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An Integration Of Geophysical Attributes For Evaluating The Santonia Effects On Aquifer Bed Units In Umuoma Nzerem Community, Imo State, Nigeria

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Abstract: This study evaluates the impact of the Santonian orogeny on aquifer characteristics in Umuoma Nzerem, Imo State, Nigeria. The area lies within the transitional zone between the Anambra Basin and Benue Trough, where tectonic deformation during the Santonian event resulted in structural reconfiguration and diagenetic cementation of the Ajali Sandstone. Electrical resistivity surveys were conducted to characterize aquifer properties and identify suitable drilling zones. Field observations revealed cement-like dust from shallow to deeper drilling intervals, indicative of lithified or over-compacted formations rather than anthropogenic contamination. These diagenetically cemented zones reduce aquifer porosity and permeability, limiting groundwater storage and flow. Results highlight significant geological control on aquifer productivity and variability, controlled by tectonic deformation and diagenesis. Identifying unconsolidated sandstone intervals is crucial for sustainable groundwater abstraction. The study concludes that cementation linked to the Santonian deformation event is a major hydrogeological constraint in the area. Targeted drilling in structurally favorable zones is recommended to enhance borehole success rates and optimize groundwater resource development.

Keywords: Santonian orogeny, Cementation, Groundwater exploration, Umuoma Nzerem, Aquifer characterization.

Introduction

Increasing demands are being made on the water resources of Umuoma Nzerem Autonomous Community, Imo State, Nigeria, because of 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. Sound management decisions can be made best when based on available information such as Geophysical investigation of the subsurface soil layers; therefore, it is desirable to gather as much data as it is economically reasonable to support these decisions.

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 (Oghonyon et al. 2025).

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However, profitable groundwater everywhere in the world exists in the sub-surface geologic material known as 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 resulted in increased risk to groundwater quality in areas of recharge. In the past several decades, climate change has resulted in unpredictable rainfall events. This generally affects groundwater recharge quality and quantity negatively and controls available surface water.

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

Superimposed on these stratigraphic units are structural features such as folds, fractures, and minor faults associated with the Santonian uplift, which exert strong control on fluid movement and sedimentary thickness variations. Post-deformation diagenetic processes particularly silica, calcite, and ferruginous cementation have further altered the original fabric of the sandstone, creating hard, over-compacted zones that often appear as cement-like dust during drilling. This condition is geological rather than anthropogenic, reflecting deep-seated tectonic and burial histories rather than surface contamination or land-use impacts.

Geologic Setting and Hydrogeology of the Area

Umuoma Nzerem Autonomous Community, Ehime Mbano L.G.A is made up of two geological formations (Figure 1), the Ogwashi– Asaba and the Benin formation which was formerly known as Coastal Plain Sands. Ogwashi – Asaba formation is characterized by alternation of clays and sands and grits and lignites. The formation occurs mainly in Asaba, Benin, Onitsha and Owerri Areas. Reyment suggested Oligocene – Miocene age for this formation. For the Benin formation, the sands and sandstones are coarse to fine grained and commonly of granular texture. The formation consists of friable sand with intercalations of shale and clay lenses occurring occasionally at some depths.

The formation is partly estuarine, partly lagoon, partly deltaic and 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 in colour or yellowish brown. Hematite grains, feldspars are also obtained. The shale is greyish, brown, sandy to silty and contains some plant remains and dispersed lignite.

The geology of Nzerem in Ehime-Mbano Local Government Area, Imo State, is closely tied to the tectonostratigraphic evolution of southeastern Nigeria, particularly the effects of the Santonian orogeny. This area lies within the transitional zone between the Anambra Basin and the Benue Trough, which experienced intense deformation during the Late Cretaceous. The Santonian event led to widespread uplift, folding, faulting, and erosion, reshaping basin geometry and strongly influencing sedimentation patterns (Murat, 1972; Hoque, 1977).

Stratigraphically, the subsurface around Nzerem is dominated by Cretaceous to early Tertiary formations, with the Ajali Sandstone being the most prominent unit. These sandstones are typically well-sorted, medium- to coarse-grained, quartz-rich, and were deposited in a high-energy fluvial–deltaic environment following the Santonian uplift. The unconformity created by this tectonic pulse provided accommodation space for thick sandstone deposition, often with minimal shale intercalation. Overlying units such as the Nsukka and Imo Formations consist mainly of siltstone, shale, and sandy inter-beds, reflecting a shift toward more marine-influenced conditions during the Paleocene (Short & Stauble, 1967).

The impact of the Santonian deformation on the subsurface is evident in the strong structural and diagenetic overprints. Uplift and compression produced localized folding and faulting, which in turn controlled sediment distribution and thickness. These structures often act as both conduits and barriers to groundwater flow, creating heterogeneity in the aquifer system. Post-deformational fluid migration enhanced diagenetic cementation, commonly involving silica, calcite, and iron oxides, which transformed portions of the Ajali Sandstone from loose, unconsolidated sediments into partially lithified, cemented layers (Hoque,

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1977). This cementation is often encountered during drilling, where the formation produces dust-like cuttings similar to powdered cement, indicating a hard, over-compacted zone rather than loose aquifer sands.

From a hydrogeological perspective, the Ajali Sandstone functions as a prolific aquifer system, but its productivity varies laterally due to the combined effects of structural deformation and diagenetic alteration. Zones of intense cementation exhibit lower transmissivity and storage potential, while relatively unconsolidated portions of the formation support higher yields and better recharge conditions. These variations are critical for groundwater development, as they influence drilling depths, borehole success rates, and long-term water availability (Short & Stauble, 1967; Hoque, 1977).

The Santonian deformation caused pronounced uplift and faulting in the Benue Trough and adjoining areas, resulting in a major unconformity that redefined basin morphology. The uplifted terrains were subjected to erosion, followed by the deposition of thick, clean, well-sorted sandstones of the Ajali Sandstone across much of Southeastern Nigeria (Reyment, 1965; Murat, 1972). These sandstones, deposited under high-energy fluvial and deltaic conditions, are laterally extensive and often form the principal aquifer systems in the area. Their textural maturity and high primary porosity make them excellent groundwater reservoirs, although localized diagenetic cementation can significantly reduce permeability in some zones (Hoque, 1977).

Hydrogeologically, these cemented zones are significant because they reduce primary porosity and permeability, limiting groundwater storage and movement. In contrast, the more unconsolidated parts of the Ajali Sandstone provide excellent aquifers, with good water yield and relatively easy penetration during drilling. However, the structural complexity imposed by the Santonian event results in irregular aquifer geometry, variable well yields, and localized perched water tables. The uplifted and eroded surfaces also influence recharge and drainage patterns, controlling the direction and quality of groundwater flow.

The purpose of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface and with the view of understanding certain point along the earth surface in which borehole drilling can be done. From these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the heavy metals, fluid content, porosity and degree of water saturation within the subsurface layers. Electrical resistivity surveys have been used for many decades in hydrogeological (involving borehole drilling activities), mining and geotechnical investigations. More recently, it has been used for environmental surveys. Extensive (Oghonyon, Rorome., and Osaki, Lawson Jack. 2025).

Overall, the geology of Nzerem reflects the interplay between tectonics, sedimentation, and diagenesis. The Santonian deformation event not only shaped the stratigraphy but also determined the present-day hydrogeological behaviour of the subsurface. Understanding these geological controls is essential for groundwater exploration, as drilling through cemented or indurated layers requires careful interpretation to avoid dry or low-yielding zones, while targeting more permeable sandstone intervals ensures sustainable groundwater development.

Understanding the geological framework of Nzerem within the context of the Santonian deformation is therefore essential for effective groundwater exploration and management. It allows for the differentiation between structurally controlled aquifer zones and cemented, low-permeability intervals, thereby guiding optimal borehole siting and ensuring sustainable groundwater abstraction.

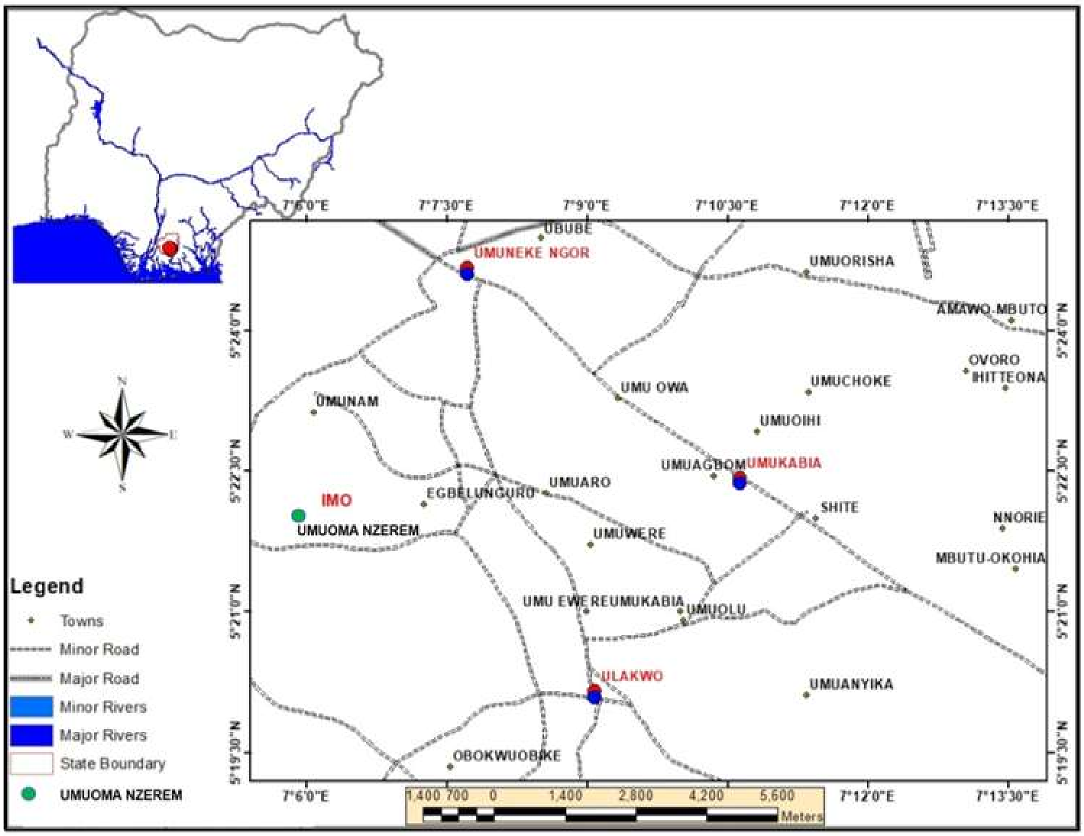

Figure 1: Geologic map of the study area.

Methodology

The work involves the use of electrical resistivity method in exploring for freshwater Formation 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 (Figure 2 and 3), so you can use the APP to realize all the operations of the instrument such as measurement signal input, data checking and processing. Using wireless sensor probe, you can complete all the measurements just by walking and stopping. No need long cable, saving time and manpower.

Many innovative designs make the instruments become more intelligent, efficient, and accurate to obtain dozens of invention patents. ADMT series products are a new generation intelligent prospecting instruments designed by AIDU and Guilin Technology Hydrogeological Investigation Institute. Based on more than 4 decades R&D experiences, we use mobile phone or table PC to run the complicated data calculation to realize the quickly calculation inversion and rapid graph drawing. Then we can quickly draw 2D/3D profile maps, contour maps and curve diagrams by an APP. This is a leap in technology because it makes the complicated geophysical survey becomes easier and simpler. With the APP you could use many intelligent functions such as field measurement control, instantly data process, data cloud backup, online expert analysis and Bluetooth data transaction etc.

Main Features

The main features include:

1. Instant Mapping: Directly drawing the 2D/3D map by the APP after data collection
2. Simple Operation: Walking and stopping to complete the measurement, so easy.
3. Efficiency: Unique wireless prospecting tech, one person can complete all work, saving time and manpower.

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4. Precision: Strong anti-interference ability, field source correction and patent tech to process data.

Figure 2**:** A digital Terrameter for Groundwater Exploration.

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Figure 3: A Pool Finder Plus for Groundwater Exploration.

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Results and Interpretation

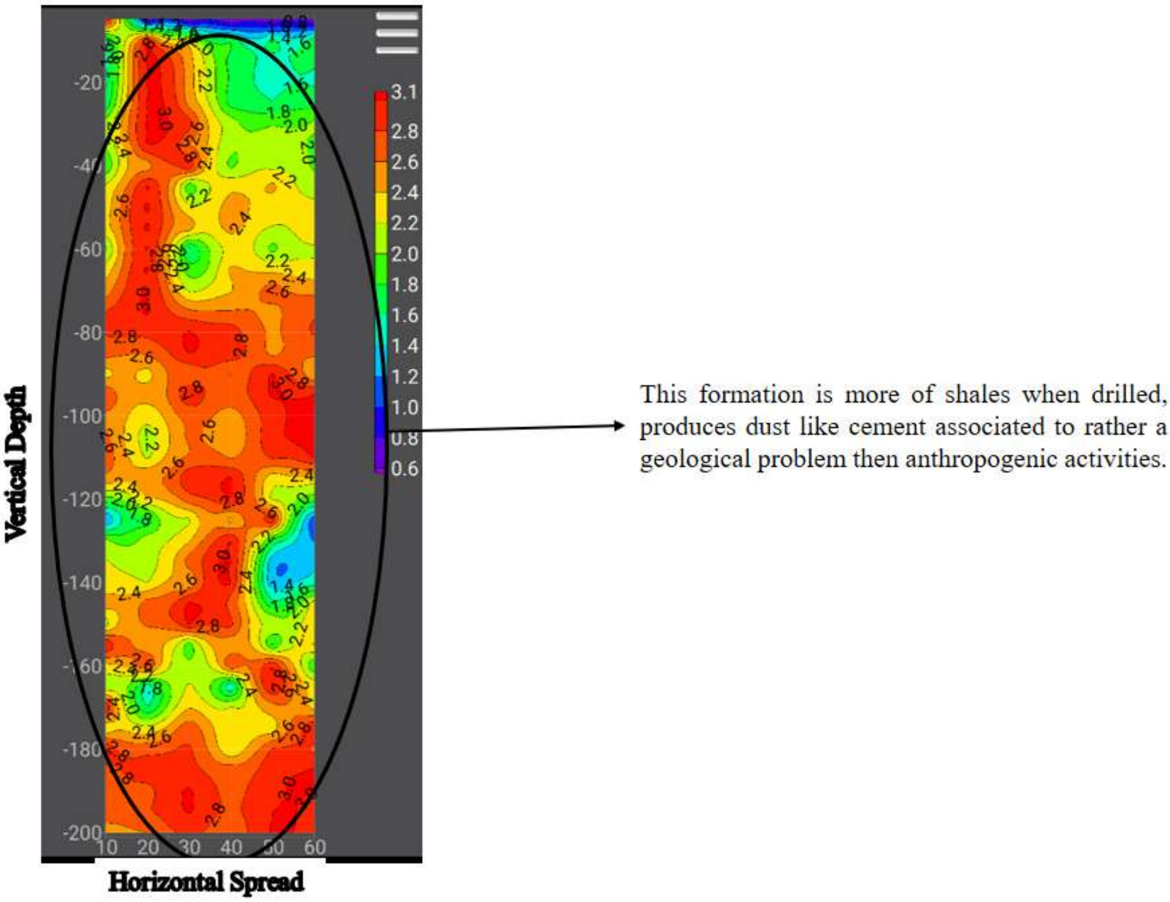

Figure 5: The ERT subsurface image of Nzerem

The formation of Nzerem is complicated as a result of the santonian deformation thereby making the subsurface formation a complex one as there are several irregularities at the subsurface formation.

The formation shown in figure 4 above is a formation whereby it is more of shale when drilled, it produces dust like cement associated to rather a geological problem than anthropogenic activities.

The occurrence of cement-like dust during drilling operations is a significant geotechnical and geological indicator of a lithified or over-compacted subsurface formation rather than contamination from anthropogenic sources. In such cases, the drilling fluid returns or cuttings often appear as fine, powdery, cementitious materials, suggesting a high degree of diagenetic alteration within the subsurface strata. This phenomenon typically reflects cementation processes that have occurred over geological time, leading to hard, compact, low-porosity zones in the stratigraphic column.

In parts of the Niger Delta and adjacent inland basins, such cemented or lithified layers can be traced to regional tectonostratigraphic events, notably the Santonian orogeny. This deformation event, which affected large portions of West Africa during the Late Cretaceous, resulted in significant basement uplift, folding, and faulting. These tectonic forces led to the reorganization of sedimentary basins, producing zones of high compaction and cementation across multiple stratigraphic levels (Murat, 1972; Hoque, 1977).

The uniformity of this cement-like material from shallow to deeper depths indicates a regional geological control rather than localized human activity. This suggests that the diagenetic front the zone where sediment grains have been bound together by secondary minerals such as calcite, silica, or iron oxides—is extensive and continuous. Over geologic time, pressure solution, mineral precipitation, and structural deformation have created a cemented formation, which poses specific drilling challenges, including low penetration rates, bit wear, and sometimes poor aquifer productivity.

This type of subsurface condition can also influence hydrogeological properties. Cementation reduces primary porosity and permeability, thereby restricting groundwater flow and storage capacity. Where aquifers occur, they may be confined or semi-confined with limited recharge potential. Unlike unconsolidated sands, these lithified zones are less responsive to modern recharge and are more structurally controlled.

Thus, the cement-like dust encountered during drilling represents a geological problem rooted in ancient deformation and diagenesis rather than modern anthropogenic impacts. Understanding this context is critical for groundwater resource evaluation, borehole design, and aquifer management in such terrains.

Conclusion

The presence of cement-like dust during drilling reflects a geological issue linked to lithification and diagenetic cementation rather than human activities. This uniform cementation from shallow to deeper depths is a result of structural deformation associated with the Santonian orogeny. Such formations reduce porosity and permeability, limiting groundwater flow and storage.

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