NJBAS

Available online at http://www.ajol.info/index.php/njbas/index
Nigerian Journal of Basic and Applied Sciences (June, 2023), 31(1): 49-59
DOI: http://dx.doi.org/10.4314/njbas.v31i1.6

ISSN 0794-5698

Full Length Research Article

# Field and Petrographic Studies of Basement Complex Rocks in Saigbe and Environs, North-Central, Nigeria

[1]Y.A. Omanayin, *[2]M. Lawal, [1]I.B. Bolaji and [3]A. Muhammad
[1]Department of Geology, School of Physical Sciences, Federal University of Technology, Minna, Niger State, Nigeria
[2]Department of Geology, Faculty of Physical and Computing Sciences, Usmanu Danfodiyo University, Sokoto, Nigeria
[3]Geography Department, Shehu Shagari College of Education, Sokoto, Sokoto State, Nigeria
[*Corresponding Author: Email: awalmuktar@yahoo.com]

**ABSTRACT**
Geological mapping and petrographic studies of rocks provide useful information on texture and mineralogical composition of rocks which can be used in the exploration and exploitation of any associated mineralization. However, few regional studies have been conducted in Minna and environs. Here, preliminary field mapping and petrography of out crops in Saigbe environ were conducted to determine their identification, structural and mineralogical composition. Twenty-one rock samples were collected, eight of which were used for thin section analysis. Joint directions were measured and plotted on rose diagram. Results show that Saigbe is underlain by schist, amphibolite and granite with minor pegmatite intrusions. Joints, faults, fold and foliations constitute main structures. Joints in the schists trend NE-SW, while those in the granites trend NW-SE, suggesting different episodes of emplacement for both rocks. Petrography revealed that the schists comprised quartz, biotite, muscovite, plagioclase and opaque mineral, while the amphibolites are composed largely of quartz, hornblende, plagioclase feldspar and opaque minerals. The granites are composed of quartz, microcline, plagioclase feldspar, muscovite and opaque minerals. The pegmatite dykes in the granites comprised quartz, plagioclase feldspar, orthoclase feldspar, muscovite and gemstones, hence interpreted as product of residual melt. The pegmatites make interesting target for mineral exploration.
**Keywords**: Older Granite, Basement Complex, Petrography, Pegmatites, Northern Nigeria

## INTRODUCTION

The Nigerian Basement complex lies within the mobile belt that separates the West African and Congo Cratons. The West African Craton is to the west while the Congo Craton is to the Southeast of Nigeria (Kroner *et al.*, 2001). These Cratons are Archean to Lower Proterozoic in age. The Basement Complex of Nigeria occupies about a half of the entire country's areal coverage (Rahaman, 1988). The geology of Nigeria is classified into three main lithologic units including the Basement Complex rocks, the Younger Granites and the Sedimentary Basins. The Basement Complex of Nigeria is further subdivided into three: Migmatite-gneiss Complex, Schist Belts and the Older Granites. The largest proportion of these basement complex rocks is found within the North-central Nigeria to which the study area belongs (Obaje *et al.*, 2006; Ajibade *et al.*, 2008; Goodenough *et al.*, 2014).

Geological field mapping and petrographic studies of rocks in a locality are used for the description and identification of different rock types and associated mineralogy, which can provide important support information in the exploration and exploitation of any associated economic mineralization. A detailed and systematic description of rocks (both in hand specimen and in thin section) can also reveal their structural characteristics. Hand specimen study is best carried out in the field by observing fresh rock samples in terms of texture, structure and mineralogy. The detailed description in thin section (petrography) provides the mineral composition and characteristics and thus permit the measurement of a sufficient number of optical properties which enables the estimation of the proportions of various mineralogical components. Hence, rocks can be identified, classified and named (Dare *et al.,* 2014). It has been noted that very little investigations of the plutonic rocks of Minna and environs (which include the Saigbe area) have been carried out (Ferre *et al.*, 1998; Goodenough *et al.*, 2014). Because the Saigbe area contain excellent exposure of the Pan African granitoids and economic mineral (e.g., tantalum, gold, etc) enrichment, some of which have been artisinally mined, are common within these group of rocks (Garba, 2003). An investigation of the rocks in the area presents a significant step towards a coordinated mineral exploration and mining in the area. Therefore, this research aimed to study the field characteristics and petrography of rocks within the Saigbe area, north-central Nigeria with a synthesis on geologic and tectonic.

## GEOGRAPHICAL AND GEOLOGICAL SETTING

### Location of Study Area

The study area, Saigbe, falls in the northwestern Nigerian Basement province. Saigbe lies between latitudes 9˚42' N and 9˚45' N and longitudes 6˚33'30'' E and 6˚36'30'' E, on the outskirt of Minna metropolis, Bosso Local Government Area (LGA) of Niger State, North-central Nigeria (Figure 1). Bosso LGA is surrounded by Kagara, Rafi, Munya and Wushihi LGAs, Saigbe locality is approximately 32 km$^2$ in size, surrounded by other villages in and around Bosso LGA such as Zinari, Pawo, Shipada,Shipana and Dangwani. The main access road to Saigbe is the new Maitunbi-Maikunkele Bye-pass, while several minor roads and footpaths are also linked to it, making the area easily accessible. The northwestern to southwestern part of Saigbe is of moderately high relief, ranging from about 330 to 350 m above sea level. Northeastern to southeastern part of Saigbe exhibits moderately low relief, ranging from about 250 to 290 m above sea level. The southwestern part of the area is rugged, contoured by hills and quartz ridges. The area is drained mainly by River Saigbe, which flows in southward direction and is fed by many other smaller streams or tributaries. The surficial hydrological system of the area is structurally controlled, consequently forcing the river to flow southwards (in the orientation of outcrops in the area). The drainage system is characterized mainly by dendritic pattern.

In terms of climate, the Saigbe area has an alternating wet and dry season. The rainy season spans between May and October of every year with a total annual rainfall of about 1324mm (NIMET, 2010), while the dry season starts from November to April with harmattan period occurring between December and February of the year. The average annual temperature range in the area is about 30ºC (NIMET, 2010). The vegetation is a typical guinea savannah grassland with scattered shrubs and short grasses of about 3 to 4.5 metres high and trees of up to 15 metres high (Omanayin and Ogunbajo, 2016).

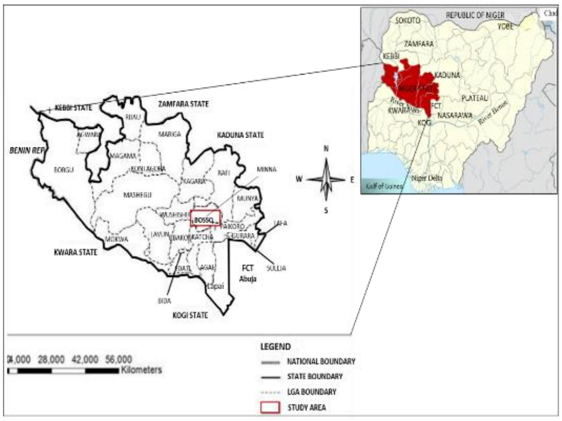


**Figure 1**: Location of Saigbe in Bosso Local Government Area, Niger State, Nigeria (Yerima *et al.* 2013)

### Geological Setting

Saigbe lies on the outskirt of Minna area, within the North-South trending Pan African (Neoprotozoic – Cambrian age) orogenic belt (i.e., the Basement Complex of NorthwesternNigeria) which lies towards the East, West and North of Africa (Figure 2; Rahaman, 1988; Goodenough *et al.*, 2014; Lawal *et al.*, 2017b; Ejiga, 2022). The major rock types in the area, similar to the rest of northern Nigeria, are deformed, Pan-African schists and granites and Archeanmigmatitic gneisses (Amadi *et al.*, 2017; Akinola *et al.*, 2021). An extensive, NNE-SSW trending faults and fractures constitute the major structural component of the geology of the area (Figure 2). The Pan African orogeny itself is a tectono-thermal, collision-related event associated with the slipping of the Eastward dipping Benioff's zone under the Pan-African region (Bessoles and Trompette, 1980; Akinola *et al.*, 2021). These Pan African rock types comprises both "syn-collisional and post-collisional" (those typified high content of lithophiles and rare earth elements) alkaline and potassic, plutonic rocks (such as the batholiths of Abuja, Minna, and Bauchi areas; Goodenough *et al.*, 2014). The plutons are distributed in "Western and Eastern" Nigeria and are said to be evident of Precambrian tectonic and magmatic activities that resulted in crustal building whose origin has been linked widespread orogeny and plutonism associated with the breakup of the supercontinent, continental drift and sea-floor spreading that affected the region occupied by the Pan-African countries (Dada *et al.*, 1995; Ferre *et al.*, 1998; Goodenough *et al.*, 2014).These events happened from 790-760 Ma and 650-450 Ma ago with mixed mantle and crustal magmas (Goodenough *et al.*, 2014) or simply over 600 Ma ago (Akinola *et al.*, 2021).

The Pan African plutonic rocks of the Minna area lie close to Saigbe and has been divided into two major groups: deformed, "peraluminousbiotite-muscovite granites" of Pan African age and a younger and undeformed, metaluminous hornblende granitoids", as well as marginally located pegmatites (Goodenough *et al.*, 2014). The plutons especially the granites (which are of the "Older Granites" group in Nigeria) may be syn-tectonic, showing elongate shape and following regional trend of NNE direction, while others ("late-tectonic" plutons) are rather rounded in shape (Ferre *et al.*, 1998; Goodenough *et al.*, 2014). This present study reveals that the Saigbe area is dominated by schists and granites with minor occurrence of veins of pegmatites and quartz which probably crystallized consequent of hydrothermal intrusions after the intrusion of the granites, consistent with the previous studies.

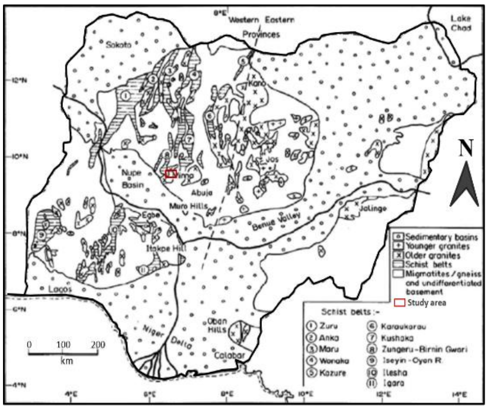


**Figure. 2**: Geological map of crystalline rocks of Nigeria showing study area, West of Minna (Modified after Woakes *et al.*, 1987; Rahaman, 1988; Lawal *et al.*, 2017a).

## MATERIALS AND METHODS

### Field Work

This study employed two methods: field and laboratory methods. The field method involved reconnaissance and detailed mapping of outcrops in the area. The reconnaissance study involved large scale traversing of the area and recording of important outcrop locations using a base map on a scale of 1: 25,000. The base map was extracted from the topographic map, Minna Sheet 164 (1: 100,000). The field mapping lasted about a month of careful observation and *in-situ* description of several outcrops. A total of twenty-one stops were made to observe and describe the rock outcrops (Figure 2B). Attention was given to mode of occurrence, field relations with adjacent outcrops, structural elements (joints and faults) and macroscopic characteristics of the rocks. Hand specimens were described based on the following macroscopic features: texture, colour, mineralogy and carefully labelled and points plotted on the base map at the different locations. Lithological boundaries were carefully mapped by observing changes in characteristics of outcrop units, nature of soil, vegetation and topography. A Silva compass clinometer was used to measure strike, dip and direction of outcrops following asimple random sampling method. Samples of the studied outcrops were collected using geological hammer. Sampling points were recorded with the aid of a Garmin model Global Positioning System (GPS), and the recorded geographic coordinates transferred to the base map (Figure 2B). Photographs of interesting outcrop features were taken. Representative outcrop samples were then prepared and labelled for laboratory studies (petrographic analysis). Details on mapping of structures, thin section preparation and petrographic study are discussed below.

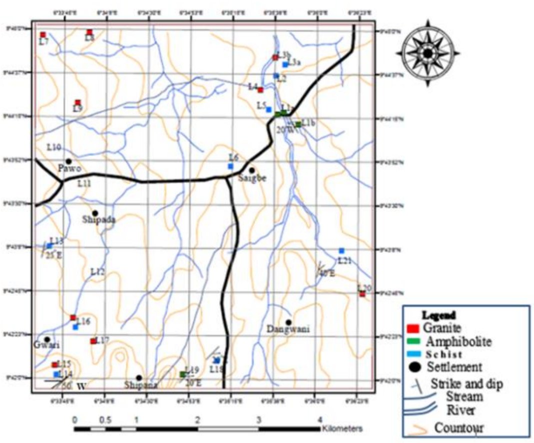


**Figure 2B**: Fact map of the study area showing sample location and measured strike and dip

### Mapping of Structures and Rose Plots

Fractures (joints and faults), foliation, folds and veins were the main structural elements present in the study area. Joints were mapped by observing areas in outcrops where loss in cohesion occurs without any relative movement of the rock along fracture plane. The orientation of these joints relative to either the strikes or dips of the rocks was taken into cognisance. The amount of displacement and the thickness of veins were measured with a metre rule and recorded. The Rose plot/diagram is a-two-dimensional descriptive tool that can be used to analyse the mapped geological structures such as attitude (geometry and orientation) associated with rocks. All measurements of trend or orientation of observed structures such as joints were made using geological compass. The measured orientations or strikes were first grouped into classes, say interval of 5˚ or 10˚, encompassing a range East-West trend through North. The measurements were then used as input to a geological software, Rockwork 15 to generate the Rose plots for the rocks in the study area.

### Thin Section Preparation

Eight representative outcrop samples (i.e., granite, schist, amphibolite and pegmatite) from the study area were selected for thin section and onward for petrographic analysis. The thin sections were done at the Nigerian Geosciences and Laboratory Research Institute (NGRI) of the Nigerian Geological Survey Agency (NGSA), Kaduna Nigeria. Thin section preparation followed the procedure described in Rowland, (1953). First, a few cm-thick rectangular slice of each rock sample was made with the aid of a diamond saw. Then the slice of rock sample is glued onto a glass slide using epoxy solution. Thereafter, the glass slide-mounted rectangular sample is further sliced and thinned to mm-thick level, and then ground gently on a diamond lap until a translucent layer is achieved on the slide (thin section slide), ready for petrographic study under a petrological microscope.

## DATA ANALYSIS

### Rose Plots

The 2-dimensional Rose plot/diagram used for the analysis of the mapped geological structures and measured orientations/strikes were first grouped into classes of 5˚ - 10˚, covering a range East-West trend through North. The frequency (or the number of readings) of structures within each class interval was tallied and recorded. The data was used to construct the Rose plot, which normally can be manually plotted by drawing a family of concentric circles, extending outward from a common point or radius common to the circles; in this case, the measured rock orientations along with frequency data were input into the Rockwork 15 software, to generate the Rose plots digitally for the rocks in the study area. The output includes attidudes of structures, orientations of joints and lineation, which are then used to describe structural elements in the geology of the area.

### Petrographic Study

The thin section slides were examined under a petrological microscope (model NP-107B) both in plane polarized light (PPL) and crossed polarized light (XPL) with the aid of transmitted light. The purpose is to identify mineral components of the rock samples and any other structural features. Description and identification of minerals under the microscope were done using characteristics such as grain shape, colour and fracture, crystal form, cleavages, twinning and presence of inclusions that may be associated with the samples. We followed the standard procedure in petrographic analysis outlined as follows:

i. Observation of form and crystallographic characteristics of minerals and grains such as shape, cleavage or twinning and presence of inclusions
ii. Study of the optical properties which include colour and pleochroism, relative index and relief of minerals in PPL
iii. Optical properties were observed further under the XPL view to confirmed

identification of minerals. Here, isotropic or anisotropic, extinction properties and determination of birefringence of observed grains.

iv. And the use of interference under XPL to determine whether it is uniaxial or biaxial (in which case optical angle, dispersion and calculation of pleochroic formula.

These procedures were used to identify and extract information on the geology of studied outcrops. Photomicrographs of the petrological observations thus made from the thin section slides were produced to support the discussion of results

.

## RESULTS

### Lithology and Field Relationship

The study area consists of three main lithologies which occur at low to moderately high topographic levels. The identified lithologies are schist, amphibolite and granite with about 1% representing minor rock types such as pegmatites associated with the granites. In general field relationship, the amphibolites extensively intruded the schists especially in areas along the main River Saigbe, while pockets of pegmatiticdykes intruded the granites. Detailed lithological characteristics with field relationship is presented below.

### Schists

The schists dominate the northeastern and southwestern parts of the study area, occupying about 58% of the area and constituting the largest lithologic group. They are commonly low-lying with a few examples showing pronounced exposure along stream and river channels. The schists are recognized on the basis of their foliated fabircs, schistocity (Figure 3). Most of the schists have been highly weathered and broken into cobbles (especially near an area where gold is being locally mined). They extend into a quartz ridge at the extreme southwestern part of the study area. The schists dip eastward at angles ranging from 20° - 47° and also exhibit distinct schistosity (Figure 3). The schistsform extensive bodies characterized by medium to coarse grained texture, with preponderance of quartz rubbles and disaggregated mica "books", showing shiny flakes (i.e., micaceous). The schists exhibit some foliations are probably low-grade type.


**Figure 3**: Example of the schist group showing high degree of schistocity(series of parallel layering of separation of minerals) that runs from top to bottom of photo, along an ephemeral stream channel (Figure 2B; location L3b) Photoed in Saigbe area.

### Amphibolites

Amphibolites belong to the metamorphic rock-types in the area. They occupy about 3% of the study area. They commonly occur as intrusions within the schists with an extensive exposure along the main River Saigbe in the study area (Figure 4). The are characterised by medium to coarse grained texture, and consist of dark minerals that exhibit slightly greenish surface appearance, suggesting the presence of amphiboles, and plagioclase feldspar. They also exhibit orientation similar to those observed with the granites i.e., westward dipping inclinations. They have a less-pronounced foliation unlike the schists. They possess joints that run in the direction of orientation of the outcrop.

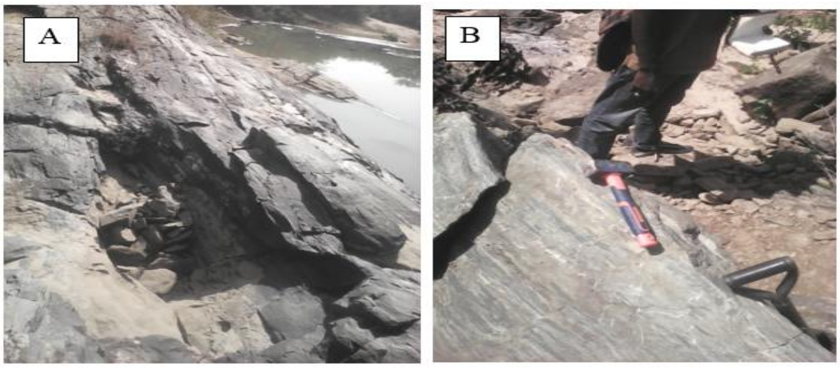


**Figure 4**. Photographs of (A) Amphibolite exposed along a river channel. (B) Amphibolite displaying a less-pronounced foliation (parallel arrangement of light and dark minerals). Photoed at location L1 and L13.Hammer scale = 25 cm

**Granites**
The granites cover about 38% of the area, commonly occupying the northwestern and southwestern parts. They show some effects of weathering such as presence of alluvium at the edges. The granites are commonly medium to coarse grained in texture (Figure 5). They are leucocratic to mesocratic in colour. They comprised minerals such as feldspar, Quartz, muscovite and mafic minerals which can be seen in the hand specimen. The grains of minerals are up to a few mm to one centimeter in size. Thegranitic outcrops commonly show NW-SE orientations. The granites exhibit structures such as faults and joints. The granitic rocks, based on field observations, intruded into the schists, suggesting that they might be younger in age.In general, the granites in Saigbe belong to the coarse grained class.

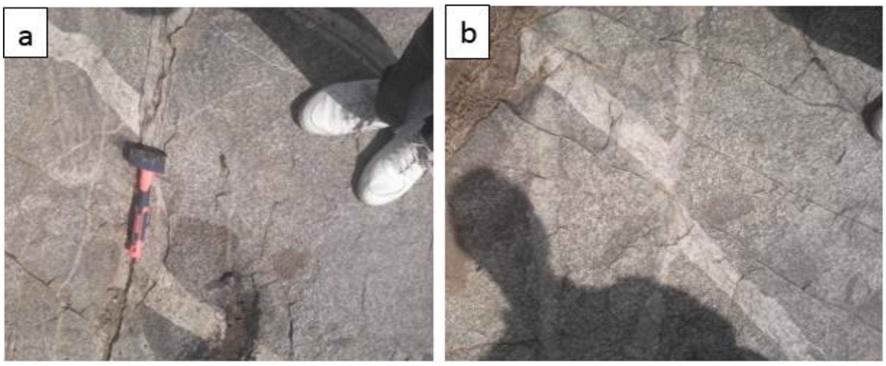


**Figure 5**: Photographs of (a) Granitic outcrop with a considerable width of displacement (the length of the hammer) along a fault line (b) a granitic outcrop with a fault of relatively lesser displacement and showing a set of joints. Both photos taken at location L7 (Figure 2B). Hammer scale = 25 cm

**Pegmatite Dykes**
Pegmatites are very coarse-grained granitic rocks composed mainly of quartz, feldspar and/or mica, formed as a result of igneous differentiation from various kinds of plutonic sources otherwise referred to as granitic provenance and which may be enriched in crystals of the aforementioned composing minerals or rare metals (e.g., Cerny, 1990; Cerny and Ercit, 2005; Dill, 2015). The pegmatites in the study area occur as extensive dykes mostly within the granites as crosscutting minor rocks. The pegmatites are generally composed of coarse grains of feldspar, quartz and mica minerals (Figure 6).Both the barren type (containing only the major minerals listed above) and to a lesser extent, the “rare metal” type of pegmatites were encountered.

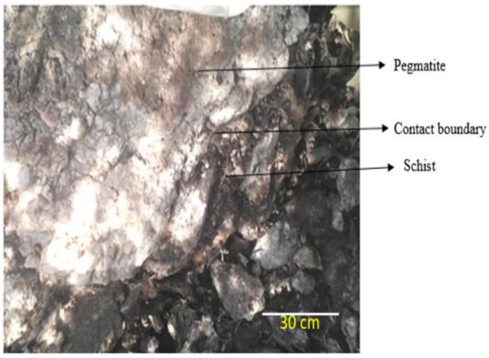


**Figure 6**: Photograph of a weathered pegmatite intrusion at location L16.

**Structural Elements**
**Joints**
Joints are common structures observed on almost all the outcrops and rock types in the area, occurring as a system of joints or set of joints (Figure 5b). In the granite outcrops, the joints trend mainly in NW-SE direction, whereas in the schists a NE-SW trending direction are recorded with occasional NW-SE trend. The distributions and orientations of the joints in the two dominant rock types in the area were used as input into the Rockwork 15 to generate a rose plots for the study area (Figure 7). Characteristics of joints within the bedrock of an area is of great value in hydrogeology, exploration and mining of economic minerals and in structural engineering works such as construction of bridges and dams

**Faults**
Faults are regarded as displacement or discontinuity in a body of rock which arises from movement of fragmented blocks of crustal rocks on opposite sides (Zhang *et al.*, 2021). Such discontinuities may either be a set-off (open displacement) or a closed displacement. Here in this study, faults observed are closed displacement and are mostly dextral (i.e., right-hand fault) (Figure 5). The faults are interpreted as belonging to the broad N-S to NNE-SSW shear zones that characterise the regional, Zungeru shear zone that runs several kilometres wide (Goodenough *et al.*, 2014).

.

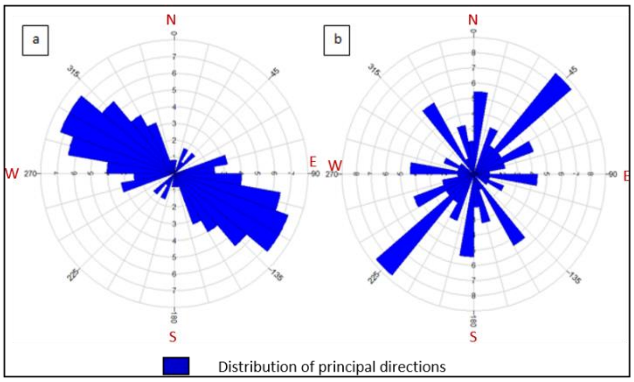


**Figure 7**: Principal joint directions in granite outcrops (a) and schist outcrops (b) from Saigbe area.

## Foliation

This refers to the parallel alignment of minerals in a prefered orientation which is a function of fabric or compositional layering, schistosity or gneissosity where they occur. In this case, foliation structures encountered on are defined by schistosity (Figure 3). Previous studies (e.g., Goodenough *et al.*, 2014) reported extensive, mylonitic foliation and "near-horizontal" lineation in areas around Minna environs.

## Folds

Folds occur as a result of bending of an originally flat or planar rock body due to the action of either tectonic or compressional forces (macrofolds) or metamorphic effect of thermal alteration (microfolds). The folds observed in the study area are mainly macrofolds and are common in the amphibolite rock type (Figure 8a). The folds are believed to evidence of strong deformations that include steeply dipping and mylonitic foliation within the regional shear zone (Fitches *et al.*, 1985). The granites and the amphibolites along with quartzofeldspathic rocks are reported to have suffered intense deformation, some of which are also traceable to another South-South-West dipping, major shear zone from Kaduna area through an area called Sarkin Pawa (e.g., Goodenough *et al.*, 2014).

.

## Veins

Veins are pre-existing fractures, cracks and displacement in a body of rock which later become filled with materials or minerals. Veins may be syngenetic (formed contemporaneously with the host rock) or epigenetic (formed after the formation of the host rock). Both syngenetic and epigenetic veins (e.g., Figures 8b and c) occur in the outcrops within Saigbe area. The veins commonly occur as quartz veins, generally crosscutting the parent rocks and are described further below

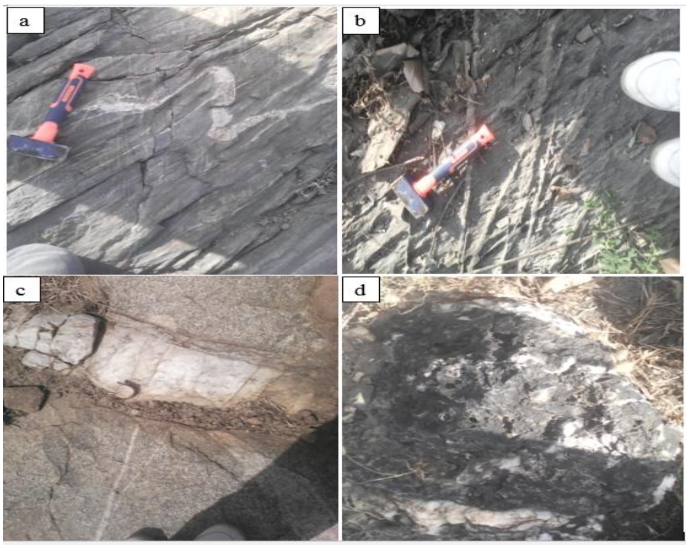


**Figure 8**: Photograph of (a) Macrofold on amphibolite (b) Cross-cutting quartzofeldspathic veins on amphibolite (c) quartz vein within the granite outcrop (d) quartz with tourmaline. Hammer scale = 25 cm

**Quartz Veins**

The quartz veins occured mainly within the granites. At location L 12, the quartz veins occurred more extensively and scattered into boulders (Fig.8c). The quartz veins are of medium-grained texture and containdispersed dark, crystalline grains which are interpreted to be mineral tourmaline (Figure 8d).

**Geological Map of Saigbe**

Ageological map of the study area is constructed based on the distribution of the identified lithologies, their field relationship and recorded geological characteristics (Figure 9). The schists constitute the most dominant rock type and occupy most of the southern half and northeastern part of the study area. The amphibolites represent minor intrusions within the schists. The granites occupy most of the northern half of the areawith a general NW-SE trend, while the pegmatites occur as intrusions (dykes) within the granites.

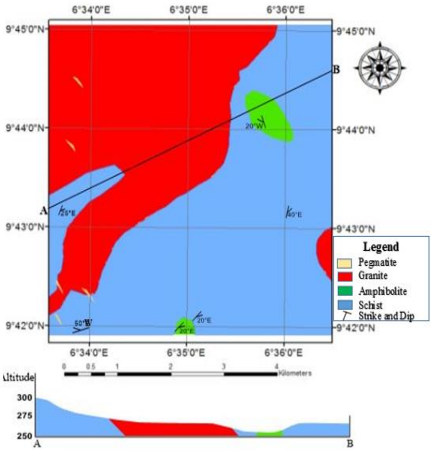


**Figure 9**: A geological map and cross section map (profile A-B) of the Saigbe area

**Petrographic Analysis**

Results of eight thin section study, representing the schists, amphibolite, granite and pegmatite lithologies revealed microscopic characteristics of the mineral components of the rocks in Saigbe area. The microscopic characteristics of the rocks aided in the discussion of the geologic history of the area and are discussed below.

**Schists**

The schists are white to light grey coloured in hand specimen, medium-to-coarse grained rocks with well-defined schistosity, largely pelitic and comprising large crystals of quartz, and large inter-granular muscovite plates with biotite, plagioclase, opaque minerals and very little feldsparthic minerals. Under plane polarized light (PPL) microscope, the quartz occurs as a colourless, anhedral-shaped, of low-moderate relief, unfractured, unaltered with no cleavage nor inclusions. Under the cross polarized light, XPL, the quartz shows grey and white interference colours, birefringence of 1st order, no twinning, and exhibiting undulose extinction. The muscovite occurs as light pink coloured, slightly pleochroic with perfect cleavage, euhedral shape with a sense of direction, neither fractured nor altered. Under the XPL, the interference colour is from pink to light green to brown, birefringence of 3rd order, with no twinning and possess oblique extinction. Biotite occurs as platy grains, sub-hedral in shape, brown in colour, non-pleochroic with some showing perfect directional cleavage and absence of fractures. Under the XPL, the biotite interference colour is light to dark green while bireferingence is of 2nd order. It exhibits straight extinction with no twinning. Plagioclase appears colourless with low relief, sub-hedral in shape, one directional cleavage seen in the direction of twinning, not fractured nor altered. While under the XPL, it shows interference colour as alternating grey and white lines, birefringence is of 1st order, polysynthetic twinning and extinction angle of 40°. Opaque minerals appear as dark to reddish dark mineral grains under both the PPL and XPL and are probably iron oxide (Figure 10).

**Amphibolites**

These rocks are medium to coarse grained, comprising quartz, hornblende and dark minerals. Observation under PPL microscope showed quartz presence as a colourless, none pleochroic and anhedral in shape. It is neither fractured nor altered. Under the XPL, the interference colour is grey to white on rotation of the stage. Birefringence is 1st order, with no twinning and exhibiting undulose extinction. Hornblende appears greenish, high relief, euhedral in shape, unidirectional cleavage with a preferred orientation. Under the XPL, the interference colour is green to brown with a birefringence is of 2nd order, without twinning and showing straight extinction. Opaque minerals, which we believe to be probably iron oxides, appear dark coloured under both PPL and XPL (Figure 11).

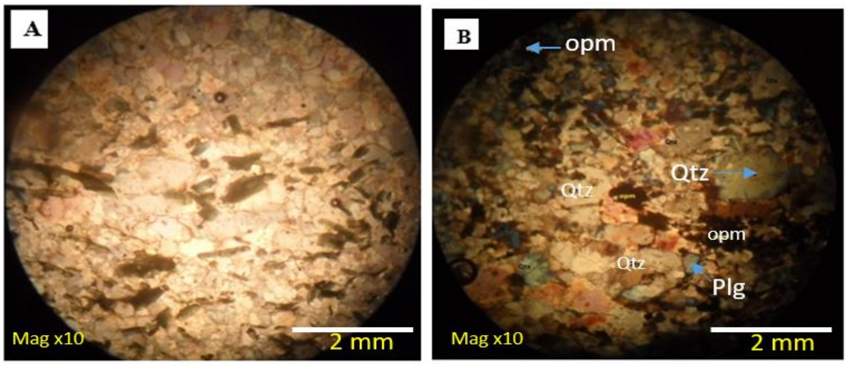


**Figure 10**: Photomicrograph of schist under PPL (A) and XPL (B) showing quartz, muscovite, biotite, plagioclase and opaque minerals (black), Qtz = quartz

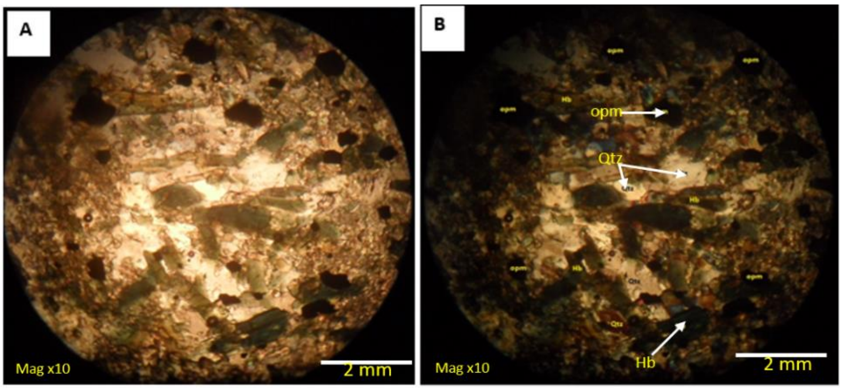


**Figure 11:** Photomicrograph of amphibolite under PPL (A) and XPL (B) showing quartz in light colour, hornblende and opaque minerals, Qtz = quartz, Hb = hornblende, opm = opaque mineral

**Granites**

The granites, which are medium to coarse grained with some weathered features, are composed of quartz, microcline, plagioclase, biotite, muscovite and trace of opaque mineral in a location L3 (Figure 2B). Under the PPL microscope, the quartz is colourless, anhedral to sub-hedral in shape, non-pleochroic, without cleavage, and showing neither fracture, alteration norany inclusions. Under XPL, the quartz has interference colour that appears as grey to white, birefringence is of 1st order, no twinning; and exhibits undulose extinction. Goodenough *et al.* (2014) reported that most of the quartz are product of recrystallization. Microcline occurs colourless to cloudy in appearance possibly due to weathering effect on some of the grains, show no cleavages, are sub-hedral to anhedral in shape, low relief, and without fractures, but some grains have suffered alterations. Under the XPL microscope, the microcline interference colour appears as grey to white, birefringence is of 1st order, cross hatched twinning; and exhibits oblique extinction. Plagioclase feldspar occurs colourless with some grains cloudy in appearance due to alteration. One directional cleavage observed in some grains, sub-hedral to anhedral in shape, low relief, no fractures. Under the XPL, interference colour appears as alternation of grey and white lines. Birefringence is of 1st order, simple to polysynthetic twinning and extinction angles of 40°- 42°. Heavy sericitisation were reportedly associated with the microcline in the granitoids around the study area (Goodenough *et al.*, 2014). Muscovite shows slightly pink colouration, pleochroic to light green, moderate relief, perfect cleavage, euhedral in shape, not having a preferred orientation. Under the XPL: interference colour of pink to light green, birefringence of 3rd order, no twinning, and exhibit oblique extinction (Fig. 12).

**Pegmatites**

The dykes of pegmatites, which intrude mainly the granites, are highly weathered, composed of coarse grains of quartz, plagioclase feldspar, orthoclase feldspar and muscovite. Under the microscope, quartz appears colourless, anhedral in shape, low relief, no cleavage, some grains are fractured but not altered. Under the XPL, the interference colour is grey to white, birefringence is 1st order, no twinning, and possesses undulose extinction. Plagioclase feldspar occurs as colourless to cloudy due to alteration, unidirectional cleavage, anhedral in shape, with grain sizes larger than field of view, no inclusions. Under the XPL, plagioclase interference colour is grey to white lines, birefringence is 1st order, polysynthetic twinning and extinction angle of 42°. Orthoclase feldspar also occurs as colourless to cloudy in appearance, anhedral shaped, with no cleavage and with size also more than the field of view. Under the XPL, grey to white interference colour, birefringence is 1st order, not very clear twinning but shows some cross-hatch patches in some grains. It exhibits oblique extinction. Muscovite appears as light pink, slightly pleochroic to light green to light brown, has perfect cleavage, and without a preferred orientation. Under the XPL, has interference colour of pink to light green to brown, birefringence of 3rd order, no twinning, and shows oblique extinction (Figure 13).

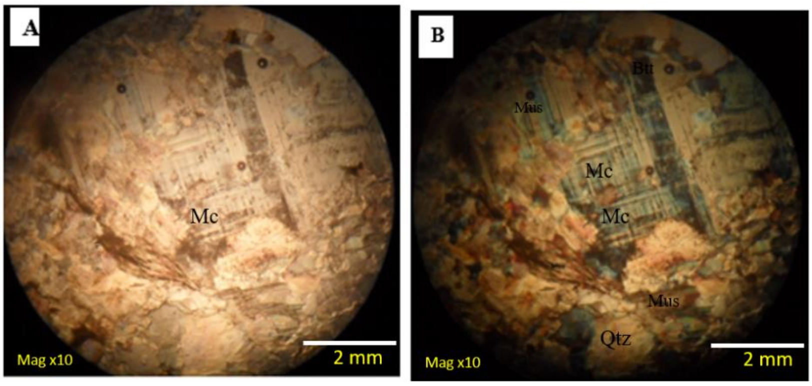


**Figure. 12**: Photomicrograph of granite under PPL (A) and XPL (B) showing microcline exhibiting cross-hatched twinning, quartz and plagioclase with anhedral to sub-hedral shape. Mc = microcline, Qtz = quartz, Mus = muscovite, Btt = biotite

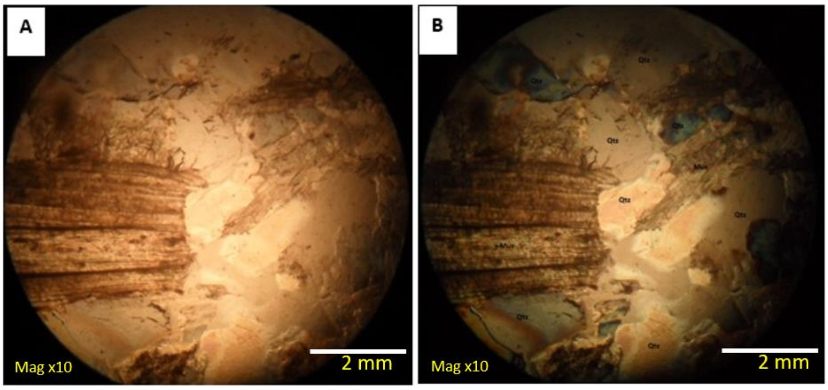


**Figure 13**: Photomicrograph of pegmatite under PPL (A) and XPL (B) showing quartz, orthoclase, plagioclase and muscovite. Qtz = quartz, Mus = muscovite.

## DISCUSSION

The field, structural and petrographic characteristics described above provide useful insights intothe geologic and tectonic history of the Saigbe area. Evidence points to the schists as likely the oldest rock-type in the area. The schists exhibit a general NE-SW trend and is intruded by granites and amphibolites (both with similar outcrop orientation). The presence of foliation in the schists with associated joints which trend in NE-SW and occasionally NW-SE directions suggest they are of as low grade (forming in the lower part of green schist and the "albite-epidote-amphibolite" metamorphic facies with temperature range (200 - 800 ˚C) (William *et al.*, 1954; Fitches *et al.*, 1985). These joints probably constitute parts of the deformation zones that form a NNE-SSW dipping shear zones reported previously in the area (Fitches *et al.*, 1985; Goodenough *et al.*, 2014). The schists likely represent a separate and earlier emplacement, followed by the amphibolites. The schists together with the amphibolites represent the meta sediment groups that predated the Pan-African event (Dada, 2008). The observed fold types in the area also support active tectonic or compressional episodes during the emplacement of the rocks. The preponderance of macrofolds in the amphibolites of Saigbe area indicate they might be related to tectonic activity.

The granites in Saigbe are generally intrusive, based on their coarse-grained nature. Their intrusion into the schists and occurrence in different orientation suggest a separate and younger intrusive episode. The studied granites most likely belong to the Older Granites and are believed to have been emplaced during movements along the shear zone (Goodenough *et al.*, 2014). The principal mineralogy of the granites in Saigbeis consistent with regional geochemical data, both suggesting mixed crustal and mantle-origin for the magmas (Garba, 2003; Goodenough *et al.*, 2014). It is tempting to interprete that the main orientation of the joints (N-S and NNE-SSW dipping) probably suggest the main path for the hydrothermal intrusion, consistent with regional shear zones, the "Zungeru shear zone" (Fitches *et al.*, 1985). Likely intrusion of the granites by hydrothermal fluid rich in pegmatitic composition and other minerals of economic value resulted in the emplacement of the pegmatite dykes. The pegmatites are products of residual melt based on their coarse grain and composition. Significant occurrence of the "rare metal pegmatites" enriched in suites of minerals, oxides and accessories (such as quartz, K-Feldspar, mica and tourmaline, beryl, tantalite and cassiterite), some of which are being artisinally mined, have been reported previously within the study area (Garba, 2003; Goodenough *et al.*, 2014). However, geochiemical data by Goodenough *et al.* (2014) suggested that the origin of the pegmatites in the area could be related to fractionated, "highly evolved" magma associated with granites or a separate event, implying a "conundrum" to be solved when more data are available. Nevertheless, associated accessories and gemstones in the cross-cutting pegmatite dykes are interesting targets for mineral exploration and mining activities.

## CONCLUSION

Field observations indicate that the Saigbe area is underlain by three major lithologies: schists, amphibolites and granite intrusions with cross-cutting pegmatitic dykes.The presence of these granitic rock-types confirms the area belongs to the Pan-African Basement Complex of central north-western Nigeria. Joints, faults, displacement, folds and foliation structures associated with the schists trend mainly in the NE-SW, while the granites trend NW-SE direction which suggest different episodes of their emplacement. The structures, by inference, are indicative of major influence of tectonic and metamorphism on mantle- and crustal-derived melt. Petrographic analyses of revealed that the schists are composed of quartz, biotite, muscovite, plagioclase and opaque mineral, whereas the granites are dominated by quartz, microcline, plagioclase feldspar, muscovite and opaque minerals (suspected oxides of iron), while the amphibolites are containquartz, hornblende, plagioclase feldspar and opaque minerals.

In terms of history, field, structural and petrographic data suggest that the schists were the oldest rock type to be emplaced, followed by the amphibolites and then granites with associated intrusions of pegmatite dykes.The pegmatites are rich in quartz, plagioclase feldspar, orthoclase feldspar and muscovite minerals with some presence of metallic minerals, making them interesting targetsoffurther investigation with respect to origin and exploration for gemstones, rare metals and other associated accessories.The established presence of economic minerals in the Basement complex of central Nigeria supports plausibility of the proposed investigation in the Saigbe area.

## ACKNOWLEDGEMENTS

Our sincere gratitude posthumously goes to late Professor M. I. Ogunbajo of the Department of Geology, Federal University of Technology, Minna, Nigeria. This work is especially dedicated to the blessed memory of the late of professor of geology.

## REFERENCES

Ajibade A. C., Anyanwu N. P. C., Okoro A. U. and Nwajide C. S. (2008). The Geology of Minna Area, *Nigerian Geological Survey Agency,* Bulletin, **43:** 20 – 51.

Akinola, O. O., Ghani, A. A. and James, E. (2021). Petrography and geochemical characterization of a granite batholith in Idanre, southwestern Nigeria. *Sains Malaysiana,* **50**(2): 315-326.

Amadi, A. N., Olasehinde, P. I., Obaje, N. O., Unuevho, C. I., Yunusa, M. B., Keke, U. and Ameh, I. M. (2017). Investigating the Quality of Groundwater from Hand-dug Wells in Lapai, Niger State, North-central Nigeria using Physico-chemical and Bacteriological Parameters. *Minna Journal of Geoscience*,**1**(1): 77-92.

Bessoles, B. and Trompette, M. (1980). Geology of Africa, the Pan-African channel "central African mobile zone (southern part) and Sudanese mobile zone. *Pascal and Francis Bibliographic Databases,* **92**: 396.

Cerny, P. (1990). Distribution, affiliation and derivation of rare-element granitic pegmatites in the Canadian Shield. *Geologische Rundschau*, **79**: 183-226.

Cerny, P. and Ercit, T. S. (2005). The classification of granitic pegmatites revisited. *The Canadian Mineralogist*, ***43***(6).

Dada, S.S., (2008). Proterozoic evolution of the Nigeria-Boborema province, in: Pankhurst, R.J., Trouw, R.A.J., BritoNeves, B.B., de Wit, M.J. (Eds.), West Gondwana: Pre-Cenozoic Correlations across the South Atlantic Region. *Geological Society of London Special Publication*, **294:**121-136.

Dada, S.S., Briqueu, L., Harms, U., Lancelot, J.R. and Matheis, G. (1995). Charnockitic and monzonitic Pan-African series from north-central Nigeria: Trace-element and Nd, Sr, Pb isotope constraints on their petrogenesis. *Chemical Geology*, **124**: 233-252.

Dare S. A. S., Barnes S. J., Beaudoin G., Méric J., Boutroy E. and Potvin-Doucet C. (2014). Trace elements in magnetite as petrogenetic indicators, *Mineralium Deposita,* **49**(7): 785–796.

Dill, H. G. (2015). Pegmatites and aplites: Their genetic and applied ore geology. *Ore Geology Reviews*, ***69***: 417-561.

Ejiga, E. G., Yusoff, I., Ismail, N. E. H., Lawal, M. and Yelwa, N. A. (2022). Application of scaling geology in magnetic basement mapping around the Middle Benue Trough in Northcentral Nigeria. *Physics of the Earth and Planetary Interiors*, ***331***: 106914.

Ferré, E. C., Caby, R., Peucat, J. J., Capdevila, R. and Monié, P. (1998). Pan-African, post-collisional, ferro-potassic granite and quartz–monzonite plutons of Eastern Nigeria. *Lithos*, ***45***(1-4): 255-279.

Fitches, W.R., Ajibade, A.C., Egbuniwe, I.G., Holt, R.W. and Wright, J.B., (1985). Late Proterozoic schist belts and plutonism in NW Nigeria. *Journal of the Geological Society of London*, **142**: 319-337.

Garba, I. (2003). Geochemical discrimination of newly discovered rare-metal bearing and barren pegmatites in the Pan-African (600±150 Ma) basement of northern Nigeria. *Applied Earth Science*, ***112***(3): 287-292.

Goodenough, K. M., Lusty, P. A. J., Roberts, N. M. W., Key, R. M. and Garba, A. (2014). Post-collisional Pan-African granitoids and rare metal pegmatites in western Nigeria: age, petrogenesis, and the 'pegmatite conundrum'. *Lithos*, ***200*****:** 22-34.

Kroner, A., Ekuweme B. N. and Pidgeon, P. T. (2001). The oldest rocks in West Africa: SHRIMP Zircon Age for Early Archean Migmatitic Orthogneiss at Kaduna, Northern Nigeria, *Journal of Geology, University of Chicago*, **19**, 399- 406.

Lawal, M., Grema, H. M., Ibrahim, H. A. and Kitha, M., Yelwa, N. A., Abdullahi, I. M. and Muhammad, A. (2017a). Determination of origin and granulometric analysis of river channel sediments of Osi, Southwestern Nigeria. *Bayero Journal of Pure and Applied Sciences*,***10***(2): 262-270.

Lawal, M., Ayomaya, S. A., Ojero, J. O., Muhammad, A., Yelwa, N. A., Bello, J. and Bello, A. (2017b). Integrated Geology and Geochemical Analysis of Eruku Basement Complex, Southwestern Nigeria. *Nigerian Journal of Basic and Applied Sciences*, ***25***(1): 63-72.

Nigeria Metrological Agency (NIMET) (2010). Abuja Report, 2010.

Obaje, N. G., Lar U. A., Nzegbuna A. I., Moumouni A., Chaanda M. S. and Goki N. G. (2006). Geology and mineral resources of Nassarawa State: an investor's guide, *Nasara Scientifique (A publication of Nassarawa State University),* **2**:34.

Omanayin, Y. A. and Ogunbajo, M. I. (2016). Geology and environmental impact of artisanal gold mining around kataeregi area, North-Central Nigeria. *Nigerian Journal of Technological Research*,**11**(2): 49-57.

Rahaman, M. A. (1988). Recent advances in the study of the basement complex of Nigeria, *Precambrian Journal of Nigeria and its Mineral Resources (ed. By Nigeria Geological Survey)*, 11 – 43.

Rowland, E. O. (1953). Rapid method for preparation of Thin Rock Sections, *Mineralogical Magazine,* **30**: 254 - 258.

William, H., Turner, F. J. and Gilbert, C. M., (1954). Petrography, an introduction to the study of rocks in thin section. University of California, Berkeley, WH Freeman and Company.

Woakes, M., Rahaman, M. A. and Ajibade, A. C. (1987). Some metallogenetic features of the Nigerian basement. *Journal of African Earth Sciences (1983)*, ***6***(5): 655-664.

Yerima M. L. and Abdulrahman A. S. (2013). Physiochemical Analysis of Chanchaga Ore, North-central, Nigeria, *Journal of Applied Sciences* **15**, 1020 – 1025.

Zhang, C., Amagu, C. A., Kodama, J., Sainoki, A., Ogawa, S., Umeda, C. and Fukuda, D. (2021). Numerical analysis of impact of fault and weak rock formation on mining-induced deformation of rock slope. In *IOP Conference Series: Earth and Environmental Science*, **861**(3): 032087.