

Comparative Study of a Lithological Description by Geoelectrical and Hydrogeological Drilling in a Basement Environment: Site of the Jean Lorougnon Guédé University in Daloa (Centre-West of the Ivory Coast)

Assoue Kouakou Sylvestre Kouadio^{1*}, Assa Maxime Abbe¹, Gountoh Aristide Douagui², Oscar Zahibo Onetie¹, Kouassi Constantin Gautier Kanga³

¹UFR Sciences Biologiques, Département de Géosciences de l'Université Péléforo Gon Coulibaly de Korhogo, Korhogo, Côte d'Ivoire

²UFR des Sciences et Gestion de l'Environnement, Laboratoire Géosciences et Environnement de l'Université Nangui Abrogoua, Abidjan, Côte d'Ivoire

³Unité de Formation et de Recherches Environnement, Université Lorougnon Guédé, Daloa, Côte d'Ivoire
Email: *sylvestreassoue@gmail.com

How to cite this paper: Kouadio, A.K.S., Abbe, A.M., Douagui, G.A., Onetie, O.Z. and Kanga, K.C.G. (2025) Comparative Study of a Lithological Description by Geoelectrical and Hydrogeological Drilling in a Basement Environment: Site of the Jean Lorougnon Guédé University in Daloa (Centre-West of the Ivory Coast). *Open Journal of Modern Hydrology*, 15, 18-31.

<https://doi.org/10.4236/ojmh.2025.151002>

Received: October 23, 2024

Accepted: January 21, 2025

Published: January 24, 2025

Copyright © 2025 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

The comparative study of electrical and hydrogeological soundings is being carried out on the site of the Jean Lorougnon Guédé University in Daloa, in central-western Côte d'Ivoire. The aim of this study is to determine the similarities in the weathering profile obtained by the hydrogeological surveys and the electrical surveys. The methodology is based on a comparative study of the characteristics of the weathering profile (number of layers, thickness of weathering and number of water inlets). The results show that the electrical sounding curves are of the KH type, giving 4 geological layers. The first layer corresponds to topsoil with a thickness of less than 1 m. The second corresponds to a thicker lateritic clay formation (20 m on average). The third layer is granitic arena, locally up to 30 m thick. Below this is the fractured granitic basement. The results also show that most of the results from the electrical boreholes are consistent with those from the boreholes. Differences exist and are essentially due to the shape of certain electrical sounding curves and to the driller's assessment of the interfaces between the geological formations.

Keywords

Electrical Soundings, Hydrogeological Soundings, Boreholes, Crystalline

1. Introduction

There are several geophysical methods, including electrical resistivity. The latter is widely used in the search for groundwater through the techniques of trailing, sounding and electric panels. These techniques are highly suitable tools for conducting a hydrogeological research programme, both to identify new resources and to improve knowledge of an underground aquifer [1]. The use of these geophysical techniques is based on the study of an intrinsic property of geological formations. This property varies with the water content and mineralisation of the geological environment [2].

In contrast to boreholes, which provide real and direct information about the subsurface, electrical boreholes provide an estimated and indirect approach to the geometric characteristics of the subsurface. For some authors, such as [3], 1D electrical surveys can lead to erroneous borehole locations. According to them, the results of electrical surveys are often far from the realities on the ground and can lead to negative boreholes. Also, the information (number of layers, thickness of alterites, position of fractures or water inlets) given by the electrical survey is often different from that obtained with the boreholes. This raises the problem of the reliability of the interpretation of the results of electrical boreholes. To provide a solution to this problem, we initiated this study, the subject of which is: “Comparative study of a lithological description by geoelectrical and hydrogeological drilling in a basement environment: site of the Jean Lorougnon Guédé University in Daloa (Centre-West of the Ivory Coast)”. The aim of this work is to establish a similarity between alteration profiles based on a hydrogeological and geoelectrical survey. Specifically, the geometry of the alteration profile of the bedrock will be determined from the electrical boreholes, the alteration profile will be identified from the borehole logs and a comparative analysis of the results of the electrical and hydrogeological boreholes will be carried out. Based on this study, it will be possible to establish a hydrogeological log from a geoelectrical borehole.

2. Study Setting and Geological Context

Daloa is a town in central-western Côte d'Ivoire. It lies between longitudes 6°24' and 6°29' West and latitudes 6°50' and 6°55' North. The town is home to the Université Jean Lorougnon Guédé (UJLoG), our study area. The UJLoG covers an area of 400 ha and is located to the north of the town of Daloa, in the Tazibouo district (Figure 1).

About the climatic, the town of Daloa is under the influence of a transitional equatorial climate (Baoule climate). The town's hydrographic system is made up of streams, giving it a scattered site of low-lying areas. These have been extensively developed for rice growing and market gardening [4].

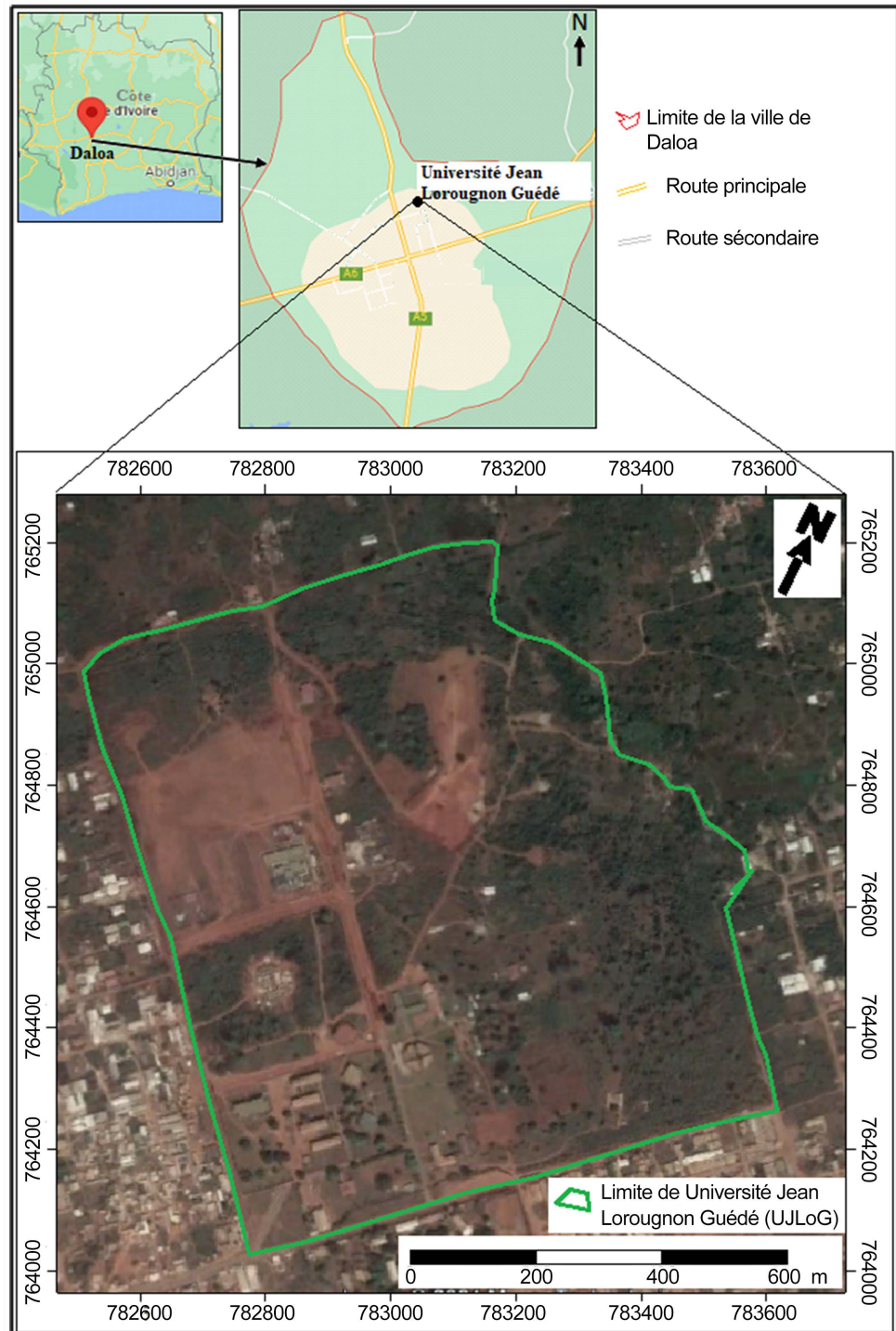


Figure 1. Location of the Jean Lorougnon Guédé University in Daloa.

There are two main geological entities in the department. These are magmatic rocks and metamorphic rocks. The geology of the Daloa department is known from the work of [5] and [6]. The magmatic rocks encountered are of the plutonic and volcanic types. They are mainly represented by granitoids. The composition of these rocks varies from granite to granodiorites [7] (Figure 2).

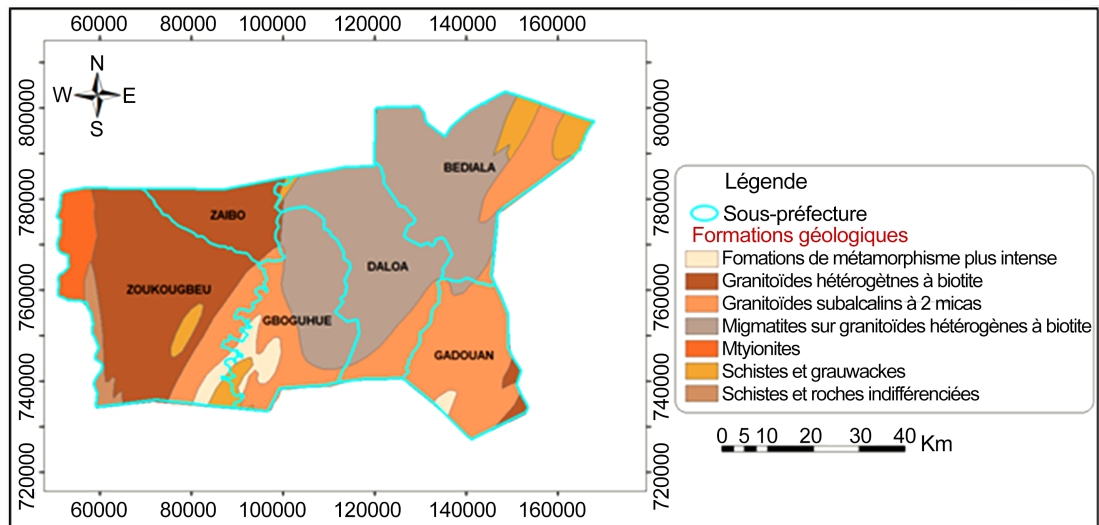


Figure 2. Géological formations of Daloa département [6].

3. Materials and Methods

3.1. Data

This study required two types of data: data from geophysical surveys and data from boreholes drilled on the University site as part of the University development project under the drinking water supply component. The geophysical data consists mainly of apparent resistivity data obtained from 11 electrical boreholes. These 11 electrical boreholes were the subject of hydrogeological boreholes. These electrical resistivity and borehole data are mapped in Figure 3 below.

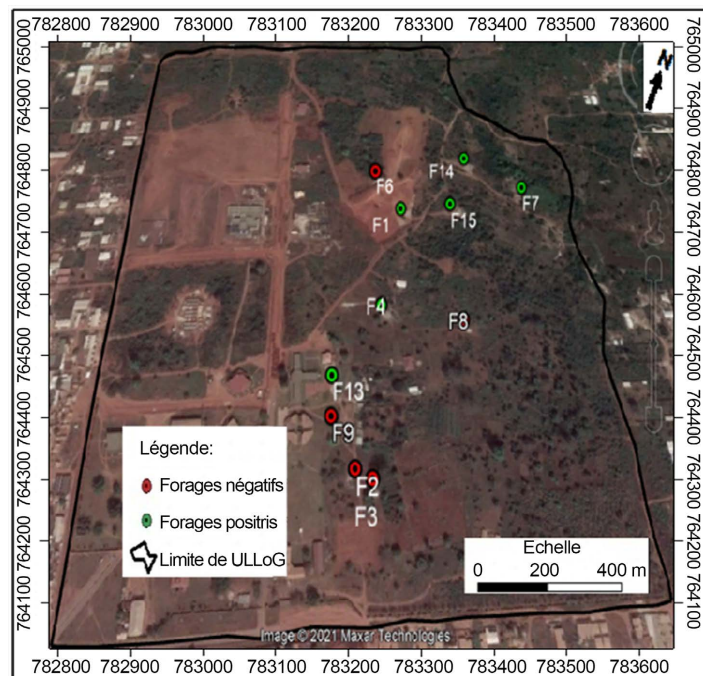


Figure 3. Borehole and resistivity distribution map.

3.2. Methods

3.2.1. Alteration Profile from Electrical Soundings

1) Electrical soundings

The electrical soundings, corresponding to a vertical investigation, were carried out at the level of the conductive anomalies revealed by the electrical tracings. The profiles obtained from the tracings were used to position the various electrical boreholes carried out in the study area (Figure 4). The boreholes and electrical profiles were carried out using the Schlumberger system. This device provides better results and is easy to use in the field. This method is most recommended for 1D geophysical surveys in groundwater prospecting. The distance between the current injection electrodes A and B was gradually increased, while keeping electrodes M and N fixed ($AB > 5 MN$). This makes it possible to gradually increase the depth of investigation. In this work, the distance between A and B varies from 2 to 300 m (Figure 5).

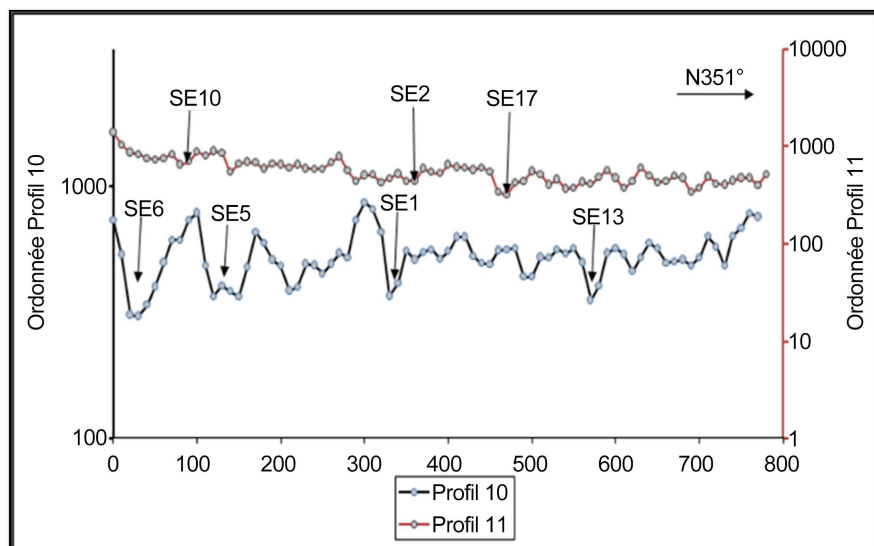


Figure 4. Parallel profiles 10 and 11 showing some of the electrical soundings carried out.

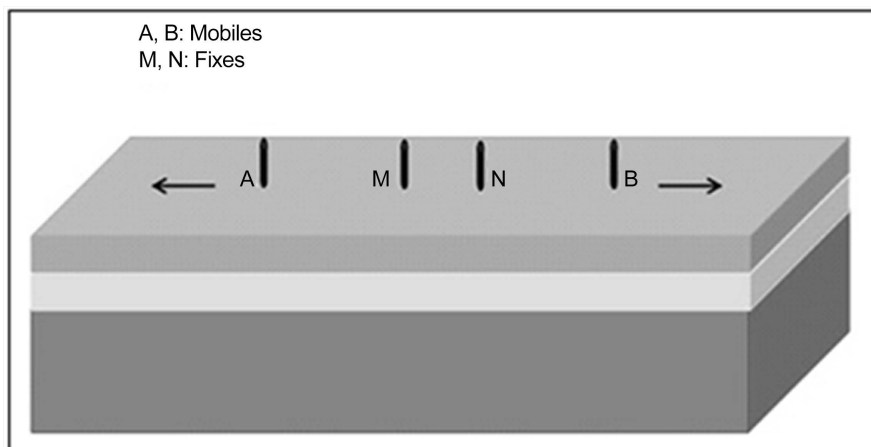


Figure 5. Illustration of electrical sounding using the Schlumberger configuration [2].

2) Processing of electrical sounding data

The IPI2WIN software is used to process and interpret the sounding data numerically. This software is used to represent the apparent resistivity data and interpret the electrical sounding curves obtained. The aim is to create a model of the subsol made up of a succession of horizontal layers, each with a certain resistivity and thickness (B), and then to calculate the response of this model (C) [8] (Figure 6).

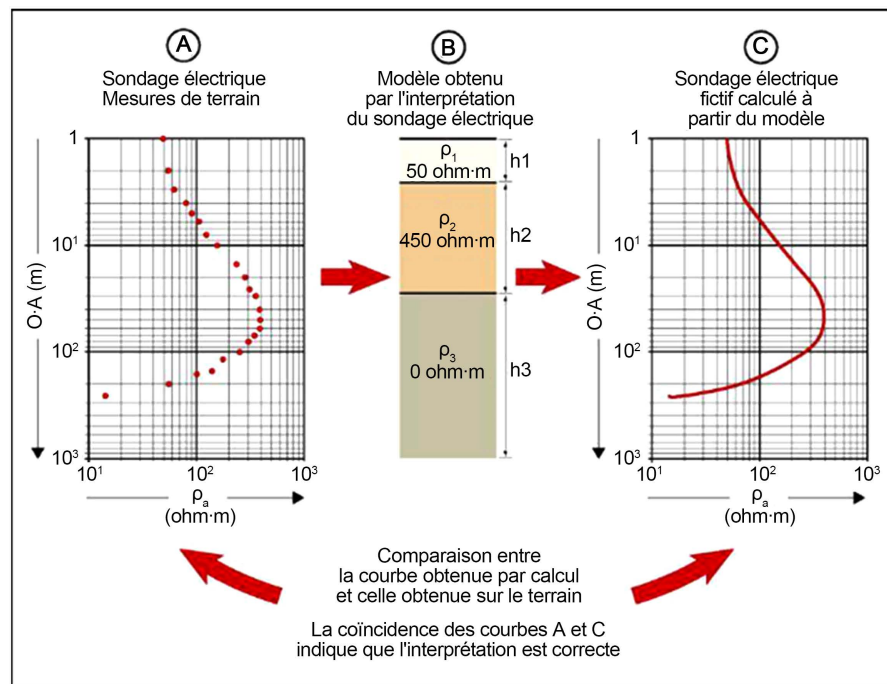


Figure 6. Automatic interpretation of electrical sounding data [8].

3.2.2. Study of the Weathering Profile Based on Hydrogeological Soundings

A macroscopic description of the rock samples taken during drilling is carried out in the laboratory. These samples are taken every 1 m of depth. Observation of each sample shows the changes and nature of the facies with depth. The nature of the facies and the facies changes are noted along with their corresponding depth. This makes it possible to establish borehole logs for each borehole. Water arrivals in the alterites and bedrock are also mentioned. This can be seen from the volumes of rock samples and the increase in the quantity of water. The parameters that will be analysed and compared are the number of layers (N_c), the thickness of each layer (E_c), the thickness of the alteration (E_a) and the depths of water arrivals (P_{ae}).

4. Results and Discussion

4.1. Geometry of Weathering Profiles from Electrical Soundings

The electrical sounding curves used in this study are of the KH type. It is

characterised by 4 layers of ground. These electrical sounding curves have a «bell shape and then the shape of the bottom of a boat» (Figure 7). This curve also characterises terrains with great depths of weathering.

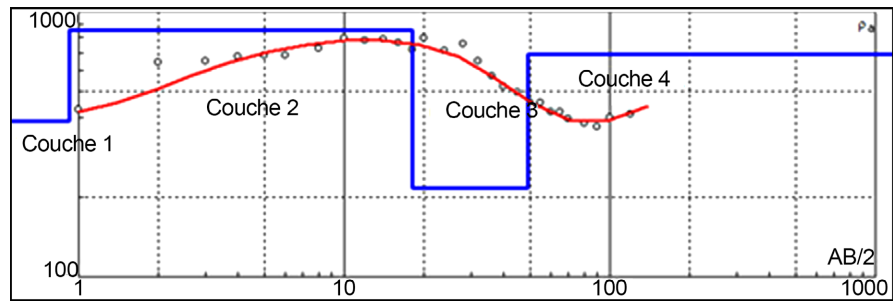


Figure 7. Electrical sounding curve (SE13).

The alteration profile obtained from the quantitative interpretation of the electrical soundings also shows four (04) layers. These layers are shown in Figure 8. The thickness of this zone is highly variable, ranging from 2.83 to 26.2 m, with resistivities ranging from 782 to 2183 Ohm.m. Horizon three (03), with a lower resistivity (58.8 to 628 Ohm.m), corresponds to a sandy clay or arenaceous zone. It is thicker, ranging from 14.5 to 35.9 m. The fourth horizon corresponds to granitic rock, the resistivity of which varies greatly depending on the quality of the bedrock. It varies from 690 Ohm to 8692 Ohm.m, corresponding to a healthy bedrock.

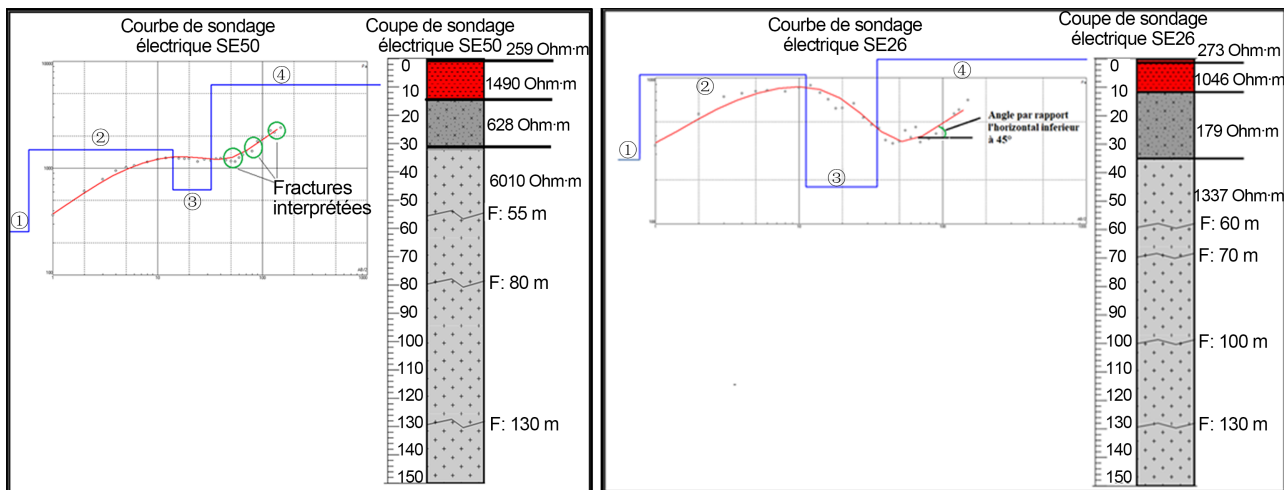


Figure 8. Interpretation of electrical sounding curves SE50, SE26 showing fractures.

4.2. Geometry of Weathering Profiles from Hydrogeological Soundings

The alteration profiles of the hydrogeological soundings made it possible to discriminate the number of layers (Nc) observed as shown in Figure 9. 4 to 5 lithological layers were observed and described from the rock samples taken during the hydrogeological sounding. The first layer is characterised by the vegetation

cover, which varies in thickness from 0 to 1 m. Then a second layer characterised by clays of varying nature. It may be lateritic, ferruginous or lateritic clay. The third layer is sandy, sometimes with mottled clay. Finally, the fourth and fifth layers are arenic and fractured granitic bedrock respectively (**Table 1**).

Table 1. Lithological description of hydrogeological soundings.

Couches	Nature des couches	Epaisseurs (m)	Sondages hydrogéologiques
C1	Top soil	0 - 1	F1, F2, F3, F4, F6, F7, F8, F9, F13, F14
	Lateritic cuirass	1 - 3	F13
C2	Ferruginous cuirass	1 - 15	F7
	Lateritic clay	1 - 25	F2
C3	Colourful clay	1 - 30	F1, F2, F3, F4, F6, F8, F9, F13, F14
	Clay sand	23 - 33	F1
C4	Oxidised coarse sand	3 - 25	F13
	Sandstone arena	15 - 48	F1, F2, F3, F4, F6, F7, F8, F9, F13, F14
C5	Granite fracture	21 - 117	F1, F2, F3, F4, F6, F7, F8, F9, F13, F14

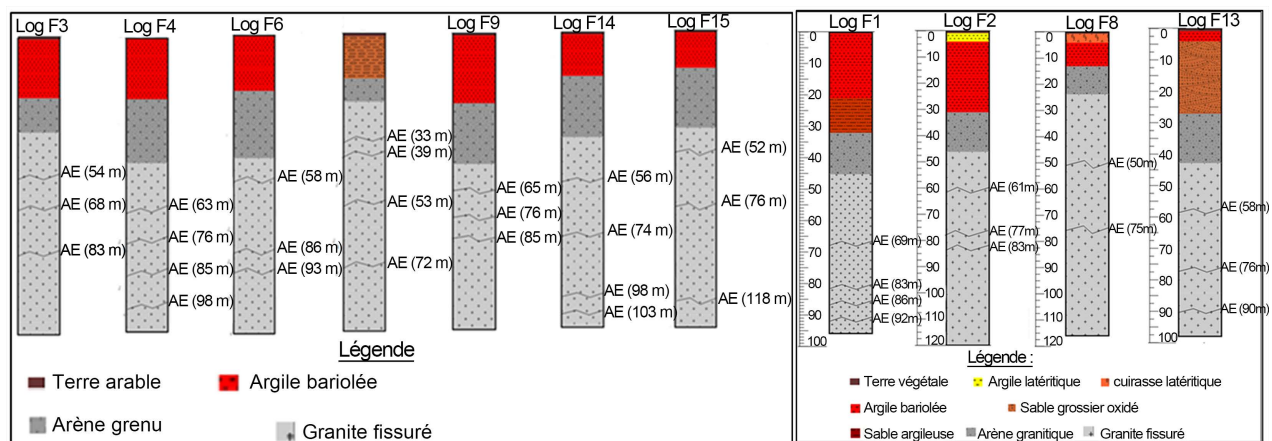


Figure 9. Alteration profiles of hydrogeological soundings with four to five layers.

4.3. Comparative Analysis of Electrical Sounding and Hydrogeological Sounding Results

This part of the study is based on a comparison of three parameters, namely the number of lithological layers, the thickness of weathering and water inflows.

4.3.1. Number of Layers

The histogram in **Figure 10** shows that the number of layers of electrical sounding and hydrogeological sounding carried out at the Jean Lorougnon Guédé University in Daloa is identical for 6 pairs of soundings, 60%. These are the pairs of boreholes (SE2; F4), (SE6; F9), (SE10; F3), (SE13; F6), (SE23; F7), (SE26; F14) et (SE37; F15). However, these results are different from those for which the interpretation of the soundings reveals 5 layers. There are 4 pairs of surveys, 40%. These are the pairs (SE5; F13), (SE9; F2), (SE17; F1) and (SE50; F8).

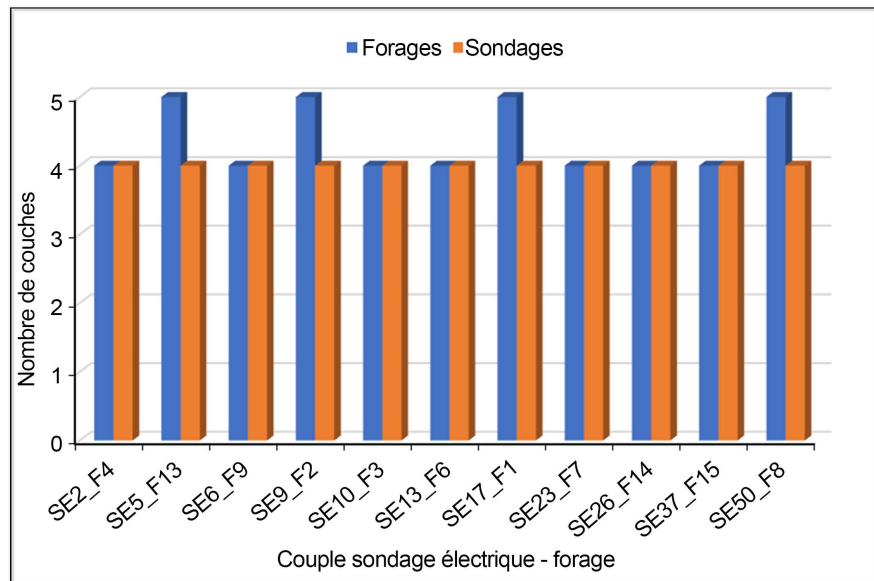


Figure 10. Histogram comparing the number of layers observed between electrical sounding and hydrogeological sounding.

4.3.2. Alteration Thicknesses

The histogram in **Figure 11** shows that the thickness of alteration varies from one borehole to another and from one electrical sounding to another. It ranged from 18.3 to 53.5 m for the geophysical boreholes and from 21.28 to 54.27 m for the hydrogeological soundings. The difference between the alteration values is not significant enough for the pairs of boreholes analysed. The range is between 0.7 and 8.57 m. With the exception of electrical sounding SE50 and hydrogeological sounding F8, where we observed alteration thicknesses of 32.3 m and 23.73 m respectively, *i.e.* a difference of 8.57 m. The other couples (SE_F) show a difference in weathering thickness of less than 3 m.

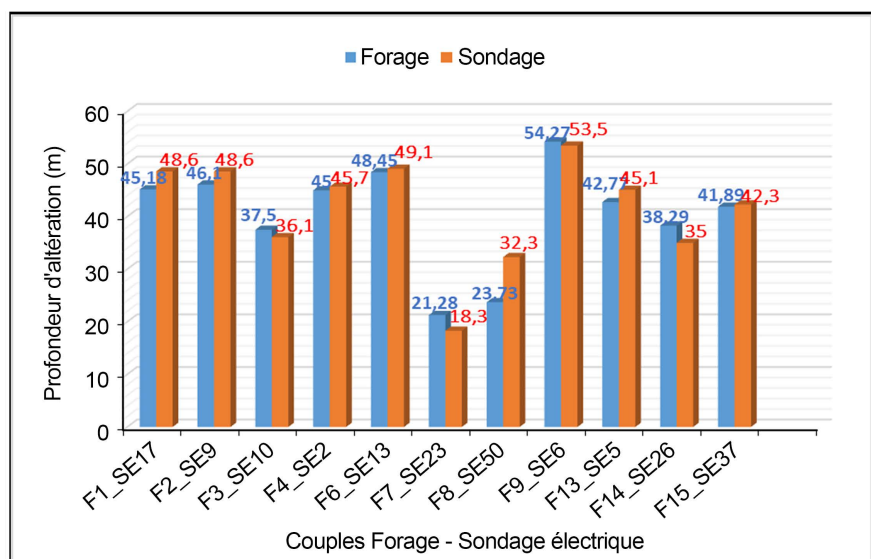


Figure 11. Histogram comparing alteration thicknesses for each pairing (SE_F).

4.3.3. Depth of Water Inlet

The depth of water arrivals is identified by the fractures encountered on the sounding curves, which fractures are also identified by the arrivals during hydrogeological sounding. The position of these fractures on the electrical sounding curve is linked to disturbances (change of trend, break or slope on the curve) on the rise of the curve at bedrock level. It is also linked to the dip of this rise. In the boreholes drilled, the depth of the water arrivals corresponds on the whole to the depth identified on the electrical sounding curves. Major fractures were identified at depths exceeding the total depths of the boreholes. **Table 2** compares the various fracture depths obtained with the boreholes and those identified on the electrical sounding curves.

Table 2. Position of the various fractures interpreted in the electrical soundings and observed in the boreholes.

Couples		Depth of investigation (m)	Fracture depth (m)				
SE17_F1	SE17	150	55	70	90	100	130
	F1	95.92	63	83	85	92	
SE9_F2	SE9	150	65	80	90		
	F2	120	61	77	83		
SE10_F3	SE10	150	50	70	80	130	
	F3	117.29	54	68	83		
SE2_F4	SE2	150	60	70	80	100	130
	F4	105.98	63	73	85	98	
SE13_F6	SE13	120	60	70	90		
	F6	118.16	58	86	93		
SE23_F7	SE23	150	32	50	70	100	130
	F7	92.88	33	39	53	72	
SE50_F8	SE50	150	55	80	130		
	F8	115.71	50	75			
SE6_F9	SE6	150	60	70	90	100	
	F9	123.22	65	76	85		
SE5_F13	SE5	150	55	70	95	120	
	F13	93.04	58	76	90		
SE26_F14	SE26	150	60	70	100	130	
	F14	107.87	56	74	98	103	
SE37_F15	SE37	150	50	60	70	90	120
	F15	128.05	52	76	118		

5. Discussion

5.1. Geometry of Alteration Profiles from Electrical Soundings

The geoelectrical boreholes analysed are of type KH. According to this study, these boreholes are characterised by 4 ground layers. This type of electrical sounding

curve is also obtained in other localities in Côte d'Ivoire, belonging to the basement domain. Examples include the departments of Dabakala [9], Sikensi and Tiassalé [1], the Bandama valley region [10] and the N'Zi-comoé region [11]. The first layer is topsoil. It is thin, around 0 to 1 m thick. Its resistivity can reach 300 Ohm.m depending on climatic conditions. According to [12], this layer is sometimes less perceptible on geoelectrical profiles. In the N'Zi-Comoé region, [12] got results. Similar. The second layer is characterised by clay formations which can vary from lateritic or cuirassed clays to bariolated clays. The thickness of this zone is highly variable, ranging from 2.83 to 26.2 m with a resistivity ranging from 782 to 2183 Ohm.m. This resistivity is all the higher when the first level of clay is armoured. Layers 3 and 4 correspond respectively to sandy clay followed by gravelly arena. This level is highly conductive, as it is sometimes supplied with water and can be used as a catchment area for boreholes for human-powered pumps or farm wells. Layer 3 rests on the fourth layer, which is the bedrock. At the University of Daloa site, this bedrock is granite. Its resistivity varies from 690 Ohm.m for a fractured rock that may be a groundwater drainage channel to 8692 Ohm.m corresponding to a healthy bedrock. Fractures in bedrock are marked by disturbances in the rise of the curve or by a rise slope of less than 45° [12]. believes that whatever the geophysical method used, the analysis of the results of a measurement will be greatly enhanced if a reconnaissance borehole is available to enable the interpretation of the geophysical data to be calibrated.

5.2. Geometry of Weathering Profiles from Hydrogeological Soundings

The results of the geophysical soundings obtained were validated by hydrogeological soundings. These results showed that the lithological sections from the hydrogeological soundings show 4 to 5 layers. The difference in layers is due to the differentiation of the layers, which can be seen in the rock samples obtained. Using the resistivity method, it is difficult to distinguish between two layers by their colour or their water saturation level. Drilling reveals four to five distinct layers, as is the case in the basement regions of Côte d'Ivoire [13] and [14]. The thicknesses of the layers vary for layer 1 from 0 to 1 m, for layer 2 from 1 to 3 or 15 m, for layer 3 they vary from 1 to 33 m and from 15 to 48 m for layer 4. Some boreholes such as F1, F2, F3, F4, F6, F7, F8, F9, F13, F14 showed 5 layers. The thickness of these layers varies from 21 to 117 m. In the N'Zi-Comoé region, [11] has shown that the lithology of certain boreholes has 5 layers.

5.3. Comparative Analysis of Electrical Sounding and Hydrogeological Sounding Results

The comparative study validated the results obtained from the geoelectrical surveys. These results showed that 63% of the geophysical soundings identified the same number of layers as the hydrogeological soundings. The results of the electrical soundings do not always agree with the borehole readings. There are two reasons for this: the water content of the formation and the nature of the geological

environment. These two factors affect the behaviour of the electrical sounding curve. Drilling allows direct observation of the alteration profile. Electrical soundings allow indirect recognition of the alteration profile on the basis of analyses of geoelectrical responses of the subsoil, translated into electrical sounding curves. On this electrical sounding curve, the presence of a single slope means that there are two superimposed terrains with different electrical properties. The change in slope on the curve marks a change in geological layer. For example, we go from two horizons to three horizons. This change in slope does not always correspond to a change in geological layer. It often corresponds to a change in the water content in the same geological formation. In the same horizon, we go from a saturated zone to an unsaturated zone and vice versa [1].

This same comparative study showed that the alteration thicknesses obtained from the geophysical soundings and those obtained from the hydrogeological soundings vary between 0.7 and 8.57 m. Comparative analysis of the water inlets also shows that the number of water inlets and the depth of these water inlets is almost identical for both the geophysical and hydrogeological soundings. These fairly convincing results show that the thickness of alteration, the number of lithological layers, the depths and the number of water arrivals can be predicted by geoelectrical drilling. This means that it is possible to assess the productivity of water boreholes from the analysis of electrical sounding curves [2]. [15] has established a mathematical equation for estimating productivity based on geophysical parameters.

6. Conclusions

This study is being carried out at the Université Jean Lorougnon Guédé (UJLoG) in Daloa (central-western Côte d'Ivoire). The aim is to compare the weathering profile obtained by drilling and electrical sounding. The results of 11 boreholes drilled using geophysics are compared with the results of the corresponding electrical soundings. The aim is to compare the characteristics of the weathering profile commonly obtained during hydrogeological sounding and electrical sounding. These are: the number of layers, the thickness of the alteration and the depth of the water arrivals. Prior to the installation of the boreholes studied, electrical sounding was carried out using a Schlumberger device, with the distance AB (electric current electrodes) varying between 2 and 300 m and the distance MN (potential electrodes) varying between 0.8 and 20 m.

The electrical sounding curves obtained in this study correspond to a single family of curves. These are type KH electrical sounding curves. These sounding curves correspond to an alteration profile, in the middle of the bedrock, with four distinct horizons, as shown by some of the boreholes drilled at the level of these electrical soundings. The superficial horizon (first layer) corresponds to topsoil or vegetation and is less than 1 m thick. Beneath the topsoil is a thick lateritic or variegated clay formation (second layer), around twenty metres thick. This layer is often coupled with a sandy clay facies. This is followed by an intermediate zone

(third horizon) between the fractured granitic bedrock and the overlying alterites. This is the granitic arena, between 8 and 30 metres thick. The weathering profile observed from the boreholes and that obtained from the electrical soundings is identical. However, there are some differences in the number of layers, the thickness of the weathering and the depth of the water inlets.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Sombo, A.P. (2012) Application des méthodes de résistivités électriques dans la détermination et la caractérisation des aquifères de socle en Côte d'Ivoire. Cas des départements de Sikensi et de Tiassale (Sud de la Côte d'Ivoire). Thèse de Doctorat, Université Félix Houphouët Boigny de Cocody (Abidjan, Côte d'Ivoire), 203 p.
- [2] Chapellier, D. (2000/2001) Cours online géophysique, prospection électrique de surface. Université de Lausanne; Institut Français du pétrole, 97 p.
- [3] Allé, C., Descloitres, M., Vouillamoz, J.M., Yalo, N., Lawson, F.M.A. and Adihou, C. (2015) Caractérisation des aquifères de socle par la résistivité électrique. Pratique de l'implantation des forages et perspectives d'amélioration au Bénin. Vingtièmes journées techniques du Comité Français d'Hydrogéologie de l'Association Internationale des Hydrogéologues juin. 8 p.
- [4] Koukougnon, W.G. (2013) Milieu urbain et accès à l'eau potable: Cas de Daloa (Centre-ouest de la Côte d'Ivoire). Thèse de Doctorat, UFR des Sciences de l'Homme et de la Société, Université Félix Houphouët Boigny (Abidjan, Côte d'Ivoire), 364 p.
- [5] Ahimon, O.A. (1990) Notice explicative de la carte géologique à 1/200 000, feuille de Daloa. Direction de la géologie, Abidjan, 28 p.
- [6] Delor, C., Siméon, Y., Vidal, M., Zeade, Z., Koné, Y. and Adou, M. (1995) Carte géologique de la Côte d'Ivoire à 1/200 000, feuille Séguéla, Mémoire n°9 de la Direction des Mines et de la Géologie, Abidjan, 19 p. de Nantes et de Lausanne (France), 208 p.
- [7] Yao, A.B. (2015) Evaluation des potentialités en eau du bassin versant de la Lobo en vue d'une gestion rationnelle (Centre-ouest de la Côte d'Ivoire). Thèse de Doctorat, UFR des Sciences et Gestion de l'Environnement, Université Nangui Abrogoua (Abidjan, Côte d'Ivoire), 192 p.
- [8] Marescot (2009) Modélisation directe et inverse en prospection électrique sur des structures 3D complexes par la méthode des éléments finis. Thèse de doctorat ès Géosciences, Université.
- [9] Sombo, A.P., Kouakou, K.E.G. and Bié, G.R. (2019) Caractérisation géoélectrique du système aquifère du département de Dabakala (Côte d'Ivoire). *Revue Ivoirienne des Sciences et Technologiques*, **34**, 277-292.
- [10] Sombo, P., Kouassi, F., Sombo, C., Kouame, L. and Kouassi, E. (2011) Contribution de la prospection électrique à l'identification et à la caractérisation des aquifères de socle du département de Sikensi (Sud de la Côte d'Ivoire). *European Journal of Scientific Research*, **64**, 206-219.
- [11] Kouadio, A.K.S. (2021) Contribution à l'étude de la productivité des forages d'eau par la méthode de résistivité électrique en milieu de socle fissure: Cas de la zone du N'Zi-Comoe. Thèse de doctorat en géophysique appliquée, Université Nangui Abrogoua

(Abidjan, Côte d'Ivoire), 243 p.

- [12] BRGM (1997) Ile de cayenne (Guyane). Hydrologie du socle fracturé. Mise au point de méthodologie de prospection, exploitation et gestion des aquifères. Rapport d'avancement au 31 decembre 1996. Rapport, BRGM R 39311, 39 p.
- [13] Savané, I. (1997) Contribution l'étude géologique et hydrogéologique des aquifères discontinus du socle d'Odienné (Nord-Ouest de Côte d'Ivoire). Apport de la télédétection et d'un système d'information hydrogéologique à références spatiales. Thèse de Doctorat d'Etat ès Sciences naturelles, Université de Cocody (Abidjan, Côte d'Ivoire), 396 p.
- [14] Biemi, J. (1992) Contribution à l'étude géologique, hydrogéologique et par télédétection des bassins versants subsahéliens du socle précambrien d'Afrique de l'Ouest: Hydrostructurale hydrodynamique, hydrochimique et isotopie des aquifères discontinus de sillons et aire granitique de la Haute Marahoué (Côte d'Ivoire). Thèse de Doctorat d'Etat ès Sciences Naturelles, Université d'Abidjan (Côte d'Ivoire), 493 p.
- [15] Kouadio, A.K.S., Ouedraogo, M., Ouattara, I. and Savane, I. (2020) Use of a Multiple Regression Model in the Estimation of Water Borehole Flows in the Middle of Cracked Basement in Côte d'Ivoire. 18 p.