Petrochemistry of Plutonic Rocks of Kanzachaung Batholith exposed in Kon gyi - Ka dat Area, Kawlin Township

Shwe Sin Nwe[1*], Maung Maung Naing[2] & Tin Aung Myint[2]

Abstract

The igneous rocks exposed in the Kon gyi and Ka dat Area are composed plutonic rocks of granite, granodiorite, diorite, monzonite and gabbro. Major- minor oxides and trace elements of igneous rocks of Kon gyi and Ka dat area, part of Wuntho massif, and other analyzed data around the study area are used to discuss the petrochemical characters. According to the chemical classification of various diagram, the plutonic rocks of the study area belongs to the acid to basic clan; within the field of high K-, low K- Series; subalkaline and calc-alkaline suit; and peraluminous to metaluminous series. Harker's variation diagram of the study area, the granodiorite was suggested that these are drived from the highly evolved melt of magma and fractional crystallization. The granodiorite of the study area shows the calc-alkaline suit of AFM diagram, and most of the metaluminous nature, with respect to the mol of [Al2O3/ (Na2O+ K2O +CaO)] and mol of [(Na2O+ K2O)/ Al2O3]. Most of the granitoids are typical I- type characteristics. According to the trace-element data, the granodiorite and diorite of the study area shows the volcanic-arc granite (VAG), I-type granitoid and upper crust associated with the mantle derived the magmatic arc.

Key words : Wuntho massif, trace-element, calc-alkaline, volcanic arc granite (VAG), I-type

Introduction

The study area, parts of the Wuntho Massif, is situated within the Kawlin Township, Sagaing Division, and Northern Myanmar. It is located about 24 km north-west of Kawlin. This area is bounded by Latitude 23° 46´ N to 23° 54´ N, and Longitude 95° 27´ E to 95° 34´ E. It covers parts of 84 M/5 and 84 M/9 one inch topographic maps and UTM map sheet No.2395/05 to No.2395/09. It is about 17 km long in N-S direction and about 12.8 km wide in E-W direction covering approximately 218 square kilometers (see Fig. (1)).

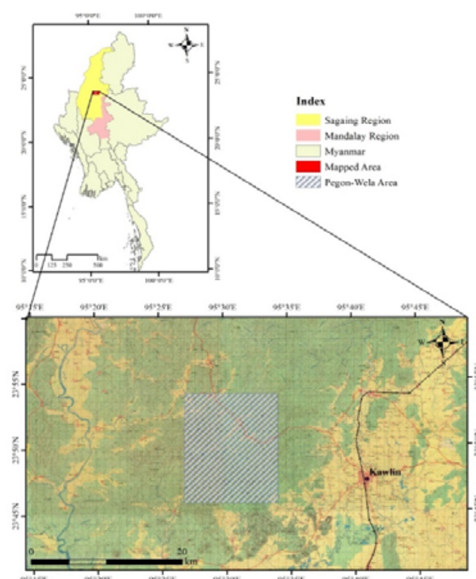

Figure (1). Location map of the study area (source: MIMU, 2010).

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Regional Geologic Setting

The Kon gyi and Ka dat area lies at southern part of the Wuntho Massif which is a part of central volcanic line. The Wuntho Massif is an elongated batholith trending NNE-SSW. It is about 40 km wide and 190 km long and consists of several types of igneous rocks. The Wuntho Massif includes the 75-km-long NNE trending Kanzachaung batholith in the south, the Pinhinga Plutonic Complex in the northeast, and the Taungthonlon extinct stratovolcano. Biotite and hornblende-biotite Granodiorites from the Kanzachaung batholith in theWuntho-Banmauk segment of the arc have given K/Ar biotite ages of 93.7 ± 3.4 Ma and 97.8 ± 3.6 Ma (UNDGSE, 1978a). Moreover, according to Mitchell (2017), isotope age on the Kanzachaung batholith is early Upper Cretaceous in age. Satellite images and regional geologic setting of the study area are shown in figure (1.1).

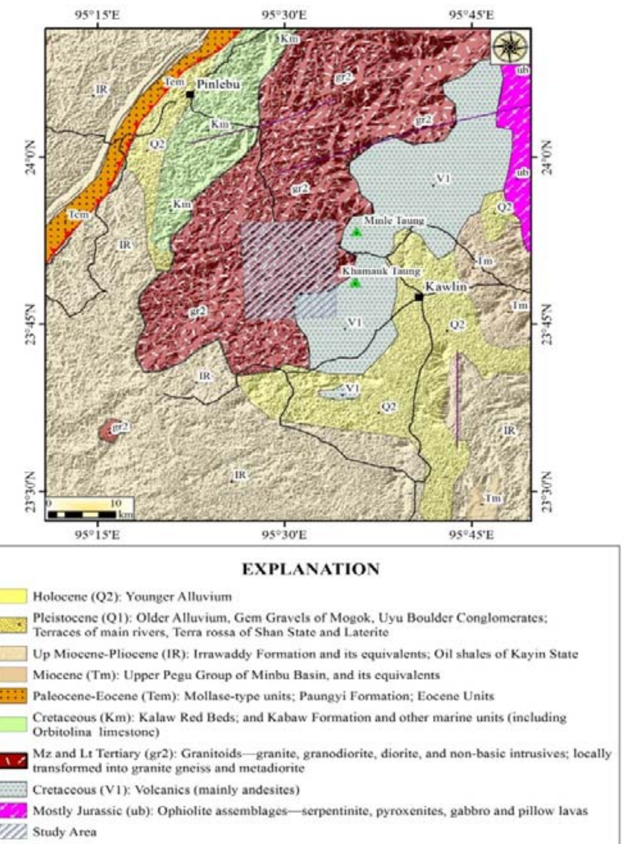


Figure (1.1). Regional Geological Map of the study area and its surroundings (Source Geological map of Myanmar, MGS, 2014)

Materials and Methods

The present study includes field methods and laboratory investigations and employs the three methods to achieve the objectives of the research. The three methods are (a) landsat image and aerial photographic interpretation were made before doing field trip, (b) detailed studies of outcrops and sampling applying the GPS method and (c) using the XRF analysis to discuss the major and trace element content. Systematic sample collection of rocks in some individual rock types. Rock samplings were made for petrological and geochemical analysis studies.

Petrochemistry

Petrochemical investigation of Fifteen representative rock samples were collected from the several locatities of research area. These samples were freshed, lacking any alteration and veining as much as possible. Major, trace element oxides and rare earth element composition were determined by wavelength dispersive XRF spectrometer. The analysis was made at DSSTRC (Defence Service Science and Technology Research Center) in PyinOoLwin Township. The igneous rocks exposed in the Kon gyi - Ka dat area are mainly biotite granodiorite, hornblende biotite granodiorite, granite, gabbroic diorite and diorite. Accuracy and precision for major oxides and trace elements were estimated to be better than 1% relative standard deviation, based on the standard analytical results and precision test. Analyzed samples, locations and their symbols are shown in Table (1).

Petrochemical Characteristics of Plutonic Rocks

Major and Trace Elements Characteristics

The considerable amount of plutonic rocks of the research area, major element values are found range for SiO_2 from (51.788 to79.346) wt.% and for other elements' Al_2O_3 (11.912-18.792%) wt.%; Fe_2O_3 (0.867-9.717) wt.%; TiO_2 (0.086-1.101) wt.%; MnO (0.010-0.274) wt.%; Na_2O (0.115-7.716) wt.%, MgO (0.124-5.235) wt.%, K_2O (0.105-3.242) wt.%; CaO (0.937-8.954) wt.%; Na_2O (1.717-7.716) wt.%, and K_2O (0.165-3.242) wt.% respectively.

Differentiation Index (DI) of plutonic rocks in the study area varies from 68.7 to 95.2. CIPW NORM with hypersthenes contents range from 1.09 to 18.21. Magnetite contents 0.54 to 4.22, ilimenite contents 0.17 to 2.09, zircon content 0.01 to 0.07, total alkali content (Na_2O+K_2O) range from 3.594 to 7.881, while (Na_2O+K_2O+CaO) contents 6.285 to 12.549 and (Al_2O_3+ Na_2O+K_2O) contents 15.901 to 24.564 were noted.

Alfred Harker (1909) proposed that the variation diagram of SiO_2 versus other major oxides of the rocks show the trend of the continuous magma process, such as magma differentiation or fractional crystallization, assimilation. It can be seen that Al_2O_3, FeO_t as total iron, TiO_2, CaO, and MgO decrease with increasing SiO_2. In the Na_2O versus SiO_2 diagram, shows positive trend. K_2O shows roughly in positive correlation characteristics. Variation of P_2O_5 is not significant in Fig (2). These facts suggest that the granitoids of the Kanzachaung batholith was derived from the highly evolved melt and fractional crystallization

Table (1). Analyzed Samples and their Locations of the Study Area

No.	Sample No.	Symbol	Lithology	Location (Lat& Long)	Analysis Department
1.	L3D3		Granite	N 23˚50'5289" E 95˚28'4099 "	DSSTRC
2.	L9 D10		Granite	N 23˚50 '4463" E 95˚28'1087"	DSSTRC
3.	L4 B11		Granite	N 23˚51'3216 " E 95˚28'303"	DSSTRC
4.	L7 D8		Granite	N 23˚51'0394" E 95˚28'3295"	DSSTRC
5.	L18 B30		Granite	N 23˚5 '2697" E 95˚27'5007 "	DSSTRC
6.	L7F8		Granodiorite	N 23˚52'2581" E 95˚29'4088 "	DSSTRC
7.	L4 E4		Granodiorite	N 23˚48 '2813" E 95˚30'0532"	DSSTRC
8.	L3E3		Diorite	N 23˚49'2670" E 5˚29'3550"	DSSTRC
9.	L13 C15		Diorite	N 23˚49 '5235" E 95˚29'0920"	DSSTRC
10.	L1 D1		Diorite	N 23˚50 '4398" E 95˚28'5223"	DSSTRC
11.	L3 F6		Diorite	N 23˚53 '0673" E 95˚30'4898"	DSSTRC
12.	L10 F8 (2)		Diorite	N 23˚47 '429 " E 95˚29 '380"	DSSTRC
13.	L2 A2		Monzonite	N 23˚47'4624" E 5˚27'0908"	DSSTRC
14.	L6 A4		Monzonite	N 23˚47'5624" E 95˚27'1918 "	DSSTRC
15.	L12 D11+		Gabbro	N 23˚49'5135" E 95˚27 '5987"	DSSTRC

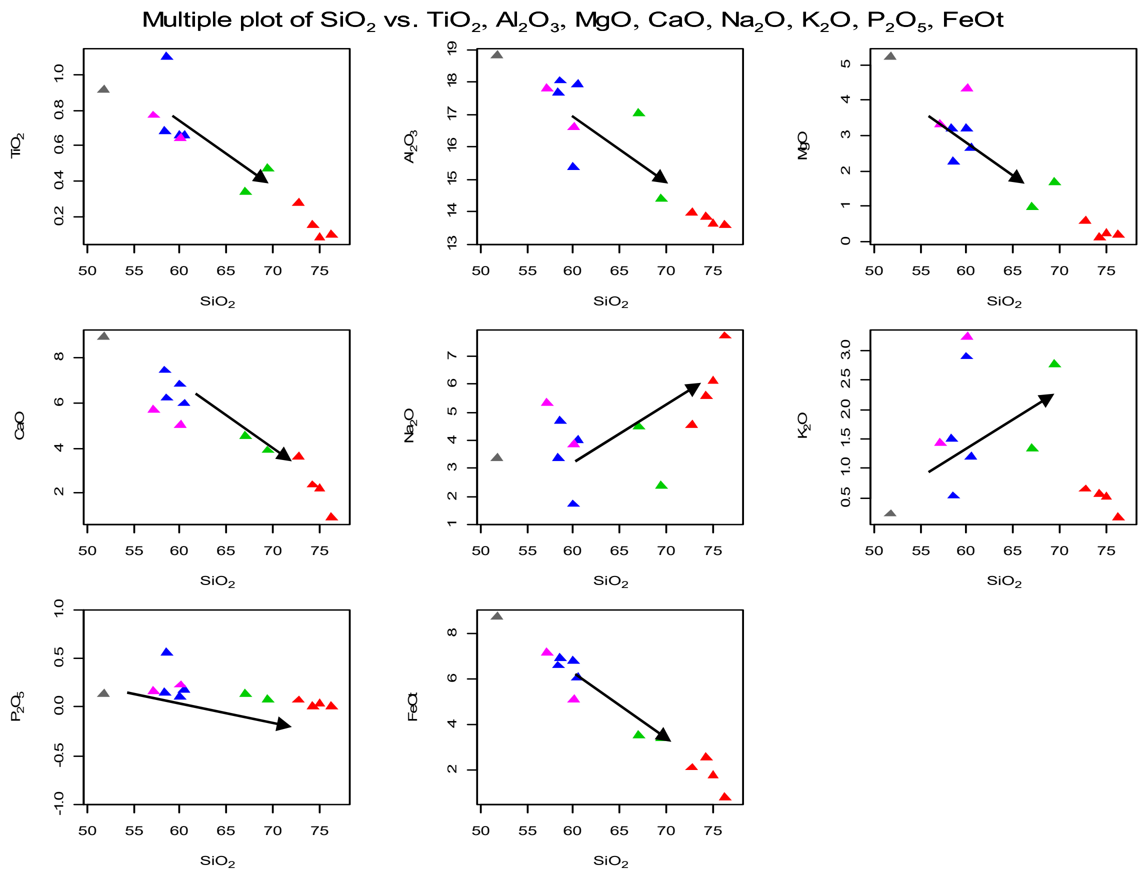
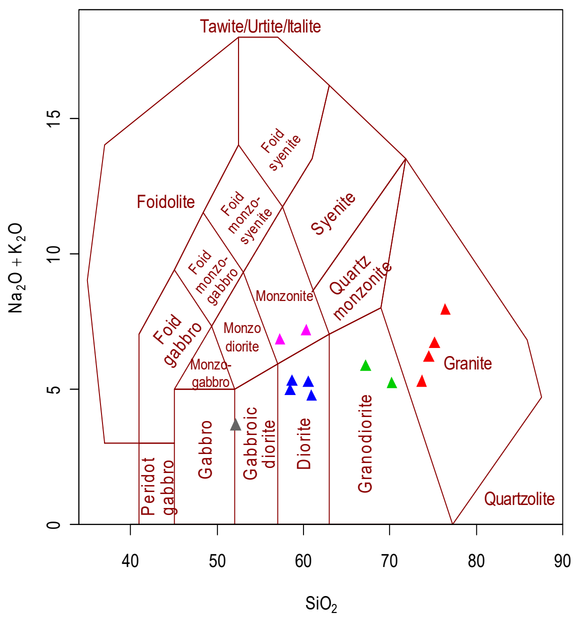


Figure (2). Harker variation diagram for major oxides verses SiO_2 for plutonic rocks of the study area (Harker, 1909 in Rollionson, 1993)

Classification of Plutonic Rocks

According to (Middlemost, 1994), major elemental plot confirmed that the plutonic rocks of study area are granite, granodiorite, gabbroic diorite, diorite and monzonite (Fig.3). The sum of Na2O and K2O content (total alkalis, TA) and the SiO2 content (S) are taken directly from XRF analysis with major wt. % oxide and plotted onto the classification diagram. Based on the silica (SiO2) and alkali feldspar (Na2O+K2O) content, (SiO2 Vs Na2O+K2O) binary plot diagram TAS, plutonic rocks of research area belong to acidic to basic rocks of granite to gabbro and showed the nature of Sub-alkaline field. The influence of silica and alkali contents is reflected in the names of the two original major series: alkalis and subalkalis. Alkaline rocks are richer in alkalis and are commonly silica-under saturated, whereas subalkaline rocks are silica-saturate to over-saturate. (Stephen A. Nelson 2011). The Sub-alkaline series is further divided into tholeiitic and calc-alkaline series by Irvine and Barragar (1971). By plotting data on AFM diagrams A= Na2O+K2O, F= Fe2O3, M=MgO (after Irvine and Barragar, 1971) for determining submagma type, is used to distinguish between tholeiitic and calcalkaline differentiation trends, it showed that plutonic rocks of the study area generally belong to the calc- alkaline group (Fig. 4).



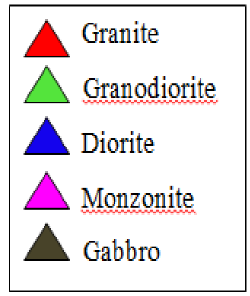
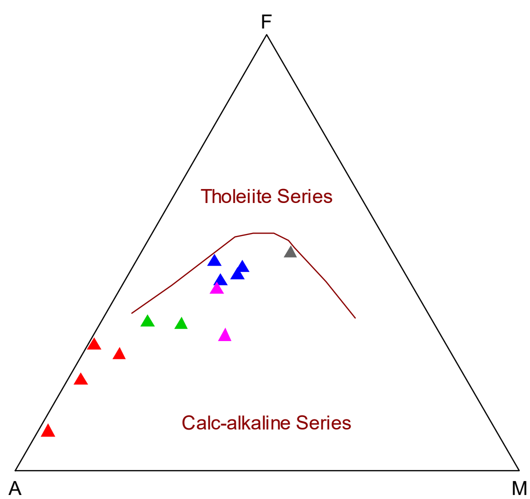


Figure (3). Alkali-silica TAS diagram by Midddlemost (1985) showing the classification of plutonic rocks of study area



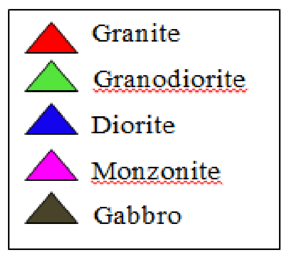
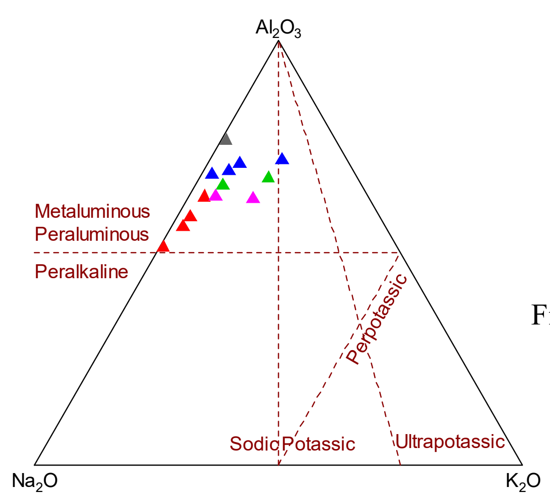


Figure (4). AFM diagram for determining submagma type (tholeiitic or calc-alkaline series) (Irvine and Baragar, 1971)



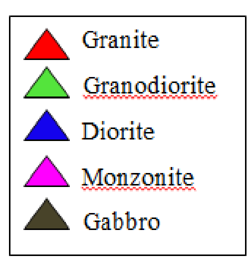


Figure (5). Molar Na_2O-Al_2O_3-K_2O diagram showing the study area falls in Metaluminous-per-aluminous field (symbols from Table. 3.1)

By plotting data on molar Na2O-Al2O3-K2O diagram, the plutonic igneous rocks of the study area fall in peraluminous and metaluminous field clans (Fig. 5). Based on the alumina saturation and alkali content, Shand (1943) classified into four groups. According to the alumina saturation content of the Shand (1949), A/NK (molecular Al2O3/(Na2O+K2O)) versus A/CNK (molecular Al2O3/ (CaO+Na2O+K2O)) diagram, most samples of the study area fall in metaluminous field whereas one sample fall peraluminous field (Fig. 6).

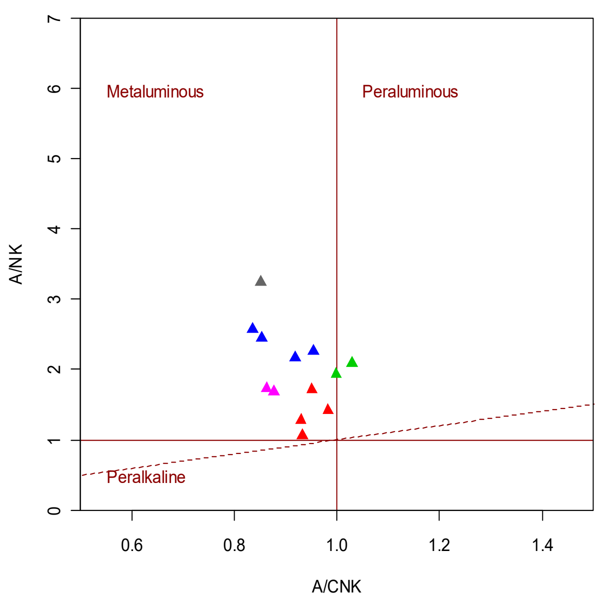
In order to establish different peraluminous series Debon& Le Fan (1983) distinguished four types of peraluminous granites. These are Highly Peraluminous granitoids (h-P), Moderately Peraluminous granitoids (m-P), they are typical S-type trend (White & Chappell, 1988). Low Peraluminous granitoids (l-P) which occupy by evolve from metaluminous from slightly peraluminous compositions, this correspond to the calc-alkaline suites (Debon& Le Fort (1983). Highly felsic Peraluminous granitoids (f-P) composed of very acidic members.

Alluminium saturation index (ASI) of granitoid rocks of the study area according to Villaseca et al., (1998) is characterized by one granodiorite in low peraluminous field and the other are metaluminous field (Fig. 7).

Molecular A/CNK vs. SiO2 diagram defines A/CNK>1.1 as S-type and A/CNK<1.1 as I-type. According to this diagram, the granitic rock falls in I-type field (Fig. 8).

The sodium contents of the I- and S-type granites are relatively high and low, respectively, as noted by Chappell and White (1974). Alluminium saturation index (ASI) of granitoid rocks of the study area is strongly metaluminous with A/CNK value <1.1, Normative corundum value <1% except one sample. Relatively hight sodium Na2O content > 3.2%, with approximate 2% K2O and higher SiO2 in general. Various plots are used to distinguish the genetic type of granitoid rocks of the study area. All variation diagrams show more irregular pattern by all major oxide (wt %) and trace elements (ppm) Vs SiO2 indicates that they are of I –type character. Notably that, the presence of porphyry-cupper of the study area more interesting case of them.

The above mentioned facts all suggest that the granitoidsrocks of the study area has I-type characteristics on the basis of the schemes of Chappell & White (1974).



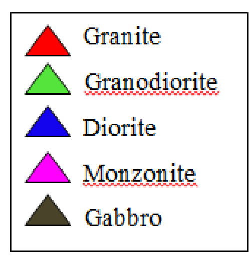
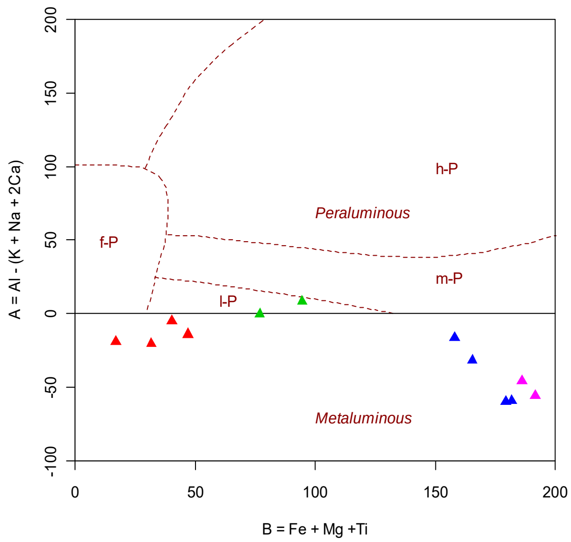


Figure (6). A/NK (molecular Al_2O_3 /(Na_2O+K_2O) versus A/CNK (molecular Al_2O_3/(CaO+Na_2O+K_2O)) diagram by Shand (1943) showing metaluminous and peraluminous field



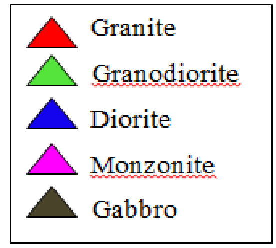
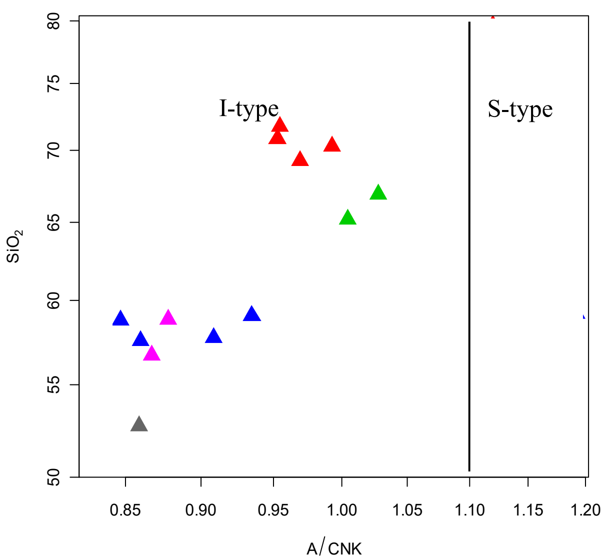


Figure (7). Composition of the granite in the A-B diagram of Debon& Le Fort (1983) modified by Villaseca et al., (1998)



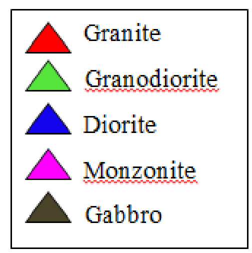


Figure (8). Molecular A/CNK vs. SiO_2 diagram for classification of I-type and S-type granitoids rocks (after Chappell & White, 1974)

Tectonic Discrimination of Granitoid Rocks Based on Major Elements Petrochemical Data

Tectonic environment for the granitoid rocks of the study area has been done by the schemes of Maniar and Piccoli (1989). They categorized the granitoid by tectonic environment as follows:

Orogenic Granitoids

(a) Island arc Granitoid (IAG)
(b) Continental arc Granitoid (CAG)
(c) Continental collision Granitoid (CCG)
(d) Post orogenicGranitoid (POG)

Anorogenic Granitoid

(e) Rift-related Granitoid (RRG)
(f) Continental epiorogenic uplift Granitoid (CEUG)
(g) Oceanic plagiogranite (OP)

The discrimination of granitoids is based on the major element chemistry. Various discrimination plots are presented which sequentially discriminate the different tectonic environments. According to Maniar and Piccoli (1989), Al_2O_3 vs. SiO_2 attempts to plot the granitic rocks into IAG + CAG + CCG and POG field. F/AFM Vs M/AFM diagram and F/ACF Vs C/ACF diagram classify the granite rocks into IAG + CAG +CCG and POG environments (Fig.9). From these figures, the granitoid rocks of the study area fall into IAG + CAG + CCG and POG fields. Based on the above data, the Kon gyi - Ka dat area granitoids fall in orogenic granitoid environment.

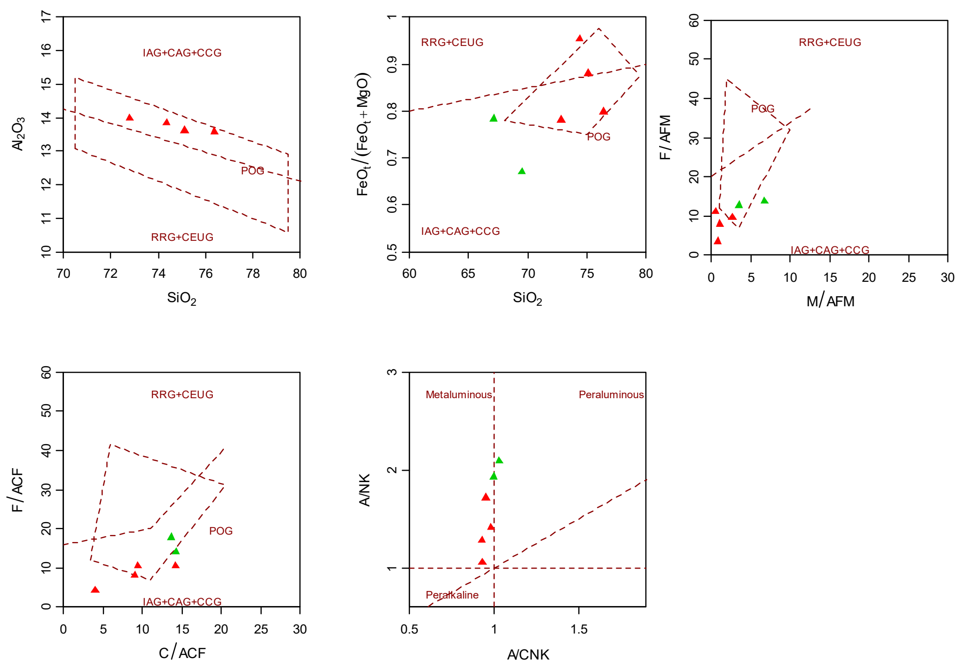


Figure (9). (Al_2O_3 Vs SiO_2), ($FeO_t/(FeO_t+MgO)$ Vs SiO_2), (F/AFM Vs M/AFM), (F/ACF Vs C/ACF) and (A/NK Vs A/CNK) diagrms showing the tectonic setting of the granitoid rocks of the study area (after Manior & Piccoli, 1989).

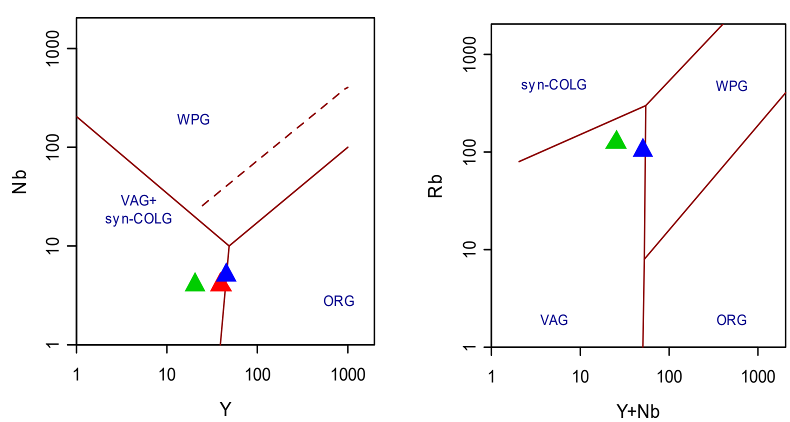


Figure (10). The Nb-Y and Rb-(Y+Nb) discrimination diagrams showing the granodiorite and diorite of the study area (Pearce et al., 1984)

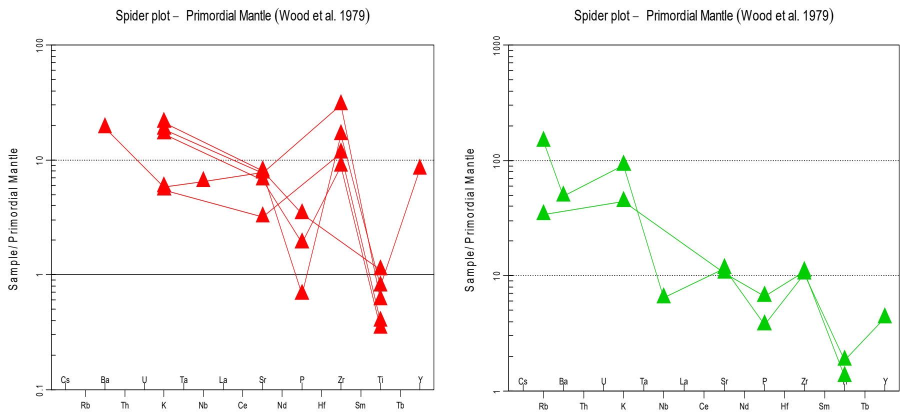


Figure (11). (a) (b) Primordial-Mantle normalized spider diagram of the granitoid rocks of the study area (source Wood et. al., 1979)

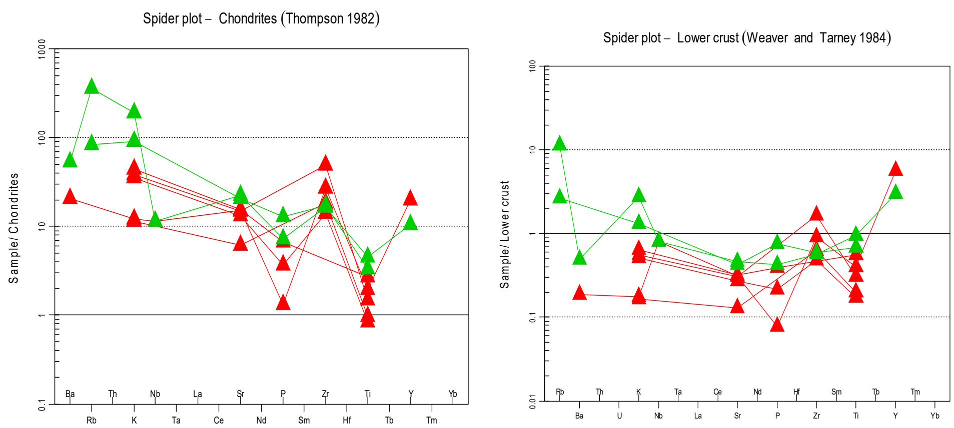


Figure (12). (a) (b) Chondrite (source Thompson 1962) and Lower crust normalized spider diagram of the granitoid rocks of the study area (source Weaver and Tarney 1984)

When the trace element data Y vs Nb are following the works of Pearce et al (1984), the granitoid rocks of the study area fall in VAG +syn-COLG and (Y+Nb) vs Rb the granitoid data cluster fall in VAG field (Fig.10). According to these diagrams, the granitoids rocks of the study area fall in the volcanic-arc (VAG) environment with I-type granitoids.

Tectonic Discrimination of Granitoid Rocks Based on Trace Elements Geochemical Data

Trace elements of the rocks are more useful to classify the igneous process than the major and minor oxides because trace elements are far more sensitive to igneous fractionation processes. The trace-element data are used in the discrimination of tectonic or geologic provinces associated with particular magma types. The results of the trace elements geochemical analysis of the study area are presented in Table (3).

Pearce et al. (1984) classified granite into four main groups:

(a) Oceanic Ridge Granite (ORG), which predominanately contains Na-rich tonalite and plagioclase (metaluminous, alkali-calcic with clinopyroxene and amphibole) fractionated from basalt.

(b) Volcanic Arc Granite (VAG) with subduction signatures; containing I-type.

(c) Within Plate Granite (WPG) contains A-type alkali granites of peralkaline composition with Na pyroxene and amphiboles.

(d) The syn-Collission Granites (syn-COLG) can be the product of continent arc collision; producing metaluminous, I-type granites with biotite or continent-continent collision ones with peraluminous, S-type granites with muscovite and biotite. Pearce et al, (1984) postulated the discriminative diagrams to integrate granite geochemistry into the plate tectonic framework.

Therefore, the content of the trace element composition, LIL elements (Cs, Rb, K, Ba, Sr, Eu), HFS elemens (Y, Hf, Zr, Ti, Nb, Ta) and normalized value diagram or spider diagram suggest that the granitoids of the study area belong to the volcanic-arc granite (VAG), I-type and upper crust associated with the mantle derived magmatic arc.

The trace elements characteristics have right slopping Primordial- normalized trace element spider diagram (Wood et., al 1979) and lower crust normalized diagram (Weaver and Tarney 1984) show high enrichment in Low field strength Large Ion Lithophile (LIL) elements such as Rb, K, Ba, Sr, Zr and distinct negative anomalies for elements such as Cr, Ti, Sr Figure (11) (a) (b) and Figure (12) (a) (b).

Lower crust normalized diagram shows positive anomaly of Rb, Zr, and Y of granitoid rocks while Ti, Sr and Ba show negatively anomaly. These signatures are compatible with those of typical crystal melt. LIL elements are more mobile, particularly if a fluid phase is involved. These elements are concentrated in continental crust and as indicator signature of crustal contamination of magmas.

Generally, the trace elements Zr (96-183 ppm) and Zn (34-161 ppm) indicate that the granitoids of the study area fall in the field of I-type granitoids. The average trace element abundance of the granitoids of the study area is very similar to that of the typical I-type granite, low in large-ion lithophile element (LILE) content, e.g- Rb (29-125 ppm) , Sr (73-263 ppm) and Ba (143-371 ppm) and low in large high field-strength element (HFSE) content, e.g- Nb (4-5 ppm), Zr (96-183 ppm) and Y(21-40 ppm). The transition elements are low to moderate for the granodiorite, e.g- V (85-217ppm), Cr (5-409 ppm), Co (6-48 ppm), Ni (8-9 ppm), Cu (40-47 ppm), and Zn (34-161 ppm). The characteristics of elemental geochemistry indicate that granitoids were the product of melt and intercalation of crustal materials. It was formed in subduction and collision related to volcanic arc of convergent plate margins.

Therefore, the content of the trace element composition, LIL elements (Cs, Rb, K, Ba, Sr, Eu), HFS elemens (Y, Hf, Zr, Ti, Nb, Ta) and normalized value diagram or spider diagram suggest that the granitoids of the study area belong to the volcanic-arc granite (VAG), I-type and upper crust associated with the mantle derived magmatic arc.

Conclusion

Therefore, the amount of the trace element composition, LILE, HFSE, and normalized value diagram or spider diagram suggest that the granodiorite of the study area is the volcanic-arc granite (VAG), I-type granitoid and upper crust associated with the mantle derived magmatic arc.

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