

CONFINED AQUIFERS AND ARTESIAN WELLS OF GANDU, NIGERIA

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Groundwater occurs in rock units which store and transmit water and are called aquifers. These aquifers maybe sandwiched or underlain by confining beds and can be classified as confined or unconfined aquifers respectively. When groundwater is confined under pressure greater than atmospheric pressure; a well penetrating such an aquifer is said to be an artesian well. Gandu, a town in Lafia Local Government Area, Nasarawa state, Nigeria is characterized by confined aquifers, with wells penetrating such aquifers being artesian. Geologically, the area is underlain by Cretaceous sediments belonging to Lafia and Awgu Formations all part of the Middle Benue Trough. The confined aquifers are found within the Awgu Formation which essentially consists of bluish-grey to dark-black carbonaceous, shales, shaly limestone, coal seams, and sand horizons. These sand horizons form aquiferous zones, confined by overlying and underlying shales. Electrical resistivity data using the vertical electrical resistivity sounding technique as well as borehole logs reveal the existence of sandy horizons; a shallow one between 30 and 45m below ground level and a deeper one between 75m and 96m below ground level. Three boreholes penetrating the Awgu Formation in the Gandu area are artesian (pressure head = 0.3m, 0.5m and 2m) and are believed to have intersected these sand horizons. These sand horizons are limited laterally as such recharge into the aquifers is suspected to be from precipitation through the confining units which may not be completely impermeable. These aquifers and artesian wells form excellent sources of water as groundwater is relatively free of contamination; in addition, boreholes drilled into these aquifers do not require pumps since the wells are free flowing.

Keywords: Confined, Aquifers, Artesian, Sediments, Cretaceous

1. INTRODUCTION

1.1. Confined Aquifers

Aquifers are geologic units porous enough to store substantial quantities of water and permeable enough to yield the water. Confined aquifers are those aquifers that in a groundwater system occur as porous and permeable units sandwiched by impermeable units known as aquitards or aquifuges. Typically such groundwater systems with confined aquifers occur in synclinal structures, however, instances where confined aquifers occur in form of lenses of porous and permeable units within impermeable units have been reported (e.g. Zhan, 1998). Groundwater in such aquifers is under immense pressure due to its confinement. Water enters a confined aquifer at intake points known as recharge areas, far away from the observation point and at a higher ground than the rest of the layer. A well drilled into such an aquifer, will have water rise above ground level, and is then known as artesian water. The potentiometric surface defines the height to which the artesian water may rise.

Gandu town is located in Lafia, the capital of Nasarawa State, Central Nigeria. Geologically it is found within the Middle Benue Trough of Nigeria, a structure filled up with a sequence of Cretaceous sedimentary strata of diverse lithologies. Two main rock types are exposed in the area i.e. Awgu Formation and Lafia Formation. Three wells drilled into the Awgu Formation in this area were found to exhibit artesian conditions, suggesting the presence of a confined aquifer in the area. This paper presents preliminary data on the nature of the artesian wells and proposes a conceptual model of the nature of the confined aquifer. Furthermore, suggestions on the source(s) of recharge into the confined aquifers are made. However, further work is required to better explain structure of the aquifer as well as groundwater movement especially source of recharge into the aquifer.

1.2. Location and Geology of the Gandu Area



Figure 1. Location of Gandu and approximate outline of the study area on a Google Map; inset is the Map of Nigeria showing Nasarawa State.

Gandu Town is geographically located in Lafia Local Government Area the Capital of Nasarawa State, Nigeria (figure 1). It is geologically part of the Benue Trough, the Middle Benue Trough precisely (figure 2). The Benue Trough is an intra- continental basin that extends NE to SW for over 1000 km and exceeds 150 km in width (Abubakar, 2014). It is geographically divided into the Upper, Middle and Lower Benue Troughs. Geology of the Middle Benue Trough has been described in details by several Authors e.g. Offodile (1976, 2014), Nwajide (2013). The oldest sediments belong to the Asu River Group and consist of shales and siltstones of marine origin. These sediments represent the Middle Albian transgression into the Benue Valley.

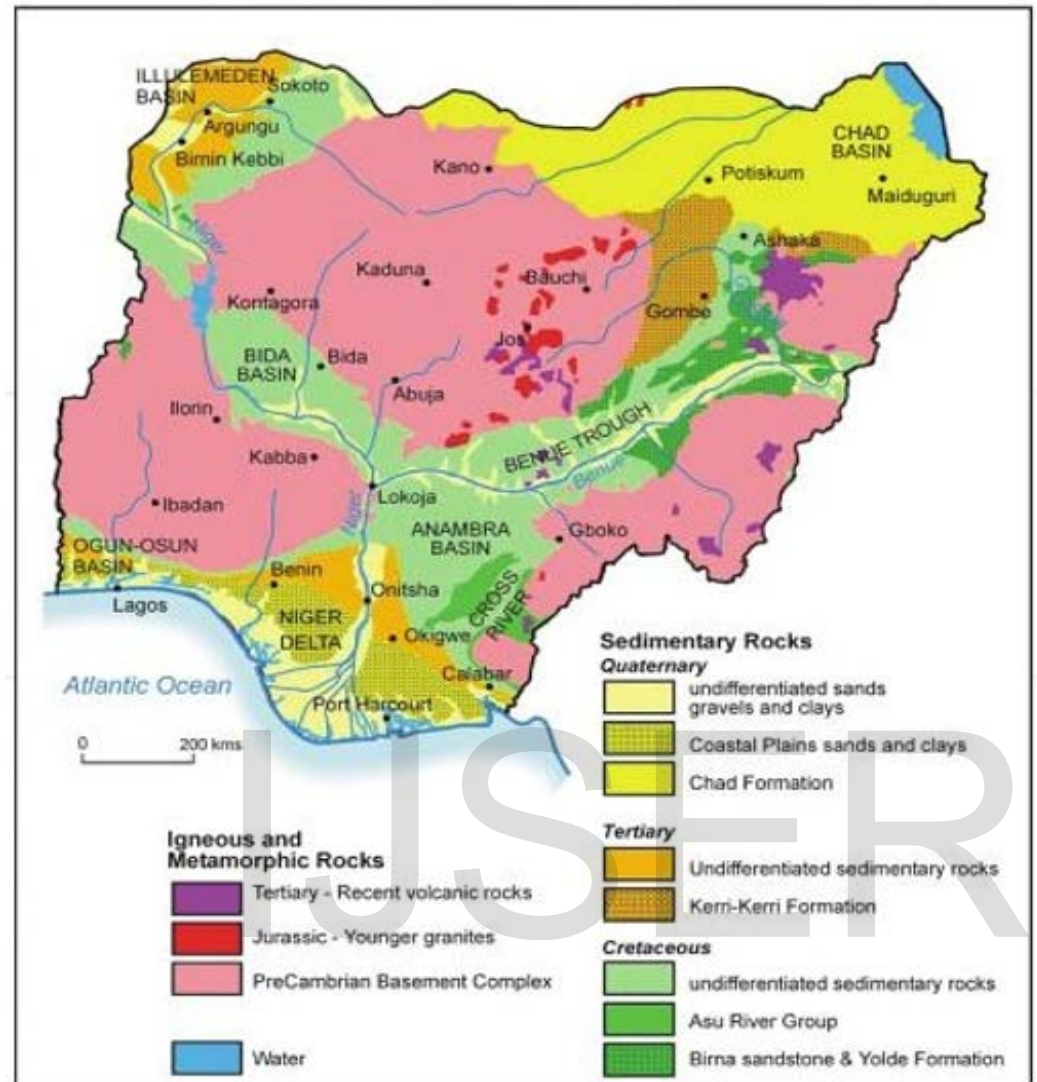


Figure 2. Geological map of Nigeria showing the Middle Benue Trough.

This was followed by a regressive phase that led to the deposition of the transitional beds of the Awe Formation which are essentially flaggy, whitish, and medium to coarse-grained sandstones interbedded with carbonaceous shales or clays. The Awe Formation is overlain by continental fluvial sands belonging to Keana Formation in Late Cenomanian-Early Turonian. The regressive Awe and Keana Formation are overlain by the marine Facies of the Ezeaku Group and the Awgu during the mid-Santonian period, The Ezeaku Formation consists essentially of calcareous shales, micaceous fine to medium – grained friable sandstones, and occasional beds

of limestones. The Coniacian Awgu Formation consists mainly of black shales, sandstones and local seams of coal. The Lafia Formation is the youngest formation reported in the Middle Benue Trough and consists of coarse-grained ferruginous sandstones, red loose sand, flaggy mudstones and clays (Offodile, 2014). The Awgu and Younger Lafia Formation are exposed in the study area (figure 3).

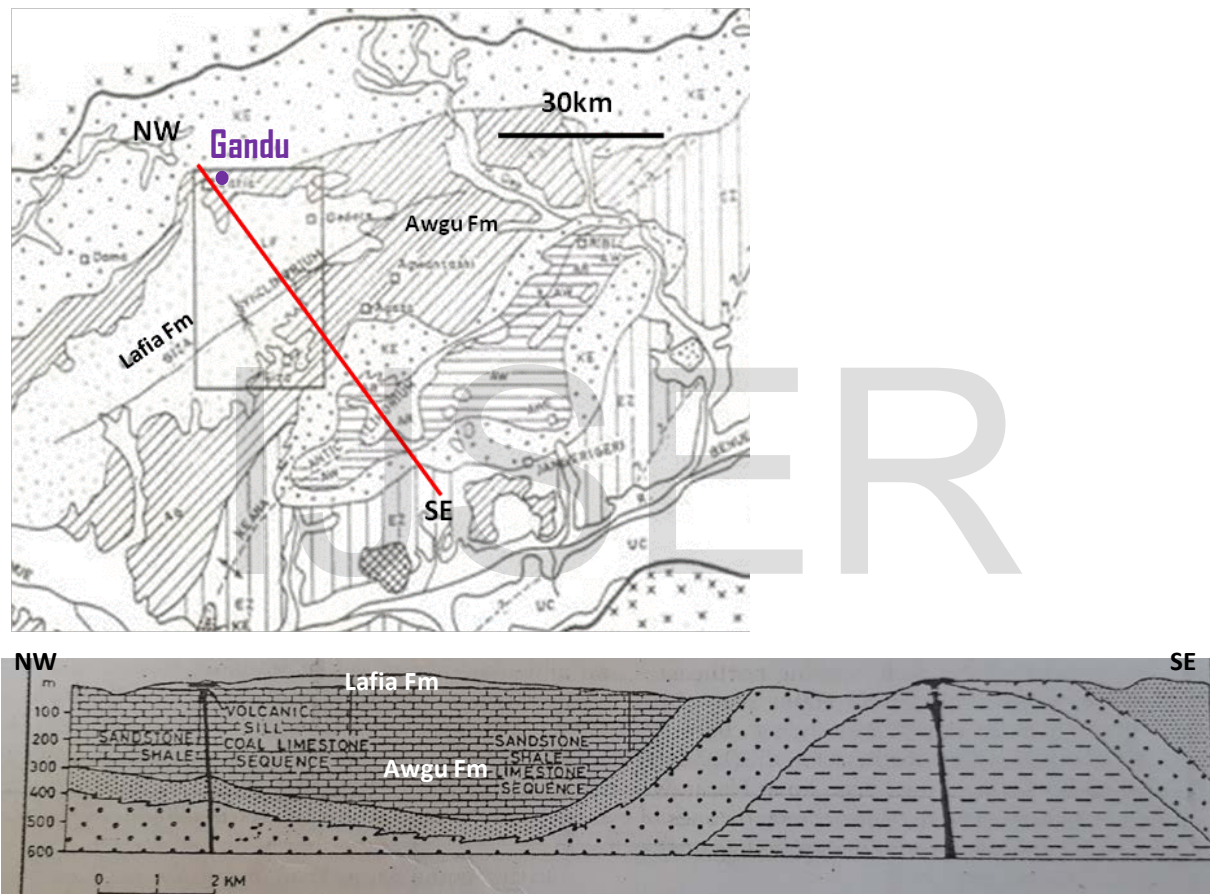


Figure 3. Geological map (top, modified from Offodile, 2012) and cross section (bottom, modified from Nwajide, 2013) of Lafia Sub Basin of the Middle Benue Trough.

1.3. Aquifers in the Gandu Area

Sandstones of the Awgu Formation – the Awgu Formation in the study area consist mainly of gray bedded shales and occasional sandstones that are permeable and hence aquiferous; they are however, limited in thickness and lateral extents and are confined by the shales (Offodile 2014).

Where fracture zones exist, groundwater potential improves. Borehole logs confirm the presence of aquiferous zones within sandy horizons and fracture zones in the Awgu Formation in the study area.

Sandstones of the Lafia Formation – the sandstones are permeable and form excellent aquifers but are very thin in the Gandu area. Elsewhere, west of the study area, the thickness increases up to 150m (Offodile 1976, 2014)

2. ARTESIAN WELLS

Three artesian wells were encountered in the Gandu area. The wells are private for domestic water supply. Figure 4 shows location of the wells on a Google Earth map.

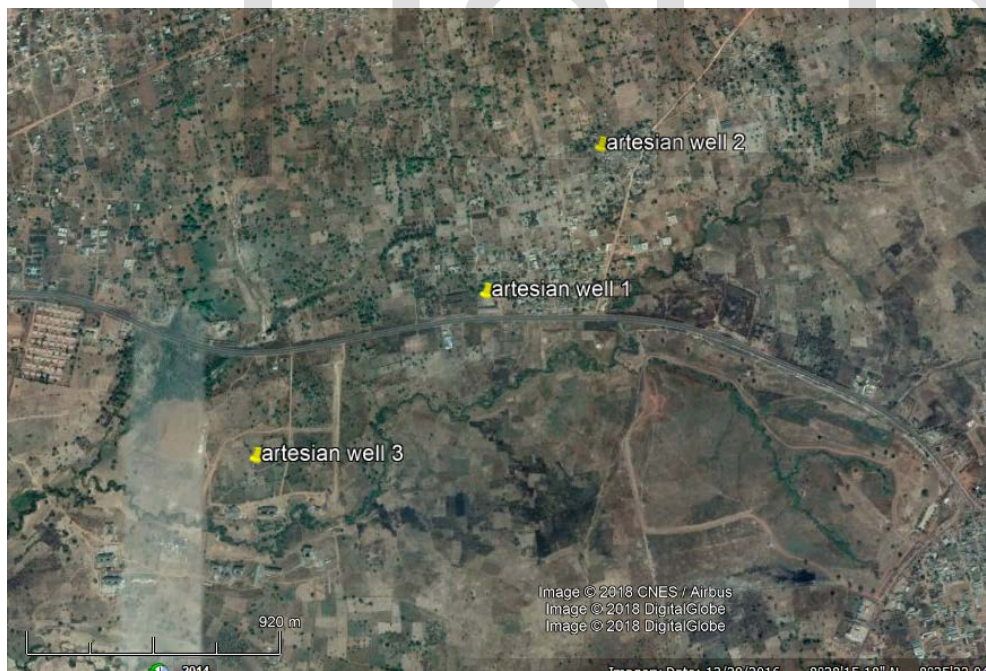


Figure 4. Location of the three artesian wells on a Google Earth Map (date accessed: 07/01/19).

Artesian well one – electrical resistivity data and corresponding borehole lithologic log for artesian well one is shown in figure 5. In this case, half a meter of lateritic soil is seen at the top,

while a low resistivity layer extending from 0.5m below ground surface to about 28m underlies the top soil. Corresponding lithology for this layer is a dark shaly rock. This layer is followed by a sandy layer which extends from 28m to the end of the borehole i.e. 120m. Electrical resistivity in this interval is between 100Ωm and 300Ωm, and the sample obtained here is sandy and light to gray in colour, it appears to be coarse grained along the entire interval although difficult to ascertain since the samples are borehole cuttings. The sandy layer is interpreted as the aquiferous unit.

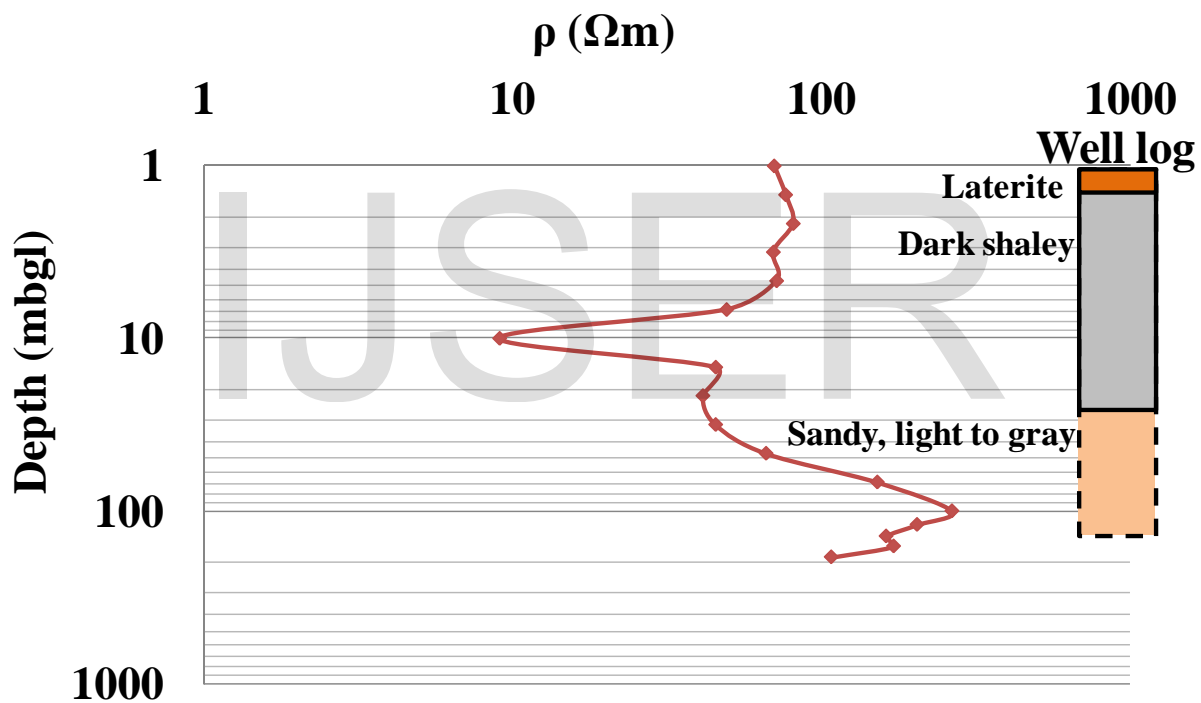


Figure 5. VES data and borehole log of artesian well one.

Artesian well two – electrical resistivity data collected at the point of the first artesian well is shown in figure 6, along with the lithological log of the borehole. It shows continuously low resistivity from the ground surface up to a depth of about 20m below ground surface where it increases with a steep gradient up to about 180m. Comparing the resistivity values with the

borehole lithologic log, three lithologies were identified: the top clayey laterite, about half a meter from the ground surface, followed by a shaly layer with electrical resistivity as low as $3\Omega\text{m}$ to $100\Omega\text{m}$ with a thickness of 26m. Below the shaly layer, a sandy lithology was encountered; this lithology had a light reddish colour with a corresponding high resistivity (up to $5000\Omega\text{m}$). It is inferred that the sandy layer corresponds to the aquiferous zone in the area i.e. the sand lenses, and that high iron content is responsible for the high resistivity value obtained (values up to 1.2ppm recorded in the area).

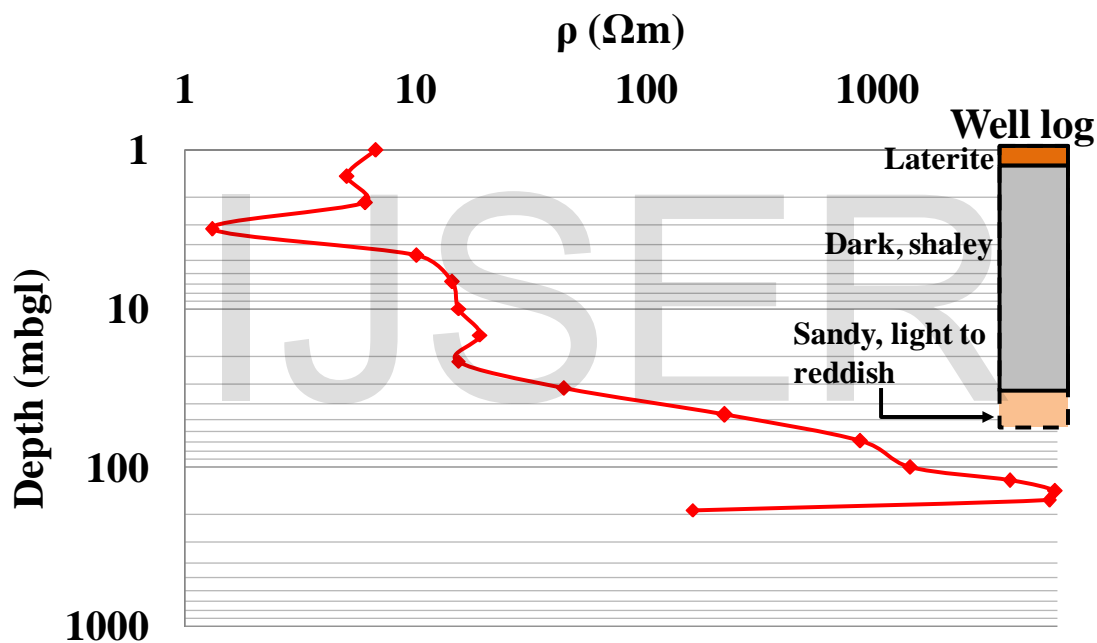


Figure 6. VES data and borehole log of artesian well two.

Artesian well three – data for this particular well differs from the other two as electrical resistivity values as well as samples obtained while drilling show the presence of a sandy lateritic layer from the ground surface up to about 8m (figure 7). Below this layer, a low resistivity layer is evident from the electrical resistivity curve, the sample obtained from this interval is dark gray and shaley. Below this layer, about 70m below ground level, resistivity value increases and the

lithology changes from the shaley samples to sandy samples, reddish in some parts but mostly gray in colour. The sample from this layer appears to be coarse grained along the entire interval although difficult to ascertain since the samples are borehole cuttings. In this case also, the sandy layer is interpreted as the aquiferous unit.

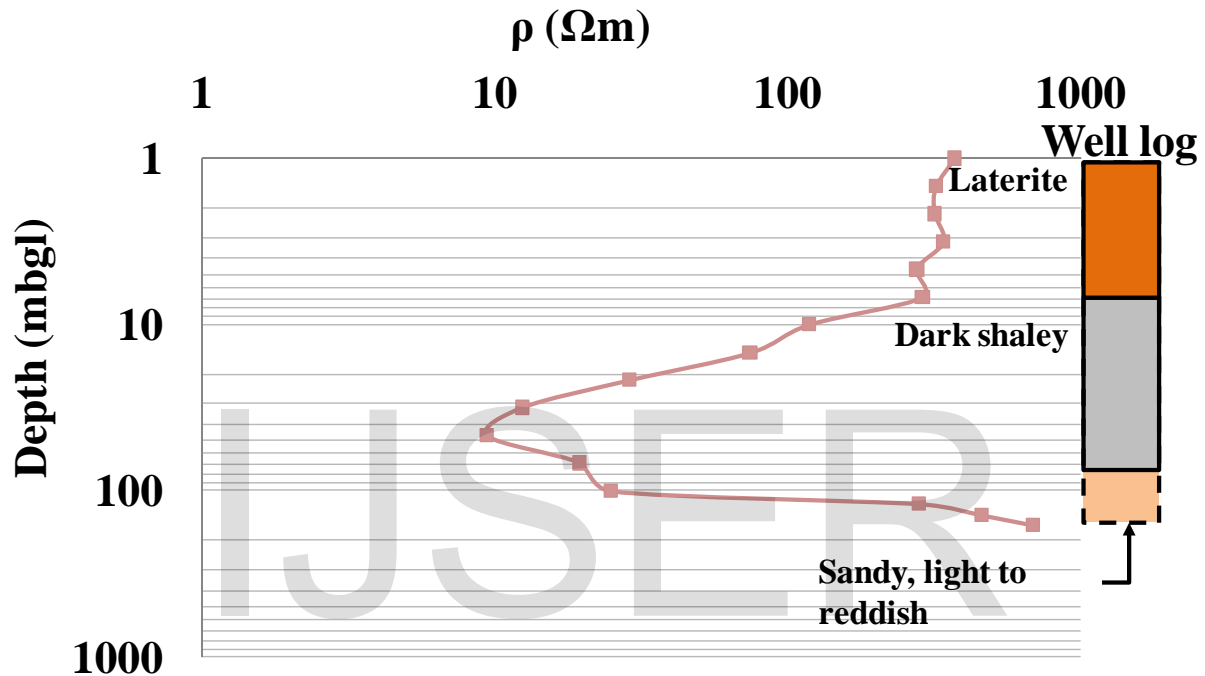


Figure 7. VES data and borehole log of artesian well three.

3. CONFINED AQUIFER MODEL

The data presented in section two above show three artesian wells which lie along a NE – SW trending line point to the presence of confined aquifers in the study area. The wells are free flowing and have pressure heads of 0.3m, 2m and 0.5m above ground level respectively. Geologically, the area is underlain by the Awgu Formation known to predominantly consist of gray shale – negligible porosity and hence permeability, however, the presence of sandy horizons which form lens like bodies have been reported (Offodile, 2012). This paper proposes that the

confined aquifers are actually lens like sand bodies confined within the impermeable Awgu Shales as evidenced from the geological cross section, electrical resistivity data and borehole lithologic logs. These aquifers are limited in extent: both laterally (no artesian wells adjacent these wells) and vertically (geophysical data suggest an impermeable unit from 180m bgl). The source of recharge to these aquifers could be from the overlying layer which may have an impermeable matrix but may contain fractures in some parts; lateral ground water flow is also a possible source of recharge but requires further investigation.

4. CONCLUSIONS AND SUGGESTIONS FOR FURTHERWORK

From the preceding discussion, the presence of confined aquifers in Gandu, Lafia can be discerned. These aquifers are being exploited by means of boreholes which exhibit artesian conditions. Geology of the study area is such that the conventional confined aquifer in form of a laterally continuous permeable unit sandwiched between impermeable layers is highly unlikely. It is more likely that the aquifers in this case are lenses of permeable rock within the impermeable Awgu Shales. Data presented here is considered as preliminary on which further research will be built. Future studies will focus on more geophysical surveys to cover a larger area in order to establish the structure of the aquifers. Secondly source (s) of recharge need to be established e.g. through isotope studies for proper management of the aquifers.

5. REFERENCES

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