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ARTICLE

Petrography and Geochemical Studies of Basement Rocks around Zango-Daji and Its Environs, North Central Nigeria

Simon D. Christopher **Onimisi A. Jimoh*** **Onimisi A. Martins**

Department of Geology, Federal University Lokoja, Nigeria

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ABSTRACT

The geology of the Zango-Daji area was investigated petrographically and geochemically to determine the study area's rock types and mineralization potential. The study area is underlain by rocks of the basement complex characterized by hilly and undulating rocks, which include granitic gneiss, migmatite gneiss, biotite hornblende granite gneiss, and pegmatites. Observation from the field shows that the study area is dominantly underlain by granitic gneiss. The granitic gneiss is dark grey, medium-coarse-grained, and characterized by weak foliation defined by the alignment of a streak of light and dark-coloured minerals. They are widespread in the area constituting about 70% of rock types found in the study area. The average modal percentage of minerals in the rocks from petrographic studies shows that granitic gneiss had quartz 45%, plagioclase 10%, microcline 20%, hornblende 2%, biotite 10%, muscovite 5%, kyanite 8% and other minerals 5%. Also, the pegmatite of the study area has no evidence of mineralization; it contains minerals like quartz, feldspars (microcline and orthoclase), and micas (mostly muscovite). Geochemical analysis of the granitic gneiss of the study area shows that silica is by far the most abundant with a value of 53.5%, Na_2O value of 32.5%, Al_2O_3, and K_2O of 6.1% and 4.0%, respectively. CaO value of 2.630% accounts for plagioclase feldspar in the granitic gneiss. The QAP diagram was used to determine the petrogenesis of the granitic gneiss. The plot shows the parent rock was a monzogranite with a low percentage of plagioclase in a thin section with a high percentage of quartz and alkali feldspar. The pegmatites of the study area are barren, as confirmed by the XRD result.

1. Introduction

The Precambrian basement complex of Nigeria lies within the Pan-African mobile belt, east of the West African craton and northwest of the Congo-Gabon craton (Figure 1). Evidence from the eastern and northern margins of the West African craton indicates that the Pan-Af-

*Corresponding Author:
Onimisi A. Jimoh,
Department of Geology, Federal University Lokoja, Nigeria;
Email: onimisi.jimoh@fulokoja.edu.ng

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rican belt evolved by plate tectonic processes which involved the collision of the passive continental margin of the West-African craton and the active margin of the Pharusian belt (Tuareg shield), about 600 Ma [1,2]. It lies within the reactivated part of the belt [3]. The geology of Zango Daji has been studied to various degrees by some authors, including [4]. These authors indicate the major rock groups, distribution, and structural relationships.

The major rock types in this area are migmatites, granite gneiss, and biotite gneiss, while there are minor occurrences of rock types like pegmatites and quartzo-feldspathic veins. Migmatites are the most comprehensive spread rock type in the area and form the country rock in which all other rocks occur. The Nigerian basement complex rock is classified into four major groups [5]. His classification was based on petrological evidence viz; the migmatite complex, the metasedimentary series, the older granites, and the miscellaneous rock types, including Bauchites and Diorite. Furthermore, the area comprises basement complex rocks, highly migmatite gneisses, and granodiorite (biotite hornblende granodiorite, biotite hornblende granite, porphyritic biotite granite, and muscovite biotite granite) intruded by the NE-SW trending pegmatite dykes and covered by medium-grained alluvium sediments [6].

The study area is a basement terrain; the metamorphic rock unit includes granitic gneiss, migmatite gneiss, biotite hornblende granite gneiss, and pegmatite intrusions (Figure 2).

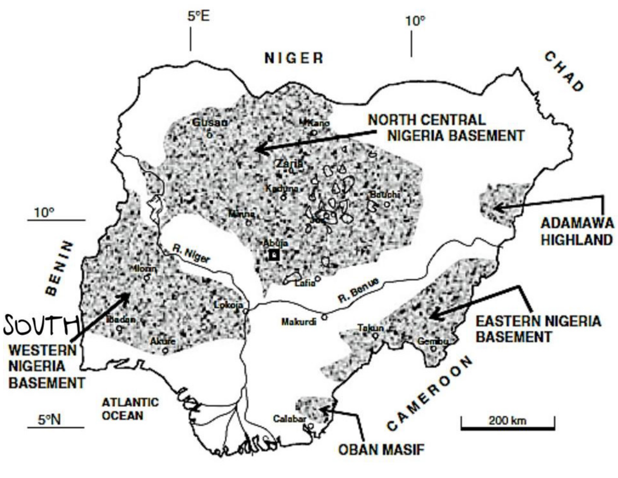

Figure 1. Geological map of Nigeria highlighting the basement complex [7].

2. Geological Settings

The migmatite gneisses are highly foliated and generally occur as low-lying outcrops, impregnated by quarto-feldspathic and pegmatitic veins; the granitic gneisses in the area occur as massive plutons affected by intense weathering with a relict product as quartz ridge, their gneissic textures are more exposed around river channels and are largely intruded by pegmatites. Around the western part are pegmatites intruding massively towards the south and traceable to the northern region (Figure 2). Some of the rocks exhibit jointing and show strong mineral lineation and foliation. The megascopic minerals observed on these outcrops include feldspar, quartz, and biotite.

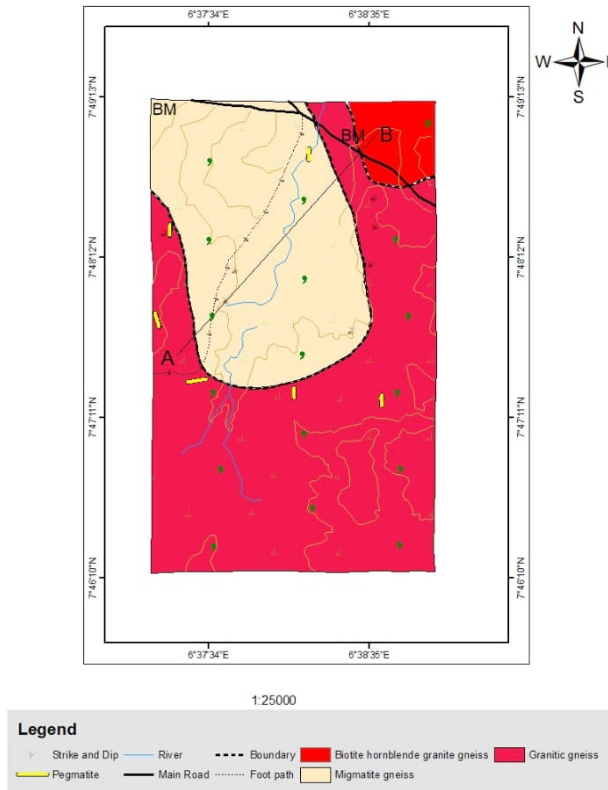

Figure 2. Geological map of the study area.

3. Methodology

The major research methods used in carrying out this research are geological field mapping, petrographic and geochemical analysis.

The first objective was to carry out a detailed geological mapping of the study area. This was done using the Global Positioning System (GPS) to locate outcrops and other geological features and subsequently followed closely spaced traverses across rivers and footpaths. Field mapping was carried out using a topographic map on a scale of 1:25,000. Representative rock samples of the rock types encountered in the study area were obtained using a sledgehammer.

Analyses of rock samples of the study area were done to determine the mineral types and their comparative proportions in the various rocks through thin sections. Major element geochemical analyses of the samples were carried out using XRF.

3.1 Thin Section Analysis

In the preparation of the thin section, the samples were cut into slabs of thin thickness, and the surfaces were smoothened with carborundum 70 and 90 grit to remove saw marks from the surfaces after thorough washing. Then, mounted on glass slides with thin araldite and pressed together (using forceps) to remove air bubbles. Furthermore, the mounted samples were allowed to cool to room temperature before reduction to about 3-4 mm on a lapping wheel. The final reduction and thinning of the samples involved grinding and smoothening with carborundum 600 and 800 grits, respectively. The thinning was done with occasional observation under the petrological microscope, and the covering of the glass slides followed this stage with a thin glass slip to preserve the surface. Excess araldite on the glass slides was washed off with acetone and soap solution. The slides were then rinsed with distilled water using a camel hair brush. The slides were labelled accordingly and ready for detailed study under a petrographic microscope.

3.2 X-ray Fluorescence (XRF) Analysis

Selected rock samples from the study area were subjected to X-ray fluorescence spectroscopy using a Rigaku RIX 3000. Qualitative and quantitative analyses were conducted to determine powdered samples' major and minor oxides. The powdered samples were used to make fusion beads to analyze most major and minor elements.

In preparation for the geochemical analysis, the samples were first pulverized (ground to a fine powder) using the Agate mortar. The ground samples were ensured to pass through the 150 micro mesh sieves to ensure homogeneity. Afterward, 5 gm of each pulverized sample was weighed into a beaker for palletisation. 1 gm of binding acid was then added to the solution.

The mixture was thoroughly mixed to ensure homogeneity and was pressed under high pressure to produce pellets. This was then labelled and packaged for analysis. For the X-Ray fluorescence (XRF) analysis, the pellet was carefully placed in the representative measuring position on the sample changer of the machine. A given periodic table guided the selection of filters for elemental analysis.

4. Results and Discussion

4.1 Field Description and Petrographic Studies of the Rocks

The area under study is generally underlain by granite gneiss, migmatite gneiss, biotite hornblende granite gneiss, and pegmatites predominant in the Zango area.

Thin sections made from the rock representative samples were carefully studied using the polarizing microscope. The minerals in the thin section were identified under both crossed and plane-polarized light. Optical properties such as colour, twinning, birefringence, pleochroism, and extinction angle were helpful in the identification of some minerals.

4.1.1 Migmatite Gneiss

This occurs in the central part extending to the northwestern portion of the study area. Migmatite rocks encountered in the study area were grey with large crystals of orthoclase feldspar, which are pinkish. The pink masses sandwiched by small dark bands rich in biotite mica consist of alternating pink and dark grey bands. Foliations are pronounced in most outcrops of the study area.

Location N 007° 47' 56"and E 006° 37' 28" occurs as low-lying outcrops intruded by quarto-feldspathic veins. The outcrops are weathered in some areas with evidence of structural elements such as joints and fractures. Lineations and foliations are well developed and preserved in the rocks of the study area (Figure 3).

Figure 3. Migmatite gneiss outcrop.

Feldspar is subhedral and consists of about 39% of the mineral composition. The hornblende is subhedral and anhedral in shape and consists of about 30% of the mineral composition, while the microcline is subhedral with crosshatching and is 20% of the mineral composition. Quartz consists of 10% of the mineral composition (Figure 4).

4.1.2 Granitic Gneiss

This occurs in the entire southern part of the study area (Figure 2). The study area is underlain predominantly by granitic gneiss that is fine to medium-grained, poorly fo-

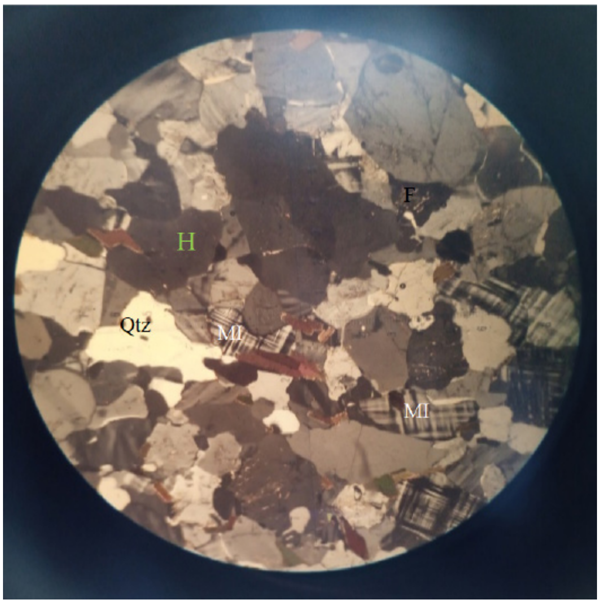

Figure 4. Photomicrograph of migmatite gneiss under XPL Magnification = X10.

H = Hornblende, F = Feldspar, MI = Microcline and Qtz = Quartz.

liated with bands of light and dark-coloured minerals as evident in (Figure 5) location N 007° 47' 56'' and E 006° 37' 28''. Quartz and quartzo-feldspathic veins are running concordantly and crosscutting the rocks. The minerals in the thin section generally show low relief; visible minerals are quartz, feldspars, biotite, kyanite, muscovite, hornblende, and other accessory minerals. Most of the crystals show a subhedral-anhedral form. The quartz mineral is colourless under plane polarised light and shows no pleochroism; it has a first-order birefringence with extinction angles at 30° and 80°. Biotite shows brown colouration with subhedral—anhedral form. The crystals of feldspar appear colourless in plane polarised light (PPL) and grey under cross polarised light (XPL); they include plagioclase and microcline, tartan and lamella twinning was a diagnostic feature used in differentiating the feldspars, with the microcline displaying a cross-hatch twinning, and the plagioclase lamellar twinning. Quartz and feldspar constitute about 70% of the thin section. Quartz is the most abundant mineral in the slide, indicating that the rock is a product of acidic magma crystallization.

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Figure 5. Granitic gneiss outcrop.

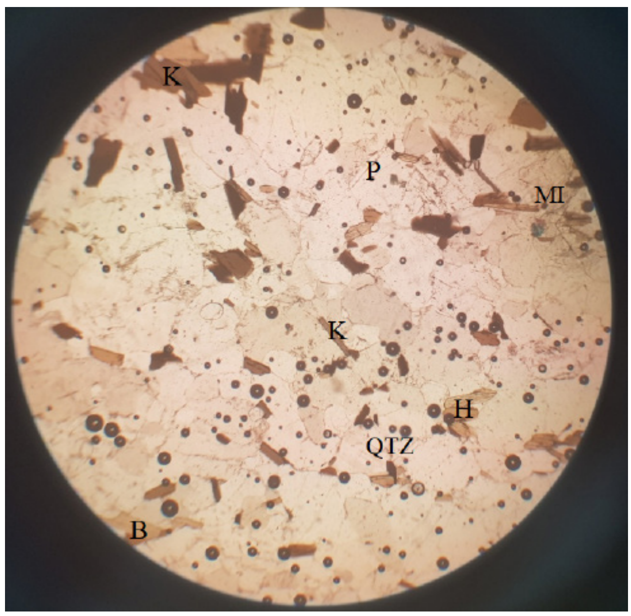

Figure 6. Photomicrograph of granitic gneiss (viewed under plane polarised light).

H = Hornblende, B = Biotite, K = Kyanite, QTZ = Quartz, MI = Microcline.

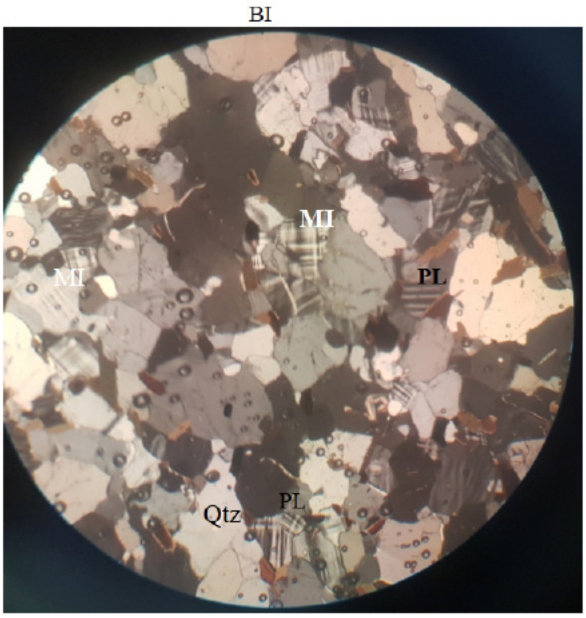

Figure 7. Photomicrograph of granitic gneiss (viewed under crossed polarised light).

Qtz = quartz, Pl = Plagioclase, MI = Microcline, B = Biotite.

4.1.3 Biotite Hornblende Granite Gneiss

This rock type occurs in the study area's extreme northeast (Figure 2). They form a minor part of the granitic gneiss terrain at location N 007° 48' 27.7" and E 006° 38' 35.3". They occur as grey-black, medium-grained batholiths intimately mixed with the granitic gneiss. The petrography of the gneiss is variable, particularly concerning quantities of individual minerals, but the rock is characterized by biotite and hornblende (Figure 8).

Figure 8. Biotite hornblende granite gneiss outcrop.

They are primarily mesocratic, coarse-grained, and equigranular, exhibiting interlocking textures, and subhedral to anhedral grains. Oligoclase is colourless and cloudy; hornblende is green and pleochroic from light green to dark green. From the thin section, biotite, hornblende, quartz, plagioclase, and feldspar are present, as shown in Figure 9. The plagioclase is subhedral to an anhedral shape, while the quartz appears to be anhedral in form. Also, the biotite is anhedral, and hornblende is subhedral to anhedral in shape.

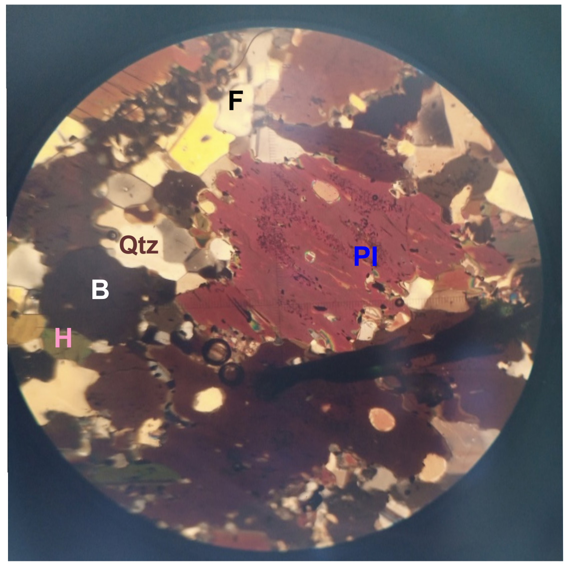

Figure 9. Photomicrograph of biotite hornblende granite gneiss under XP L. Magnification X10.

H = Hornblende, B = Biotite, Pl = Plagioclase, F = feldspar and Qtz = Quartz.

4.1.4 Pegmatites

Pegmatites were found throughout the study area, most intruding on the surrounding rocks. They are more concentrated at the base of the granitic gneisses and are foliated in the migmatite gneiss (Figure 10). Field observations show that pegmatite is associated with other rock types, such as migmatite gneiss and granite gneiss. It is evident from the geological map (Figure 2) that pegmatite, which intrudes into the gneiss, is the predominant rock type in the study area. Pegmatite in the study area trends in the NE-SW direction and are found in different forms as vein, irregular bodies, and sometimes as a cross-cutting discordant dyke. Pegmatite existing as vein and dyke is very common in other rock units such as granite gneiss and migmatite gneiss of the study area.

The relationships of pegmatite with the host rock are cross-cutting, oblique, and sometimes concordant to foliations of the general trend. These pegmatite dykes and veins range from a few centimetres to tens of metres. In some cases, there are abrupt terminations. The pegmatites within the mining site at Zango have been extensively and deeply weathered, revealing the high resistance of fractured quartzitic bodies. The quartzites are of different varieties, with common ones that include transparent rock crystals, milky white quartz, and smoky quartz, which could be irregular in shape, while some assume hexagonal crystal shapes. The topography of the pegmatite mining site is composed of the sloppy highland, deeply weathered pegmatite, and flat-lying unweathered pegmatite outcropping discontinuously within the mining site.

Figure 10. Pegmatite in migmatite gneiss (N 07° 47' 43.8'' and E 06° 37' 25.5'').

The petrographic study of pegmatite in thin sections (Figure 11) shows the predominant minerals are quartz, microcline, muscovite, plagioclase, biotite, and accessory minerals in varying compositions, with sizes ranging from veinlet of about a few kilometres to a few millimetres in width. Muscovite is the more abundant mica occurring in the pegmatite of the study area, while biotite is very few. Minerals in pegmatite have large crystals identifiable and recognizable in hand specimens.

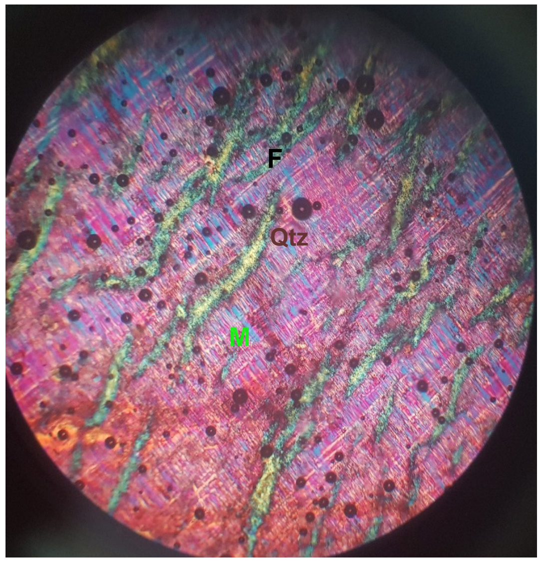

Figure 11. Photomicrograph of pegmatite under XPL. Magnification x10.

F = feldspar, Qtz = Quartz and M = Muscovite.

The pegmatite observed in the study area is barren, confirmed by the XRD result presented in Figure 12. Barren pegmatite has no evidence of mineralization; it contains minerals such as quartz, feldspars (microcline and orthoclase), and micas (mostly muscovite). The Muscovite present here is compacted into dark colouration.

X-Ray Diffractogram (XRD) analysis (Figure 13) of the pegmatite reveals an average mineralogical composition of quartz (36%), albite (18%), orthoclase (29%), chlorite (3.6%), illite (8%) and garnet (4.7 %). Quartz,

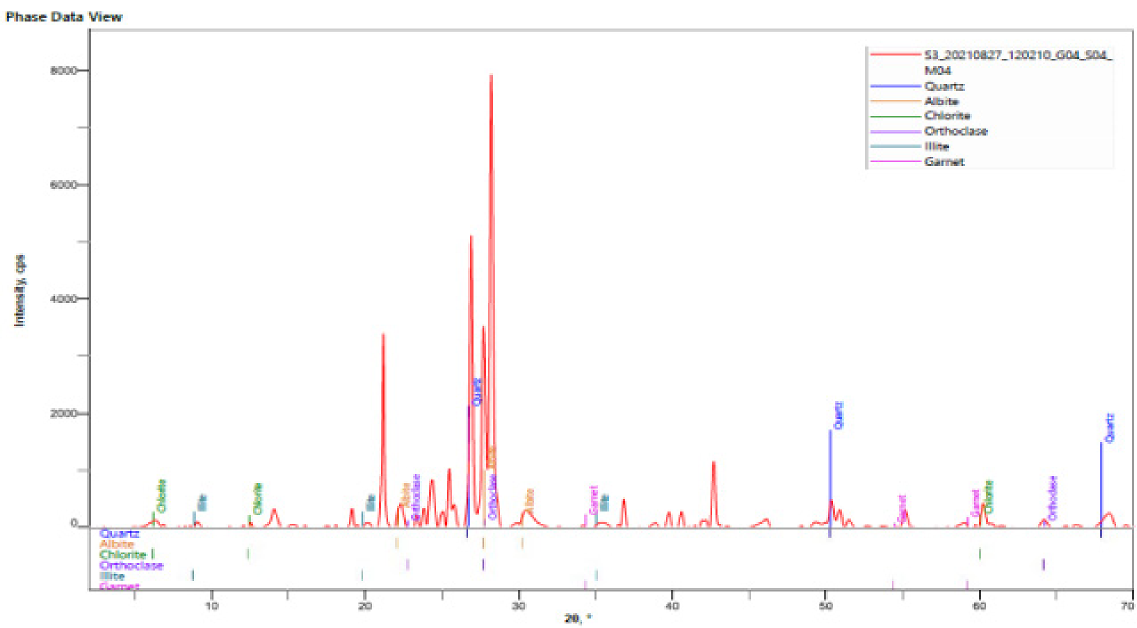

Figure 12. XRD of Zango pegmatite.

orthoclase, and albite are the dominant minerals in the pegmatite of the study area. This result shows that the pegmatites in this area are simple (barren) pegmatites.

4.2 Major Element Geochemistry

Results of geochemical analysis of the granitic gneiss from the study area, as presented in Table 1, show that silica is by far the most abundant with values in mole percentage of 53.5%, Na_2O values of 32.5%, Al_2O_3 and K_2O of 6.1% and 4.0% respectively. CaO value of 2.630, which accounts for the plagioclase feldspar in the granitic gneiss, FeO_3 and MnO values are generally low with values of 0.806% and 0.045%, respectively, while TiO_2 has a value of 0.225%.

Table 1. XRF result of major oxides.

S/N	OXIDES	MOL%
1	SiO_2	53.473
2	F_2O_3	0.806
3	Na_2O	32.525
4	Al_2O_3	6.111
5	P_2O_5	0.000
6	MnO	0.045
7	K_2O	4.092
8	MgO	0.000
9	CaO	2.630
10	TiO_2	0.225

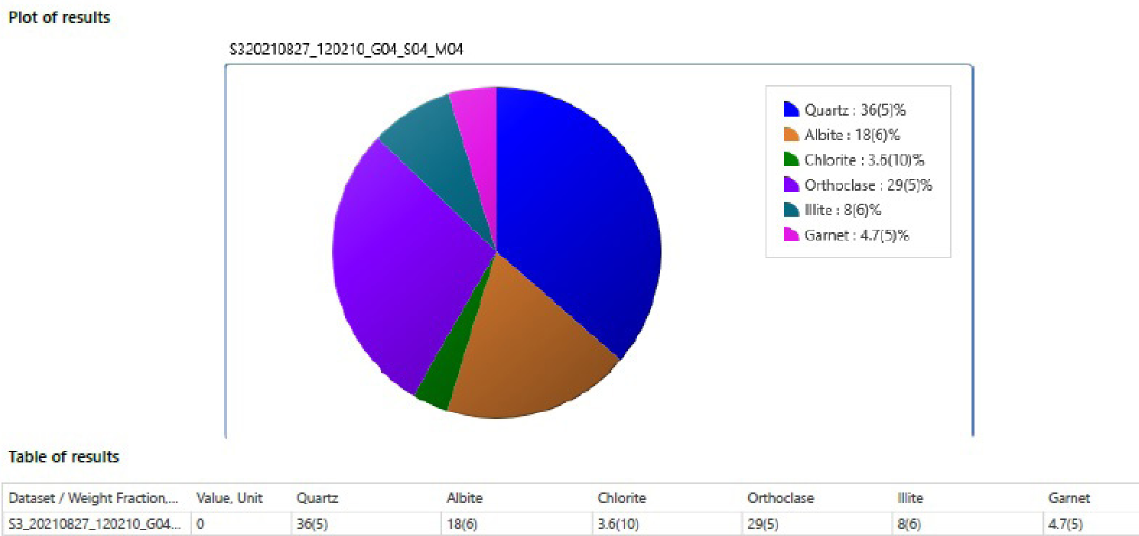

Figure 13. Mineralogical composition of Zango pegmatite determined from identified peaks of the X-Ray diffractogram.

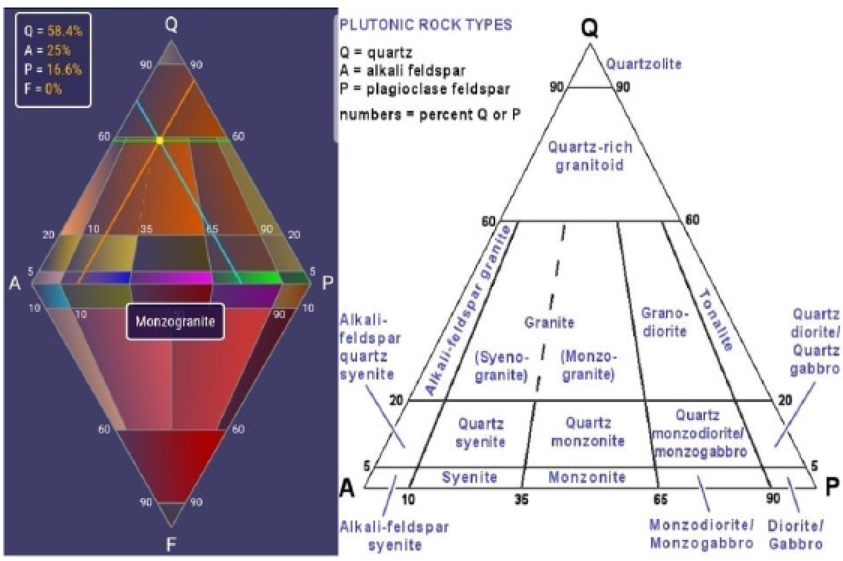

Figure 14. QAP diagram classifying the granitic gneiss of the study area.

4.3 Protholith and Petrogenesis

The protolith and petrogenesis of the granitic gneiss in the study area were derived using the QAP diagram; the QAP plot is particularly useful in classifying intrusive rocks. The granitic gneiss plotted in the Monzogranite field (Figure 11) indicates that the parent rock is Monzogranite.

5. Conclusions

This research discussed the petrography and geochemistry of basement rocks of Zango-Daji and its environs, a typical example of the Precambrian basement complex of Nigeria. It is underlain by the basement complex rocks characterized by hilly and undulating rocks such as granitic gneiss, migmatite gneiss, biotite hornblende granite gneiss, and pegmatite. The migmatite gneiss is highly foliated and occurs as low-lying outcrops; granitic gneisses are widespread in the study area and occur as massive, rugged hills heavily impregnated with pegmatite intrusions. Pegmatite occurs as outcrops and intrusions in the area with minerals such as quartz, feldspar, micas, and chlorite.

The granitic gneiss is a metamorphosed granite rock that displays light and dark minerals banding. It is composed of mafic minerals such as biotite and hornblende; felsic minerals include quartz feldspars (microcline) and muscovite mica. The average modal percentage of minerals in the rocks from petrographic studies shows that granitic gneiss contains; quartz 45%, plagioclase 10%, microcline 20%, hornblende 2%, biotite 10% muscovite 5%, kyanite 8%, and other minerals 5%. Pegmatite of the study area has no evidence of mineralization; it contains quartz, feldspars (microcline and orthoclase), and micas (mostly muscovite).

The QAP diagram was used to plot the modal percentages of minerals in the granitic gneiss rock sample. The plot shows the possible parent rock was a monzogranite, with a low percentage of plagioclase in the thin section and a high percentage of quartz and alkali feldspar. This research seeks to contribute knowledge on the geology of the area by geochemical and mineralogical observation of rocks around the area.

Conflict of Interest

There is no conflict of interest.

Acknowledgment

The authors are grateful to the Geology department, Federal University Lokoja, for providing a petrographic microscope to analyze the samples to determine the mineral types and their relative proportions in the rocks through the thin section.

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