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Geology and Geoelectrical Appraisal of Panda and its Environs parts of Gitata Sheet 187NE North-Central Nigeria

B. S. Jatau; S. A. Adamu and A. B. Oleka
Department of Geology and Mining, Nasarawa State University, Keffi: Corresponding email

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ABSTRACT: *Geological mapping and Geophysical investigations were carried out in Panda and its environs, with the aim of studying the geology (rock types and their structural features; joints & fractures) and its groundwater potentials. The area is underlain by the Basement Complex rocks of the North Central Nigeria consisting of porphyritic granodiorite, migmatized-gneiss and mica schist. The structural features associated with rocks in the study area include; exfoliation, joints, fault, pegmatitic and quartz veins. Twenty eight (28) Vertical Electrical Sounding (VES) were carried out away from cultural interferences. Interpreted data shows a dominance of KH and H type curve. The quantitative and qualitative interpretations revealed weathered and fractured basement. Iso-resistivity of the true aquifer, depth to basement, basement resistivity and, piezometric maps were delineated. Out of the twenty eight VES,only areas within the center of the study area (Kuban SE, Tanga North, Panda market, Jababe, Idur West, Idur and MusheJaba) have been delineated as the most viable locations for good water potentials due to the resistivity value of the rock materials (fractured and weathered basement) around those areas (50Ωm - 200Ωm) and some of the structural features (fractures, joints and faults) which serves as secondary reservoir for groundwater on account of their low resistivity values due to the high conductivity of groundwater that occupies the voids and fissures of the rock. The potential for groundwater in the study area are moderate at AngwanKwaro, AngwanMaje, and Chandap North, Kukuri area where depth to basement is shallow and occupied by fresh basement rocks (porphyritic granodiorite). While the least expected yield lies in AngwanPaa North and GidanSarki North. The two types of aquifer in the study area are weathered basement and fractured basement. This study will serve as guide for groundwater exploration and development in the study area.*

KEYWORDS: Geological mapping, geophysical investigations, rock types, structural features and groundwater potentials

INTRODUCTION

Groundwater is the largest available reservoir of fresh water and has significant importance to North-Central Nigeria where the amount of rainfall is limited to very few months of the year with annual rainfall of 1000-1500mm (Eduvie, 1998). Surface water sources are often inadequate or non-existent (Baba *et al* 2013, Baimba, 1978; Perez & Barber, 1965). There is need for scientific identification of parameters governing ground water resources, assessment and management, particularly if satisfactory living conditions of the inhabitants are to be catered for. Groundwater in most cases is free from pathogenic organism and need no purification (treatment) before usage, chemical and biological contamination of most groundwater is difficult compared to surface water. Inadequacy of surface water in most places and underground water which has been stored by nature through many years of recharge is available and dependable than surface water supplies hence can readily be trapped (Todd, 1980). He further stated that groundwater being the most important natural resources available to man, its role as a supporter of life on earth, it's also govern the economic industries and agricultural growth of nation hence its requirement in sufficient quantity as well as accruable quality by humans lead to a healthy life. Surface geological mapping, geophysical survey, using electrical method has been extensively used in the search for groundwater in the Basement terrain with high success rate. The geophysical, geological and hydrogeological methods were relied upon to achieve a meaningful success in groundwater assessment for development in the study area. The objectives of the work involved geological mapping of the area in other to determine rock types and structural pattern, correlate or relates the rock types and structural pattern and electrical resistivity result as to groundwater potential, determine the layer's thicknesses and resistivity's, estimates the depth to basement (bedrock) of the area, the overburden thicknesses and infer the groundwater potential of the area. The study area is a combination of rural communities in the area, where only surface water, which is invariably exposed to contamination, has been in use (Fedele *et al* 2013, Adama *et al* 2016, 2011, Jatau *et al* 2013, 2014 and 2020). The study area is Panda development area and environs of Nasarawa State and lies between longitude 7^0 45' 00" E to 7^0 54' 00" E and between latitudes 9^0 15' 00"N to 9^0 19'20"N. It forms part of Gitata sheet 187 N.E and covers an approximately landmass of 528km^2 with the following localities: Panda, Panungwa, Pazi, Chandap, AngwanMaje, and BakinKogi. Other minor localities not stated in the map are KukamJaba, Gwalagi, AngwanKwaro, Girgwa, GidanWaziri, GidanSarkin ago, Kulmi, Tanga, Kuban, Gidan Abe, MusheYeskwa, Jababe and Girgos. The accessibility to the study area is through Gitata-Kaduna road and other minor roads and footpaths. (Figure1). The area therefore lies within the tropics and experience tropical climate. The area has two seasons; the rainy season that lasts from April to October and a dry season from November to March however, a transitional hot season maybe notice in March and April. The mean monthly rainfall ranges from 2.0mm to 240.5mm. The maximum and minimum temperatures of the area range between 19.8^{0}C to 41^{0}C with an annual mean values between 22.9^{0}C to 32^{0}C, the relative humidity ranges from 35% to 86% (Metrological Centre Lafia, 2009). The natural vegetation is typical of the Guinea savannah characterized by presence of tall grasses and trees with broad leaves, scattered and deciduous trees that is they shed their leaves during the dry season. Important trees include Locust Bean trees, Shea-butter and Isobelina. The study area is located on relatively high altitudes and consists of low-lying terrain and few hills. The area is typified by relatively flat and mountainous landscape. The area is drained by majorly river Panda and its minor tributaries. The structural pattern of the area controls the flow of the streams which are all seasonal. The flow of the streams in the area is mainly in the N-S, NNW-SSE directions but the major river (river Panda), has flow direction towards NNE-SSW. The study area is characterized by dendritic drainage pattern..

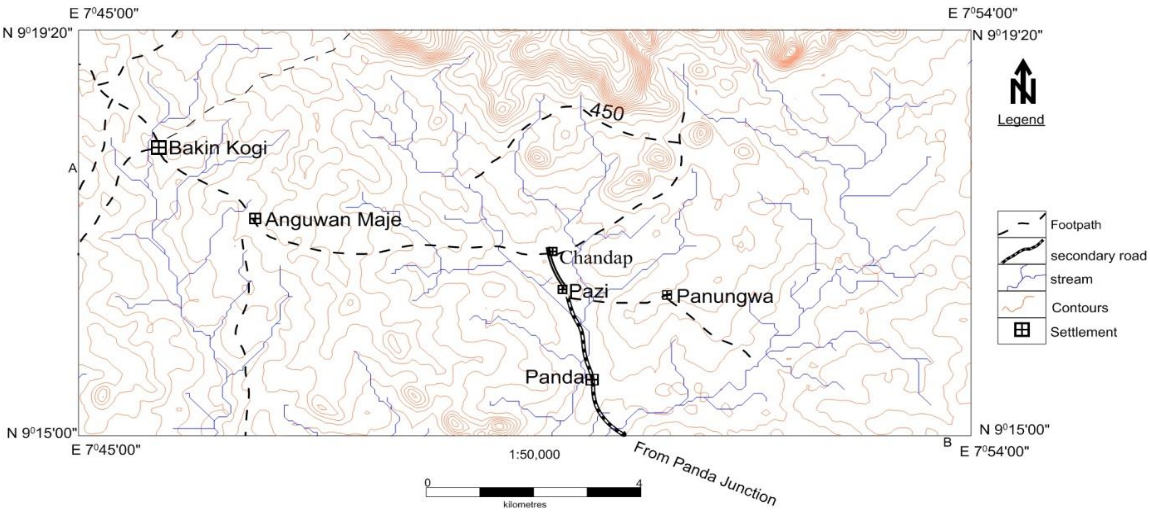

Figure 1: Location, extend and accessibility Map of the Study Area (Extracted and modified from topographical map of Gitata sheet 187 NE.

Geological setting

Nigeria lies within the mobile belt affected by the Pan African Orogeny and is sandwiched between the geologically more stable and Older West African Craton and the Congo Craton (Turner 1983). Nigeria is a large country with area coverage of about 923,768km^2. The geology of Nigeria is made up of three major litho-petrological components namely, the Basement Complex, Younger Granites, and Sedimentary Basins. The Basement Complex, which is Precambrian in age, is made up of the Migmatite-Gneiss Complex, the Schist Belts and the Older Granites. The Younger Granites comprise several Jurassic magmatic ring complexes centered in parts of north-central Nigeria. They are structurally and petrologically distinct from the Older Granites. The Sedimentary Basins, containing sediment fill of Cretaceous to Tertiary ages. Nasarawa State is underlain by the three geologic components: Basement Complex, Younger Granites and Sedimentary Basin. The Precambrian rocks of the Basement Complex comprise the Migmatite-Gneiss Complex, the Schist Belt, the Older Granites and the Undeformed Basic and Acidic Dykes covering areas of Akwanga, Keffi, Nasarawa-Eggon and Wamba; the Jurassic Younger Granites are exposed around Afu, Andaha (Mada) and Farin-Ruwa (Shakaleri) Complexes; and the Cretaceous sedimentary rocks covering the greater part of the state in the south and east, running from Lafia through Obi, Jangwa, Jangerigeri, Awe and Keana. Panda and environs is part of the Basement Complex of North-Central Nigeria.

The area of study is underlain by the Basement Complex rocks consisting of porphyritic granodiorites, mica schist and migmatized gneisses. The migmatite gneiss exhibit a granoblastic texture and characterized with light and dark bands visible minerals includes quartz, biotite, muscovite, and plagioclase. The porphyritic granodiorites are found to be scattered particularly around, AngwanMaje and occupies north-central parts of the study area re low lying isolated exposures of height less than 3m particularly towards southern parts

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mostly along the stream channels. The rock type is grey in colour with pegmatites intrusions and quartz mineralization as veins. Minerals visible in hand specimen are notable quartz and feldspar with muscovite. The migmatized gneisses are exposed also in the stream channels having sharp contact with porphyritic granodiorite at the western part of Panda market while the muscovite mica is exposed along the road cut and occupies western Panda market.

LITERATURE REVIEW

The Nigerian Basement Complex is the oldest of the three litho-petrological components that make up the geology of Nigeria (Dada, 2006). The different sections of the Basement Complex are the North-Central, South-Western and South-Eastern and the Obudu Section. The North-Central section is the largest continuous area of basement in Nigeria about 6,600km^2 (Obaje, 2009). The Basement Complex forms part of the Pan-African mobile belt and lies between the West African and Congo Craton and South of the Tuareg shield (Black, 1984). It is intruded by the Mesozoic calc-alkaline ring complexes and uncomfortably overlain by the Cretaceous and younger sediments. The Nigerian basement was as affected by the Pan-African Orogeny (600Ma) and it occupies the reactivated region which resulted from the plate collision between the passive continental margin (Burke and Dawey, 1972) of the West African Craton and the active margins of the PharusianTuareg shield. The Basement Complex rocks show a general NW-SE structural trend, which seems to lie parallel to the limbs of the major folds. Oyawoye, (1972) and McCurry, (1976) have provided reviews dealing with Basement Complex rocks of Nigeria. The resistivity method is used in the study of horizontal and vertical continuities in the electrical properties of the ground and also in the delineation of 3-dimensional bodies of anomalous electrical conductivity. It is routinely applied in engineering, archaeology, minerals and hydrogeology investigation to investigate the shallow surface geology. Electrical method generally uses direct current $(\boldsymbol{DC})$ or low frequency alternating current $(\boldsymbol{AC})$ to investigate the electrical properties of subsurface (Kearey *et al.*, 2002). Most rock forming minerals are however insulators and electrical current is carried through a rock mainly by the passage of ions in the water. Thus most rocks conduct electricity by electrolytic rather than electronic process (Kearey et al., 2002). Change in value of apparent resistivity $(\boldsymbol{\rho})$ with electrode spacing makes it possible to determine the variation of resistivity with depth (Dorbin, 1981). The great advantage of such direct reading instrument is their great speed of their operation but the potentiometer apparatus is more flexible in area of consistently high electrode resistance (Telford *et al.*, 1990).

METHODOLOGY

Geological mapping was carried out on a base map of 1.12,500 to delineate rock types, boundaries, structures, physical and optical properties which entails the megascopic and microscopic microscope, respectively. The vertical Electrical Sounding (VES) also known as Schlumberger method or array or configuration was adopted for the study to observe the variation of resistivity with depth. The equipment used for the surveying was $\boldsymbol{L \,\&\, R}$ Terrameter. The field work was outlined inspected and guided. East-West (EW) trending, profile were marked with inter-profile spacing and inter grid spacing of $528Km^2$ Total area covered.

RESULT AND DISCUSSION

Geology of the Study Area

The study area lies within the Basement Complex of Nigeria. The rock units include Migmatized Gneisses, Amphibolites, Schist, Phyllite and Porphyritic Granites/Granodiorites (Figure 3).

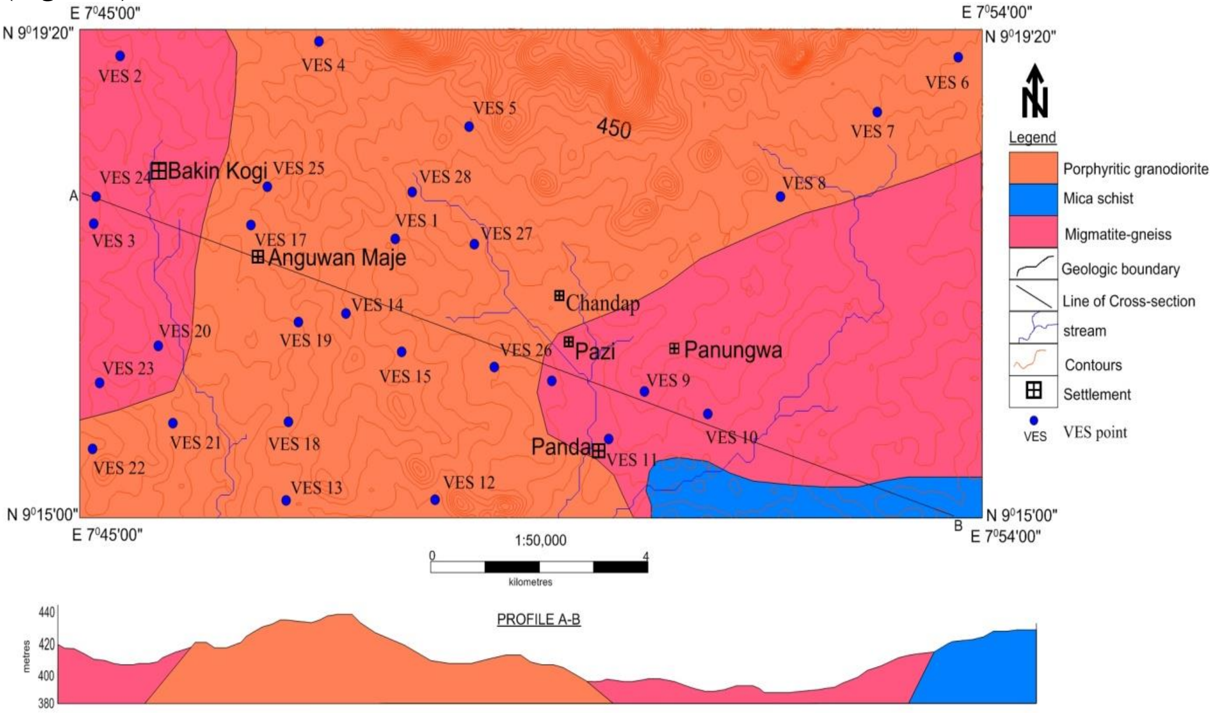

Figure 3: Geologic Map of the study Area showing 28 VES stations

Porphyritic Granodiorite

Porphyritic is a rock that has a distinct difference in the size of the crystals clearly much bigger than the rest as in porphyritic granodiorites. These rocks occur as hilly masses (Plates1 & 2) sometimes consisting huge blocks that have been derived from weathering. Mineralogically, composed of quartz, feldspars and biotite. When fresh, they are grayish-blue due to the prominence of biotite, and where weathered exhibit brownish colour. Porphyritic granodiorites dominate a wide portion of the study area, mostly around northern part extents down to the southern part and completely weathered at the centre particularly at AngwanMaje. The porphyritic granodiorites have sharp contacts with migmatized gneiss mostly at eastern Chandap down to Panda Market, exposed in the stream channel have contact with the migmatized gneisses in the western part at Bakinkogi area. In the field, the porphyritic granodiorite consists of large white prismatic phenocrysts of microcline. The rock is grey in appearance and constitutes about 60% of the rock units. Outcrops are highly jointed and strike in N-S and sometimes in E-W directions **(**Plates 1&2).

Plate: 1 Porphyritic Granodiorite
N9^0 17' 24.9"E7^0 51' 10.0"Elevation 421m

Plate: 2 Porphyritic granodiorite at close view

Plate: 3 Migmatite-Gneiss with Pegmatite intrusion. N9^0 15' 30.4" E7^0 48' 35.6" Elevation: 408m.

Plate: 4 Mica Schist
N9^0 15' 00.5", E7^0 50' 35.6"

Migmatized-Gneiss

Texturally, the Migmatized-Gneisses commonly show granoblastic texture and foliation with flow structures. Visible minerals include quartz, biotite and plagioclase. They vary in texture from being medium, even grained to coarse porphyroblastic with alternate light and dark bands. Pegmatites and quartzo-feldspathic veins occur on migmatites. The rocks are grey, strongly foliated with veins containing quartz mineralization but composed essentially of plagioclase, quartz, amphibole, biotite, feldspar minerals. The migmatized gneiss outcrops in Panungwa and some parts of Pazi area having sharp contact with the body that changed it due to high temperature that was released or injected into the surrounding rock bodies (porphyritic granodiorite) and a wide pegmatitic vein exposed particularly in the stream channel. It appears as low-lying body and outcrops in area around Panungwa. (Plate 3 and 4)

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Schist
The schist in the study area has been completely weathered into particles of muscovite and quartz everywhere around Panda market and up to Kuda, at the extreme part of the study area towards the south after the Panda bridge (Plate 4).

Structural Geology
Some of the structural features observed in the area are Joints, Exfoliations, Faults, Quartz Veins, Xenoliths and Fold. Reading were obtained and used to plot rose diagram.

Joints
The term joint refers to a fracture in a rock where there has been no lateral movement in the plane of the fracture (up, down, and sideways) one side relative to the other. A break or crack along zones of structural weakness resulting from the brittle behaviour of rocks along which there has been no relative movement. Joints were observed mostly on the migmatite-gneisses around north eastern extreme (Plate 5). Most of the joints were planner, parallel to sub parallel and trend mainly in the NNE-SSW and NW-SE directions.

Quartz Veins
Veins are intrusions produced along openings such as fractures and faults were faults were residual magmatic fluid ejects, cools and precipitates to fill up the openings. Quartz veins with average length of 10cm and width of 1.5cm were observed on the migmatized-gneiss and granodiorites. Most of the quartz veins are linear in shape.

Plate 5: Joints Observed Porphyritic Granodiorite in Western Panda

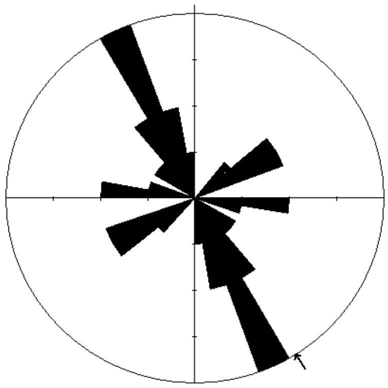

Figure 4 Rose plot of joints

The rose plot of the strike directions of joints and quartz veins measured on rocks in the study area shows major trends in the NNW-SSE direction with minor trends in NNW-SSE and NW-SE directions (Figures 4). These trends are indication of the deformational stresses probably due to the effect of the wide spread of Pan-African Orogeny.

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Pegmatite Vein

These are structures form during the final states of magma chamber crystallization when the high water content solution allows rapid crystal growth. It is a coarse-grained igneous rock, usually granite that is characterized by large well-defined crystals and often contains gemstones (example; tourmaline etc).

Xenoliths

These are fragment of pre-existing rock formations left behind or included within an igneous rock body after a destructive event has occurred. Commonly, it is an inclusion of country rock fragments that has been intruded by igneous rock. It occurs when a country rock has undergone complete melting. In the study area, this feature is commonly found everywhere in the porphyritic granodiorite.

Exfoliation

Is the separation of successive thin onion-like shells from bare surfaces of massive rock such as banded gneiss or botite gneisses. It is common in region of moderate rainfall. Exfoliation (onion-peeling) occurs along planes of weaknesses making it look like a baked body. Rocks around this region appear to be prone to weathering because of the extent of the heat resulting to its baked nature. On the field, exfoliation was seen mostly on porphyritic granodiorite.

Faults

Faults are defined as fractures in bedrock along which movement has taken place. Faults are result from failure of the fold during shear or movement of plate. The Sinistral faults which are strike – slip faults where observed mostly on migmatized gneisses in the study area, striking 110^0 and the fault plane strike 283^0 50^0S (Plate 6). It trends mainly in the N-S directions with an average horizontal displacement of about 28cm.

P

Plate 6: Sinistral faults observed at Chandap.

Hydrogeology

The source of ground water in the study area comes from hand dug wells and seasonally streams. It occurs in fractured, jointed and weathered zoned beneath the surface (sub-surface)

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which serves as aquifers. However, recharge and discharge is made possible by the presence of fractured zones. Water gotten from this source is been used for domestic as well as agricultural purposes. These sources are surface and groundwater. The surface water in the study area is use for domestic, irrigation and agricultural purposes. This may be described as all water run-offs on the surface which in most cases exists as rivers and streams. It is important to mention that the study area has a major river (River Panda) but seems to be seasonal. Ground Water here includes all waters that are stored in weathered and fractured zones. The groundwater here is utilized by sinking hand dug wells and used largely for domestic, irrigation and for agricultural purposes.

Presentation of geoelectric Result

The geophysical survey field data gave QH, KH and H type of curves for the study area. The results of quantitative geoelectric study of this area are presented in Table 1 while the qualitative results are depicted by iso-resistivity map, piezometric map, depth to basement map and basement map. The area is basically of 3-4 layered thickness.

Resistivity of Rocks and Minerals

The electrical resistivity of natural rock and sediments displays a wide range depending on a number of factors. The amount and interconnectivity of various minerals will play a role.

Geoelectric Parameter Interpretation

The geoelectric sections display lithologic sequence composed of lateritic top soil, partly weathered basement, weathered basement, fractured basement and fresh basement.

Table 1: Quantitative Interpretation Data (Summary) for Schlumberger Array

			LAYER'S THICKNESS (M)				LAYER'S RESISTIVITY (Ωm)					
VES Point	**No. of layers**	**Type of curve**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**Elevation (m)**	**Total Depth (m)**
VES 1	4	QH	3.08	6.66	18.4	-	633	205	693	439	425.6	40.92
VES 2	4	KH	0.375	1.03	28.1	-	170	210	62	122	410.4	31.285
VES 3	4	QH	2.11	6.76	12.9	-	1127	157	46	199	410.4	32.78
VES 4	3	H	1.03	21.2	-	-	1127	76	199	-	440.8	23.43
VES 5	3	H	2.27	8.78	13.5	-	86	54	319	-	425.6	13.37
VES 6	4	KH	0.667	0.92	10.6	-	122	562	141	570	395.2	14.457
VES 7	3	H	1.83	8.85	-	-	641	203	837	-	395.2	12.53
VES 8	3	H	1.15	14.7	-	-	198	35	113	-	410.4	16.95
VES 9	4	KH	1.03	2.63	13	-	240	440	214	460	395.2	21.38
VES 10	4	KH	0.6	4.7	39.7	-	568	577	107	332	395.2	50.9
VES 11	4	QH	0.741	4.02	15	-	326	103	70	175	395.2	25.301
VES 12	4	KH	0.486	2.18	12.3	-	83	210	83	160	395.2	18.056
VES 13	4	KH	1.25	0.489	10.6	-	791	859	132	332	410.4	15.29
VES 14	4	QH	1.17	1.44	21	-	1197	893	278	606	425.6	27.48
VES 15	4	KH	0.98	0.737	15.8	-	786	835	74	458	410.4	20.2
VES 16	4	KH	1.11	1.84	12.3	-	1128	2776	582	194	395.2	19.26
VES 17	4	KH	1.70	1.38	22.7	-	626	973	229	495	425.6	28.72
VES 18	4	KH	0.921	1.4	16.3	-	495	871	219	475	410.4	21.841
VES 19	4	QH	2.02	1.21	17	-	661	266	145	346	425.6	25.45
VES 20	4	KH	1	1.59	27.5	-	277	802	108	252	410.4	32.69
VES 21	4	KH	1.01	2.19	24.1	-	281	747	120	376	410.4	30.51
VES 22	3	H	2.27	24.1	-	-	485	101	253	23	425.6	28.67
VES 23	3	H	3.38	20.3	1.08	-	672	286	760	-	410.4	26.98

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VES 24	4	KH	1.08	1.13	23.7	-	613	834	161	137	410.4	29.19
VES 25	4	QH	1.43	8.77	34.7	-	206	79	414	241	425.6	56.53
VES 26	4	KH	1.22	3.27	17.3	-	1105	2131	162	431	410.4	27.51
VES 27	4	KH	1.11	0.517	15.9	-	301	347	92	162	395.2	20.33
VES 28	3	H	3.46	19.7	-	-	6580	218	307	-	410.4	26.66

The geoelectric characteristics are as following: 1stLayer: Top soil/Laterite: Resistivity: 672-485 ohm-m; Thickness: 3.0-2.0m. 2ndLayer: Weathered basement: clay, sandy clay and clayey sand. Resistivity: 286-101ohm-m; Thickness 21-23.0m. 3rd Layer: Partly Weathered Basement with resistivity values: 760-253ohm-m table 1. The weathered layer constitutes the major aquifer unit. The layer is significantly thick in the eastern part, north eastern and south-western parts of the area but clayey with characterised with low permeability and low groundwater discharge capacity.

Interpretation of Result (Quantitative Result)

The true Aquifer resistivity (iso-resistivity Map) of the study Area

The individual true aquifer resistivity of the study area is obtained from the processed data of quantitative analysis (Table 1) and was plotted and contoured as shown in (Figure 6). The contour map reveals a NW-SE trend similar to that of the piezometric map (Figure 7). The dark red-army brown coloured contour lines reveal a high resistivity values (180Ωm-280Ωm), moderate values (170-220Ωm) and lowest (50-150Ωm) in blue-pale red coloured. The North–western trend reveals a good aquiferous zone in southeastern Kuban, Panda market, Tanga, Jababe north and all other areas in pale red colour. All of these resistivity values obtained from the study area reveal a probable weathered basement (Table 1).

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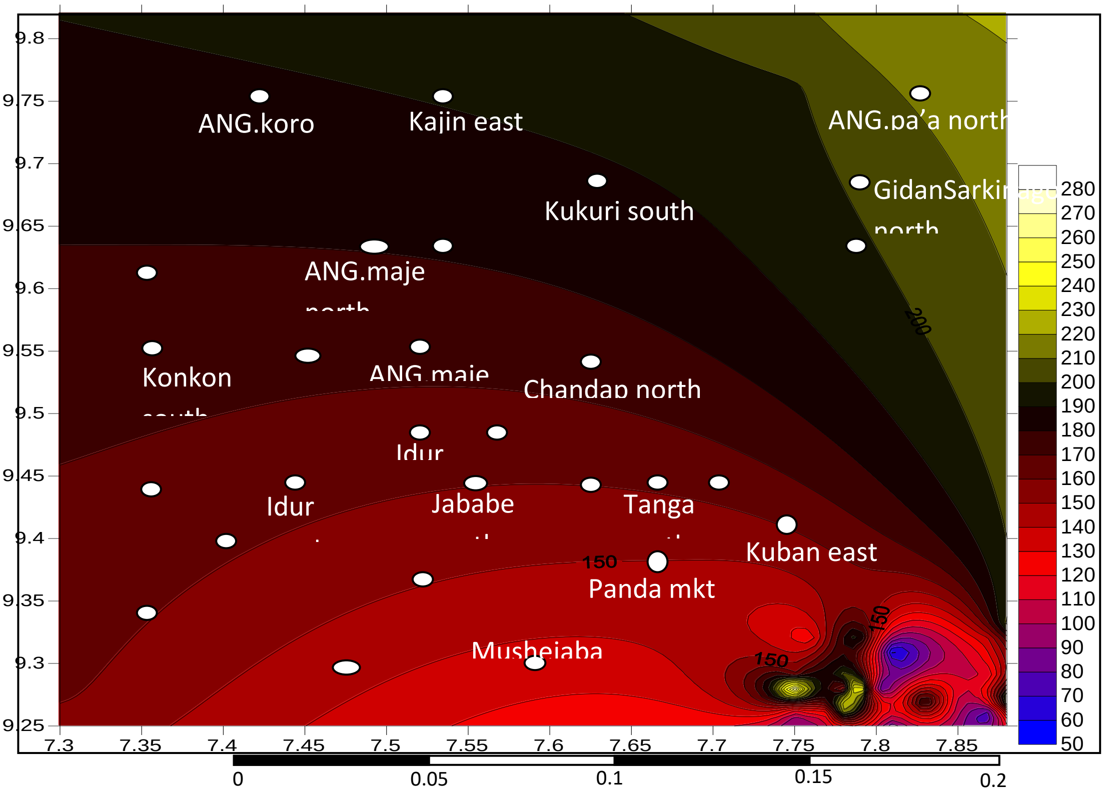

Figure 6: True Aquifer Resistivity Map of the study Area.

Piezometric map of the study Area.

The piezometric map was obtained by subtracting the field spot elevation by the depth of the overburden thickness for each location (Table 1) . This help in determining the direction of groundwater flow of the aquifer in the study area. The direction of groundwater movement can be understood in the fact that groundwater always flows in the direction of decreasing head. The piezometric map reveals some depressions and ridges. The depression trend approximately NW-SE direction. This confirms that the flow of the streams lies within the basement depression and also controlled structurally.

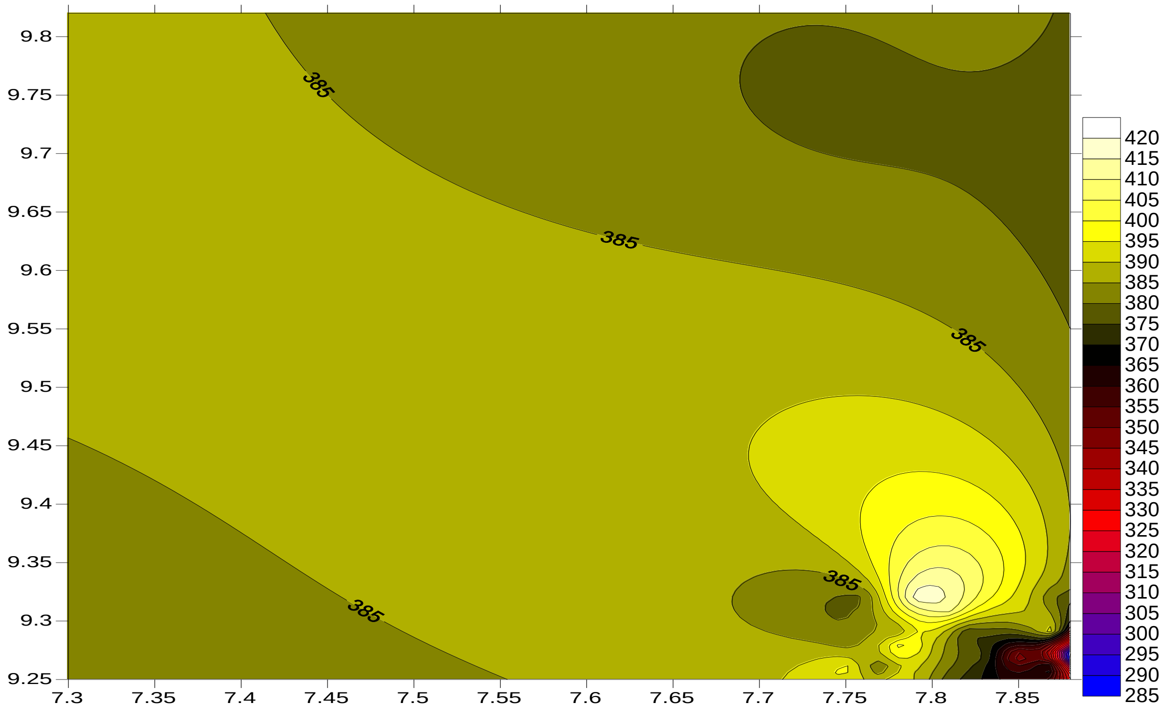

Figure 7: Piezometric Map of the study Area.

Depth to Basement map of the study Area

The depth to basement map is obtained from the quantitative result (Table 1) and contoured at 0.05m interval. This is the depth to the basement rock beneath the surface. The depth to basement rocks in the study area ranges from 12m-48m. The basement is deeper at the south-eastern Kuban and eastern Panda market (48m), this makes the south-eastern portion a groundwater receptacle zone, since groundwater will flow down topography to it. Generally, the depth to the basement increases at south-eastern portion of the study area but decreases northward, southward and westward from the central portion which could be attributed to heavy outcrop of porphyritic granodiorites found on or near the earth's surface. Thus the overburden is said to be thinnest at those area. Places with shallow depth to basement are poor aquifer potential but may provide civil engineering work materials (gravel, coble, pebbles and boulders).

Basement resistivity Map of the study Area

The basement resistivity for each sounding point was obtained and were plotted and contoured at an interval of 50Ωm. From the interpreted geoelectrical data, (Table 1) the basement resistivity was recorded as the last layer resistivity. The basement resistivity of the sounding point defines the type, nature and character of the layer. The contour map shows a NNW-SSE and N-S trend which are controlled by structures (fractures and weathered). The basement resistivities in the eastern part of Kuban and around Panda market (areas in blue colour (100Ωm-250Ωm)), revealed a high groundwater potential area, medium at areas painted red (300Ωm-550Ωm) and low at areas with yellow paint (600Ωm-850Ωm) due to the low resistivity values obtained in those areas.

RESULTS DICUSSION

The geological mapping carried out in the study area reveal three different lithologic units (porphyritic granodiorite, migmatite gneiss, schist and associated pegmatitic vein that intruded porphyritic granodiorite) and several structural features (sinistral faults, joints, exfoliations, and quartz veins) which serves as secondary reservoir for groundwater and control the flow of groundwater. The Schlumberger array quantitative results, reveals three (3) layers mainly H- curve type. The topsoil being Fadama loam-fresh basement has thicknesses ranging from 1.03m-3.46m and resistivity values of 86.0Ωm - 6580Ωm. Second layer composed of Fadama loam-weathered laterite, has thickness varies from 8.78m - 24.1m and resistivity value varies from 35Ωm - 286Ωm. The third layer is probably made up of weathered laterite with thickness and resistivity values of 1.08m - 13.5m and 113Ωm - 837Ωm respectively.

The four (4) layers were recorded mainly KH & QH curves. The first layer is probably made up of weathered lateritic to fresh basement with the thicknesses ranges between 0.375m-308m and the resistivity values of 83Ωm-1197Ωm. The second layer is made up of weathered laterite and has thickness ranges between 0.489m-8.77m and resistivity values of 79Ωm-2776Ωm. The third layer is made up of weathered laterite and has thickness of 10.6m-39.7m with resistivity values of 46Ωm-693Ωm. The last layer being sandy and fractured basement rock unit has resistivity values ranges 122Ωm-606Ωm. The low resistivity values < 100Ωm is diagnostic of lateritic clay with clayed sand, while the high resistivity values < 100Ωm is typical compacted sand clay and clayed sand.

CONCLUSION

The general geology of the study area comprises porphyritic granodiorite, migmatized gneiss mica schist and associated pegmatitic veins that intruded the rocks that constitutes the study area. The geologic sequence beneath the study area is likely to be composed of topsoil weathered layer, partly weathered/fractured basement and fresh basement. The rose plot of the strike directions of joints measured on rocks shows major trends in the NNW-SSE direction with minor trends in NNW-SSE and NW-SE directions with sinistral faults trend in N-S direction. These trends are indication of the deformational stresses probably due to the effect of the wide spread of Pan-African Orogeny. This confirms that the flow of the streams lies within the basement depression and controlled structurally. The geological structures correlated well with resistivity interpretations of piezometric map with the depression trend approximately NW-SE direction and the basement resistivity map of the study area, the contour map shows a NNW-SSE and N-S trend which are controlled by structures (fractures and weathered). The geoelectric studies revealed a three-four layer case mainly H, QH and KH curve types, in which the weathered and fractured basement is believed to be the main aquifers. Configuration map of groundwater table and directions of the groundwater flow (Piezometric map) shows NW-SE direction. Piezometric map of the study area range between 285-420m, the true aquifer resistivity ranges 50-280m, basement resistivity 550-850Ωm, depth to basement 12-48m, and the true aquifer resistivity range between 50-280Ωm. The groundwater potential of the area varies with high potential around eastern Panda market with true aquifer resistivity value from 50-280 Ωm overburden thickness range from 10-28m, this is followed by a moderate and low potential. Their resistivity values ranges from 800-1000Ωm with overburden thicknesses from 8-18m. The weathered fractured basement is the main aquifer. The river and its tributaries rivers in the study area flow within the basement depression (river Panda), and are controlled structurally.

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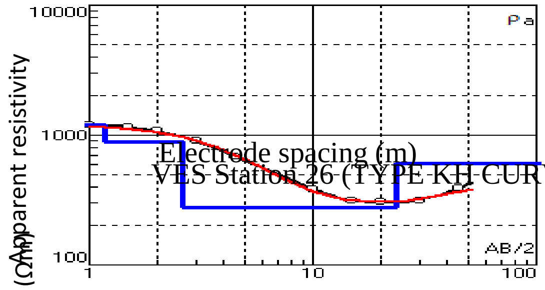
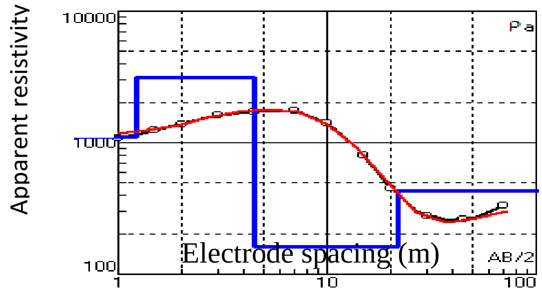
TYPICAL CURVE TYPES AND MODELS OBTAINED FROM THE STUDY AREA

Electrode spacing (m)
VES Station 13 (TYPE KH CURVE)



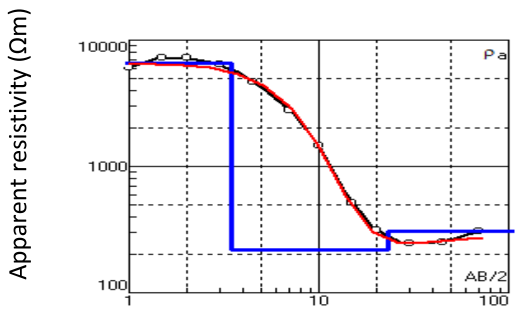
N	ρ	h	d
1	1197	1.17	1.17
2	893	1.44	2.61
3	278	21	23.7
4	606		

Electrode spacing (m)
VES Station 26 (TYPE KH CURVE)



N	ρ	h	d
1	1105	1.22	1.22
2	2131	3.27	4.49
3	162	17.3	21.8
4	431		

Electrode spacing (m)
VES Station 28 (TYPE H CURVE)



N	ρ	h	d
1	6580	3.46	3.46
2	218	19.7	23.2
3	307		