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*Original Article*

# A Geophysical Frontier for Investigating Aquifer Depth Variations Caused by Santonia Deformational Event in Umuoha, Umuoma Nzerem Autonomous Community, Ehime Mbano L.G.A, Imo State, Nigeria

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**ABSTRACT:** *This study investigates the subsurface characteristics of Umuoha Village, Umuoma Nzerem, located in Ehime-Mbano Local Government Area of Imo State, with emphasis on the geological factors influencing aquifer quality and distribution. Drilling observations and geoelectrical interpretations revealed the dominance of shale-rich, cemented sandstone formations that produced cement-like, powdery cuttings. This behaviour is linked to natural diagenetic cementation and compaction processes rather than anthropogenic contamination. The lithified layers are interpreted as products of tectonic deformation and post-depositional alteration associated with the Santonian orogeny, which profoundly reshaped the region's structural and stratigraphic architecture. The formations encountered reflect alternating shale and sandstone units with varying degrees of cementation, resulting in heterogeneous aquifer conditions. Shale units act as aquitards, restricting vertical groundwater movement, while interbedded sandstone layers provide moderate aquifer potential. The structural complexity created by the Santonian deformation further influences fluid flow, groundwater storage, and aquifer vulnerability. These findings highlight the importance of understanding tectono-sedimentary controls on groundwater occurrence in southeastern Nigeria. Effective groundwater development in the area will require careful borehole siting, consideration of cemented zones, and integrated geological–geophysical characterization to avoid low-yielding horizons and ensure a sustainable water supply.*

**KEYWORDS:** *Nzerem, Santonian deformation, Cementation, Shale formation, Aquifer vulnerability, Diagenesis, Hydrogeology.*

## 1. INTRODUCTION

Groundwater exploration and development in Nzerem, located within Ehime-Mbano Local Government Area of Imo State, require a sound understanding of the underlying geological framework and its tectonic history. This part of southeastern Nigeria falls within the transition zone between the Anambra Basin and the Benue Trough, an area that has been profoundly shaped by the Santonian orogeny of the Late Cretaceous period. This tectonic event not only reconfigured the regional structural framework but also influenced sedimentation, compaction, and fluid migration patterns (Murat, 1972; Hoque, 1977).

Increasing demands are being placed on the water resources of Umuoha Village, Umuoma Nzerem Autonomous Community, Ehime Mbano L.G.A, Imo State, Nigeria, due to its expanding population, especially in towns and villages. Proper management, development, and use of fresh water in these areas are necessary to prevent heavy metal contamination of existing water supplies. Understanding the effect of the Santonian deformation is crucial, as it controls the lithologic characteristics encountered during drilling, particularly the presence of shale-rich, cemented layers that produce powdery, cement-like cuttings. These lithified formations are geological rather than anthropogenic in origin and strongly affect groundwater occurrence, flow dynamics, and aquifer productivity (Reyment, 1965; Nwachukwu, 1972).

Sound management decisions can be made best when based on available information, such as geophysical investigations of subsurface soil layers; therefore, it is desirable to gather as much data as is economically reasonable to support these decisions. However, groundwater everywhere in the world exists in the subsurface geologic material known as an aquifer. Since it exists below the earth's surface and is not visible to anybody, its occurrence, movement, flow direction and other attributes are poorly understood by most people. Consequently, rapid urban expansion has often increased the risk to groundwater quality in recharge areas. Over the past several decades, climate change has led to increasingly unpredictable rainfall events. This generally affects groundwater recharge quality and quantity negatively and controls available surface water.

Leachate, a highly conductive liquid formed during the decomposition of organic and inorganic waste, is a major environmental concern due to its potential to contaminate soil and groundwater resources. In academic institutions like the University of Port Harcourt, located in the Niger Delta region of Nigeria, high waste generation from student activities, coupled with inadequate waste management practices, exacerbates the risk of leachate infiltration (Rorome, O. et al, 2025)

All these pose enormous challenges and threaten groundwater, thereby affecting the continued provision of adequate and safe potable water for present and future generations everywhere on the planet. Imo State is not excluded from such negative impacts. The geophysical mapping and delineation of aquifers in Umuoha Village, Umuoma Nzerem Autonomous Community, Ehime Mbano L.G.A, at a time like this, has therefore become necessary to ensure adequate planning for continued domestic activities through the sustainability of groundwater. It is anticipated that this process will bring about unprecedented economic progress and a continued supply of safe potable water now and in the future.

### *1.1. GEOLOGIC SETTING AND HYDROGEOLOGY OF THE AREA*

The geologic framework of Nzerem is rooted in the tectono-sedimentary evolution of southeastern Nigeria, particularly during and after the Santonian orogenic phase. Prior to the Santonian, the region was part of a stable passive margin influenced by extensive sedimentation within the Benue Trough. However, during the Santonian (approx. 84Ma), compressional forces caused intense folding, faulting, uplift, and regional deformation of the Benue Trough sediments (Murat, 1972; Hoque, 1977). This event led to the inversion of the trough, the creation of structural highs, and the development of the adjacent Anambra foreland basin.

Subsequent erosion of uplifted terrain during and after the deformation resulted in the deposition of thick fluvial–deltaic sandstones, including the Ajali Sandstone, unconformably overlying the older Cretaceous sequences. These sandstones are generally well-sorted, quartz-rich, and laterally extensive, making them key aquifer units. However, tectonic uplift and post-depositional diagenesis have locally cemented some of these sands, reducing permeability and making them appear as compacted, cement-like formations during drilling (Hoque, 1977; Reyment, 1965).

Interbedded with the sandstones are shale-rich layers that were compacted during burial and tectonic loading. These act as aquitards, restricting vertical groundwater movement but also defining the geometry and productivity of underlying aquifers. The effects of the Santonian deformation are still evident in subtle structural features such as gentle folding and faulting, which influence fluid pathways, aquifer connectivity, and groundwater vulnerability in the area (Nwachukwu, 1972; Murat, 1972).

Overall, the geologic setting of Nzerem reflects a dynamic tectono-sedimentary history in which Santonian deformation played a central role in shaping the lithology, structure, and hydrogeological properties of the subsurface. The Umuoha Village, Umuoma Nzerem Autonomous Community, Ehime Mbano L.G.A., is made up of two geological formations: the Ogwashi–Asaba and the Benin formations, which were formerly known as Coastal Plain Sands. Ogwashi – Asaba formation is characterized by alternation of clays and sands, grits, and lignites. The formation occurs mainly in Asaba, Benin, Onitsha and Owerri Areas. Reyment suggested an Oligocene –Miocene age for this formation. In the Benin formation, the sands and sandstones are coarse to fine-grained and commonly granular. The formation consists of friable sand with intercalations of shale and clay lenses, which occur occasionally at some depths.

The formation is partly estuarine, partly lagoon, partly deltaic, and partly fluvid-lacustrine in Origin. The sands and sandstone in this formation are coarse-grained, very granular, pebbly to very fine-grained. They are either white or yellowish-brown. Hematite grains and feldspars are also obtained. The shale is greyish to brown, sandy to silty, and contains some plant remains and dispersed lignites. The formation has an average thickness of 600ft (196.85m). Benin formation is continental in origin and accurately represents the delta plain facies. The two formations are known to have reliable groundwater that could sustain borehole production. The high permeability of the Coastal Plain Sands, the overlying lateritic earth, and the weathered top of this formation provide the hydraulic conditions that favour the formation of an aquifer in Umuoha Village. The copious rainfall that prevails in the area makes the aquifer prolific and continuously provides groundwater recharge. It is indeed an excellent source of groundwater reserve.

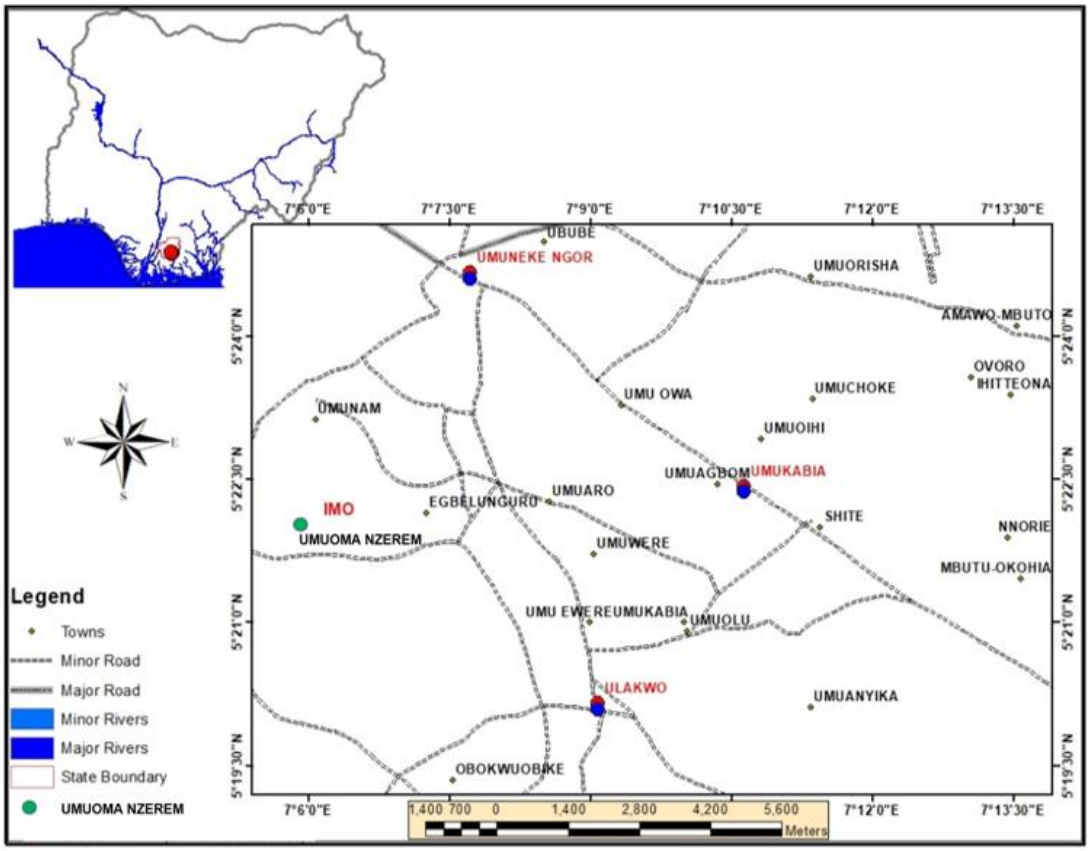


**FIGURE 1 Geologic map of the study area**

## 2. METHODOLOGY

The work involves the use of the electrical resistivity method (Figures 2, 3, and 4) in exploring for freshwater formations for borehole drilling and to evaluate suitable depths within the subsurface layers where freshwater zones occur. The instrument is connected to the APP through the built-in Bluetooth, so use the APP to realize all the operations of the instrument, such as measurement signal input, data checking and processing. Using a wireless sensor probe, complete all measurements by simply walking and stopping. No need for a long cable, saving time and manpower. Many innovative designs have made the instruments more intelligent, efficient, and accurate, resulting in dozens of invention patents.

ADMT series products are a new generation of intelligent prospecting instruments designed by AIDU and Guilin Technology Hydrogeological Investigation Institute. Based on more than 4 decades of R&D experiences, we use a mobile phone or tablet PC to run the complicated data calculation to realize the quick calculation inversion and rapid graph drawing. Then we can quickly draw 2D/3D profile maps, contour maps, and curve diagrams using an app. This is a leap in technology because it makes the complicated geophysical survey becomes easier and simpler. With the APP, one can use many intelligent functions, such as field measurement control, instant data processing, data cloud backup, online expert analysis, and Bluetooth data transfer.

### *2.1. MAIN FEATURES*

The main features include:

1. Instant Mapping: Directly drawing the 2D/3D map using the APP after data collection
2. Simple Operation: Walking and stopping to complete the measurement, so easy.
3. Efficiency: Unique wireless prospecting tech lets one person complete all work, saving time and manpower.
4. Precision: Strong anti-interference ability, field source correction and patent tech to process data.

**FIGURE 2 A digital terrameter for groundwater exploration**


**FIGURE 3 A pool finder plus for groundwater exploration**

**FIGURE 4 Groundwater resistivity meter**

## 3. RESULTS AND DISCUSSION

The subsurface formation at Nzerem shows a distinctive response during drilling, characterized by cement-like dust and shale fragments, indicating a geological control rather than anthropogenic influence. This suggests the presence of lithified or compacted strata, likely associated with diagenetic cementation within the alternating sand and shale sequences of the Ogwashi–Asaba Formation and Benin Formation. The shale-rich intervals are known to compact significantly over time, often producing fine, powdery cuttings when penetrated by drilling tools. Unlike loose aquifer sands, such lithified layers reflect reduced porosity and permeability, which are typical of older, more consolidated geological units.

The approach used is similar to an investigation and methodology carried out by Rorome et al (2024). The cement-like dust encountered is therefore a result of natural geological processes such as compaction, pressure solution, and mineral cementation (e.g., silica, calcite, or ferruginous cement), rather than surface contamination or human activity. This diagenetic process is common at shallow to intermediate depths in the Ogwashi–Asaba and Benin formations, where sand–shale intercalations have undergone varying degrees of lithification. The alternating lithologies create heterogeneous hydrogeological conditions, with permeable sandy zones serving as aquifers and compacted shale or cemented sandstone intervals acting as aquitards or confining units.

This geologic behavior is consistent with the tectono-sedimentary history of southeastern Nigeria, which has experienced several cycles of uplift, subsidence, and sediment loading. Over time, these processes increase compaction and drive pore-fluid expulsion, further enhancing cementation. As a result, drilling through these formations produces characteristic fine, dusty cuttings rather than clean, coarse sand associated with productive aquifers. This is not indicative of contamination or external influence but reflects inherent geotechnical properties of the formations.

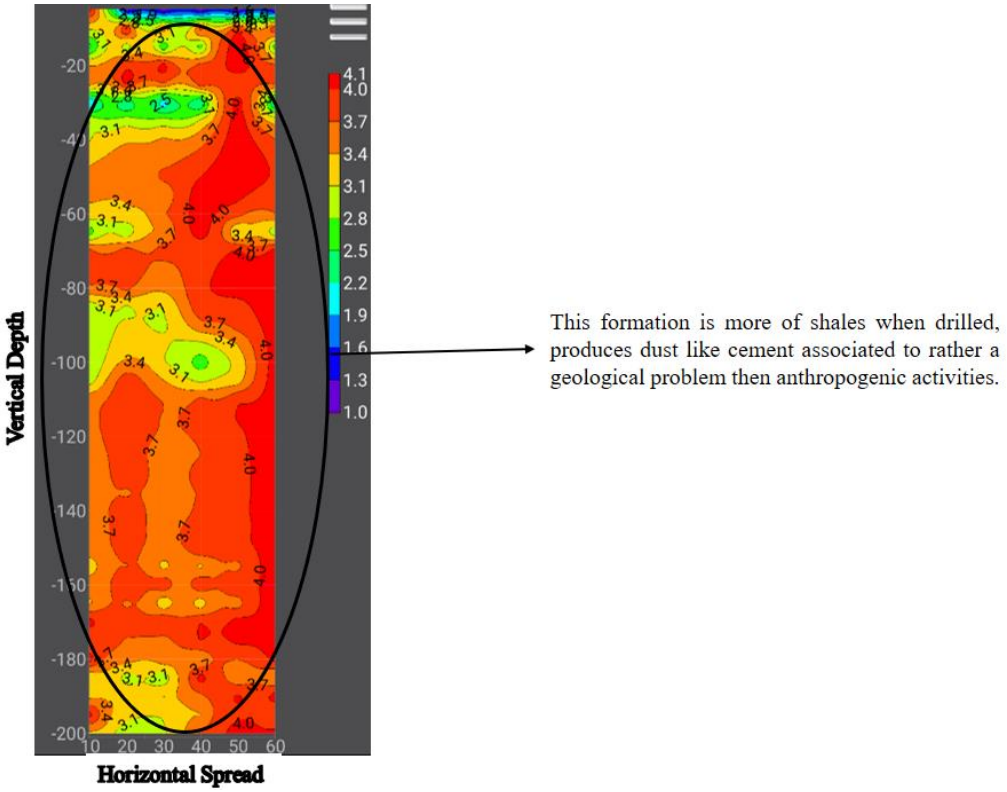


**FIGURE 5 The ERT subsurface image of Umoha Nzerem**

## 4. SUMMARY AND CONCLUSION

The ERT data and drilling behavior indicate a subsurface dominated by shale and cemented sandstone intervals. The powdery, cement-like cuttings encountered during drilling are due to natural lithification and compaction of the Ogwashi–Asaba and Benin formations. These layers exhibit low porosity and permeability and are part of the natural geologic framework rather than anthropogenic contamination.

In conclusions;

1. The cement-like dust observed during drilling is a geological indicator of shale-rich, compacted, or cemented formations.
2. This is caused by natural diagenetic processes, not human activities.
3. Such intervals may act as aquitards, while underlying or interbedded sand layers may host aquifers.
4. Understanding these geological characteristics is crucial for proper borehole design and groundwater resource development.

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