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Investigating clay deposit resistance and resistivity using ground tester model 6470-B

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Abstract

The resistance and resistivity of clay has been investigated at Wilberforce Island Bayelsa State, Nigeria. This research focused on investigating the resistivity of clay using ground tester model 6470-B. Objectively, this will be achieved by testing the resistivity of clay at different depths and investigating it resistivities. Furthermore, the resistivity of clay depends on ground water salinity, humidity and temperature. Therefore, clay resistivity values varies depending on the type of terrain. Moreover, series of resistivity can be computed from resistance data at various depths interval and same plotted against depths. Hence, this research imbibed the four point Wenner method which uses four electrodes spaced at equidistances across the surface of the ground in a straight line, which defines the testing depth into the soil (clay). Nevertheless, resistivity tests on clay wereinvestigated in four different locations in Niger Delta University Wilberforce Island, Bayelsa State, Nigeria. The data collected from the tests were analysed and represented graphically using Microsoft Excel 2013. The results obtained from the experiment shows that increase in the distance between the electrodes leads to decrease in the resistivity values which determines the level of corrosiveness in the soil (clay). At a depth of 0.25m, the resisivity value was 50.8 Ωm. Also, at a depth of 0.28m and 0.31m, the resistivity was 48.4 Ωm and 42.6 Ωm respectively. Thus, same distance at different depths of electrodes has high resistivity values. With a distance of 2m at a depth of 0.25m, the resistivity was 57.9 Ωm and at depths of 0.28m and 0.31m, the resistivity was 57.5 Ωm and 57.8 Ωm respectively. Consequently, this research further profer solutions whichare relevant, to geological analysis, the exploration andestimation of clay depositsand hydrological studies for ground water exploration and exploitation, which is also a medium to improve the country's economy.

Keywords: Clay resistance, clay resistivity, Wenner method, and ground tester.

Introduction

In the last few decades, drilling an oil or gas well and wire line logging the well for formation evolution have been a major activity in the exploration and production (E&P) sector. The oil and gas industry uses drilling and logging techniques to acquire continuous information about the formation's rock, to drill a safe, usable, and economic wellbore[1]. However, some geological formation that are composed of sandstone, clay, and shale are very threatening to E&P operations. Therefore, knowing the composition of the soil, mostly clay's resistance and resistivity is very important. A considerable amount of clay minerals is compose with 50% clay sized particles with clay minerals, which forms at least 25% of the total sampled deposit[2]. Clay minerals present in the reservoir plays a vital function. This function impacts both the capacity and production of the pay zone in the reservoir. This poor capacity and production of the pay zone, is due to the low effective porosity and permeability of the shale or clay formation. This explained that the clay's grain particle size are very small, and of poor void network[3]. Therefore, the presence of clay mineral in a reservoir as a geological formation, directly affects the reservoir properties and it economic viability. Clay minerals assist in the compression of organic matters under high temperature and pressure using the principle of adsorption, while acting as a catalyst to generate hydrocarbon. The hydrophobic nature of clay limits the E&P operations, thus many drilling challenges interaction of clay water, this causes it to expand as water molecules squeeze between lattice layers[4]. In addition, this increases the volume of the clay particles, reduces it density and often causes a reduction in rock permeability[5]. In the orient, oil exploration encompassed the prediction of the origin of oil and gas, its quality and quantity, all from organic source rock, in which in most cases is clay deposit.

Resistivity can be described as the capability of a clay substance or any geologic formation, to obstruct the flow of a supplied electrical current through it. Resistivity is very vital in investigating clay or rock properties. These tests on resistivity explain and predict what fluid is saturated in a given geologic formation. The test of resistivity disclosed that a clay formation which exhibits a poor conductive characteristic of electricity current, saturated with hydrocarbon. In contrast, those clay with good conductive characteristic of electricity current are saturated with saline water or water. However, resistivity is very difficult to measure owing to the complexity caused on the geologic formation during and after drilling of a well, and which may also occur during logging. Based on the defilement of formation resistivity, Hynes[3] outlined that environmental factors are also responsible for distortion of formation resistivity measurement. Accordingly, Anderson[6] proffered that various tools can be used to evaluate resistivity at different depths, to cushion the effects of the aforementioned factors militating against accurate measurement of resistivity. Moreover, the main concern in the development of resistivity logging devices have been focused at eliminating the response from unwanted zones of the formation and restoring near *in-situ* resistivity. As a result, the main goal of resistivity logging device is to output resistivity profiles, which can be accomplished by integrating devices with at least three, and if possible more depth of investigations should be used[7]. Generally, in the oil and gas industry E&P, clay reduces the permeability of any reservoir geologic formations or near soil surface, and this very predominate at the cap rock of the reservoir[8,9].

Therefore, clay minerals' resistivity determine the hydrocarbon saturation in the formation pore. Consequently, alternative methods for resistivity measuring systems have been designed and put into use to obtain the more accurate and reliable information under unfriendly and friendly conditions[5]. The resistivity of the shale or clay formation is a function of the amount of the quantity of water present, and the clay's structure and geometry of the voids. The shale formation or clay resistivity are estimated either by passing a known current through the core formation and measuring the electrical potential or by inducing a current distribution in the core formation and measuring its magnitude of the resistance. It should be noted that resistivity cannot be read correctly over the entire measurement range of the core sample. The resistivity of clay linearly increases as temperature increases. Though, the resistivity of clay can be expressed logarithmically. In another development, soil resistivity measurement can be used conveniently as a precursor, to identify ore deposit and clay deposit. Thus, testing for clay resistivity is very vital, but factors such as temperature of the soil, clay composition, moisture content of the soil, impact on the clay resistivity. From researches, it had been observed that, clay is hardly ever homogeneous, thus its resistivity varies with depths, and moisture content[10,11]. The usefulness of clay resistivity and resistance have been contextualized; however, there is still room to improve on existing methods for evaluating clay resistivity and resistance, this have been birth to new sophisticated commercial equipment. Therefore, this research is tailored at investigating the resistivity of clay in solving related problems in Wilberforce Island, Bayelsa state, Nigeria.

Materials and methods

Materials: i. Ground tester model 6470-B, ii. Four electrodes, iii. Cable wires, iv. Measuring tape rule, v. Umbrella, vi. Clay.

Programming the Distance for Electrode Placement: The distance can be programmed before or after the measurement. If it is not programmed, only the values of $R_{S\text{-}ES}$ will be displayed since the value of the resistivity (ρ) remains indeterminate.

Therefore, the following is carried out: i. Set the switch to ρ, ii. Press the 2nd button, then the Distance button. The hundredths will blink. iii. To modify the hundredths (of meters or feet), press the right button and then the up button until the desired digit is displayed (0-9). iv. To select and modify the units and tenths of a unit, press the right button and the up button until the desired digits are displayed (0.0-9.9). v. To terminate the programming of distance, press the 2nd button and then the DISTANCE button. Hence, it is also necessary to program distance d.

Wenner Method[12]: i. Set the switch to ρ (Figure-1), ii. Place the 4 earth electrodes, on a straight line, at a distance d from one another and at a depth of $p < 1/3d$. Distance d must be between 2 and 30m (Figure-2). iii. Connect the cables to the electrodes, then to terminals H (Z), S (Y), ES (Xv) and E (X) in sequence. iv. Program the distance into the instrument.

In order to avoid electromagnetic interference, it is best to unwind the full length of each cable from the reel, to keep the cables as far apart as possible on the ground taking care not to form loops and to avoid placing the cables near or parallel to metallic conductors (cables, rails, fences).

Start the measurement by pressing the START/STOP button. To display the measurement parameters, press DISPLAY several times. Then the device displays the parameters. Hence, to measure the resistance of the auxiliary electrodes H (Z), S (Y), ES (Xv) and E (X), or if the electrodes resistance is too high, start the measurement by a long press of the START/STOP button.

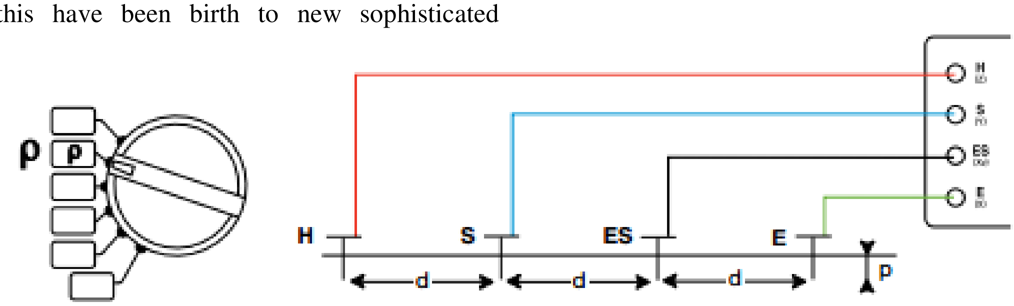

Figure-1: Four point Wenner method of measuring resistivity[13].

H (Z) – an auxiliary electrode through which a measurement current flows. S (Y) – an auxiliary electrode used for measuring the potential of the reference earth. The voltage, which is proportional to the resistance of the earth connection, is measured between this electrode and the earth electrode. ES (Xv) – a connection on the earth electrode used for measuring the potential of the earth electrode. E (X) – a connection which is buried in the earth and makes electrical contact with it.

Memory function: Measurement results can be saved by performing the following: i. Press the MEM button. The tester will automatically suggest the next free memory location (Free message). ii. Press the MEM button a second time to save to the OBJ/TEST location. iii. Without saving your results, press DISPLAY to exit MEM mode.

Erasing measurement from memory: i. Set the switch to SET UP. ii. Push once on the MEM button to display the number of free and available records, iii. Push a second time on the MEM button. iv. The display will show 'dEL ALL'. Change the blinking No to YES. Then perform a long press (>2s) on the MEM button. This will delete all saved records. v. To exit without erasing perform a short press on the MEM button.

Results and discussion

This section will focus basically on the data collected for the purpose of answering research questions formulated in the study, presented and analysed giving interpretations on the analysis. Test were conducted to analyse the opinions that regard the test of this research – 'Investigation of clay resistance and resistivity using Ground tester model 6470-B'.

Analysis of personal variables: From the soil group such as clay, a site was chosen and resistivity measurements were taken in different locations at depth of 0.25m, 0.28m, and 0.31m respectively. The instrument used was the Ground tester model 6470-B which uses the four point method to calculate resistivity values. The electrode distances were maintained at 2 to 4m depending on the depth of the electrodes. Therefore, the following graphs analyses the values gotten from the various tests conducted in this research. The results are presented in Figure-3 to 6.

Figure-2: Kaolinite clay undergoing resistivity test.

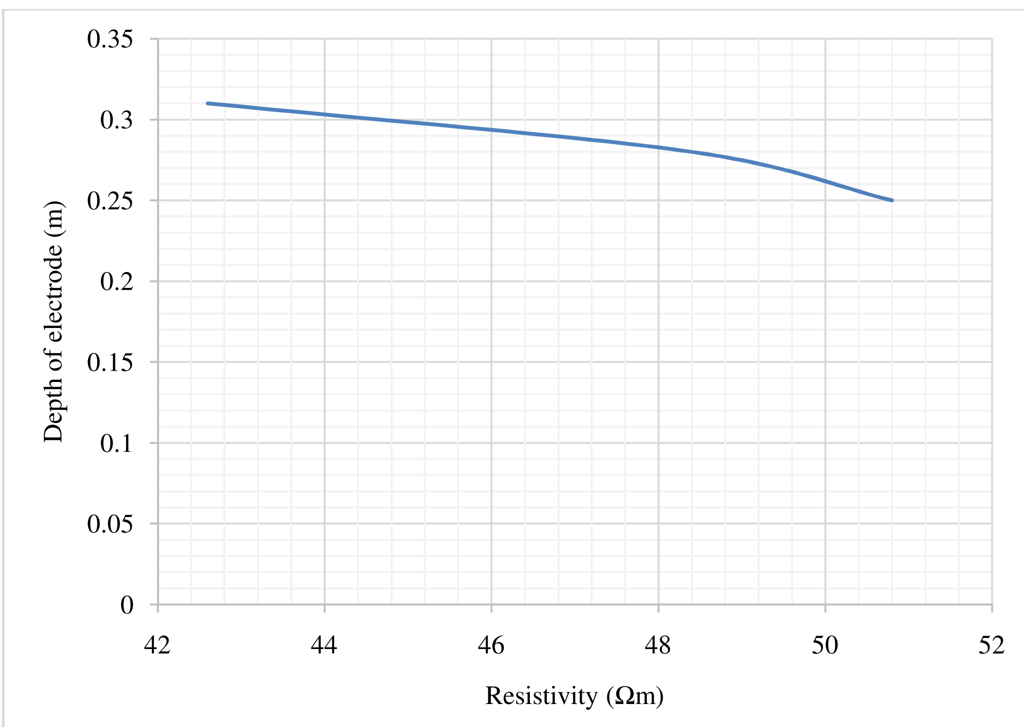

Figure-3: A graph of Depth of electrode against Resistivity values (test 1).

Figure-3 describes the resistivity values of clay at different depths. Also, it was observed that increase in the distance between the electrodes leads to decrease in the resistivity values of clay. At the depth of 0.25m, there was a slight increase in the resistivity value (50.8Ωm). Hence, the depths at 0.28m and 0.31m has slightly low resistivity value.

Furthermore, at the depth of 0.25m and 0.28m, the resistivity has a high value of 59.9Ωm and 52.2Ωm compared to the depth of 0.31m with low resistivity value of 46.8Ωm, this is shown in Figure-4. As indicated in Figure-4, increase in the distance between the electrodes leads to decrease in the resistivity value of clay.

Increase in the distance between the electrodes leads to decrease in the resistivity values of clay. Therefore, from the above graph at the depth of 0.25m, the resistivity was high with a value of 54.2Ωm compared to the resistivity at the depth of 0.28m and 0.31m with low resistivity values of 43.0Ωm and 32.1Ωm.

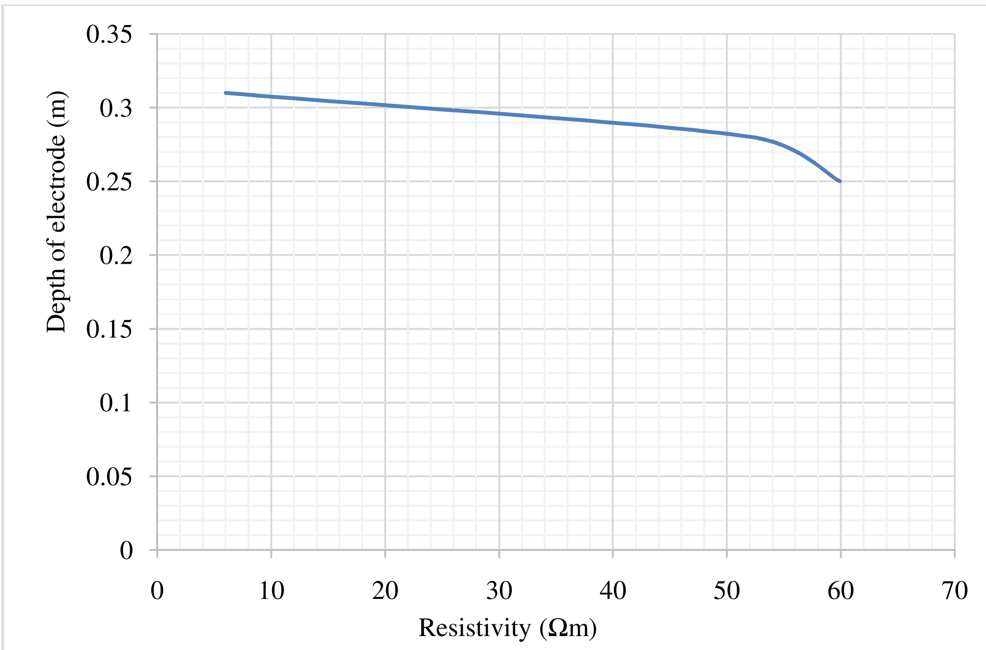

Figure-4: A graph of Depth of electrode against Resistivity values (test 2).

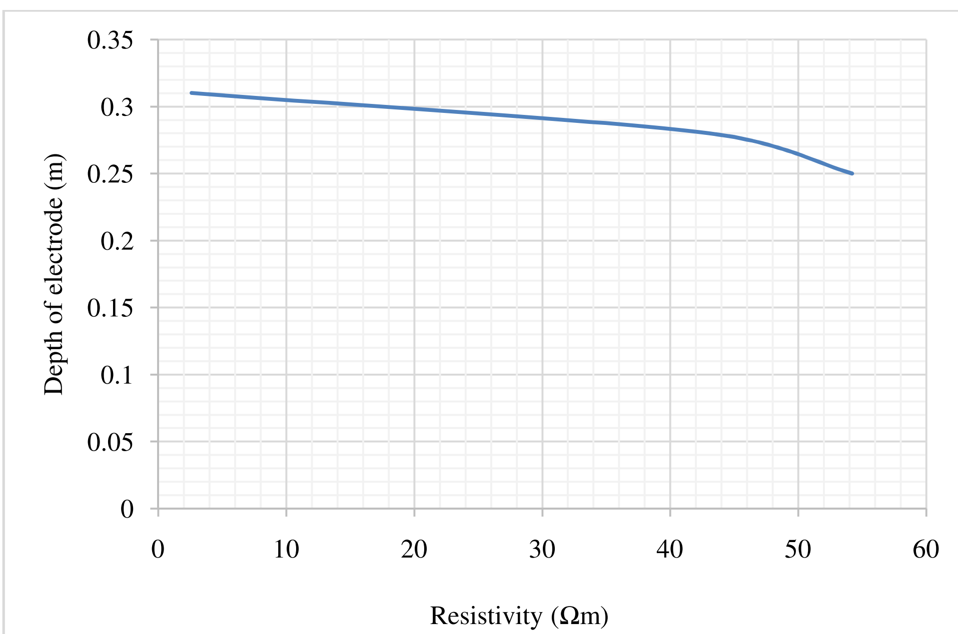

Figure-5: A graph of Depth of electrode against Resistivity values (test 3).

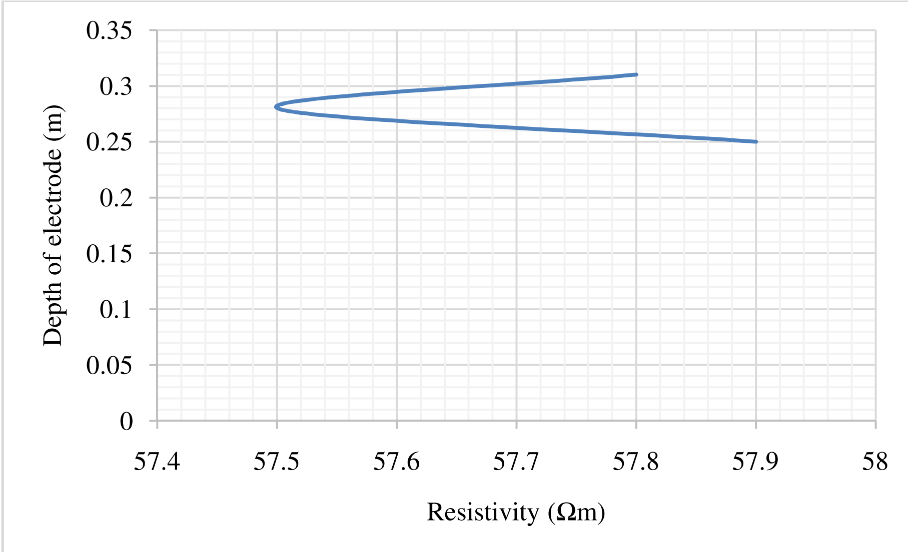

Figure-6: Resistivity values at different depth of Kaolinite clay (test 4).

Figure-6 shows that, the same distance at different depths, depicts that, the resistivity values slightly varies. Also, at a depth of 0.25m, the resistivity value was high which gave a value of 57.9Ωm. Similarly, at a depth of 0.28m, the resistivity value was also high which gave a value of 57.5Ωm. More so, at a depth of 0.31m, the resistivity value was high with 57.8Ωm. Furthermore, it was observed that due to the type of clay (highly compacted), high long press of the device was required to attain various resistivity values.

Discussion: The tests conducted shows that, the resistivity values of clay at different depths decreases. At was also observed that, an increase in the distance between the electrodes leads to decrease in the resistivity value of clay. At 0.25m, there was slight increase in the resistivity value (50.8Ωm). Hence, the depths at 0.28m and 0.31m has a slightly low resistivity value. Also, from the second test conducted, at the depth of 0.25m and 0.28m, the resistivity has a high value of 59.9Ωm and 52.2Ωm compared to the depth of 0.31m with low resistivity value of 46.8Ωm. From the graph above, increase in the distance between the electrodes leads to decrease in the resistivity value of clay. Furthermore, the third test shows that with an Increase in the distance between the electrodes, there would be a decrease in the resistivity values of clay. Therefore, from the above graph at the depth of 0.25m, the resistivity was high with a value of 54.2 Ωm compared to the resistivity at the depth of 0.28m and 0.31m with low resistivity values of 43.0Ωm and 32.1Ωm. Hence, the fourth test entails that with the same distance at different depths, the resistivity values slightly varies. Also, at a depth of 0.25m, the resistivity value was high which gave a value of 57.9Ωm. Similarly, at a depth of 0.28m, the resistivity value was also high which gave a value of 57.5Ωm. More so, at a depth of 0.31m, the resistivity value was high with 57.8 Ωm. Furthermore, I observed that due to the type of clay (highly compacted), high long press of the device was required to attain various resistivity values.

Conclusion

Based on the findings, the research concludes as follows: i. Testing the resistivity of clay at different depths resulted, to low and high resistivity values. ii. The investigation of clay resistivity using ground tester model 6470-B at Wilberforce Island shows that the resistivity values with same distance of electrodes at different depths slightly varies.

Recommendations: Based on the findings in this research, it is strongly recommended that: i. Ground tester model should be used when carrying out a test on the resistivity of clay at different depths and at different locations. ii. Also, it is advisable to locate the area of lowest clay resistivity in other to achieve the most economical grounding installation. iii. Besides the use of the Wenner method previously described in this research for calculating resistivity based on the depth of electrodes used, other methods can also be practiced in situations where Wenner is not the most suitable.

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