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An Integration of Geophysics and Petrophysics in Study of Rock at Elete, Lokoja Southwestern Nigeria

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ABSTRACT: *Granitic Gneiss and Banded Gneiss make up the bulk of the local rock types, and quartz veins are the most common intrusions seen there. Tectonic upheavals in the earth's crust are responsible for the region's structural features, including as foliations, folds, joints, and fissures. The goal of this research is to integrate several scientific techniques to subsurface structure definition. For this study, 16 Vertical Electrical Sounding (VES), petrophysical study, and background knowledge of geology were used to delineate subsurface rock. The Schlumberger array with a maximum electrode separation of 300m was employed for VES. Elete's true aquifer resistivity map shows that the South-Eastern and North-Eastern axis has relatively low resistivity values, which may indicate the presence of an aquiferous zone, while the North-Central and Southern regions have a wider range of resistivity values, which may not be consistent with a water-bearing zone. Additionally, petrographic analysis of the rock reveals that the mineral composition of Granitic Gneiss is Quartz (41.72%), Plagioclase (10.79%), Biotite (25.17%), Muscovite (19.42%), and Opaque (2.87%). While biotite makes up the granite gneiss. Biotite (45%), Muscovite (9.93%), Quartz (36.87%), Plagioclase (4.26%), and Opaque (3. 55%).Hydrogeologically, it stands to reason that Elete and its surroundings are situated in a region with medium to good groundwater potential based on the information at hand and the results of the geophysical investigation. Weathered/fractured basements are anticipated to contain productive aquifers.*

KEYWORDS: resistivity, gneiss, rock aquifer, elete, Nigeria.

INTRODUCTION

The assessment of the earth's subsurface's geophysical and petrographic properties is of utmost importance, particularly in locations chosen for hydrogeology and other geological studies. This is because close-to-surface geologic phenomena such as clay pockets, sinkholes, voids, fractures, faults, and/or heterogeneities in subsurface geo-materials are significant sources of danger for civil engineering projects (Eyankware, et al., 2022). The hydrogeology of these study locations is also directly impacted by certain of these geologic formations (Obasi, et al., 2022). Petrography is the microscopic analysis of the mineral makeup of rocks and the in-depth study of the mineral makeup of rocks (Ike, et al., 2021). The preparation of thin sections of mineral and lithological materials in the lab is essential for optical mineralogy and petrography, according to a prior study by Eyankware, et al. (2021). The preparation of thin sections of mineral and lithological materials in the lab is essential for optical mineralogy and petrography, according to a prior study by Eyankware, et al. (2021). On the other hand, electrical surveys help to determine the distribution of resistivity values inside the subsurface by capturing samples from the earth's surface (Eyankware and Aleke, 2021). These surveys have been used for years in hydrogeological, mining, geotechnical, and environmental investigations (Opara, et al., 2022). Following that, the true resistivity values are estimated using the obtained data (Oli, et al., 2021). The number of minerals and fluids present, porosity, permeability, and the degree of water saturation in the rock, for example, can all be used to connect these resistivity measurements with various geological factors (Obasi, et al., 2022). The field of research includes specialized fields like petrophysics and hydrogeology. The field of geology known as petrology investigates the factors that lead to the formation of rocks. Any given rock sample can be classified using the petrographic examination of that rock sample. Akindele and Goki et al., (2011), Onimisi et al. (2013), Folorunso et al. (2013), Olatunji et al. (2013), Olusiji (2015), Ogunyele et al. (2018), Adegbuyi et al. (2018), and Gideon, (2019) are just a few of the researchers who have studied the Precambrian Basement Rocks near the Southwestern Basement Complex. The Eburnean and the Pan-African Orogeny were the key events that changed the study area and the Precambrian geology of Nigeria, according to Akindele and Oyinloye's (2011) analysis of all tectonic episodes. His geological and geochemical results showed that these crystalline rocks are all genetically related and that the protoliths of the amphibolites were generated by the slow differentiation of a parent basaltic magma, which is how all these crystalline rocks evolved. He concluded that a back-arc tectonic context was present where these rocks were located. Onimisi et al. (2013) claim to have discovered two marble outcrops, known as Mass I and Mass II, close to Itobe. Studying these rocks' petrographic properties is required in order to understand their deformation trait, particularly within the research area. To assess the impact of the petrographic characteristics of the rocks in the Elete in Lokoja, Kogi State Nigeria a geophysical analysis and evaluation of petrographic content were conducted.

Location and Accessibility

The region has the normal savannah wet and dry seasons, with the dry season often lasting from December to March and the rainy season typically extending from April to October. The temperature fluctuates between 15°C and 32°C between December/January and March/April. The average annual rainfall in the area is approximately 1270 mm, according to a thirty-year record. For the annual potential evapo-transpiration, Thonthwaite's technique produced 767.2 (Eduvie, 1991). The annual rainfall ranges from 1100 mm to 1600 mm, according to (Ajibade and Wright, 1988). The study area is located in the Guinean Savanna Vegetation Zone of Nigeria, which has two distinct types of vegetation: the forest, which is predominantly composed of woody plants, thorn bushes, and trees and in which grasses are almost nonexistent, and the savanna herbs and shrubs.

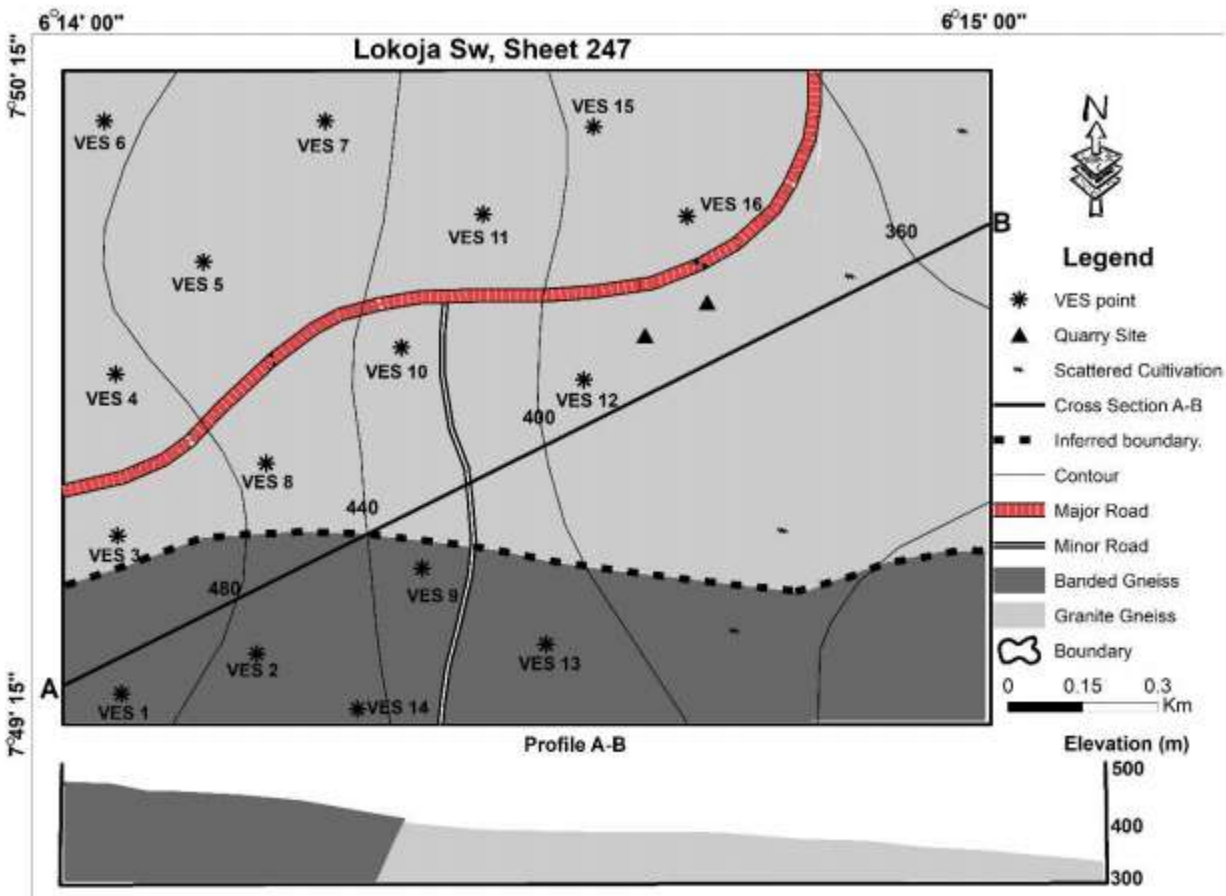

Fig.1: Topographical map of the study area.

Geology of the Study Area

The geology of the study area has been described by many scholars, including (Ajibade, 1976; Mc-Curry, 1985; Ajibade, et al., 1983). The research region is composed of cretaceous sedimentary rocks from the Bida Basin, which make about 15% of the land surface, and Precambrian sedimentary rocks from the Nigerian Basement Complex, which account for roughly 85% of the land surface. Field mapping indicates that the Migmatite-gneiss, Biotite granites, Quartzites/Quartzite-schists, and Amphibolite-Schists/Amphibolites are the principal lithological constituents of the research region. The Basement complex is filled with a variety of rocks.

1) **The older metasediments**

The migmatite gneiss is the most common form of rock in the Nigerian Basement complex. The two main gneisses found there are banded gneiss and biotite gneiss. The parallel arrangement of contrasting dark and light minerals results in substantial foliation in the biotitic gneisses, which are highly widespread. These banded gneisses have delicately folded bands with contrasts of light and dark hues. Thought to have sedimentary beginnings, the migmatite gneiss complex, the oldest basement rock, has since experienced considerable metamorphic and granite alteration. The older metasediments were among the earliest rocks to develop on the Nigerian Basement Complex. The older metasediments, which had a wider distribution and were originally of sedimentary origin, underwent extensive, repeated metamorphism and are now found as quartzites, marble, and other calcareous rocks as well as the remains of highly altered clayey sediments and igneous rocks.

2) The younger metasediments

Older Pre-cambrian sedimentary and volcanic rock belts with a roughly north-south trend, known as the younger metasediments, cover the majority of the Basement complex. The primary types of rocks include quartz-biotite-muscovite schist, which is the modern name for the ancient shaly rocks. These laterally change into schists with rich graphite, phyllites, and chlorite, as well as micaceous schists with coarse-grained feldspar. Additionally, ferruginous quartzites exist.

3)The older granites

The composition of the prior granites varies greatly. The composition of the granite in these rocks varies greatly.

4) The younger granites

Granitic alkaline ring complexes and the intruding volcanic rock.

METHODOLOGY

The field of geology was scaled at 1: 25,000. Geophysics and petrography were used to analyze the rocks in Elete and the area. Schlumberger's array was used for this study's 16 VES; see Figure 1. Between 2 and 300 m was the spread length of electrode (AB). Ohmega resistivity meter was the instrument used to gather the data. Field curves were created by graphing the measured values of apparent resistivity against electrode spacing AB/2 on bi-logarithmic graphs. Visual inspection of the field curves allowed for the identification of different curve types. The field curves were interpreted using partial curve matching techniques as well. The interpreted parameters (layer resistivity and thickness) were then entered into the computer as an initial modeling technique using Win RESIST (***), and the interpretation results were used to produce geoelectric sections along various directions. Then, each sample was subjected to extensive petrographic laboratory experiments, including modal analyses and photomicrographs of the thin sections. Photomicrographs were taken using digital cameras, and the modal contents were examined by comparing the photomicrographs with ImageJ. The results of human and computer-aided data interpretation of the Vertical Electrical Sounding (VES) were utilized to create maps, charts, and graphs that can be used to evaluate the hydrogeology and detailed geology of the research area. Surfer 10, ImageJ, WIN-RESIST, and Transfo were the applications used.

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RESULTS AND DISCUSSION

Table 1: Quantitative Interpreted Data (Summary) for VES of Elete and its Environs

VES	Layer Resistivity (ohm-m)						Layer Thickness					No of Layers	Curve Type
	1	2	3	4	5	6	1	2	3	4	5		
VES1	133.56	77.48	144	2012	2911	-	0.35	1.43	16.18	6.8	-	5	HA
VES2	181.26	155	145	1002	1320	-	0.8	0.3	2.53	3.9	-	5	H
VES3	333.3	148.2	2361.9	155	746	-	1.4	0.78	1.9	8.92	-	5	KH
VES4	49.4	1874.7	297	1048.8	1652	-	0.236	0.65	1.55	3.73	-	5	KH
VES5	25.6	2898	363.1	415	759	1868	0.018	1.06	1.22	2.4	3.24	6	KH
VES6	157.7	17289	91.48	294.1	959	-	0.619	1.64	6.31	20.47	-	5	KH
VES7	315.2	2.95	371.6	1558.1	1254	-	2.54	0.466	1.45	2.46	-	5	H
VES8	191.4	1166.1	166	97.5	586	-	0.386	0.95	17.36	8.43	-	5	KH
VES9	500.5	1006.5	202.8	99	640	-	1.23	0.71	11.91	12.11	-	5	KH
VES10	528.2	358.6	152.6	1134.3	1444.2	-	0.82	7.15	9.86	10.77	-	5	H
VES11	42.78	20673	3061	157	1450	-	2.24	1.61	1.9	0.9	-	5	A
VES12	198	872	213	481	1079	-	0.877	1.98	3.81	6.62	-	5	A
VES13	205	604	137	732	4124	-	0.95	3	2.75	9.37	-	5	A
VES14	377.3	173.4	2801	425	8774	-	1.28	1.05	2.32	8.21	-	5	KH
VES15	54.87	2188	106	57.7	793	-	1.64	2.66	6.1	21.13	-	5	HA
V`ES16	31	1592	96	817	5865	-	0.14	0.77	2.55	7.54	-	5	KH

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Table 2: Qualitative Data used for Interpretation from theVES Quantitative Data of Kuchibuyi and its Environs

VES POINTS	LATITUDE Northing	LONGITUDE Easting	Elevation (m)	Aquifer Thickness (m)	Aquifer Resistivity (Ωm)	Basement Resistivity (m)	Depth of Basement (m)	Overburden Thickness (m)
VES1	6.235556	7.821111	487	16.18	145	2911	60	15
VES2	6.236667	7.822222	459	2.53	146	1001	45	10
VES3	6.236111	7.825001	473	8.92	156	746	19	6
VES4	6.235833	7.830001	474	1.55	298	1652	45	4.5
VES5	6.236389	7.831944	487	2.5	414	759	30	4.5
VES6	6.235556	7.817222	217	20.47	295	959	80	7
VES7	6.238333	7.817222	470	1.45	370	1559	70	15
VES8	6.236944	7.827501	476	17.36	167	586	65	4.5
VES9	6.239722	7.823611	480	12.11	98	640	77	7
VES10	6.238889	7.830278	491	9.46	152	1133	38	10
VES11	6.241111	7.830278	470	1.9	156	1450	36	7
VES12	6.242222	7.831667	481	3.81	212	1079	45	10
VES13	6.241667	7.829167	478	2.75	138	731	30	4.5
VES14	6.240278	7.821667	510	8.21	424	874	60	4.5
VES15	6.244444	7.821111	490	6.1	107	793	55	15
VES16	6.235556	7.821111	430	2.6	97	816	56	7

Interpretation of geo-electric section

The shape of the VES curves depends on the resistivity, thickness, and number of layers in the subsurface. Table 2 makes and provides an interpretation of the field curves. The geoelectric characteristics determine the relevant layer resistivity values and thickness. The result of the interpretation in terms of geoelectric layering is as follows:

First layer (Lateritic topsoil) The composition consists of clay, sandy clay, clayey sand, and laterite with resistivity values ranging from 26.6 m to 529.2 m. The layer thickness is between 0.01 and 2.54 meters.Clay, sandy clay, and clayey sand make up the second (Lateritic) stratum.This layer has resistivity measurements ranging from 2.94 to 2899 m. The thickness of the layer ranges from 2.8 to 19.4 meters;

Third Layer (Weathered Basement) Tectonic activity in this zone increases the amount of pore space. Resistivity measurements for this stratum range from 91.49 to 2362.9 m.

Fourth Layer (Fractured basement) In the basement complex terrain, fractured strata with substantial depths, thicknesses, and low resistivities make up aquiferous units.

Fifth or Sixth(Fresh Basement layer) This layer is made up of fresh, unaltered basement with resistivity readings between 586 and 1868 m.

Interpretation of Aquifer Parameters

Overburden thickness, aquifer thickness, basement depth, true aquifer resistivity, basement resistivity, and elevation map (Figures 2, 3, 4, 5, 6, and 7) of the research area have been produced to define the water-bearing units in the area. The principal structure in the study area that can store water is the weathered and fractured basement. This is due to its purportedly advantageous porosity and permeability characteristics. The north-eastern and northwestern axes exhibit relatively low resistivity values, which may point to the presence of an aquiferous zone, according to the actual aquifer resistivity map of the research area (Fig. 5). It might not be consistent with a water-bearing zone to have a higher range of resistivity values in the lower South. The weathered unit may have a thickness ranging from 1.45 to 20.47 meters, according to deductions obtained from the Elete Aquifer thickness map (Figure 4.8). Olorunfemi and Fasuyi (1993) observed that weathered and fractured aquifers with enhanced permeability through secondary porosity have higher groundwater yield in foundation complicated terrain than clay-bearing/low permeability weathered layer pools. Aquiferous zone groundwater exploration requires the (weathered/fractured zone), as demonstrated by Dogara et al. (1998). They discovered that the zone's capacity to store water was enhanced by thickness. The area might therefore have a lot of hydrogeological potential. It would be feasible to build groundwater tubes near to the intersection of the north-central and south-eastern axes based on the geo-electrical features of the research area. These on-site observations and interpretations are consistent with earlier research of a similar nature on groundwater exploration in hard rock terrains in Nigeria (Olorunfemi and Fasoyi, 1993; Olasehinde, 1999; Ariyo and Adeyemi, 2009; Anudu et al., 2011; Oyedele et al., 2011).

Overburden Thickness map of the study

The overburden thickness is the thickness of the subsurface prior to the aquifer depth. The topsoil and lateritic layer thicknesses are included. From Fig. 2 and Table 2, it was deduced that the map in

Fig. 2 had high overburden, with values between 13 and 15 m. While in the northeast and northwest of the research region, there was minimal overburden thickness with a green color.

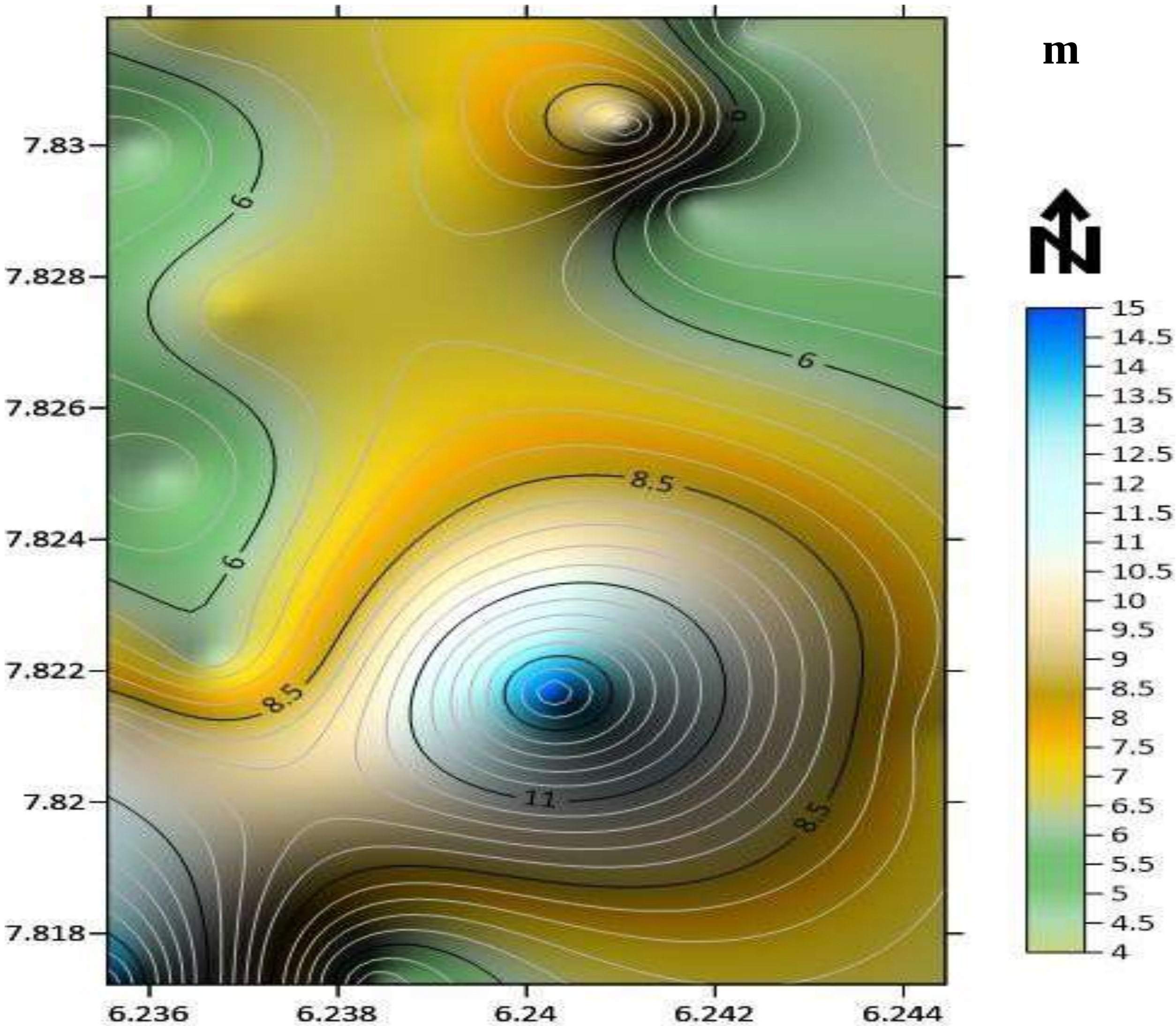

Fig. 2: Overburden thickness map ofthe study are

Aquifer Thickness map of study area

This is an estimation of the water-saturated rock pore spaces within the hydrogeological defined aquifer. Take note that water yield increases with aquifer thickness and vice versa. According to Fig. 3 and Table 2, the centre of the study region, which makes up 68% of the study area, has an aquifer thickness that ranges from 6 to 11 meters. Around the chosen northwest and southwest regions of the study area, high aquifer thickness values were noted.

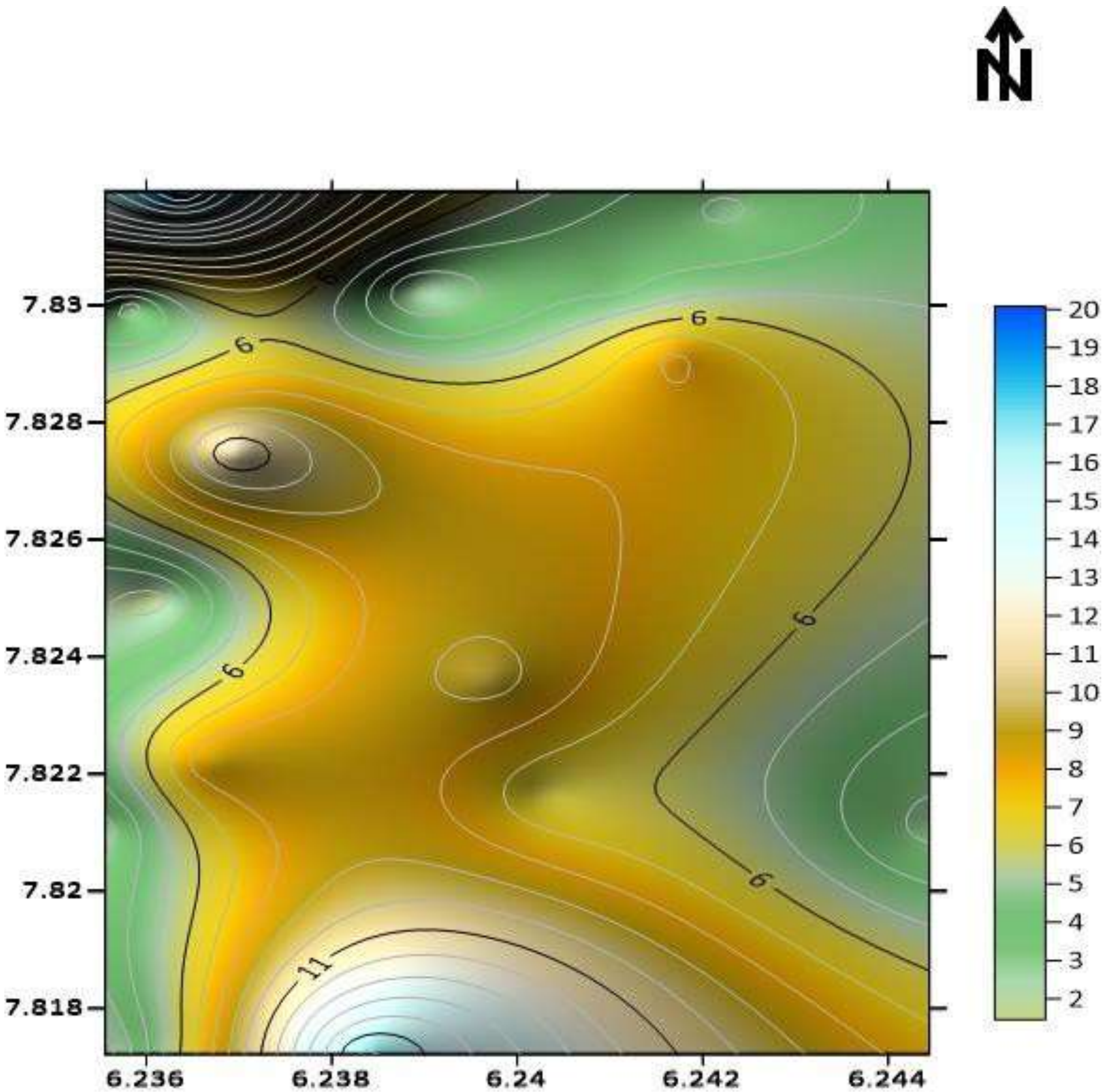

Fig. 3: Aquifer Thickness map the study are

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Depth to aquifer map of the study area

The aquifer depth reveals the differences between the basement and topsoil in depth. Areas of high aquifer were found around specific regions in the northwest, southwest, and southwest of the research area, as shown in Fig. 4 and Table 2.

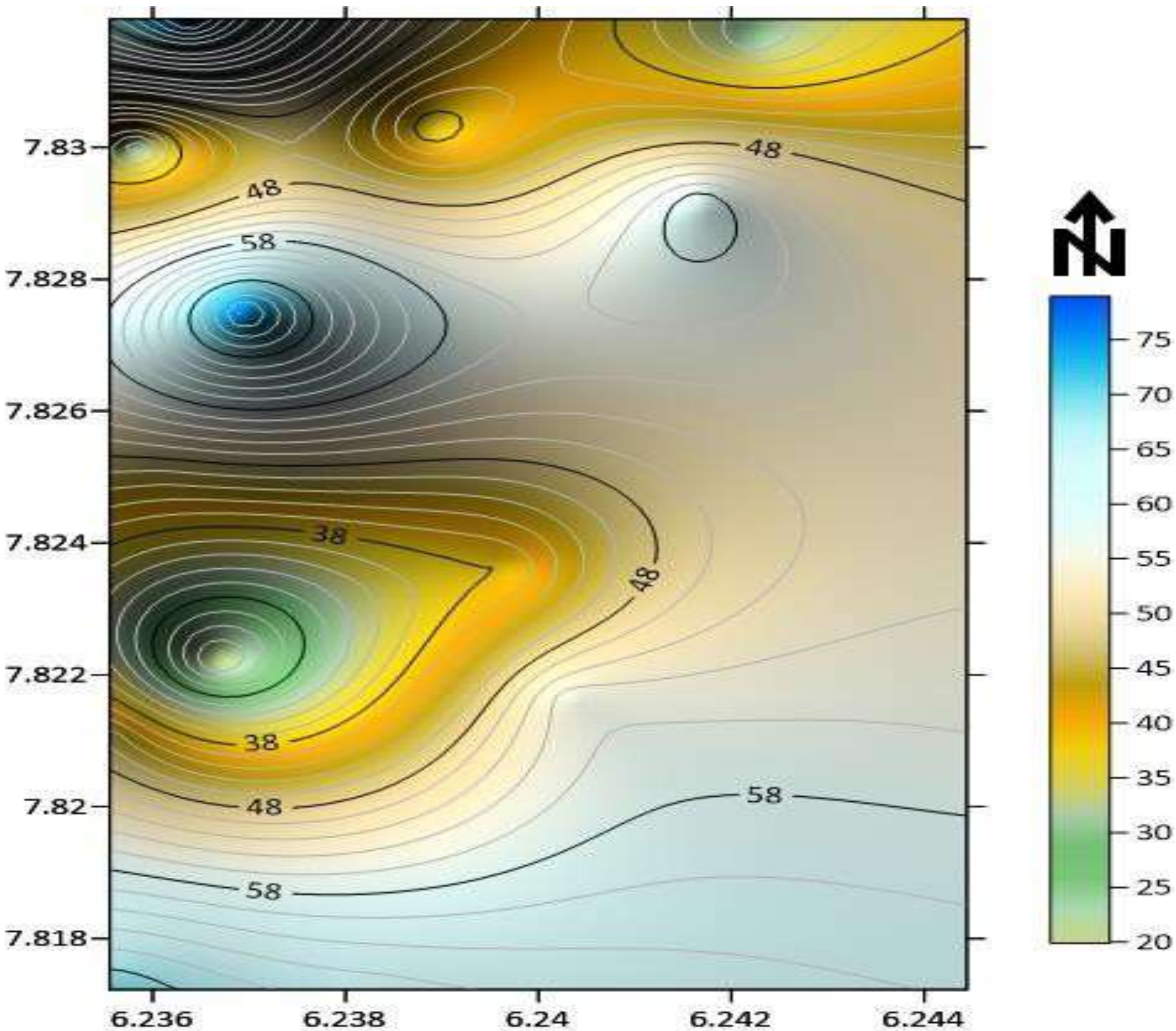

Fig.4: Depth to basement map of the study area

Aquifer Resistivity map of the study area

This shows the water reserve's resistance, whether it is in a weathered zone or a zone with fractures. Aquifer resistivity values were found to vary from 2 to 5.5 /m2 in a few locations in the southwest, southeast, northwest, and northeast. Based on deductions from Fig. 5 and Table 2, it was determined that 62% of the research region had an aquifer resistivity value range of 6 to 12 /m^2.

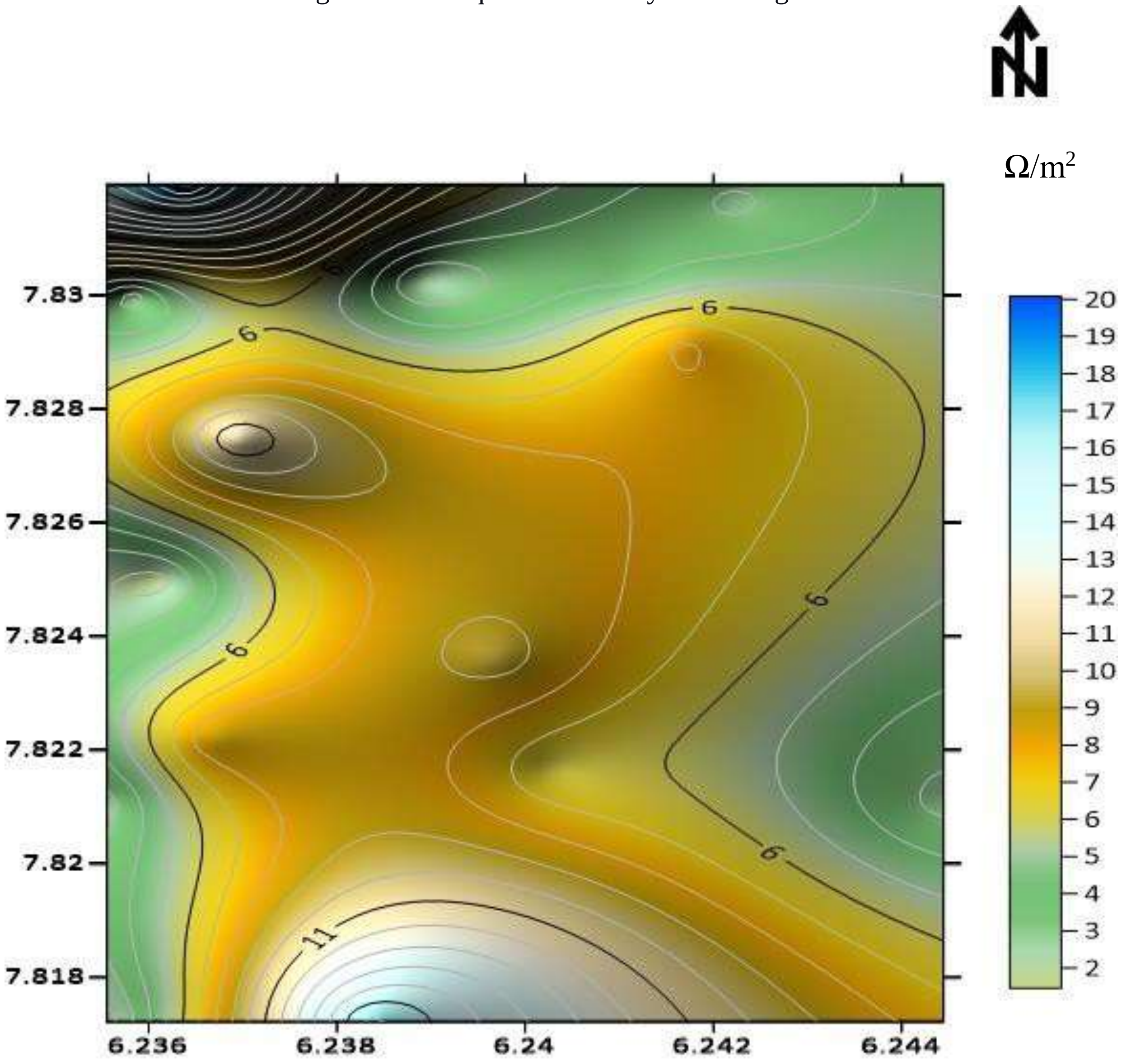

Fig. 5: Trueaquifer resistivity map the study area

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Basement Resistivity map of the study area

This illustrates the basement's resistance in the study area. According to study results, the southwest and northwest portions of the study region with resistivity values between 1250 and 1600 /m were found to have high resistivity values within the basement terrain (see Fig. 6 and Table 2). In the middle and certain areas of the research area, a region with slightly higher resistivity values was found, with a resistivity value of 850 to 1100 /m and a brown color.

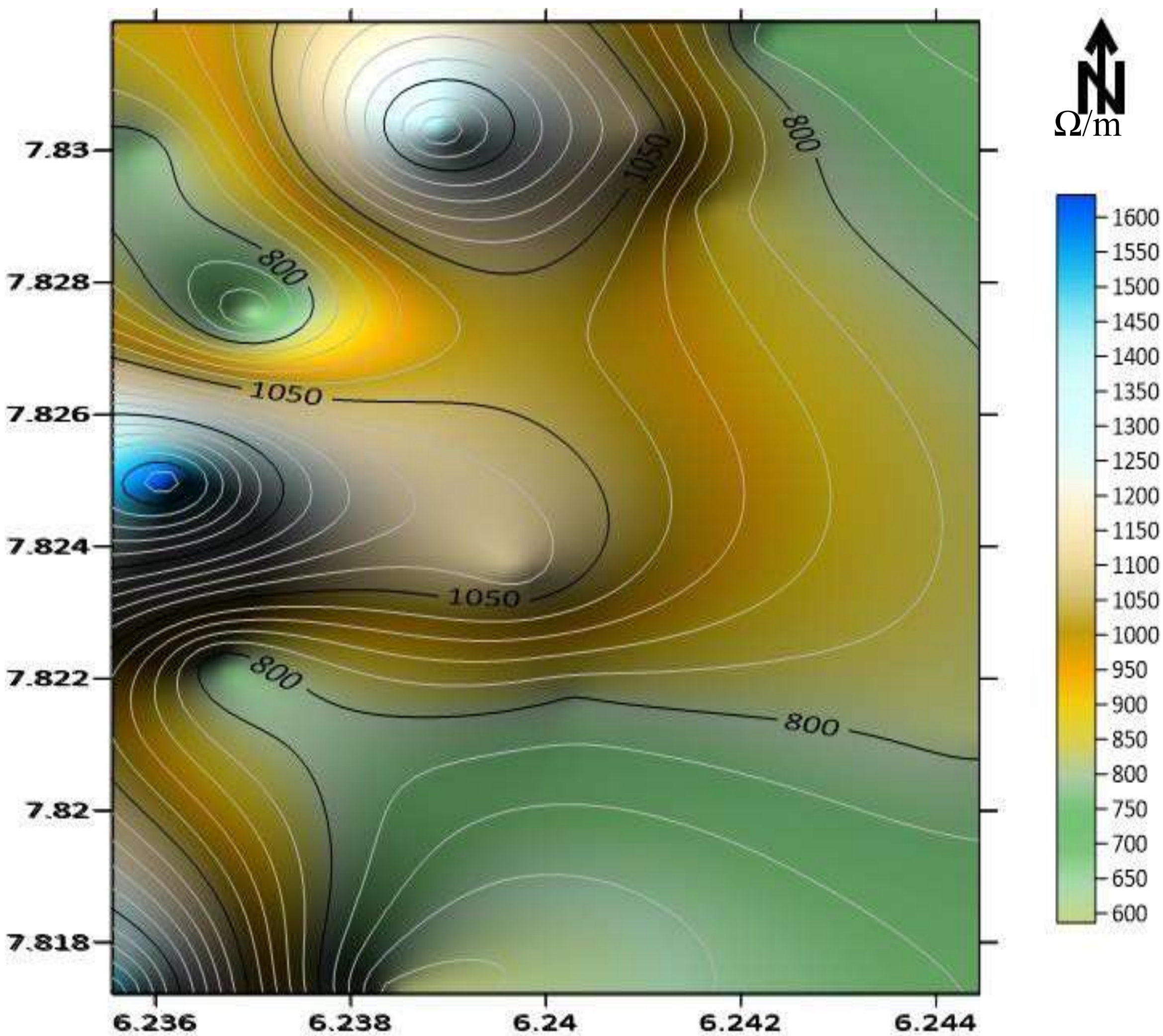

Fig. 6: Basementresistivity mapthe study area.

Elevation Map of Elete

On an elevation map, several sites' heights above sea level are shown. According to (Fig. 7, and Table 2), the study area's southeasterly regions are where the research area has a low height. Water naturally flows toward the southwest and southeastern regions of the study area because it moves from high to low elevations.

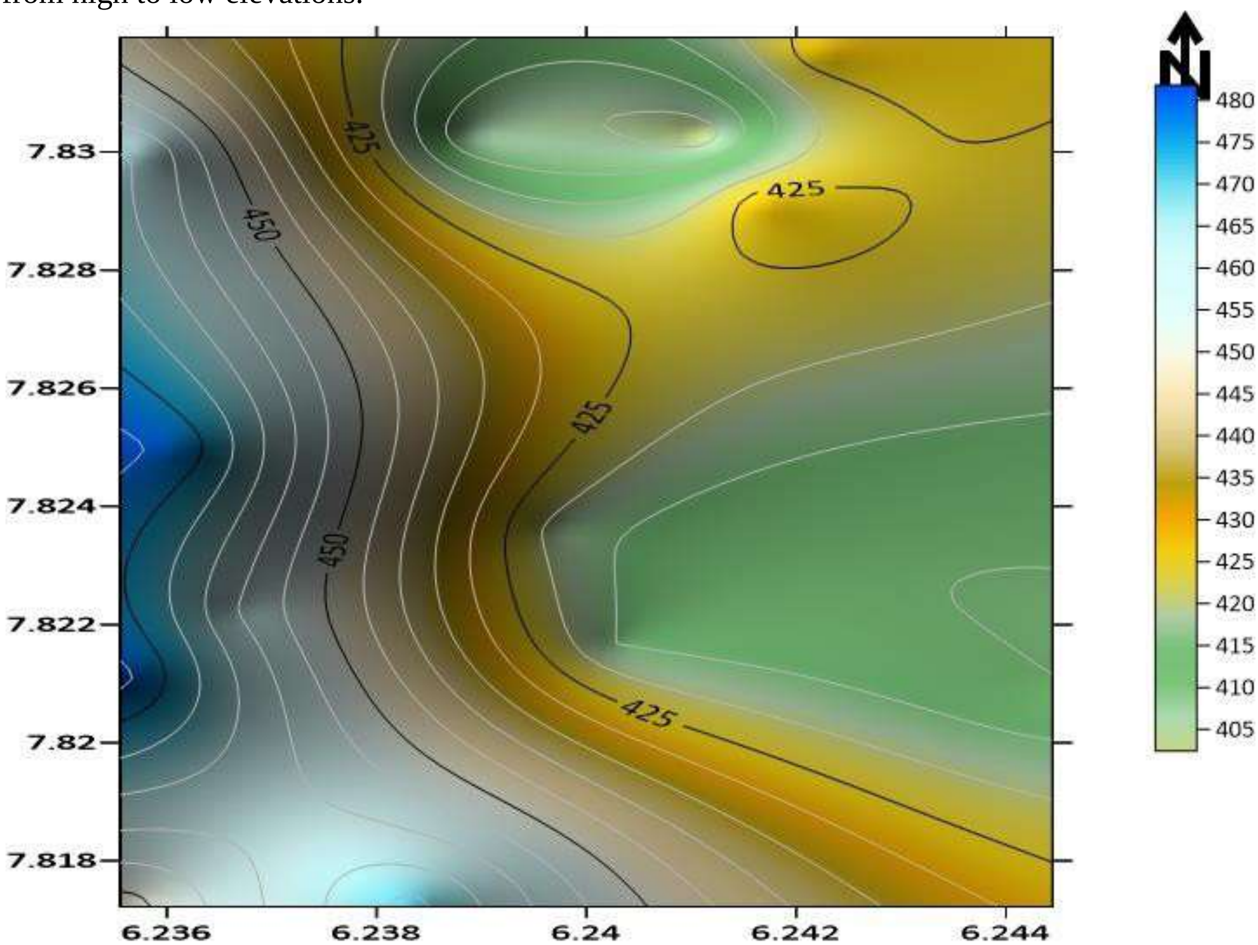

Fig. 7: Elevation map of the study area

Description of Curve type within the study area

In the research area, the vertical electrical sounding curve types that were seen were HA, KH, HA, and A (Fig. 8 and Table 1). The most prevalent curve in the study area was found to be the curved KH. The variation in curve type, according to Eyankware et al. (2022), can be related to the variable geology of the research area (2020).

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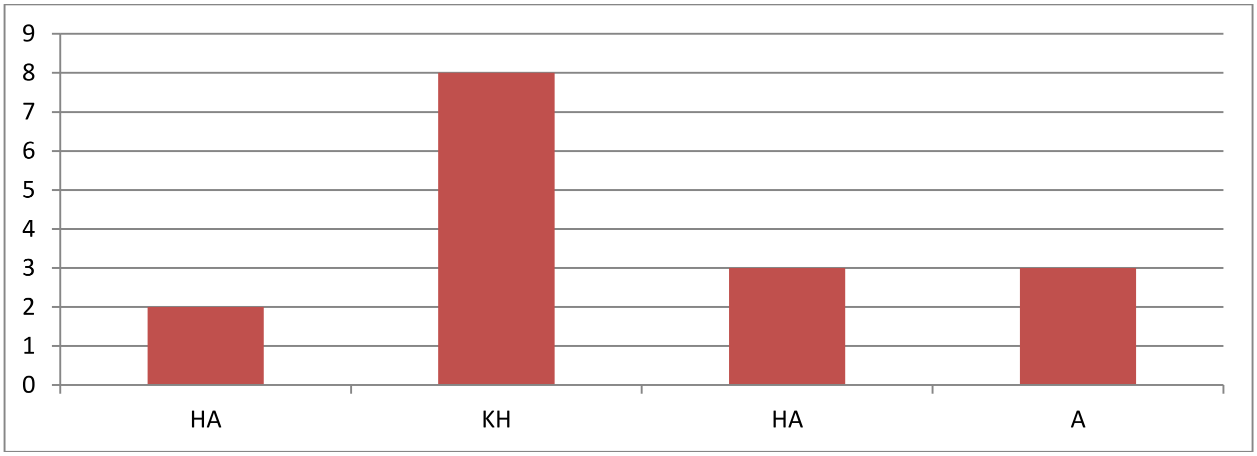

Fig. 8. Plot of VES points against Curve Type

Description of petrographic study

The geological units exposed in the research area are gneiss and schist. Granitic gneiss and Mica schist make up the area. The Gneiss are migmatite gneiss that is part of the pan-African gneiss complex. The Schist makes up the majority of the rock types on the field. Minor quartz veins are a minor lithological unit. Joints, faults, and foliations make up the study area's structural features.

Description of major rock

Banded Gnesis

The rocks are a low-lying outcrop that can be found in the NNE to SSW of the area shown in Fig. 9a and b. They range in size from 20 to 65 meters, and they can be located at the following locations: The mineral composition includes quartz, feldspar, and biotite, and its features range from medium to coarse-grained. Veins, faults, fractures, and joints were among the other structural components seen. Approximately 35% of the entire area is made up of banded gneiss.

Fig. 9a and b: showing bandedgneissinthe area.

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Granitic Gnesis
Within the layering of the quartz, biotite, and magnetite bands, the study area is composed of typical elliptic or lenticular shear-bound feldspar porphyroclasts, which are typically microcline. It is a coarse-grained gneiss produced when granite underwent metamorphism, as shown in Fig. 10a and b.

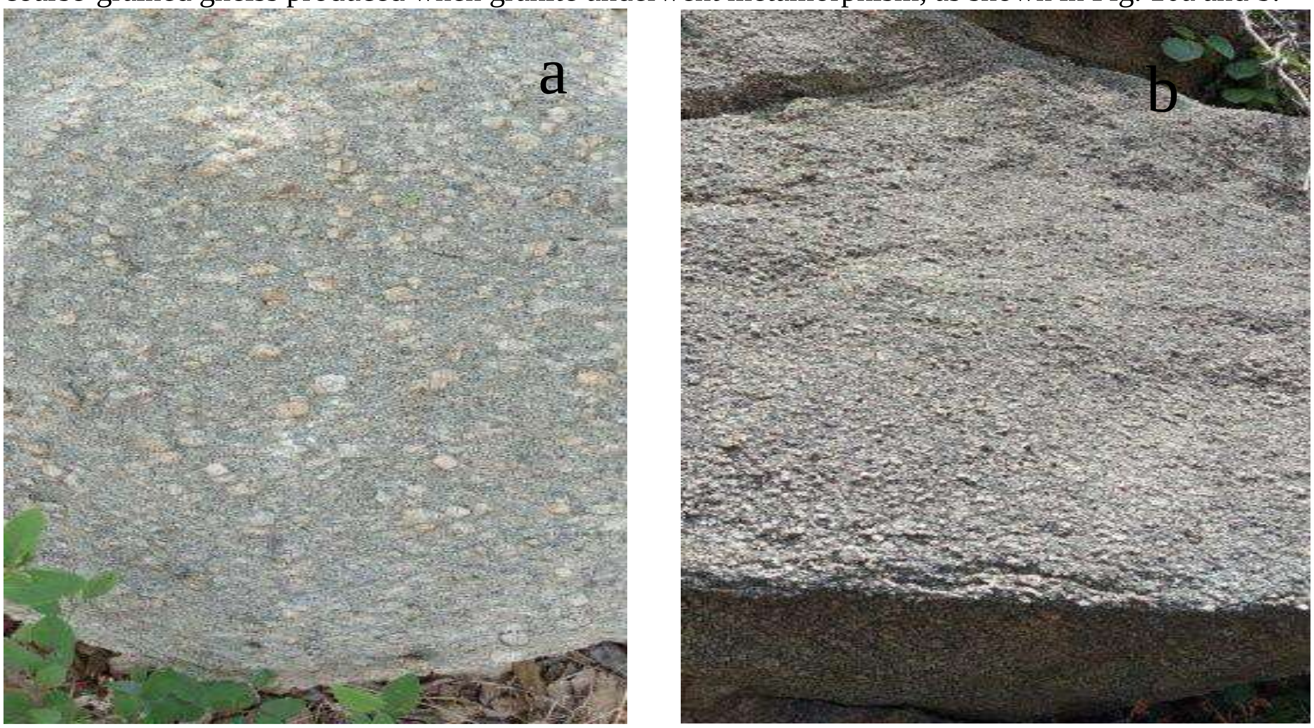

Fig. 10a, and b: showing GraniticGneissinthe study area.

Banded Gneiss:
In a hand specimen, biotite clearly dominates the fine-grained, banded gneiss. Dark mica flakes that are parallel to one another and separated by lighter-colored material, primarily quartz crystals that are millimeter-sized, can be seen in some detail. Quartz, Biotite, Muskovite, Plagioclase, and Opaque make up the banded gneiss when it is examined in thin section under a microscope. According to plate 9 below, Biotite accounts for 45.39% of the rock's composition, followed by Quartz (36.7%), Muscovite (9.95%), Plagioclase (4.26%), and Opaque (3.55%)as shown in Fig. 11, and 12.

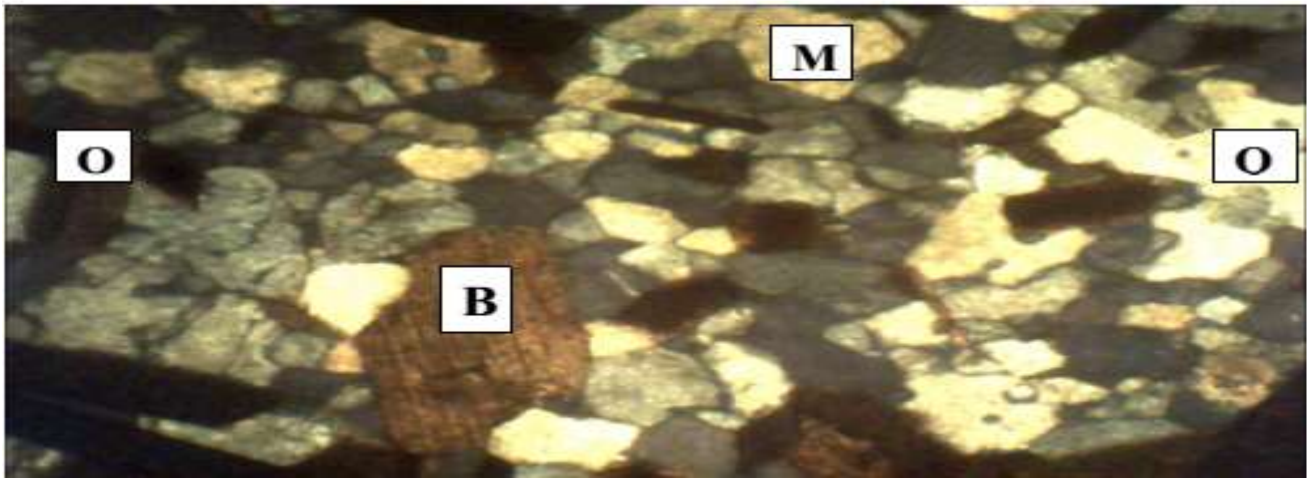

Fig. 11: Photomicrograph of Banded Gneiss under plane polarized light

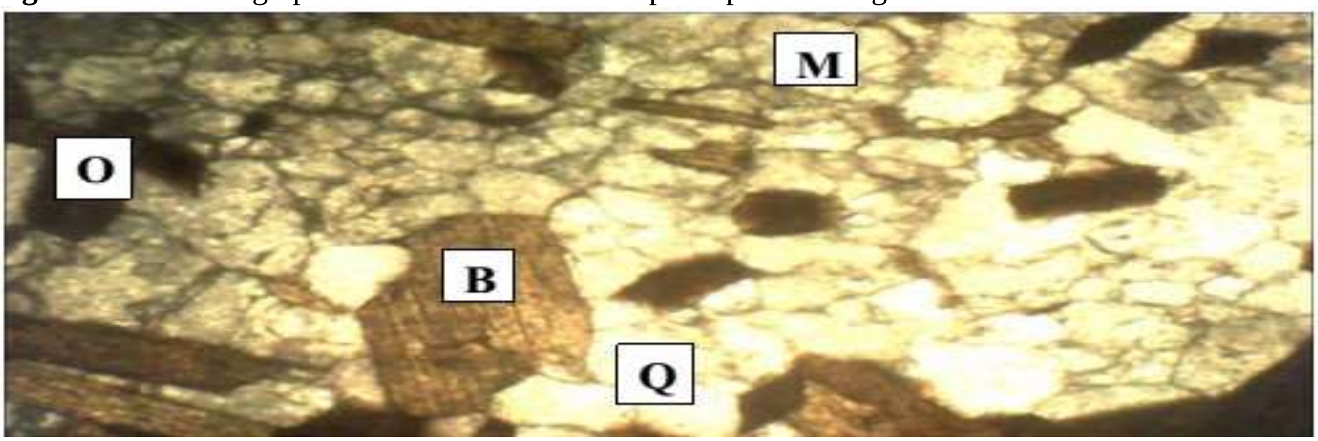

Fig. 12: Photomicrograph of Banded Gneiss under cross polarized light

Granitic Gneiss: Granitic gneiss formed from a granite is coarse-grained in the hand specimen. Large feldspar crystals must have been present in the granite that gave rise to the gneiss, which was a porphyritic rock. These have rounded and slightly flattened as a result of the rock's deformation, and the matrix has produced a banding and mineral alignment. According to a research by Adamu, et al. (2021) in another location in southwestern Nigeria, the matrix of the gneiss and the vein of granite both include pink feldspar (potassium), grey quartz, and dark mica. When observed in thin section under microscope, the banded gneiss is composed of Quartz, Biotite, muscovite, Plageoclase, Opaque. The rock is dominated by Quartz 41.72%, followed by Biotite 25.17%, Muscovite 19.42%, Plageoclase 10.72% and Opaue 2.87% as shown in Fig. 13 and 14

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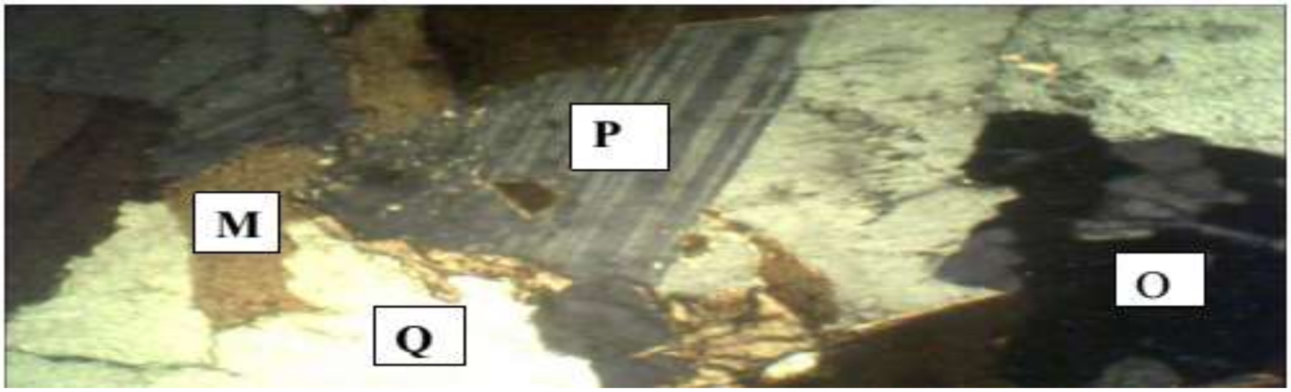

Fig. 13: Photomicrograph of Granitic Gneiss under plane polarized light

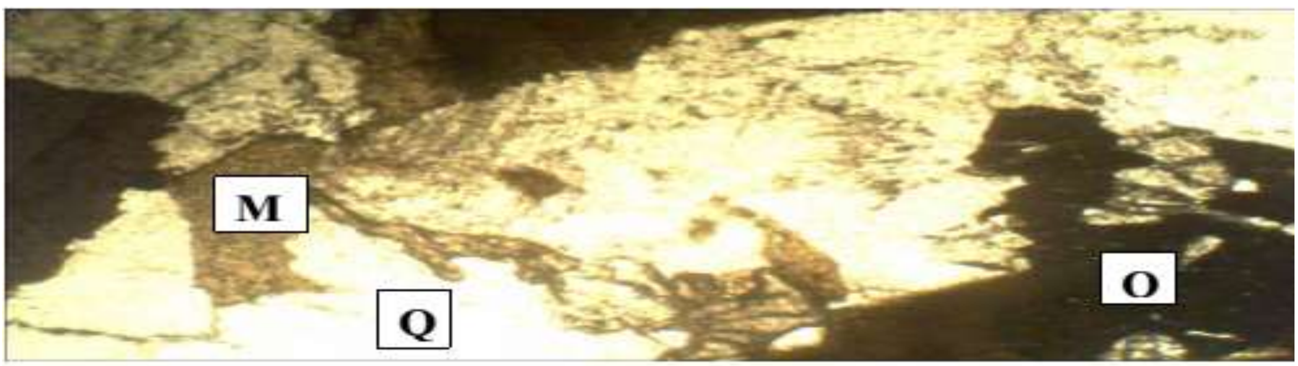

Fig. 14: Photomicrograph of Granitic Gneiss under plane polarized light

Quartz: is white under cross nicols and colorless under plane polarized light. It has a 35° extinction angle and is pleochroic. The shape is irregular, ranging from Anhedral to subhedral. It is characterized by low relief and absence of twinning and cleavage in their structure see Table 3, and 4.

Biotite: It is grey to brownish colour and has prismatic, subhedral to anhedral habit with perfect cleavage. It shows no twinning and occurs in patches with moderate to high relief. Brown pleochroism occurs in biotite interstitial lamellae. There is no extinction angle in the mineral, and birefringence is of the first order.

Muscovite: It is colorless under plane polarized light but exhibits a dirty reddish-yellowish colour under the cross nicols, they also have a moderate relief.

Plagioclase: Under cross nicols, it is colored, yet it is colorless in plane polarized light. It has albite twinning and is pleochroic, ranging from dark to light grey..

Opaque Minerals: these are minerals which do not allow transmitted light to pass through them. They remain dark on rotation of the stage either in plane or crossed polarized light

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Table 3: Petrographic readings and modal composition (Sample Banded Gneiss)

Minerals	1st count	2nd count	3rd count	4th count	5th count	Total	Composition (%)
Quartz	10	7	12	9	14	52	36.87
Biotite	10	15	11	12	16	64	45.39
Muscovite	3	2	2	3	4	14	9.93
Plagioclase	1	1	2	1	1	6	4.26
Opaque	1	0	1	2	1	5	3.55
						141	**100%**

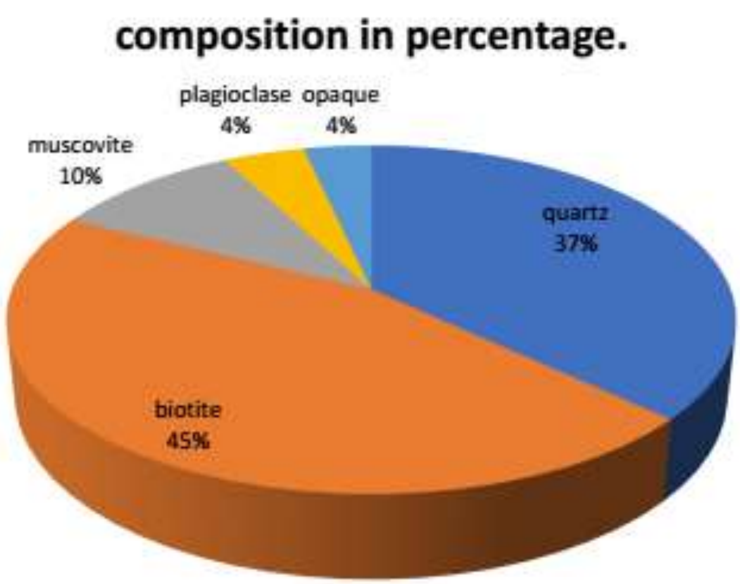

Fig. 15: Chart of mineral percentage of the study area

Table 4: SampleGranitic Gneiss

Minerals	1st count	2nd count	3rd count	4th count	5th count	Total	Composition (%)
Quartz	12	13	11	10	12	58	41.72
Biotite	10	7	9	6	5	35	25.17
Muscovite	3	2	4	3	3	15	19.42
Plagioclase	5	6	4	7	5	27	10.27
Opaque	2	1	0	0	1	4	3.55
						139	**99.97%**

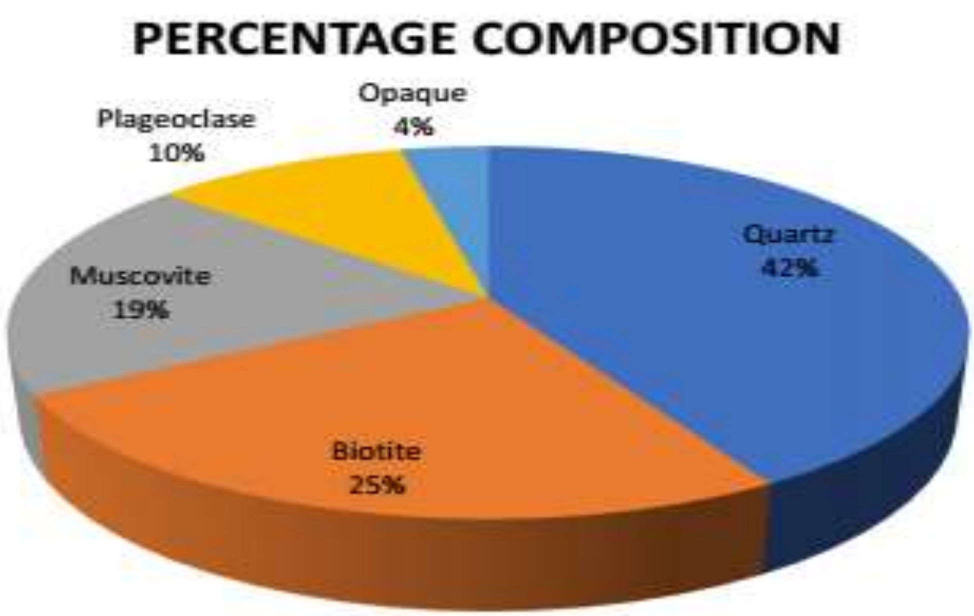

Fig. 16: Chart showing percentage of mineral.

MINOR ROCKS Quartzveins

In a fissure on rock deposits or exposures, veins are thin, sheet-like igneous intrusions. In the majority of outcrops in the study region, quartz veins can be found see Fig. 17a, and b. They range in size from around 1- 12 cm wide to about 15-38 cm long or greater at certain points, and they mainly trend NE- SW. The quartz veins are newer than the country rocks because they form as an incursion and contain more than 90% quartz see Fig. 15 and 16.

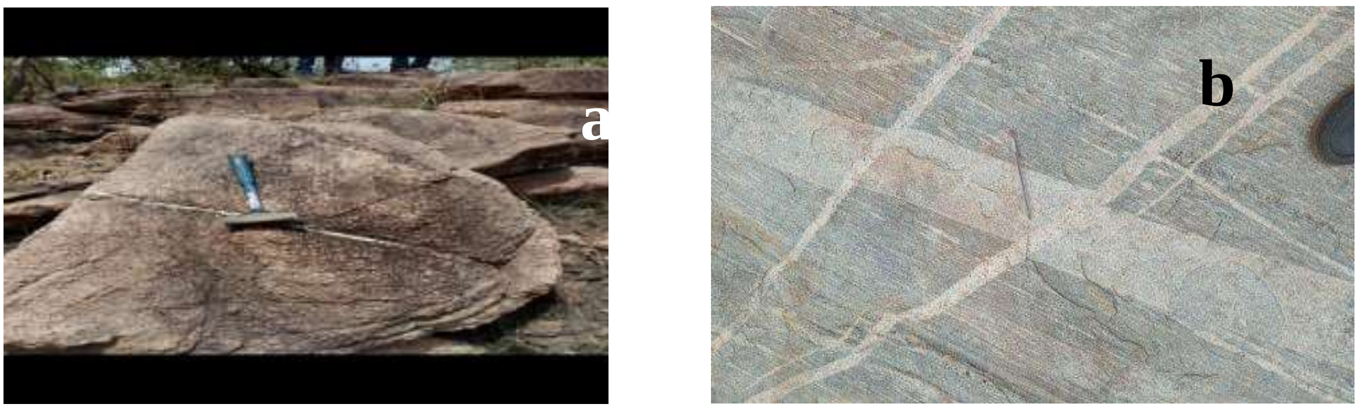

Fig 17a, and b: showing quartzveininthe area

Structure of rock of the study area

The structure is the physical manifestation or imprint of deformational experiences. In the numerous outcrop in the studied region, tectonic activity signatures may be found. They most likely result from the rocks' exposure to metamorphism and deformation. Joints, faults, foliation, veins, and folds make up the majority of the region's structural features.

Joints

Findings from the study suggested that all of the rocks in the study area had joints, or fracture surfaces, along which there had been no displacement parallel to the defining plane (Fig. 18), which is a feature of most crystalline rocks. They are classified as brittle structures, some of which have been cracked open, while others have been filled with quartz to form veins. The majority of the research area's rocks have clearly defined joints and fissures. The components of the joint show shearing that is parallel to the fracture front's direction of propagation. The joints' strike measurements show that both the Granitic Gneiss and the Schist exhibit a general NE-SW trend see Table 5, and Fig.19.

Fig. 18: showing Joint withinthe outcrop within the study area

Table 5: Dataforstrikemeasurement ofJoint asobtained in thestudy area

Joints S/N	Strike Direction
1	82°
2	150°
3	128°
5	138°
6	138°
7	138°
8	138°
9	166°
10	136°
11	210°
12	164°
13	146°
14	352°
15	94°
16	128°
17	162°
18	164°
19	136°
20	190°

Source: Study area

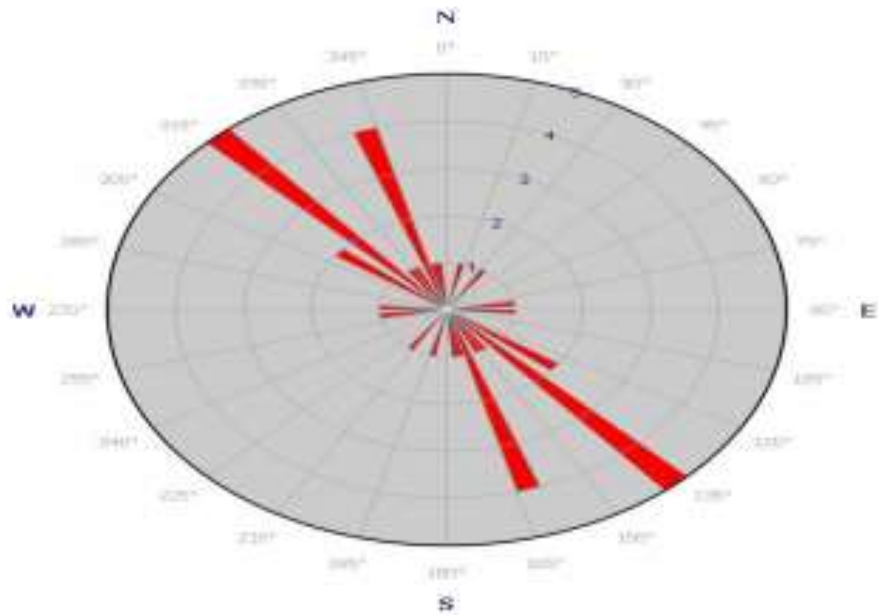

Fig. 19: Rose diagram of joint (Dominant trend NW-SE)

Fold

Rock may have folds, which are bends or flexures that result from tectonic forces. A reference surface is bent to represent a fold. Rock folds can range in size from microscopic to mountainous. On various scales, they appear both alone as solitary folds and in large fold trains of various sizes. In the study area chevron folds were observed on the rock see Fig. 20.From detailed study within the study area it was observed that the dominant folds trend in NE-SW see Table 6, and Fig. 21.

Fig. 20: showing fold within the Outcrop

Table 6: Data for measurement of foliation as obtained from the study area

Foliation S/N	Strike direction
1	41°
2	86°
3	66°
4	74°
5	244°
6	208°
7	255°
8	236°
9	242°
10	81°
11	52°
12	78°
13	63°
14	299°
15	245°
16	86°
17	352°
18	305°
19	67°
`20	195°

Source: This study

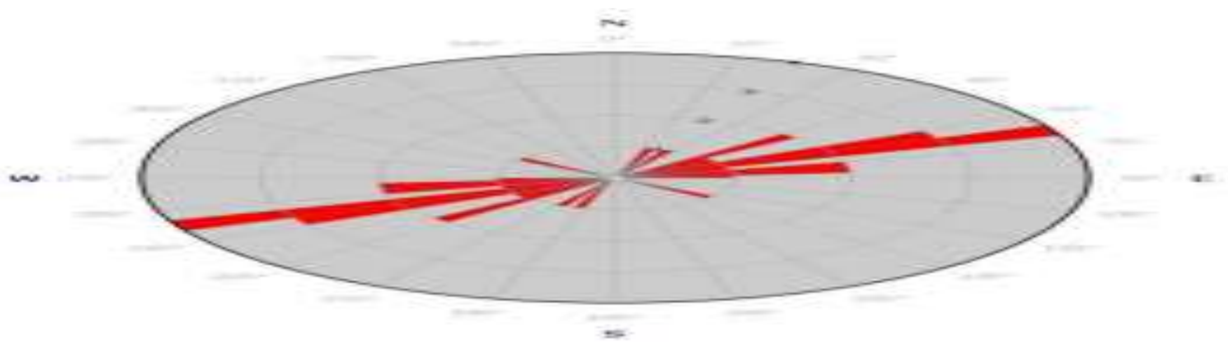

Fig. 21: Rose diagram of foliation (Dominant trend is NE-SW)

Vein

Veins are mineralized fractures or other cracks within a rock in a sheet-like or tabular shape filled with mineral material. Veinlet are smaller veins; it's called a lode when it occurs extensively over a large area. Veins and veinlet occurred in most of the Schist outcrops seen and observed in the area see Fig.22. Findings from the study revealed that the dominant vein are in NE-SW trends as shown in Table 7, and Fig. 23.

Fig. 22: showing vein within the outcrop within the study area.

Table 7: Data for strike measurement of veins as obtained in the study area

Vein S/N	Strike direction
1	154º
2	156º
3	224º
5	236º
6	40º
7	26º
8	188º
9	230º
10	236º
11	18º
12	48º
13	352º
14	138º
15	66º
16	65º
17	236º
18	138º
19	76º
20	68º

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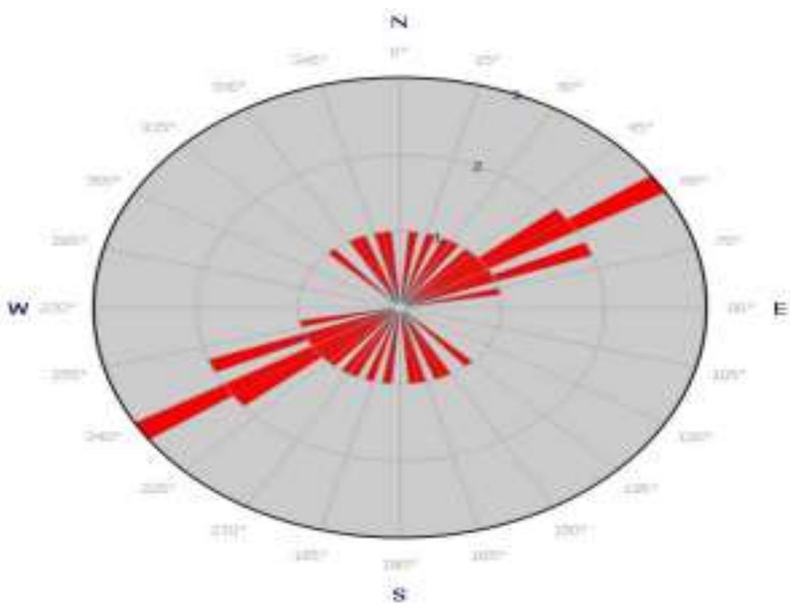

Fig. 23: Rose diagram of vein (Dominant trend is NE-SW)

Foliation Folds in rock are bends or flexures brought on by tectonic pressures. A fold is simulated by bending a reference surface. Rock folds can be as big as mountains or as small as a micron. They show up on different scales as both single folds and big fold trains of different proportions.

Fig. 24: Showing foliation within the outcrop within the study area

Fractures

Fractures are evident on some rocks because they are subjected to high degree of thermotectonic events brought about by intense regional metamorphism, crystallization, migmatization and granitization as shown in Fig. 25.

Fig. 25: Showing Fractures within the outcrop within the study area

CONCLUSION

In order to ascertain the field distribution of the various lithologic units, their petrography, and the subsurface layer, the study primarily focuses on the geology, geophysical investigation, and petrography of the studied region. Within Elete and its surroundings, a geo-resistivity and petrography exploration has been done. It is located in the Basement Complex region, which is underlain by Precambrian-aged igneous and metamorphic rocks. The worn and fractured basement is the main source of water in the studied region, according to the geophysical examination. This is as a result of its supposedly favorable porosity and permeability qualities. The true aquifer resistivity map of Elete reveals a higher range of resistivity values in the north-central and southern part, which may not be consistent with the water-bearing zone, but the relatively low resistivity value in the southeastern and northeastern axis suggests the presence of an aquiferous zone. It is advised to cite groundwater tubes in this part of the study region because it is particularly hydro-geologically promising. According to the Petrographic Analysis (Thin Sectioning), the research area's rock is made up of Granite Gneiss and Banded Gneiss. Structures with faults, fractures, folds, foliation, veins, and joints have been observed.

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