

## Investigation of Groundwater Potential in Oreke Community, Southwestern Nigeria Using Electromagnetic Method

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### ABSTRACT

The assessment of groundwater potential using the electromagnetic method at Oreke community located in part of Kwara State, Nigeria was carried out to determine the groundwater potential, depth and productivity of the aquifer in the study area. A combination of eight traverses was investigated using the electromagnetic method by means of PQWT –TC 200 geophysical equipment. The information recorded with the use of PQWT-TC 200 at each reading station was plotted at the midpoint of the distance between the two electrodes along the established profiles. Electrode spacing used was between 5 – 10m and a station interval of about 0.5 – 2m was maintained. Based on the results generated, it was revealed that the study area has good groundwater potential except for traverse seven (7) which do not show good groundwater potential for domestic use. The interpretation of the electromagnetic data obtained within the study area showed that the depth to the aquifer in the study area is between 120m to 195m which shows good yield and potential zones.

**Keywords:** Groundwater; Electromagnetic; Aquifer; PQWT-200; Oreke

### Introduction

Water is a highly prevalent resource found abundantly on the Earth's surface. According to Willis *et al.* (2011), the necessity of it for the everyday sustenance of every individual is evident. Water is commonly referred to as the most universal solvent (Lindström, 2002). The existence of water resources plays a crucial role in shaping our livelihoods and economic endeavours (Nwankwo and Igboekwe, 2011). The availability of water is crucial for human existence, as it is widely recognised as one of the most valuable and

precious natural resources (Osunkiyesi, 2012; Gbadebo *et al.*, 2022). In the past, rainwater and water from streams were the major sources of water, but they are unsuitable sources of drinkable water because of pollution and contamination as a result of human activities (Abiola *et al.*, 2013).

Groundwater exploration is defined as the application of surface or subsurface techniques to identify subsurface formations that has the ability to store and sustainably transmit water for human consumption (Kekwaru *et al.*, 2022). Sources of groundwater include water that infiltrates from

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surface water, such as lakes, river, and streams. However, groundwater is the most suitable source of portable water. Also, groundwater is precipitation that penetrates the soil through the zone of aeration and finally reaching the water table and become part of the groundwater system.

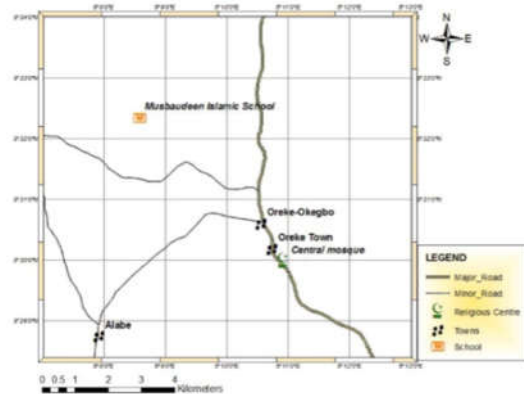
In recent years, there has been a notable increase in interest in the field of groundwater exploration. This spike can be attributed to the recognition of groundwater's crucial role in sustaining livelihoods, enabling development, and fostering industrial growth. The exploration of groundwater in certain areas, particularly those characterised by hard rock topography, poses notable difficulties and intricacies as it relies on the thickness of the weathered or fractured layer situated above the underlying basement. Nevertheless, it has been argued that doing a thorough hydrogeological analysis can be a useful strategy for addressing these difficulties (Al-Garni, 2009). The Oreke settlement currently relies on shallow, hand-excavated wells for its water supply. The discovery of marble deposits has resulted in an increase in population, increasing the demand for improved groundwater resources, particularly for potable use, agricultural operations, and other household applications. This research is being conducted to identify underlying geological frameworks conducive to groundwater accumulation and to determine the depth at which feasible aquifers can be found for borehole installation within the study region.

## Materials and Methods

### Location and Geology of Study Area

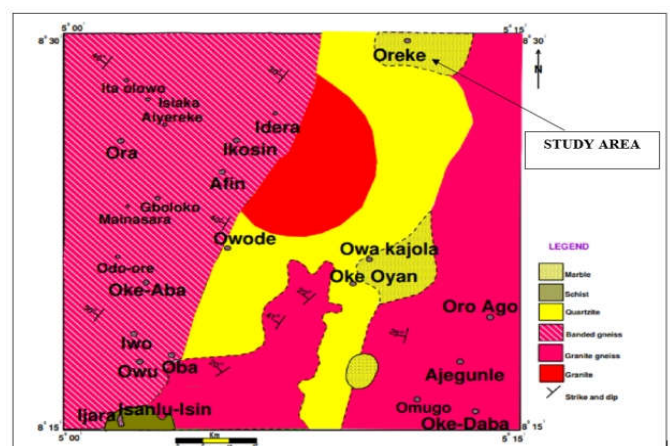
Oreke is a small community located in Ifelodun Local Government in Kwara state, Nigeria. It has a geographical coordinate of 8°31'0" North, 5°11'0" East (Figure 1). Oreke community is richly blessed with marble which has been continuously mined for over two decades. The area under study is essentially a Precambrian suite of intensely deformed metasediments which occupy a

linear belt underlain by rock of migmatite gneiss complex (Adedoyin, 2015).



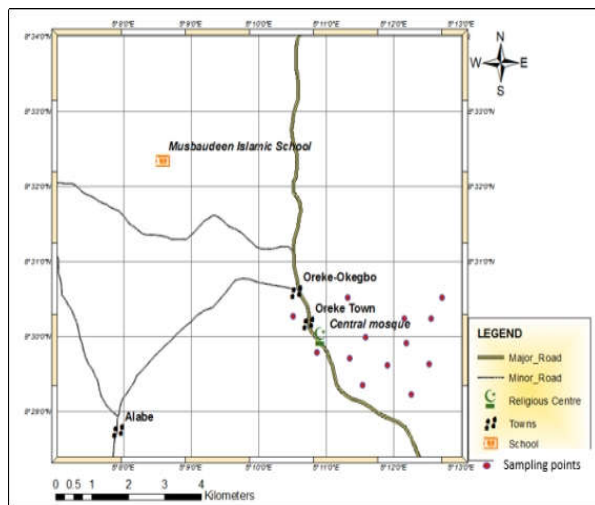
**Fig.1:** Location map of study area

The rock types found in the study area include; quartzite, schist, marble, pegmatite and dolerite. The marble deposit has a general trend from North-South around Elewa River, extending for about 2.5km as shown in Figure 2. It is coarse to medium-grained in texture, whitish to grayish in color and lies between the quartzite ridge and mica schist. The Oreke marble, a very large deposit of dolomitic marble in southwest Nigeria, has been well studied in terms of its mineralogy and industrial applications (Adedoyin, 2015) but its effect of its mining on groundwater quality on the area is needed to be studied.



**Fig 2:** Geological map of Oreke (After Okunlola *et al.*, 2015)

The geophysical method that was adopted for this study involved the electromagnetic method by means of PQWT-TC 200 series geophysical prospecting device that uses natural electric field source as a working tool to map out resistivity contrasts in the subsurface along eight (8) sampling points (Figure 2). The PQWT-TC 200 consists of two electrodes and in order to accurately locate anomaly in the subsurface, a measuring tape was used along the point to be surveyed. The information recorded at each reading station was plotted at the midpoint of the distance between the two electrodes along the established profile. Electrode spacing used was between 5 – 10 m and station interval of 2m was maintained. After taken a particular reading, the first electrode was moved to 2m while the second electrode to 12m and the movements continued until the total length of the profile was achieved.



**Fig 3:** Location map of study area showing data points

The profile generated by the PQWT does not require any special software for processing as the PQWT device possesses an in-built program that plots the readings to generate the profile which were displayed instantly after each data collection exercise. To ensure the integrity of PQWT data, the following precautions were taken: All connections and disconnections were done only when the resistivity meter was switched off.

Electrodes were properly hammered down to make good contact with the ground and there was no leakage of current through the cables during data acquisition.

**PQWT-TC geophysical prospecting**

This study employs the PQWT-TC, a geophysical prospecting instrument designed to measure the Earth's electromagnetic field's electrical component. The instrument utilises natural electric fields as functional tools to delineate subsurface resistivity variations. The principle underlying this approach is the generation of a plane electromagnetic wave that propagates perpendicularly into the Earth's subsurface. This incites an induced electromagnetic field with a frequency identical to the original field. Surface-level observations of electric field strength provide insights into the resistivity distribution at varying depths within the Earth's subsurface.

It should be noted that while qualitative analyses are feasible through mere observations of electric field strength, quantitative resistivity analyses are not possible without additional data. Therefore, the study focuses on interpreting the electric field's strength at multiple frequencies to gain an in-depth understanding of the Earth's electrical structure at different depths. In areas distant from the field source, the electromagnetic field can be approximated as a plane wave with a distribution nearly perpendicular to the Earth's surface. The change of the field is subject to Maxwell equation given as:

$$\rho_s = \frac{1}{5f} \left( \frac{E_x}{H_y} \right)^2 \tag{Equation 1}$$

In equation 1 above,  $\rho_s$  represent AC resistivity,  $f$  is the operating frequency,  $H_x$  is magnetic field component and electric field component respectively. According to the attenuation field characteristics of the plane electromagnetic wave propagating in the formation, the penetration depth of the electromagnetic wave in the medium is:

$$\delta = 503.3\rho f \quad \text{Equation 2}$$

In the equation 2,  $\delta$  is the representative depth. It can be seen from the above, the penetration depth of electromagnetic waves and frequency, resistivity. When the frequency remains constant, an elevation in resistivity is correlated with a concomitant augmentation in penetration depth. On the other hand, in cases where resistivity remains consistent, a decrease in frequency demonstrates a positive correlation with an increase in penetration depth. Therefore, altering the operating frequency will allow for the manipulation of depth. The constancy of the magnetic field component inside a limited region allows for its treatment as a stable entity. Hence,

the correlation between the electric field component and resistivity can be used to evaluate the high and low resistance characteristics of the geological formation. The equipment has been specifically engineered to measure and determine the frequency of electromagnetic waves.

### Result

Points were chosen by carefully observing the profiles utilizing the legend in the profiles and the relief of the subsurface picture because the interpretation of the map produced by the PQWT is completely qualitative. The colours which are blue, light blue, red, yellow, orange, and green must also be carefully observed.

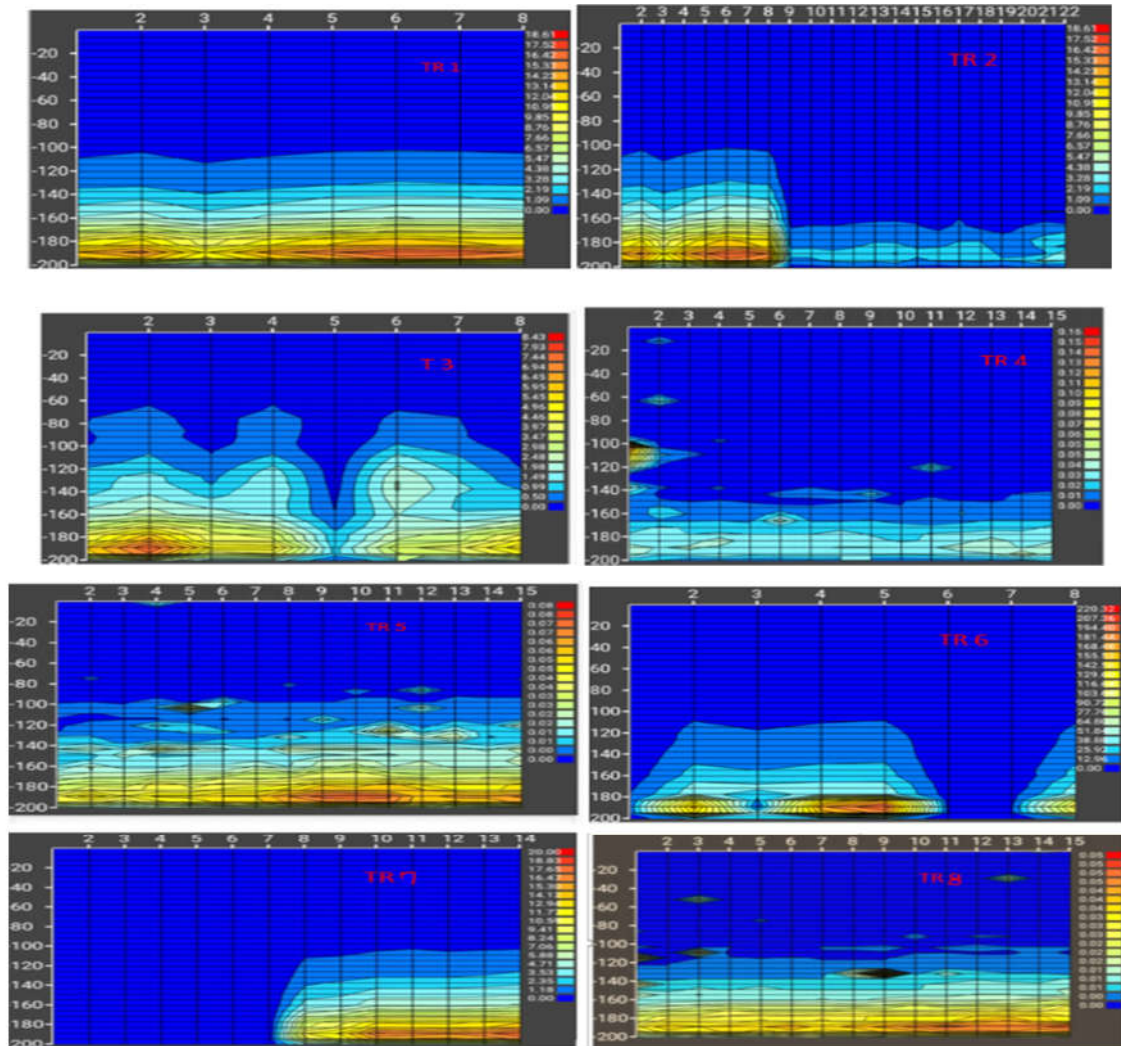


Fig 4: Showing typical 2-D profiles generated using the POWT-TC device for traverses 1 to 8

These colour changes indicate various resistivity changes in the groundwater exploration zones.

Figure 4 displays representative 2-D profiles created using a PQWT instrument. These profiles feature graphs that depict both real and imaginary components for each traverse, derived from plotting depth against station interval.

Traverse 1 indicates good chances of getting water in the zone by drilling to a depth of 140m at point 3 and also shows that the zone possesses soft rock formation or water bearing formation which will be capable of yielding water at an appreciable amount which can serve multiple purposes. In traverse 2, there are good chances of getting water at point 3 to a depth of 140m and also at point 19 to a depth of 195m, and it also shows that the zone is capable of yielding water at an appreciable amount for both domestic and mining purpose. Traverse 3 shows high likelihood of getting water at point 3 down to a depth of 130m as well and good amount of water would likely be produced and traverse 5 indicates that the water bearing points for this traverse occurs at points 2 and 3 to the depth of 120m, and it also shows that it would yield water at an appreciable amount. Traverse 5 demonstrates water bearing points that occurs at a depth of 100m and above. The explored subsurface contain a number of fractures which are important geologic condition for groundwater exploration.

Traverse 6 indicates chances of getting water at point 3 to a depth of 120m and above and there is a presence of good aquifer at about 170m, and it will also yield water at an appreciable amount for multiple uses either for domestic or industrial uses. The image shows that traverse 7 indicates water bearing zone at point 12 and to a depth of 140m and it will yield water at an appreciable amount which can only be sufficient for domestic usage on. It is not prolific and it is not advisable to be drilled for commercial purpose.

Traverse 8 shows a good representation of aquifer in which is advisable to drill for borehole development because of the fracture and low

resistivity points present on it. It will be recommended for drilling at least 140m to 160 meters for a prolific discharge of water.

### Conclusion

The groundwater potential of Oreke community was investigated using electromagnetic method by means of PQWT geophysical equipment. According to the results of the study, the region has good groundwater potential. The study also indicate that the potential groundwater zones are deep in the study area but they have good aquifers that can produce a high amount of water for domestic, agriculture and industrial uses with depth of aquifer ranges between 120m to 195m. This study has also proved that PQWT geophysical equipment can be adopted in areas of space constraint to delineate water bearing zones. In order to have more understanding of the groundwater potential of the aquifer zones in the study area, other geophysical method such as electrical resistivity method could also be employed.

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