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THE TECTONIC SETTING OF THE ROCKS AROUND SHINTAKU AREA SOUTHEAST OF LOKOJA, NORTH-CENTRAL, NIGERIA

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Abstract
Samples collected from eight locations in the Shintaku area were analyzed using AAS and interpreted with tectonic discrimination diagrams to ascertain the tectonic setting, a major factor controlling the lithology, chemistry, and preservation of deposits. The TiO_2-K_2O-P_2O_5 plot shows that the samples obtained from the study area show continental characteristics. More plots were made which show the type of magma that formed the rocks and their tectonic settings: The Ti vs Zr diagram shows varieties ranging from island arc lavas to within-plate lavas. The R1-R2 plot shows that the formation of the rock varied from anorogenic to post-orogenic environments. Syn-collisional and post-orogenic environments are synonymous with volcanic arc granites (VAG) in the scheme and this environment is related to the process of crustal thickening often by the under thrusting of a crustal "slice" below another. The geotectonic discrimination plots revealed that the samples from the study area were formed from island arc granites (IAG), continental arc granites (CAG), continental collision granites (CCG), continent-epeirogenic uplift granites (CEUG), post-orogenic (PO), and rift-related granitoid (RRG). From the Nb/Yb vs TiO_2/Yb diagram the samples obtained from the study area plot within OIB or near theT mantle array field strongly support continental than any other environment. The rocks in Shintaku area, from the foregoing, are formed because of the subduction of the oceanic plate into/under the continental plate. The oceanic plate subducted and basaltic rocks in the oceanic crust melted as a result of heat and pressure to form magma. This magma moved to the continental region to be subducted along with a few oceanic basaltic rocks reflecting continental environmental setting of the plots. Hydrothermal alteration processes in altered granites and magmatic/post magmatic processes could have influenced the variation and redistribution of the major oxides and trace elements distribution, respectively.
Keywords: *Continental environment, Continental crust, Granites, and subduction.*

Introduction

The recent review of the studies on the PreCambrian rocks of the Nigerian Basement Complex by Ominigbo (2022) was silent on those of the Shintaku areas of the southeastern part of Lokoja, NC, Nigeria. The same is true for a similar but more comprehensive efforts by Obaje (2009). This apparent neglect of this part of the Nigerian Basement Complex is despite the potential for the mineralization of the basement rocks in the zone and its unique features as a transition zone with exciting geologic characteristics. It is in a bid to integrate the geologic information from this area and attempt bridging the observed gap with respect to igneous petrology in this area that led Chukwu *et al.*, (2023a) and Chukwu *et al.*, (2023b) to publish on the structural attributes and sequence of entry of index minerals in the rocks around Shintaku area of southeastern part of Lokoja, NC, Nigeria and on the aspects of the petrogenetic evolution of the Shintaku area, Lokoja, NC, Nigeria, respectively. The geology of the area was substantially discussed in those contributions. This is yet another effort to update the geoscience community on the area. The tectonic setting is the major controlling factor shaping lithology, chemistry, and the preservation of earth materials in their depocenters. Supracrustal rocks that formed surficially (including volcanics and sediments), for instance, lost many of their primary or inherent features during metamorphism and deformation. The relationship that exists between tectonic setting and mineral deposition is so significant that it cannot be ignored (Park. and Macdiarmid, 1975). In fact, the major control of mineral deposition is the geological processes operating because of the energy released at the plate boundaries. Mineral deposits, therefore, form in particular tectonic environments which are, in turn, related to plate tectonic activities. Similarly, tectonic plate movement provides suitable conditions for the igneous rocks to form from the magma. The igneous rocks form where plates diverge as lava rises and occupies the openings created between the plates. Igneous rocks equally form where plates converge. The subducting plate melts as it sinks into the earth's crust and the melts rise into the overriding plate forming volcanoes and rocks. This study becomes so necessary because of its importance in addition to the knowledge gap that exists in the area owing mainly to the dearth of publications in related areas especially in recent times.

The tectonic settings of rocks are determined using trace element discrimination diagrams (Pearce, and Cann, 1973; Floyd, and Winchester, 1975; Pearce, 1975; Wood *et al.*, (1979); Winchester and Floyd 1977; Shervais, 1982). This study is centered on the tectonic settings of rocks in the Shintaku area, southeast Lokoja, North-Central, Nigeria. The study is conducted via two different stages: field mapping and the laboratory analysis. The field occurrence of the geology in the study area basically suggests the orientation of the underlying rocks.

Location, accessibility and geology of the Area of Study

The Shintaku area, is located between the latitudes 7°40' N and 7°45' N, and longitudes 6°45'E and 6°50'E (Figure 1). The study area is part of the Basement Complex-Sedimentary transition zone where both crystalline and sedimentary rocks are juxtaposed. Prominent towns and communities in the area are Shintaku, Emi Momo, Kpata, Kpata-kpali and Icheu and other smaller villages. The area has low to moderate relief with a few hillocks of elevation ranging from 100 - 900ft above. A network of all season roads that connects the main parts of Lokoja to Shintaku always makes the area accessible and the rivers can be crossed by boats and ferries from Lokoja town to the area.

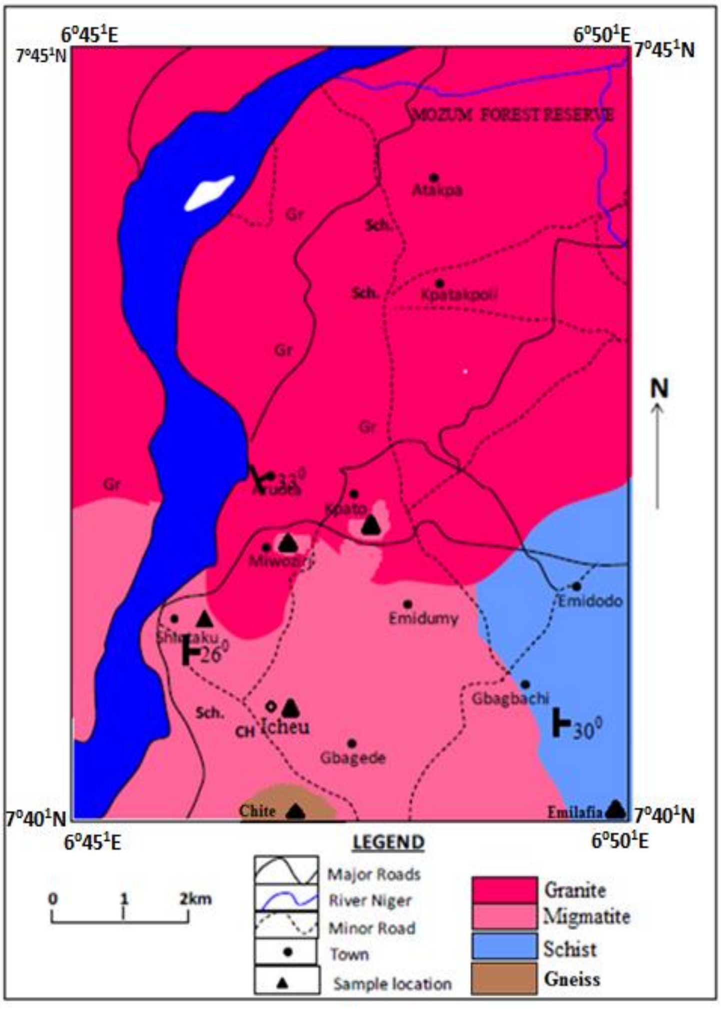

Figure 1: Geologic map of Shintaku (After Chukwu et al., 2023a).

Structural Geology

In the mapped area, some of the structures resulted from tectonic forces and changes in the original conditions of the formation of the rocks (Figures 2-8). This is an indication that the area forms part of the area affected by the regional tectonic activities of the Pan African Orogeny (450±150ma) which affected a greater part of the Nigerian Basement Complex rocks (Chukwu *et al.*, 2023a). Tectonic activities are believed to have deformed pre-existing rocks of the gneiss complex. These imposed NW-SE compressional forces with resulting NNE-SSW structural trends superimposed over an initially dominant N-S trend, E-W trends are also evident (Chukwu *et al.*, 2023a).

It has been observed that the Pan-African granite development most probably exploited existing structures in the older basement (Oluyide, 1988). The tectonic structures are indications of deformation stress that is higher than the natural values the rocks can withstand hence, their consequent deformation. The magnitude of the resultant deformation usually depends mainly on the competence of the rocks and the ratio.

The primary mineralization of the area depends largely on the structural trends of the host rock because geologic structures control the localization of ore fluids (Oluyide, 1988).
The common structures observed are joints, fractures, foliation, lineation, dykes, veins, and folds (ptygmatic folds). Most of the outcrops encountered in the Shintaku area contain structures in various degrees, as shown in Figures 3 to 8.

From field observations, the joints in the Shintaku areas appear to have been created by either strict movement of the rock body perpendicular to the fracture or by varying degrees of lateral displacement parallel to the plane of the fracture that remains invisible at the scale of observation (Figure 3).

Figure 2: Joint on the L5

A pegmatitic quartzo-feldsparthic vein (a crack filled with quartz and feldspar group of minerals) was mapped close to the mega mosque near the Omachi palace. It is dominated by very coarse-grained quartz and feldspar minerals. These veins can be found in a variety of settings, including in granite, granitic pegmatites, and some metamorphic rocks. They are often associated with mineral deposits, such as quartz, mica, and tourmaline. These veins can also be a source of rare minerals, like beryl and topaz (Figure 3).

Figure 3: Pegmatitic quartzo-feldsparthic vein on a migmatite gneiss (L8)

Faults, type of geological structure that form when rocks break and move past each other with obvious displacement, were also encountered and mapped within the study area. These faults may have been caused by tectonic forces, like when two plates collide or when one plate slides past another, or they could have been caused by stresses within the crust itself, like when there is a change in temperature or pressure. (Figures 4 and 5). Both the dextral and sinistral types of faults abound in the area.

Figure 4: Reversed fault on migmatite gneiss at L2Figure 5: Dextral fault on migmatite-gneiss at L8

Aim and objectives of this work

The major aim is to investigate the tectonic setting of rocks around Shintaku area, south-east Lokoja, North-Central, Nigeria, with the objective of producing a geologic map of the Shintaku area and using Atomic Absorption Spectrophotometer (AAS) equipment of analyses to obtain information about the major oxides and some other relevant variables from the rock samples to achieve the interpretation of the area.

Materials and methods

Field mapping and Laboratory sample analyses using Atomic Absorption Spectrophotometer are the methods deployed for the different aspects of this study. AAS has had profound effects not only in exploration geochemistry but equally in water quality studies, metallurgy, biology, agronomy, environmental control and some other fields in which inexpensive, accurate, precise and rapid methods for the determination of many elements, at low levels of detection (high sensitivity) are needed (Levinson, 1974).

Field Mapping

Methods of Data Collection

The methods in this study are field mapping and laboratory analyses. The field work requires outcrops descriptions, measurement, and sample collection. The rock textures and possible minerals were observed in the field. Field mapping was done around Shintaku areas to investigate the local geology of the area. The study started with geological mapping, which lasted for a week, was intensive and then the laboratory analyses of the samples.

Laboratory analysis

Eight representative samples were subjected to geochemical analyses to obtain the major oxides and other relevant variables using the Atomic Absorption Spectrophotometer (AAS) equipment thus:

A fresh representative sample was first pulverized with mortar and pestle.
About 1g of each sample was weighed and put into the dry digesting tube.
5ml of conc. per chloric acid was added in the ratio and stirred.
The digesting tube is placed on the water-bath set at 100^0C to boil for 2 hours.
To avoid caking, the sample was shaken vigorously to produce a stock solution.
The stock solution is filtered and made up to 50mls with distilled water.
The stock solution was used directly to determine the elements.

The hydride generation technique of the AAS equipment was deployed which separates the analyte from the matrix by conversion to the volatile hydrides and offering a pathway to trace analyses of elements such as As, Sb, and Se that cannot be analyzed by the conventional methods

Results

Lithological Description

The major lithological units mapped in the study area include granites, banded gneisses, migmatite-gneisses, granite-gneisses, and mica schist (Figure6; Table 3.1).Others include pegmatitic veins, aplites and other minor intrusives such as quartz veins and quartzofeldspathic veins. Alluvium, laterites and soils occur as superficial deposits

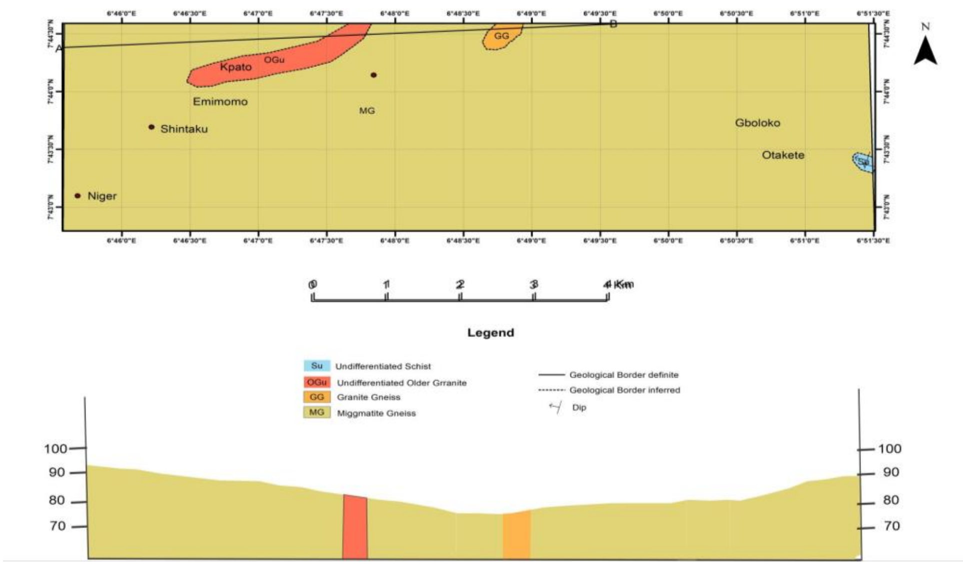

Figure 6: Geologic map of the Shintaku area showing the cross-sectional area (Chukwu et al., 2023b)

The geology of the area is similar to those of the adjoining areas in the southwestern part of Lokoja and substantially reflects the effects of the Pan-African Orogeny whose impacts were pervasive in the Nigerian Basement Complex.

Table 3.1: Megascopic description of outcrops

LOCATION	LONGITUDE AND LATITUDE	ELEVATION	STRUCTURE	TEXTURE	TREND OF INTRUSION AND VEIN	MODAL ANALYSIS	STRIKE/DIP	LITHOLOGY	NATURE OF OUTCROP
KPT-1	N-07°43′02 □ E-O6°47′08□	100m	Fracture; Recumbent folds; Intrusion	Coarse grained	302^0NS	Quartz-25% Feldspar- 45% Biotite-20% Hornblende-10%	Strike-360°N Dip-18°E	Granitic gneiss	Local
ICH-1	N- $07^0$42'545" E- $06^0$46'600"	61.6m	Presence of planar surface, presence of joint, presence of folds	Porphyroblastic	Trend of vein 232^0W	Feldspar-50% Quartz- 40% Biotite- 10%	Strike- 276^0NWW Dip-54^0W	Migmatitic	Extensive
SHT-2	N- $07^0$43'293" E- $06^0$45'73"	51.9m	Presence of quartzo-feldsparthic vein in form of a dyke, presence of cracks, joints, fold and fault.	Porphyritic	Trend of vein 340^0NW. Trend of fault-120^0SE	Quartz-40% Feldspar-50% Biotite-8% Muscovite-2%	Strike-50^0SE Dip-40^0SW	Granitic	Local
SHT-4	N- $07^0$43'379" E- $06^0$45'745"	56.2m	Presence of quartzo-feldsparthic vein	Medium grained		Feldspar-10% Quartz-90%		Quartz vein	Local
SHT-3	N- $07^0$48'410" E- $06^0$45'791"	59.0m	Presence of planar structure, presence of feldspar vein,	Medium to coarsed grain	Trend of vein 20^0SW	Feldspar-50% Quartz-40% Biotite-10%	Strike- 268^0NWW Dip-40^0E	Migmatitic	Extensive
ICH-2	N-07°43′ 23″ E-O6°51 27″	120m	Boulder; Folds & Veins.	Medium grains	118^0NS	SiO_2=55% $KAlSi_3O_8$=20% Mica =25%	Strike: 264^0NW Dip: 53^0E	Mica-schist	Local
KPT-2	N- $07^0$44'182" E- $06^0$47'533"	95.7m	Presence of cross-cutting Quatzo-feldsparthic vein, presence of exfoliation.	Medium grained size	318^0NS	Quartz-30% Feldspar-30% Biotite- 40%	Strike- 296^0NWW Dip-74^0E	Granitic	Extensive
EMM	N- $07^0$44'089" E- $06^0$46'787"	56.3m	Presence of exfoliation, presence of vein,	Medium-coarsed grain	Vein trend=348^0NS	Feldspar- 30% Quartz-20% Biotite-50%	Strike-182^0SE Dip-44^0SE	Migmatitic	Extensive

Geochemical Results from the Laboratory Analysis.

The bulk rock geochemistry (result of the major oxides) arising from the AAS equipment shows enrichment in SiO_2, Al_2O_3 and less so inK_2O and total iron (Fe_2O_3) but depletion across the other oxides (Table 3.2). Similarly, the enrichment levels for the Ba, Sr, Zr, Rb and Zn, Sc (in some locations) in Table 3.3 are remarkable. The occurrences of Cd, Co, Cu, Cr, and Nb appear somewhat even. Hydrothermal alteration and magmatic processes could be implicated for this variations and redistributions, respectively.

Table 3.2 Major Oxides composition of the rocks mapped in the area (w%)

Sample ID	SiO_2	AI_2O_3	Fe_2O_3	TiO_2	CaO	P_2O_5	K_2O	MnO	MgO	Na_2O
L1	76.27	11.65	2.97	0.25	0.23	0.03	5.2	0.01	0.04	3.02
L2	79.5	13.48	0.4	0.01	0.27	0.22	3.53	0.04	0.11	2.26
L3	69.36	16.25	3.17	0.45	4.08	0.1	1.3	0.03	1.54	3.65
L4	62.7	13.5	8.44	1.19	3.78	0.26	2.94	0.06	0.97	3.21
L5	69.56	10.25	3.52	0.42	0.36	0.08	3.21	0.01	0.5	3.2
L6	79.7	13.35	0.43	0.01	0.27	0.22	3.5	0.06	0.14	2.24
L7	62.32	14.25	3.15	0.51	4.08	0.12	10.3	0.03	1.52	3.65
L8	63.72	10.52	3.44	1.19	3.78	0.26	9.9	0.06	0.97	3.21

Table 3.3. Trace and Rare Earth elements composition of the rocks in the area (ppm)

Sample ID	L1	L2	L3	L4	L5	L6	L7	L8
Ba	1130	1512	1445	1300	6345	1512	1469	1340
Cd	10	10	12	14	8	10	12	16
Co	43	26	22	21	12	26	20	25
Cu	25	26	24	28	25	26	22	24
Cr	17	58	22	19	12	58	12	29
Nb	25	35	15	12	15	35	15	12
Ni	83	62	10	5	10	62	10	5
Pb	21	157	25	25	62	157	22	20
Sc	90	10	110	8	10	10	120	8
Sr	189	965	77	120	180	956	74	120
Rb	10	191	150	140	18	191	158	140
Zn	120	96	50	72	8	96	55	72
Zr	180	250	283	320	13	250	290	350
Be	0.72	0.48	0.64	0.63	0.52	0.43	0.6	0.65
Ce	2.42	0.24	0.38	0.25	0.22	0.22	0.4	0.23
Sc	1.2	1.22	10.2	21.3	0.3	1.2	10.5	21.5
Nd	0.2	0.37	0.92	0.3	0.4	0.34	0.9	0.33
Ga	0.22	0.3	0.44	0.5	25.4	0.33	0.57	0.52
Pr	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Eu	0.33	0.8	0.6	0.34	0.66	0.8	0.58	0.35
La	0.22	0.2	0.24	0.24	0.2	0.2	0.25	0.2
Tb	0.6	0.2	0.7	0.2	0.2	0.2	0.65	0.2
Gd	0.2	0.2	0.2	0.22	3.2	0.2	0.2	0.22
Er	0.34	0.3	0.3	0.2	0.22	0.3	0.32	0.2
Yb	0.6	0.5	0.32	0.6	0.2	0.5	0.3	0.6
Dy	0.54	0.4	0.46	0.52	0.55	0.4	0.44	0.52
W	0.022	0.052	0.04	0.045	0.03	0.052	0.04	0.045

Discussions

Plotting TiO_2-K_2O-P_2O_5in line with Pearce *et al.,* (1975) – Figure 7), shows a differentiation between the oceanic basalt field from the continental basalt field. It shows that the samples obtained from the study area show continental tholeiites' characteristics i.e. continental basalt field. This suggests that they may have been derived from mantle plumes or the melting of the subcontinental lithosphere due to mantle plumes (Condie, 1967) to form the continental crust.

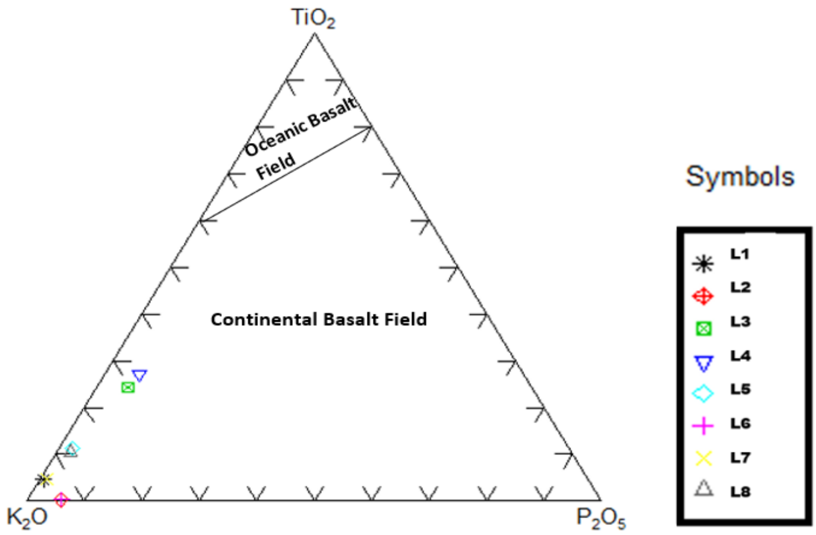

Figure 7: TiO_2-K_2O-P_2O_5

When the geochemical results from the samples obtained from the study area were plotted on the Ti vs Zr diagram after Pearce (1982), they show varieties ranging from island arc lavas to within-plate lavas, whereby a sample plots within the island arc lava, two within-plate lava, and another undefined (Figure. 8). Some of the lava might have been moderately contaminated by crustal materials but the result favours the continental than the oceanic crust environments.

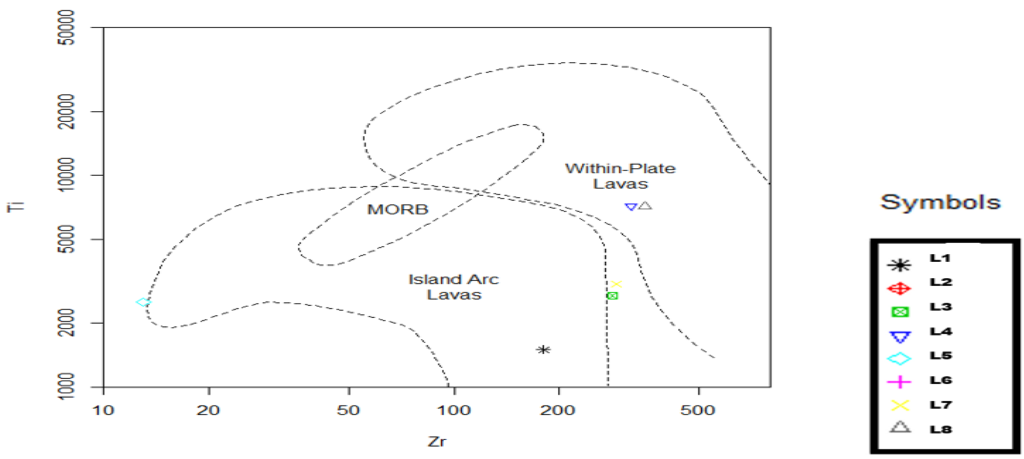

Figure 8: Ti vs Zr diagram

On the R1-R2 plot (Figure 9) after Batchelor and Bowden (1985), most of the sample plots range from anorogenic to post-orogenic fields. This shows that the formation of the rock varied from anorogenic to post-orogenic periods. Syn-collisional and post-orogenic periods are synonymous with volcanic arc granites (VAG) in the classification of Pearce *et al.*, (1984) and this environment or setting is usually related to the process of crustal thickening often by the under-thrusting of crustal "slice" below another, Batchelor and Bowden (1985). This then suggests that the samples may have resulted from crustal thickening and formed from the metamorphism of the orogenic granitoid on the continental crust.

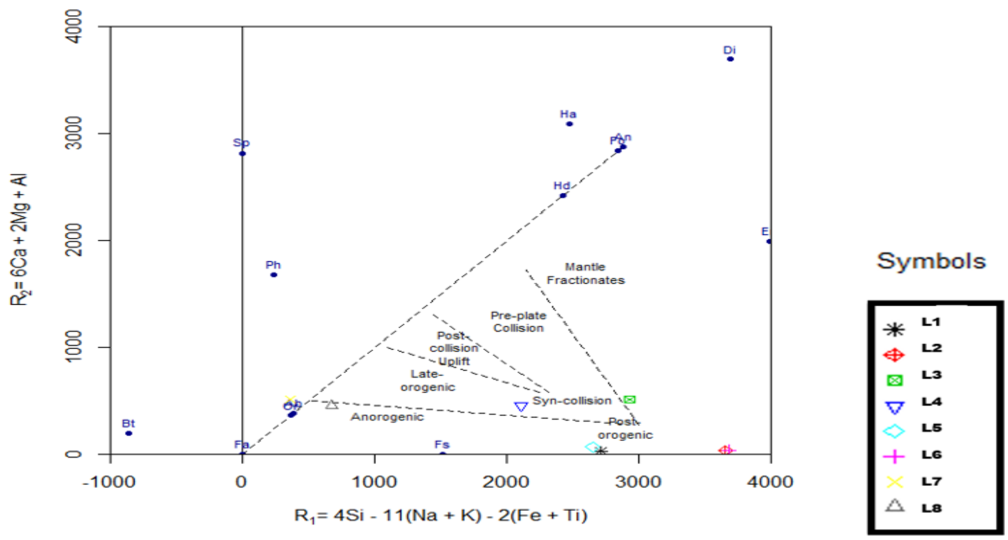

Figure 9: R_1-R_2 diagram

The geotectonic discrimination plots of Maniar, and Piccoli, (1984) – Figure 10, suggests that the rock samples from the Shintaku areas were formed from island arc granitoids (IAG), continental arc granitoids (CAG), continental collision granitoids (CCG), continent-epeirogenic uplift granitoids (CEUG), post-orogenic (PO), and rift-related granitoid (RRG). These features indicate that the protolith lithology around Shintaku area rocks is arc-related and thus suggests arc tectonic environmental setting of the continental crust.

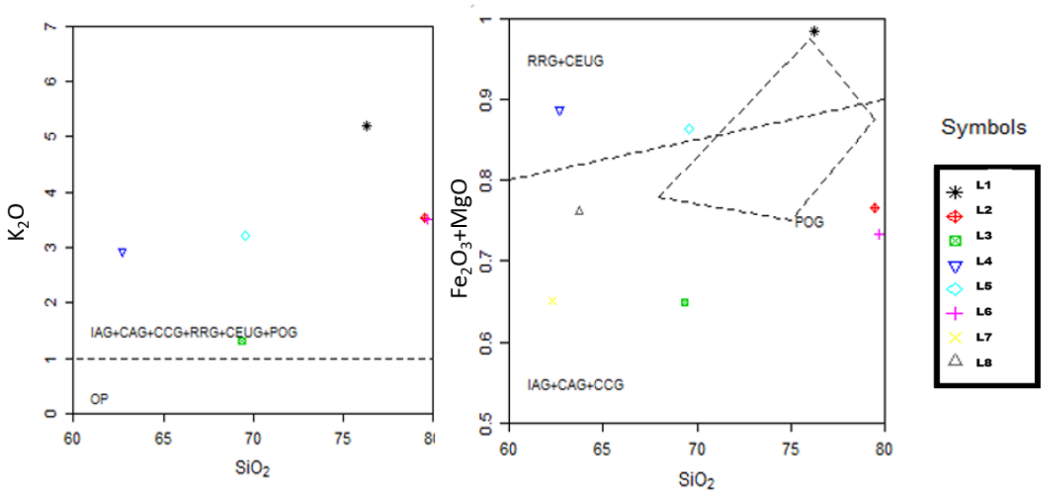

Figure 10: Tectonic discrimination diagram (abbreviations: IAG-island arc granites, CAG-continental arc granites, CCG- continental collision granites, POG-post-orogenic granites, CEUG- continent-epeirogenic uplift granite, RRG- rift related granites).

The Nb/Yb vs TiO_2/Yb diagram after Pearce (2008) is deployed for the identification of crustal signature of magmas that have interacted with continental crust on ascent, or have a subduction component, or are displaced. The diagram has a diagonal MORB-OLB array containing N-MORB, E-MORB and OIB end members. It was observed from the diagram (Figure 11) that the lithology obtained from the study area plots within OIB or near mantle array field which supports others on the continental crust setting.

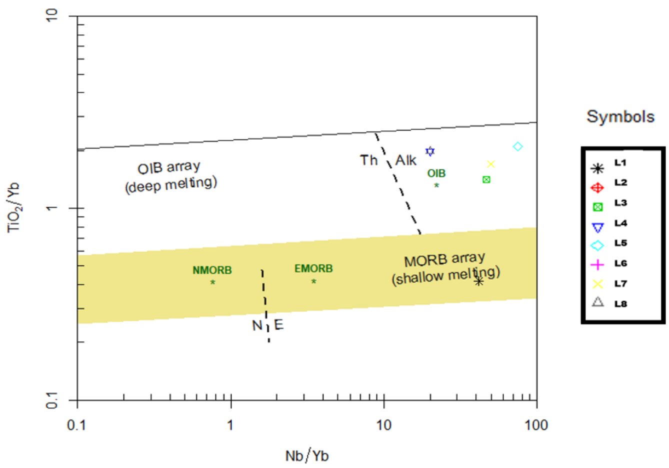

Figure 11: Discrimination diagram of Nb/Yb vs TiO_2/Yb

Conclusions and Recommendations

Conclusions

The main types of rocks in the examined region are granites, banded gneisses, granitic-gneisses, mica schists, and migmatite-gneisses, most of which are the consequence of the metamorphic reworking of the original granitic rocks. These rocks could be associated with and host valuable mineral resources. They are equally valuable as construction materials in almost all types of terrains.

The TiO_2-K_2O-P_2O_5 plot in Pearce *et al.*, (1975) shows that the samples obtained from the study area have the characteristics of continental tholeiites suggesting that they may have been derived from mantle plumes or melting of the subcontinental lithosphere occasioned by mantle plumes. The Ti vs Zr diagram after Pearce (1982), shows varieties ranging from island arc lavas to within-plate lavas.

On the R1-R2 plot, most of the sample plots range from anorogenic to post-orogenic fields. This shows that the formation of the rock varied from anorogenic to post-orogenic situations. Hence, the samples can be inferred to have resulted from crustal thickening and formed from the metamorphism of the orogenic granitoids. The Nb/Yb vs TiO_2/Yb diagram has the lithologies obtained from the study area plot within OIB or close to the mantle array field. This, again, is more related to the continental than other environmental settings.

The geotectonic variation plots in Maniar and Piccoli (1984) suggest that the samples from the Shintaku area were formed from island arc granites (IAG), continental arc granites (CAG), continental collision granites (CCG), continent-epeirogenic uplift granites (CEUG), post-orogenic (PO), and rift-related granitoid (RRG). These characteristics imply that the protolith lithology around Shintaku area rocks is arc-related and thus arc tectonic setting could be strongly recommended.

Hydrothermal alteration processes in the altered granitic rocks may have caused the variation in the major oxides distribution. Similarly, weak to moderate effects of magmatic processes may have, as well, affected the distribution of the trace elements. The later could equally have been so redistributed by post magmatic processes, surficial or underground water, which greatly influences such redistributions.

Recommendations

We recommend further studies on the area using more sensitive and sophisticated instruments and instrumentation such as microprobe for the buck rock chemistry, LA-ICPMS for the trace elements and the REEs and trying the age dating of the rocks with the more accurate U-Pb methods. The results from the recommendations with be insightful given the potentials presented by the area for mineral resources endowment.

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