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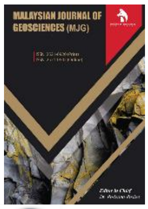

RESEARCH ARTICLE

GEOLOGICAL MAPPING OF BASEMENT ROCKS IN KADUNA POLYTECHNIC MAIN CAMPUS AND ITS ENVIRONS, KADUNA, NORTHWESTERN NIGERIA

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ABSTRACT

Geological mapping of basement rocks in Kaduna Polytechnic Main Campus and its Environs was carried out. The study area is bounded by latitude 10°30’0.00”N to 10°36’0.00”N and longitude 007°24’0.00”E to 007°30’0.00”E of sheet 123 Kaduna. The study aims at identification and classification of the rock units within the study area. Results of the Geological Mapping within the study area reveals that the study area falls within the Migmatite Gneiss Complex of Nigeria. The result also shows that there are various structural features prevalent within the study area namely; fractures, joints, faults and intrusion of quartz veins. Rose diagram generated shows structural trend of mineralization along northwest to southeast (NW-SE) direction. Petrographic studies on the rock samples indicates that the study area is predominantly underlain by the Migmatite Gneiss Complex with Medium to coarse grain Migmatitic Gneisses and Amphibolite which is part of the Older Granite suite of the basement complex whose mineralogy, color, relative time of emplacement, and texture vary greatly. The results of petrographic analysis of Migmatitic Gneiss shows the modal mineralogical composition of Medium to coarse grain granite reveals a percentage ratios of 40% Orthoclase feldspar: 40% Quartz: 20% Biotite whereas Amphibilite has 40% Biotite: 30% Quartz and 30% Orthoclase feldspar. The rock aggregate in the study can provide good construction materials such as in the construction of roads, bridges, houses etc. The Geophysical investigation indicate the presence of shallow layer of disturbed soil as the top lithology (< 320 m/s) underlain by basement rocks with high seismic velocities of > 2139 m/s.

KEYWORDS

Petrography, Rose Diagram, Fault, Older Granites, Igneous intrusions

1. INTRODUCTION

The geology of Nigeria is very well studied and documented by several authors and scholars (Caxito et al., 2020). These studies have shown that the so-called geology of Nigeria is made up of three major geological components which include the Basement Complex in which the study area is located, the Younger Granites, and Sedimentary Basins (Lawal et al., 2020). The basement rocks are believed to be the results of at least four major orogenic cycles of deformation, metamorphism and remobilization corresponding to the Liberian (2,700 Ma), the Eburnean (2,000 Ma), the Kibaran (1,100 Ma), and the Pan-African cycles (600 Ma) (Sunkari et al., 2022). The first three cycles were characterized by intense deformation and isoclinal folding accompanied by regional metamorphism, which was further followed by extensive migmatization.

Observations made with the petrographic microscope through rock thin section and observations made with hand specimen as well as outcrop descriptions indicate that the study area is predominantly underlain by migmatitic gneiss and amphibolites. Textural relations between grains however are noted, for these not only help in the classification but provide evidence of processes active during the formation of the rocks. Different geologic structures were also encountered on the outcrops in the study area.

The area mapped in this work lies largely within the roughly circular area of so-called “Basement rocks” in Northwest Nigeria. Regional descriptions of rock outcrops have been made to gather possible information about the rock exposures in the study area. Different lithological variations were observed and various geologic structures were very well examined and studied at in-situ in this report with the main aim to produce detailed geological map of Kaduna Polytechnic Main Campus and environs which lies within. It is an integral part of Kaduna,Sheet 123, North-western Nigeria bounded by latitudes 10°30’0.00”N to 10°36’0.00”N and longitudes 007°24’0.00”E to 007°30’0.00”E.

The study is ultimately aimed at describing the geological attributes and revealed the geological features in the study area. The outcome of the mapping exercise shows different types of outcrop exposures including whaleback outcrops, inselberg outcrops, low-lying ridge outcrops, outcroups along the river channel etc. the mapping exercise also reveals features and structures such as fault breccias, faults, fractures, folds, foliations, weathered outcrops, intruded pegmatites and quartz veins as well as aplite dykes. Data from the structural features measured at in-situ in different outcrops of the study area reveal the strike and dip values ranging from 012°-60° and 173°-36°, respectively.

1.1 Aim and Objectives

This work is aimed at identifying and examining the rock exposures through detailed geological mapping of Kaduna Polytechnic Main Campus with the following objectives:

1. Rock outcrop description based on the modal mineralogy of the rock

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exposures.

2. Examining the structural features exhibited on the rock outcrops.
3. Measurements of the geometric features such as strike and dip to determine the general trending of the rocks within the study area.
4. To serve as a reference frame for future-related researchers within the study area.
5. To serve as a roadmap for the selection of suitable locations for civil engineering projects and other infrastructural provision within the study area.

2. Regional Geology

The geology of Nigeria is very well documented by several authors. Almost 50% of the entire surface of Nigeria is covered by the Basement Complex and consist of gneiss, migmatites, and the metasedimentary series of Precambrian age (Adeoti & Okonkwo, 2016; DANGA et al., 2021; IBE, 2020; Salawu et al., 2020). The Nigeria basement lies within the reactivated part of the Pan African mobile belt to the east of the West African craton and Congo craton to the south east and to the north is the Tuareg shield (Caxito et al., 2020; Trompette, 2020).

Rocks of the basement complex of Nigeria are composed predominantly of migmatitic and granitic gneisses, quartzite and schist, and meta-igneous rocks which are Precambrian to Lower Paleozoic in age (Chukwu & Obiora, 2021a; Sunkari et al., 2022)(McCurry, 1976, Rahaman, 1976).

Geologically, the mapped area lies within the Basement rocks of Northwestern Nigeria - an integral part of Kaduna,Sheet 123, North-western Nigeria, bounded by latitudes 10^{o}30’0.00”N to 10^{0}36’0.00”N and longitudes 007^{0}24’0.00”E to 007^{0}30’0.00”E. The area is characterized by a series of hilly structures such as inselbergs, whalebacks and boulders along the sides of the outcrops. In addition, the area is easily accessible through residential roads and footpaths.

2.1 Drainage

The study area is well drained by a network of small water channels onto River Kaduna. However, only River Kaduna is perennial while other streams and tributaries area seasonal that containing water only during the rainy season, with little or no water in the dry season (Ahmed et al., 2020; Muhammad et al., 2020). The pattern of these rivers seems to suggest features of structural significance, which tend to drain almost entirely from the central part. Along its path of flow, it forms dendritic flows both in the north and south direction. The elevated outcrops as well as the fractures associated within the rocks also control the flow pattern.

2.2 Climate

The climate of the study area is a tropical continental north, climatic zone of Nigeria, with distinct wet and dry seasons. The area experiences six (6) months of rainy season and six (6) months of dry season, respectively. The rainy season is from May to late October, while the dry season is from early November to April, this is as a result of the interplay of the two dominant air masses within the region.

3. Materials and Methods

The methodology involved several key stages: preliminary (reconnaissance) survey, geological fieldwork, laboratory analyses, and report writing. Each stage was executed in accordance with geological principles. The objective of this workflow was to produce all necessary interpretations and inputs for creating a geological map of Kaduna Polytechnic Main Campus and its environs in Kaduna South Local Government Area, Kaduna State, Nigeria. During the preliminary survey, initial reconnaissance was conducted to gather an overview of the study area. This involved identifying key geological features and planning the detailed fieldwork. Subsequent geological fieldwork included systematic data collection through rock sampling, measurement of geological structures, and recording of field observations. Various tools such as a geological hammer, Brunton Compass, hand lens, GPS device, and camera were utilized to ensure accurate and comprehensive data collection.

Following fieldwork, laboratory analyses were performed on the collected samples to determine their mineralogical and petrological characteristics. The laboratory work involved geochemical and petrographic analyses, which aided in the description and classification of the specific rock types in the study area. These analyses provided critical data needed to understand the geological composition and history of the study area. Finally, the collected data and analysis results were compiled into a detailed report. This report included interpretations of the geological data and the production of a geological map, which accurately represented the geological features of Kaduna Polytechnic Main Campus and its surrounding areas.

4. Results and Discussion

4.1 Geology

In the study area, a variety of rock types were encountered, including granites, schists, quartzites, and gneisses. However, the predominant rock type is migmatitic gneiss with amphibolite intrusions, which characterizes this region as part of the Basement Complex of northern Nigeria. Additionally, there are significant intrusions of quartz veins, pegmatites, and aplite dykes. The exposed outcrops in the area display a range of geological structures, both primary and secondary. These outcrops, which vary in size from small to large, are accompanied by numerous boulders. The rocks have undergone extensive weathering, deformation, and metamorphism, leading to the formation of various geological structures and the disintegration of some rock types. The metamorphic processes have significantly altered the original rock formations, contributing to the complexity and diversity of the geological features observed in the study area.

Table 1: Summary of Field Geological Mapping within the Study Area.

Location	Coordinates	Measurement	Outcrop Description	Economic activity	Geology
1. KPT Staff Quarters	Lat: 10.52055556”N Long: 7.41388889”E Elevation: 484m	Strike: 211 Dip48^0	Low lying ridge of mainly migmatiticgneiss. Instrusives are prevalent around the outcrop. Joints are present.	None	Migmatitic Gneiss
2. Tudun Wada	Lat: 10.52055556”N Long: 7.41194444’E Elevation: 476m	Strike: 190 Dip 32^0	Dome-shaped of migmatiticgneiss with pegmatites veins. Joints and fractures are present.	None	Migmatitic Gneiss
3. KPT Main Campus	Lat: 10.52066”N Long: 7.41219 “E Elevation: 460m		Migmatitic Gneiss	None	Migmatitic Gneiss
4. KPT Main Campus	Lat: 10.53138889”N Long: 7.41222222“E Elevation: 459m		Low lying ridge of mainly migmatiticgneiss	None	Migmatitic Gneiss
5. Tudun Wada	Lat: 10.525”N Long: 7.42055556“E Elevation: 462m	Strike: 350 Dip50^0	Low-lying Gnessic rock with quartz veins. The rock is well compacted. No fractures and joints.	None	Gneiss
6. KPT Main Campus	Lat: 10.51444444”N Long: 7.41472222“E Elevation: 480m	Strike: 310 Dip 70^0	Dome-shaped outcrop with boulders along its sides. There is inclusion of foreign materials as xenoliths.	None	Amphibolite
7. Tudun Wada	Lat: 10.51666669”N Long: 7.41555556“E Elevation: 485m		Dome-shaped outcrop with boulders along its sides. There is inclusion of foreign materials as xenoliths.2.4m.	None	Amphibolite

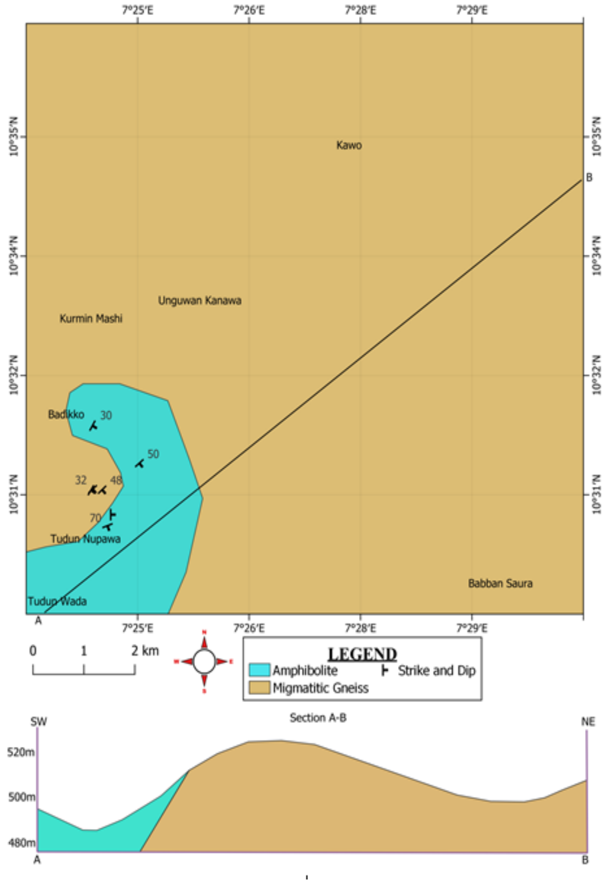


Figure 1: Geologic Map of the Study Area

From Figure 4 above, it is evident that migmatitic gneiss and amphibolites constitute the predominant lithology in the study area. Although there are minor occurrences of other metamorphosed rocks, such as schists, quartzites, and gneisses, these are less prevalent. The dominant presence of migmatitic gneiss and amphibolites highlights the geological complexity of the region.

These rocks are part of the Basement Complex of northern Nigeria, a geological formation known for its diversity in age and composition. The Basement Complex rocks exhibit a wide range of mineralogical and chemical compositions, reflecting the complex geological history and processes that have shaped the region over time (Adabanija et al., 2020). The presence of such a variety of rock types indicates a history of significant metamorphic activity, which has transformed the original rocks into the migmatites, amphibolites, schists, quartzites, and gneisses observed today (Agbi et al., 2023).

The migmatitic gneisses, in particular, are indicative of high-grade metamorphic conditions and partial melting, while the amphibolites suggest significant amphibolite-facies metamorphism (Chukwu & Obiora, 2021; Oshilike et al., 2020). The minor occurrences of schists and quartzites further attest to the dynamic metamorphic history of the area, involving varying pressures and temperatures that have resulted in a rich tapestry of rock types. These lithological characteristics underscore the geological significance of the Basement Complex in northern Nigeria and provide valuable insights into the region's geological evolution (Okeke et al., 2022).

4.2 Structural Features

In the study area, a multitude of geologic structures were encountered and scrutinized, indicative of a complex geological evolution shaped by diverse processes acting upon the constituent rocks. The rocks within this region exhibit a varied geological history, resulting in the development of structural elements characterized by their distinct genetic properties and the differential stress and strain conditions prevalent during successive tectonic events. These structural features are broadly categorized into two groups based on their mode of emplacement and temporal occurrence.

The first group comprises syn-tectonic structures, commonly referred to as primary structures, which manifest during the initial emplacement of the rock formations. These primary structures include foliation and other features that are intrinsic to the rock's formation process. Conversely, the second group encompasses post-tectonic structures, often termed secondary structures, which form subsequent to the initial rock emplacement. Examples of such secondary structures include faults, folds, and fractures, which arise as a result of post-depositional deformation and tectonic activity acting upon pre-existing rock formations. This classification scheme aids in understanding the temporal sequence of structural development within the study area, shedding light on the dynamic interplay of geological processes over time. The geometric measurement shows that joints are generally trending towards N-S and NNE- SSW directions with an average dip value of 47^{o} (figure 2)

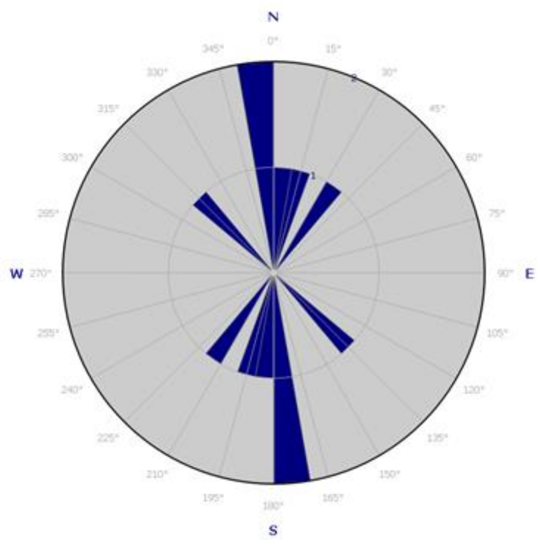


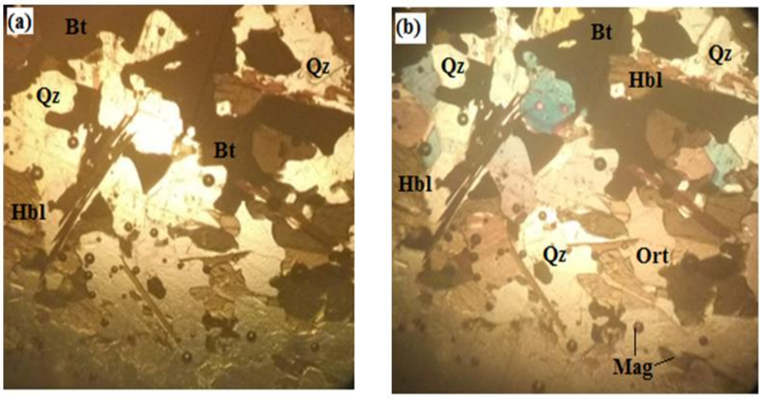
Figure 2: Rose Diagram showing Joints Trend

4.3 Petrography

4.3.1 Petrographic Description of Migmatitic Gneiss

The migmatitic gneiss under examination primarily comprises quartz, biotite, orthoclase, hornblende, and magnetite, each displaying distinct optical characteristics discernible under both plain-polarized and cross-polarized light (fig. 3). The granular texture of the migmatitic gneiss is predominantly constituted by several key mineral constituents. Quartz constitutes approximately 29% of the rock, forming small to medium-sized subhedral crystals characterized by moderate relief and undulose extinction, devoid of pleochroism and cleavages. Biotite, comprising 25% of the gneiss composition, exhibits a black hue under plain-polarized light (PPL) and transitions to brown in cross-polarized light (XPL). The mineral demonstrates strong pleochroism and presents an euhedral habit with notable relief. Orthoclase, constituting 35% of the rock, manifests as colorless crystals in both PPL and XPL, appearing fibrous in shape and frequently intergrown with quartz. In XPL, orthoclase displays gray coloration, first-order birefringence, and oblique extinction, with subhedral crystals exhibiting moderate relief and displaying weak cleavage in PPL.

Hornblende, accounting for 6% of the rock's composition, presents a dark brown coloration in XPL, forming roughly prismatic individuals with cleavages in two intersecting sets of planes parallel to the direction of elongation, resulting in a brownish overall appearance. In plain-polarized light, hornblende exhibits pleochroism in shades of brown and pale green, along with twinning in XPL view. Cleavage occurs in two directions, displaying high birefringence and inclined extinction. Magnetite, constituting 5% of the rock, is identified as the sole accessory mineral within the sample.



(A)SM1 PP M40 (B) SM1 XP M40

Figure 3: Photomicrograph of Migmatitic gneiss under (a) Plane polarized light (PPL) and (b) Crossed polarized light (XPL) Bt =Biotite, Qz=Quartz, Hbl =Hornblende, Ort =Orthoclase, and Mag=Magnetite Mag. =X100.

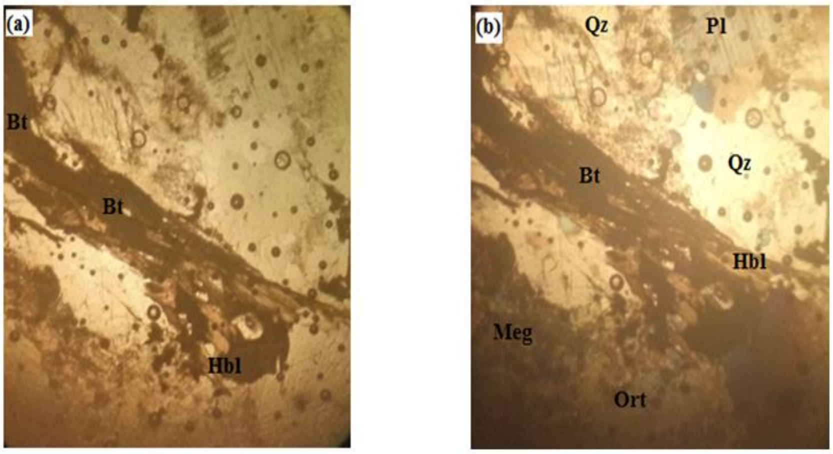
4.3.2 Petrographic Description of Amphibolite

4.3.2.1 Petrographic Description

The petrographic examination of amphibolite revealed a diverse array of mineral constituents (fig. 4). Biotite, constituting approximately 22% of the sample, manifests as anhedral to subhedral crystals displaying strong pleochroism, with a dark-brown hue becoming prominent upon stage rotation. Under plain-polarized light (PPL), biotite exhibits moderate relief and well-defined cleavage. In cross-polarized light (XPL), it demonstrates near preferential extinction and high birefringence.

Quartz, comprising 27% of the gneiss, presents as subhedral crystals with moderate relief. Lacking pleochroism and cleavage, quartz displays undulose extinction and weak birefringence in XPL. Plagioclase, accounting for 5% of the mineral composition, appears colorless in PPL with low relief and absence of pleochroism. Displaying anhedral to subhedral crystal forms, plagioclase exhibits signs of incipient alteration, contributing to its rough and scratchy appearance. Albite twinning is evident in cross-polarized light, where the mineral appears white to gray with low birefringence and straight extinction. Orthoclase, constituting 35% of the rock, is observed as colorless to cloudy crystals in XPL, featuring low relief, anhedral crystal forms, and oblique extinction. In XPL, orthoclase displays medium-sized crystals with weak birefringence.

Hornblende, accounting for 4% of the sample, exhibits low relief and wavy extinction, with visible cleavages interlocking with biotite minerals. Magnetite, comprising 7% of the gneiss, is identified as the sole accessory mineral. During observation, the presence of bubbles on the slides was noted, likely originating from the sample preparation process. Notably, no opaque minerals were observed within the analyzed sample.



(A) SM2 PP M40 (B)SM2 XP M40

Figure 4: Photomicrograph of Amphiboloite under (a) Plane polarized light (PPL) and (b) Crossed polarized light (XPL)(BIO)=Biotite,(QTZ)=Quartz,(M) =Microclne, and (ORTH)=Orthoclase, Mag. =X100

4.4 Geochemistry

The findings of the geochemical analysis conducted on two rock samples sourced from Kaduna Polytechnic Main Campus are detailed in Table 2. Amphibolite, from a geochemical perspective, is typified by its composition featuring low silica ($SiO_2 < 45$wt%), diminished alkali content ($Na_2O + K_2O < 2$wt%), elevated iron content ($Fe_2O_3 > 20$wt%), and heightened magnesium levels, indicative of a mafic protolith akin to either basalt or gabbro. Furthermore, it conforms to the characteristics outlined by the calc-alkaline series, as demonstrated in the AFM (Al_2O_3-FeO-MgO) diagram (fig. 5).

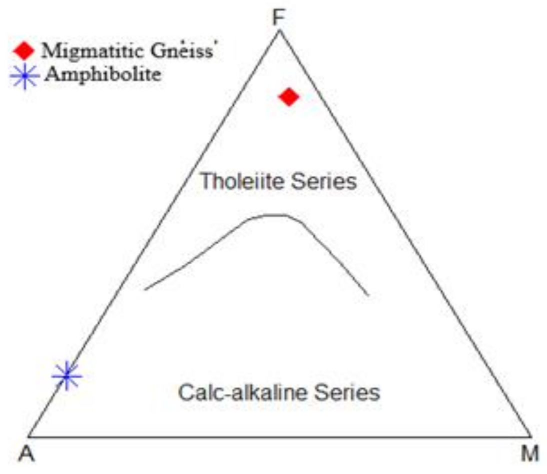


Figure 5: AFM Diagram of rock samples.

In contrast, the geochemical profile of the migmatitic gneiss starkly contrasts with that of amphibolite, consistently reflecting features characteristic of granitic rocks. Silica (SiO2) content is notably high, measuring at 67.809 wt%, accompanied by an Al_2O_3 content of 13.662 wt%. In contrast, magnesium oxide (MgO) and manganese oxide (MnO) exhibit significant depletion, while potassium oxide (K2O) is markedly enriched, registering at approximately 10.7 wt%. Consequently, these observations point towards the characteristics of granodiorite, as corroborated by the Hacker Variation diagram (fig. 6). In the AFM diagram, the sample aligns with the tholeiite series, further supporting its granitic nature. This stark contrast in geochemical composition between amphibolite and migmatitic gneiss underscores the distinct protoliths and geological processes involved in their formation within the study area.

Table 2: Showing results of Geochemical Analysis

Specimen	Amphibolite	Migmatitic Gneiss
SiO_2 (wt%)	42.119	67.809
TiO_2(wt%)	2.046	0.204
Al_2O_3 (wt%)	14.953	13.662
Fe_2O_3(wt%)	21.392	2.114
MnO (wt%)	0.302	0.036
MgO (wt%)	2.306	0
CaO (wt%)	13.816	3.406
Na_2O (wt%)	0	0
K_2O (wt%)	1.449	10.646
P_2O_5 (wt%)	0.022	0.114
ClO_2 (wt%)	0.914	0.674
V_2O_5 (wt%)	0.134	0.024

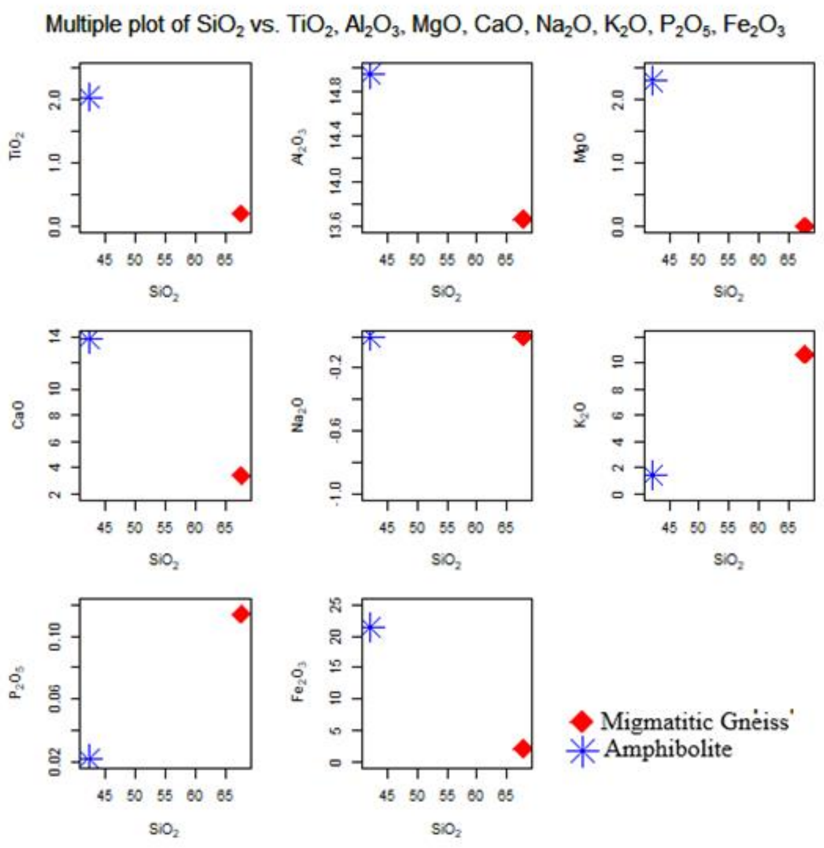


Figure 6: variation diagram of SiO_2 vs major oxides.

4.5 Geophysical Investigation

A seismic refraction profile was systematically acquired within the study area, as depicted in Figure 7. A discernible discrepancy in velocities has been observed with respect to depth. The measured velocities of P-waves serve as an indirect indicator of lithological variation within the subsurface. Notably, the velocity profile delineates a shallow layer characterized by weathered soil, evidenced by velocities falling below 320 m/s. Beneath this superficial layer, basement rocks are inferred to dominate, exhibiting significantly higher seismic velocities exceeding 2139 m/s. This marked contrast in velocities suggests a distinct lithological boundary between the surface layer and the underlying basement rocks.

The variation in seismic velocities not only delineates lithological contrasts vertically, but also imparts valuable insights into the lateral heterogeneity of the subsurface lithological units. The discernible fluctuations in velocity across the profile underscore the spatial complexity of the geological setting, with distinct lithological units exhibiting characteristic seismic responses. Such variations in seismic velocities are indicative of diverse lithological compositions, structural discontinuities, and geological boundaries within the study area. The integration of seismic refraction data thus offers a powerful tool for elucidating the subsurface geological architecture, facilitating a comprehensive understanding of the lithological distribution and structural configuration both vertically and horizontally.

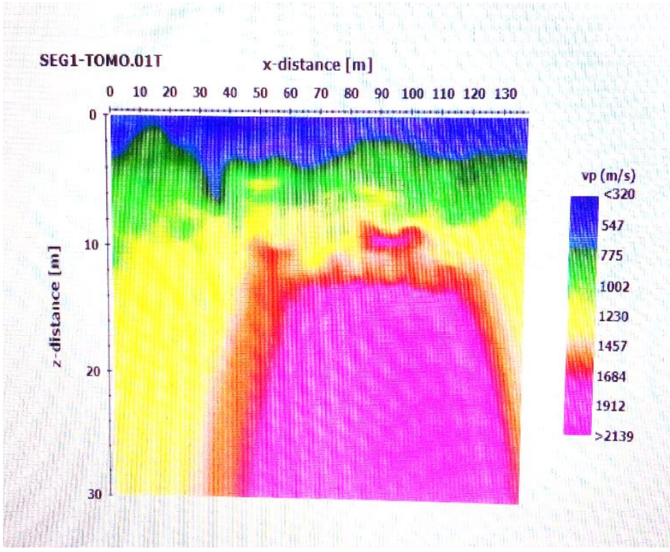


Figure 7: Seismic profile across the basement in the area

5. Conclusion

The study area predominantly comprises the Migmatite Gneiss complex, Gneisses, and Amphibolites, forming integral components of the Older Granites suite of Northern Nigeria. To facilitate effective mapping endeavors, an array of geological field equipment was employed within the study area. This facilitated comprehensive characterization of various geologic structures, including faults, fractures, and joints, observed within the exposed outcrops. Petrographical analysis of two rock samples sourced from the study area highlights the prevalent presence of migmatites, gneisses, and amphibolites. The amphibolite exhibits distinct geochemical characteristics, typified by low silica (SiO2< 45wt%), diminished alkali ($Na_2O + K_2O < 2wt\%$), elevated iron (Fe_2O_3> 20wt%), and heightened magnesium content. These attributes align with the traits indicative of a mafic protolith akin to basalt or gabbro. Furthermore, the geochemical profile reflects characteristics of the calc-alkaline series, corroborating the compositional attributes observed.

Geophysical investigations further augment the geological characterization of the study area, revealing the presence of a shallow layer of disturbed soil as the superficial lithology (< 320 m/s), underlain by basement rocks characterized by notably high seismic velocities (> 2139 m/s). Such findings underscore the suitability of the area for civil engineering construction and ground exploitation schemes, given its favourable geological attributes and stable subsurface conditions. This comprehensive characterization provides valuable insights for informed decision-making regarding land use planning and infrastructure development initiatives within the study area.

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