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Interpretation of "ERT" Data Using ADMT Method from Industrial Waste Migration into Groundwater Depth in an 'X' Location

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ABSTRACT

This study investigates the subsurface impact of industrial waste migration into groundwater systems using Electrical Resistivity Tomography (ERT) around the Choba Campus, University of Port Harcourt. The area lies within the highly porous and permeable Benin Formation of the Niger Delta, making it susceptible to leachate infiltration. Industrial activities in this region produce poorly managed wastes, which percolate through sandy soils and unconfined aquifers, threatening potable groundwater sources. Using Apparent Diffusion Magnetic Technology (ADMT), a digital resistivity technique, multiple 2D resistivity profiles were acquired to identify zones of contamination. The tomographic sections revealed low resistivity values (<100Ωm), especially within the upper 30 meters of the subsurface consistent with leachate saturation. These anomalies were widespread, suggesting both vertical and lateral migration of contaminants. The hydrogeological setting characterized by sandy loam topsoil, fine-to-medium sands, shallow water tables (1.5–7m), and poor drainage further enhances leachate transport. The resistivity data were corroborated by geological information, showing alignment with porous sandy layers typical of the Benin Formation. The spatial extent and depth of anomalies underline the vulnerability of groundwater in the area. This study confirms ERT's efficacy as a non-invasive environmental monitoring tool for delineating contaminant plumes. The findings emphasize the need for proactive groundwater protection, proper industrial waste management, and potential remediation strategies in industrial-residential interface zones. ERT proves valuable not only for detecting existing pollution but also for guiding future land-use and environmental policy in developing regions facing industrialization pressures.

1. INTRODUCTION

Industrial development has been a cornerstone of economic growth globally, especially in emerging economies where it contributes substantially to employment, gross domestic product (GDP), and technological advancement. However, industrialization also brings with it a wide range of environmental challenges, most notably the improper disposal of industrial waste into the environment. This challenge is more critical in developing countries like Nigeria, where enforcement of environmental regulations is often weak or inconsistent (Akintorinwa and Okoro, 2016). One of the most dangerous and far-reaching

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consequences of industrial waste mismanagement is the pollution of groundwater systems, which serve as a major source of potable water for both urban and rural populations.

Groundwater is one of the most significant freshwater resources available to mankind, especially in regions where surface water is scarce or heavily polluted. In Nigeria, an estimated 60–70% of the population depends on groundwater for drinking and domestic use (Olayinka and Osinowo, 2009). Despite its critical importance, groundwater is increasingly threatened by the migration of contaminants from industrial waste, including heavy metals, hydrocarbons, acids, and toxic organic compounds. These pollutants typically infiltrate through the soil profile, percolating into aquifers and rendering the water unfit for human consumption, agriculture, and other uses. The slow but persistent migration of such contaminants through the subsurface underscores the urgent need for effective monitoring tools.

Industrial activities produce both solid and liquid wastes which, if improperly managed, can become major sources of environmental pollution. These wastes may be directly discharged into open land, unlined pits, or poorly engineered waste containment systems. In many Nigerian cities, the industrial sector is largely concentrated near residential areas with minimal spatial buffer, making the threat of groundwater contamination even more imminent (Ogunbode et al., 2018). Moreover, the geological formations in many parts of Nigeria, including sandstones, gravels, and fractured basement rocks, tend to be porous and permeable, making them highly susceptible to the downward migration of leachate from industrial sites.

Groundwater contamination is typically a slow but cumulative process that begins when pollutants seep into the soil and percolate through unsaturated zones before reaching aquifers. Unlike surface water, contaminated groundwater is not readily observable, making detection difficult until effects manifest in health crises or ecological degradation. According to Fetter (1994), the movement of fluids and contaminants through porous media is governed by Darcy's Law, which emphasizes the importance of permeability and hydraulic gradients. Contaminants are transported via advection, dispersion, and diffusion, and their movement can be influenced by geological heterogeneity, fracture systems, and soil chemistry.

In regions characterized by permeable sediments, such as sandy aquifers or fractured basement rocks, the downward migration of industrial leachates is often faster and more pervasive (Akintola et al., 2020). These contaminants, usually in liquid form, tend to be highly conductive due to their elevated concentrations of dissolved ions such as nitrates, chlorides, sulfates, and heavy metals. As such, they create anomalously low resistivity zones within the subsurface. This relationship between pollutant concentration and electrical resistivity forms the foundational principle behind the application of geoelectrical methods, particularly Electrical Resistivity Tomography (ERT), in environmental monitoring (Binley and Slater, 2020).

ERT has emerged as a powerful geophysical technique for subsurface investigations, especially in environmental and engineering geophysics. It operates on the principle that the electrical resistivity of a given volume of earth varies depending on its moisture content, porosity, mineral composition, and the presence of conductive fluids. In contaminated zones, the infiltration of leachates significantly reduces resistivity values, which can then be captured as anomalies on ERT pseudo-sections

(Reynolds, 2011).

One of the most significant advantages of ERT is its non-invasive nature. It allows for continuous spatial coverage, is relatively inexpensive compared to extensive drilling or laboratory testing, and can be used repeatedly to monitor changes over time. Furthermore, it has proven effective in various hydrogeological settings—ranging from shallow sedimentary environments to complex fractured bedrock systems. According to Loke, Acworth, and Dahlin (2003), ERT profiles can be used to delineate lithological boundaries, identify saturated zones, and monitor the movement of contaminant plumes.

Empirical studies across Africa and other continents provide strong validation for the use of ERT in assessing industrial pollution. In southwestern Nigeria, Adagunodo et al. (2019) used ERT to map the distribution of leachate from an urban dumpsite. Their results revealed a continuous low-resistivity zone, interpreted as a leachate plume, extending to depths beyond 15 meters. This zone corresponded with nearby borehole samples that tested positive for heavy metal contamination, thereby confirming the geophysical interpretation.

Similarly, Akintorinwa and Okoro(2016) applied ERT techniques to monitor leachate migration around a municipal dumpsite in Ondo State. Their findings showed that the contaminated zones had resistivity values as low as 12 Ωm, compared to the background values of 150–250Ωm. These findings were corroborated with hydrochemical analyses, demonstrating high concentrations of nitrates and iron, both indicative of anthropogenic pollution.

Outside Nigeria, Ateba and Njitchoua (2015) conducted a related study in Douala, Cameroon, where they applied ERT to assess the impact of industrial activities on groundwater. The study identified low-resistivity zones up to 20meters deep, which were attributed to leachate infiltration from nearby industries. Chambers et al. (2004) also used ERT to monitor landfill leachate movement in the UK, demonstrating the method's capability in tracing dynamic changes over time.

The success of ERT lies not only in detecting pollution but also in mapping the geometry and depth of contaminant migration. With advancements in inversion algorithms and software like RES2DINV, researchers can now generate detailed 2D and even 3D models of subsurface resistivity. These models enhance the interpretation of complex geophysical signals and allow for the integration of geological and hydrochemical data (LaBrecque et al., 2008).

Despite its advantages, ERT is not without limitations. One major challenge is the ambiguity in interpretation due to overlapping resistivity values among different materials. For instance, a clay-rich layer can exhibit low resistivity values similar to those of contaminated zones. Similarly, saline intrusion in coastal areas may mimic the resistivity signatures of industrial waste (Olayinka and Osinowo, 2009). To overcome these challenges, researchers advocate for the integration of ERT with other methods such as borehole logging, water sampling, and hydrochemical analysis to provide validation and improve interpretation accuracy (Abiola et al., 2020).

2. GEOLOGY OF THE STUDY

The study area lies within the Niger Delta Basin, specifically within the Benin Formation, which is part of the Tertiary Niger Delta sequence as seen in Figure 1 below. The Benin Formation is predominantly composed of coarse to medium-grained sandstones as seen in the table below in Table 1, with occasional lenses of shale and clay. This formation is known for its high porosity and permeability, making it an excellent aquifer but also increasing its susceptibility to pollution (Short and Stauble, 1967) seen in Table 2.

According to Reyment (1965), the Niger Delta sequence is made up of three major stratigraphic units:

Akata Formation (deep marine clays, shales – base)

Agbada Formation (alternating sand and shale – middle)

Benin Formation (continental sands – top)

Choba specifically sits within the Benin Formation, which can reach depths of over 2,000 m in some areas. The upper parts of this formation consist of unconsolidated sands and gravels, which allow for rapid infiltration and horizontal movement of fluids, including contaminants. These geologic conditions enhance the risk of leachate migration from surface waste deposits into shallow aquifers used for domestic and agricultural water supply (Ehirim et al., 2009).

Figure 1: The Geologic Map of the Study Area

Due to these geological conditions, the use of Electrical Resistivity Tomography (ERT) is highly suitable for detecting leachate zones, as variations in lithology and saturation directly affect resistivity values.

Table 1: The lithological characteristics of the study area

Topsoil	**Mostly sandy loam**
Subsurface	Dominated by fine-to-medium-grained sands, some lateritic clay lense
Depth to Water Table	Ranges between 1.5m to 7m depending on season and location

Table 2: The Summary of Environmental Sensitivity Parameter Condition in the Study Area

Soil type	**Sandy, porous, permeable**
Aquifer type	Unconfined shallow aquifer
Vulnerability	High
Vegetation	Secondary Forest, grasses
Drainage	Seasonal streams, poor surface run-off
Population pressure	High
Geology	Benin Formation – porous, sandy

3. METHODOLOGY

This study employs a non-invasive geophysical technique the Digital Resistivity Method using Apparent Diffusion Magnetic Technology (ADMT) to investigate the extent of leachate percolation and its interaction with the groundwater system around the Choba Campus of the University of Port Harcourt. The method is complemented by field reconnaissance and geospatial referencing to enhance interpretation and ensure accurate mapping of subsurface features. It is a new method digitally based and neither created nor introduced by the authors. It is the method implored for the accomplishment of this research.

A preliminary field reconnaissance was conducted to identify potential dumpsites, locate groundwater sources (boreholes and hand-dug wells), and determine suitable locations for geophysical survey lines. This stage involved physical observation, interaction with residents and campus staff, and the use of a GPS device to map out the coordinates of interest points. The survey helped define zones suspected of leachate infiltration based on visible waste accumulation, waterlogging, and proximity to residential or utility boreholes.

It is a digital resistivity-based technique that relies on low-frequency electromagnetic (EM) field measurements to estimate variations in apparent resistivity and related geoelectric parameters in the subsurface. The instrument, which includes a main data collector and signal-receiving electrodes, automatically scans a specified area by emitting and detecting electromagnetic signals that interact with subsurface structures. The ADMT method is widely recognized for its portability, speed, and depth penetration, often ranging from 0 to 300 meters depending on the geological conditions and model used.

The instrument used in this study is equipped with a digital display interface and is capable of real-time resistivity profiling, enabling easy detection of anomalies linked to moisture content, salinity, and contaminant presence, all of which are common characteristics of leachate plumes.

Electrode Configuration: The ADMT device does not require traditional electrode spreading like conventional vertical electrical sounding (VES). Instead, it utilizes sensor probes or coils placed at marked points across the survey line to collect resistivity data.

Line layout is a multiple survey lines were established across the Choba Campus and around visible dumpsites or suspected zones of contamination. Each line was laid out with a length between 50 to 150 meters, depending on site accessibility. The instrument was moved systematically along each line with readings taken at regular interval.

Data collection at each station, the ADMT system recorded apparent resistivity, depth, and coordinate location. The device's internal GPS aided in geo-referencing each point automatically.

Depth range Is the measurements were taken up to a maximum depth of 100 meters, capturing both the unsaturated and saturated zones of the subsurface, which are critical in leachate transport analysis.

Environmental Conditions: Data collection was primarily done during the dry season to minimize interference from surface water and to better capture resistivity contrast between dry and wet subsurface zone.

The resistivity data acquired from the ADMT instrument were downloaded and processed using its proprietary interpretation software.

4. RESULTS

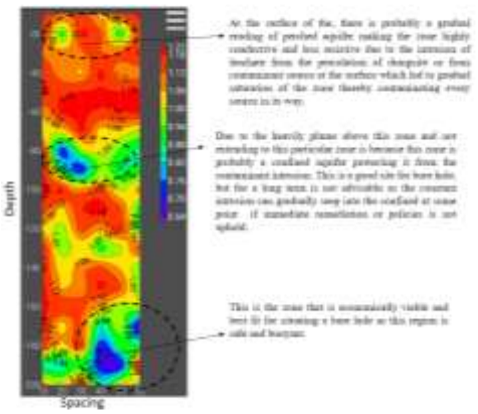

Figure 2: The 2D Tomogram of the study area line 1

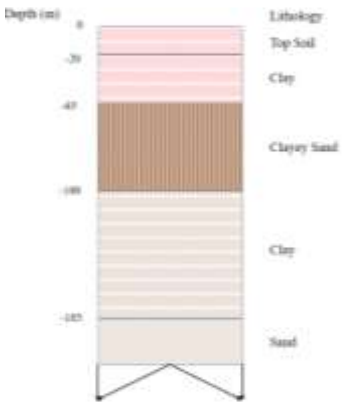

Figure 3: The Geoelectric Section of The 2D Tomogram Line 1

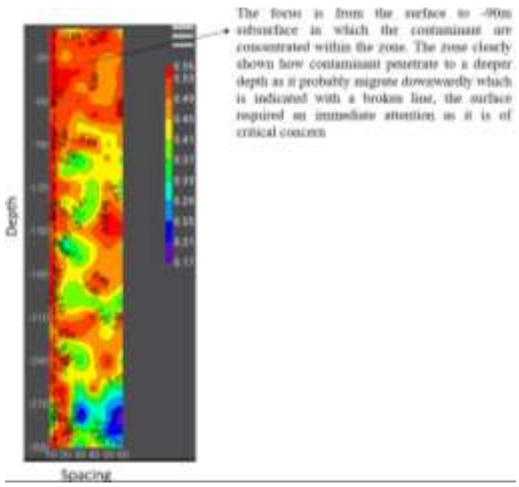

Figure 4: The 2D Tomogram of the study area line 2

5. DISCUSSION

The Electrical Resistivity Tomography (ERT) survey conducted across two distinct lines in the Choba area yielded critical geophysical insight into the extent of industrial leachate infiltration. Both the 2D tomograms and the inverted geoelectric sections generated from the ADMT system form the backbone of the interpretative analysis, helping to delineate zones of subsurface contamination.

The 2D resistivity tomogram for line 1 in Figure 2 and Geoelectric Section in Figure 3, the 2D resistivity tomogram of Line 1 shows a variation in subsurface resistivity ranging from less than 30Ωm to over 500Ωm, where the low resistivity zones (< 100Ωm) are dominant in the shallow subsurface (0–20m depth) and some discontinuous pockets extending deeper (20–40m).

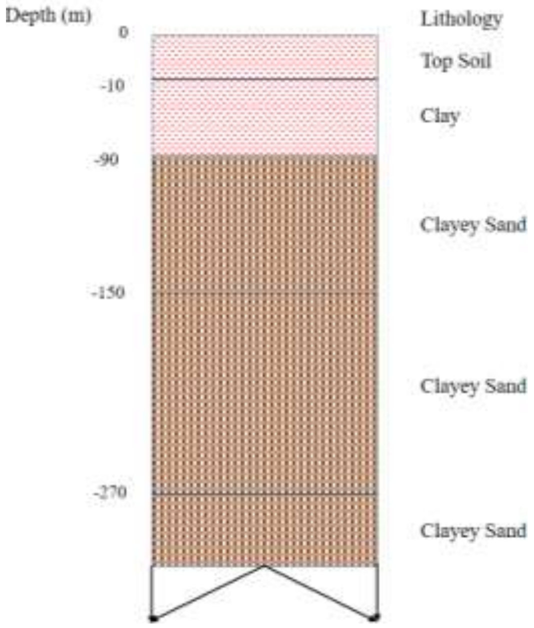

Figure 5: The Geoelectric Section of The 2D Tomogram Line 2

These low-resistivity anomalies are indicative of moisture saturation and high ionic content, typically associated with industrial leachate or contaminated zones (Binley and Slater, 2020).

The presence of low resistivity in zones that correspond to sandy and gravelly subsurface layers of the Benin Formation suggests enhanced porosity and permeability, which facilitate downward leachate migration.

The moderately resistive zones (100–250Ωm) are interpreted as less contaminated or weakly saturated layers, possibly acting as semi-permeable boundaries or transition zones.

High resistivity zones (> 300Ωm) at depth are inferred to be dry sands or compacted lateritic layers, offering some resistance to further migration but not acting as complete barriers due to their discontinuity.

The spatial spread of contamination suggests that the industrial effluents have not only percolated vertically but may also be migrating laterally following subsurface flow gradients. The most vulnerable zones are within the top 30 meters, which corresponds to the depth range of the unconfined aquifer system used by the local population (Ehirim et al., 2009).

The 2D tomogram for line 2 in Figure 4 and Geoelectric Section (Figure 5) confirm and strengthen the interpretation from Line 1.

Widespread zones of extremely low resistivity (< 50Ωm) dominate the central and right flanks of the section from the surface to depths of about 25–35meters. These areas are interpreted as zones of intense contamination likely resulting from nearby surface waste deposits and possibly fault-enhanced vertical pathways.

The resistivity layering shows a near-surface sandy loam (topsoil) underlain by more saturated fine sands, matching the known lithology of the Benin Formation (Short and Stauble, 1967). The continuity of the low resistivity zone across several meters laterally indicates a broad contaminant plume, likely sustained by continuous waste discharge and poor drainage.

The unconfined nature of the aquifer coupled with high permeability soils (Table 2) greatly increases the susceptibility of the water table to contamination.

These findings corroborate reports by residents on changes in borehole water quality (taste, odor, and color), affirming a strong link between industrial activity and groundwater pollution.

The resistivity anomaly patterns across both lines depict a characteristic contamination model, where conductive leachate infiltrates through permeable sandy layers, especially in areas where natural vegetation has been removed, and waste has accumulated.

Based on the depth to water table (1.5-7m) and the depth range of the anomalies (up to 30–35m), the plumes have likely infiltrated through the vadose zone into the saturated aquifer.

The geoelectric sections reflect multi-layered subsurface conditions, with zones of concentrated contamination representing prime targets for groundwater remediation or alternative water sourcing.

Soil Type Sandy, porous — facilitates contaminant transport

Aquifer Type Unconfined — directly exposed to contamination

Drainage Poor runoff — increases infiltration time of leachates

Geology (Benin Formation) Highly porous and permeable — favors rapid contaminant flow

Vegetation loss Exposes soil to surface

waste and enhances downward percolation

The resistivity data interpreted from both 2D tomograms and geoelectric sections strongly indicate the presence of industrial leachate contamination in the shallow subsurface, affecting the aquifer system within the Choba area. The spatial continuity and resistivity signatures confirm that contaminants have penetrated to significant depths, posing risks to groundwater safety. The use of ERT has successfully mapped both vertical and lateral migration patterns of industrial waste, reinforcing its relevance in environmental monitoring and groundwater protection in vulnerable industrial settings.

This study directly addressed previously highlighted gaps by adopting a high-resolution, digital ERT method (ADMT) and multi-line tomography, which revealed both vertical and lateral migration of contaminants. Unlike prior studies that used conventional VES or limited single-line ERT, our work provided a detailed spatial model integrating geology and geoelectric data, thus improving interpretation accuracy. These findings align with recent advances in similar studies (Mohammed and Abubakar, 2021; Ogungbemi et al., 2022; Akinlalu and Adewumi, 2023; Dalas et al., 2024), which demonstrate the value of detailed tomographic imaging and digital tools for monitoring leachate impact on groundwater.

6. CONCLUSION

The study concludes that there is clear geophysical evidence of industrial waste infiltration into the shallow aquifer system in the study area and the Benin Formation, being highly permeable, has facilitated both vertical and lateral migration of leachates into groundwater-bearing zones.

Zones of very low resistivity identified on the 2D tomograms and geoelectric sections are consistent with regions impacted by industrial contamination and the risk to potable water supply is high, particularly in areas closest to industrial waste deposits and open dumping sites.

The use of ERT proved effective in mapping subsurface anomalies without the need for invasive drilling, highlighting its suitability for environmental monitoring in urban and industrial regions.

Conflicts of interest

All the financial relevance influencing the research procedure entirely from the Authors with no outsider aside the authors.

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REFERENCES

Abiola, O., Afolabi, A. S., and Olorunfemi, M. O. (2020). Application of Geoelectric Method in Mapping Subsurface Contaminant Migration. Nigerian Journal of Geophysics, 16(2), 12–19.

Adagunodo, T. A., Sunmonu, L. A., and Akinwumi, S. A. (2019). Electrical Resistivity Imaging for Leachate Plume Delineation around a Dumpsite in Ibadan, Nigeria. Environmental Monitoring and Assessment.

Afolabi, A. S., Omonona, O. V., and Olorunfemi, M. O. (2015). Application of Geoelectric Method in Mapping Subsurface Contaminant Migration. Nigerian Journal of Geophysics, 16(2), 12–19.

Akinlalu, A. A., and Adewumi, O. T. (2023). Geophysical imaging of leachate migration using 2D ERT and inversion models in Lagos, Nigeria. Environmental Earth Sciences, 82, 431.

Akintola, A. I., Ojo, J. S., and Ogunleye, P. O. (2020). Mapping Groundwater Contamination Using ERT in Ogun State, Nigeria. African Journal of Environmental Science.

Akintorinwa, O. J., and Okoro, O. (2016). Geophysical Investigation of Leachate Migration Around a Dumpsite in Ondo State. Nigerian Journal of Physics, 27(1), 45–54.

Ateba, B., and Njitchoua, R. (2015). Electrical Resistivity Tomography Investigation of Groundwater Contamination in Douala, Cameroon. African Earth Sciences Journal.

Binley, A., and Slater, L. D. (2020). Resistivity and Induced Polarization: Theory and Applications to the Near-Surface Earth. Cambridge University Press.

Chambers, J. E., et al. (2004). Hydrogeophysical Monitoring of a Managed Aquifer Recharge Scheme Using Electrical Resistivity Tomography. Journal of Hydrology.

Dalas, E., et al. (2024). Advancements in ERT monitoring of industrial waste in coastal aquifers. Journal of Hydrology, 636, 129721.

Ehirim, C. N., and Ebeniro, J. O. (2010). Electrical resistivity imaging of contaminant leachate migration at a waste disposal site in Port Harcourt, Nigeria. Environmental Research Journal, 4(4), 281–285.

Ehirim, C. N., Eke, J. O., and Nwankwo, C. N. (2009). Application of the Electrical Resistivity Method in the Investigation of Subsurface Contamination at Municipal Solid Waste Dumpsites in Port Harcourt, Nigeria. Pacific Journal of Science and Technology, 10(1), 604–613.

Fetter, C. W. (1994). Applied Hydrogeology (4th ed.). Prentice Hall.

Iloeje, N. P. (1981). A New Geography of Nigeria. Longman.

LaBrecque, D. J., et al. (2008). Time-Lapse Electrical Resistivity Tomography for Imaging Subsurface Contamination. Journal of Environmental and Engineering Geophysics.

Loke, M. H., Acworth, R. I., and Dahlin, T. (2003). A Comparison of Smooth and Blocky Inversion Methods in 2D Electrical Imaging Surveys. Exploration Geophysics, 34(3), 182–187.

Mohammed, A., and Abubakar, A. (2021). Electrical resistivity tomography for assessing landfill leachate impact on groundwater in Abuja, Nigeria. Journal of African Earth Sciences, 175, 104108.

Ogunbode, E. B., Akinyemi, L. P., and Adebayo, K. O. (2018). Urban Waste Disposal and its Environmental Impact: A Case Study of Southwestern Nigeria. Journal of Environmental Management and Safety, 9(1), 120–135.

Ogungbemi, O., Ayolabi, E. A., and Sanuade, O. A. (2022). Integration of ERT and hydrochemical analysis in detecting contaminant plumes in southwestern Nigeria. Environmental Monitoring and Assessment, 194(2), 152.

Olayinka, A. I., and Osinowo, O. O. (2009). Evaluation of Groundwater Contamination Using Geoelectrical and Hydrochemical Methods at a Landfill Site in Ibadan, SW Nigeria. Journal of Environmental Geology, 56(1), 145–156.

Reyment, R. A. (1965). Aspects of the Geology of Nigeria. Ibadan University Press.

Reynolds, J. M. (2011). An Introduction to Applied and Environmental Geophysics (2nd ed.). Wiley-Blackwell.

Short, K. C., and Stauble, A. J. (1967). Outline of the Geology of the Niger Delta. AAPG Bulletin, 51(5), 761–779.