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2D Resistivity Imaging Survey for Siting Water Wells and Shallow Boreholes in a Typical Basement Terrain, Southwestern Nigeria

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Abstract:
Background: *2D resistivity imaging was conducted around major depressions of a rocky terrain located within the western part of Adekunle Ajasin University Campus, Akungba-Akoko, Southwestern Nigeria. The study was aimed at mapping and identifying subsurface layers and discontinuities such as aquifer structures or geological interfaces for groundwater prospects.*
Materials and Methods: *2D resistivity imaging was conducted around major depressions of a rocky terrain located within the western part of Adekunle Ajasin University Campus, Akungba-Akoko, Southwestern Nigeria. The study was aimed at mapping and identifying subsurface layers and discontinuities such as aquifer structures or geological interfaces for groundwater prospects.*
Results: *2D resistivity models/sections revealed three subsurface layers; thin topsoil with resistivity range of 60 - 569 Ωm and thickness range of 0.7 - 3.5 m, weathered/fractured layer with resistivity values that ranged from 35 - 655 Ωm and thickness values of 1.1 - 23.0 m, and the fresh bedrock with resistivity in excess of 1000 Ωm. The sections also imaged distinct low resistivity zones, cutting into a continuous and consistently high resistivity basement/basal layer which were typical of near-vertical discontinuities/geological fractured interfaces/weathered basement troughs. Two prominent groundwater seepage points A and B at stations 30 and 95 m along traverse 2 were overlaid the distinct low resistivity zones.*
Conclusion: *Continuous/fractured - controlled nature of the discharges in the area, with overburden in excess of 20 m thick, was suggestive of a potential for shallow water boreholes and wells development.*
Key Word: *Discontinuities, geological, imaging, interfaces, resistivity, wells*

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I. Introduction

Non-invasive geophysical methods are rapid, cost effective and have remained the state-of-the-art tools commonly used in the investigations of cavities and seepage zones [1], complex aquifer structures/fractured aquifers and/or subsurface structures [2], [3] and [4]. The electrical resistivity technique is particularly suited for the above utilities or subsurface probe owing to the resistivity contrast between the groundwater saturated strata and the surrounding media. For this reason, electrical resistivity method was considered suitable and therefore, 2D imaging through dipole – dipole profiling technique was employed for this study.

Recent advances in groundwater exploration and structural features with hydrogeological significance in crystalline basement complex rocks have shown that groundwater can occur within rocky terrains, provided there are discontinuities within the rock unit(s). These discontinuities may occur as linear geological structures, shear zones, fractures/fissures, network of joints, lithological contacts and faults [1], thus enhance groundwater storage, aid groundwater flow and seeps. Groundwater seeps are associated with precipitations particularly when surface water being a residue of precipitation seeps downward into extensive layers of porous soil and pervious rock to emerge as groundwater discharge and/or stream flow in low topographical areas. The quality and quantity of groundwater within a body of a discharge zone depend on its extensive layers of porous media, depth extents, fracture density and the composition of the host rock.

The present geophysical tool deployed will focus on delineating the groundwater discharge zones, their structural disposition and possibility of the development of shallow groundwater boreholes and wells in a sustainable manner, in this part of the Adekunle Ajasin University campus, Akungba – Akoko. The geophysical method has been successfully employed in the study of fractured aquifers, springs and their potentials for groundwater resource and development in both basement and sedimentary terrains in Nigeria. Few of the earlier workers include [3], [5], [6], [7], [8] and [9]. The above, thus inform the choice of the 2D electrical resistivity imaging survey for this study.

1.1 Location, Geology and Hydrogeology

The study area is located within western part of the Adekunle Ajasin University Campus, north of Akungba-Akoko, Ondo State, Southwestern Nigeria. It is confined to Latitudes 7^{o} 27’ 5.82’’ and 7^{o} 27’ 41.63’’ N and Longitudes 5^{o} 43’ 41.43’’ and 5^{o} 44’ 29.43’’ E which approximate Northings and Eastings of 825739 mN and 802713 mN and 801047 mE and 824429 mE of the Universal Traverse Mercator (UTM) Minna Zone 31 coordinates respectively (Figure 1). The area is surrounded by granitic hills to the north, west and southeast leaving a lowland valley for habitation.

The local geologic setting of the study location and its surroundings is shown in (Figure 2). The area is underlain by Precambrian Basement Complex of Southwestern Nigeria. Generally, the rocks found within the area can be grouped under the Migmatite – gneiss-quartzite complex and the older granites of pan-African age [10] and [1]. According to [12], the major rock types include granite gneiss, biotite-rich gneiss, grey gneiss and minor occurrences of charnokites (Figure 2).

The volume of water available for municipal supply depends on the amount of rainfall, size of watershed, the slope of the ground, the type of soil. Alaitan stream and other ephemeral streams are located within the study site, and remain the major sources of watershed. The volume of the discharge arising from these streams is appreciable and continuous enough to flood the adjoining motorway and entire landmass particularly during the wet season. High flow rate is observed at the peak of the wet season between June to October [13] while continuous low discharge occurs during the dry season, thus making the average discharge of the seepages suspiciously not enough for a dependable supply of surface water all through the seasons.

II. Material And Methods

Three geophysical traverses were established in the study area in approximately E-W azimuth/direction (Figure 3). The electrical resistivity measurements were carried out using the ABEM SAS 1000C equipment. 2D dipole – dipole resistivity imaging survey, with electrode separation of 10 m and n factor of 5 for a maximum separation of 70 m, was carried out over the traverses (Figure 3). Two seepage zones A and B on the traverse 2 were designated for correlation purposes. The 2D dipole dipole resistivity datasets were processed by the use of Dippro^{TM} software/ algorithm for a finite element modelling inversion of the data to obtain inverted resistivity pseudosection and 2D structure/model along each of the traverses [14], [15], [16] and [17]..

III. Results

Results are presented as two dimensional (2D) resistivity structure models or sections (Figures 4, 5 and 6). Figure 4 shows traverse 1 with a length of 120 m. It was established close and parallel to the foot of an extensive gneissic inselberg running E-W direction. The extensive weathered/fractured and porous layers of the earth materials are evident by the low resistivity responses as shown in the 2D imaging section/model.

Figure 5 shows 2D structure model over the traverse 2, which covers a total length of 120 m. The traverse was established East-West direction along and across the two groundwater discharge points A (major) and B (minor). Resistivity responses from the section show low characteristics particularly over 30, 60 and 95 m along the traverse, suggesting extensive weathered and porous layers of the earth materials at these zones.

Figure 6 shows the 2D structure model over the third traverse 3. The traverse covers a distance of 120 m. It runs East – West parallel but offset the second traverse 2. The traverse overlay a tectonized, extensively fractured lowlying and exposed migmatitic outcrop with surface run offs during the wet season. The section in Figure 6 shows generally high resistivity responses except for the first two upper layers between stations 40 - 100 m along the traverse.

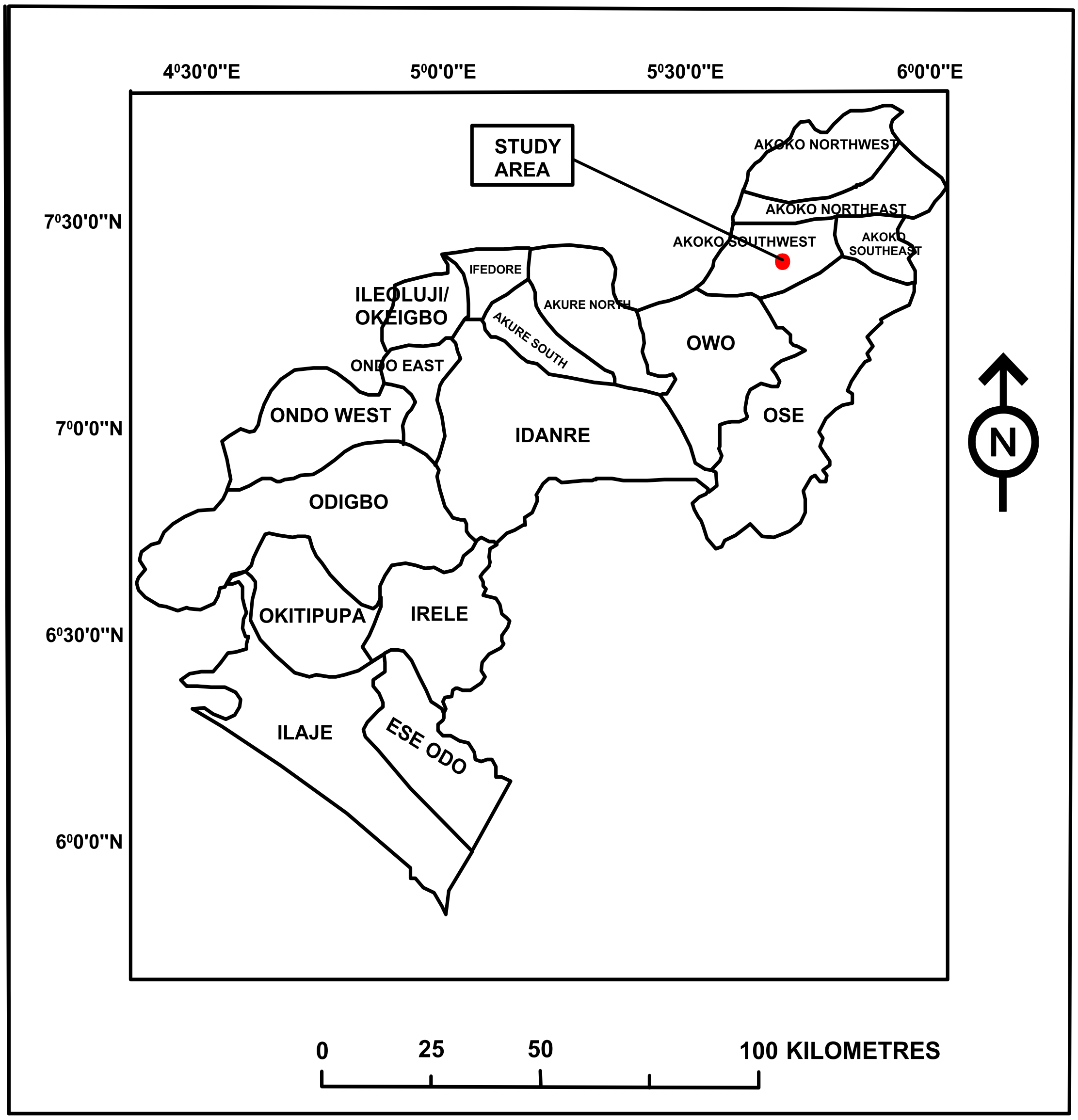

Figure 1: Map of Ondo State showing the study area

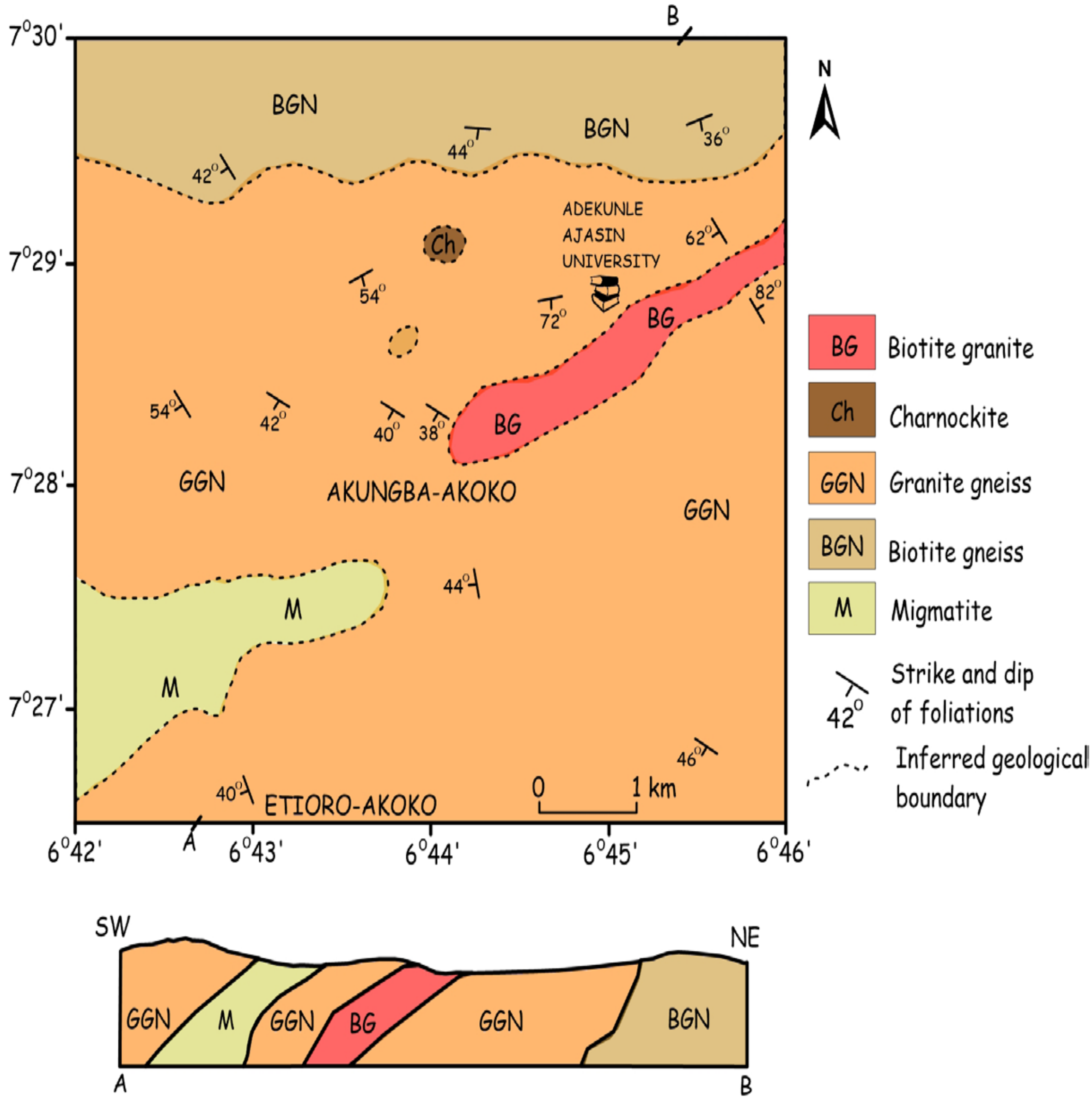

Figure 2: Geological map and cross-section of Akungba-Akoko snd the study area [12]

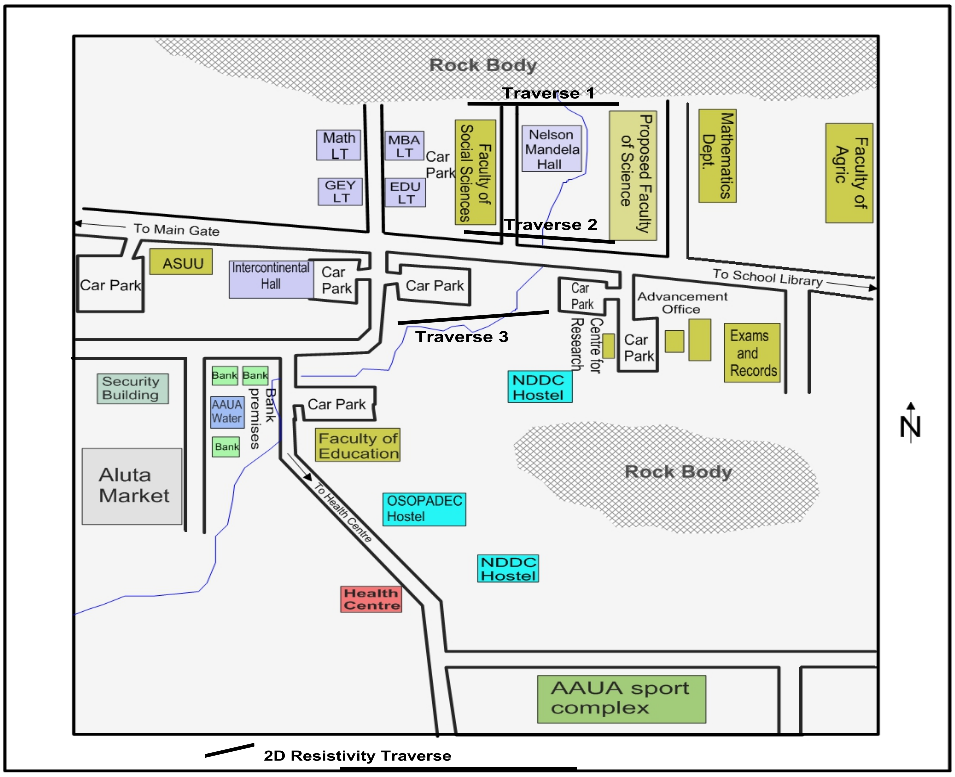

Figure 3: Site sketch showing data acquisition traverses

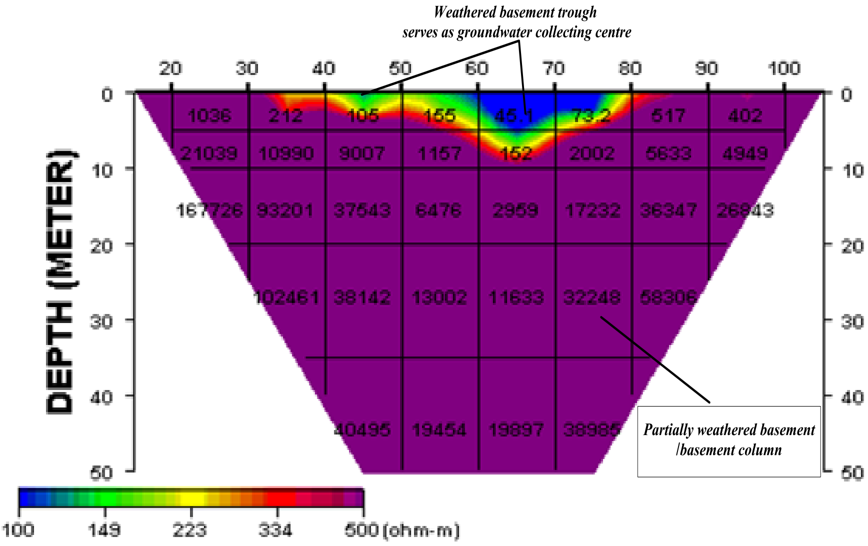

Figure 4. 2D electrical resistivity structure along traverse 1

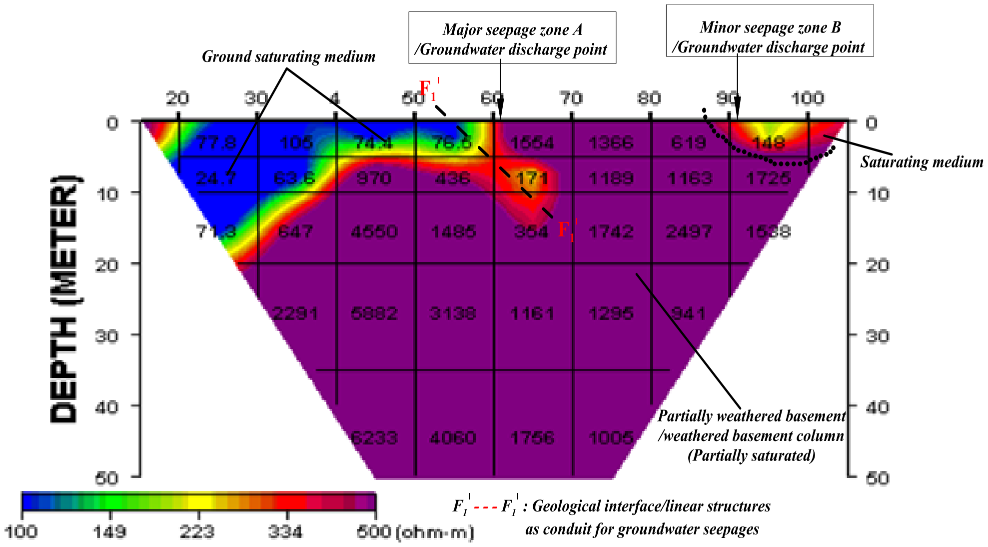

Figure 5. 2D electrical resistivity structure along traverse 2

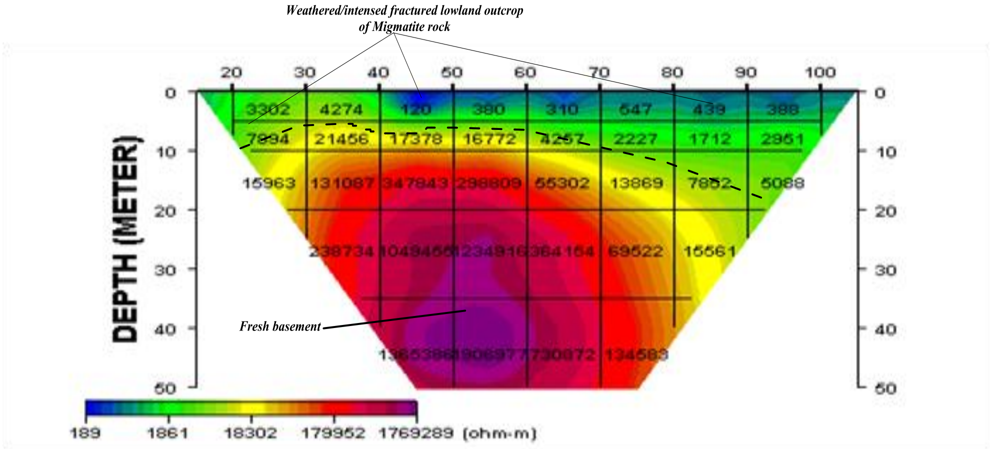

Figure 6. 2D electrical resistivity structure along traverse 3

IV. Discussion

Interpretation and discussions of the results involve inspection of the 2D resistivity sections/models for diagnostic features in line with the objectives of the study. The sections over the traverses show generally two peaks or responses; the low and high resistivity zones very important for delineating discontinuities/transition zones and/or mirroring uneven basement topography which are significant for this study.

The 2D section in Figure 4, reveals three subsurface layers to include; the upper topsoil layer, weathered / fractured basement column and fresh bedrock unit. The section/model, in addition, delineates an extensive very low resistivity zone that mirrors the configuration of a major basement depression between stations 60 and 80 m, and bounded at both ends by two near geological interfaces. The weathered basement depression, underlain by water – saturated fractured strata, is observed up to a depth of about 15 m. This may have served as the groundwater storage resource for shallow groundwater abstraction.

Specifically, the 2D model/section delineates two distinct low resistivity zones, cutting down into the basement, typical of near - vertical discontinuities/geological interfaces and/or narrow basement trough (Figure 5). These zones coincide with the groundwater discharge points A and B with anomalously low resistivity ranges. Also in this low category are the strata overlying the dipping/buried basement stratum at approximately 45^0 at the western end of the traverse between 0 and 60 m spread. The discharges are suspected to have been caused by the vertically disposed linear structures given rise to a typical valley or fault induced dischage in the environment.

The 2D resistivity model/section (Figure 6) images the subsurface geological layers to include trough-like water-saturated strata and a transition from high resistivity (greater than 10,000 ohm –m) to low resistivity (less than 10,000 ohm – m) in the eastern end where intense weathering and structures on migmatitic outcrop were evident, given a weathering depth of about 5 m. This zone is of limited groundwater storage resource capability.

V. Conclusion

2D resistivity structures or sections identify low resistivity zones cutting into the basement column as discontinuities. The discontinuities and/or transition zones are typical of near / vertically disposed geological linear features/interfaces or fault zones across traverses 2 and 3. Near – homogeneous low resistivity zones are also identified as development of thin layer of aquitard on the basement (Aminu, 2015), thus creating water – saturated weathered troughs, while two of the narrow basement depression zones coincide with the groundwater discharge points A (major) and B (minor) along traverse 2. The groundwater discharges may have been caused by the vertically disposed linear structures to give rise to a typical valley or fault - induced discharge in the area.

The 2D sections delineate three subsurface geological layers; the topsoil, weathered layer and partially weathered/fresh bedrock with the resistivity ranges of 100 – 569 ohm-m, 125 – 755 ohm-m and over 1,000 ohm-m respectively. The thicknesses of the topsoil and weathered basement layer were estimated as 0.7 – 3.5 m and 1.1 – 23 m respectively. The overburden is generally thin in the vicinity of the outcropping rocks along traverse 3 but relatively thick away particularly at the trough-like water-saturated weathered /fractured basement column within traverses 2 and 3. The vertically disposed aquifer structures and the localized water saturated strata along the traverses are prospective sites for shallow water wells and boreholes with optimum depth of 10 and 40 m respectively in the area.

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