INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

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OPEN ACCESS

Received: 10.09.2020

Accepted: 13.10.2020

Published: 03.12.2020

Citation: Abdus-Salam M, Bolarinwa A, Olatunji A, Fullen M, Afolabi A, Omotunde V, Olajide-Kayode J, Olisa O (2020) Geochemistry and mineral chemistry of quartz mica schists within Iseyin-Oyan Schist Belt, Southwestern Nigeria. Indian Journal of Science and Technology 13(41): 4319-4331. https://doi.org/10.17485/IJST/v13i41.1628

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Funding: African Union Commission through the Pan-African University scholarship scheme at the Pan-African University of Life and Earth Sciences Institute (PAULESI)

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Geochemistry and mineral chemistry of quartz mica schists within Iseyin-Oyan Schist Belt, Southwestern Nigeria

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Abstract

Background/Objectives: The Iseyin-Oyan schist belt is made up metasedimentary rocks, gneisses, granites and pegmatite intrusions. The study was aimed at identifying the schist within this belt and assess their metamorphism, geochemical characteristics and tectonic origin. **Methods**: Detailed geologic field mapping was undertaken where rocks were located, studied in-situ and identified. Samples of the schist were prepared for petrographic studies. Mineralogical contents were determined using X-Ray Diffraction technique. Polished sections were studied for mineral chemistry using Scanning Electron Microscope-Energy Dispersive Spectroscopy. Rock samples were analysed using X-Ray Fluorescence Spectroscopy and Inductively Coupled Plasma Emission Spectrometry. Geochemical data were elucidated using diverse geochemical discrimination diagrams. **Findings**: The schists are quartz mica schists and occur in close association with amphibolites, intrusive granitoids and pegmatites. The Mineral assemblage indicates upper (at the western part) to lower (at the central part) amphibolite facies grade metamorphism in the area. Pyrope-almandine garnets occur in quartz mica schist at the western parts reinforcing higher pressure-temperature metamorphic conditions. The concentration (in %) of SiO_2 ranged from 56.4-71.6; Al_2O_3, 13.7-21.1; Fe_2O_3, 2-8; MgO, 0.7-2.4; and K_2O, 2.1-5.5 supporting the evidence for differential degrees of metamorphism. Large iron lithophile and high field strength elements are similar to the average upper continental crust. Pronounced negative Europium anomaly pointed to the major roles played by feldspars during the geological processes. Plagioclase ranged from albite-oligoclase and oligoclase- andesine. The precursors of the quartz mica schist are possibly arkosic and greywacke sands deposited within the active continental margins. Evidence of uplift and overturning suggested for the differential metamorphism may be due to these events usually associated with active continental margins. **Applications**: This study has identified the once named undifferentiated schist in the study area to be quartz mica schist with details in their grades of metamorphism elucidated.

Keywords: Quartz mica schist; geochemistry; mineral chemistry; Iseyin-Oyan schist belt; precambrian basement complex

1 Introduction

The Iseyin-Oyan schist belt, within the southwestern part of Nigeria, (Figure 1) is one of the of Upper Proterozoic supracrustal rocks which have been infolded into the ancient polymetamorphic migmatite–gneiss basement complex rocks.[1–3] The syn- to late-tectonic Pan-African intrusive granitoids intrudes the supracrustals and the migmatite gneiss complex.[2,3]

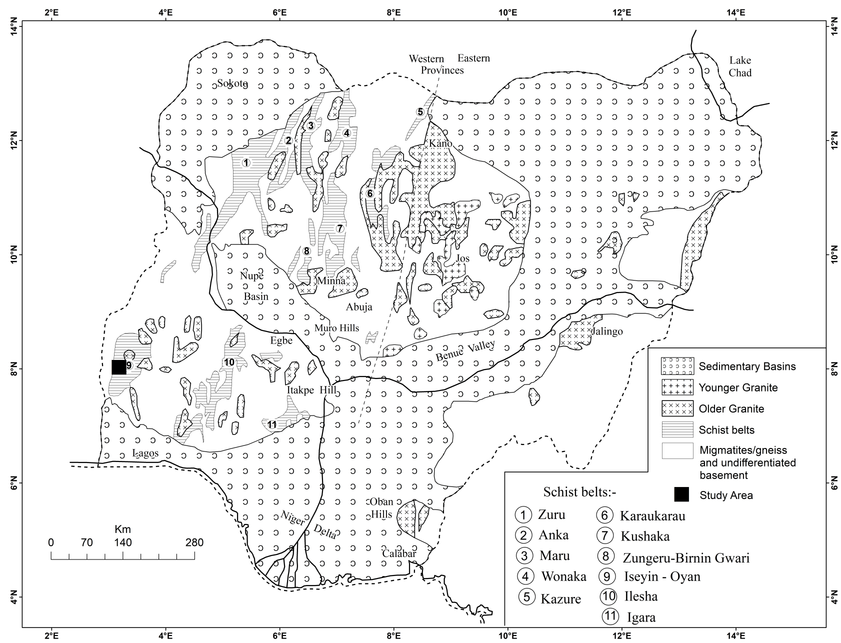

Fig 1. Localization of the study area in the Iseyin- Oyan Schist Belt on the Geological map of Nigeria. Modified after Woakes et al.[4]

The Iseyin- Oyan schist belt continues into the Ibadan area and forms part of the late Archaean to Palaeoproterozoic banded gneiss–quartzite–schist sequence.[5,6] Previous studies revealed undifferentiated schists as the most widespread lithology; quartzites occur near the margins of the schist belt while massive amphibolites represent mafic igneous rocks.[5] More recent geological mapping[7–11] within the schist belt reported the occurrence of lithologic units similar to those reported in earlier studies. Based on mineral assemblages recorded in pelitic schist mapped within the Belt, higher grade metamorphism was suggested in the belt than in most northern schist belts[12], whose structural style and magnetic properties are well elucidated.[1,12]

The Precambrian Basement Complex rocks in the Itasa area, have previously received little attention. Much of the information on the geology of the area is contained in the geological map produced by the Nigerian Geological Survey Agency (NGSA)[13] where it is revealed to be underlain by “Undifferentiated Schist” associated with many igneous intrusion of Older granite that metamorphosed surrounding rocks during the Proterozoic era [13]. This study was therefore carried out to identify the type of schist within the area by undertaking detailed petrographic, geochemical studies and mineral chemistry on the rocks for proper assessment of their grade of metamorphism, geochemical characteristics and tectonic origin.

2 Study location and Geologic setting

The present area is located within the Iseyin-Oyan schist belt in Southwestern Nigeria. It is defined by the geographical coordinates of Latitude 8° 00′ N and 8° 08′ N and Longitude 3° 00′ E and 3° 07′ E.

The area is situated at the western fringe of South-West Nigeria. In this section, the main exposed lithologic units are the granite gneiss, quartz mica schist, amphibolite, porphyritic granite, biotite alkali granite, quartz diorite and pegmatite (Figure 2).

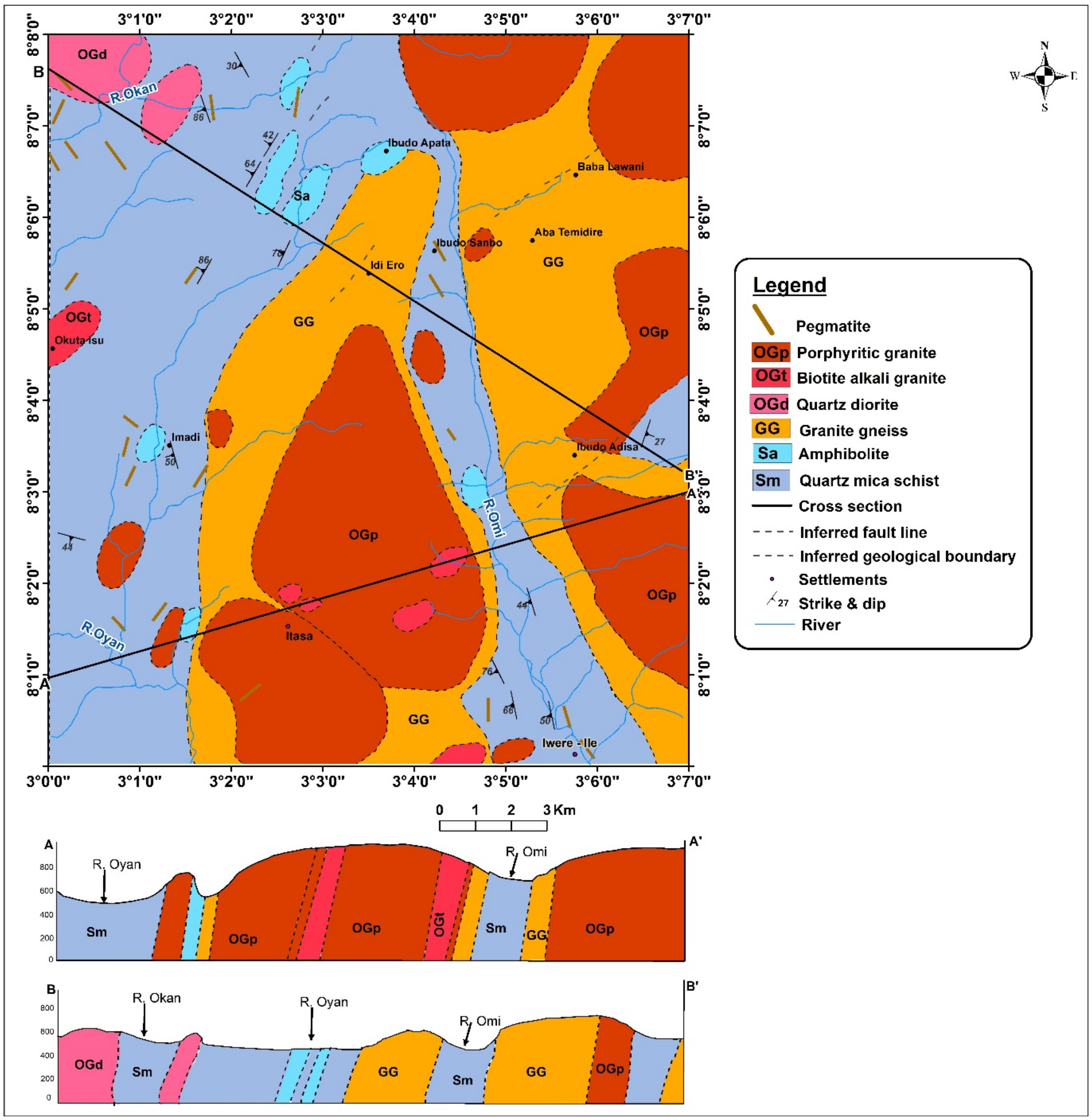

Fig 2. Geological map of the study area

The quartz mica schists, which are the focus of this study, generally trend in the NE-SW and dip to the southwest. Amphibolites occur in close association with the quartz mica schist as discontinuous lensoid bodies of small to large rocky boulders, trending NNE-SSW. Granite gneiss dominates the eastern and the central part of the area. Based on field relationship, it is regarded as an Older granitoid and occurs at the rim of other Older granitoid intrusives, notably, the coarse porphyritic granite. The granite gneiss is weakly foliated to porphyroblastic and with shearing around granitoid intrusions. Structural features on the sheared outcrops include ptygmatic quartzo- feldspathic veins of about 2 to 10 cm thick. The veins are either concordant or crosscutting to the regional foliation trends. Quartz- diorite is mesocratic, medium to coarse-grained granitoid outcropping as bosses and low-lying discontinuous body intruding the quartz mica schist at the north-western part of the area. Porphyritic granite occurs as a high-level intrusion of Older granitoid outcropping as bosses, low-lying body and huge boulders. The porphyritic texture is defined by phenocrysts of feldspars and quartz surrounded by inequigranular groundmass of biotite, quartz and feldspars. Biotite alkali granite is medium grained mesocratic to melanocratic Older granitoid which mostly occur as minor enclaves within coarse porphyritic granite at the southern part of the study area with hand specimen showing mafic minerals and feldspars.

3 Material and Methods

A comprehensive fieldwork was undertaken where rocks within the study area were located, studied in-situ and sampled. Geological data related to the occurrence, field relationships and mineralogical-textural characteristics were obtained.

Petrographic studies were carried out in the petrography laboratory of the Department of Geology, The Polytechnic, Ibadan, Nigeria, using an Olympus binocular microscope. The mineral phase identification, mineral chemistry and geochemical analyses were performed at the University of Wolverhampton, United Kingdom.

Mineral phase identification was done using PANalytical Empyrean X-ray Diffractometer. X-ray diffraction pattern of these samples was recorded over a 2θ range of 50° to 70°. The diffractometer was equipped with a graphite monochromated Cu Kα radiation source (8987 eV; λ= 1.5418 Å) operated at 40 kV and 40 mA for 30 s. A portion of each pulverised rock samples was put on the flat auto-plate and mounted on an auto-stand. A proportion of the X-rays were diffracted by the regular crystal structure of the samples. Mineral phase identification was made by searching the International Centre for Diffraction Data (ICDD) and Joint Committee on Powder Diffraction Standards (JCPDS) database files. Data processing was carried out using Xpert HighScore Plus software on a DEC Microvax Minicomputer interfaced to the diffractometer.

Fresh representative samples of quartz mica schists were selected after geological mapping exercise of Itasa area for detailed analysis. Mineral phases identifications were investigated using the XRD, mineralogical composition using Scanning Electron Microscopy equipped with an Energy-Dispersive X-ray (EDX) analyser and elemental composition analysed using X-Ray Fluorescent (XRF) and Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES).

Mineral chemistry studies were carried out using a Zeiss EVO 50 (Zeiss, UK) Scanning Electron Microscope (SEM) attached to an EDX with an INCA 350 software (Oxford Instruments, Incax-sight, UK). Operating conditions of the instrument were 20 - 25 kV accelerating voltage, 15–20 nA beam current and counting times of 20–35 s per element. Analytical standards were high purity metals, well-characterized synthetic oxides and natural minerals. Analyses were made of plagioclase, biotite, garnet and other accessory minerals.

Geochemical analyses of the major oxides and some trace elements was determined using Epsilon XRF spectrometer by PANanalytical at 4 kV using powder pellet discs. To prepare the pellet, 8.50g of the sample powder was weighed accurately, to which was added 1.50g of Licowax C Micropowder PM- Herzog organic binder. The homogenous mixture was placed in an aluminium cup and hydraulically pressed into pellets under high pressure of 20 tonnes. This was done to ensure the integrity of the sample under vacuum and the consistency of the surface to receive X-rays. Trace elements and rare earth elements (REE) within the samples were analysed using ICP-OES model SPS 3 Argilent Technology. Sample digestion was done using fusion following the method described by a team of researchers.[14] Fusion with ammonium biflouride (NH_4HF_2) salt in a perfluoroalkoxy alkaline (PFA) vial has been recommended for complete recovery of trace elements particularly the REE in rock samples.

4 Results and Discussions

4.1 Petrography

The schist is identified as quartz mica schist and covered about 40 percent of the area mapped. Petrologic evidence revealed that the quartz mica at the western part of the study area are closely associated with amphibolites, quartz diorite, biotite alkali granite and pegmatites. They are grey shaded, silk lustred, highly compacted and usually display clear schistose texture, with small quartz bodies (Figure 3 A-D). The rocks are medium-grained and less contorted with thin foliation planes that are typically a few centimeter. The foliation planes are usually truncated by either ptygmatic folds, microfolds, 'boudinage' quartz or pegmatitic veins. Others are mainly restricted to the central part of the study (Figure 3E-G) and closely associated with granite gneiss, porphyritic granite, small to large pegmatite bodies but rarely with amphibolite. They vary from highly weathered to the relatively fresh outcrop. Where fresh, they show grey-silver-brown shades with silky lustre and a well-defined schistose structure, usually characterized by the presence of anatectic pegmatites swarm and small quartz bodies. Quartz veins which are either parallel or crosscutting the foliation are common. Their grain size ranged from fine to medium grained with a pelitic appearance.

Fig 3. Field photographs quartz-mica schist showing schistose texture (A) (coordinate 8° 2′ 30.7′′ N 3°0′ 24.8′′ E Strike/Dip: 343°/49° SW); (B) showing ptygmatic fold of quartzofelspathic vein (coordinate 8° 0′ 26.6′′ N 3° 5′ 16.1′′ E; Strike/Dip: 142°/56° SW); (C) showing shearing on a quartz vein; (D) showing minor fold on the outcrop; (E) along a river channel; (F) showing minor joint and (G) road cut exposure intruded by a pegmatite vein (coordinate: 8° 0′ 28.8′′N, 3° 5′ 23.3′′ E; Strike/Dip: 314°/50° SW).

Mineralogically, the quartz mica schist at the western part are composed of biotite, muscovite, quartz, plagioclase, sillimanite, microcline and garnet while accessory minerals include titanite, zircon, apatite, magnetite and ilmenite (Figure 4 A-D). Biotite is usually dominant over muscovite; with the slim flakes longitudinally aligned. Muscovite generally intergrow with biotite. Sillimanites are observed as fibroid aggregate of acicular fibrolite in the quartz mica schist. The quartz mica schist at the central part are composed of biotite, muscovite, quartz, plagioclase, K-feldspars and opaque minerals while accessory minerals include titanite, magnetite, ilmenite and zircon (Figure 4E-H). Thin quartz aggregates occur between the schistose layers of the rock defining the thin banding noticeable in the rock. X- Ray diffractograms (Figure 5) is consistent with the petrographic data. Quartz, biotite, sillimanite plagioclase, orthoclase and microcline were identified on the diffractograms, of which, sillimanite (Figure 5C) is identified on the diffractrogram from the western part of the study area. On the basis of the mineral paragenesis, the quartz mica schist reached amphibolite facies conditions.

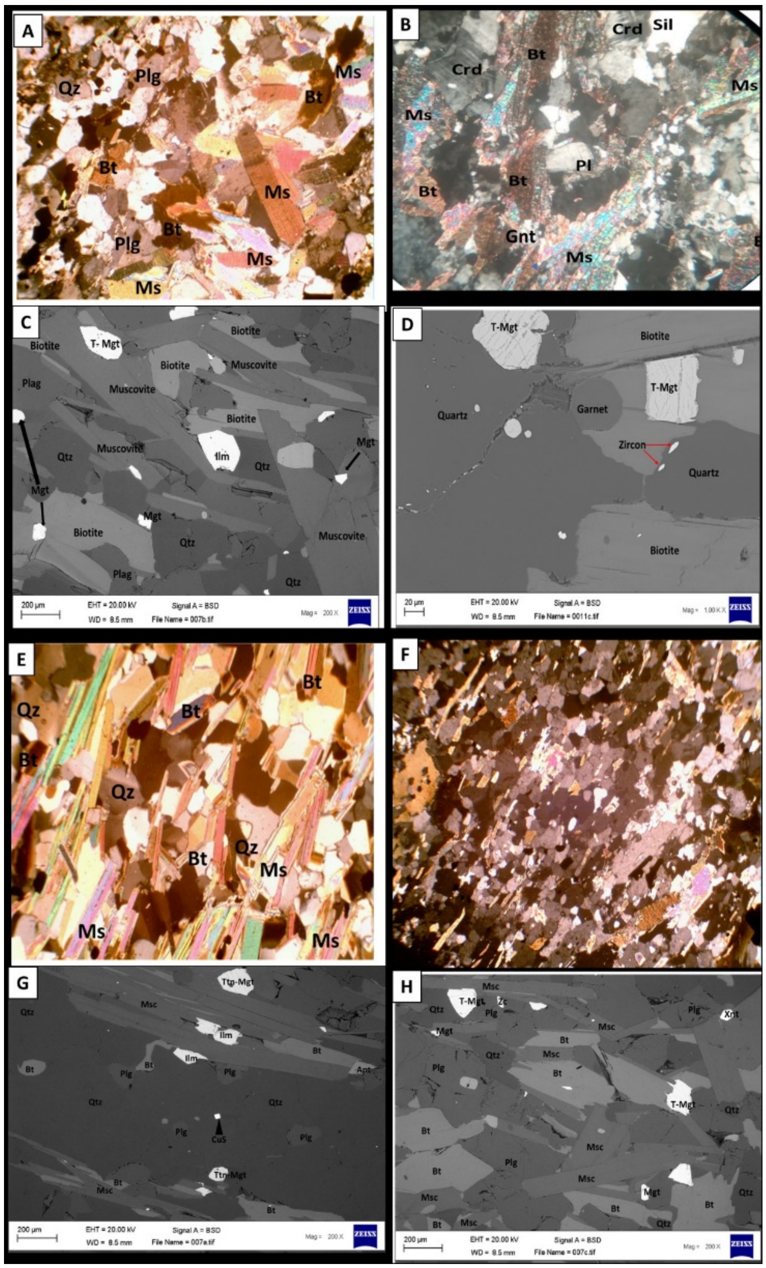

Fig 4. Photomicrographs and Backscattered electron images showing prominent foliation. Plag- Plagioclase, Qtz- Quartz, Msc- Muscovite, Bt- Biotite, Zrc- Zircon, T-Mgt- Titanomagnetite, Mgt- Magnetite, Ilm- Ilmenite. Sil- sillimanite, Crd- cordierite Gnt-garnet.

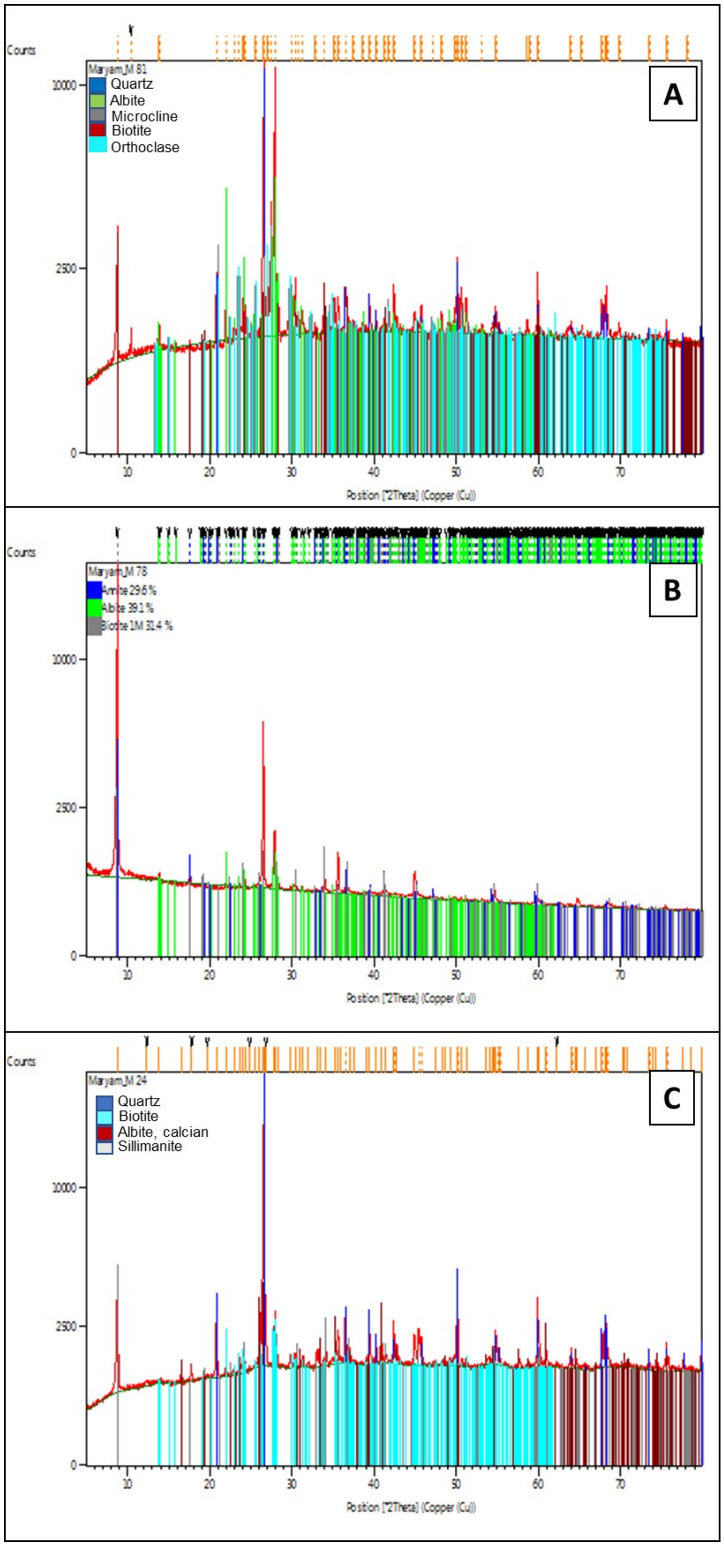

Fig 5. X- ray diffractograms of the quartz mica schist showing peaks of quartz, biotite, albite, orthoclase, microcline with (c) minor peaks of sillimanite.

Structural imprints show the different orientations of foliation in terms of dipping direction within the quartz mica schist (Figure 2) with implications for uplift/overturn folding. This may be linked with the occurrence of granitoid intrusives in close association with the schist. Lithostructural evidence suggests a clockwise overturn that may expose deeper roots of the quartz mica schist at the western part of the study. Growth of small grains of garnet and presence of sillimanite from quartz mica schist at the western part of the study implies higher metamorphic grade as these index minerals are absent in the central part of the area. These evidence suggest overturn of the schist as a contemporaneous event during the intrusion of granitic magma during Proterozoic era.

4.2 Geochemistry and geotectonic setting

A general petrographic description of the representative samples selected for geochemistry and mineral chemistry is given in the above-mentioned petrography. The geochemical characteristics of the quartz mica schists in the Itasa area are shown in Figure 6 while its chemical composition is shown in Supplementary Table 1.

Major oxide geochemistry showed SiO_2 concentration ranging from 56.4 – 71.6 wt.% with average concentration of 65.56 wt.%. The quartz mica schist from the central part of the study was more silica enriched with concentration exceeding 70 wt. %. This enrichment may be due to contamination from more acid intrusions closely bordering this area of the study underlain by quartz mica schist or were topmost layer of the metasediment that suffered from Paleo-weathering during or after the deposition of supra-crustals that were buried before metamorphism. Paleo-weathering may also account for the selective removal of Al and K during possible degrading of feldspars. Quartz mica schist from the western part revealed relatively lower silica concentrations (56.4 – 64.2 wt.%) and higher Alumina concentrations than those observed for samples from the central part of the area. Concentrations of other major oxides support differential degrees of metamorphism. Fe_2O_3 concentrations were slightly higher in samples obtained from the western part of the study as well as in MgO concentrations. CaO concentrations are varied and ranged from 1.5 – 3.1 wt.%. The alkali concentrations were discriminated and may be linked with different modal proportions of feldspar. Samples with lower SiO2 concentrations revealed higher K_2O and lower Na_2O values.

The petrogenesis of the quartz mica schist as indicated on the Na2O – Fe_2O_3+MgO – K_2O diagram[15] (Figure 6A) shows that the protoliths of the quartz mica schist are greywacke at the central part and arkose at the western part of the study area. The chemical composition of the quartz mica schist clearly explains the nature of chemical weathering that produced the arkose and greywacke. The SiO_2/Al_2O_3 ratios in the quartz mica schist ranged from 2.67 to 5.24. The ratio is a common sedimentary maturation index that increases during weathering, transportation and recycling, due to an increase in modal framework quartz than the less resistant constituents, such as, feldspar and lithic fragments.[16] It varies from around 3 in basic rocks to around 5 in acidic rocks, and greater than 5 or 6 in matured sediments.[16] This implies that weathering and transportation increase from the central part of the study area to the western part of the study which is probably the alluvial fan sediments. Following the work of Nesbitt and Young,[17] as applied to clastic rocks[18], the values of Chemical Index of Alteration (CIA) ranged from 58 to 71. CIA is the most frequently used geochemical index to quantitatively estimate source-area weathering intensity and understand paleoclimate conditions.[16] It is defined as the molar ratio [Al2O3 / (Al_2O_3 + CaO*+Na_2O+ K_2O)] x100 (CaO* is the Ca in silicates). The CIA values in this study also increase towards the western part of the study area from relatively unweathered to moderate alteration of the protoliths before removal, transportation and subsequent deposition.[19]

The relatively immobile High Field Strength Elements (HFSE), Zr, Nb, Y in the schist show contents similar to those of the upper crust[20] (Figure 6B). HFSE are incompatible during most magma crystallization and anatectic processes[21], and are usually less water-soluble, thus, are resistant to change during weathering and alteration processes, hence, reflecting provenance compositions.[20] The Large Ion Lithophile Elements (LILE) Rb, Sr and Ba show slight variation with respect to the upper crust and within the samples. Generally, there is a slight impoverishment in Sr with respect to the UCC[20]. Ba contents in the central part are higher than in the upper crust which may be related movement of metamorphic remobilized fluid during the Pan African or earlier event.[19]

The primitive mantle[22]-normalized rare earth elements (REE) diagram (Figure 6C) displays a relatively similar pattern in the schists, indicating progressive depletion in the Light REE and a weak depletion to almost flat characteristic in heavy REEs. The fractionated LREE/HREE pattern, (LaN/YbN = 15 to 23), the fractionated Light REE (LaN/SmN = 4 to 8), nearly flat Heavy REE patterns, (GdN /YbN = 1-2) and characteristic negative Eu anomaly. These features suggested derivation from the upper continental crustal materials.[20]

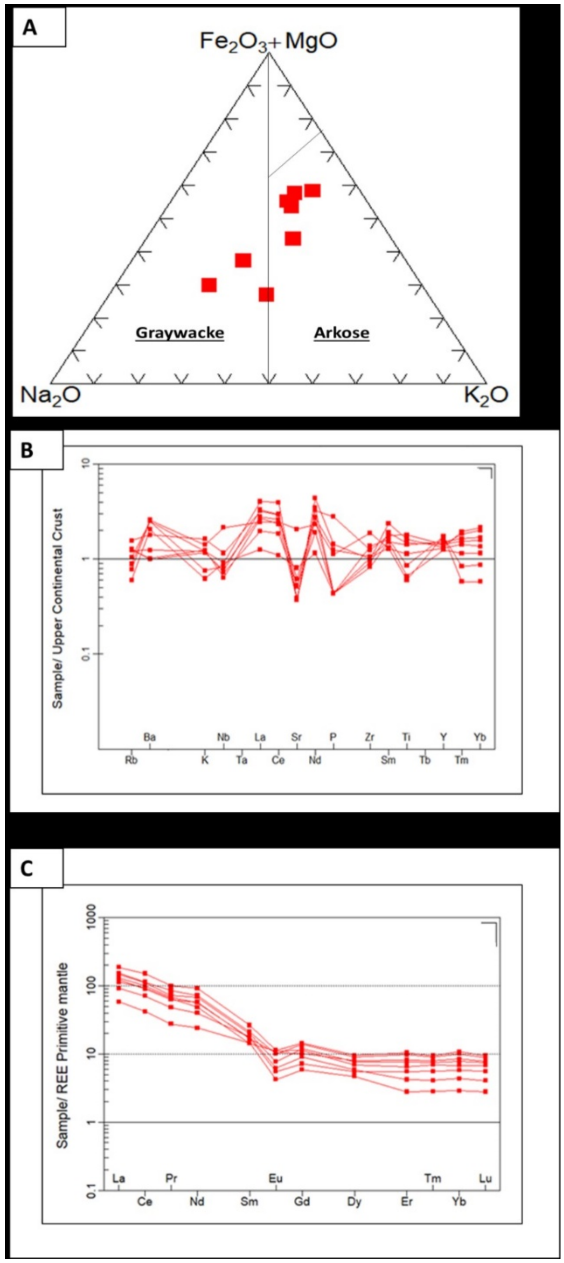

Fig 6. (A) Geochemical characteristics of the quartz mica schist on the Na_2O – Fe_2O_3+MgO – K_2O diagram [15] (B) UCC [20] normalized spidergram; and (C) Primitive mantle [22] normalized REE patterns

It has been reported that sediments geochemical abundances can be related to the processes of plate tectonics, thus, making geochemistry a reliable tool in the recognition of ancient tectonic environments. [23,24] Many major oxide discrimination diagrams have been used to discriminate different tectonic settings. [24,25] Systematics of SiO_2- K_2O/Na_2O have been linked to geotectonic environment [24] because both variables increase from volcanic arc to active continental margin to passive margin setting. In this study, however, the SiO_2- K_2O/Na_2O trend matches with those sediments deposited at the active continental margin (ACM) (Figure 7 A). A similar trend was also observed on the SiO_2/Al_2O_3 versus K_2O/Na_2O diagram [25] (Figure 7B). The ACM includes thick continental margins of the Andean type sedimentary basins and the strike-slip types. These basins are found on or neighbouring to a thick continental crust made up of rocks of older fold belts and the sediments are derived from granite-gneisses and siliceous volcanics of the uplifted basement. On the basis of evidences from the eastern and north-eastern margins of the West African Craton, it has been noted by previous authors that the Pan-African trans-Saharan belt emerged by plate tectonic processes involving collision of the active margin of the Taureg shield and the passive continental margin of the West-African Craton, about 600 ± 10 Ma.[6,26,27] There was crustal melting towards the end of the collision between the Tuareg shield and the subducted oceanic crust which is concluded to have reactivated the internal region of the Pan African belt forming the Pan African granitoids.

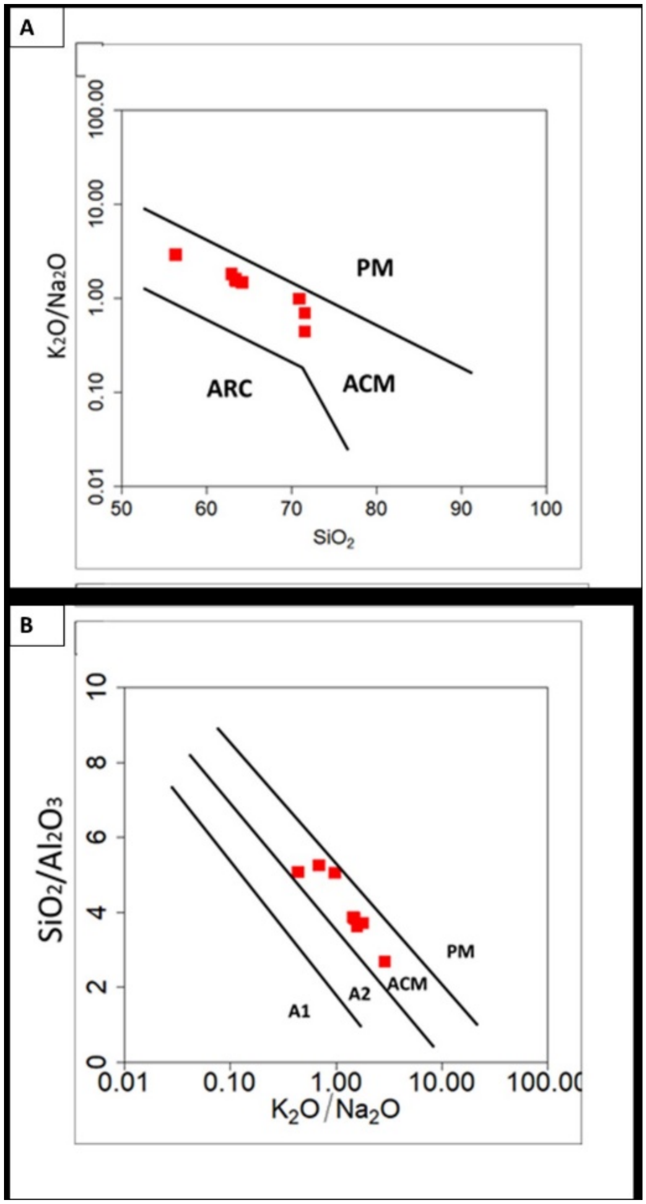

Fig 7. Tectonic discrimination diagrams for the quartz mica schist (A) SiO_2- K_2O/Na_2O[23] and (B) SiO2/Al_2O_3 versus K2O/Na_2O[25] indicating deposition of sediments in the active continental margin (ACM). PM- passive margin; ARC -oceanic island arc margin; A1- arc setting, basaltic and andesitic detritus; A2 -evolved arc setting, felsic plutonic detritus.

4.3 Mineral chemistry

Biotite: The mineral chemistry of biotite in the quartz mica schists are presented in Supplementary Table 2. The table includes structural formulae of the biotite calculated on the basis of 22 Oxygen. The analyses indicated that two types of biotites were formed in the schists. According to classification diagrams (Figure 8 A-B)[28,29], the biotites in samples of quartz mica schist at the central part of the study are rich in Fe, thus annitic- siderophilitic end members, and characteristics of granitic rocks while those from the western part are rich in Mg, thus phlogopitic-eastonite end member and characteristics of mafic rocks.

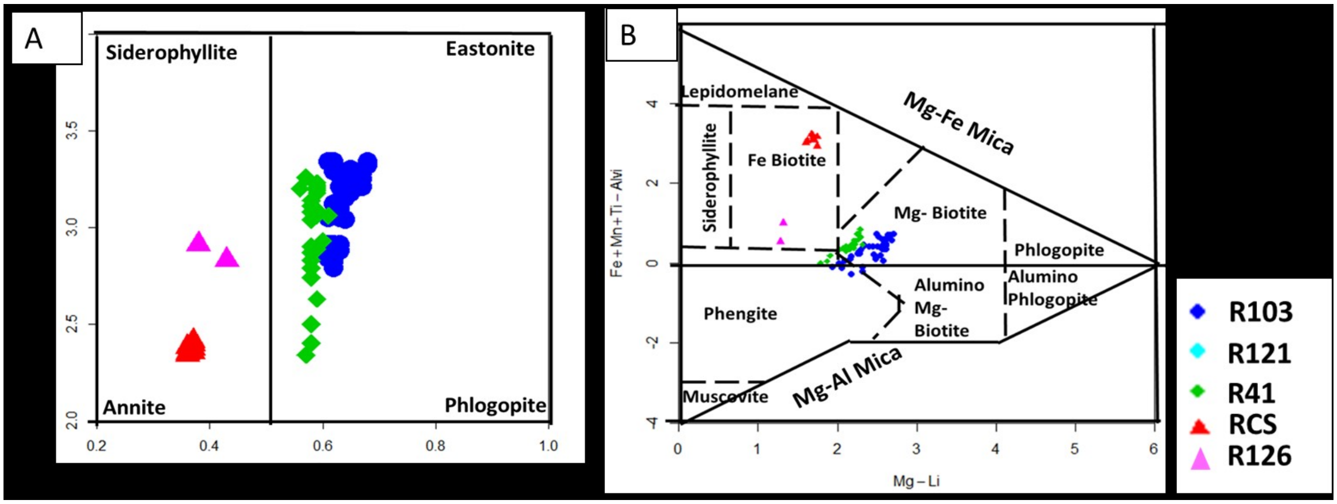

Fig 8. Plots of (A) Al^{IV} against Mg/ (Mg + Fe) [28]; and (B) (Mg–Li) vs. (Fetot +Mn + Ti- Al^{VI}) [29] showing the biotite types.

Plagioclase: The mineral chemistry of plagioclase in the quartz mica is presented in Supplementary Table 3. This table includes their structural formulae calculated based on 32 Oxygens. It was revealed that the albitic content (very high Na_2O but low CaO contents) of plagioclase decreases towards the western part of the study area. They are oligoclase with subordinate andesine in the west, whereas, albite in the central part of the study area (Figure 9).

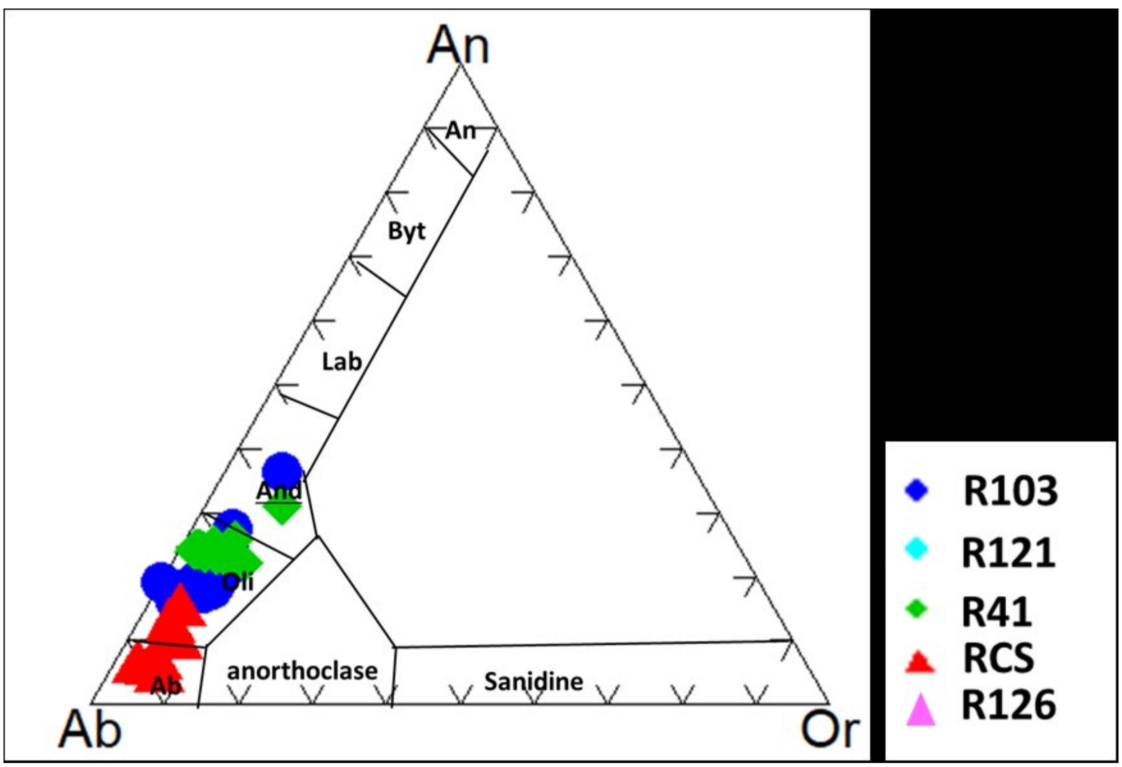

Fig 9. Classification of the plagioclase in the quartz mica schist into albite to andesine compositions as shown on the Ab-An-Or diagram. [30]

Garnets: The mineral chemistry of garnets in the quartz mica are presented in Supplementary Table 4. The pyrope component is predominant in this garnet with content between 56 to 58%. The almandine component is less predominant with content between 32 and 34 %. The garnet is essentially pyrope-almandine solid solutions (Figure 10) with the garnet being more of pyrope than almandine [31] indicating the formation of the schist under high-pressure metamorphic conditions. There is no difference between the analysis from the core and rims of these garnets possibly indicating temperature equilibrium during its growth.

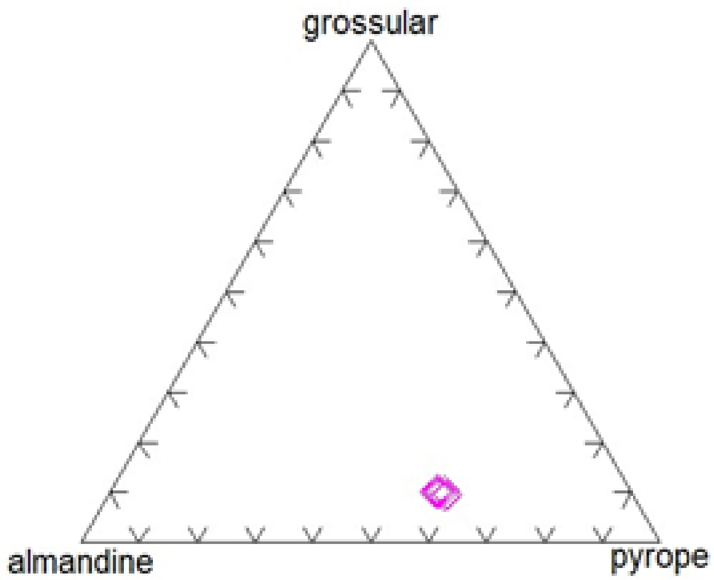

Fig 10. Composition of the garnet in the quartz mica schists of Iseyin-Oyan schist belt after Coleman et al. [31]

5 Conclusion

The undifferentiated schist has been identified as quartz mica schist having lateral variation in grade of metamorphism from medium to high grade. Field evidence revealed that the schists are silky lustred with well-defined schistosity. Mineral assemblages indicate lower to upper amphibolite facies grade of metamorphism. Structural imprints with implications on uplift and possible folding within the schist may be linked with their close association with granitoid intrusives. These evidences suggest a clockwise overturn which explains an upper amphibolite facies schist exposed at the western part of the study with mineral-ins of garnet and sillimanite believed to be deeper layers of the regionally deposited supracrustals metamorphosed during probable Eburnean times.

Geochemical characteristics of major oxides supported discriminations based on metamorphic facies. This evidence implies differential degrees of metamorphism during deep burial metamorphism from the central and western part of the study. HFSE and LILE are similar to the average upper crustal, though, Ba and Ti showed slight differences that may be linked with mobility of ions during metamorphism. Crustal contamination during metamorphism and uplift associated with granitoid emplacements may be adduced for the enrichment in LREE pattern. Depletion of heavy rare earth element with pronounced Eu anomaly pointed to influence of upper continental crust and that feldspars played major role during these geologic processes. The mineral chemistry revealed presence of pyrope-almandine garnet in the quartz mica schist, which implies high pressure-temperature metamorphism in the western part of the study but completely absent within the schist that underlain the central part.

The precursors of the quartz mica schists are possibly arkosic and greywacke sands deposited within active continental margins that form narrow belts of schistose rocks with the Precambrian Basement complex of Nigeria. The events associated with this active margin may be responsible for the uplift and overturning of deeper layers of metamorphosed supracrustals.

Acknowledgments

This publication is part of the Ph.D. thesis of the first author funded by the African Union Commission through the Pan-African University scholarship scheme at the Pan-African University of Life and Earth Sciences Institute (PAULESI). The Two anonymous reviewers are highly appreciated for their comments and criticisms towards the improvement of this paper.

References

1) Fagbohun BJ, Omitogun AA, Ayotunde OA, Ayoola FJ. Remote Detection and Interpretation of Structural Style of the Zuru Schist Belt, Northwest Nigeria. *Geocarto International*. 2020. Available from: https://doi.org/10.1080/10106049.2020.1753822.
2) Elueze AA. Rift system for Proterozoic schist belts in Nigeria. *Tectonophysics*. 1992;209:167–169.
3) Garba I. Origin of Pan-African mesothermal gold mineralisation at Bin Yauri, Nigeria. *Journal of African Earth Sciences*. 2000;31(2):433–449. Available from: https://dx.doi.org/10.1016/s0899-5362(00)00098-1.
4) Woakes M, Rahaman MA, Ajibade AC. Some metallogenic features of the Nigerian Basement. *Journal of African Earth Sciences*. 1983;6:655–664. Available from: https://doi.org/10.1016/0899-5362(87)90004-2.
5) Jones HA, Hockey RD. The Geology of part of Southestern Nigeria. *Nigeria Geological Survey Bulletin*. 1964;31:87.
6) Burke KC, Dewey JF. Orogeny in Africa. In: Dessauvagie TFJ, Whiteman AJ, et al., editors. Africa Geology. Ibadan, University of Ibadan Press. 1972;p. 583–608.
7) Okunlola OA, Akintola AI. Geochemical Features And Rare - Metal (Ta-Nb) Potentials Of Precambrian Pegmatites Of Sepeteri Area, South Western Nigeria. *Ife Journal of Science*. 2008;9(2):203–214. Available from: https://dx.doi.org/10.4314/ijs.v9i2.32250.
8) Okunlola OA, Oyedokun MO. Compositional trends and rare metal (Ta-Nb) mineralization potential of pegmatite and associated lithologies of Igbeti area, Southwestern Nigeria. *RMZ - Materials and Geoenvironment*. 2009;56(1):38–53.
9) Adetunji A, Ocan OO. Tectonic Environments and Rare Metal Mineralization In Pegmatites Of Komu Area, Southwestern Nigeria. *Global Journal of Geological Sciences*. 2010;8:109–115. Available from: https://doi.org/10.4314/gjgs.v8i2.62767.
10) Akintola AI, Ikhane PR, Laniyan TA, Akintola GO, Kehinde-Phillips OO, Ojajuni PO. Compositional trends and rare metal (Ta- Nb) mineralization potential of Precambrian pegmatites in Komu area, Southwestern Nigeria. *International Journal of Current Research*. 2012;4(2):31–39. Available from: https://doi.org/10.1179/037174503225011270.
11) Bolarinwa AT, Adeleye MA. Nature and Origin of the Amphibolites in the Precambrian Basement Complex of Iseyin and Ilesha Schist Belts, Southwestern Nigeria. *Journal of Geography and Geology*. 2005;7(2):6–17. Available from: https://doi.org/10.5539/jgg.v7n2p6.
12) Rahaman MA. Review of the Basement geology of Southwestern Nigeria. In: Kogbe CA, et al., editors. Geology of Nigeria. Elizabeth Publishing Company. 1976;p. 39–56.
13) Nigeria Geological Survey Agency (NGSA). Geological map of Nigeria. Kaduna. 2011.
14) Zhang W, Hu Z, Liu Y, Chen H, Gao S, Gaschnig RM. Total Rock Dissolution Using Ammonium Bifluoride (NH_4HF_2) in Screw-Top Teflon Vials: A New Development in Open-Vessel Digestion. *Analytical Chemistry*. 2012;84(24):10686–10693. Available from: https://dx.doi.org/10.1021/ac302327g.
15) Blatt HJ, Middleton GV, Murray RC. Origin of Sedimentary Rocks. New Jersey. Prentice-Hall. 1980.
16) Roser BP, Cooper RA, Nathan S, Tulloch AJ. Reconnaissance sandstone geochemistry, provenance, and tectonic setting of the lower Paleozoic terranes of the West Coast and Nelson, New Zealand. *New Zealand Journal of Geology and Geophysics*. 1996;39(1):1–16. Available from: https://dx.doi.org/10.1080/00288306.1996.9514690.
17) Nesbitt HW, Young GM. Early Proterozoic climates and plate motions inferred from major element chemistry of lutites. *Nature*. 1982;299(5885):715–717. Available from: https://dx.doi.org/10.1038/299715a0.
18) Maynard JB, Ritger SD, Sutton SJ. Chemistry of sands from the modern Indus River and the Archean Witwatersrand basin: Implications for the composition of the Archean atmosphere. *Geology*. 1991;19(3). Available from: https://dx.doi.org/10.1130/0091-7613(1991)019<0265:cosftm>2.3.co;2.
19) Olobaniyi SB. Geochemistry of semipelitic schist of Isanlu area, south west Nigeria: implication for the geodynamic evolution of the Egbe-Isanlu schist belt. *Global Journal of Geological Sciences*. 2003;1(2):113–127. Available from: https://dx.doi.org/10.4314/gjgs.v1i2.18661.
20) Taylor SR, Mclennan SM. The Continental Crust: Its Composition and Evolution. Oxford, Blackwell.. 1985.
21) Feng R, Kerrich R. Geochemistry of fine-grained clastic sediments in the Archean Abitibi greenstone belt, Canada: Implications for provenance and tectonic setting. *Geochimica et Cosmochimica Acta*. 1990;54(4):1061–1081. Available from: https://dx.doi.org/10.1016/0016-7037(90)90439-r.
22) Mcdonough W, Sun SS. The composition of the Earth. *Chemical Geology*. 1995;120:223–253.
23) Bhatia MR. Plate Tectonics and Geochemical Composition of Sandstones. *The Journal of Geology*. 1983;91:611–627.
24) Roser B, Korsch RJ. Determination of tetonic setting of sandstone-mudstone suites using SiO_2 content and K_2O/Na_2O ratio. *Journal of Geology*. 1986;94:635–650.
25) Maynard JB, Valloni R, Yu HS. Composition of modern deep-sea sands from arc-related basins. In: K LJ, et al., editors. Trench-Forearc Geology: Sedimentation and Tectonics on Modern and Ancient Active Plate Margins. Geological society. 1982;p. 551–561.
26) Caby R, Bertrand JML, Black R. Pan-African ocean closure and continental collision in the Hoggar-Iforas segment, Central Sahara. In: Kroner A, editor. Precambrian Plate Tectonics. Elsevier. 1981;p. 407–434.
27) Obiora SC. Petrology and geotectonic setting of the Basement Complex rocks around Ogoja, Southeastern Nigeria. *Ghana Journal of Science*. 2006;46:13–46. Available from: https://doi.org/10.4314/gjs.v46i1.15912.
28) Rieder M, Cavazzini G, D'yakonov YS, Frank-Kamenetskii VA, Gottardi G, Guggenheim S, et al. Nomenclature of the micas. *Mineralogical Magazine*. 1999;63(2):267–279. Available from: https://dx.doi.org/10.1180/minmag.1999.063.2.13.
29) Tischendorf G, Gottesmann B, Forster HJ, Trumbull RB. On Li-bearing micas: estimating Li from electron microprobe analyses and an improved diagram for graphical representation. *Mineralogical Magazine*. 1997;61:809–834. Available from: https://doi.org/10.1180/minmag.1997.061.409.05.
30) Deer WA, Howie RA, Zussman J. An introduction to Rock forming Minerals. England, Longman. 1966.
31) Coleman RG, Lee DE, Beatty LB, Brannock WW. Eclogites and Eclogites; Their Differences and Similarities. *Geological Society of America Bulletin*. 1965;76:83–508.