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Evaluation of Drilling Prospects for Geological Interpretations in Parts of Okirika Using Resistivity and Digitized Resistivity Data Tools

Sonny Inichimba[1], Oghonyon Rorome[2]*; Ogaji Margaret Folake[3]; Izonfadei Matthew[4]

[1,2,3,4]Department of Geology, University of Port Harcourt, Rivers State, Nigeria.

*Corresponding Author's Email: Rorome.oghonyon@uniport.edu.ng Tel: 08037977351

Co-Author Email: sonny.inchinbia@uniport.edu.ng, folake.ogaji@uniport.edu.ng, izonfadeitimi@gmail.com.

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Abstract: This paper evaluates drilling prospects for geological interpretations in parts of Okrika, Rivers State, Nigeria, using an integrated geophysical approach involving one-dimensional (1D) Vertical Electrical Sounding (VES) cross plots and two-dimensional (2D) digitized resistivity imaging models. The investigation was undertaken to overcome the challenges associated with lateral facies variations and the limitations of single-method geophysical exploration during subsurface characterization. Data acquisition involved dual-line field measurements, which were analyzed using depth-calibrated resistivity cross-plots and digitized resistivity inversion contour maps. The geoelectrical cross-plot results revealed heterogeneous subsurface conditions characterized by KH-type and HA-type curve signatures, indicating variations in lithology across the study area. The interpreted geoelectric layers suggest the occurrence of laterally continuous resistive sand units and conductive horizons, which are significant indicators of potential drilling zones and subsurface geological boundaries. The digitized resistivity tomograms further delineated porous and permeable formations, highlighting zones suitable for drilling and geological investigations. The integration of VES and ADMT data enhanced interpretation reliability by minimizing single-method artifacts and providing a high-resolution subsurface model. The study demonstrates the effectiveness of resistivity and digitized resistivity data tools in evaluating drilling prospects and improving geological interpretations within the Coastal Plain Sands of the Niger Delta.

Keywords: Electrical Resistivity; Vertical Electrical Sounding (VES); Drilling Prospects; Geological Interpretation; Benin Formation.

1. INTRODUCTION

The Niger Delta Basin is characterized by complex subsurface geological conditions resulting from prolonged fluvial, deltaic, and continental depositional processes. These processes have produced thick sedimentary sequences belonging predominantly to the coastal plain sands of the Benin Formation (Reijers, 2011). Within Okirika and its surrounding environments, the subsurface commonly exhibits significant lithological heterogeneity, resulting in abrupt changes in layer thicknesses, sediment composition, and hydrogeological characteristics over relatively short distances (Akpokodje, 1987). Such geological complexities often present major challenges during drilling operations and subsurface investigations.

Successful drilling activities require adequate knowledge of the subsurface architecture, including the depth, thickness, continuity, and distribution of lithological units. Conventional drilling methods, when undertaken without adequate geophysical support, frequently encounter difficulties resulting from poor geological prediction, unidentified clay lenses, discontinuous sand bodies, and unexpected formation changes (Loke, 2004; Oghonyon & Njoku, 2024). These

uncertainties often increase exploration risks and drilling costs.

Recent advances in geophysical techniques have demonstrated that the integration of vertical electrical sounding (VES) and digitized electrical resistivity imaging provides a reliable approach for evaluating drilling prospects and improving geological interpretations (Dahlin, 2001; Loke *et al*., 2013; Oghonyon, *et al*., 2026; Ugwu *et al*., 2016). While VES provides detailed information on vertical resistivity variations, digitized resistivity tomography enables

continuous lateral imaging of subsurface formations. The combination of both methods therefore improves the delineation of geological structures and potential drilling horizons.

Drilling activities in many parts of the Niger Delta are often hindered by insufficient knowledge of subsurface geological conditions. The occurrence of localized clay lenses, saturated formations, buried channels, and rapid lateral facies changes can adversely affect drilling success and lead to inaccurate geological interpretations (Oghonyon, and Layefa., 2026).

In Okirika, reliable information concerning the vertical and lateral distribution of subsurface formations remains limited. Dependence on single geophysical methods or isolated drilling data may result in incomplete characterization of geological units and uncertainty in the identification of potential drilling targets. Consequently, there is a need for an integrated geophysical investigation capable of accurately delineating subsurface structures and evaluating prospective drilling horizons. The aim of this study is to evaluate drilling prospects for geological interpretations in parts of Okirika using integrated resistivity and digitized resistivity data tools.

The specific objectives are to: Determine the geoelectrical characteristics, delineate lithological units, identify potential drilling horizons, and establish the lateral and vertical continuity of geological formations within Okirika area.

Description of the Study Area*:* The study area is located in parts of Okrika, Rivers State, Nigeria, within the Niger Delta Basin (see Figure 1 below). The area falls within the Coastal Plain Sands (Benin Formation), which is composed predominantly of unconsolidated to poorly consolidated medium-to-coarse-grained sands with occasional gravelly deposits and clay intercalations (Akpokodje, 1987). The geology of the area reflects a complex depositional history resulting from continental and deltaic processes. The subsurface stratigraphy is characterized by alternating sand and clay units whose distributions influence drilling conditions and geological interpretations. Understanding the geometry and continuity of these formations is essential for successful drilling operations and accurate subsurface characterization.

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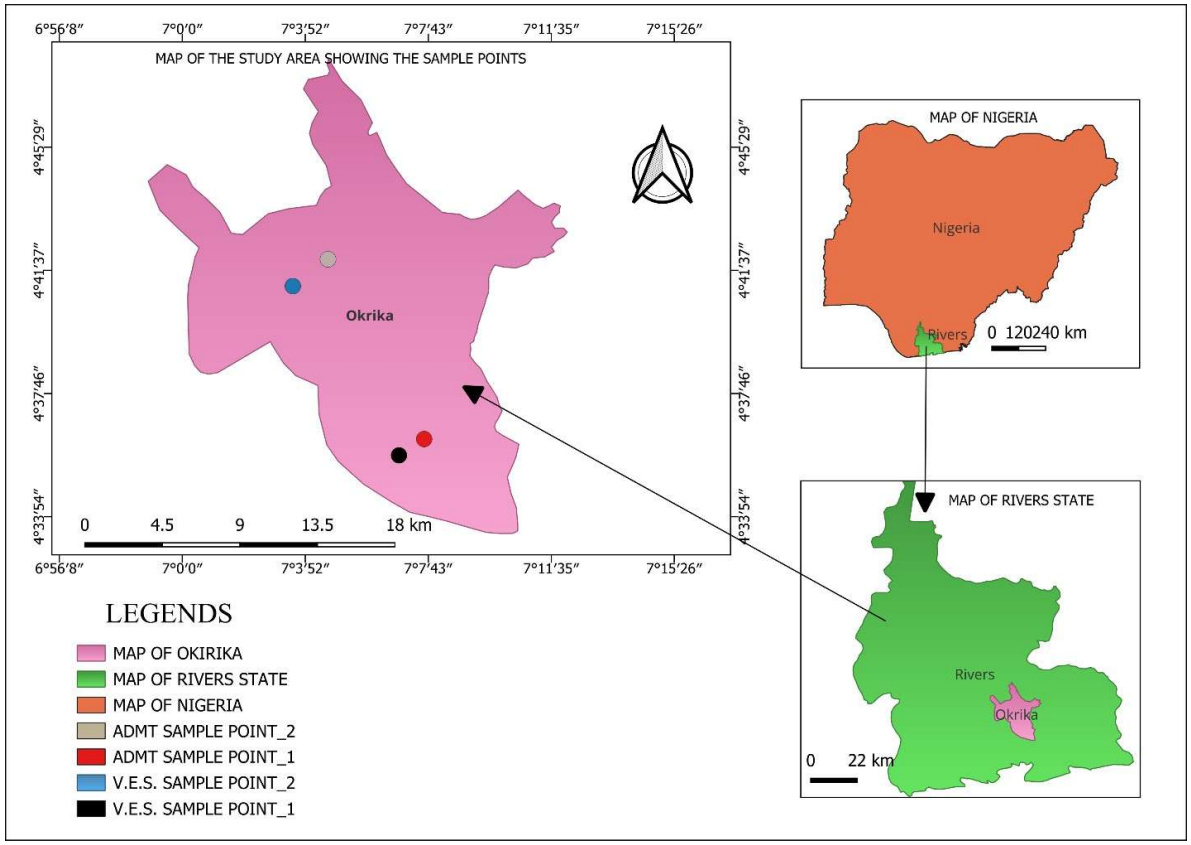


Figure 1: Map of Study Area

2. MATERIALS AND METHODS

Materials: The study employed an integrated geophysical approach involving Vertical Electrical Sounding (VES) and Advanced Digital Magnetic Tomography (ADMT) methods. Equipment used during the investigation included a digital terameters, electrodes, connecting cables, measuring tape, hammer, Global Positioning System (GPS), and supporting software for data acquisition, processing, and interpretation (see Figure 2 & 3 below).

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Figure 2: Digital terameter and software career for subsurface exploration Oghonyon et al., 2026).



Figure 3: Resistivity equipment for subsurface investigation (Okereke, *et al*., 2026). ***Methods:*** The ADMT system was utilized for acquiring digitized resistivity data and generating two-dimensional subsurface images. The technology incorporates automated

inversion and graphical display capabilities, enabling rapid generation of resistivity contour maps and subsurface models. The vertical electrical sounding using the Schlumberger array configuration was carried out by pegging current to the ground through two electrodes (C1 and C2, as shown in Figure 3) and then measuring the resultant potential difference (V) between the potential electrodes (P1 and P2, as shown in Figure 3). The center point of the electrode array remains fixed, but the spacing of the electrodes was increased so as to obtain information about the stratification of the Earth's subsurface (see Figure 3).

Firstly, four electrodes were driven into the ground with the use of hammer. The two electrodes in the middle are potential electrodes (C1 and C2, as shown in Figure 3), the two other electrodes at both ends are called current electrodes P1 and P2 (see Figure 3). Installed cables are connected to both the current and potential electrodes to the terminals (positive and negative) of the terameter, which is positioned adjacent to the center of the arrangement of the electrodes. When the circuit is properly set up and the electrode configuration is found to be alright, the terameter is then switched on to obtain readings, which are referred to as resistance values for each sounding station. The values obtained from the terameter are then seen and read from it. The Schlumberger array, which is often preferred for speed and convenience (Oghonyon *et al*., 2025), was adopted for this study. The midpoint of the array (potential electrodes) was kept fixed in each case while the current electrodes were progressively increased. This is because current lines penetrate increasingly at greater depths just as the current electrode separation is increased (Oghonyon et al., 2025). The Schlumberger array configuration was employed not only because it is faster and less likely to be influenced by lateral variations but also because it requires a lower number of operators (as only the current electrodes C1 and C2 are displaced). Other equipment employed as accessories to the terameter during data acquisition include electrodes, hammer, cables, measuring tape, global positioning system (GPS), and water to moisturize the Earth's subsurface where it is hard and non-

conducting (see Figure 3 below). The raw field data was processed by first of all calculating for the apparent resistivity using the equation (modified from Oghonyon *et al*., 2025):

$$\rho\boldsymbol{a} = \boldsymbol{k} \times \boldsymbol{R} \quad (\mathbf{1})\ Modified\ from\ Oghonyon, et\ al., 2026$$

Where $\rho\boldsymbol{a}$= Apparent Resistivity, $\boldsymbol{k}$=Geometric factor, $\boldsymbol{R}$=Resistance.

But geometric factor $\boldsymbol{k}$, is calculated using the equation (modified from Oghonyon *et al*., 2025):

$$\boldsymbol{k} = \frac{\boldsymbol{\pi}}{\mathbf{4}}\left(\frac{\boldsymbol{L^2 - a^2}}{\boldsymbol{a}}\right) (\mathbf{2})\ Modified\ from\ Oghonyon, et\ al., 2026$$

Where 'L' is the current electrode spacing from A-B (see figure 4) and is calculated using the equation (modified from Oghonyon *et al*., 2025):

$$\boldsymbol{L} = \boldsymbol{AB} \qquad (\mathbf{3})$$

But,

$$\boldsymbol{AB} = \mathbf{2}\boldsymbol{n} \qquad (\mathbf{4})$$

Where 'n' is the half current electrode spacing (AB/2);

'a' is the product of the potential electrodes between A, M, N, and B (see Figure 4).

Mathematically; $\boldsymbol{a} = \boldsymbol{MN}$ (**5**)

But, $\boldsymbol{MN} = \mathbf{2}\boldsymbol{n}$ (**6**)

Where 'n' is the halve, potential electrode spacing (MN/2) that is $n = MN/2$

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Each resistivity value was plotted on the vertical axis against the half-current electrode spacing on the horizontal axis using a log-log graph (Oghonyon & Ogaji, 2026) using resistivity software. These plots, called cross plots, allow initial assessment of curve type (e.g., H or K shape) and layer estimates. 1D VES data acquired at specific intervals along the ADMT profile are converted into depth-resistivity cross-plots. By overlaying these plots onto the 2D tomogram, the tomographic image was calibrated with precise depth values. This dual-validation ensures that the identified resistive zones are not geophysical artifacts but represent actual lithological units like gravelly sand or compact sand for geological interpretation.

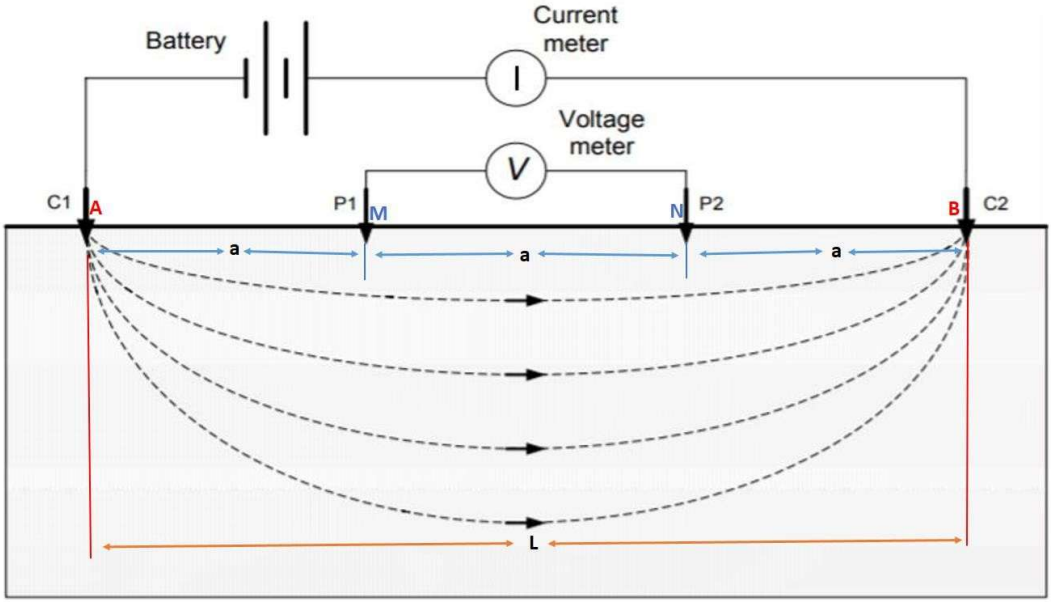


Figure 4: A hypothetical diagram for Schlumberger array configuration (Oghonyon and Juliet, 2026).

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3. RESULTS

The integrated geophysical investigation revealed significant variations in the subsurface resistivity characteristics of the study area. The geoelectrical cross-plot for line 1 (in Figure 5) produced a KH-type curve characterized by alternating resistive and conductive layers. The resistivity pattern indicates the occurrence of competent sand formations separated by more conductive horizons, suggesting varying lithological units within the subsurface.

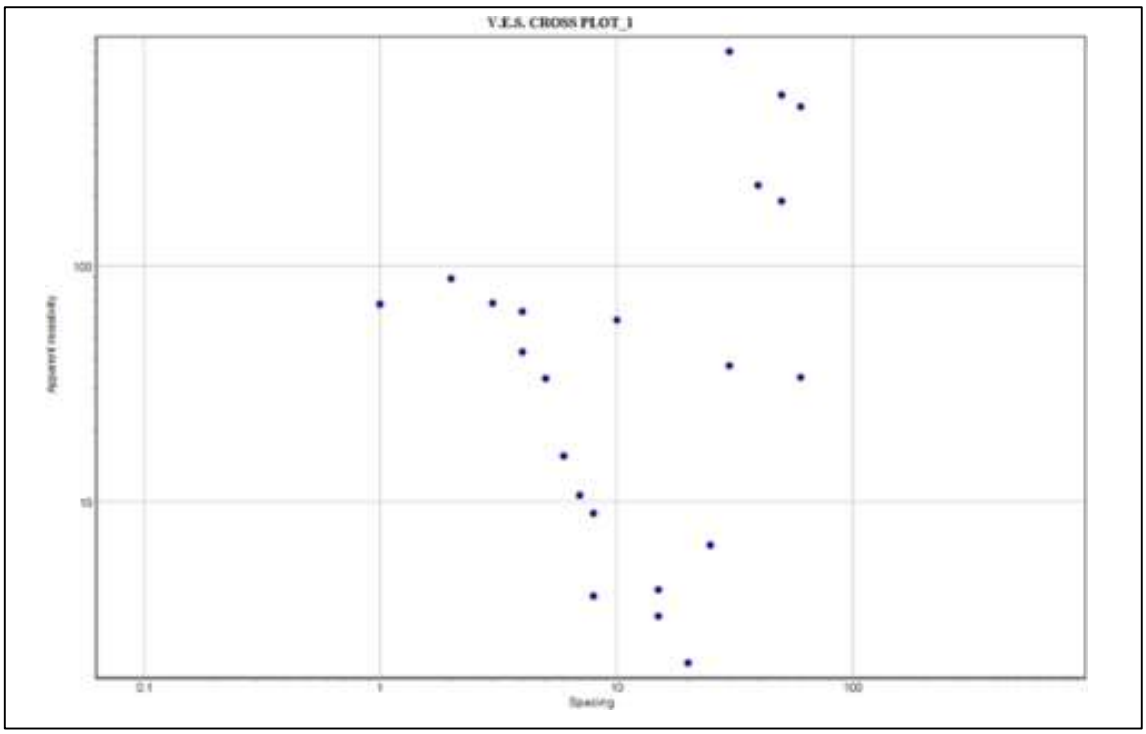


Figure 5: Resistivity cross-plot for line-1

The geoelectrical cross-plot for line 2 (in Figure 6) exhibited an HA-type curve characterized by low-resistivity near-surface materials overlying relatively resistive subsurface layers. This geoelectric behavior suggests the presence of clay-rich surface deposits underlain by compact sand formations with favorable drilling characteristics (Oghonyon *et al*., 2025).

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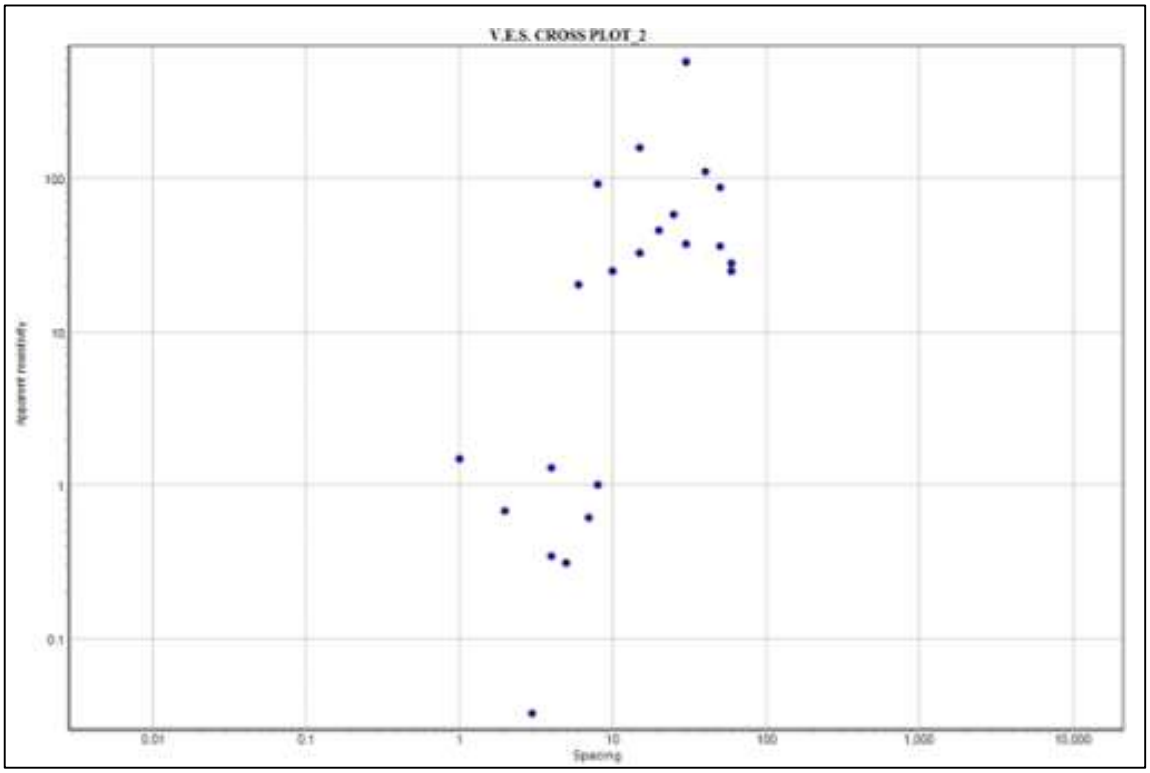


Figure 6: Resistivity cross-plot for line-2

The ADMT resistivity contour maps (in Figure 7 & 8) provided detailed images of the subsurface architecture, suggesting high-resistivity zones with compact sand formations delineated across the profiles, with conductive zones on the models suggesting a porous and permeable geological unit (Oghonyon *et al*., 2026). These formations exhibited varying degrees of continuity and depth distribution across the study area.

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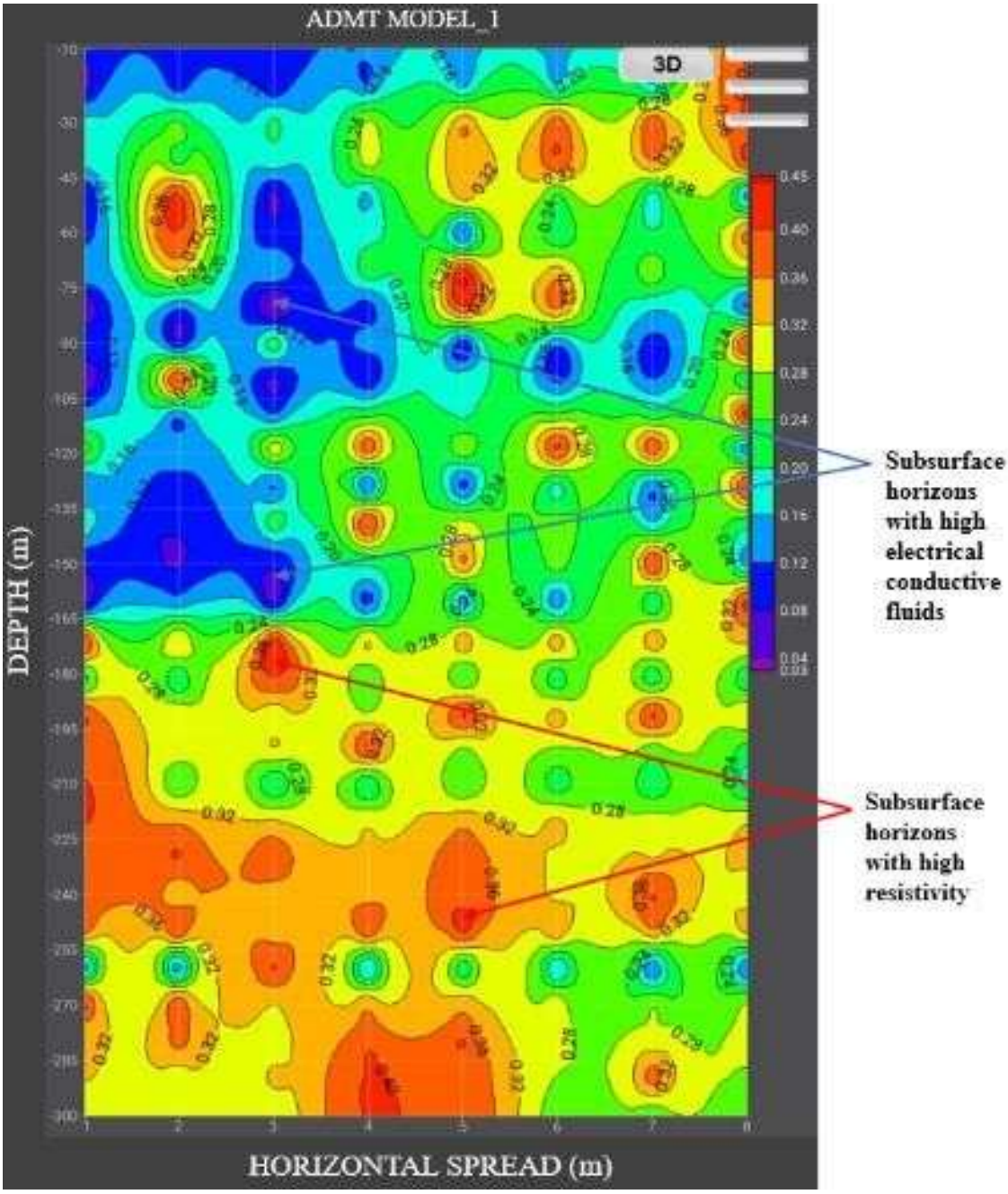


Figure 7: ADMT resistivity contour map for line-1

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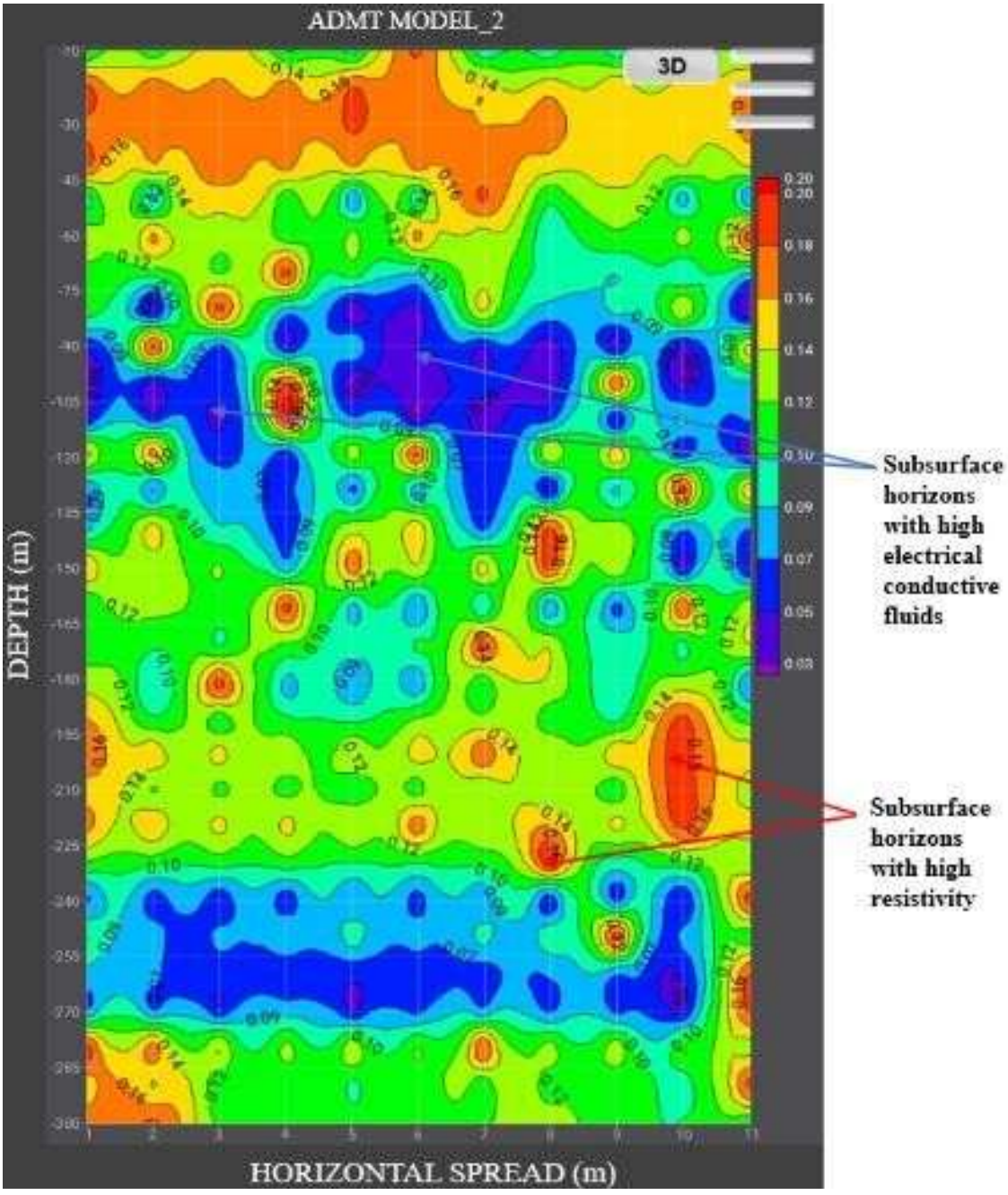


Figure 8: ADMT resistivity contour map for line-2

4. DISCUSSION

The integrated interpretation of VES and ADMT data revealed a complex subsurface environment characterized by alternating resistive and conductive formations. The identified KH-type and HA-type geoelectric responses (as shown in Figures 5 & 6) indicate lithological variability typical of coastal plain sand deposits within the Niger Delta Basin. The observed resistivity contrasts reflect variations in grain size distribution, sediment compaction, moisture content, and clay concentration.

The correlation between the VES results and digitized resistivity sections (in Figure 5…8) demonstrates the effectiveness of combining both methods for geological interpretation. The resistive zones identified across the profiles are relatively compact sand units that constitute porous and permeable layers within the Earth's subsurface, while the conductive horizons suggest clay-rich materials, fluid-saturated formations, and zones of increased pore fluid concentration.

The digitized resistivity models (in Figures 7 & 8) further revealed lateral continuity of several geological units, thereby improving confidence in drilling target delineation and subsurface mapping. The integration of conventional resistivity measurements with digitized resistivity imaging significantly reduced interpretation ambiguities and enhanced the accuracy of geological characterization.

Conclusion: The study demonstrates that geoelectrical cross-plots and digitized resistivity models provide a dependable framework for evaluating drilling prospects and mapping subsurface geological structures. The resulting geological models offer valuable information for future drilling prospects, groundwater exploration, and subsurface investigations within the Niger Delta. This research significantly contributes to regional geological knowledge by validating a dual-method exploration workflow that integrates 1D Vertical Electrical Sounding and 2D Advanced Digital Magnetic Tomography to overcome single-method artifacts in highly

variable environments. By establishing a high-resolution, laterally continuous subsurface model of the Coastal Plain Sands, this paper provides an innovative framework for resolving subtle lateral facies changes and identifying structural boundaries. Ultimately, this work offers a reliable blueprint for future engineering and hydrogeological micro-zonation within the Niger Delta basin, ensuring precise alignment between infrastructure development and complex subsurface conditions.

5. DECLARATIONS:

Ethical Approval: This study did not involve human participants or animal experimentation and therefore did not require formal ethical approval. All procedures involving data handling and analysis were conducted responsibly and in accordance with standard academic and institutional guidelines.

Disclaimer (Artificial Intelligence): Author(s) hereby declare that no generative Artificial Intelligence (AI) technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

Declaration of Conflict of Interest: The authors declare that no known conflict of interest or personal relationships could have influenced the work reported in this paper.

Declaration of Data Availability Statement: Data are available upon request from the second author.

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