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ORIGINAL RESEARCH ARTICLE

Exploring the Geological Formation and Sub-Surface Lithology Modelling of Hadejia, Jigawa State Nigeria.

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ABSTRACT

This research aims to explore the geological formation and sub-surface lithology modelling of Hadejia, Jigawa State using the VES (vertical electrical sounding) method. The VES method is a geophysical technique that measures the electrical resistivity of the subsurface, which is related to the lithology of the rock units. The study area is located in the north-western part of Nigeria, on latitudes 12°25'23.73"N and longitudes 10°04'06.74"E, and is characterized by a chad formation geological setting with a variety of rock units, including sandstones, shales, and limestone. The research was conducted using a total of 50 VES stations, which were distributed over the study area in a grid pattern. The data collected from the VES stations were analysed using the IPI2WIN software. The results were used to create a subsurface electrical resistivity model, which was then used to infer the lithology units present in the subsurface. The results showed that the study area is characterized by a complex subsurface structure, with several rock units present, including sandstones, silt, and clay. The subsurface electrical resistivity model revealed that the sandstone units are located at shallow depths, while the silt units are found at deeper depths. The clay is present at intermediate depths and is interbedded with sandstones and clay. The results provide valuable information for hydro-geological and mineral exploration in the area.

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Sub-surface, Lithology, Geologic Formation, Vertical Electrical Sounding.

INTRODUCTION

Nigeria is located in West Africa with a diverse geology that includes Precambrian basement rocks, sedimentary basins, and volcanic rocks. The geology of Nigeria has been the subject of numerous studies, with the majority focusing on the sedimentary basins and their hydrocarbon potential. Study by Adegoke *et al*. (2011) used seismic data and well logs to investigate the stratigraphy and structure of the Anambra Basin in south-eastern Nigeria. The study found that the basin is divided into three main stratigraphic units: the Lower Benin Formation, the Akata Formation, and the Agbada Formation. The authors also identified several structural features, including normal faults and anticlines, which have influenced the distribution of hydrocarbons in the basin. Another study by Olu-Owolabi (2015) focused on the subsurface lithologic modelling of the Anambra Basin. The authors used well-log, seismic, and geological information to construct a 3D lithologic model of the basin. The study found that the basin is characterized by a complex structural and stratigraphic architecture, with several sandstone reservoirs in the Agbada Formation, A third study by Adebanji *et al*. (2018) used a combination of well-log data, seismic data, and geological information to investigate the geology of the Niger Delta Basin in southern Nigeria. The study found that the basin is divided into several stratigraphic units, including the Agbada and Benin Formations. These units contain

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several sandstone reservoirs that have the potential for hydrocarbon production.

Another area of particular interest the field of geology has long been focused on understanding the formation and structure of the Earth's surface and subsurface. One area of particular interest is the study of lithologic modelling, which involves creating detailed representations of the different types of rock and soil that make up the subsurface. One of the key challenges in subsurface lithologic modelling is understanding the complex interactions between different rock types and the fluids that flow through them. A study by Wang et al. (2018) used a combination of field observations, laboratory experiments, and numerical simulations to investigate the effects of fluid flow on rock deformation and failure in a subsurface sandstone reservoir. The researchers found that fluid flow can significantly alter the mechanical properties of the rock, leading to changes in the way it deforms and fails. This work highlights the importance of considering fluid flow when modelling the subsurface, as it can have a major impact on the behaviour of the rock.

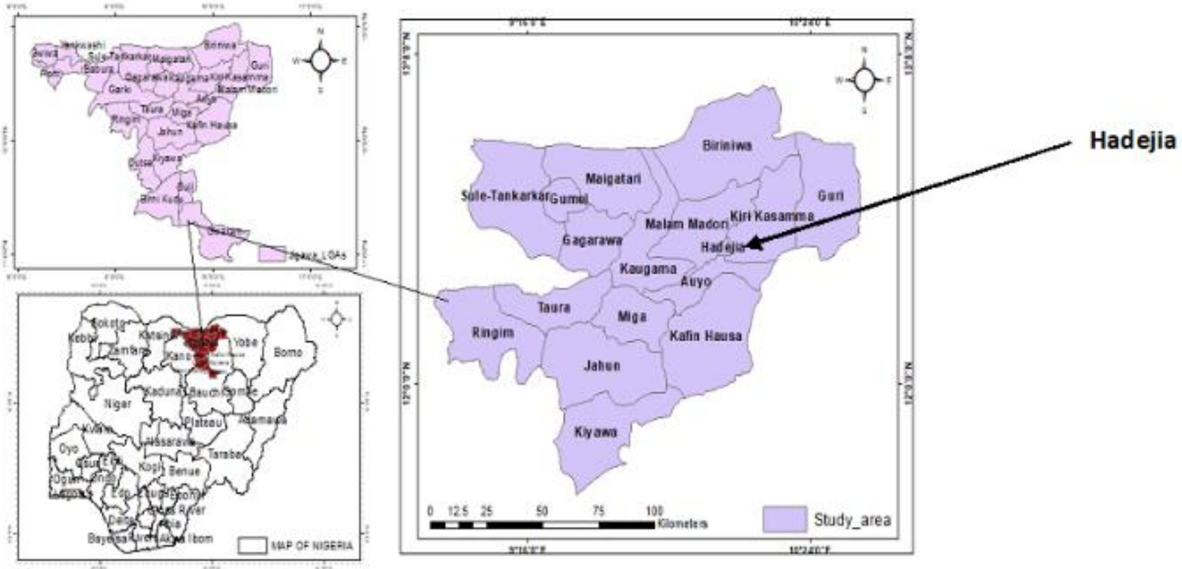

Figure 1: Map of Jigawa Showing the study area (Source GIS Lab BUK).

Another important aspect of subsurface lithologic modelling is understanding the processes that led to the formation of different rock types. A study by Li *et al*. (2019) used a combination of field observations, geochemical analyses, and numerical simulations to investigate the formation of a complex, multistage carbonate reservoir. The researchers found that the reservoir was formed by a combination of dissolution, precipitation, and diagenesis, with different stages of formation controlled by changes in the chemistry and pressure of the fluids flowing through the rock. This work highlights the complexity of the processes involved in sub-surface formation and the need for detailed, multidisciplinary studies to addition to these studies, there have been several recent advancements in the tools and techniques used for subsurface lithologic modelling. For example, a study by Chen *et al*. (2020) used machine-learning algorithms to improve the accuracy of subsurface lithologic predictions. The researchers trained a neural network on a large dataset of well-logs and rock samples and found that the resulting model was able to make more accurate predictions of subsurface lithology than traditional methods. This work highlights the potential of machine learning to improve subsurface lithologic modelling and suggests that it may become an increasingly important tool in the future.

While there are still many challenges to be overcome, the recent work discussed here suggests that progress is being made in understanding the complex interactions between rock types and fluids in the subsurface and the processes that led to the formation of different rock types.

The many rock types in an area, structures, geological formations, geothermal manifestations, age correlations, distribution of mineral ore deposits, fossils, and other features will all be shown on a geological map, which may be superimposed over a topographic map or a base map. Its scale mostly determines a map's level of information, and a smaller scale will inevitably reveal finer detail. The accuracy and precision of the fieldwork will determine how good a geologic map is. Additionally, the thoroughness with which specific geographic and geologic data are portrayed on the maps, as well as the care with which scale, colour, and other design elements are chosen to provide the greatest results, all affect the quality (Eckel, 2016). But as technology has advanced, geological maps are now more accurate than ever thanks to the application of Geographic Information Systems (GIS) advancements, high-tech geological equipment, precise satellite imaging, and aerial photography. The methods utilized, one's background, and interests all play a role in how a geological map is interpreted. Examining geological maps depends heavily on the ability to visualize possible scenarios that may have been involved in the development processes of the structures represented. In actuality, the most important aspect of interpreting geologic maps is the capacity to create a three-dimensional representation from a two-dimensional plan (Bolton, 2011).

Many different places around the globe (Richey *et al*. 2015). As a result, examining groundwater survey wells for groundwater storage changes is critical for identifying stress zones that face groundwater storage loss. As a result, understanding the hydrological cycle and its relationship to changing climate requires a thorough understanding of groundwater storage. Over the years, the use of remote sensing and geographic information systems to delineate groundwater potential zones has proven fruitful (Malik *et al*. 2016). Gravel, sand, sandstone, or limestone make up the aquifers. Because these rocks contain enormous linked spaces that make them porous, water can pass through them. The water table is the depth below the surface where groundwater can be discovered. The water table can be rather high.

Due to the scarcity of surface water resources, population development and modern urban and agricultural activities are not only increasing the demand for groundwater resources but are also contaminating groundwater resources by releasing untreated pollutants. As a result of these operations, research has increased, not only in terms of groundwater resources but also in terms of locating groundwater of excellent quality for human use (Srinivasa and Jugran 2003). The main objective is to create a geological map of the study area and to establish a relationship with lithology of the area.

Hadejia is a town in Jigawa State located in the north-western part of Nigeria and lies on latitudes 12025'23.73"N and longitudes 10°04'06.74"E (Figure 1).

MATERIALS AND METHODS

Geological investigations often begin with base maps, proceed through field locations, and conclude with sample analysis in a laboratory. The ultimate goal is to explain the region's geology and structure. The strategy is quite useful. The fundamental requirements of a nation are geological investigations. A geologic map graphically communicates important details regarding the distribution of rocks and other unconsolidated materials on and near the Earth's surface (Balasubramanian, 2019).

Sub-surface lithology modelling is the process of creating a detailed 2D representation of the different rock types and geologic structures present beneath the surface of the earth. This is typically done using a variety of geophysical techniques, including VES (Vertical Electrical Sounding).

A VES of the electrical resistivity method was carried out using an Ohmega resistivity meter with Schlumberger configuration. VES principle is based on the fact that sub-strata is a resistor to the flow of electric current and that any sub-surface variation in conductivity will alter the current which affects the electrical resistivity of overburden and bedrock varies considerably in relation to moisture content. Electric current is pass into the ground between two outer electrodes while two inner electrodes measure the resultant potential difference. The electric field produced is measured by the instrument in the form of Resistance which when multiplied by a constant (k) gives the apparent resistivity value. The electrode spacing was progressively increased keeping the center point of the electrode array fixed. The maximum half-current electrode separation (AB/2) was between 1 and 100m while the half-potential electrode separation (MN/2) was maintained between 0.5 and 10m. The apparent resistivity measured at each point was plotted on a log-log paper. The plots gave an idea of the position and forms of the interface. A total of 50 VES points were collected field data was interpreted as done quantitatively using IPI2WIN software to identify the thickness and resistivity of different layers. (Idris *et al*. 2018).

Figure 2: Google earth map of Hadejia showing VES points.

Once the VES data has been collected, it can be used to create a 2D model of the subsurface. This is typically done using a process called inversion, which involves using mathematical algorithms to convert the VES data into a model of the subsurface.

The resulting 2D model can be used to identify different rock types, such as sandstone, limestone, and shale, as well as geologic structures like faults and fractures. This information can be used to help predict the location of natural resources, such as oil and gas, and to inform the design of civil engineering projects like dams and tunnels

RESULTS

Geology

The research results show that sand granules are compressed and bonded together over thousands or millions of years, and sandstone, a sedimentary rock, is created. The minerals quartz or feldspar that were worn off. Other rocks and pulverized into pebbles are frequently present in the sand grains. All components of soil, including minerals, living things, and animals, go towards its creation. The minerals, flora, and fauna remnants are ground into tiny particles over time by the pressure of the water. Sand and rocks filter out larger particles, leaving silt to settle into beds of clay.

The study area is located in the chad formation of northern Nigeria, which is dominated by the Kerri-Kerri formation. This formation is primarily made up of a thick sequence of interbedded clays, silts, sands, and permeable clayey sandstone that ranges in grain size from coarse to fine, grit, siltstone, and quartzite sand. A sizable portion of the soils in the study region, particularly in the northern parts, is made up of Aeolian deposits from the Sahara Desert. The clayey sub-soil that predominates in the northern region was created as a result of the sub-soils mixing in these deposits (Obaje, 2009). The main hydro-geological unit in the area includes fine to coarse quartz sand, fine quartz gravel, and laterite gravel occurring at a depth ranging from 30m to 70m. Water levels is 4m beneath the ground of the topographic high.

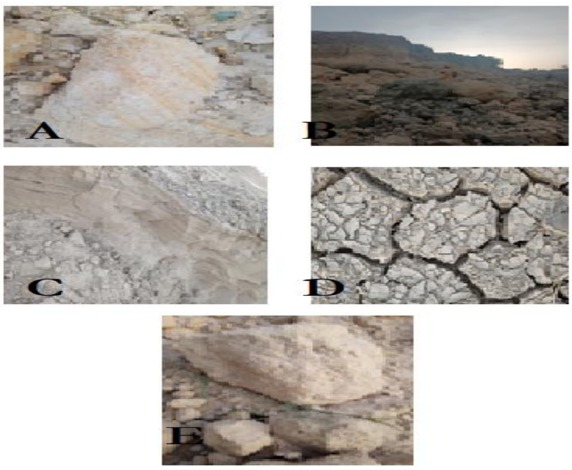

Figure 3: Lithologies of the Study Area (A = Coarse fine sand, B = Silty sand, C = Sandy clay, D= Clay and E = Fine Sand).

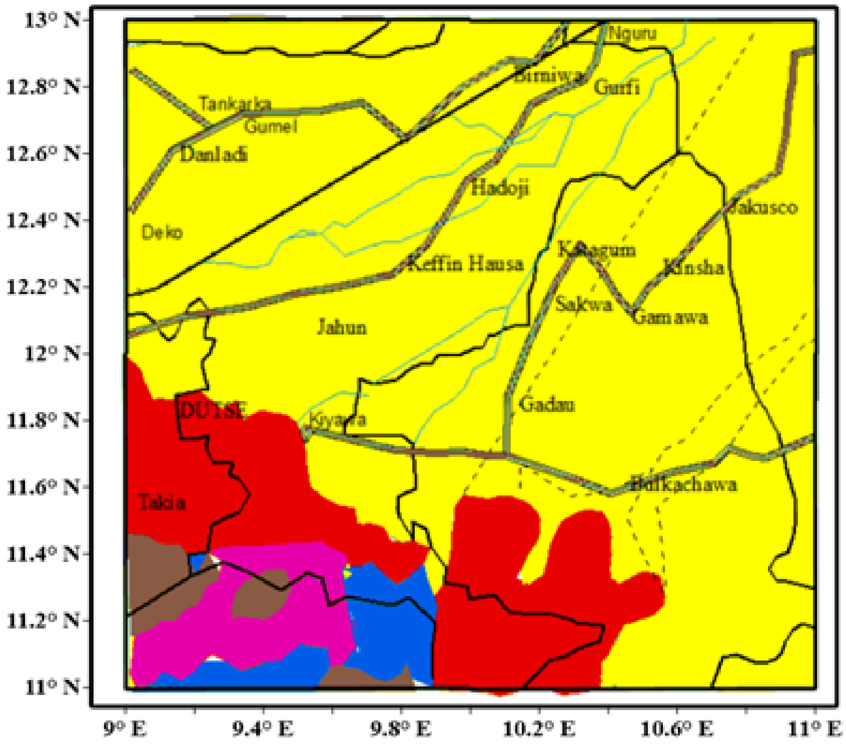

Figure 4: Geological Map of Hadejia.

Geophysical

The method was used to identify the various geo-electric layers in the sub-surface, using the findings of the interpreted vertical electrical soundings (VES) data. According to the interpreted vertical electrical sounding data, the research area has four geo-electric strata.

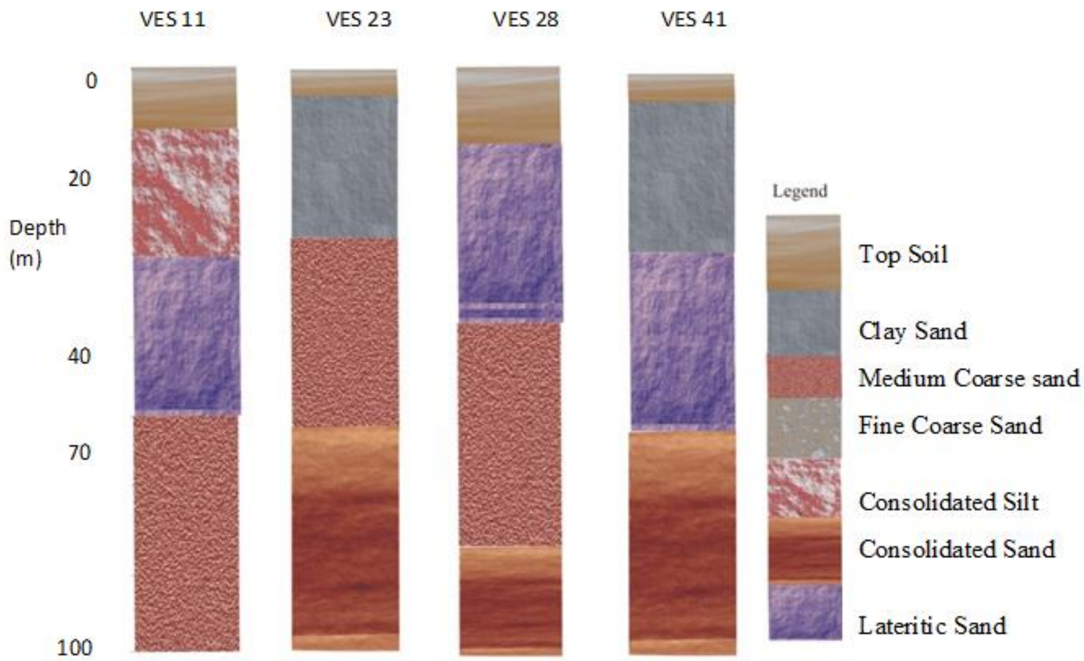

Figure 5: Lithologic section.

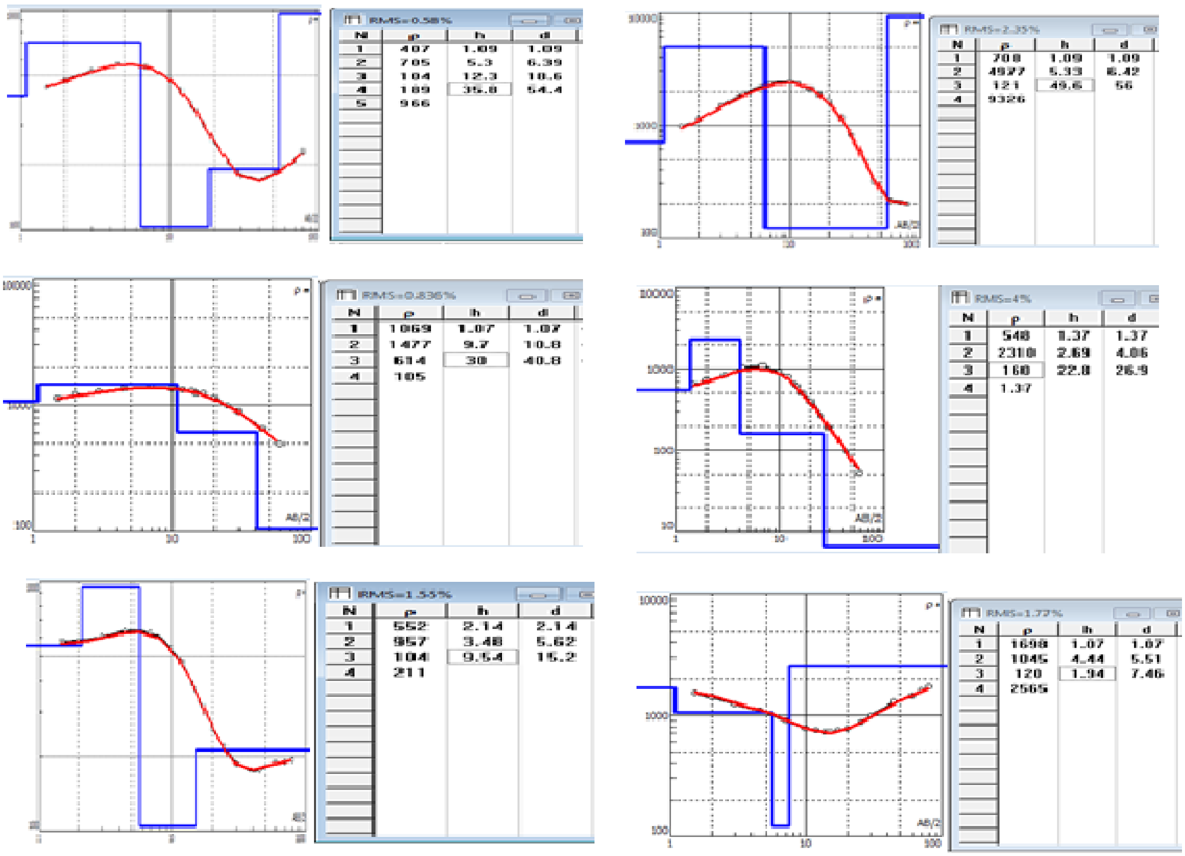

Figure 6: Vertical Electrical Sounding result.

DISCUSSION

During the Plio-Pleistocene, rivers moving towards Lake Chad deposited the lacustrine-derived Chad Formation on the Basement Complex. The Formation consists of clays, including sandy clays, diatomite, and trace amounts of carbonaceous minerals. Clays intercalated between the beds of sand and gravel, and lenses of sand and gravel frequently found inside the clays. The clays range in texture from fine to gritty and are pale and greenish-grey in hue. The vertical electrical sounding shows the various sub-surface geo-electric layers.

Vertical electrical soundings were randomly distributed, in the study area (Figure 2). VES location point 11 is HK curve type as shown in figure 6, characterized by $\rho1<\rho2>\rho3>\rho4$. Table 1 displayed VES 11 result and interpretation with the (topsoil) having 1069Ωm as the resistivity value and a thickness of 1.07m, and the second layer has a resistivity value of 1477Ωm with a thickness of 9.7m, with sand clay. The third layer has a resistivity value of 614Ωm with a thickness of 30.6m at the depth of 15.2m, which is lateritic sand. The fourth layer represent the fresh basement/bedrock with a resistivity value of 105Ωm having an infinite thickness.

The geo-electric layers a grouped: The first layer is interpreted as topsoil, the second layer clay sand/consolidated silt/lateritic sand, the third layer medium coarse sand/lateritic sand/fine coarse sand and, fourth layer medium coarse sand/consolidated sand, beneath this layer at a great depth is inferred to be the fresh basement/bedrock.

CONCLUSION

Conclusively, the aim of Vertical electrical sounding is to determine the different geo-electric layers in the sub-surface, the aquifer units and their characteristics, as well as general hydro-geological conditions. Three layered-type curves were obtained from the VES points in the study area. Plots of some calculated apparent resistivity in ohm-m against electrode spacing in m were calculated. From the geophysical and geological, we can prove that the stratigraphy of the sub-surface is comprised of sandstone, silt, and clay, as reported from a geological map of Nigeria, and this shows that the research proves that the study area is covered by sandstone consolidated silt, clay, fine and coarse to medium coarse sand and finally lateritic sand.

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