

# Use of Electrical Resistivity Tomography (ERT) for Detecting Underground Voids on Electrical Pylon Installation Sites: Case Studies from Labé Prefecture, Republic of Guinea



Ahmed Amara Konaté, Oumar Barou Kaba,  
Mohamed Samuel Moriah Conté, Muhammad Zaheer, Baye Mbaye Thiam,  
Fassidy Oularé, and Moussa Diallo

**Abstract** This study was carried out within the framework of the Gambia River Basin Development Organization Energy Project (OMVG), which brings together Gambia, Guinea, Guinea-Bissau and Senegal. The construction of a high voltage interconnection network fed by a hydro-electricity power station to supply power to OMVG member states must be done on stable ground. During the construction of the installation pits for the pylons in Labé Prefecture, cavities in the geological formations were discovered on the initial planned route. Regarding to geotechnical context of subsurface cavities risk it is mandatory to know their exact location in study areas to reduce the potential degree of risk. A field study was conducted to investigate the lithology, as well as in detecting the presence of apparent faults. Geophysical data was collected using Two Dimensional ERT with different electrode spacing to delineate associated subsurface cavities on each site and each cavity respectively. The target depth was 20 m. The result shows that the observed cavities were because of the dissolution of certain minerals constituting the weathering crust due to the infiltration and the seasonal variation in the level of the watercourses. The cavities were almost entirely empty such as in the cases of pylons 213 and 210 indicated that the weathering crust is due to the groundwater infiltration and the seasonal variations in the river flow level. The finding of this study showed that the ERT method have a good applicability in the detection of underground cavities in the study area.

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A. A. Konaté (✉) · O. B. Kaba · M. S. M. Conté · F. Oularé · M. Diallo  
Laboratoire de Recherche Appliquée en Géoscience et Environnement, Institut Supérieur Des  
Mines Et Géologie de Boké, BP 84, Boké, Baralandé, Republic of Guinea  
e-mail: [konate77@yahoo.fr](mailto:konate77@yahoo.fr)

M. Zaheer  
School of Civil Engineering and Mechanics, Lanzhou University, Lanzhou 730000, Gansu, China

B. M. Thiam  
GEOTEC Afrique, BP 96, Conakry, Republic of Guinea

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## 1 Introduction

Our basement is crossed by a considerable number of underground natural cavities which are linked to the human activities. Engineering structures such as electrical pylon installation require subsurface investigation to map and assess the presence of cavities, which reduces geotechnical hazards risks such as subsidence or complete collapse [1]. The risk of collapse requires firstly the identification and localization of the origin of cavity by the geophysical tool fits. From a technical point of view, an underground cavity is characterized by: its geological context, i.e. the physical characteristics of the rock; its origin anthropic or natural cavity; and its dimensions (the geometry of the cavity itself).

Applied geophysics is one of the reconnaissance tools used to investigate a cavity. It involves a number of different techniques that help to identify the anomalies in the physical and chemical properties of the subsurface including the propagation of electromagnetic, gravity, acoustic, and electrical, or magnetic signals [2]. These methods based on the different principles, which depend on the context and faced problem, their advantages and their limitations. One of these techniques is electrical resistivity tomography (ERT), which involves for the determination of the subsurface distribution of electrical resistivity by making measurements on the ground surface. Electrical resistivity is a bulk physical property of materials that describes how difficult it is to pass an electrical current through the various materials.

ERT as applied to geotechnical engineering problems, have been extensively used as a method for the detection of cavities ([2–15, 15]). ERT offers a rapid and cost-effective imaging of the shallow subsurface with acceptable resolution [6]. Despite the applicability success, ERT investigation often leads to the non-unique models of the subsurface. This is because the inversion of electrical resistivity data is a non-linear problem, while the solutions were obtained using a linearized forward model [12]. Consequently, it is necessary to increase a priori information on the environment and the cavities sought.

This study is carried out within the framework of the Gambia River Basin Development Organization Energy Project (OMVG), which brings together Gambia, Guinea, Guinea-Bissau and Senegal. Referring to [16], the purpose of the OMVG Energy Project is to contribute to the socio-economic development of the OMVG member countries through increased access of the population to electricity. It aims to enable energy exchanges and increase the quality of electricity supply in OMVG member countries by giving renewable, clean and cost-competitive energy. The project is financed by numerous institutions including: the African Development Bank (AFDB), the World Bank, and the ECOWAS.

The OMVG involves the development of the Sambangalou hydro-electricity dam with an installed capacity of 128 MW and the construction of an interconnection

network for the evacuation of energy, comprising 1,677 km of 225 kV lines, 15 high voltage /medium voltage transformer stations, and 2 load dispatch centers [16]. The electrical interconnection or electricity transmission is ensured by high voltage lines supported by pylons. The construction of a high voltage interconnection network fed by a hydro-electricity power station to supply power to OMVG Member States must be done on stable ground. During the construction of the installation pits for the pylons in Labé Prefecture, Republic of Guinea, cavities in the geological formations were identified on the initial planned route. The length of the route is about 12 km. Thirty-seven (37) sites planned for the locations of electricity pylons were investigated. The spacing between the pylons varies from 300 to 500 m. Early discovery of cavities in the areas where these were viewed can considerably decrease the risk to infrastructure, personnel, project time lines and the budgets.

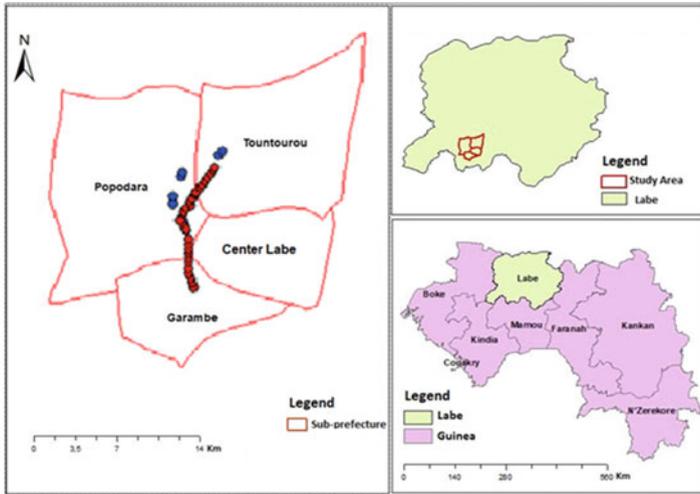
This study aims to find the presence of cavities likely to cause surface damage on the location of electricity pylons along a high voltage line route in Labé Prefecture in Republic of Guinea. The main objective of this paper is to study the extent of these cavities and where these features were located in the study area. A geological field observations supplemented by a geophysical campaign was carried out. Selected sites are shown in this paper as an example of the capabilities of the methods employed. Results are promising, and the ERT method combine with the geological field observations proved to be a helpful approach to define and detect cavities.

## 2 Materiel and Methods

### 2.1 *Presentation of Study Area*

Labé is in the northwest of the Republic of Guinea, in Middle Guinea, also called the Fouta Djallon highlands, more precisely in the Labé region, 308 km from the capital Conakry (see Fig. 1).

It is administratively bounded by the regions of Pita, Mali, Gaoual, Tougué, Lélouma and Koubia. Its relief rich in mountainous massifs and its abundant rainfall are dominant factors in Middle Guinea where the study region is located, constitutes the source of several rivers in the sub-region. The study area is located in the central part of the Fouta Djallon, which corresponds to the watershed line of the Niger basin, going towards the east and the basins of the rivers flowing into the Atlantic Ocean to the West [17]. Given its particular relief and its significant hydrography, the region has been the subject of several studies ([17, 19, 18, 19]). The study area is located on the geological sheet of Labé, which consists of two structural-tectonic zones that differ from each other by the conditions of their accumulative sedimentation until before the Paleozoic [17].



**Fig. 1** Presentation of study area

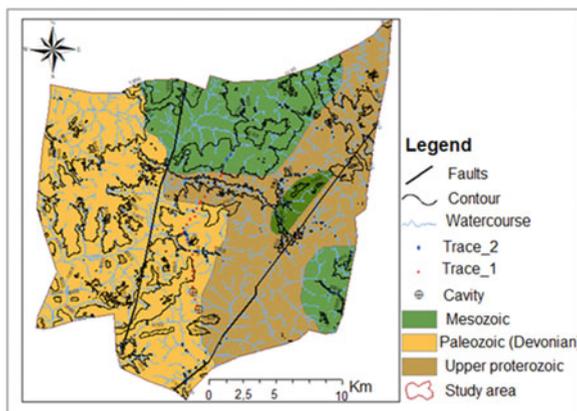
## 2.2 Geological Field Observation

A field study was consisted in studying the lithology, the geomorphology as well as in detecting the presence of apparent faults on the developed route. The geological field observations were done by researchers from Higher Institute of Mining and Geology of Boke, Guinea.

## 2.3 Electrical Resistivity Tomography Method

ERT is based on an ABEM acquisition system which contains the measurement protocols. The electrical device comprises forty (40) copper or nickel electrodes, spaced 5 m apart; two (02) cables (yellow) to connect the electrodes to the acquisition system; Dipole–Dipole array configuration was chosen to detect the cavities. This Dipole–Dipole is recommended for vertical structures in an area that is not too noisy, with a fairly sensitive resistivity meter and good contact with the ground ([2, 8, 12, 15, 20–22]). 48 ERT profiles of 100 m, and a test board on the cavities were carried out respectively on each site and on each cavity. The target depth was 20 m. The correct field/electrode coupling was monitored by wetting the electrode. The results of the electrical method are pseudo-section representing the apparent resistivities of the subsoil as a function of depth (20 m) in a vertical plane plumb with the line of surface electrodes. The inversion of the pseudo-section makes it possible to obtain a 2D image of the resistivities of the basement. The apparent resistivity pseudo-section inversion software used were Res2Dinv and Erigraph. The

**Fig. 2** Geological map of the study area



geophysical data acquisition and processing were made by the geophysical survey staff from the university of Thiès, Senegal. The presence of a cavity was obtained by an electrical profile. A significant increase in resistivity indicated that the cavity is filled with air (vacuum) and a significant drop in electrical resistivities values reflected that the cavity is filled with water. Thus, this study approach is used for the detection of potentially unstable cavity or zone. Any geotechnical horizons, which were showing higher values of electrical resistivities such as greater than 30,000  $\Omega\text{-m}$  indicates that the cavities were filled with air. Very low resistivities values such as less than 200  $\Omega\text{-m}$  reflects that the cavities were filled with water (Fig. 2).

### 3 Results and Discussions

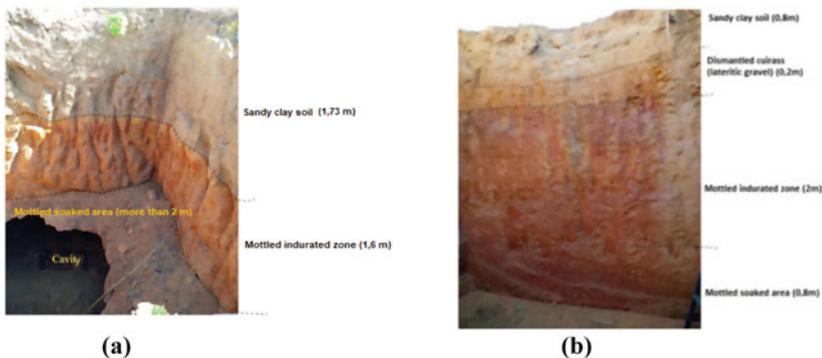
The study area is bounded by two major normal faults to the East and West trending northeast which control the emplacement of Mesozoic basic and ultramafic intrusions (dunite, dolerite, basalt, gabbro, and pyroxene) as can be seen in Fig. 2. The emplacement of these major faults was not generate a fault network on the surface as well these were not bring deformations to the surrounding formations apart from the contact metamorphism. In the study area, there are no cracks or joints of tectonic origin observed at the limit of the excavations and their environment. However, cracks were observed in places because of the chemical and/or mechanical weathering. It was found that intrusions of dolerites in the beds of watercourses, in particular one of the tributaries of the Kakrima river near the village Leila in the district of Nadhel.

The presence of these dolerites in this stream would explain the relationship between the tectonics and the valleys/streams. Also, it was visible on the geological map of the region in places of rivers controlled by these two major faults as shown in Fig. 2. The Paleozoic (Ordovician, Silurian) tabular formations in the study area are essentially of low dips between  $10^\circ$  and  $15^\circ$ . These formations experienced brittle

tectonics due to the opening of the continent to the ocean in the Mesozoic. No ductile deformations were observed.

Mottled zone was observed in at P210 and P213 as shown in Fig. 3. It corresponds to the transition zone between the parent rock and the lateritic gravel levels. It was subdivided into mottled soaked zone and mottled indurated zone. Field observations at P210 and P213 showed the presence of cavities. However, no genetic or functional relationship was found with the faults network (Fig. 2). This was probably the result of the dissolution of certain minerals that make up the weathering crust due to infiltration and underground waters and the seasonal variation in the level of rivers. The cavities observed in P210 and P213 were near watercourses. Figure 4 shows the ERT profiles of P210 pylon installation site. The ERT profiles show a very heterogeneous terrain with the presence of cavities and were partially saturated soils. The large cavity was visible on the site footprint as can be seen in Fig. 3a, which was appeared clearly on profile P2\_210. Around pylon 210, It was conducted an additional ERT profile (named P\_210') centered 50 m north of P210 to verify the lateral extension of the cavity which was visible on the surface in the study area. It was noted that the cavities make border between the pylon to the North and South. Figure 5 shows that the ERT profiles on the P213 pylon installation site. It was noted that on profile P1\_213, higher resistivity as compared to a cavity visible in Fig. 3a. This cavity has a diameter of less than 5 m and a thickness of about 2.5 m. The air-filled cavity will give high resistivity values than those to water filled or water-saturated sediments ones [23, 24]. On P3\_213 in Fig. 5, it was also found that another structure of low resistivities (between 200 and 400  $\Omega$ .m) which could also correspond to a cavity filled with muddy soil. However, it is far enough from the right-of-way of the pylon, on the South-West side, not to require any treatment.

The discoveries of underground cavities by using traditional methods such as local surveys are somehow difficult because of the occurrence of heterogeneities and random dispersal of the cavities. Geophysical investigations may integrate all information on a larger scale and therefore it will be highly acceptable criterion for the subsurface investigations.



**Fig. 3** a P210 lithology. b P213 lithology.

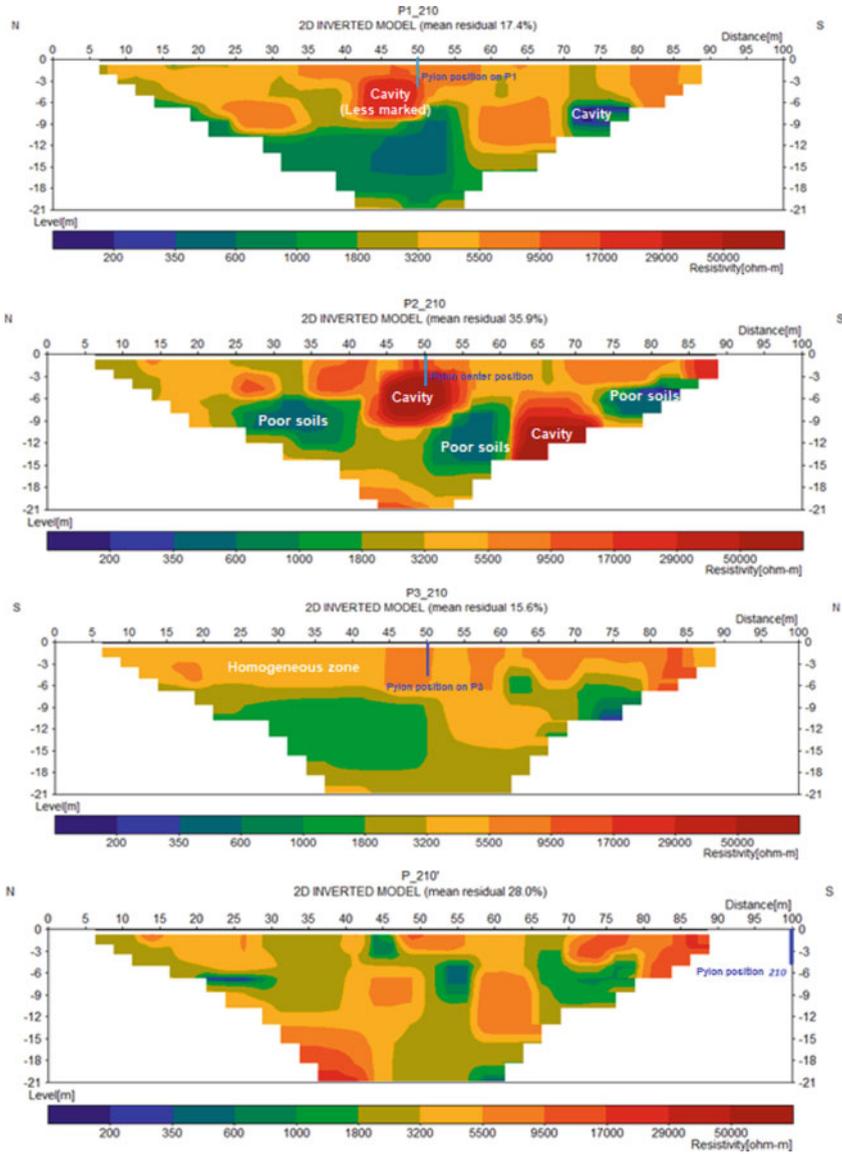
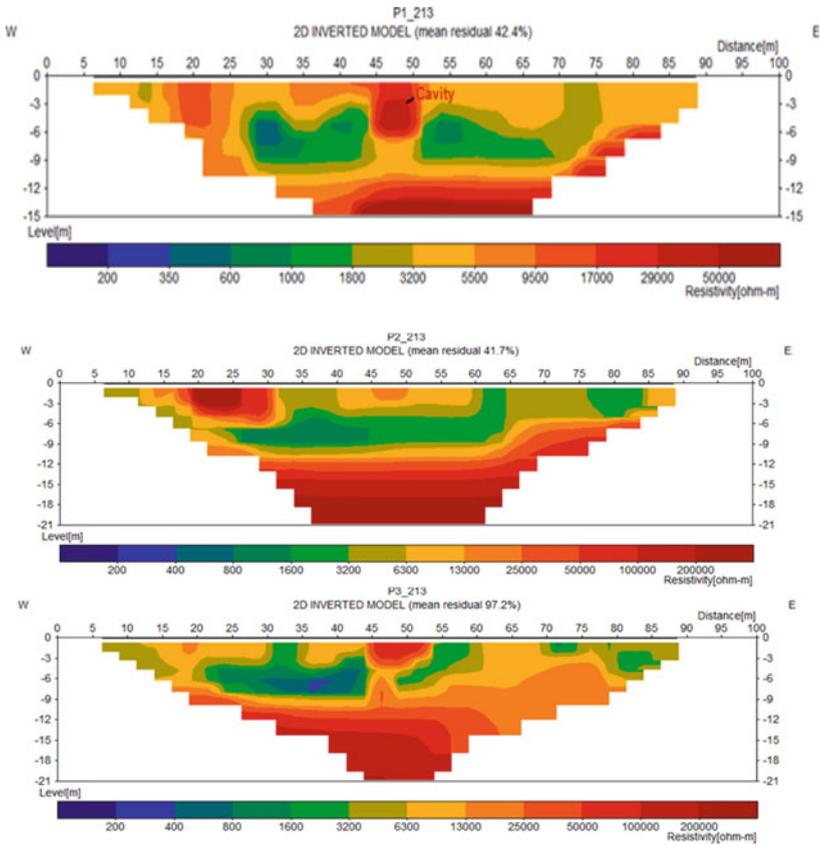


Fig. 4 ET profiles of the P210 pylon installation site. In order to locate and characterize the cavity zones, four ERT profiles (referred as P1, P2, P3 and P) were measured on Pylon 210



**Fig. 5** ERT profiles obtained on the P213 pylon installation site. In order to locate and characterize the cavity zones, three ERT profiles (referred as P1, P2, and P3) were measured on Pylon 213

### 4 Conclusion

The study carried out made it possible to detect on the grip of some pylons structures similar to cavities. The cavities observed (located near the watercourses) were the result of the dissolution of certain minerals constituting the weathering crust due to infiltration and underground waters and the seasonal variation in the level of the watercourses (floods and low water levels). In the study area, there are no cracks or joints of tectonic origin observed at excavations sites and their environment. However, it was observed cracks at some places because of the chemical and/or mechanical weathering.

The cavities are entirely empty, as in the case of pylons 213 and 210. Mottled zone was observed at Pylon 210 and Pylon 213, which corresponds to the transition zone between the parent rock and the lateritic gravel levels. Field observations at P210 and P213 showed the presence of cavities but no genetic or functional relationship

with the faults. They are probably the result of the dissolution of certain minerals that make up the weathering crust because of the groundwater infiltration and the seasonal variation in the level of rivers. The air-filled cavity will give high resistivity values than those to water filled or water-saturated sediments ones.

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