



Geology and Mineralogy of Batola and its Environs, Southwestern Nigeria

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ABSTRACT

The Basement complex and Sedimentary Basin Makes up the Geology of southwest Nigeria. This research work is intended to comprehend the geology and mineralogy of Batola, Ago, Ladele, Koroyi and Aregbe which falls within the Ikomu sheet in Southwest Nigeria. A highly detailed topographical map and a GPS gadget were used for navigation during the Field Mapping process. Fresh samples that were representative of each outcrop were taken in all locations throughout the Field Mapping process. The slides were then examined under a microscope in an effort to confirm the provisional names for the rocks in the field. This allowed for the determination of the lithology of the rocks in the research region as well as the petrography of these outcrops in both plane and cross polarised light. The lithology in the study area was identified by the Field and Petrographic results as Granite (Porphyritic and Coarse Grained), Granite-gneiss and Pegmatite. Additionally, Pegmatitic intrusions and dykes were also seen. Further minerals found during the Petrographic analysis of the rock units included Mica, Biotite, Plagioclase Feldspar, Microcline, Quartz and a few tiny opaque minerals. The geology and mineralogy suggested that the study area is heterogeneous in nature, with lithologies varying from igneous to metamorphic rocks with structural imprints that can be characterized to the Pan-African orogeny. This study provided additional support of previous researches carried out on the Geology of Southwestern rocks.

Keywords: Geology, Mineralogy, Batola, Field mapping, Geological map.

1.0 INTRODUCTION

1.1 General Statement

The rocks underlying Batola and its environments belong to basement complex rocks that are heterogeneous in composition, structures, textures, and origin. The basement rocks are considered to be Precambrian and have undergone many cycles and phases of metamorphism, migmatization, and tectonic activity postdating the emplacement of the rock formation.

In a variety of environmental applications, such as landslip investigations, hydrogeology, and mineral exploration, structural trends originating from different deformation processes can be identified in a variety of forms, including faults, joints, bedding planes, and/or foliation. In addition to ground mapping, remotely sensed data, including satellite photography and traditional aerial photographs, can be used to identify this discontinuity, which manifests as a lineament.

The strong correlation between field-mapped structures and remotely sensed lineament systems allows lineaments to be regarded as reliable indicators of the structural framework of a given area (Adepoju et al., 2021).

1.2 Aims and Objectives

The objectives of this study are to classify the various rock types present in the research area based on their

field characteristics, occurrence, and relationships; to analyze the petrographic features of selected samples to understand their mineralogical composition and textural properties; to identify and interpret the structural features that define and affect the rock units, including joints, folds, foliations, and lineations; and ultimately, to produce a detailed geological map that reflects the spatial distribution, orientation, and interrelationships of the lithological and structural elements within the area of investigation.

1.3 Scope of Study

To achieve the aims and objectives stated above, the investigation involves both field and laboratory investigations. The field exercise entails geological mapping of the study area using topographical map on a scale of which show topography, streams, rivers, settlement, footpaths, minor and major roads of the area.

1.4 The study area's location and accessibility

The research region is situated between latitudes 8° 22' N – 8° 30' N and 03° 14' E – 03° 19' E longitudes respectively, the study area is located along Batola, Ago, Ladele, Koroyi and Aregbe in oyo state. The study area is traversed by a network of roads (motorable roads and footpaths); there are other accessible routes within this area, minor roads and some pathways that are sparingly motorable. The study

region has a nucleated settlement layout, and farming is the primary occupation of the local population.

1.4.1 Climate and Vegetation

Batola is located in south-west Nigeria, which is characterized by rather humid climate. During the field study, the weather was categorically wet and dry and enjoys typical western Africa monsoonal wind climate which is marked by distinct seasonal shift in wind pattern and a distinct double maxima rainfall during wet season; wet season begins in April and ends in November, with a short dry period in August known as 'August break'. Dry season usually occurs within November and February; however, amount of rainfall varies yearly and temperature conditions vary constantly within the months. Tropical rain forests are present in study area, as well as grasses, shrubs and trees (see Figure 1.1). Human activities present in the area include farming, mining sites and some of the outcrops were used as prayer grounds or mountains.

1.4.2 Drainage and Topography

The topography can generally be described as lowland and laterally extensive with few high elevations. Not many rivers drain the study area, they are probably seasonal. The drainage pattern observed is dendritic. The topography map is shown in Figure 1.2



Figure 1.1: Vegetation of the Area

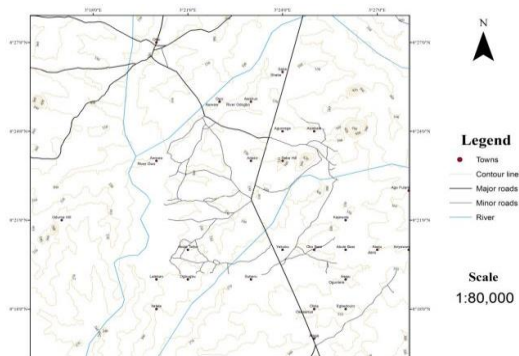


Figure 1.2: Drainage and Topography of the Area

1.5 Review of the Precambrian Basement Complex

The Nigerian Basement Complex, a critical geological feature of Nigeria, is situated within the Pan-African mobile belt, south of the Tuareg Shield, northwest of the Congo-Gabon Craton, and east of the West African Craton. It is intruded by Mesozoic Younger Granites of the Jos Plateau and partially overlain by Cretaceous sediments. Recent geophysical studies confirm a significant collision event between the Pharusian belt and the West African Craton around 620–590 Ma, with ophiolitic remnants identified in northwestern Nigeria (Akinyemi et al., 2023).

The Basement Complex is polycyclic, recording multiple orogenic cycles, with the Pan-African orogeny (650–450 Ma) being the most prominent, characterized by ensialic processes rather than extensive plate tectonics in central Nigeria (Bello et al., 2025). Using the updated International Geological Time Scale, these cycles align with Neoproterozoic to Early Paleozoic events (1,000–541 Ma) (Gradstein et al., 2020). The Pan-African orogeny involved eastward-dipping subduction, collision, and crustal extension, forming schist belts in back-arc basin settings, followed by ocean closure around 600 Ma (Ominigbo, 2024).

The complex is divided into eastern and western provinces. The eastern province features migmatite-gneiss complexes intruded by Pan-African granites and Younger Granites, while the western province (west of 8°E) contains N-S trending schist belts within migmatite-gneiss matrices (Ominigbo, 2024). Recent geochemical analyses highlight the economic potential of these granites, hosting tantalum and lithium mineralization (Ogunleye & Akingboye, 2022).

Four Petro-lithological units define the Basement Complex:

- A. Migmatite Gneiss
- B. Schist Belts
- C. Older Granites
- D. Undeformed Acid and Basic Dyke

1.5.1 Migmatite Gneiss

Migmatite gneiss, the oldest unit, consists of medium to coarse-grained gneiss and granite-gneiss, forming low-lying outcrops or folded hills. It exhibits leucosome (granitic veins) and melanosome (biotite-rich material) formed during prograde metamorphism. Recent studies identify eastern-dipping joints and pegmatites rich in lithium and tantalum, with weathered surfaces and solution holes prevalent in western areas (Ogunleye & Akingboye, 2022).

1.5.2 Schist Belts

Schist belts, trending NE-SW in western Nigeria, comprise low- to medium-grade meta-sediments, including mica schists, quartzites, and amphibolites. Northwestern belts (e.g., Anka, Zungeru) feature

greywacke-derived metapelites, while southwestern belts include marbles and calc-silicates. U-Pb zircon data (~2,100 Ma) confirm Palaeoproterozoic origins, with Pan-African reworking evidenced by isotopic fractionation (Akinyemi et al., 2023; Bello et al., 2025). These belts likely formed in a back-arc basin, supported by geophysical evidence (Ominigbo, 2024).

1.5.3 Older Granites

Older Granites, distinct from Jurassic Younger Granites, include granodiorites and porphyritic granites with mild foliation, tied to Pan-African subduction-collision tectonics. Recent studies reveal rare earth element (REE) and tantalum mineralization, with calc-alkaline geochemistry indicating orogenic origins (Ogunleye & Akingboye, 2022).

1.5.4 Undeformed Acid and Basic Dykes

Late to post-tectonic Pan-African dykes, including felsic pegmatites and basic dolerites, crosscut the complex. Geophysical mapping identifies these as markers of post-orogenic extension (Ominigbo, 2024).

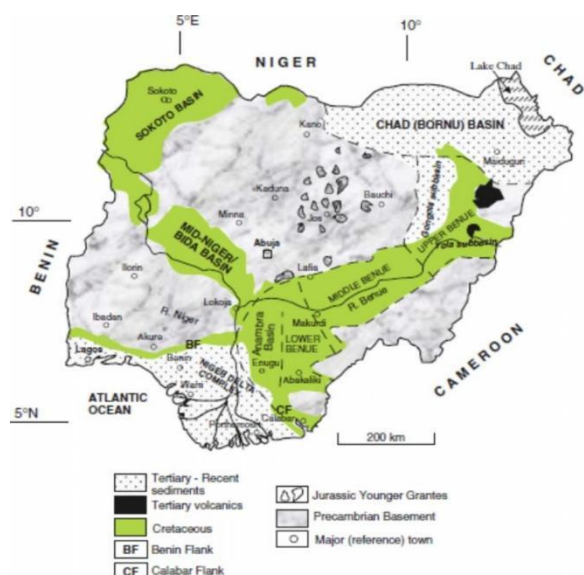


Figure 2.1: Geologic Map of Nigeria (Adapted from Obaje, 2009)

1.6 Geology of Southwestern Nigeria

Southwestern Nigeria's Basement Complex (7°N–10°N, 3°E–6°E) features amphibolites, migmatite-gneisses, granites, pegmatites, and schists (Rahaman, 1988). Recent studies emphasize gold and REE deposits in schist belts and granites (Ogunleye & Akingboye, 2022).

1.6.1 Amphibolite and Hornblende Gneiss

Amphibolites and hornblende gneiss occur as low-lying outcrops in Ilesha and Ife, with faulted and foliated structures (Akinyemi et al., 2023). Recent structural analyses link them to Pan-African shear zones (Ominigbo, 2024).

1.6.2 Migmatite-Gneiss Complex

Covering over 75% of Southwestern Nigeria, the Migmatite-Gneiss Complex, comprising partially melted gneisses and granitic rocks, evolved through Early Proterozoic (~2.1 Ga) crust formation, granite emplacement, and Pan-African orogenic events (600–550 Ma) (Okunlola & Oyedokun, 2019). Ramesh et al. (2025) documented multiple tectonic episodes, with dolerite dykes as the youngest intrusions, reflecting late-stage magmatism. Recent geophysical surveys, using magnetic and resistivity methods, map the complex's subsurface extent, aiding gold exploration in Ilesha (Adepoju et al., 2020).

1.6.3 Metamorphism

Southwestern Nigeria's rocks exhibit greenschist to amphibolite facies, with biotite and sillimanite as prominent index minerals (Adepoju et al., 2020). Recent studies in Ilesha confirm upper amphibolite facies, characterized by gneissic foliation and mylonite, a rock deformed under high shear stress (Ozeigbe et al., 2022). Olatunji et al. (2021) highlight a transition from greenschist to amphibolite facies during the Pan-African orogeny, driven by tectonic compression around 600–550 Ma. Okunlola and Oyedokun (2019) identify three metamorphic episodes (M1–M3) in the Nigerian Basement Complex, with M1 reaching lower amphibolite conditions, reflecting progressive metamorphism in the region.

1.6.4 Geochronology

The Nigerian Basement Complex is polycyclic, recording multiple orogenic cycles, including the Liberian (2,750–2,500 Ma), Eburnean (2,500–2,000 Ma), Kibaran (2,000–1,100 Ma), and Pan-African (750–450 Ma) orogenies, as aligned with the International Geological Time Scale (Gradstein et al., 2020). The Eburnean and Pan-African events are particularly significant, with the latter dominating the region's tectonic evolution. Recent U-Pb zircon dating refines the Pan-African orogeny to 620–550 Ma, confirming a major collision between the Pharusian belt and West African Craton (Akinyemi et al., 2023). Additional U-Pb zircon data from schist belts (e.g., Kabba-Okene) indicate Palaeoproterozoic ages (~2,100 Ma), supporting Eburnean activity, with isotopic evidence of Pan-African reworking (Bello et al., 2025).

2.0 MATERIALS AND METHOD

2.1 Materials:

Below are some of the equipment used to carry out the field mapping operations:

- i. **Topographical Base Map:** This contains details of the area at an approximate scale. It is used for location of oneself on the field at any given point in time and contains sufficient contours of the different elevation depicting ridges, hills, valleys, cliffs (high

and low), roads, footpaths, rivers and river channels, bridges and settlements. Observations were plotted on an overlay placed on the base map with map orientation to the north. All information mapped and plotted was transferred to a duplicate or replica map daily. It is this replica map that is used to produce the geological map.

- ii. **Global Positioning System:** This is used to know the exact geographical co-ordinates of the outcrops and is also used for direction.
- iii. **Field Notebook:** Notebook is used to record observation made on the field.
- iv. **Geological Hammer:** geological hammer is used for hammering and chipping of samples from outcrop encountered.
- v. **Rock Sacks/Bags and Paper Tape:** Were used for carrying samples collected in the field and systematically labeling them.
- vi. **Compass clinometer:** it is an instrument that contains the four cardinal points (N, S, E, W) used in obtaining position in the field. It was also used for measuring the strike and dip of the outcrops.

Other important equipment used in the mapping operation include hand lens, tracing paper, camera, goggles, mathematical set, and protective cloth

2.2 Method

2.2.1 Sampling

This project used a range of methods, including field mapping and laboratory analysis, to gather geological and structural data. The primary technique was grid-controlled geological field mapping. This method involved dividing the base map into segments and collecting rock samples from each. GPS technology ensured accurate positioning of geological outcrops. The mapping was guided by a topographical map (scale 1:500,000), showing essential features such as topography, streams, and roads. Sampling was done after necessary field measurement have been obtained such as Strike and Dip, Joint orientation, Measurement of the length and width of the outcrop and Also the distance from Notable Landmark was also noted.

The samples were properly labelled and carefully transported to the labs. The reconnaissance survey, a preliminary step, assessed the region's general geological features to identify feasible routes and sites. This survey focused on potential outcrop locations, determining the most efficient mapping direction, which was east-west (E-W) due to expected north-south (N-S) rock trends. It also considered river and stream channels for natural rock exposure. Detailed field mapping involved gathering background information from geological maps and literature. Fieldwork included direct observation of rocks, their structures, and relationships using the topographical map. Structural features and mineral content were recorded using a compass clinometer, and samples

were collected for further analysis. Field notes, sketches, and photographs documented observations. Samples were labeled and prepared for petrographic analysis in the laboratory. Measurements were plotted on the topographic map to produce a geological map with outcrop locations. Thin sections of rock samples were examined under a microscope to confirm their mineralogical composition.



Fig.2.2: Fresh Samples collection at Batola Hill



Fig.2.3: Sample from Location 2 (Onipako)

2.2.2 Thin Sectioning

Obtained rock samples were bulky and thus can only be described using one's eyes and a hand lens. However, for a more detailed study and also to observe the mineral crystal arrangement of the samples, thin sections were prepared and were carried out within the premises of the Department of Geology, University of Ibadan, Ibadan Nigeria .

Thin sections were prepared following these steps:

- i. **Cutting a Slab:** A suitable size slab for mounting on a slide was cut from the rock

- samples.
- ii. **Initial lapping slab:** The slab was labelled on one side and the other side was lapped flat and smooth on a glass plate with grit carborundum.
 - iii. **Glass slide is added:** After drying on a hot plate, a glass slide was then glued to the lapped face of the slab with epoxy.
 - iv. **Slab Sectioning:** Using a thin section saw, the slab was cut-off close to the slide. The thickness was further reduced on a thin section grinder.
 - v. **Final Lapping:** A finished thickness of 30 microns is achieved by lapping the section by hand on a glass plate with 600 grit carborundum.
 - vi. **Polishing:** The section was placed in a holder and spun on a polishing machine using nylon cloth and diamond paste until a suitable polish was achieved for the microscope.
 - vii. Final inspection.

After all these have been done and the slide has been determined to be properly cut out and lapped, one then proceeds to study the slides under the petrological microscope and commence a procedure known as point

counting which will be used for modal analysis of the rock sample.

The Minerals seen in the slide was also labeled and several features also noted as seen on the Petrological Microscope.

The slide was viewed under both Plane Polarized Light (PPL) and Cross Polarized light to get a detailed feature of the rock.

3.0 RESULTS AND DISCUSSION

Petrographic analysis on thin sections from the rock samples obtained from the field are carefully observed under the microscope to identify the mineralogy of the rocks in the mapped area and furthermore, name of these rocks due to the modal analysis of these results. The predominant rock types found in the research region include pegmatite, gneiss and granite. Granite (of various textures) predominates in the study region, with a few minor rock types, such as pegmatite, appearing in small veins. Farming is the primary human activity; several outcrops have also been utilised as church mountains or prayer grounds. There aren't many river and stream networks in the research area.

Table 4.1 Modal Analysis of Granite

Location No	Quartz (%)	Microcline (%)	Plagioclase (%)	Biotite (%)	Hornblende (%)	Muscovite (%)	Opaque (%)
3	32	25	34	6	--	4	--
4	29	20	33	10	3	5	--
6	31	19	32	8	6	4	--
7	27	24	28	8	3	10	--
8	31	21	37	6	2	3	--
9	29	23	33	9	3	3	--
11	26	23	30	10	6	5	--
17	28	23	31	9	4	5	--
Average	29.1	22.3	32.3	8.3	3.4	4.9	--

Table 4.2 Modal Analysis of Pegmatite

Location No	Quartz (%)	Microcline (%)	Plagioclase (%)	Biotite (%)	Hornblende (%)	Muscovite (%)	Opaque (%)
2	30	20	40	5	--	5	--
5	33	17	40	6	--	4	--
10	32	16	40	7	--	5	--
12	31	18	37	5	4	5	--
15	31	16	36	8	4	5	--
Average	31.4	17.4	38.6	6.2	4	4.8	--

Table 4.3 Modal Analysis of Gneiss

Location No	Quartz (%)	Microcline (%)	Plagioclase (%)	Biotite (%)	Hornblende (%)	Muscovite (%)	Opaque (%)
13	27	22	32	11	4	4	--
14	30	23	33	7	3	4	--
Average	28.5	22.5	32.5	8.5	3.5	4	--

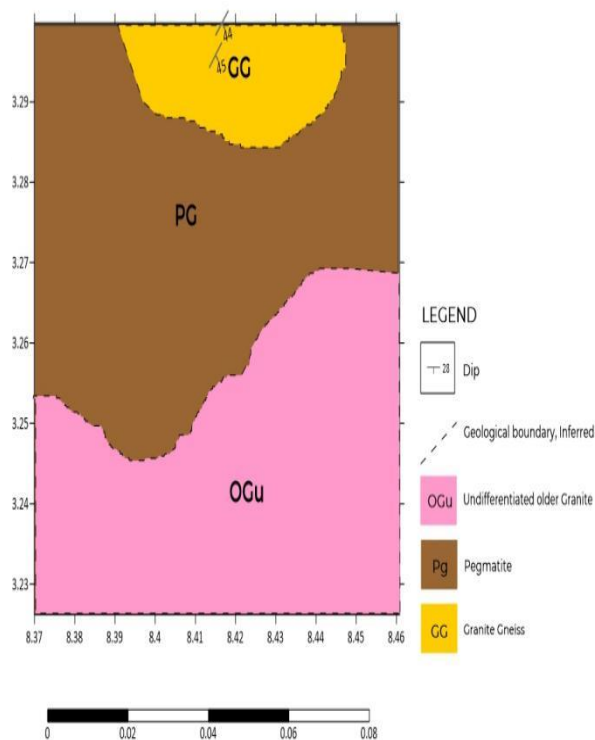


Figure 4.1 showing Geological Map of the study area

5.0 DISCUSSION

5.1 Geological Structures

Geological structures in rocks, resulting from stress and strain, manifest as deformational features. In the study area, tensional and compressional forces have caused metamorphism and tectonic activity, creating joints, solution holes, veins, and intrusions. These structures facilitate rock weathering, crucial for groundwater movement and accumulation. The area's geological history, shaped by various orogenic events, provides insights into its tectonic history and stress patterns. Structures are classified into primary (formed during outcrop creation, like lineation and xenoliths) and secondary (formed after the host rock, like joints, exfoliation, and solution holes).

- A. **Joints** are brittle fractures with minimal displacement, typically vertical, prominent in weathered rocks, and essential for quarrying. They facilitate the formation of caves and underground rivers, especially in limestone.
- B. **Veins** are mineral-filled joints or fissures, mainly quartzitic or quartzofeldspathic in the study area, indicating their emplacement age through cross-cutting relationships. They range from centimeters to meters in size.
- C. **Solution Holes** result from chemical weathering, vary in shape and size, and can be isolated or interconnected, common in outcrops.
- D. **Strike and Dip** describe planar feature orientations. The strike is the direction of a line

formed by the intersection of a planar feature with a horizontal plane, while the dip is the angle of inclination relative to the horizontal plane, indicating fault, bed, joint, and fold positions.

- E. **Intrusions** occur when magma cools before surface eruption, forming pegmatitic and basaltic structures like **veins**, dikes, plutons, and batholiths.
- F. **Folds** result from tectonic forces bending rock layers, forming undulations at various scales, influencing geological processes and fluid accumulation, like oil and gas. In the study area, simple and recumbent folds were observed.
- G. **Faults** form from tectonic forces moving rocks along fractures, creating mountains, valleys, and pathways for mineralization. Types of faults include:
 - I. **Normal Faults:** Downward movement on one side relative to the other.
 - II. **Reverse Faults:** Upward movement on one side relative to the other.
 - III. **Strike-Slip Faults:** Horizontal movement along the fault plane.

6.0 CONCLUSION

The Basement Complex in South-western, Nigeria is home to the igneous and metamorphic rocks found in Batola and its surroundings. The study involved two main approaches: Geological field mapping, which involved gathering fresh representative rock samples at various locations and Petrographic Examinations of the thin sections of the samples.

Based on petrology, Field Mapping of the study area found that the dominant rock types include Granite (Porphyritic and Coarse Grained), Granite-gneiss and Pegmatite. The rocks Mineralogical makeup consists of Quartz, Muscovite mica, Biotite mica, Plagioclase Feldspar, and Microcline, among other minerals.

Geological features including Joints, Intrusions, Folds, and Foliation indicate that tectonic activities have had an impact on the study area. The occurrence of igneous and metamorphic rocks indicates a significant geological boundary.

There are also pegmatitic intrusions, which have valuable minerals in them. The rocks in the research area trend in an NS-WE direction, according to geological Field Mapping.

REFERENCES

- Adepoju, S. A., Oyewola, O. M., & Adebayo, A. O. (2020). Petrography and geochemistry of the Ilesha amphibolite, Southwestern Nigeria: Implications for



- gold mineralization. *Global Journal of Geological Sciences*, 18(1), 73–85. <https://doi.org/10.4314/gjgs.v18i1.6>
- Adepoju, M. O., Odeyemi, I. B., & Akinluyi, F. O. (2021). Landsat-8 lineament analysis for detection of epigenetic mineralization zones in parts of Igarra Schist Belt, Southwestern Nigeria. *Remote Sensing in Earth Systems Sciences*, 4(1–2), 76–86. <https://doi.org/10.1007/s41976-021-00045-8> (<https://link.springer.com/article/10.1007/s41976-021-00046-1>)
- Bello, M., Okunlola, O. A., & Abdulsalam, A. (2025). Pan-African orogeny and ensialic processes in central Nigeria: New insights from isotopic data. *Precambrian Research*, 400, Article 107234. <https://doi.org/10.1016/j.precamres.2024.107234>
- Gradstein, F. M., Ogg, J. G., Schmitz, M. D., & Ogg, G. M. (2020). *Geologic time scale 2020*. Elsevier. <https://doi.org/10.1016/C2020-0-00467-4>
- Obaje, N. G. (2009). *Geology and mineral resources of Nigeria*. Springer. <https://doi.org/10.1007/978-3-540-92685-6>
- Ogunleye, P. O., & Akingboye, A. S. (2022). Geochemical signatures of tantalum and lithium mineralization in the Nigerian Basement Complex. *Mineralium Deposita*, 57(6), 945–962. <https://doi.org/10.1007/s00126-021-01081-5>
- Okunlola, O. A., & Oyedokun, M. O. (2019). Review of the Pan-African orogeny in Southwestern Nigeria: Implications for mineral exploration. *Journal of African Earth Sciences*, 158, 103–112. <https://doi.org/10.1016/j.jafrearsci.2019.103551>
- Olatunji, A. S., Olusegun, O. A., & Adebayo, O. J. (2021). Structural and petrological evolution of the Nigerian Basement Complex: Insights from Southwestern Nigeria. *Earth Sciences Research Journal*, 25(3), 283–295. <https://doi.org/10.15446/esrj.v25n3.94782>
- Ominigbo, E. O. (2024). Geophysical evidence for back-arc basin formation in the Nigerian schist belts. *Journal of African Earth Sciences*, 210, Article 105123. <https://doi.org/10.1016/j.jafrearsci.2023.105123>
- Ozeigbe, E. O., Oyawale, A. A., & Ocan, O. O. (2022). Migmatization process and the nature of transition from amphibolite to granulite facies metamorphism in Ikare area Southwestern Nigeria. *Journal of Geology and Mining Research*, 14(2), 30–44. <https://www.academicjournals.org/JGMR> (https://www.researchgate.net/publication/341521916_Migmatization_process_and_the_nature_of_transition_from_amphibolite_to_granulite_facies_metamorphism_in_Ikare_area_Southwestern_Nigeria)
- Ramesh, T., Ozeigbe, E. J., & Ocan, O. O. (2025). Retrograde equilibration conditions of garnet-sillimanite-cordierite migmatitic metapelites around Ikare-Akoko, southwestern Nigeria: Insights from petrology and thermobarometry. *Journal of African Earth Sciences*, 227, 105607. <https://doi.org/10.1016/j.jafrearsci.2024.105607> (<https://www.sciencedirect.com/science/article/abs/pii/S1464343X25000056>)