures. The conductive anomalies are faintly pronounced and oriented N70 and N107.

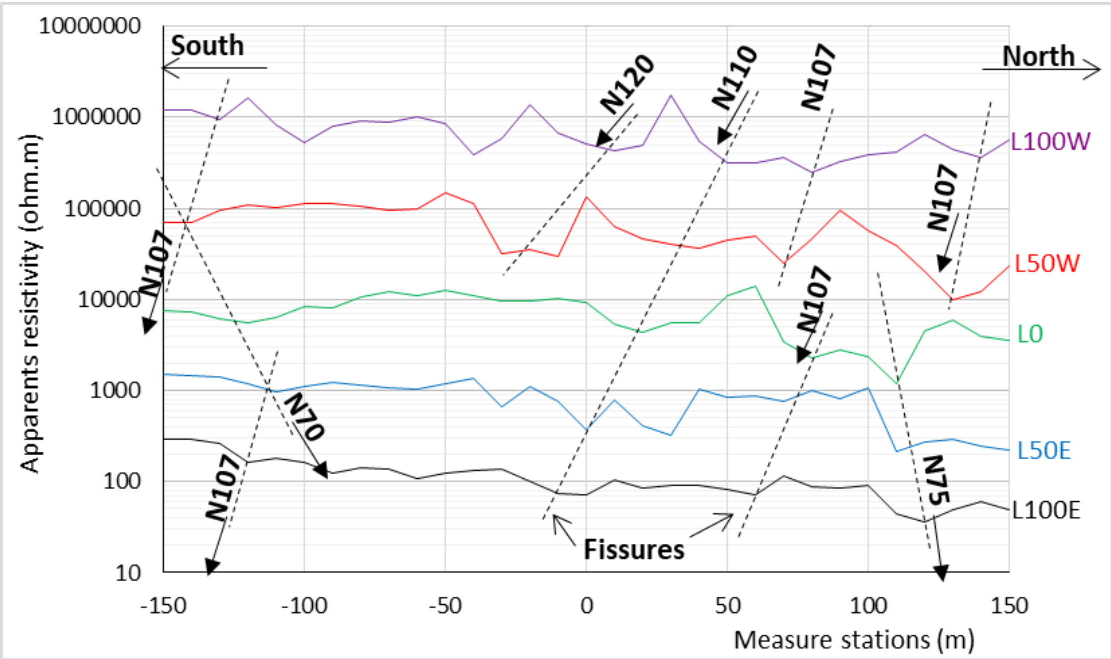

Figure 6: Resistivity profiles of the Gbamakro granite deposit

The figure 7 shows the resistivity map established, from the results of electric profiling. On this map, two distinct geoelectric zones are identified. In the far north, there is an area lows resistivity. In Central and South, we find areas highs resistivity. The fractures that affect the North of the deposit are the cause of lows resistivity. As on the resistivity profiles, these geological accidents have an orientation between N70 and N120. This part of basement is potentially weathered. Eventually, fractures in the north are associated with chemical alteration of the granite. The Central and South of the site have not weathered, because weakly fractured. The fractures identified in these areas are oriented N50, N110 and N120, as identified on the electric profiling. In the Central and South, fracture's resistivity values are high compared to those mapped in the North. These values are between 3000 and 8000 ohm.m. The accidents in the Central and South of the study site are not associated to chemical alteration of granite.

From the apparent resistivity map, zone of extraction of the healthy granite is delimited. This is the area from the central to the south of the deposit. The high resistivity values and the almost absence of fractures in this area justify this choice. Indeed, it is inappropriate to use weathered granite for the construction in civil engineering works. This makes it possible to avoid an early deterioration of the structures.

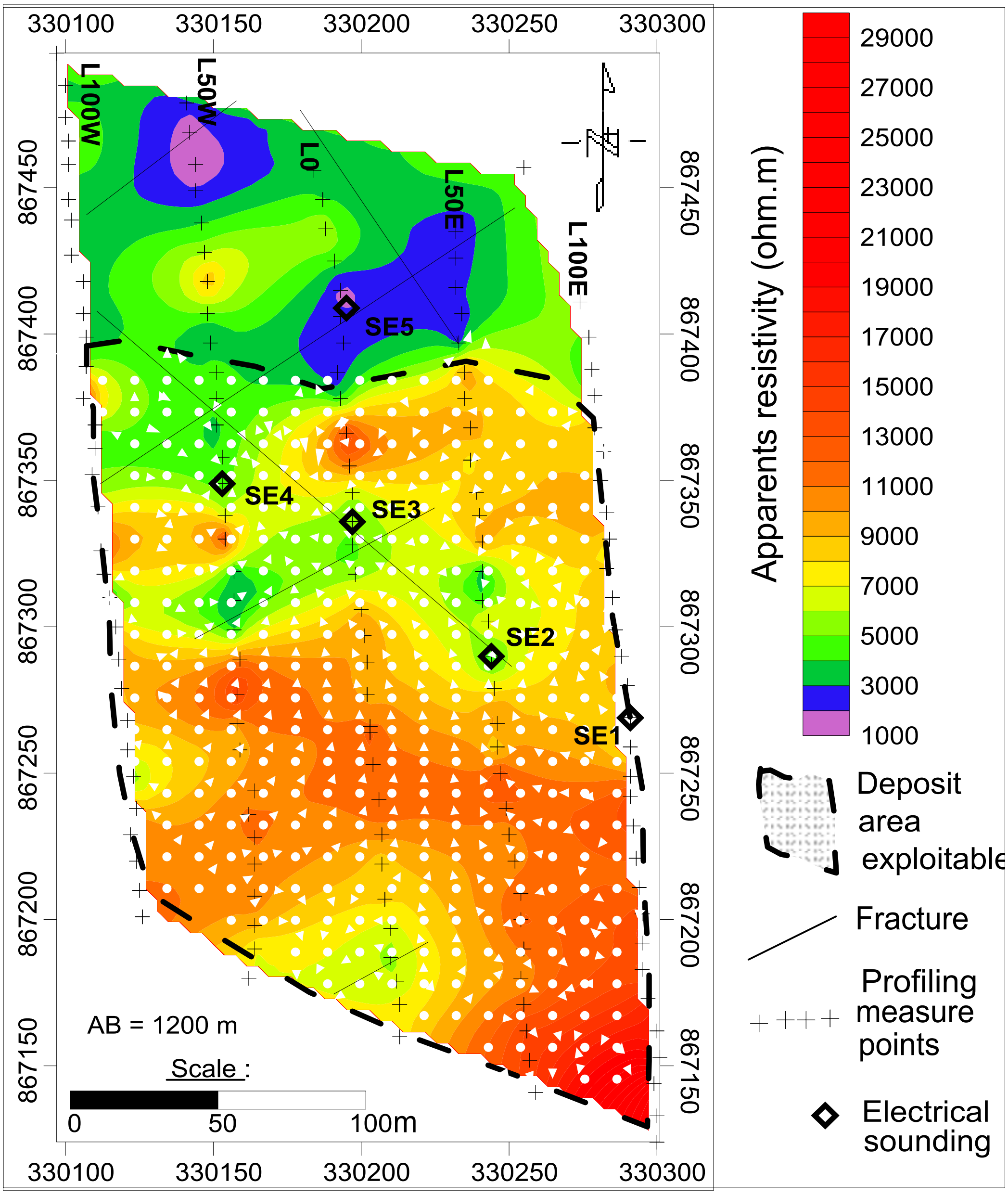

Figure 7: Apparent Resistivity Map of the Gbamakro Granite Deposit.

4.2 Analysis and interpretation of the electrical sounding results

4.2.1. Sounding curves type H

Two (02) sounding curves types are obtained. These are the sounding curves type CH1 and H. These are the sounding curves SE1, SE4 and SE5. They have a single ascending branch and highlight two-layer formations (Fig. 8). It is a very resistant granitic basement (greater than 5000 ohm.m), which is surmounted by an altered horizon (granite arena or clay sand) of small thickness (less than 3.3 m) and resistivity included between 290 and 3568 ohm.m. The granitic basement is materialized by the ascending branch part of the sounding curves, which is to 45°. The weathered layer corresponds to the part of the curves before the ascending branch. The short thickness of the weathered horizon is an advantage for the extraction of the underlying granite. Indeed, to reach the healthy granite, will be done at low cost.

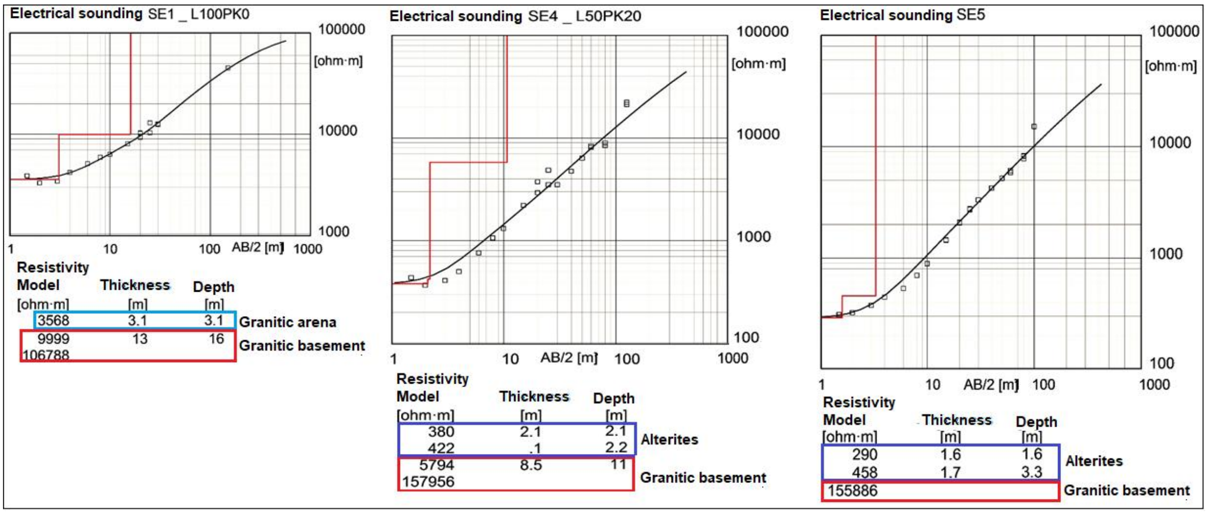

Figure 8: Sounding curves type CH1.

4.2.2. Sounding curves type H

These are the sounding curves SE2 and SE3 (Fig. 9). They highlight three (03) geological horizons. The granitic basement corresponds to the ascending part, at 45°, of the sounding curves. It is surmounted by two (02) horizons. From the surface of the ground, the first is composed of granitic arena of short thickness (1 to 4 m). It corresponds to the beginning of the curves. The second is the fractured basement, characterized by a relatively low resistivity (2200 to 4550 ohm.m) compared to the healthy granitic basement (greater than 40000 ohm.m). Il a une épaisseur considérable (entre 12 et 13 m). Le granite sain est donc situé entre 14 et 16 m de profondeur.

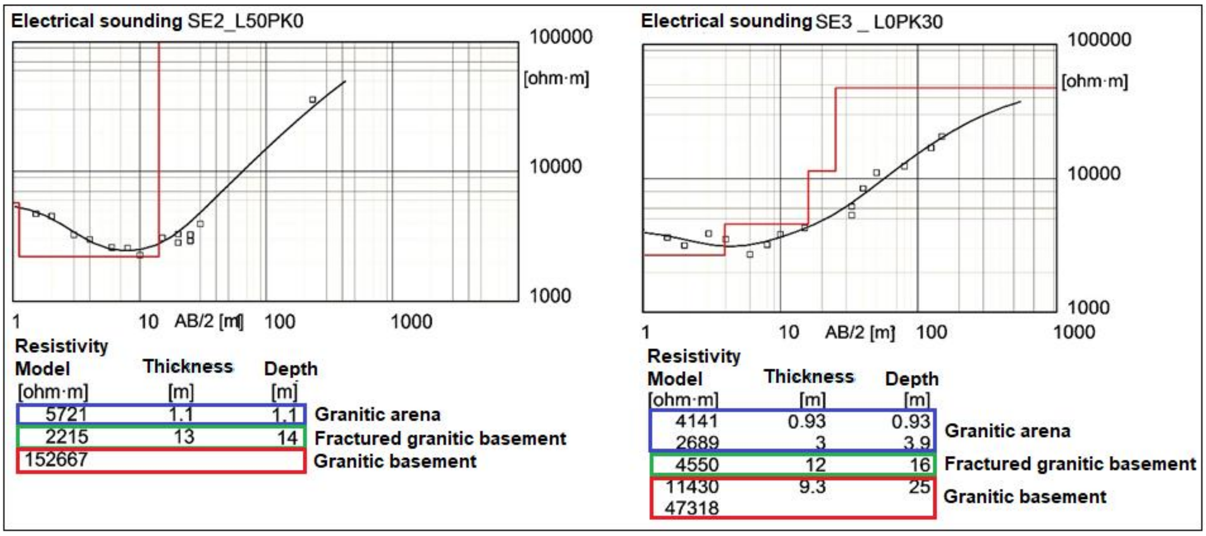

Figure 9: Sounding curves type H.

4.3 Analysis and interpretation of electrical tomography results

Following the North-South and East-West directions, electrical tomography L0, L100W and L100E, respectively, LB and LB+10N allow a 2D imaging of the lithostructural characteristics of the Gbamakro deposit.

4.3.1. Pseudo-section L0

The 2D model of resistivity of the electrical tomography L0, shows a resistant basement, except the northern part of the profile (Fig. 10). It is the weathered granite massif, in north. Throughout of pseudo-section

L0, the thickness of the weathering is low. It is less than 2 m. The L0 electric tomography present also a resistant granitic substratum. Except north, where it has a 15 m depth, on the granitic basement weathered. Healthy granite is at short depths. The outcrops observed around the studied site confirm this. The granite massif is fractured and the fractures plunge in opposite directions. One plunges to the south, the other to the north. These are deep fractures because they pass through all pseudo-section. Around of fractures, there are areas of very high resistivity.

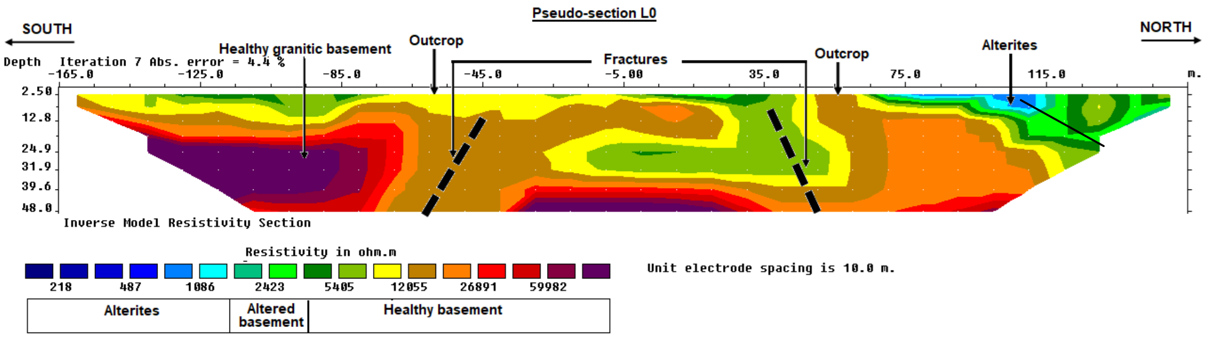

Figure 10: Pseudo-section L0.

4.3.2. Pseudo-section L100W

The pseudo-section of electrical tomography L100W presents a resistant granitic basement (Fig. 11). The extreme north and south of the granite massif are weathered (low resistivity). All the profile shows a little weathered thickness (less than 2 m). Except, the North and South extremities, which have a great weathered thickness (20 m). The profile also shows that the granitic massif is fractured. These fractures plunge to the South and cross all the pseudo-section. The one in the central of the profile tends to close up from 30 m depth.

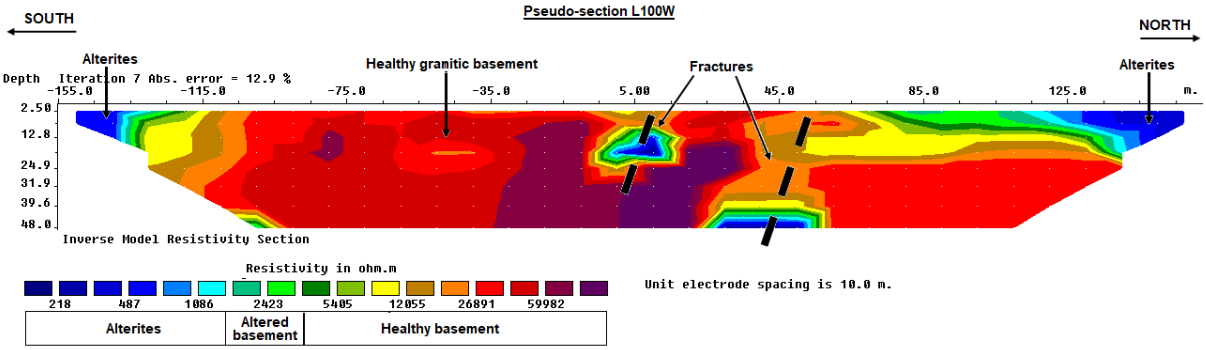

Figure 11: Pseudo-section L100W.

4.3.3. Pseudo-section L100E

The pseudo-section of the electrical tomography L100E shows a resistant granitic basement, with superficial fractures (Fig. 12). The deep fracture also through all the pseudo-section. North of the L100E profile, the thickness of alteration is significant (12 m). All the rest of profile shows little weathered thickness (less than 2m).

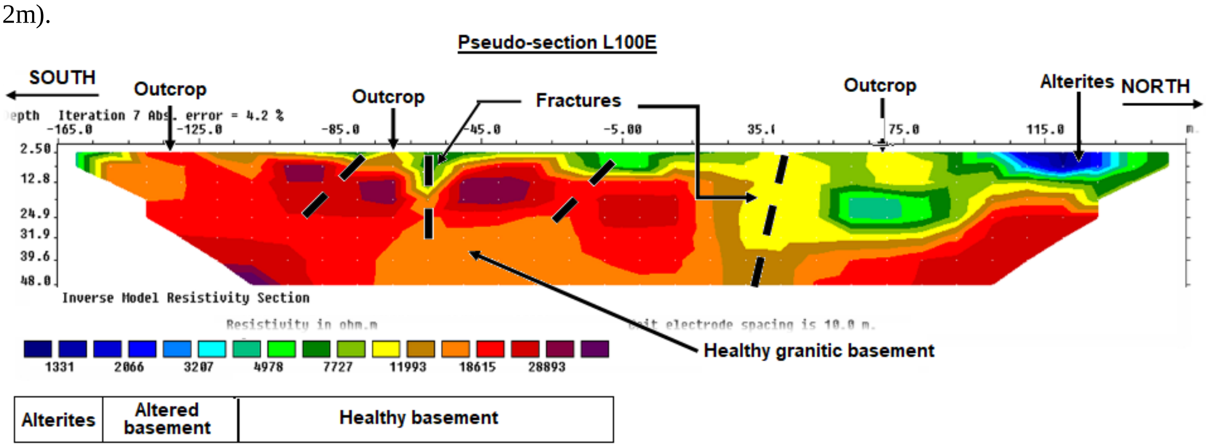

Figure 12: Pseudo-section L100E.

4.3.4. Pseudo-section LB

The result of the pseudo-section of the electrical tomography LB shows no fracture into the resistant granitic basement (Fig. 13). The roof of the granitic massif is located at significant depths (12 m), to West of the LB profile. It is located at less depths (less than 5 m) on the rest of the profile.

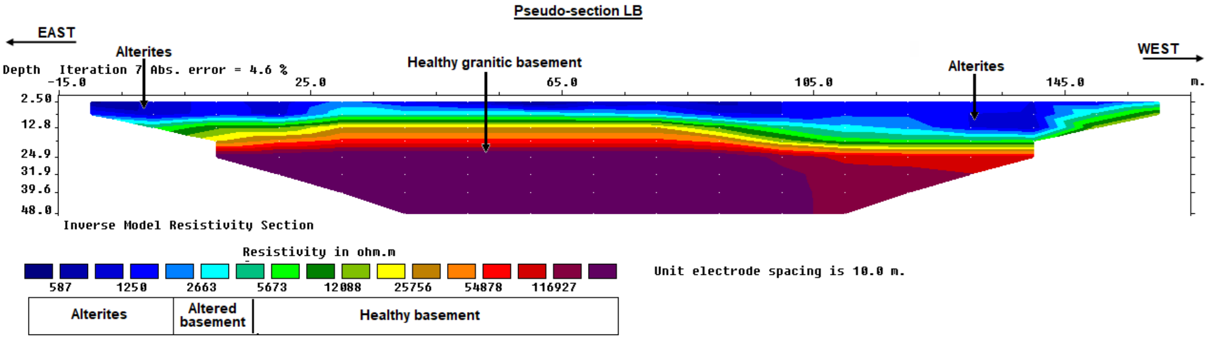

Figure 13: Pseudo-section LB.

4.3.5. Pseudo-section LB+10N

The pseudo-section of the profile LB+10N presents a resistant granitic basement, with a roof less than 3 m deep (Fig. 14). The resistivity model of the profile LB + 10N also shows that the granitic basement is fractured. The fracture is locale and plunge to the West.

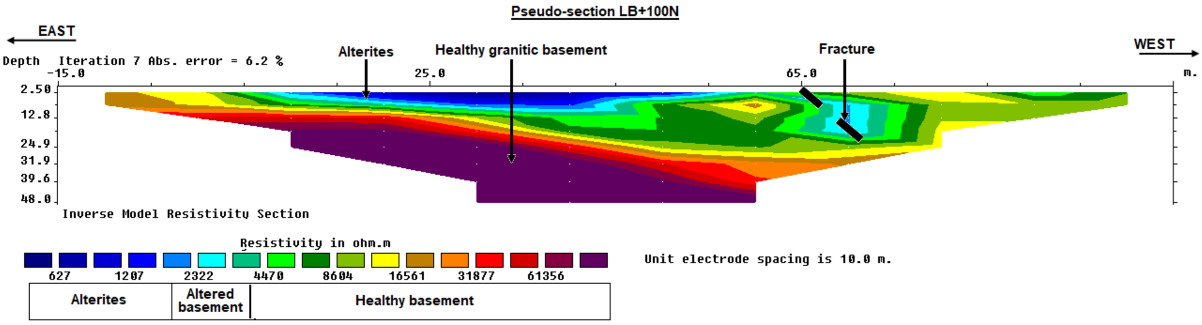

Figure 14: Pseudo-section LB+10N.

V. Discussion

Prospecting by geophysical methods of resistivity (profiling, sounding and electrical tomography) makes it possible to identify the extraction zones of a granite massif. The electric profiling allows to identify resistant anomalies corresponding with healthy granite formations and conductive anomalies, synonymous with fractures or weathered basement. For [8], this geophysical technique is useful in the mapping of massive rock deposits. In particular, it is used in Ferkéssedougou, Bouaké and Ayamé, respectively in the North, Central and South-East of Côte d'Ivoire. They present the geometry of the basement, from the resistivity maps obtained, by electrical profiling. The electrical profiling also makes it possible to identify the orientations of the geological accidents, which affect the granite massif. Many works are made in Côte d'Ivoire, by electric profiling, to identify the geometrical characteristics of the geological accidents in basement zone. For example, [9] and [4] have determined the fractures orientations, from the electrical profiling measures, which affect, respectively, the basement in Sikensi-Tiassalé localities (South of Côte d'Ivoire) and the district of "vallée du Bandama" (north of Côte d'Ivoire).

The sounding curves show an ascending part, with a incline greater than 45 °. These curves are characteristic of a crystalline basement, surmounted by a small thickness of weathered horizon. They have similar characteristics to those obtained by [10].

Technique 2D of electrical tomography assesses the depth of the basement and give an imagery of the subsoil (altered areas, fractured, etc.) of the Gbamakro granite deposit. According to, [11], [12], [13] and [14], the 2D inversions allow to characterize the anomalies observed on the pseudo-sections. These inversions present a geological model, with the depths and extensions of geological discontinuities. The 2D profiles expose a heterogeneity of the basement, related to the variations of resistivity of the subsoil. The 2D tomography is made, according to the pole-dipole configuration. For [14], this configuration presents resistivity resistant anomalies near the surface. However, electrical tomography, in this study, show, in depth geological accidents in the resistant granite massif.

VI. Conclusion

The application of geophysical methods of resistivity (profiling, sounding and electrical tomography) shows their advantages in the determination of the lithological and structural characteristics of the geological formations. These methods have been, particularly useful in the research for massive rock deposits at Gbamakro (Central of Côte d'Ivoire). They showed that the roof of the granitic massif is located under a weathered little thickness horizon (0 to 5 m), except, the North part of the deposit, where the alteration is thickness locally 16 m. They also show that the massif is fractured and the fractures are oriented N70 to N120. These fractures do not deteriorate the quality of the granite. Those identified to the north of the deposit are associated with granite chemical alteration. This makes it possible to affirm that the area from the central to the south of the deposit is exploitable, because of the little thickness of alteration and the almost absence of weathered rock in this zone. In perspective, it would be important to made mechanical soundings, with a view to confirming or invalidating these results.

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