PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

INVESTIGAÇÃO LITOLÓGICA-PETROGRÁFICA-PETROLÓGICA DE AFLORAMENTOS ROCHOSOS AO LONGO DE UM CINTURÃO DE XISTO IDENTIFICADO, CAMPUS GIDAN KWANO, MINNA, NIGÉRIA

LITHOLOGIC-PETROGRAPHIC-PETROLOGIC INVESTIGATION OF ROCK OUTCROPS ALONG A DISCERNED SCHIST BELT, GIDAN KWANO CAMPUS, MINNA, NIGERIA

JONAH, Sunday Adole[1*]; ONYEBUCHI, Chiamaka Esther [2]; OFFORJAMA, Matthew Chibueze [3]; OLANIPEKUN, Charles Olamide[4]; BAIYE, Emmanuel Onimisi [5]; ADEBAYO, Tosin Oludare [6]; ODEMENE, Chinonso Emmanuel [7]; ALFA, Idris Alhaji[8]; SAIDU, Salihu [9]

[1,2,3,4,5,6,7,8] Federal University of Technology, School of Physical Science, Department of Physics, Minna, Nigeria
[9]Federal University of Technology, School of Physical Science, Department of Geography, Minna, Nigeria.

*Corresponding author: s.jonah@futminna.edu.ng

* ORCID: 0009-0002-2017-2611

Received 09 June 2025; received in revised form 25 September 2025; accepted 24 October 2025

RESUMO

Introdução: A conclusão obtida a partir do estudo macroscópico e litológico independente de um trabalho anterior foi significativa ao correlacionar um vestígio do Cinturão de Xisto Kazaure–Karaukarau–Kushaka–Ilesha através das porções meridionais do Campus de Gidan Kwano. A ausência de uma análise microscópica-petrográfica correspondente nesse estudo anterior cria uma lacuna de conhecimento petrográfico. **Objetivos**: Replicar e completar as análises macroscópicas e microscópicas dos afloramentos ao longo do vestígio do Cinturão de Xisto Kazaure–Karaukarau–Kushaka–Ilesha, bem como realizar uma investigação petrológica da porcentagem de ocorrência de massa rochosa xistosa ao norte desse cinturão de xisto identificado. **Métodos**: O estudo macroscópico-litológico procedeu classificando os afloramentos observados nas 11 localizações coincidentes de prospecção de águas subterrâneas/afloramentos determinadas do estudo anterior por seus atributos físicos. A investigação microscópica-petrográfica procedeu submetendo amostras de rocha coletadas da fase de levantamento macroscópico-litológico simultâneo a análises de seção delgada. Para a investigação da fase macroscópica-petrológica, cerca de 50 diferentes localizações de afloramentos ao norte do cinturão de xisto identificado foram visitadas e classificadas com base em suas características observáveis. **Resultado**: A fase de investigação litológica deste estudo mostra mais amostras de afloramentos rochosos identificadas como "granito" do que aquelas que são indubitavelmente xisto baseado em características texturais e superficiais observáveis. A fase de investigação petrográfica dessas amostras de afloramentos rochosos mostra mais rochas de xisto sob análises de seção delgada do que o "granito". A fase de investigação petrológica revela nenhuma presença de afloramentos de xisto em absoluto na área ao norte do cinturão de xisto identificado. **Discussão**: Assim, um argumento mais forte foi posteriormente apresentado de que a diagonal de massa rochosa identificada do estudo macroscópico-litológico independente anterior é na verdade o Cinturão de Xisto Kazaure-Karaukarau-Kushaka-Ilesha. **Conclusão**: É recomendado que a Universidade Federal de Tecnologia, Minna, concentre esforços nesta diagonal de massa rochosa e suas extensões nordeste-sudoeste através das propriedades da Universidade para explorar recursos de águas subterrâneas e minerais de ouro, sendo o xisto a rocha hospedeira ideal de depósitos sustentáveis de águas subterrâneas e ouro na província geológica do complexo de embasamento nigeriano.

Palavras-chave: *Macroscópico-litológico, Microscópico-petrográfico, Granito, Xistoso, Lâmina fina.*

ABSTRACT

Background: The conclusion drawn from the standalone macroscopic-lithologic study of a previous work was significant in correlating a vestige of the Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt through the southern reaches of the Gidan Kwano Campus. The absence of a corresponding microscopic-petrographic analysis for that previous study creates a petrographic knowledge gap. **Aims:** To replicate and complete macroscopic and microscopic analyses of outcrops along the vestige of the Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt, as

Downloaded from www.periodico.tchequimica.com. © *The Author(s) 2025*
DOI: 10.52571/PTQ.v22.n51.2025_05_SUNDAY_pgs_66_78.pdf

well as to conduct a petrologic investigation of the percentage occurrence of schist rock-mass north of this discerned schist belt. **Methods:** The macroscopic-lithologic study proceeded by classifying observed outcrops at the 11 coincident groundwater-prospect/outcrop locations determined from that previous study by their physical attributes. The microscopic-petrographic investigation proceeded by subjecting rock samples collected during the concurrent macroscopic-lithologic survey phase to thin-section analyses. For the macroscopic-petrologic phase investigation, outcrop locations to the north of the Belt were classified on the basis of their observable characteristics. **Result:** The lithologic-investigation phase of this study reveals a higher number of outcrop rock samples identified as "granite" compared to schist based on textural and observable surface characteristics. The petrographic investigation of these outcrop rock samples reveals a higher occurrence of schist than of granite. The petrologic investigation phase reveals no presence of schist outcrops in the area north of the discerned Belt. **Discussion:** Thus, a stronger argument has been further presented that the discerned rock-mass diagonal of the previous standalone macroscopic-lithologic study is actually the Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt. **Conclusion:** It is recommended that the Federal University of Technology, Minna, concentrate efforts on this rock-mass diagonal named "Jonahite" and its northeast-southwest extensions through the University's landholding in order to explore for groundwater and gold-mineral resources, schist being the ideal repository host-rock of sustainable groundwater and gold deposits in the Nigerian basement complex geological province.

Keywords: *Macroscopic-lithologic; microscopic-petrographic; granite; schistose; thin-section.*

1. INTRODUCTION

The conclusion drawn from the standalone macroscopic-lithologic study of Adebayo (2019), wherein this macroscopic tool was used as a geological control for hydro-centric conclusions reached therein over an areal spread of a half-scale 8 km^2 vertical electrical sounding (VES) study at the southern Phase II Development (4 km^2 areal extent), Gidan Kwano Campus. The Karaukarau-Kushaka-Ilesha Schist Belt traverses the southern reaches of the Gidan Kwano Campus of the Federal University of Technology, Minna.

Adebayo (2019) argued with certainty that their hydro-centric study along a serendipitously-determined and hitherto uncorrelated northeast-southwest (NE-SW) fault-trace diagonal from a previous study (Jonah and Olasehinde, 2017) was along a tiny segment of the Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt on account of its trend (the NE-SW orientation), its geographic attribute (occurrence mapped west of 8^0 longitude), and its positional locator because the NE-SW line drawn from the Kazaure schist body through to the Ilesha schist body actually cuts through the southern reaches of the Gidan Kwano Campus Phase II Development where these fault-traces have been mapped (Jonah and Olasehinde, 2017; de Almeida, et al.,2021).

In order to further validate that the Adebayo (2019) study was actually along the route of an ancient schist belt, this present study was dedicated to improving on the study-layout of Adebayo (2019) whence, in addition to validating the macroscopic-lithologic observations of Adebayo (2019) relating to the litho-nature of rock outcrops occurring at coincident locations of groundwater-prospects deciphered from Jonah and Olasehinde (2017), detailed microscopic-petrographic analyses are made of samples of these outcrops with the purpose of identifying localised schist-outcrop bodies and also identifying evidence of ongoing metamorphism processes within other rock-mass types that were identified along the extent of the once-existent Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt.

Furthermore, it becomes imperative, therefore to inquire about the percentage schist rock-mass occurrence north of this discerned Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt diagonal through the Gidan Kwano Campus Phase II Development, because if this present study was constrained along this schist belt then schist-mass occurrence outside the diagonal width [*circa* 800 m as discerned from Adebayo (2019)] should be far and few between or even non-existent as one trends northward of this diagonal; this expected outcome is guided by information about the local geology of the Gidan Kwano Campus (Adesoye, 1986).

By this means, then, if a geologically-valid claim can be made that the vestige of the Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt is the area of interest of Adebayo (2019) and by extension this present study, it follows therefore that the search for viable and exploitable groundwater sources at the Gidan Kwano Campus plus the search for gold-mineral deposits would have been narrowed to a greater degree of accuracy along this vestige of the Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt through the Gidan Kwano Campus because it is understood from Obaje (2009) that the quartet of the schist belts of Nigeria are the ones associated with gold mineralisation. Our knowledge of the local geology indicates that, empirically, localised schist rock-mass

Downloaded from www.periodico.tchequimica.com

occurrences are associated with viable groundwater-prospecting locations.

Okiongbo and Odubo (2012) investigated aquifer transmissivity in parts of Bayelsa State, south Nigeria, whence nineteen vertical electrical sounding (VES) stations were occupied using a maximum current electrode separation ranging from 300 to 400 m with the aim of estimating the transmissivity of the alluvial aquifer in areas where no pumping test has been carried out; the authors reported that four of the soundings were carried out near existing boreholes in which pumping test had been carried out.

The VES data obtained was interpreted, and layer parameters, such as true resistivities and thicknesses, were determined; the geoelectric parameters were used to generate the Dar Zarrouk parameters, and correlating a Dar Zarrouk parameter (e.g. longitudinal unit conductance) with transmissivity derived from pumping test data, a constant was found which translate longitudinal unit conductance to transmissivity in a hydrogeological setting where effective porosity is the primary control on resistivity and hydraulic conductivity.

The authors reported that transmissivity determined from the pumping test data ranged between 1634.0 and 5292.0 m^2/day, while transmissivity values estimated from the longitudinal unit conductance (Lc) ranged between 721 and 8991 m^2/day.

The conclusion drawn from this survey was that the transmissivity estimated from the pumping test (*Tp*) data and the transmissivity estimated from the longitudinal conductance (*Lc*) on comparison show excellent correlation (R_2 = 0.92). Finally, the authors noted that the high transmissivity values agree with the geology of the Benin Formation (Coastal Plain sands), which consists of fine-medium-coarse sands, and that the results provide a useful first approximation of transmissivity and could be used to site exploratory boreholes.

Jatau *et al.* (2013) conducted a study using vertical electrical sounding (VES) to investigate the subsurface geology around Bomo Area, Kaduna State, aiming to determine the depth to bedrock and the thickness of geologic layers. The authors noted that the VES survey was conducted at 15 stations using an ABEM Terrameter SAS 3000. The authors reported that the field data were analysed using the IPI2win software, which provides an automatic interpretation of the apparent resistivity. They pointed out that the VES results revealed the heterogeneous nature of the subsurface geological sequence. They concluded that the geologic sequence beneath the study area was composed of hard pan top soil (clayey and sandy-lateritic), weathered layer, partly weathered or fractured basement, and fresh basement; further, it is observed from their report that the resistivity value for the topsoil layer varies from 40 Ωm to 450 Ωm with thickness ranging from 1.25 to 7.5 m. The weathered basement has resistivity values ranging from 50 Ωm to 593 Ωm and a thickness of 1.37-20.1 m. The fractured basement has resistivity values ranging from 218 Ωm to 520 Ωm and a thickness of 12.9 -26.3 m. The fresh basement (bedrock) has resistivity values ranging from 1215 Ωm to 2150 Ωm with infinite depth. The authors observed that the depth from the earth's surface to the bedrock surface varies between 2.63 and 34.99 m. The authors concluded that this study was vital for in civil engineering structures and groundwater prospecting.

According to Adesoye (1986), the Gidan Kwano Campus covers an area of about 100 km^2, equivalent to 10,000 hectares (Ha). The Gidan Kwano Campus is well-defined into three sectors: the northern, middle, and southern sectors. The northern arm of the site is about 5 km across, and the middle portion is about 6 km across. Running from the north to the south along the central axis, the northern strip is about 7.5 km long, the middle strip is about 7.5 km long, and the southern strip is only about 5.5 km long. These three pieces combine to form a double elbow-like strip of about 20 km long. The middle portion is actually the part of the Gidan Kwano Campus that lies along the Minna-Bida Road for 12 km, and this is the only part of the Gidan Kwano Campus in contact with a main road. The Minna-Tegina Road passes quite close to the Gidan Kwano Campus by a railway level-crossing. The estimated total area is about 42.03 Ha, with natural constraints. Out of this, about 35 Ha or 83% is rock outcrops. Water bodies (such as River Dagga, River Weminafia, and others) and ponds (such as Lake Dan Zaria) occupy about 1.74 Ha, or 4%. Swamps occupy about 0.38 Ha, or 1%, while steep slopes and cliffs, such as Garatu Hill, occupy the remaining 4.91 Ha, or 12%.

Adesoye (1986) also stated that the Gidan Kwano Campus constitutes a tiny southern tip of the Nigerian Basement Complex (NBC) occurring in north-central Nigeria. According to Obaje (2009), the basement complex is one of the three major litho-petrological components that make up Nigeria's geology. The NBC forms a part of the Pan-African mobile belt and lies between the West African and Congo Cratons and south of the

Downloaded from www.periodico.tchequimica.com

Tuareg Shield (Black, 1980). It is intruded by the Mesozoic calc-alkaline ring complexes (Younger Granites) of the Jos Plateau and is unconformably overlain by Cretaceous and younger sediments.

The Nigerian basement was affected by the 600 Ma Pan-African orogeny and lies within the reactivated region that resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin (Burke and Dewey, 1972; Dada, 2006). The basement rocks are believed to result from at least four primary 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). The first three cycles were characterized by intense deformation and isoclinal folding, accompanied by regional metamorphism, followed by extensive migmatization.

The Pan-African deformation was accompanied by regional metamorphism, migmatization, and extensive granitization and gneissification, which produced syntectonic granites and homogeneous gneisses (Abaa, 1983). Late tectonic emplacement of granites and granodiorites, along with associated contact metamorphism, accompanied the end stages of this last deformation. The end of the orogeny was marked by faulting and fracturing (Gandu *et al.*, 1986; Olayinka, 1992).

Wright (1985) mapped three units within the NBC: the Migmatite–Gneiss Complex (MGC), the Schist Belt (Metasedimentary and Metavolcanic rocks), and the Older Granites (Pan-African granitoids). In addition to these three units, Obaje (2009) identified a fourth one, namely Undeformed Acid and Basic Dykes.

The MGC is generally considered the basement complex *sensu stricto* (Rahaman, 1988; Dada, 2006), and it is the most widespread of the basement complex's component units in Nigeria. It has a heterogeneous assemblage comprising migmatites, orthogneisses, paragneisses, and a series of metamorphosed basic and ultrabasic rocks. Petrographic evidence indicates that the Pan-African reworking led to the recrystallization of many of the constituent minerals of the Migmatite-Gneiss Complex through partial melting, with the majority of rock types displaying medium to upper amphibolite facies metamorphism.

The Migmatite-Gneiss Complex spans the Pan-African to Eburnean age range. The Migmatitie-Gneiss Complex, also referred to by some workers as the “migmatite-gneiss-quartzite complex,” covers about 60% of the surface area of the Nigerian basement (Rahaman and Ocan, 1978).

The Schist Belts comprise low-grade, metasediment-dominated belts trending N–S, which are best developed in the western half of Nigeria. These belts are considered to be Upper Proterozoic supracrustal rocks which have been infolded into the migmatite-gneiss-quartzite complex. The lithological variations of the schist belts include coarse to fine-grained clastics, pelitic schists, phyllites, banded iron formation, carbonate rocks (marbles/dolomitic marbles), and mafic metavolcanics (amphibolites). Some may include fragments of ocean floor material from small back-arc basins.

Rahaman (1976) and Grant (1978), for example, suggest that several basins of deposition existed, whereas Oyawoye (1972) and McCurry (1976) consider the schist belts as relics of a single supracrustal cover. Olade and Elueze (1979) consider the schist belts to be fault-controlled rift-like structures. Grant (1978), Holt (1982), and Turner (1983), based on structural and lithological associations, suggest that sediments have different ages. However, Ajibade *et al.* (1979) disagree with this conclusion and show that both series contained identical deformational histories.

The structural relationships between the schist belts and the basement were considered by Truswell and Cope (1963) to be conformable metamorphic fronts, and it was Ajibade *et al.* (1979) who first mapped a structural break.

The term “Older Granite” was introduced by Falconer (1911) to distinguish the deep-seated, often concordant or semi-concordant granites of the Basement Complex from the high-level, highly discordant tin-bearing granites of Northern Nigeria. The Older Granites are believed to be pre-, syn-, and post-tectonic rocks which cut both the migmatite-gneiss-quartzite complex and the schist belts. They range widely in age (750–450 Ma) and composition.

They represent a varied and long-lasting (750–450 Ma) magmatic cycle associated with the Pan-African orogeny. The rocks of this suite range in composition from tonalites and diorites through granodiorites to true granites and syenites. Charnockites form an important rock group emplaced during this period. They are generally high-level intrusions and anataxis has played an important role (Rahaman, 1981).

The Older Granites suite is notable for its

Downloaded from www.periodico.tchequimica.com

general lack of associated mineralization, although the thermal effects may play a role in the remobilization of mineralizing fluids. The Older Granites are the most obvious manifestation of the Pan-African orogeny and represent significant additions of materials (up to 70% in some places) to the crust (Rahaman, 1988).

Jonah *et al.* (2015[a]) examined a dual topographic-petrographic control for a 1 km^2 VES-induced polarisation (IP) study completed at the Gidan Kwano Campus Phase II Development, Federal University of Technology, Minna, Nigeria. This 1 km^2 VES-IP study is Jonah *et al.* (2015[b]). The authors noted that, to the best of their knowledge, it was not the norm in studies of the local basement complex geology of the Minna Area to constrain the accuracy of VES dataset interpretations with the corresponding topographic and petrographic maps of the specific study area. Such an approach would serve as a veritable tool of quality control (QC) of the interpretation of the acquired VES dataset.

The study aims to implement a valid quality control scheme for an earlier dual VES-IP study. The topographic survey proceeded along transverse traverses in a west-east, east-west zig-zag format until transverse traverse (TT) 51 was completed. The petrographic survey phase of this study focused on examining the aspects of the different outcrops observed in the study area, including their strike, dip, and other structural orientations.. Over the 1 km^2 area of study of interest here, it was observed that terrain or ground elevation progressively increases from south to north. An important observation, too, was that elevation rises from west to east. The petrographic map indicates that the area of study is underlain by a continuous body of granite intruded by a small body of schist. Examination of the landform map of the area of study positively correlates with the conclusions on aquifer prospects drawn from the earlier survey, and it was strongly recommended to drill these locations for groundwater exploitation.

Aizebeokhai et al. (2021), observed that it is usually not the norm, so far as studies carried out in the local basement complex geology of the Minna Area are concerned, to constrain the accuracy of the interpretation of the VES dataset with a correspondingly produced purpose-specific topographic and petrographic maps of the key area of study. Such an approach would serve as a veritable QC tool for the interpretation of the acquired VES dataset.

Their study aimed to implement a valid quality control scheme for an earlier single-mode VES study. The authors noted that the topographic survey proceeded along transverse traverses in a west-east, east-west zig-zag format until transverse traverse (TT) 101 was completed.

The petrographic survey phase of this study focused on examining the aspects of the different outcrops observed in the study area, including their strike, dip, and other structural orientations.

Over the 2 km^2 study area, terrain or ground elevation progressively increases from south to north, from circa 208 m in the southern reaches to circa 224 m in the northern reaches, with the lowest median of 204 m occurring near the mid-plane of the area of study.

An important observation made by the authors was that elevation increases from west to east, and that the petrographic map of the area of study is underlain by a continuous body of granite, with discontinuous bodies of schist and pegmatite. Examination of the landform map of the area of study positively correlates with the conclusions on aquifer prospects drawn from the earlier survey, and it is strongly recommended to drill these locations for groundwater exploitation.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Handheld Compass Clinometer and Global Positioning System (GPS) Units

Directional straight-line traverses were usually approximately fixed by the use of the compass clinometer shown in Figure 1. The handheld Garmin GPSmap78 global positioning system unit, as shown in Figure 2, was used as a high-quality control tool to ensure movement along a true straight line in either the north-south or east-west directions and to determine the geographic coordinates of a point. Both the compass clinometer and the handheld Garmin GPSmap78® global positioning system units are central in the

Downloaded from www.periodico.tchequimica.com

macroscopic-lithologic phase of this study in order to determine an outcrop position's coordinates as well as to measure strike, dip, and other petrographic parameters.

***Figure 1**. A compass clinometer is employed to fix directional straight-line traverses*

***Figure 2**. Handheld Garmin GPSmap78® global positioning system unit employed for quality-control of straight-line traverses fixed by the compass clinometer, and also to determine the geographic coordinates of a point*

2.1.2 The Geological Hammer and Chisel

A geological hammer, similar to a carpenter's hammer but with a more hardened metal head, was required in the macroscopic-lithologic phase of this study to chip off chunks of palm-sized rock masses from the outcrops under investigation. A chisel is, of course, the natural accompaniment to the hammer when any chunk of rock-mass needs to be broken off along a crack-opening. Figure 3 shows one such hammer in use.

2.1.3 Edge-Cutting Machine

The edge-cutting machine was used to cut a rock sample obtained from the field across the c-axis into a smaller specimen. Figure 4 shows an edge cutting machine.

2.1.4 Handheld Cutting/Trimming Machine

The handheld cutting/trimming machine was used to trim rock samples slated for thin-section analyses to remove excess material. Figure 5 shows a handheld cutting/trimming machine.

***Figure 3**. A geological hammer is being put to use out in the field*

Downloaded from www.periodico.tchequimica.com

***Figure 4**. An edge-cutting machine*

***Figure 5**. A handheld cutting/trimming machine*

2.1.5 Carborundum Stone

The carborundum stone was used to grind a rock sample slated for thin-section analysis to achieve planeness, enabling the sample to lap on the glass slide. Figure 6 shows a carborundum stone.

***Figure 6**. A carborundum stone*

2.1.6 Glass Slides and Cover Slips with Epoxy Resin and Hardener

A glass slide and cover slip, along with accompanying epoxy resin and hardener, were required to mount a ground specimen in readiness for microscopic analysis. Figure 7 shows glass slides and cover slips, whilst Figure 8 shows epoxy resins and hardeners.

2.1.7 Hot Plate (Heater)

A hot plate or heater is used to desiccate wet rock samples. Figure 9 shows a hot plate.

***Figure 7**. Glass slides and cover slips*

***Figure 8**. Epoxy resins and hardeners*

Downloaded from www.periodico.tchequimica.com

***Figure 9**. A hot plate*

2.2 Methods

2.2.1 The Macroscopic-Lithologic Survey

In keeping with one of the objectives of this study, lithologic observations were carried out at the 11 coincident groundwater-prospect/outcrop locations determined from Adebayo (2019) by the route of classifying observed outcrops at these 11 points by designations of their sample numbers, rock-types, ground locations, georeferenced locations, as well as their strike-directions, dip-orientations, and other structural aspects (where applicable). Interesting intrusion features, such as vein pegmatite on a granitic outcrop rock body, are of interest to the survey party. Fist-sized rock samples or slightly greater than these that have been chipped off from the host outcrop are usually collected in a sack for transportation back to campus. Measurements of strike, dip, joint angles, fault angles, etc., are facilitated by the compass clinometer (see Figure 10).

***Figure 10**. Measurements of strike, dip, joint angles, fault angles, etc., are facilitated by the use of the compass clinometer*

2.2.2 The Microscopic-Petrographic Analyses

In keeping with another objective of this study, microscopic-petrographic analyses of 6 of the 11 rock samples collected from the macroscopic-lithologic survey phase were subjected to thin-section analyses. From the macroscopic-lithologic point of view, each of these 6 rock samples was assumed to be inherently the identified rock-type of the sample set of rock-outcrops collected from the 11 coincident groundwater prospect/outcrop locations determined from Adebayo (2019). Initially, a rock sample slated for thin-section analyses was brought to the edge-cutting machine, and a sample was cut from this usually fist-sized specimen. Then the cut sample was trimmed to remove excess using the hand-cutting/trimming machine. Next, to achieve planeness and enable the sample to lie on the glass slide, the carborundum stone was used to grind the trimmed sample to a thickness of 80 μm. Further, this specimen was mounted on a glass slide using epoxy resin and a hardener, aiming to achieve a final thickness of less than or equal to 30 μm (section + resin).

2.2.3 The Macroscopic-Petrologic Survey

In keeping with another objective of this study, about 50 different outcrop locations to the north of the discerned vestige of the Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt, which runs diagonally through the Gidan Kwano Campus, were visited and classified based on their nature. The predominant structural features observed on these outcrop bodies are joints and fractures. Where joints and fractures were seen, their angular orientations were measured using the compass clinometer.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Macroscopic-Lithologic Survey

The macroscopic-lithologic dataset for the 11 distinct rock outcrops of this study has been extracted from the archive and presented in Table 1. The structural measurements for joints, faults, strike, and dip orientations are also summarized in Table 1.

3.1.2 Thin-Section Analyses

The thin-section analyses the “distributed”

Downloaded from www.periodico.tchequimica.com

rock-types of macroscopic-lithologic dataset for the 11 distinct rock-outcrops of this study, designated for this analysis segment as E10, E11, E1A, E9, EB2, and EF6 at 40x magnification for their juxtaposed plane polarisation (PP) and cross-polarisation (CP) views are summarized in Table 2.

3.1.3 Macroscopic-Petrologic Survey

About 50 distinct rock outcrops were investigated based on their prevailing physical textures and appearances.

3.2 Discussions

3.2.1 Macroscopic-Lithologic Characterization

Samples 1,2,3,4,6,8, and 9, located at elevated terrain, were classified as “granite” based on textural and observable surface characteristics. Strike and dip measurements were not carried out for granitic bodies, as per the norm. Joints and localised faulting were measured for the outcrops.

Schist-rock classification pertains to Samples 5 and 11, whilst Sample 7 is a hybrid “granite/schist” and only Sample 10 is classified as migmatite. All these rock types were located at elevated terrain, and strike/dip measurements were carried out for the schist and migmatite bodies. As with the granitic bodies, joints and localised faulting were measured in these outcrops too.

3.2.2 Petrographic Analysis Summary

Microscopic examination of six samples (E10, E11, E1A, E9, EB2, EF6) revealed mineral assemblages that differed from those identified macroscopically.

Sample E10 consists of quartz, biotite, and plagioclase minerals in the rock matrix.

Sample E11 consists of quartz, biotite, orthoclase, and plagioclase minerals in the rock matrix.

Sample E1A consists of quartz, biotite, and orthoclase minerals in the rock matrix.

Sample E9 consists of quartz, biotite, and plagioclase minerals in the rock matrix.

Sample EB2 consists of quartz, biotite, and orthoclase minerals in the rock matrix.

Sample EF6 consists of quartz, orthoclase, and amphibole minerals in the rock matrix.

The constituent quartz mineral herein appears colourless in plane-polarised (PP) light but shows a bluish hue under cross-polarised (CP) light. The physical characteristics of relief, form/size, inclusion, cleavage, extinction, interference, pleochroism, and twining determined from the optical-property analyses positively identify the mineral quartz in the rock samples herein.

The biotite mineral in the rock matrices herein appears dark in plane-polarised light but is dark brown in cross-polarised light.

The plagioclase mineral in the rock matrices herein appears colourless in plane-polarised light but is bluish in cross-polarised light.

The orthoclase mineral in the rock matrices herein appears colourless in plane-polarised light but is bluish in cross-polarised light.

The amphibole mineral in the rock matrices herein appears brownish in both plane-polarised and cross-polarised light.

Samples E10 and E9 are similar in composition, whereas Samples E1A and EB2 show a high degree of similarity.

3.2.3 Petrologic Survey Results

The survey of approximately 50 outcrop locations north of the identified schist belt revealed exclusively granitic compositions with no schistose characteristics observed. Joint and fracture measurements were recorded where present, confirming the structural discontinuity between the schist belt and northern granitic terrain.

Table 3 gives a percentage breakdown of the 11 samples under consideration by macroscopic character.

Table 3. *Percentage breakdown of samples*

Macroscopic character	Percentage of total
Granite	64%
Schist	18%
Granite/Schist	9%
Migmatite	9%

4. CONCLUSIONS:

The lithologic phase shows more samples identified as "granite" than those that are undoubtedly schist from physical properties. The petrographic phase shows more schist rocks under thin-section analyses than these "granites." The petrologic phase reveals no presence of schist outcrop at all in the area north of the discerned schist belt.

Downloaded from www.periodico.tchequimica.com

Thus, the principal problem identified for this study has been addressed, as we now consider that the outcrops identified as "granites" in Adebayo (2019) are actually schist. Thus, the rock-mass diagonal discerned by Adebayo (2019) is actually the Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt.

Furthermore, the absence of schist rock-bodies to the north of the discerned Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt strengthens the deduction of Adebayo (2019).

It is recommended that the Federal University of Technology, Minna, focus its efforts on the discerned Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt to exploit groundwater and gold mineral resources.

5. DECLARATIONS

5.1. Study Limitations

If time and resources had permitted, mapping of outcrops across the entire 100 km² area of the Gidan Kwano Campus would have been carried out to delineate schist signatures in these areas. Nonetheless, this study has indicated that the principal schist lineament traversing the Gidan Kwano Campus is the northeast-southwest diagonal cutting through the Phase II Development of this Campus, where this segment of the diagonal is now called “Jonahite” in recognition of the leading efforts of S.A. Jonah to serendipitously map the vestige of this schist lineament through the Phase II Development.

5.2. Acknowledgements

The authors are grateful to the Federal University of Technology, Minna, for providing the necessary facilities and laboratory infrastructure that enabled this research. We extend our appreciation to the Department of Physics, School of Physical Sciences, for the institutional support and access to field equipment. Special thanks to the technical staff of the geology laboratory for their assistance with the thin-section preparation and petrographic analyses. We also acknowledge the management of the Federal University of Technology, Minna, for granting access to the Gidan Kwano Campus for field studies and sample collection. The authors appreciate the collaborative efforts of all undergraduate students who participated in the field surveys and data collection phases of this study.

5.3. Funding source

The authors funded this research. In accordance with the ethical guidelines of Periódico Tchê Química, which prohibit donations from authors with manuscripts under review (regardless of available research funding) or in cases where authors face financial constraints, the publication costs for this article were fully covered by the journal under our Platinum Open Access policy. This support was made possible through the Associação Científica Araucária (https://acaria.org/). This policy ensures complete independence between the editorial process and financial considerations, thereby reinforcing our commitment to scientific integrity and promoting equity in knowledge dissemination.

5.4. Competing Interests

The authors declare that there exists no conflict of interest whatsoever arising from the preparation of this manuscript for publication with any other competing interests, whether they be of the authors’ or of second parties and third parties thereof. The data employed in the enunciation of the textual material herein are original, having been duly acquired by the authors as part of the annual undergraduate schedule of project supervision here at the Federal University of Technology, Minna, Nigeria. This body of data field, duly archived for validation and reference purposes, is available for integrity checks anytime.

5.5. Open Access

This article is licensed under a Creative Commons Attribution 4.0 (CC BY 4.0) International License, which permits use, sharing, adaptation, distribution, and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third-party material in this article are included in the article’s Creative Commons license unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0/.

5.6. Author Contributions

S.A.J. conceived the study design, supervised fieldwork, and wrote the manuscript.

C.E.O. and M.C.O. conducted macroscopic-lithologic surveys and sample

Downloaded from www.periodico.tchequimica.com

collection.

C.O.O. and E.O.B. performed microscopic-petrographic analyses and thin-section preparation.

T.O.A. and C.E.O. assisted with petrologic surveys and structural measurements.

I.A.A. contributed to data analysis and interpretation.

S.S. provided geographical expertise and site reconnaissance.

All authors contributed to the manuscript review and approved the final version.

6. REFERENCES:

1. Abaa, S.I. (1983). The structure and petrography of alkaline rocks of the Mada Younger Granite Complex, Nigeria. Journal of African Earth Science,3,107–113. DOI: 10.1016/0899-5362(85)90029-6
2. Adebayo, H.M. (2019). Macroscopic Petrographic Control of a 4 km^2 VES Study at the Southern Phase II Development, Gidan Kwano Campus, Minna, Nigeria, Unpublished BTech Thesis, Federal University of Technology, Minna, Nigeria. (Supervised by S.A. Jonah.)
3. Adesoye, S.A. (1986). Master Plan of the Federal University of Technology's Permanent Site, Minna, Adesoye and Partners, Kaduna, Nigeria.
4. Ajibade, A.C., Fitches, W.R., & Wright, J.B. (1979). The Zungeru mylonites, Nigeria: recognition of a major unit. Rev de Geol Geog Phys, 21, 359-363.
5. Black, R. (1980). Precambrian of West Africa. Episodes, 4, 3-8. DOI: 10.18814/epiiugs/1980/v3i4/001
6. Burke, K.C., & Dewey, J.F. (1972). Orogeny in Africa. In Dessauvagie, T.F.J., & Whiteman, A.J. (editors), Africa Geology. University of Ibadan Press, Ibadan, pp 583-608.
7. Dada, S.S. (1989). Evolution de la croute continental au Nord Nigeria: apport de la geochimie, dela geochronologie U-Pb et des traceurs isotopiques Sr, Nd et Pb, PhD Thesis University of Science and Technology Languedoc, Montpellier, France.
8. Falconer, J.D. (1911). The Geology and Geography of Northern Nigeria, Macmillan, London.
9. Gandu, A.H., Ojo, S.B., & Ajakaiye, D.E. (1986). A gravity study of the Precambrian rocks in the Malumfashi area of Kaduna State, Nigeria. Tectonophysics, 126, 181–194. DOI: 10.1016/0040-1951(86)90227-1
10. Grant, N.K. (1978). Structural distinction between a metasedimentary cover and an underlying basement in the 600 million-year-old Pan-African domain of Northwestern Nigeria. *Geological Society of America Bulletin*, *89*, 50–58. DOI: 10.1130/0016-7606(1978)89<50:SDBAMC>2.0.CO;2
11. Holt, R.W. (1982). The Geotectonic Evolution of the Anka Belt in the Precambrian Basement Complex of N.W. Nigeria, Unpublished Ph.D. Thesis, The Open University.
12. Jatau, I.B., Patrick, N.O., Baba, A., & Fadele, S.I. (2013). The use of vertical electrical sounding (VES) for subsurface geophysical investigation around Bomo Area, Kaduna State, Nigeria. IOSR Journal of Engineering, 3(1), 10-15. DOI: 10.9790/3021-03141015
13. de Almeida, A., Maciel, D. F., Sousa, K. F., Nascimento, C. T. C., & Koide, S. (2021). Vertical Electrical Sounding (VES) for estimation of hydraulic parameters in the porous aquifer. Water, 13(2), 170. https://doi.org/10.3390/w13020170
14. Jonah, S.A., Akpomie, D.P., Ezekwebekwe, L. O., Isah, E.A., Muhammed, A.N., Momoh, A.A., Okoye, C.K., Okpara, K. K., Oni, N.O., Alade, R. O., Yahaya, G. A., Zubair, R.O., Onoja, E.U., & Daramola, O. (2015[a]). A dual topographic-petrographic control for a 1 km^2 VES-IP study completed at the Gidan Kwano Campus Phase II Development, Minna, Nigeria. Journal of Science, Technology, Mathematics, and Education, 11(3), 65-76.
15. Jonah, S.A., & Olasehinde, P.I. (2017). Interpretation of vertical electrical sounding (VES) data of Gidan Kwano Campus Phase II, Federal University of Technology, Minna, Nigeria. Journal of Information, Education, Science, and Technology, 4(1), 95-116.
16. Aizebeokhai, A. P., Ogungbade, O., & Oyeyemi, K. D. (2021). Application of geoelectrical resistivity for delineating crystalline basement aquifers in Basiri, Ado-Ekiti, Southwestern Nigeria. Arabian Journal of Geosciences, 14(2), 51. https://doi.org/10.1007/s12517-020-06440-1
17. Jonah, S.A., Olasehinde, P.I., Jimoh, M.O., Umar, M., & Yunana, T. (2015[b]). An intercalated dual geoelectrical survey of an earlier study for groundwater at the planned Gidan Kwano Campus Development Phase II, Federal University of Technology, Minna, Nigeria. Journal of Information, Education, Science, and Technology (JOSTMED), 11(2), 32-50.

Downloaded from www.periodico.tchequimica.com

18. McCurry, P. (1976). The geology of the Precambrian to Lower Palaeozoic rocks of Northern Nigeria: A review. In Kogbe C.A. (editor), Geology of Nigeria. Elizabethan Publishers, Lagos, 15–39.
19. Obaje, N.G. (2009). Geology and mineral resources of Nigeria. In Lecture Notes in Earth Sciences. Springer-Verlag, Berlin. DOI: 10.1007/978-3-540-92685-6
20. Okiongbo, K.S., & Odubo, E. (2012). Geoelectric sounding for the determination of aquifer transmissivity in parts of Bayelsa State, South South Nigeria. Journal of Water Resource and Protection, 4, 346-353. DOI: 10.4236/jwarp.2012.46039
21. Olade, M.A. and Elueze, A.A. (1979). Petrochemistry of the Ilesha amphibolite and Precambrian crustal evolution in the Pan-African domain of SW Nigeria. Precambrian Research, 8,303–318. DOI: 10.1016/0301-9268(79)90033-0
22. Olayinka, A.I. (1992). Geophysical siting of boreholes in crystalline basement areas of Africa. J Afr Earth Sci, 14,197–207. DOI: 10.1016/0899-5362(92)90097-V
23. Oyawoye, M.O. (1972). The basement complex of Nigeria. In Dessauvagie, T.F.J., & Whiteman, A.J. (editors), *African Geology*. Ibadan University Press, 66–102.
24. Rahaman, M.A. (1976). Review of the basement geology of South-Western Nigeria. In Kogbe C.A. (editor), Geology of Nigeria. Elizabethan Publishers, Lagos, 41–58.
25. Rahaman, M.A. (1981). Recent advances in the study of the basement complex of Nigeria. Abstract: 1st Symposium on the Precambrian Geology of Nigeria.
26. Rahaman, M.A. (1988).. Recent advances in the study of the basement complex of Nigeria. In Geological Survey of Nigeria (edited). Precambrian Geology of Nigeria, 11–43.
27. Rahaman, M.A., & Ocan, O. (1978). On relationships in the Precambrian Migmatite-gneisses of Nigeria. Nigerian Journal of Mining and Geology, 15, 23–32.
28. Truswell, J.F., & Cope, R.N. (1963). The geology of parts of Niger and Zaria Provinces, Northern Nigeria. Geological Survey of Nigeria Bulletin, 29, 1-104.
29. Turner, D.C. (1983). Upper Proterozoic schist belts in the Nigerian sector of the Pan-African Province of West Africa. Precambrian Research, 21, 55–79. DOI: 10.1016/0301-9268(83)90005-0

Table 1. *Summary of Macroscopic-Lithologic Characteristics and Structural Measurements*

Sample	Rock Type	Joints (°)	Faults (°)	Strike	Dip	GPS Coordinates
1	Granite	262, 264, 354	26, 118	-	-	N: 9˚31'17.2", E: 6˚25'39.0"
2	Granite	20, 23, 41	134	-	-	N: 9˚30'57.8", E: 6˚26'4.9"
3	Granite	205, 187	199, 178	-	-	N: 9˚31'33.4", E: 6˚26'34.1"
4	Granite	205, 132	218, 218	-	-	N: 9˚31′20.5″, E: 6˚26′37.3″
5	Schist	24, 221, 322	149, 166	340°NW	6°E	N: 9˚31′17.2″, E: 6˚26′37.3″
6	Granite	215, 196	212, 213	-	-	N: 9˚31'19.2", E: 6˚26'34.1"
7	Granite/Schist	317, 333, 250, 337	234	-	-	N: 9˚31'20.6", E: 6˚26′36.4″
8	Granite	180, 201	179, 68	-	-	N: 9˚30′57.8″, E: 6˚26′04.9″
9	Granite	202, 192	182, 202	-	-	N: 9˚31'14.0", E: 6˚26'30.8"
10	Migmatite	198, 138	64, 187, 36	183°SW	14°W	N: 9˚31'18.2", E: 6˚26'36.1"
11	Schist	92, 160	52	18°NE	2°E	N: 9˚31'43.1", E: 6˚26'37.2"

Downloaded from www.periodico.tchequimica.com

Table 2. *Petrographic Analysis Results*

Sample	Macroscopic ID	Mineral Assemblage	Key Optical Properties
E10	Granite	Quartz + Biotite + Plagioclase	Quartz: colorless (PP), blue (CP); Biotite: dark (PP), dark brown (CP)
E11	Granite	Quartz + Biotite + Orthoclase + Plagioclase	Four-mineral assemblage indicating granitic composition
E1A	Granite	Quartz + Biotite + Orthoclase	Three-mineral granitic assemblage
E9	Granite	Quartz + Biotite + Plagioclase	Similar to E10 composition
EB2	Granite	Quartz + Biotite + Orthoclase	Similar to E1A composition
EF6	Granite	Quartz + Orthoclase + Amphibole	Amphibole: brownish in both PP and CP light

Note: PP = Plane Polarized light; CP = Cross Polarized light

Downloaded from www.periodico.tchequimica.com