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Full Length Research

Geodynamics and its implications to environmental protection: A case study of Aule area, Akure, Ondo State, Southwestern Nigeria

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ABSTRACT: This research work evaluates the effects of geodynamics processes on the emerging local geology of an area, especially against the background of global tectonic activities, the gradual but continuous earth movement and the depletion of the ozone layer, as it were and its implications on the local geology of a place, especially as it affects the rate of weathering, fracturing and other geologic processes which may pose environmental challenges. A ten year template was adopted for this study, while geophysical and metrological approach was engaged in the study with the use of electrical resistivity method and rainfall data. Two techniques involving lateral resistivity profiling of near E-W orientation with a profile length of 150 m with electrode separation at a = 10 and 20 meters while electrode movement was at 5 meters. Nine vertical electrical soundings (VES) with maximum spread AB/2 = 100 m was carried out at same locations and period (July to August) as was obtained ten years ago for the purpose of effective correlation from the point of data acquisition, data analysis, interpretation, results and findings. Rain data within study area was also collected covering a period of ten (10) years was analysed and presented as bar chart. The result obtained revealed the nature of changes that has taken place within the study area in terms of weathering, and the rate of weathering in the last ten years. Vertical variation/changes occurred at a weathering rate of 1.573, 1.489 and 1.711 cm along the three traverses with average rate of 1.591 cm per year. Horizontal variations also indicated some changes in position of strata, implying an average yearly weathering of about 1.591 cm when compared with the principle of plate tectonics and gradual but continuous earth movement which is at the rate of about 2 cm per year. Therefore, the local geodynamic constant was determined from product of lateral movement and vertical earth weathering trend/gradient which is 3.182 cm^2. The rainfall analysis reflects the global weathered changes which is a major contributory factor to geological processes/weathering.

Keywords: Geodynamics, geoelectric section, rainfall trend, weathered layer and wenner profiling.

INTRODUCTION

World-wide estimate of the rate of plate motion indicates that the African plate is moving slowly towards the Northeast at the rate of about 2 cm per year (Frank and Raymond, 1982). The world has been in existence according to geological time scale, about 4.5 to 4.7 billion years ago with the present been traced to recent events within the last 500 million years and now (Dalrymple, 2001; Braterman, 2013; Boltwood, 1907). However, some events continue to shape our past, present and future earthly existence. These are geological events and phenomena that will constantly experience changes (Ozegin et al., 2019). The Gradual earth movement; vis-à-vis plate tectonic activities leading to Earthquakes, tremors, subsidence, fracturing, weathering, jointing and cracking against this background of earth movement and other tectonic activities (Isogun and Adepelumi, 2014). The idea of a continuous weathering (gradual earth decay) is a fundamental issue that cannot be ignored, therefore, this research attempts to evaluate the weathering rate in the form of a decay constant that will continue to affect or dominate both local and regional geological trends. Therefore, as a solution to agro-geophysics, environmental, mineral, groundwater and engineering geophysics (Olorunfemi et al., 2000), there is need to evaluate the decay constants base on the principle and phenomena of earth decay and weathering parameters over time. In this study, the earth decay refers to the earth weathering processes which is gradual and a continuous processes leading to breakdown of the original earth/geologic materials into smaller but weaker units, whose strength and competence are subjected to stress, strains and geodynamic pressure and activities of temperature variations, internal and external pressures on the earth and tectonic activities overtime may lead to a geological dynamic process, that may affect both micro, macro and super structure (Taber, 1930; Hall, 1999; Paradise, 2005; Burt et al., 2008). Upon this, it then became a matter of necessity to take a step further to find out the possible implications of this processes with respect to a local geological variations and possible gradual but continuous changes that may occur with the local geoelectric parameters of a place within a space of ten years in the face of plate tectonics and gradual but continuous earth movement. Ten years ago, a geophysical investigation was carried out for the evaluation of the extent of hydrocarbon plume contaminations in Aule area of Akure. In carrying out this study electrical resistivity was engaged to determine the weathered layer thickness within the study area (Adelusi et al., 2013). The present effort and other relevant information is to apply the vertical electrical resistivity survey to evaluate the weathered layer thickness, and to compare the thickness then and now after ten year, in order to know if there was any change in depth or not after ten years as a result of tectonic activities and weathering processes. Therefore, the concept behind this work is to be able to make a provision for this processes in such a way as to sustain the environment in terms of safety and development, through a deliberate provision for what is considered as a local geodynamic constant which are ultimately an inevitable processes and overtime may account for environmental safety/development or otherwise as the case maybe. The local geodynamic constant is not only relevant in engineering structures but in agriculture, groundwater, mineral exploration, environmental safety and protection.

METHODOLOGY

Description and geology of the study area

The study area is located along Aule road, Akure, Ondo State, southwestern Nigeria. It is situated between the UTM coordinates of Eastings 738600 to 739300 m and Northings 804100 to 804500 m as shown in Figure 1. Generally, the study area has a moderately undulating topography. Surface elevation ranges between 354 and 368 m. The highest elevation in the study area is about 368 above sea level. The study area is surrounded with buildings. The area lies within the tropical rain forest climate region of Nigeria. It is characterized by two distinct seasons, the wet season (between April and October) and the dry season (between November and March). The average annual rainfall is about 1000 to 1700 mm, while the average daily temperature is 29°C. Aule area is underlain by crystalline rock of the Precambrian basement complex of the southwestern Nigeria (Rahaman, 1989). The lithological units include migmatite gneiss complex, granite gneiss and charnokites. Outcrops of biotite gneiss and granitic gneiss occur in some locations around the western part of the study area (Figure 2). Likewise, boulders of granite and charnokites occur at the western part of the study area. The hydrogeological setting of the area is such that various rock types of both igneous and metamorphic origin occur but in general, they are impermeable except in cleaved, sheared, jointed and fissured areas (Olayinka, 1972). The study area exhibits varieties of structures such as foliation, schistosity, folds, faults, joints and fractures. Generally, the structural trends in the study area are NNW-SSE and NNE-SSW. These structural trends fall within the principal basement complex fracture direction (Oluyide, 1988).

Method

The research involved electrical resistivity method and metrological rainfall data. The Electrical resistivity method involves two techniques; 2D- Wenner profiling and the Vertical Electrical Sounding (VES). The 2D-Wenner profiling and Vertical Electrical Sounding techniques were done in such a way that the positions of the earlier survey (Adelusi et al., 2013) were reoccupied to create a time lapse resistivity survey (Figure 3). Twelve VES points and a number of Wenner profiling were acquired using the R-50 resistivity meter. The rainfall data acquired over a space of ten years (daily, monthly and yearly) using rain-gauge apparatus from the university observatory weather station, Federal University of Technology Akure. The rainfall data was plotted in form of bar chart using excels words to reflect the rain pattern within a space of ten years. The electrode configuration for Wenner was occupied with a constant spacing of “a” equals to 10 and 20, and corresponding values of ‘N’ being varied between 1 and 2

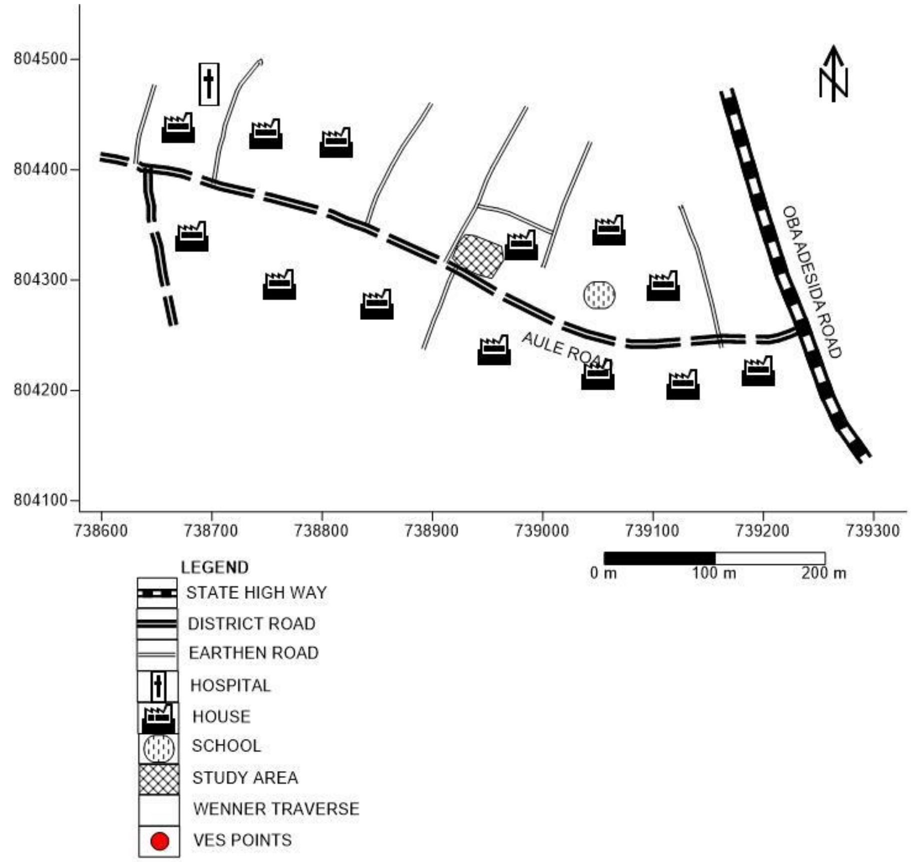

Figure 1. Location map of study area.

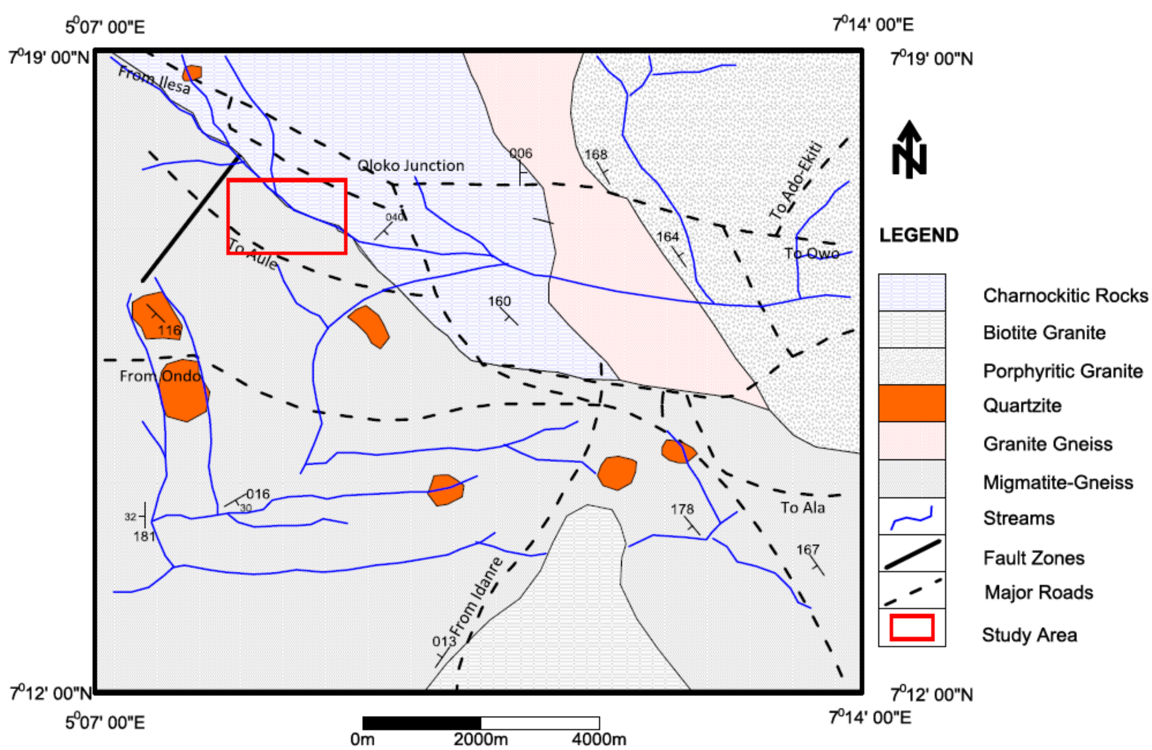

Figure 2. Geological map of Akure showing the study area (Adelusi et al., 2013).

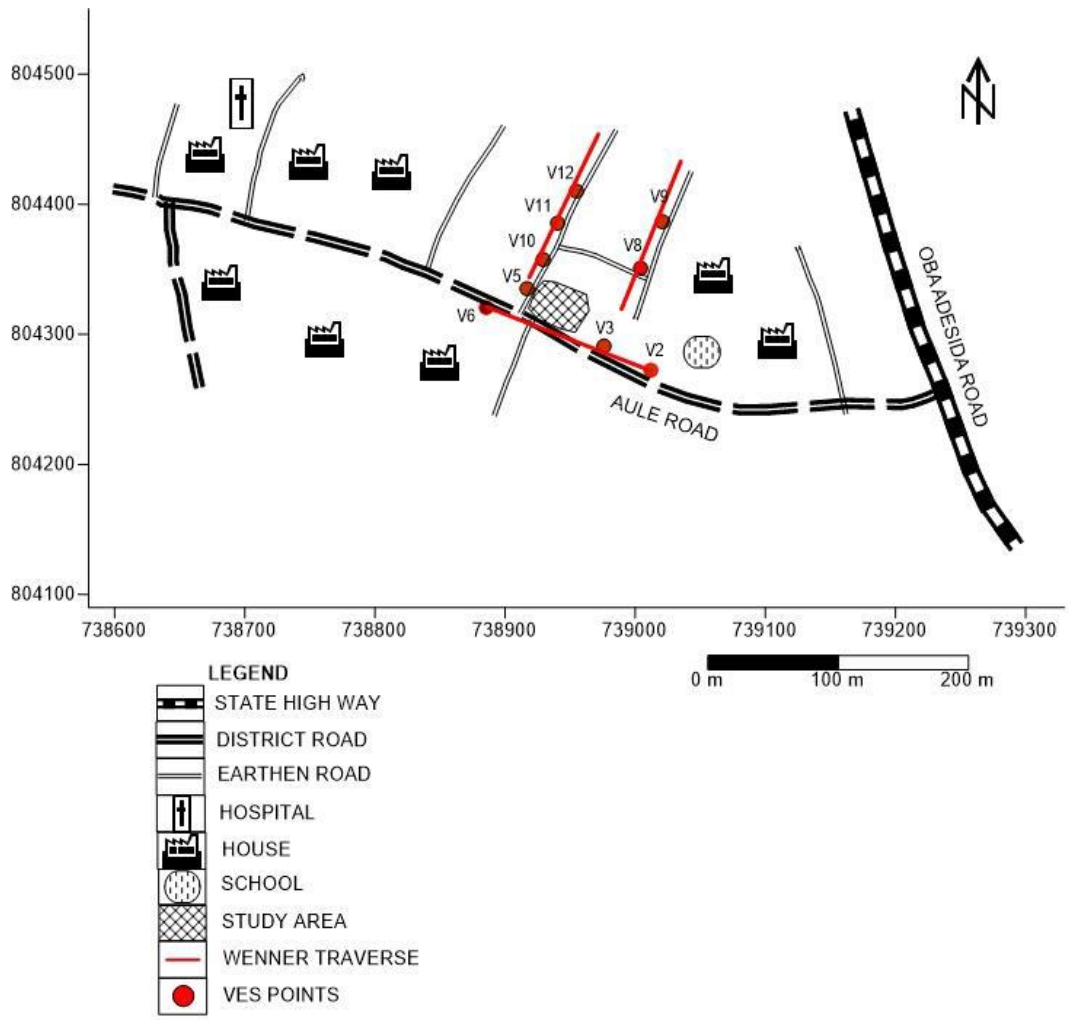

Figure 3. Data acquisitions map of the study area.

while electrode movement was at 5 m intervals. The VES data were presented as sounding curves, which are plots of apparent resistivity values against electrode separation (AB/2) on bi-logarithmic paper resulting in a VES curve. The VES curve showed the change of resistivity with depth, since the effective penetration increases with increasing electrode spacing. The interpretation of the VES curve is both qualitative and quantitative. The qualitative interpretation involved visual inspection of the sounding curves while the quantitative interpretation utilized partial curve matching technique using 2-layer master curve which was later refined by a computer iteration technique Resist version (Vander Velpen, 2004) that is based upon an algorithm of Ghosh (1971). The quantitatively interpreted sounding curves gave interpreted results as geoelectric parameters (that is, layer resistivity and layer thickness). The geoelectric parameters were used to determine the local geodynamic variation per year with the following equations.

$A = A^{i} + A^{ii} + A^{iii}/3$ ………………………(i)

$B = B^{i} + B^{ii} + B^{iii}/3$ ………………………(ii)

$C = C^{i} + C^{ii} + C^{iii}/3$ ………………………(iii)

$\frac{A + B + C}{3}$………………………..…………(iv)

Present study – previous study = weathering trend

Therefore, average local weathering trend/rate per year = $\frac{TR1+TR2+TR3}{3}$……………(v)

RESULTS AND DISCUSSION

The results of the study were presented as wenner pseudo section, sounding curves, geoelectric sections and graphs.

2D Wenner pseudo- section along Traverse 2

Typical 2D Wenner pseudo section within the study area

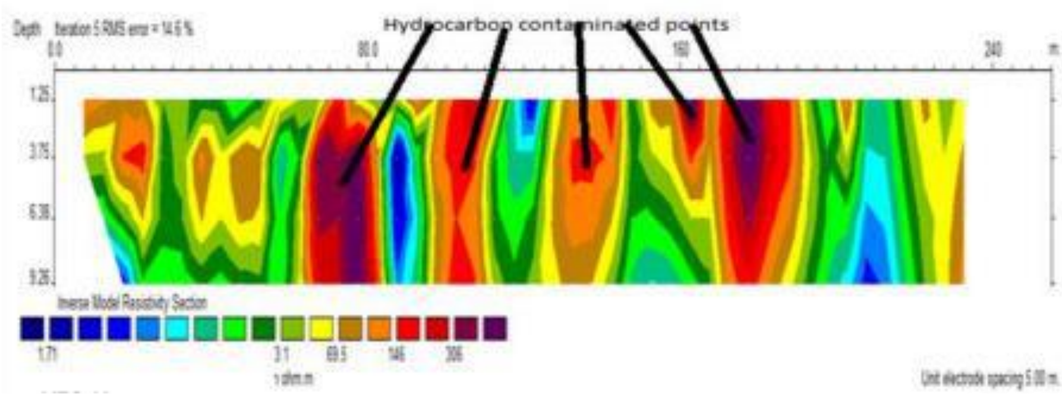

Figure 4. 2D Wenner pseudo section along traverse two (2010).

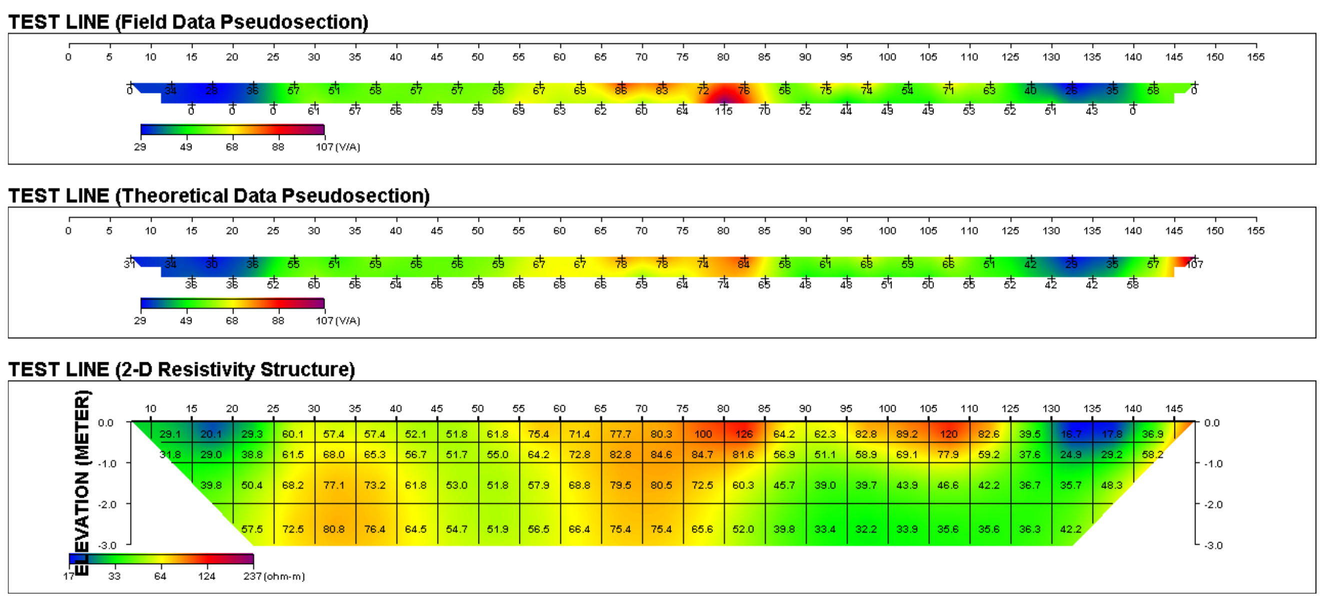

Figure 5. 2D Wenner pseudo section along traverse two (2019).

was generated ten years ago and a period of 10 years after. Figure 4 illustrates high resistivity value (> 200 Ωm) which occurs at a distance of about 5.5 and 150 m at a depth of 2.5 m and at distance 170 m at a depth of 9.26 m which indicate the presence of weak zones in varying concentration (Adelusi et al., 2013). However, Figure 5 displays the monitor result of the 2D Wenner pseudo section done on traverse two (2) after nine years and this shows resistivity value (< 200 Ωm) around 80 and 105 m at a shallow depth of <10 m and this indicates the presence of clay/clayey material, which further established that the effect gradual decay of the earth. The implication of this is to further establish that due to time lapse, there is gradual changes/movement within the subsurface, thereby living behind the effect of the natural geological processes in the study area.

2D Wenner pseudo section along Traverse 3

Figure 6 shows a typical 2D Wenner pseudo section within the study area obtained nine years ago on Traverse 3. It indicated that a resistivity value of (> 200 Ωm) occur at distance 20 m at a depth of 6.38 m, 58 m at a depth of 9.26 m and 95 m at a depth of 2 m which indicate the presence of weak zone within the study area (Adelusi et al., 2013). While Figure 7 exhibits the monitor result of the 2D Wenner pseudo section on the same traverse after nine years and this shows resistivity value (< 200 Ωm) at around 15 m, 60 m and 85 m respectively at a shallow depth of less than 20 m and this indicates the presence of shallow bedrock with geological structures within 30 to 50 m, which indicated the presence gradual change in the earth decay process compared to that of nine years ago, thereby living behind

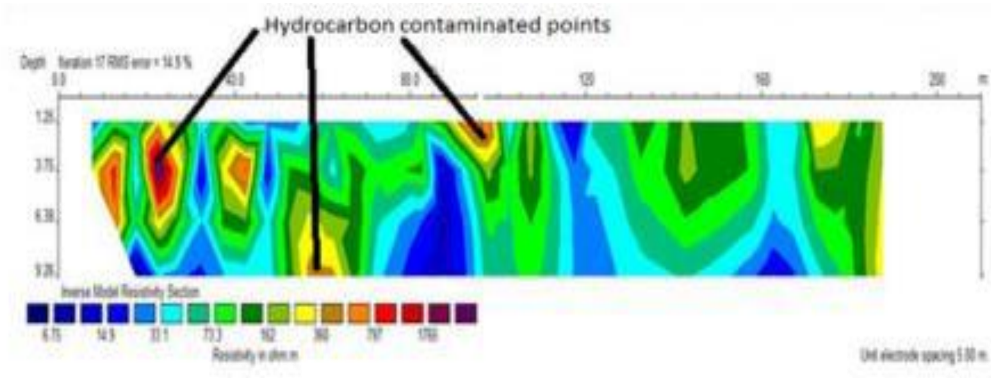

Figure 6. 2D Wenner pseudo section along traverse three (2010).

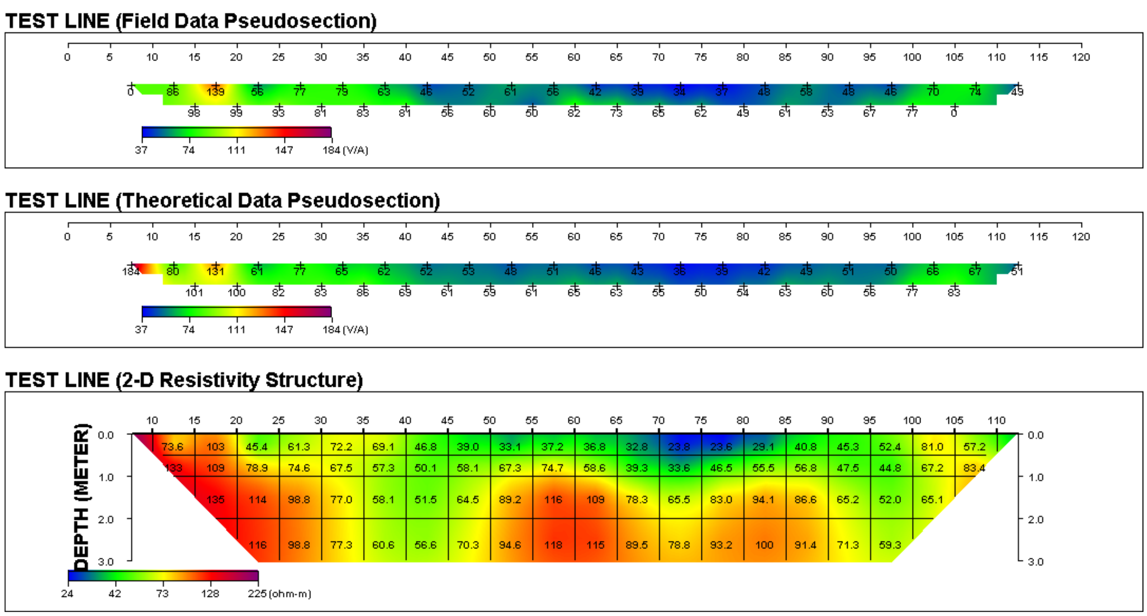

Figure 7. 2D Wenner pseudo section along traverse three (2019).

the effect of the natural geological process of the area.

Vertical Electrical Sounding (Characteristic of the VES Curves)

Curves types identified ranges from H and KH varying between three to four geo-electric layers. The H curve type predominating. Typical curve types in the area as shown in Figure 8a and 8b.

Geoelectric and lithological characteristic along the three within a space of nine to ten years

Geoelectric section along Traverses 1 in 2010 and 2019

The geoelectric sections were represented by the 2-D view of the geoelectric parameters (depth and resistivity) derived from the inversion of the electrical resistivity sounding data. The geoelectric section along Traverse 1 (Figures 9a and 9b) correlates the geoelectric sequence across the study area within nine years. The geoelectric sections identified three geoelectric/geologic subsurface layers. The topsoil comprising of clayey sand, sandy clay and sand with the resistivity values ranges from 20 to 99 Ωm with its thickness varies from 0.8 to 4.5 m, the weathered layer resistivity values range from 25 to 398 Ωm and thickness ranges from 1.1 to 23.8 m. The fresh basement has a resistivity values ranged from 231 to 2517 Ωm with depth to basement ranging from 12 to 23.8 m.

Geoelectric section along Traverses 2 in 2010 and 2019

On Traverse 2 (Figures 10a and 10b), three subsurface

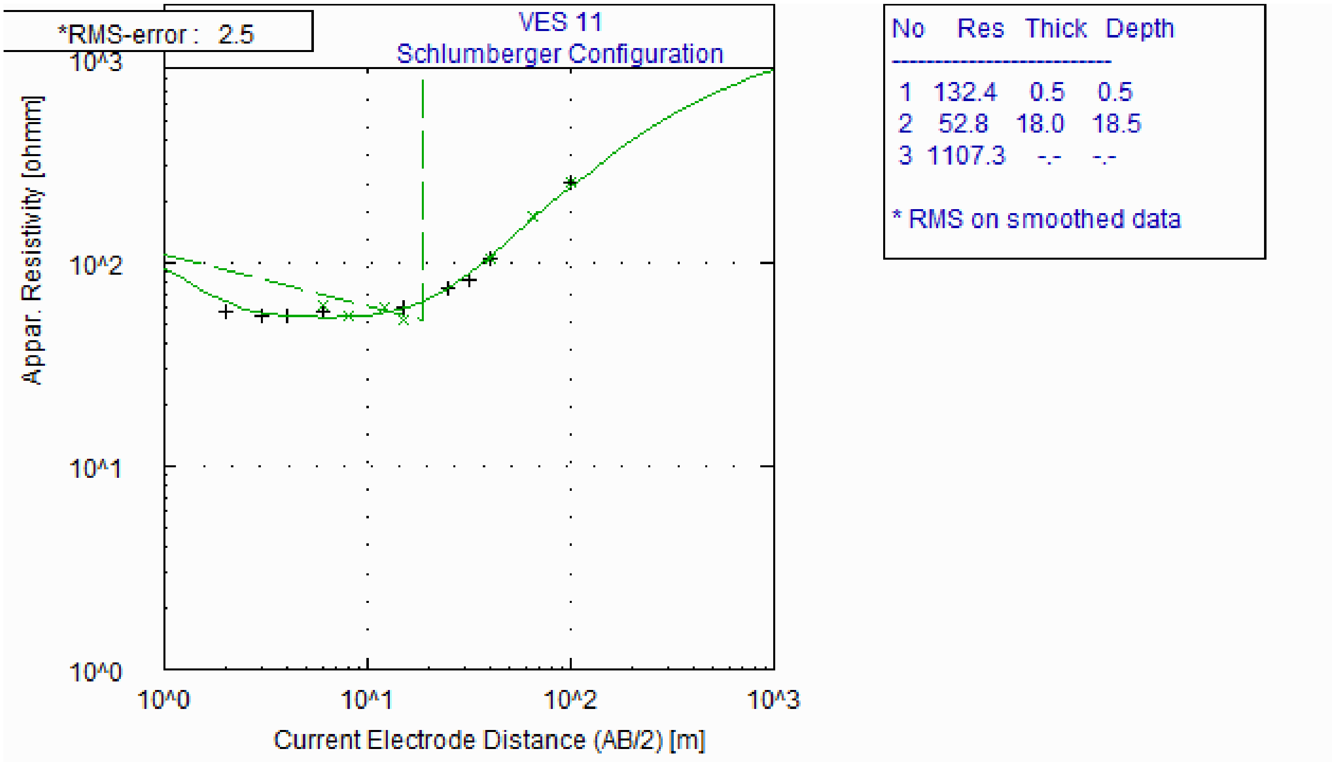

Figure 8a. Typical H sounding curve.

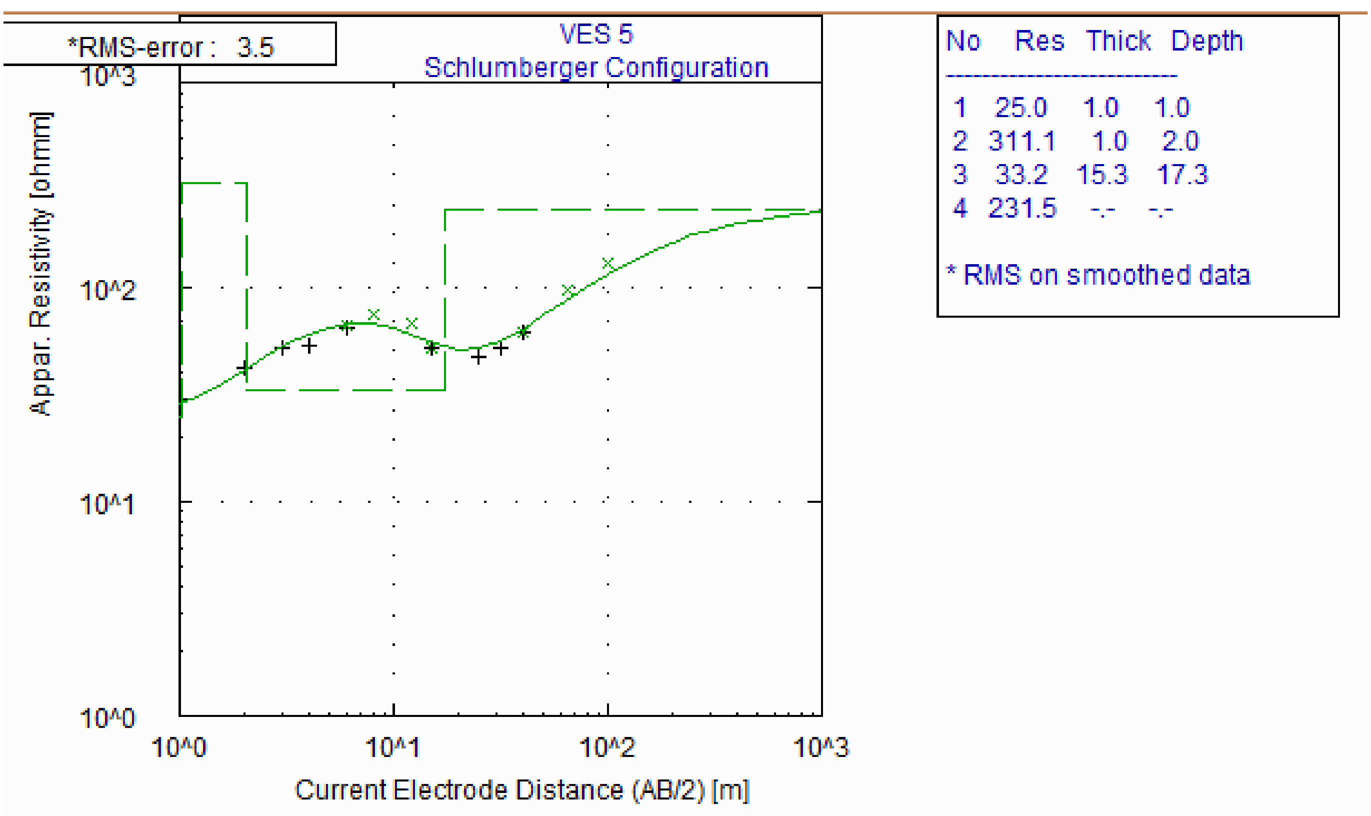

Figure 8b. Typical KH sounding curve.

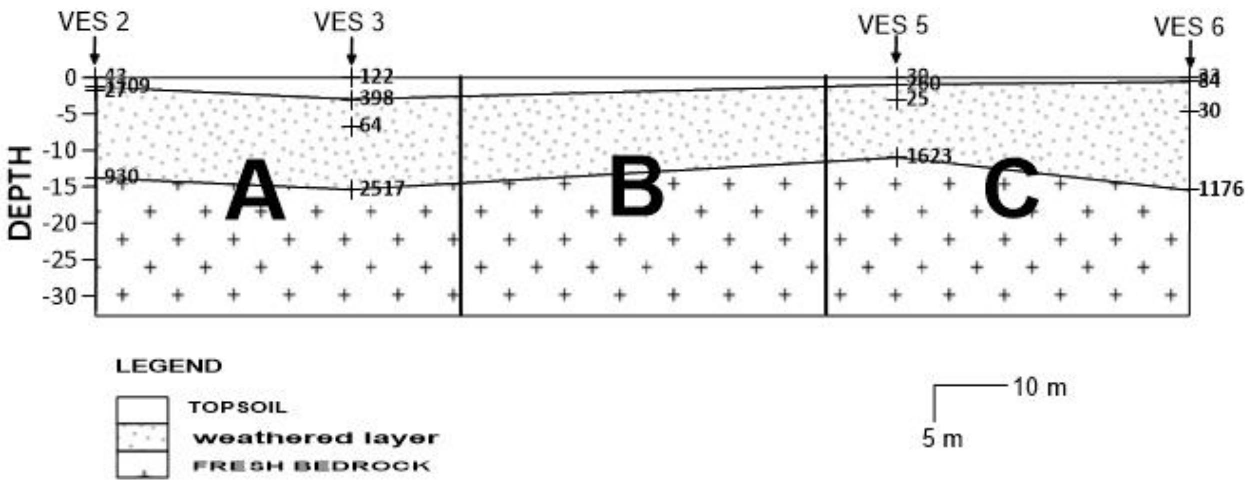

Figure 9a. Traverse 1 previous study geoelectric section (2010).

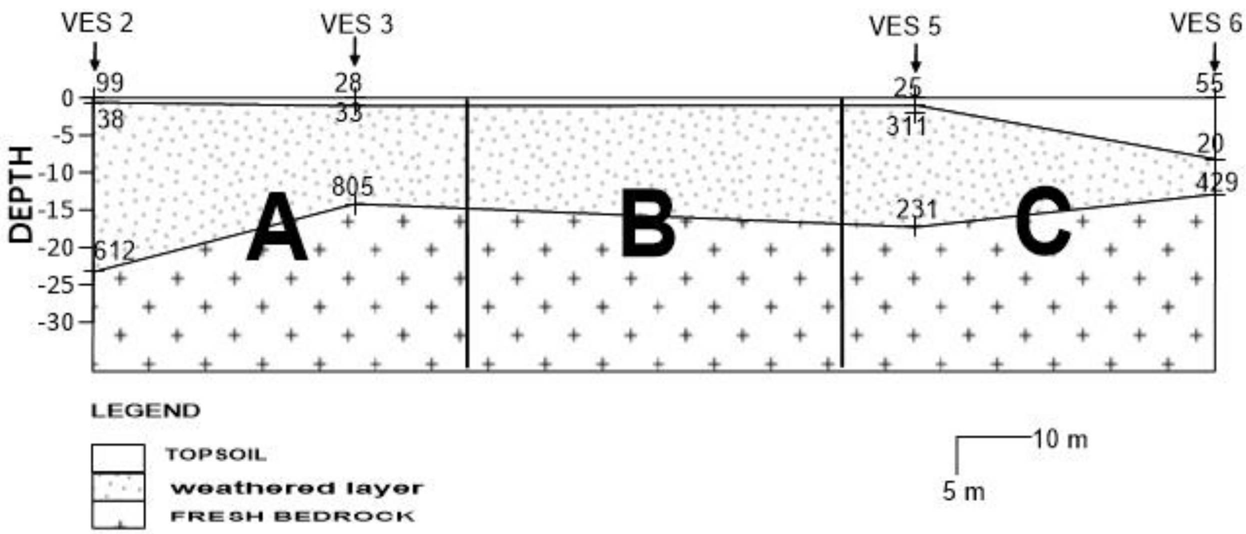

Figure 9b. Traverse 1 recent study geoelectric section (2019).

geologic layers were also delineated along this traverse. From the geoelectric section, the top soil, weathered layer and fresh basement were determined. The topsoil comprising of clayey sand sandy clay and sand with the resistivity values ranges from 30 to 132 Ωm with its thickness varies from 0.9 to 3.1 m, the weathered layer resistivity values range from 23 to 191 Ωm and thickness ranges from 1.8 to 27.3 m while the fractured basement resistivity varies from 286 to 1107 Ωm with depth to basement ranging from 14.3 to 27.3 m.

Geoelectric section along Traverses 3 in 2010 and 2019

Three subsurface geologic layers were also delineated along traverse three (Figures 11a and 11b). From the geoelectric section, the top soil, weathered layer and fresh basement were determined. The topsoil comprising of clayey sand sandy clay and sand with the resistivity values ranges from 34 to 42 Ωm with its thickness varies from 0.8 to 2.2 m, the weathered layer resistivity values range from 27 to 179 Ωm and thickness ranges from 0.9 to 19.9 m while the fresh basement resistivity varies from 194 to 753 Ωm.

Determination of geodynamic variation from geoelectric section using weathered layer analysis

The geoelectric section was divided into three blocks (A, B

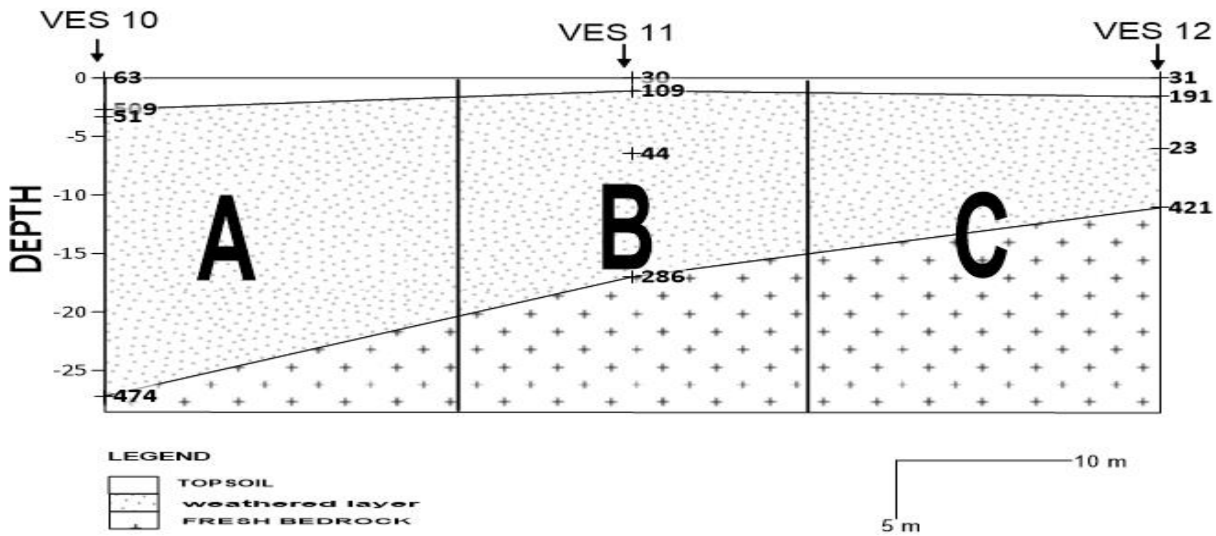

Figure 10a. Traverse 2 previous study geoelectric section (2010).

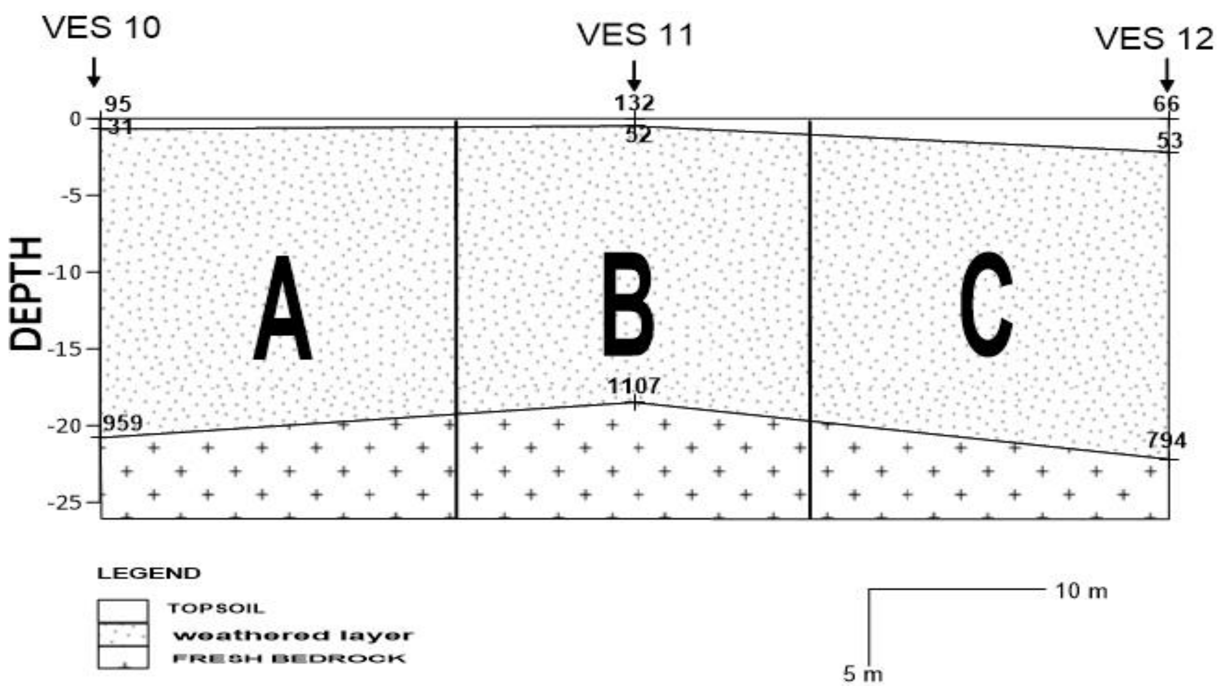

Figure 10b. Traverse 2 recent study geoelectric section (2019).

and C) along the three traverses for a better assessment and correlation of events correlation of events, therefore the average weathered layer thickness while considering the variations between a space of ten years ranges between 13.73 to 15.48 m (Figures 12a and 12b, 13a and 13b, 14a and 14b). In order to allow a fair statistical analysis taking into consideration that the layers thickness varies from one point to another, each of the blocks were further divided into $A = A^i + A^{ii} + A^{iii}$, $B = B^i + B^{ii} + B^{iii}$ and $C = C^i + C^{ii} + C^{iii}$ respectively. An average of which gave a fair representation of the depth in respective of the variations. This was done for traverses one, two and three after which the totality of it was subjected to another overall average of A, B and C along the traverses i.e average of average of traverses one plus average of traverse two and average of traverse three, all subjected to overall average.

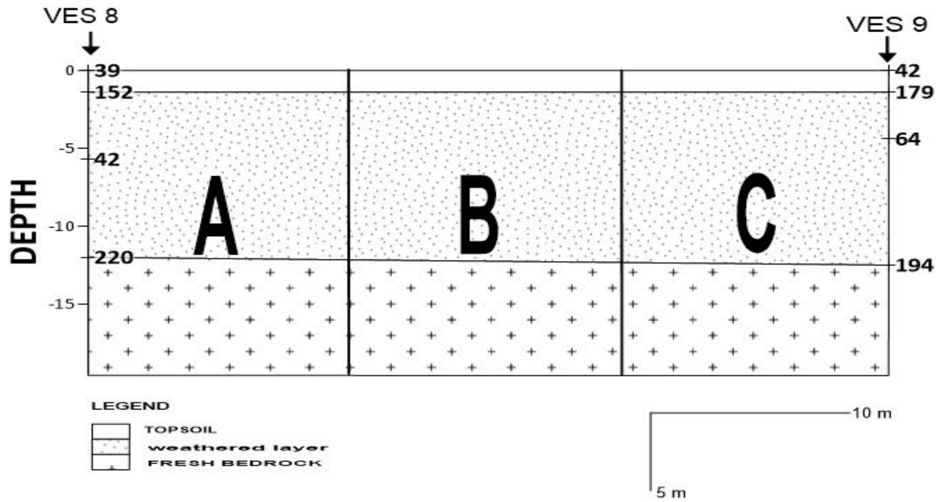

Figure 11a. Traverse 3 previous study geoelectric section (2010).

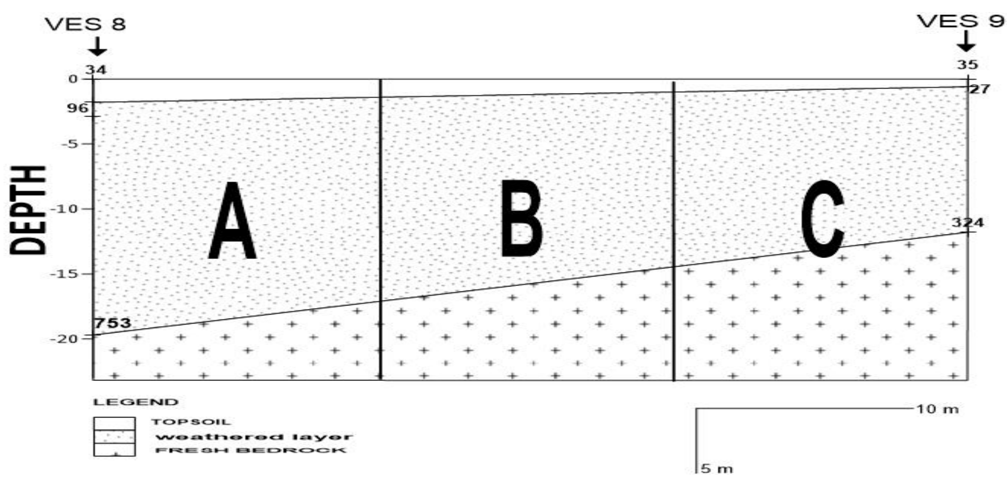

Figure 11b. Traverse 3 recent study geoelectric section (2019).

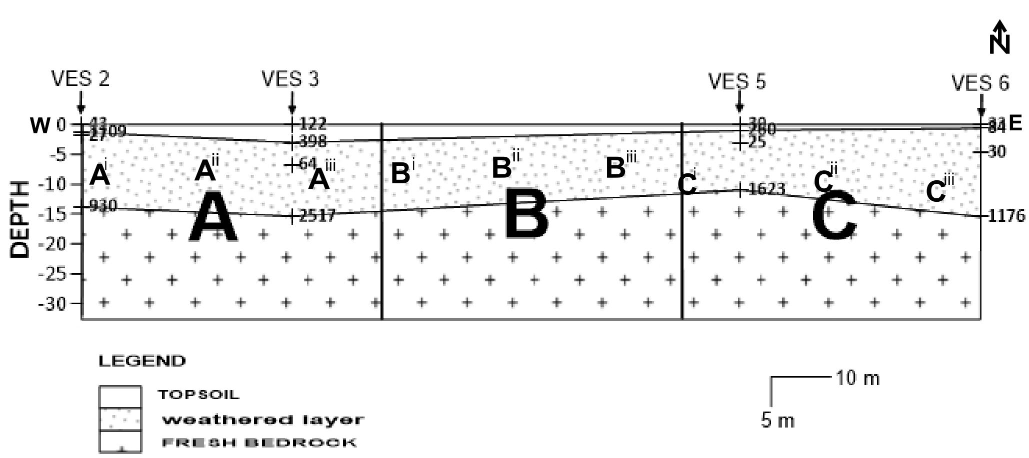

Figure 12a. Previous geoelectric section along Traverse 1 (2010).

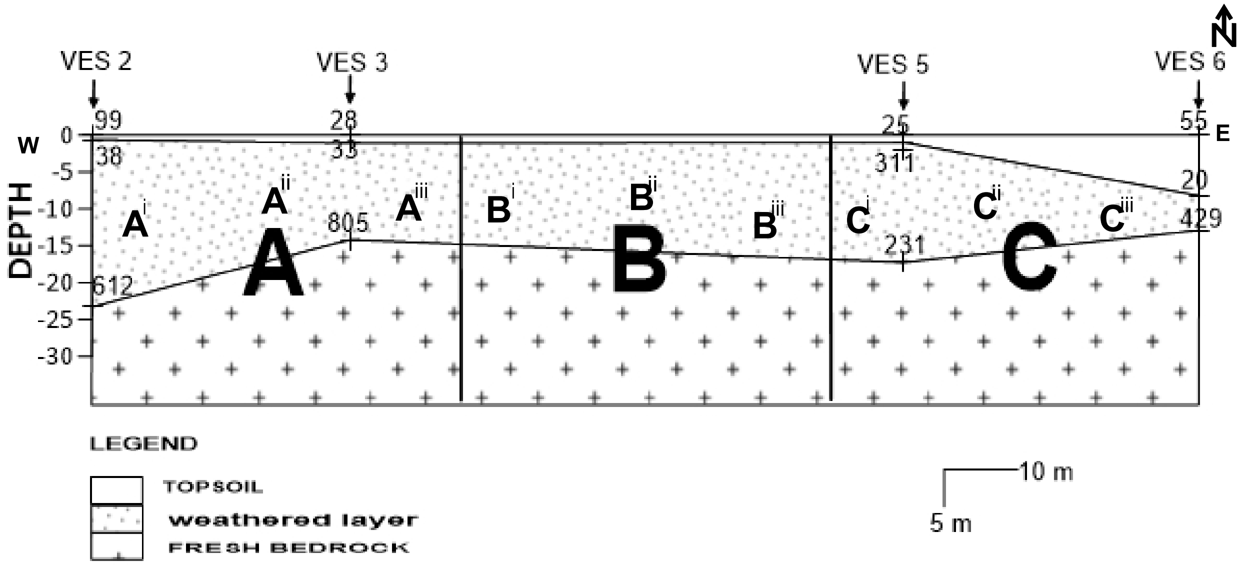

Figure 12b. Previous geoelectric section along Traverse 1 (2019).

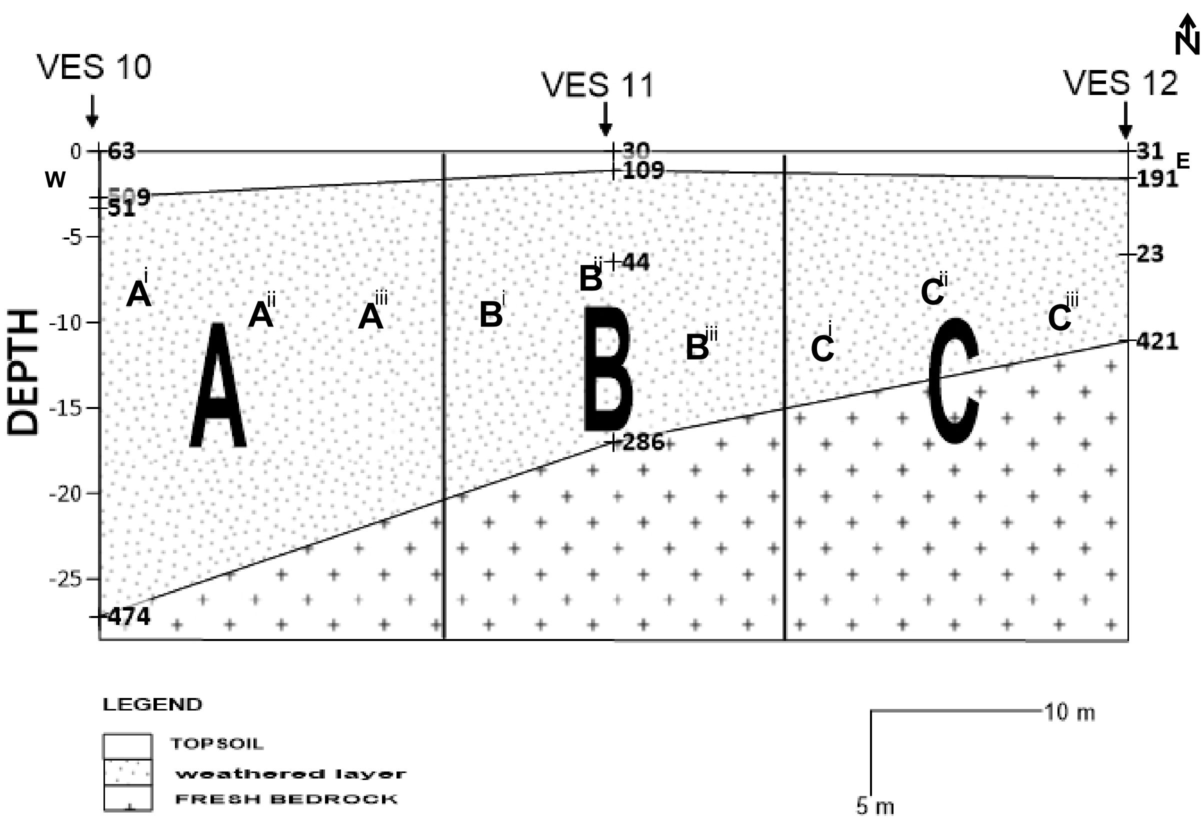

Figure 13a. Previous geoelectric section along Traverse 2 (2010).

Subsequently, changes in depth between the last nine to ten years were determined through the subtraction of previous depth from recent depth, which represents changes in depth in the last ten years. These was divided by ten (10) and converted to centimeter, and furthered divided by 12 month which represent a year, to be able to

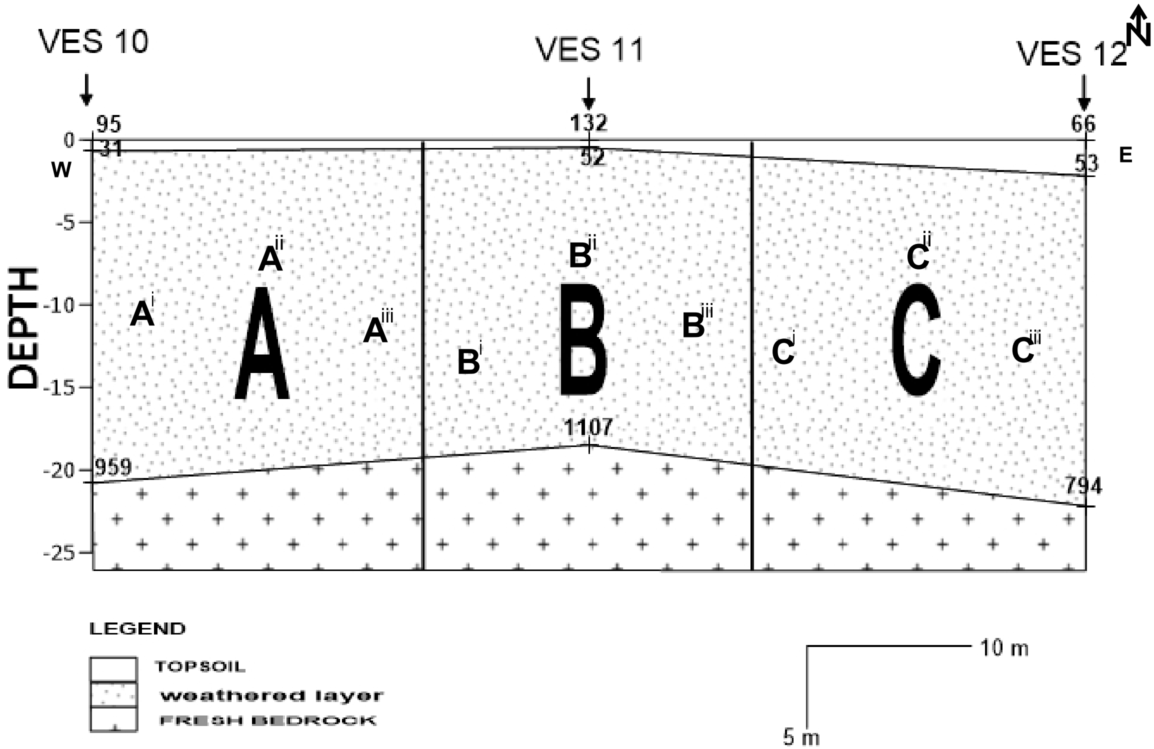

Figure 13b. Recent geoelectric section along Traverse 2 (2019).

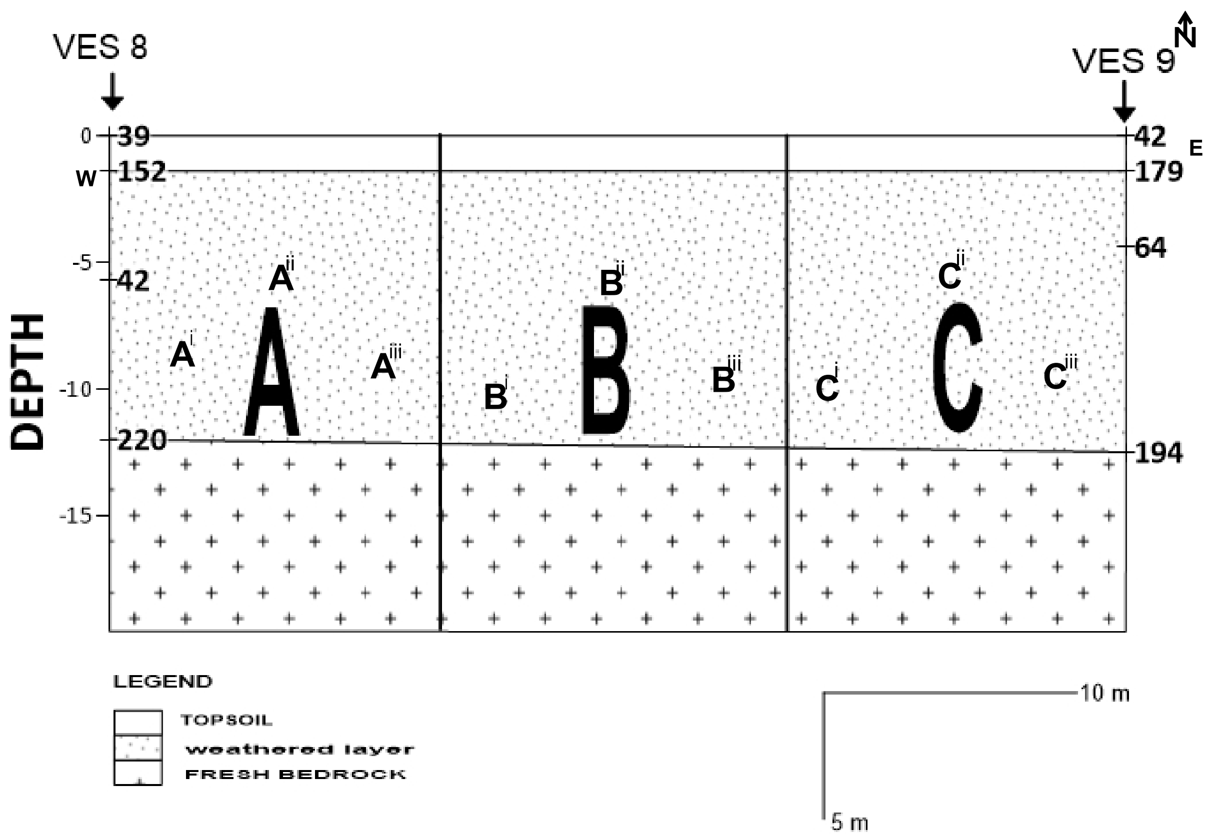

Figure 14a. Previous geoelectric section along Traverse 3 (2010).

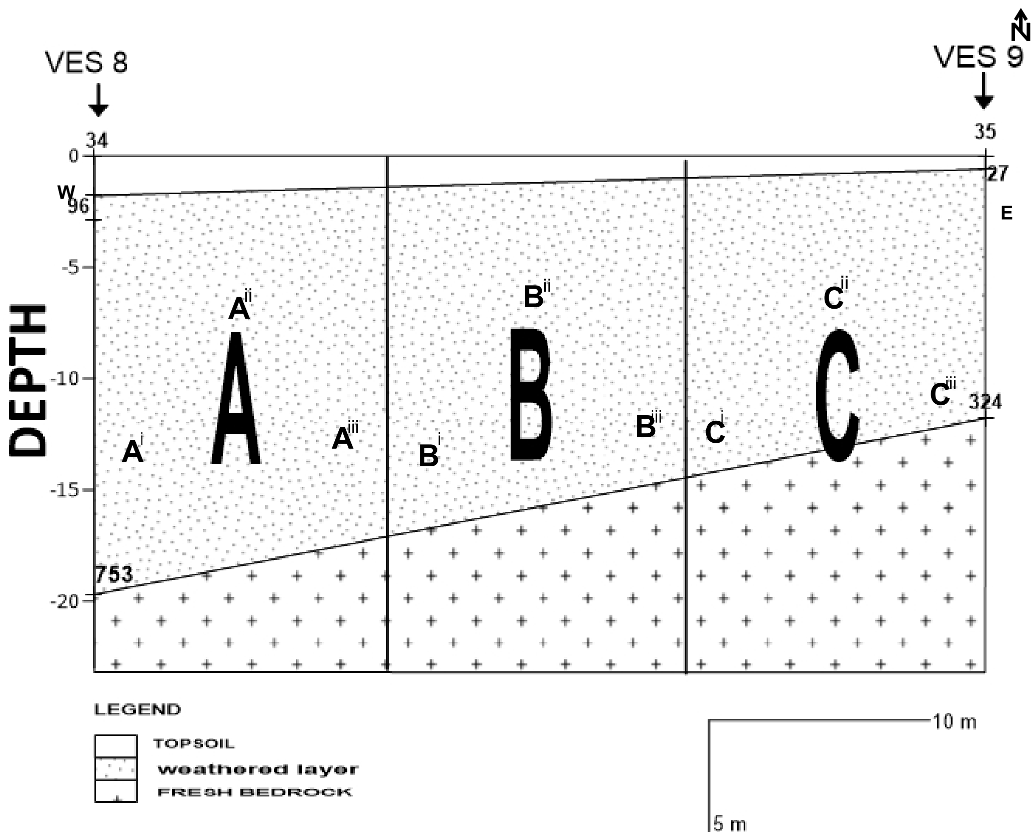

Figure 14b. Recent geoelectric section along Traverse 3 (2019).

Table 1. Showing the rate per year along traverse one.

Zone 1	A			B			C		
	2009/2010	**2019**	**Remarks**	**2009/2010**	**2019**	**Remarks**	**2009/2010**	**2019**	**Remarks**
Average	12.667	13.667	1	11.667	14.33	2.663	12	14	2
In ten year			1/10 = 0.1			2.663/10 = 0.2663			2/10 = 0.2
Conversion to cm			0.1 x 100 = 10cm			0.2663 x 100 = 26.63 cm			0.2 x 100 = 20cm
Rate per year			10/12 = 0.833 cm			26.63/12 = 2.219 cm			20/12 = 1.667 cm

determine the weathering rate per year (Tables 1, 2 and 3). Therefore, the average local weathering rate per year was determined from the weathering rate of all the traverses (TR1, TR2 and TR3) which gave a value of 1.591 cm per year. The global tectonics in relation to earth movement (horizontal) is averagely about 2 cm per year (Frank and Raymond, 2000.), when considered along the local weathering rate (vertical decay). The local geodynamic variation per year was obtained by the product of horizontal earth movement and the factor of local earth decay (weathering) which is 3.182 cm^2 per year.

Traverse 1 (VES 2,3,5 and 6) Geoelectric Section

Previous study (2010) Traverse 1

Using equation (i) to (iv)

$\frac{14+12+12\ m}{3}$ = 38/3 = 12.667

$\frac{12+11+12\ m}{3}$ = 35/3 = 11.667

$\frac{10+12+14\ m}{3}$ = 36/3 = 12

Table 2. Showing the rate per year along traverse two.

Zone 2	A			B			C		
	2009/2010	2019	Remarks	2009/2010	2019	Remarks	2009/2010	2019	Remarks
Average	17.30	19.33	2.03	17.67	19.0	1.33	17.0	19.0	2
In ten year			2.03/10 = 0.203			1.33/10 = 0.133			2/10 = 0.2
Conversion to cm			0.203 x 100 = 20.3cm			0.133 x 100 = 13.3 cm			0.2 x 100 = 20 cm
Rate per year			20.3/12 = 1.692 cm			13.3/12 = 1.108 cm			20/12 = 1.667cm

Table 3. Showing the rate per year along traverse three.

Zone 3	A			B			C		
	2009/2010	2019	Remarks	2009/2010	2019	Remarks	2009/2010	2019	Remarks
Average	11.50	15.0	3.50	11.50	13.50	2	12.33	11.67	0.66
In ten year			3.5/10 = 0.35			2/10 = 0.2			0.66/10 = 0.066
Conversion to cm			0.35 x 100 = 35cm			0.2 x 100 = 20 cm			0.066 x 100 = 6.6cm
Rate per year			35/12 = 2.917 cm			20/12 = 1.667 cm			6.6/12 = 0.55 cm

$\frac{12.667+11.667+12\ m}{3}$ = 36.334/3 = 12.11

Weathered layer thickness + topsoil (overburden thickness) of the previous study = 12.11 m

Present study (2019) Traverse 1

Using equation (i) to (iv)

$\frac{15+13+13\ m}{3}$ = 41/3 = 13.667

$\frac{14+14+13\ m}{3}$ = 43/3 = 14.33m

$\frac{16+14+12\ m}{3}$ = 42/3 = 14 m

$\frac{13.667+14.33+14\ m}{3}$ = 41.997/3 = 14 m

Weathered layer thickness + topsoil (overburden thickness) of the present study = 14 m

Present study – previous study = weathering trend = 14 – 12.11 = 1.89 m

Zone 1 rate per year average = $\frac{0.833+2.219+1.667\ cm}{3}$ = 1.573 cm

Traverse 2 (VES 10, 11, 12) Geoelectric Section

Previous study (2010) Traverse 2

Using equation (i) to (iv)

$\frac{17+17+18\ m}{3}$ = 52/3 = 17.30

$\frac{18+18+17\ m}{3}$ = 53/3 = 17.67

$\frac{18+17+16\ m}{3}$ = 51/3 = 17.0

$\frac{17.30+17.67+17\ m}{3}$ = 51.97/3 = 17.32

Weathered layer thickness + topsoil (overburden thickness) of the previous study = 17.32 m

Present study (2019) Traverse 2

Using equation (i) to (iv)

$\frac{20+19+19\ m}{3}$ = 58/3 = 19.33 m

$\frac{19+18+19\ m}{3}$ = 19.0 m

$\frac{20+19+18\ m}{3}$ = 19 m

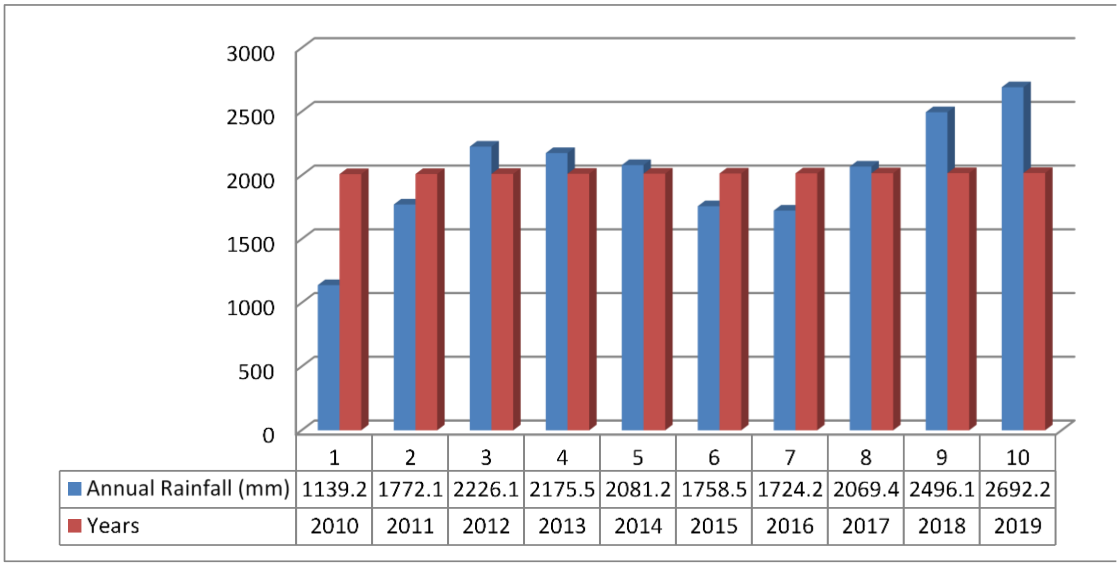

Figure 15. Rainfall Distribution/trend in the last ten years.

57.33/3 = 19.11 m

Weathered layer thickness + topsoil (overburden thickness) of the present study = 19.11 m

Present study – previous study = weathering trend = 19.11 – 17.32 = 1.79 m

From equation (v); Zone 2 rate per year average = $\frac{1.692+1.108+1.667\ cm}{3}$ = 1.489 cm

Traverse 3 (VES 8, 9) Geoelectric Section

Previous study (2010) Traverse 3

Uisng equation (i) to (iv)

$\frac{11.5\ +11.5+\ 11.5\ m}{3}$= 34.5/3 = 11.50

$\frac{11.5\ +11.5+\ 11.5\ m}{3}$= 34.5/3 = 11.50

$\frac{11.5\ +12.5+\ 13\ m}{3}$= 37/3 = 12.33

$\frac{11.5\ +11.5\ +\ 12.33\ m}{3}$= 35.33/3 = 11.77

Weathered layer thickness + topsoil (overburden thickness) of the previous study = 11.77 m

Present study (2019) Traverse 3

Using equation (i) to (iv)

$\frac{16\ +15+\ 14\ m}{3}$= 45/3 = 15.0 m

$\frac{15\ +13+\ 12.5\ m}{3}$ = 13.5 m

$\frac{12\ +11.5+\ 11.67\ m}{3}$ = 11.67 m

$\frac{15\ +13.5\ +\ 11.67\ m}{3}$= 40.17/3 = 13.33 m

Weathered layer thickness + topsoil (overburden thickness) of the present study = 13.3 m

Present study – previous study = weathering trend = 13.33 – 11.77 = 1.54 m

Zone 3 rate per year average = $\frac{2.917+1.667+0.55\ cm}{3}$ = 1.711 cm

From equation (v), the average local weathering trend/rate per year = $\frac{1.573+1.489+1.711\ cm}{3}$ = 1.591 cm per year.

Recall that global tectonics in relation to earth movement (horizontal) is averagely about 2 cm per year. Therefore, local geodynamic variation per year = horizontal plate tectonic in relation to earth movement multiply by the vertical derivative (decay rate/weathering) per year= 2 x 1.591 = 3.182 cm^2

Metrological data

The principles of stress, strains and geodynamic pressure and activities of temperature variations, internal and external pressures on the earth and tectonic activities overtimes ultimately has a direct effect on rainfall pattern which invariably affect rate of weathering. Since chemical decay and physical breakup, join with rainfall, accounts for a major factor controlling the weathering processes (Frank and Raymond, 1982). It is imperative to consider rainfall variations in understanding possible/dynamic changes in the earth decay processes. Figure 15 illustrate the bar chart of the rainfall distributions in the last ten years. This trend which is a reflection of the rain pattern and a rising trend in the rainfall pattern between 2010 and 2012, a gradual decline from 2014 to 2016 and a suddenly rise between 2016 with its peaks in 2019. These changes also have a fair reaching effect on geological processes vis-à-vis rate of weathering trend, with temperature and rainfall, being contributing factors to geological processes.

Conclusion

This research work evaluates the effects of geodynamics processes on the emerging local geology of an area, especially against the background of global tectonic activities, the gradual but continuous earth movement and the depletion of the ozone layer, as it were and its implications on the local geology of a place, especially as it affects the rate of weathering, fracturing and other geologic processes which may pose environmental challenges. The result obtained revealed the nature of changes that has taken place within the study area in terms of weathering, and the rate of weathering in the last ten years. Vertical variation/changes occurred at a weathering rate of 1.573 cm, 1.489 cm and 1.711 cm along the three traverses with average rate of 1.591 cm per year. Horizontal variations also indicated some changes in position of strata, implying an average yearly weathering of about 1.591 cm when compared with the principle of plate tectonics and gradual but continuous earth movement which is at the rate of about 2 cm per year. Therefore, the local geodynamic constant was determined from product of lateral movement and vertical earth weathering trend/gradient which is 3.182 cm^2. The rainfall analysis reflects the global weathered changes which is a major contributory factor to geological processes/ weathering. There is no doubt that everyday mankind is faced with an ever increasing challenges arising from global changes and earth geological dynamics processes resulting into earthquakes, tremor, slides, faulting and weathering processes. Ultimately, this calls for a change in approach by our land developers, environmentalist, town planners and civil engineers on the need to bring on board new strategies and ingenuity, through a deliberate effort involving geoscientist in order to effectively cope with this gradual but continuous earth processes. Therefore, this research has been able to identify the earth dynamic processes and the implications of its changes has may affect both local, regional and global environment in term of safety and making provision for future researcher.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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