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Integrated Geophysical Investigation of a Suspected Spring in Igbokoran, Ikare-Akoko, Southwestern Nigeria

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Abstract: *An integrated geophysical investigation involving self potential (SP), very low frequency electromagnetic (VLF-EM) and electrical resistivity methods (VES) were conducted around a suspected spring in Igbokoran, Ikare Akoko, Ondo State, Nigeria in other to understand the nature of the spring as well as evaluate the feasibility of ground water development in the area. Three geophysical traverses of length 240m each were established in the study area in approximately E-W direction. VLF-EM measurements with station spacing of 10m was used as reconnaissance to delineate conductive zones between 70-160m along traverse 1, 80-170 m along traverse 2 and 60-180m along traverse 3.This was then followed by a total of six (6) VES stations along traverses 2 and 3 using the Schlumberger array with electrode spacing (AB/2) ranging from 1 to 150m. Three geoelectric layers (Top layer, weathered layer, and fresh basement) were delineated along all traverses and a suspected fractured basement along traverse three .The Self Potential (SP) measurements were carried out at 5m electrode separation employing the total fixed base array. SP profiles were generated which show anomalies with short negative amplitudes some of which coincides with the spring zone. From the geophysical investigation, the spring is suspected to be fault induced but cannot be recommended for groundwater development due to the thin overburden and the low fracture density of the basement.*
Keywords:-*Geophysical, Integrated, investigation, Spring, Igbokoran.*

I. Introduction

In most developing countries like Nigeria, access to portable water is a serious problem. Most rural dwellers rely on rain water, streams and in some fortunate communities, springs for their daily supply of water. Springs which have had several mythical explanations in the past, have doubtlessly served as an important source of water for both nomadic and agrarian people since prehistoric times. Today, we know that a spring is a location where groundwater naturally emerges from the Earth's subsurface in a defined flow and in an amount large enough to form a pool or stream-like flow (Water Encyclopedia); we also know that springs are fed by groundwater, which in turn is fed by infiltrating precipitation.

Springs are usually formed when the ground water, which is constantly under pressure, is forced out through natural vents in the ground such as faults, fractures and joints or points where the water table have been brought very close to the surface by erosion and other activities. Several factors are considered when classifying springs. They include: The source of the spring, The Temperature of its water and the volume of discharge. Using source as a criteria of classification, there are different types of springs, some owe their origin to the arrangement of the pervious and the impervious layers (e.g. stratum springs, overflow springs, valley springs and bourne springs) while others are controlled by geological structures (joint springs and fault springs) (Olorunfemi et. al., 2000).

Structural features with hydrogeological significance in crystalline basement complex rocks include faults, lithological boundaries/contacts, dykes, network of joints, fractures/fissures and shear zones (Olorunfemi et. al., 2000; Mohammed 2007). These geologic features may deform the basement rocks creating inhomogeneities which in turn enhance groundwater storage and groundwater flow and the occasional appearance of seepage or springs (Mohammed 2007; Olorunfemi et. al., 2000).

Due to the nature of their source, springs remain an excellent source of potable water which rarely require any form of treatment and can sustain a very large community if the storage capacity is large, (Olorunfemi et.al. 2000). Also, Beyond serving as a source of portable water, springs have enriched many communities and even countries through tourism and have been used for a variety of human needs including, irrigation, powering of mills, navigation, and more recently for electricity generation (Wikipedia). It is on this note that integrated geophysical methods involving the self potential (SP), very low frequency electromagnetic (VLF-EM) and electrical resistivity methods (VES) were employed to assess the nature of a spring system in Igbokoran, Ikare Akoko, Ondo State, Southwestern Nigeria and to evaluate its potential for development into a water supply project that will serve its immediate environment and possibly beyond.

II. The Study Area

The study area is located in Igbokoran, Ikare-Akoko, in Akoko North West local government area of Ondo state (Fig 1). It lies between latitudes $7^0$35'- $7^0$36' and longitudes $5^0$35'- $5^0$38'. The study area is a relatively flat exposure which slopes southward and is bounded by a granitic gneiss exposure at the northern end. The dominant rock type in the study area is granite gneiss with specs of ferromagnesians (Fig 2) and it occurs as low-lying units. The rock is grayish in colour being rich in light coloured minerals notably quartz. The other minerals present are biotite and feldspars (microcline). The strike of the foliation is approximately north-south. The texture of the rock is medium to coarse grained.

The area is underlain by Precambrian crystalline basement rocks that are susceptible to faulting and fracturing. It was thought that if these geological features extend to the surface, they might serve as conduits for groundwater and discharge point for seepages and springs (Olorunfemi et. al., 2000). Groundwater has been found to accumulate within the weathered and or fractured basement rocks (Olayinka and Olorunfemi, 1992; Olorunfemi and Fasuyi, 1993).

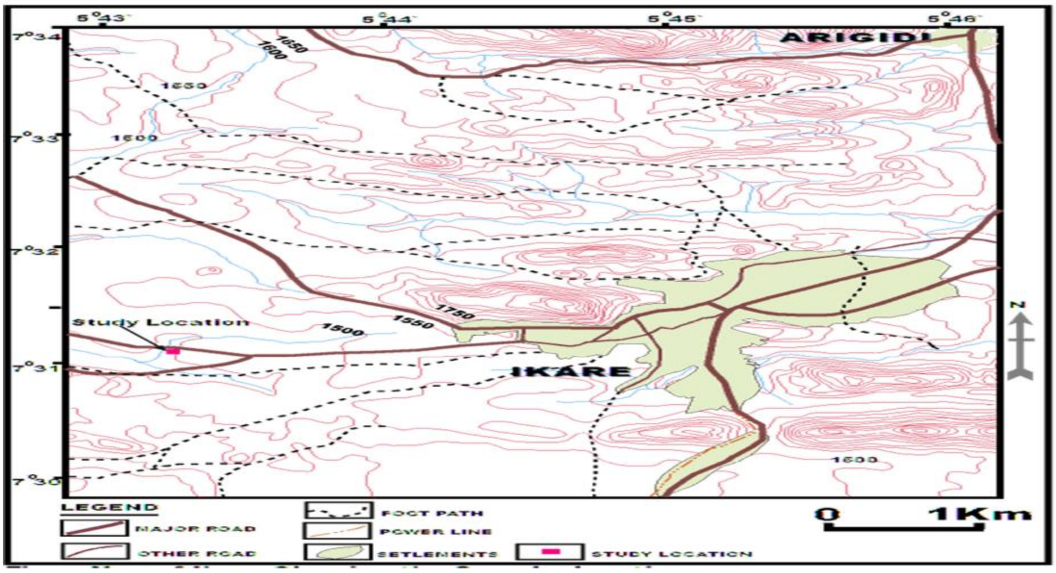


Fig 1: Topographical Map of Ikare-Akoko showing the study location (Extracted from topographical map of Owo North-West, Ondo State-sheet 265).

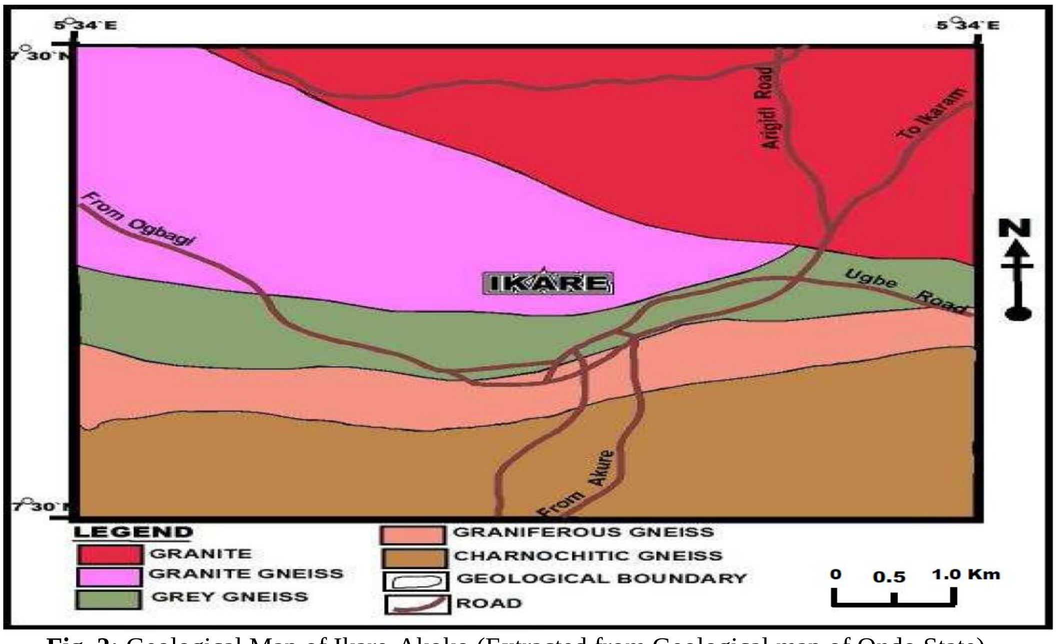


Fig. 2: Geological Map of Ikare-Akoko (Extracted from Geological map of Ondo State).

III. Method Of Study

Three geophysical traverses of length 240m each were established in the study area (Fig 3) with two of the three traverses (TR2 and TR3) encompassing the spring zone. Very low frequency Electromagnetic Method (VLF-EM) was used as a fast reconnaissance tool for mapping structural features within the subsurface and to locate sites with presumably large weathering depth. The VLF-EM measurements were made on the three traverses with station spacing of 10m using Geonics – EM 16 receiver. Areas suspected of having geologic structures (fractures and faults) and large weathering depth were subsequently depth sounded using Electrical Resistivity (Vertical Electrical Sounding – VES technique) in other to obtain a more accurate definition of the subsurface geologic sequence. ABEM SAS 300C resistivity meter was used for a total of six (6) VES stations occupied on two traverses using the Schlumberger array with electrode spacing (AB/2) ranging from 1 to 150m. These traverses encompass the spring / seepage zone.

Self Potential (SP) measurements were made along the three traverses at 5m electrode separation, employing the total fixed base array and the data was processed using the computer software Microsoft Excel and SURFER 8 to generate profiles. The VLF-EM data was processed and inverted into 2D sections using the Karous-Hjelt filtering (Karous and Hjelt, 1983). Fraser filter is also applied in order to increase the signal to noise ratio (Fraser, 1969). The electrical resistivity data was processed by plotting the apparent resistivity values against the electrode separation (AB/2). This was then interpreted quantitatively using partial curve matching and computer assisted 1D forward modeling with WinResist version 1.0 software (Vander Velpen, 2004).

The SP and VLF-EM data are presented as profiles. The VLF-EM profiles were generated by plotting the real and the imaginary components against the station spacing. Also, the Fraser filtered data were presented as depth sections, while The VES data are presented as depth sounding curves. Geoelectric sections were prepared from the results of the inversion and presented.

Interpretation of the SP profiles, Fraser filtered depth section and geoelectric section involved the detection of signatures or patterns that are diagnostic of fluid flow and fluid flow paths such as lithological contacts, fractured and faulted zones and similar zones of discontinuity.

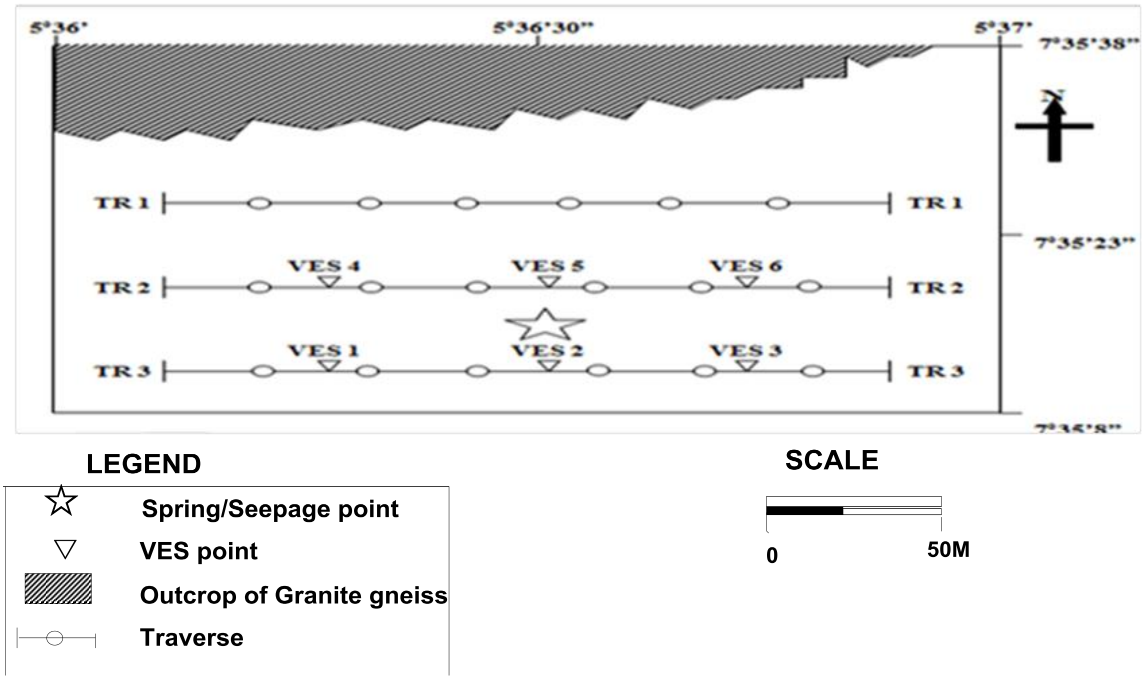


Fig 3: Geophysical Layout of the Study Area.

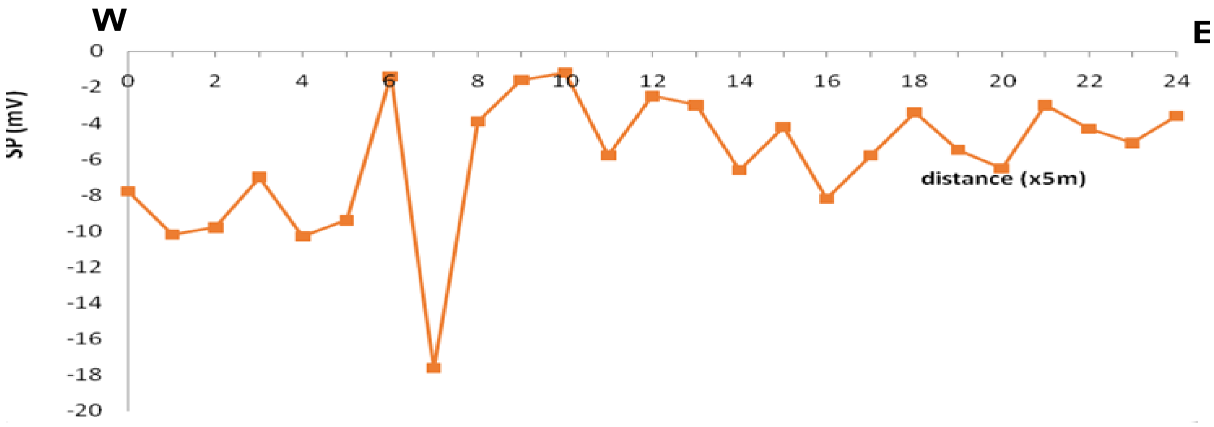
IV. Results And Discussion

1.1 Spontaneous potential (SP)

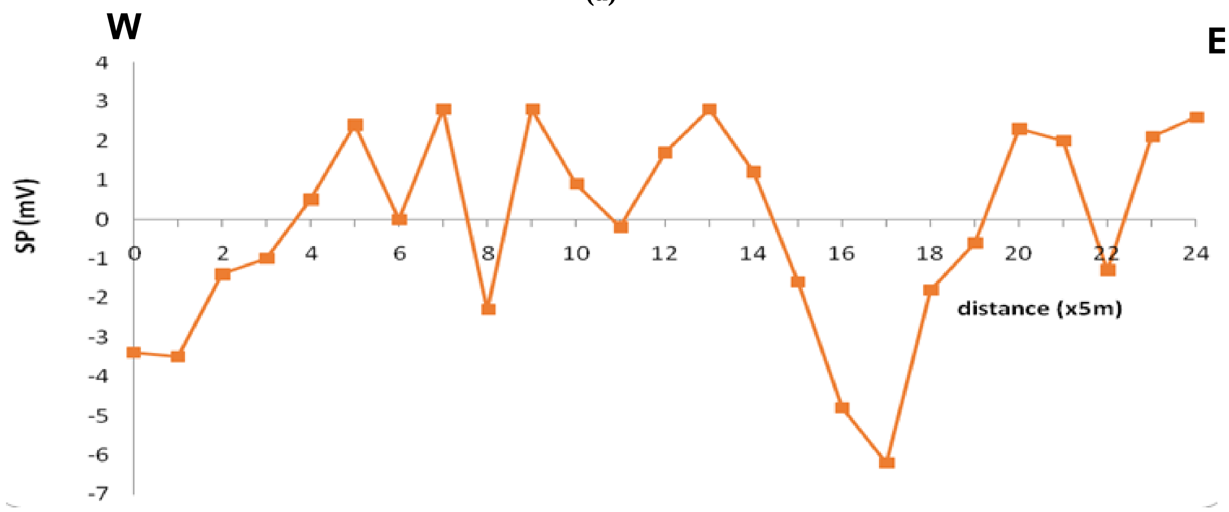
The observed SP values from the SP profiles (Fig 4) generally vary from +17.1 to -17.6 millivolts. SP values along traverse 1(fig 4a) ranged from -0.2 to -17.6 millivolts and show one negative anomaly peak at station 7 (70m) and another at station 16 (160m). These are indicative of probable fractured or faulted zones.

Along traverse 2, the SP profile (Fig 4b) show values varying from +2.8 to -6.2 millivolts with one negative peak anomaly at station 8 (80m) and another at station 17 (170m). This can also be considered a fractured or faulted zone. Traverse 3 presents an SP profile (Figure 4c) which shows two positive anomaly peaks at station 1(10m) and 17 (170m) and two negative anomaly peaks at stations 6 (60m) and station 18

(180m) all of which are diagnostic of a faulted or fractured zone. The SP profiles along the three traverses indicate a linear structure trending in the NE-SW direction and this structure is suspected to be the source of the groundwater seepage / spring.



(a)



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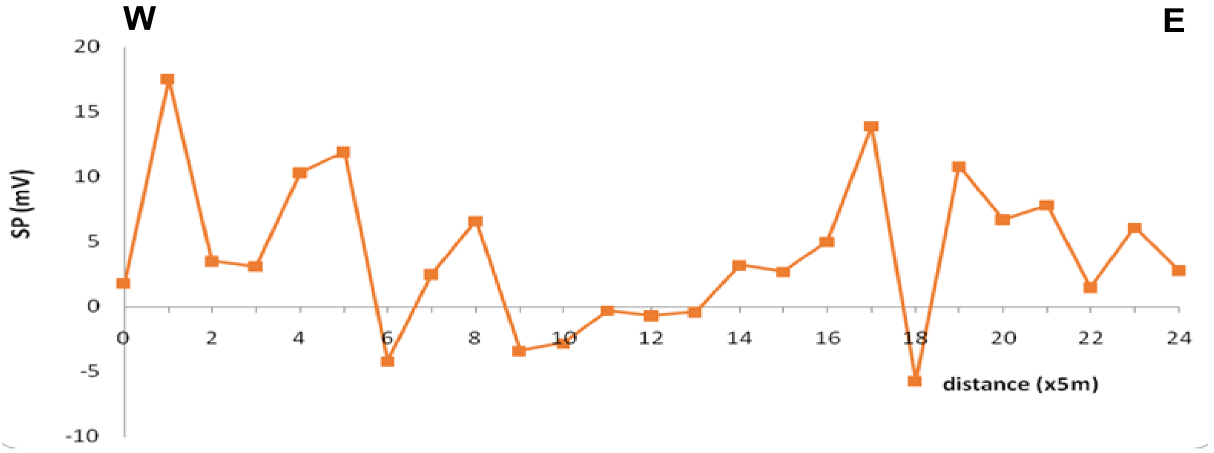


(c)

Fig 4: SP profiles measured along (a) Traverse 1 (b) Traverse 2 (c) Traverse 3

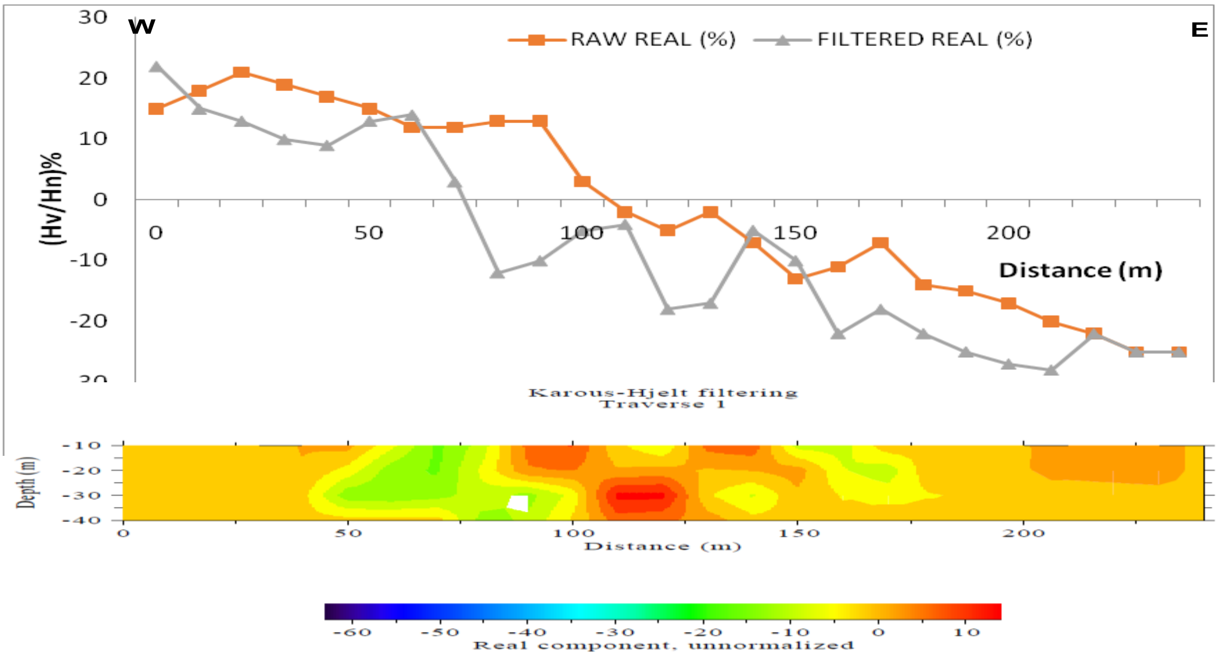
4.2 Electromagnetic method (VLF-EM)

The VLF-EM profiles were interpreted based on the relationship between the raw real and the filtered real (Fraser filtered) plots. Figure 5(a, b and c) Present the VLF-EM profiles (raw real and filtered real) and the KH section along traverses 1, 2 and 3.

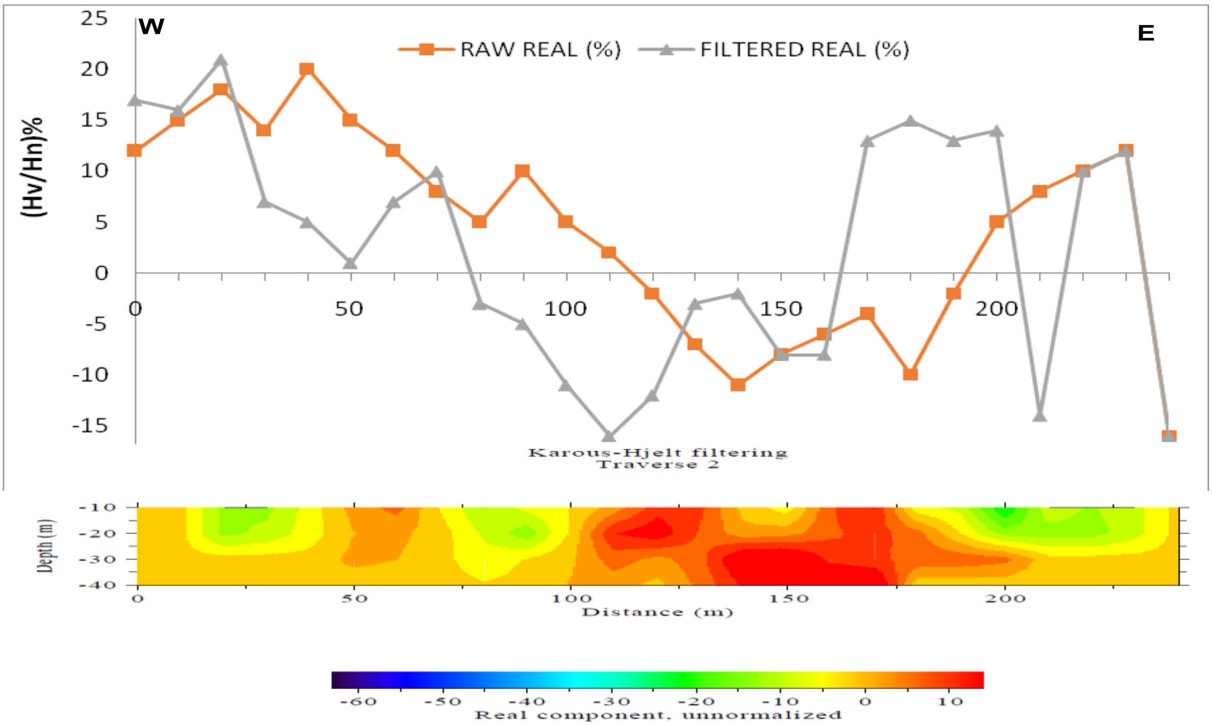
Along traverse one (1), the profile is observed to show conductive zones at distances of 60m and 150m which are indicative of a linear structure or conductive substance such as water or clay. This observation is in agreement with the conductive zones delineated by the KH section at distances 50m and 145m. The KH section also delineated a highly conductive zone between 110 and 120m at an approximate depth of 22m which happens to coincide with the seepage point.

The profile generated for traverse two (2) is as shown in figure 4b. Conductive zones were delineated at distances 65m, 140m and 180m and they are all in agreement with the KH section along the same traverse which also delineated conductive zones at 65m and between 110 –170m. The conductive zone delineated by the KH section between 110 – 170m did not only coincide with the seepage point but appear to indicate a more conductive and extensive material.

Along traverse three (3), the profile indicated conductive zones at 60m and 200m while the KH section delineated conductive zones at distances between 20 – 70m and 120 -200m both of which are in clear agreement. Delineated structures along all three traverses are suspected to be conductive weathered / fractured basement and are prominent along traverse 2 and 3 between 110-170 m and 120-200 m respectively and this is probably due to their proximity to the seepage point. This conclusion is also indicative of the NS-EW linear structure proposed from the result of the SP method as the source of the groundwater seepage / spring.



(a)



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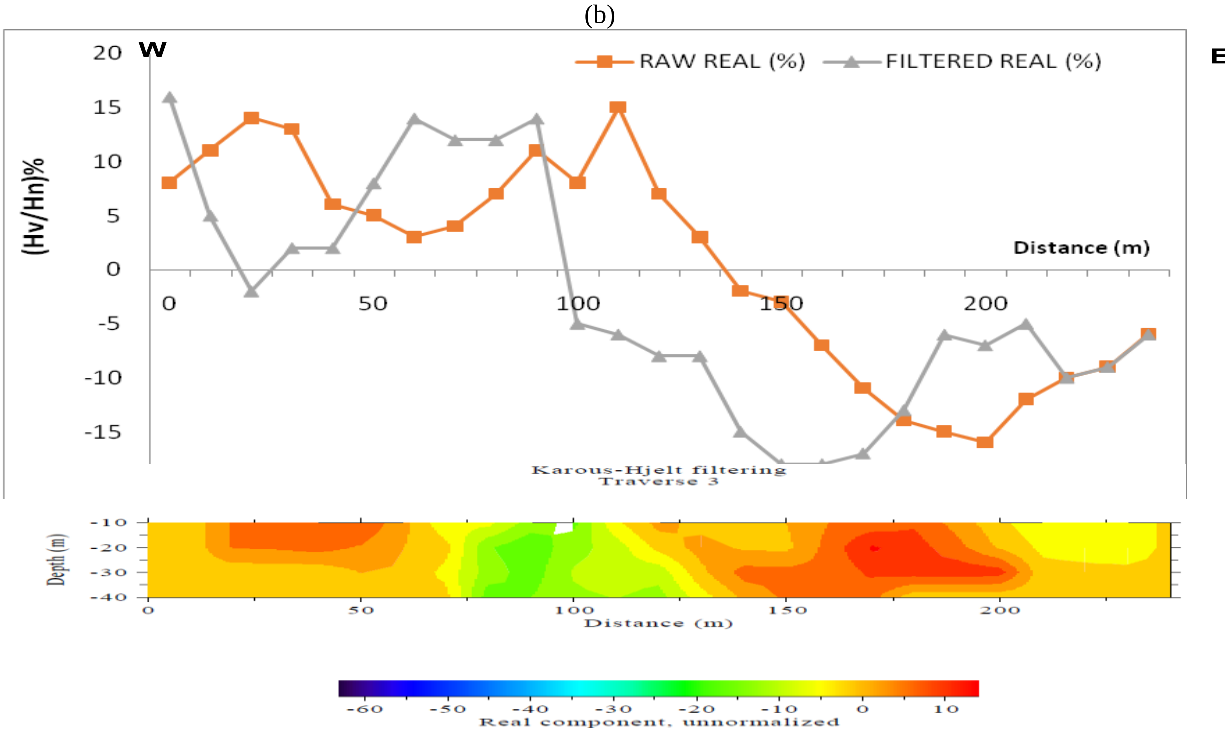


(C)

Fig 5: VLF Profile and KH Section along (a) Traverse 1 (b) Traverse 2 (c) Traverse 3.

4.3 Electrical resistivity method

VES curves (Fig 6) were produced by plotting apparent resistivity values against the current electrode spacing (AB/2). The curves are of the type H, HA and QH and the results of the interpreted sounding curves are presented in table 1 below. Two geoelectric sections were drawn from the results of the VES data interpretation. These sections were drawn along traverses 2 and 3.

4.3.1 Geoelectric section

The geoelectric section along traverse 3 contains VES stations 1, 2 and 3 (Fig 7) while that along traverse two contains VES stations 4, 5 and 6. Three geoelectric layers were delineated. These are the top soil, weathered layer and fresh basement. The first layer is the top soil with resistivity values varying from 137 to 331Ωm and thickness ranging from 0.5 to 1.2 m. The second layer is the weathered layer with resistivity values ranging from 18 to 49Ωm and thickness varying from 0.9 to 1.5m. The third layer which is the fresh basement has resistivity values tending to infinity. However, VES 6 along traverse two shows a fourth layer with resistivity value of 846Ωm which is suspected to be fractured Basement. It therefore shows that the overburden on this traverse is very shallow with maximum depth at 3m.

Table 1: Computer Assisted VES results

VES NO	NUMBER	THICKNESS (m)	DEPTH (m)	RESISTIVITY (Ωm)	INTERPRETATION LITHOLOGY	TYPE OF CURVE
1	1	0.5	0.5	331	Top Soil	H
	2	0.9	1.4	18	Weathered layer	
	3	-	-	∞	Fresh basement	
2	1	0.7	0.7	137	Top Soil	H
	2	1.5	2.2	35	Weathered layer	
	3	-	-	∞	Fresh basement	
3	1	1.2	1.2	195	Top Soil	HA
	2	0.7	1.9	27	Weathered layer	
	3	1.1	3.0	49	Weathered layer	
	4	-	-	∞	Fresh basement	
4	1	1.5	1.5	363	Top Soil	H
	2	0.6	2.1	34	Weathered layer	
	3	-	-	1355	Fresh basement	
5	1	1.4	1.4	247	Top Soil	H
	2	0.8	2.2	21	Weathered layer	
	3	-	-	3102	Fresh basement	
6	1	0.7	0.7	336	Top Soil	QH
	2	3.1	3.8	181	Weathered layer	
	3	4.5	8.3	111	Weathered layer	
	4	-	-	846	Fractured basement	

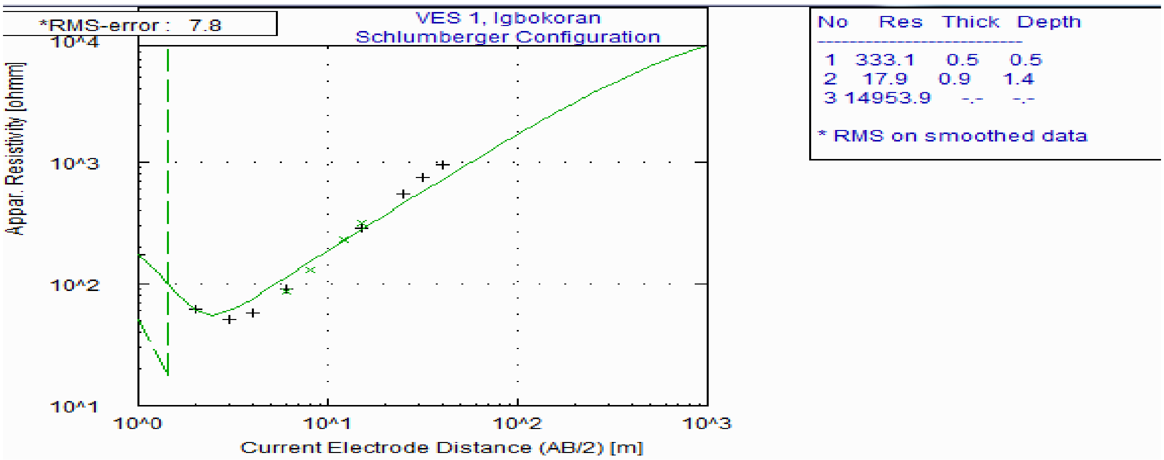
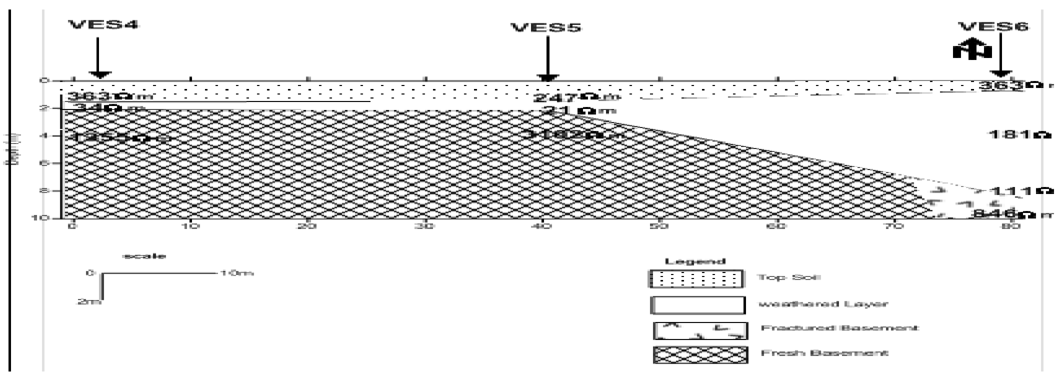
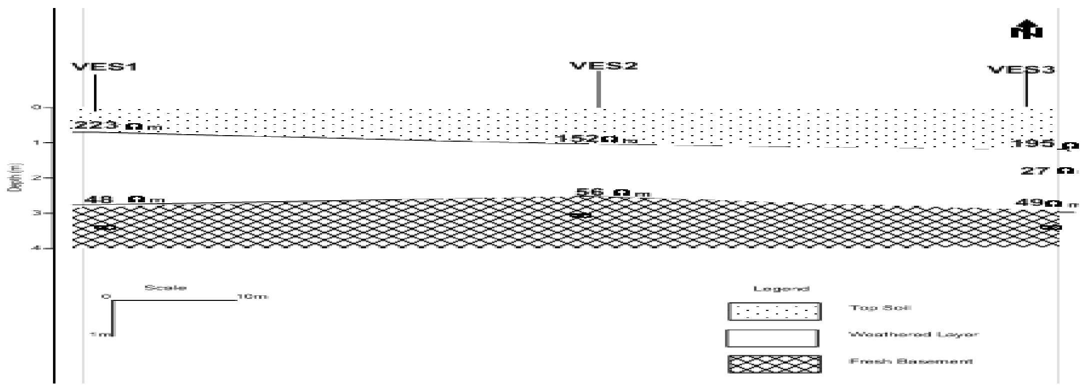


Fig 6: Typical Vertical Electrical Sounding Curve and Model Parameters.



(a)

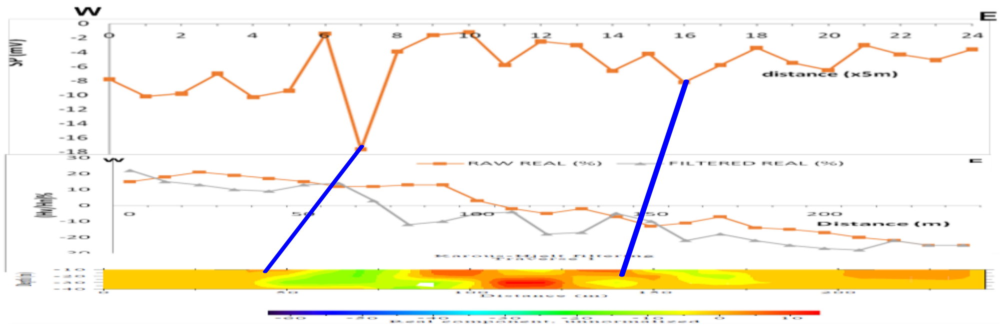


(b)

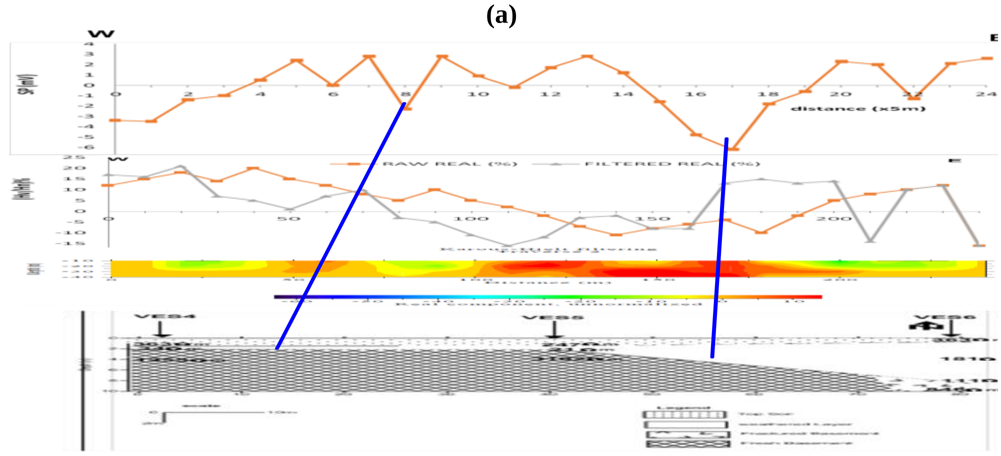
Fig 7 Geoelectric section along (a) traverse 2 (b) Traverse 3

V. Integration Of Results

Figure 8 is an integration of all three geophysical methods. The zones interpreted as probable fractured/ faulted zone by all three methods are joined by a line for all three traverses to aid easy correlation. The Low SP values depict conductive zones, and these zones are in agreement with the geological feature identified by the VLF-EM result. The result of the vertical electrical sounding also delineated at a depth of 8.2m, a fractured basement at VES point 6 along traverse 2. All three methods delineated a linear structure which is thoght to be inclined in the NE – SW direction and extends to the surface (seepage point). The groundwater is suspected to seep through this interface or discontinuity.



(a)



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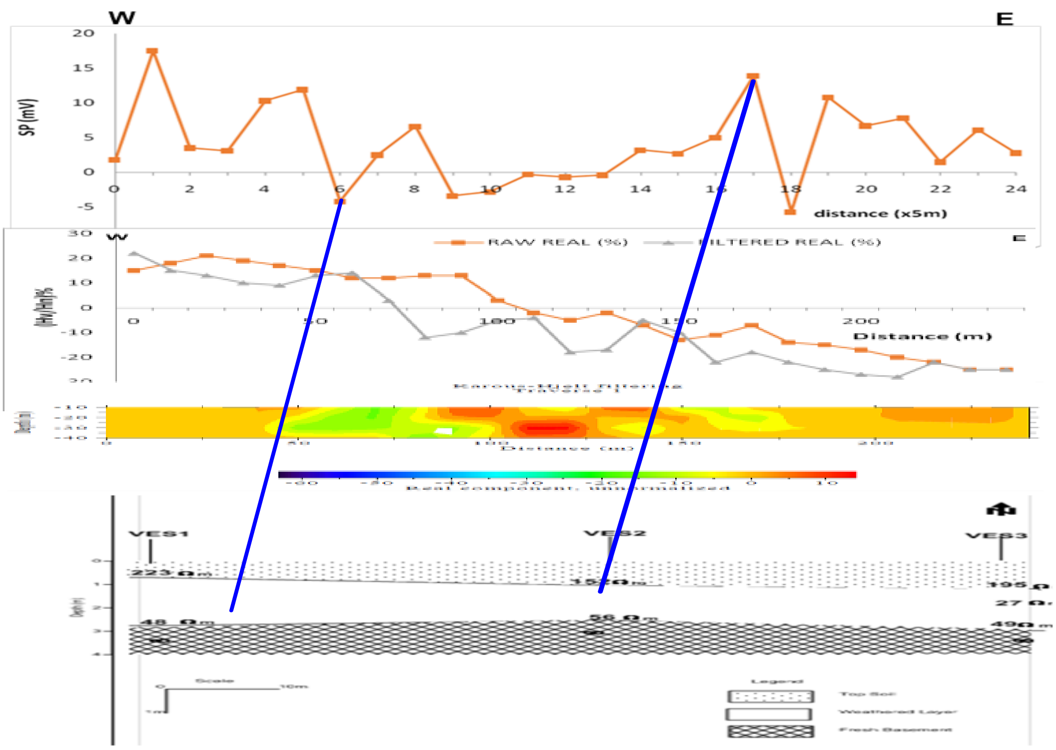

(C)

Fig 8 Integrated result along (a) Traverse 1 (b) Traverse 2 and (C) Traverse 3

VI. Conclusion

The interpretation of the geophysical methods applied in this investigation (Spontaneous potential (SP), very low frequency electromagnetic (VLF-EM), and electrical resistivity (ER)) have allowed the delineation of Three (3) geoelectric layers (Top layer, weathered layer, and fresh basement) along Traverse Three and a fourth layer (Fractured Basement) along traverse two. It has also shown that the weathered / fractured basement constitute the aquifer unit. The spring is suspected to be fault/fracture iduced since the short wavelength negetive amplitude anomalies indicated by the SP method,the low resistivity readings of the ER as well as the signatures of the VLF-EM plots are all diagnostic of a linear feature. However, groundwater development in the study area is not feasible due to the thin overburden (8.2m) and the low fracture density of the Basement.

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