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Detection of Fractures for Groundwater Development in Oha Ukwu using Electromagnetic Profiling

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ABSRACT: Electromagnetic profiling technique was used in this study to detect fractures for groundwater development in Oha Ukwu Local Government Area in the Albian Asu River Geological Formation. The data showed that conductivity anomalies, 297-506mmho/m.was obtained along the fractured zone. Where the conductivity values did not change much, (12.3-37.9mmohm/m), the rock was not generally fractured, for instance, between the distances 0 and 800m; and 1000-1200m. It was discovered that the higher the peak, the deeper the rock fracture. This was confirmed from the cross section drawn from the manually contoured values of the data. It was further discovered that the producing water borehole along the traverse which coordinate is 007.966E and 06.466N and lies between 960 and 1000m situates within the fractured zone while the abortive wells fall within the non-fractured zone @ JASEM

The application of electromagnetic techniques to the measurement of terrain conductivity has been described (Keller and Frischnecht, 1966 and Wait, 1962). The present study is based solely on practical field survey with electromagnetic equipment – Geonics EM 34-3, to solve the problem of drilling abortive water wells The survey area is located in the northwestern part of Ebonyi state, Nigeria between longitudes 7°55' – 8°00'E and Latitudes 6^0 20' - $6^0$25'N in the Benue Trough. (Fig.1)

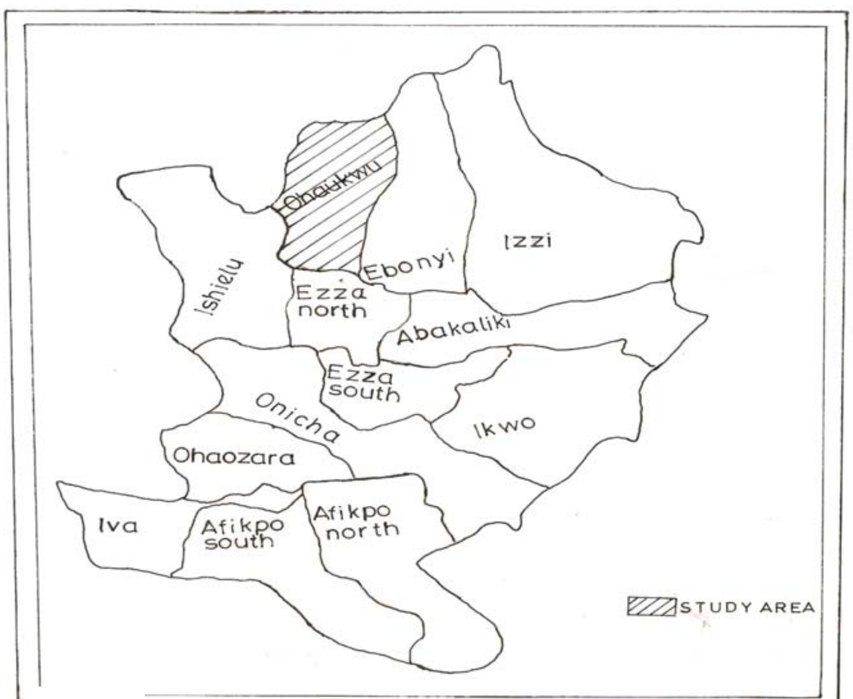

Fig.1 Sketch map of Ebonyi State Showing the Study Area

The application of geophysical methods in the study of Benue trough geology has centered mainly on mapping of regional structures of the trough using mainly gravity method (Ajayi and Ajakaiye 1981)), aeromagnetic anomaly interpretation (Ofoegbu and Onuoha, 1991) resistivity and magnetic surveys (Mamah et al, 2000) Spontaneous potential survey (Ugwu, 2006) . Drilling of abortive water boreholes is common in this shally area. For this reason acute water shortage is often experienced in this environment. The surface sources of water in the area is seasonal, hence the dire need to exploit the groundwater resource no matter how poor the yield might be. However, the study area is underlain by

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shales, clays and mudstones of the Albian Asu River Group. Consequently the occurrence of groundwater is due largely to the development of secondary porosity and permeability by weathering and/or fracturing of the parent rocks (Olurufemi and Fasuyi, 1993; Edet and Okereke, 1997, Olayinka et al 1997 and Ugwu, 2009). While the weathering profiles are highly variable in the formation concerned especially in thickness, the fracture pattern which is the target of exploration is unpredictable. The target aquifers (fractures) are concealed by thick overburden especially along unpredictable fracture zones. The objective of this research is to detect fractures in this environment which is the secondary aquifer and to demonstrate the importance of electromagnetic surveys in basement or shally environment before attempting to drill a borehole to avoid drilling abortive water wells.

GEOLOGY OF ABAKALIKI: The sequence of events that led to the formation of the Benue trough and its component units are now well documented (Benkeliel, 1982; Ofoegbu, 1984). The lower Benue trough is underlain by a thick sedimentary sequence deposited in the Cretaceous. The Albian Abakaliki shales (Formation) is an inlier in the medial portion of the Abakaliki Basin. It is continuous for about 180km stretching from Oju, north of the Workum hills in the northern part through Abakaliki to Lokpaukwu in the southern limit (Umeji, 2000). It is more or less spindle shaped with the broadest middle zone at Abakaliki up to 65km across. The rocks are packages of thinly layered olive green to dark gray blush black shale, which are frequently calcareous, subordinate fine-grained micaceous sandstone; micaceous siltstone, sandy shales and shelly limestone are present. The sandstones are feldspathic (15%), rock fragments mainly muscovite (3%) and matrix comprising clay and silt-size quartz mica, feldspars and heavy minerals (16%) (Umeji, 2000). These sedimentary sequences were affected by large scale tectonic activities which occurred in two phases and culminated in the folding of the sediments. The predominant compressional nature of the folds that developed during this period is revealed by their asymmetry and the reverse faults associated with them (Ofoegbu and Onuoha, 1991). The development of Geology of Abakaliki occurred in a complete orogenic cycle including sedimentation, magmatism, metamorphism and compressive tectonics (Benkeliel, 1988).

HYDROGEOLOGY OF THE STUDY AREA: The study area is located within the cross-River Basin hydrogeological province of Nigeria. The Cross River Basin is a hydrogeologically problematic groundwater basin (Ofodile, 2002). The Awgu-Enugu escarpment forms a water divide between the west trending Anambra Basin and the East trending Cross River Basin. In the study area (Fig. 1) the major litho units within the Albian Abakaliki Formation is shale. Other minor litho component includes limestones, feldsparthic sandstone and siltstone with disseminations of pyrites and some pyroclastics. Low permeability rocks such as shales, clays, mudstones and siltstones underlay the study area. These rocks generally do not allow water to flow through them and they do not store significant quantities of groundwater, hence the occurrence of surface water such as Rivers, Ebonyi, Asu, Okporo and other smaller rivers. Prolonged exposure of these rocks to a tropical climate, changes the top few meters to a thick complex soil known as Ferrosol. Generally a ferrosol comprises a very permeable layer near to the surface underlain by thick plastic clay which changes to a mudstone with depth (McDonald and Davies, 1998). The major litho component above, generally, has very low transmissivity and therefore not regarded as a good aquifer. Fracture permeability is therefore, very important for groundwater development. The objective should be to detect fractured or weathered mudstones, shales, clays, siltstones and sandstones (where available) hence the need for an electromagnetic survey.

MATERIALS AND METHODS

Geonics EM 34-3 terrain conductivity meter was used in this electromagnetic profiling to gather the data. The Profile starts from the Ngbo court to Ogwudu junction (towards Effium). The length of the traverse is one thousand meters (1000m) with inter-coil separation of 20m, taken normal to the strike.

GEONICS EM 34-3: This two-man portable equipment is based on the principle of electromagnetic induction. The time-varying magnetic field arising from alternating current in the transmitter coil induces very small currents in the earth. These currents generate a secondary magnetic field H_S which is sensed, together; with the primary field, H_P, by the receiver coil. The secondary magnetic field is a complicated function of the inter coil spacing, s, the operating frequency, f, and the ground conductivity, σ.These are incorporated in EM 34-3 design McNeill (1980), whence,

$$H_S / H_P \approx i\omega\mu_o\sigma s^2 / 4 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where H_S=secondary magnetic field

H_P=primary magnetic field at the receiver coil.

$\omega = 2\pi f$

f =frequency (Hz)

μ_o =permeability of free space (Darcy)

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σ =ground conductivity (mmho/m)
s = intercoil spacing (m)
$i = \sqrt{-1}$

The apparent conductivity indicated by the instrument from (1) is

$$\sigma_a = 4/\omega\mu_o s^2 (H_S / H_P).......(2)$$

A search coil is held horizontally (to measure the vertical component) and vertically (to measure the horizontal component). To measure the terrain conductivity, the transmitter operator stops at the measurement station, the receiver's operator moves the receiver coil backwards or forwards until his meter indicates correct inter-coil spacing (in this case 20m). Then he reads the terrain conductivity from a second meter.

Three different intercoil spacing are possible with Geonics Em34-3 equipment, 10m, 20m, and 40m, each operating at different frequency. McNeill (1980) showed that horizontal and vertical orientation of the equipment has different responses with depth. Barker (1992) calculated the depth of penetration for the three coil separations (10m, 20m and 40m) as 3.7m, 7.6m and 15.2m respectively for vertical coils and 8.7m, 17.4m and 34.8m respectively for horizontal coils. The vertical coil reading gives information about the shallow zones while the horizontal coil penetrates deeper into the fractured zones. An inter-coil separation of 20m was maintained throughout the electromagnetic profiling. The Profile crosses a productive water borehole at a distance between 960 and 1000m, at a coordinate of 007.966E and 06.466N. The profile was plotted, Em reading (conductivity – mmho/m) both the vertical and horizontal resolution vertically against the distance in meters horizontally (Fig.2).

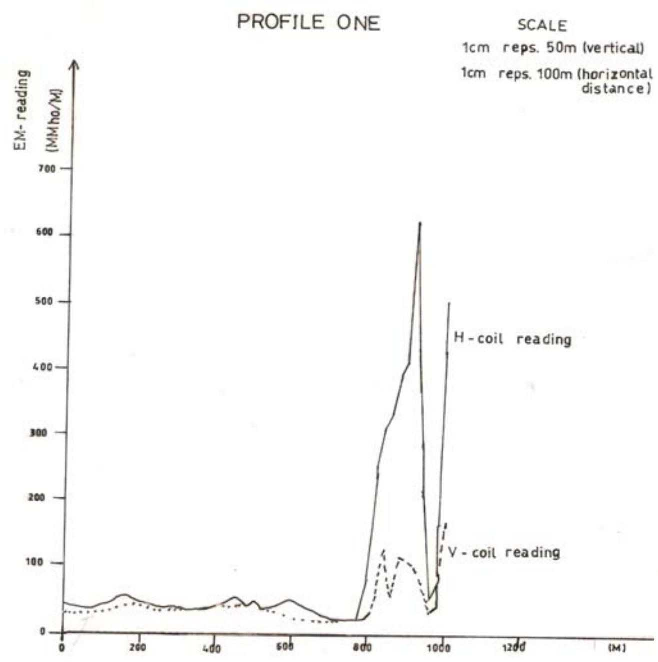

Fig.2 **Vertical and Horizontal Coil Resolution from Profile 1**

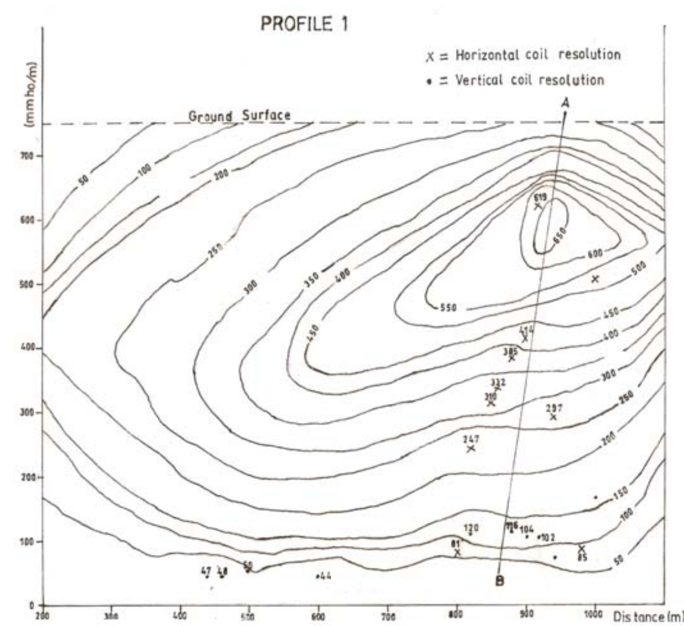

Fig.3 **Contour Map of Profile 1**

The profile was later contoured with a contour interval of 50m (fig.3).

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A cross section (A-B) was drawn across the peak of the profile anomaly (Fig.4).

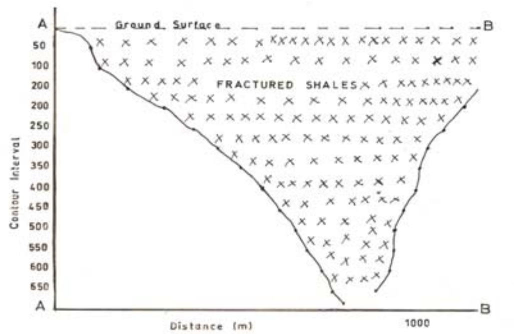

Fig 4 **Cross Section A-B of Fractured Shales from Profile 1**

The electromagnetic technique for citing of water boreholes is more prevalent in crystalline and basement areas. However, in sedimentary hydrogeological problematic areas, like the area under study, the electromagnetic method is found useful (to detect fractures) for groundwater development (Ugwu, 2009).The electromagnetic instrument measures terrain conductivity rather than resistivity. Completely dry shale/clay is an aquitard and an insulator. Groundwater development here utilizes fractures developed within the shale/clay and any introduction of moisture into the fractures changes them from insulators to conductors. The electromagnetic method is employed to identify high conductivity anomalies which are thought to be the result of moisture contents from weathering or fracturing.

RESULTS AND DISCUSSION

The electromagnetic profiling traverse was carried out in the above direction normal to the strike in Oha Ukwu Local Government Area. The results/data obtained (both vertical and horizontal coil resolutions) in conductivity (mmho/m) are plotted vertically against the distance (m) traversed in a horizontal direction. The result is presented in figure 2. This result is further contoured manually with a contour interval of 50m and cross section drawn across the highest peak anomaly of the profile. These are further presented as figures 3 and 4 respectively. The conductivity of the rock is generally high at the fractured zone that is (297-506mmho/m) (Fig 2). Where the conductivity values did not change much the rock was generally not fractured (McNeil, 1980, Ugwu, 2009). This was observed in the figure 2 between 0 and 800m and the abortive wells are located here. The higher the peak the deeper the rock fractured. This can be verified from the cross-section of the contoured profile (Fig.4). Clay/shale near the surface where the rock has little fracture and the moisture content low exhibit low conductivity values but with increasing depth the conductivity values increase as shale/clay become more fractured and saturated with water. There are two abortive wells and one producing water borehole which coordinates is 007.966E and 06.466.N along the profile. This research explains why abortive and productive water wells could occur along this same stretch of road. It was discovered that the productive well situates within the fractured shale while the abortive well does not. This emphasizes the importance of electromagnetic survey in a shally terrain before a water borehole construction is made.

Conclusion: The research has revealed the reason for the occurrence of abortive and producing wells within the research area. It has been shown that producing wells occur within fractured zones while abortive wells occur within the non-fractured zones. The fractured zones within the study area have been delineated to guide future drillers in their subsequent operations The research has shown the importance of Em survey within the Abakaliki zone before any borehole drilling is carried out.

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