Petrography and Geochemical Characteristics of the S-type Granitoids in the Kaduda Taung Area, Singu Township

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Abstract

Representative rocks of the metasediment suite granitiods (S-type granitoids) were selected from the Kaduda Taung for geochemical analyses. Nine granite samples were analysed for their major, trace and rare earth elements using X-Ray Fluorescence (XRF). The SiO_2 contents range between 66.4 and 68.2 wt. %, Al_2O_3 (20.3 - 21.7 wt. %), K_2O (2.58 -3.16 wt. %), Na_2O (7.08 -8.04 wt. %) and (Na_2O+K_2O) (9.66 – 11.2 wt. %). Major element data suggest that the rocks are syenite, quartz syenite, quartz monzonite. The CIPW normative mineral shows that the Kaduda granitoids are Trondhjemite and granite. The alumina saturation index (ASI) defined by molecular ratio Al_2O_3/ Na_2O+K_2O+CaO is greater than unity (one) in all the rock samples by values ranging from 1.7589 to 2.0009 wt. % implying that the granitic rocks are peraluminous. Low ratio of Na_2O/K_2O and Low concentrations of CaO (0.43 - 0.912 wt. %), MgO (0.0949 - 0.296 wt. %), Fe_2O_3 (0.226 – 0.6 wt. %) are attributes of peraluminous rocks. The minerals contained in Kaduda granite are plagioclase, microcline, biotite and mica as well as moderate silica and all these are characteristic features of peraluminous and S-type granitic rocks. Result analysis showed melts that are characteristics features of the upper crustal domain.

Keywords: granitoids, peraluminous, S-type, metasediment

Introduction

The majority of granitoid intrusive rocks of the study area have been located in the northeastern part of the Singu Township, Mandalay Region. It is situated about 40 miles north Mandalay and bounded by Latitudes 22° 35′ 00′′ to 22° 36′ 15′′ N and longitudes 96° 03′ 45′′ to 96° 04′ 45′′ E, covering about square miles in one inch topographic map of 93_ B/2 (Fig. 1). The above-mentioned intrusive rocks have intruded in metacarbonates and metasedimentary rocks of Upper Paleozoic to Mesozoic. Therefore, it is younger than them in terms of age and it is known related to the Tertiary age. The geological map of the study area and its environs is shown in (Fig. 2).

Petrographic classification of granitoids based upon their modal abundances of quartz, plagioclase and alkali feldspar has been used by Streckeisen (1967). Granitoids generally come from mixtures of mantle-derived mafic melts and melts of crustal rocks that may or may not contain metasedimentary components (John &Wooden, 1990; Miller *et al*., 1990). Granites have been classified based on their modal composition, location within the crust, their chemical composition and mineralogy as well as tectonic regime to make deductions about their origin.

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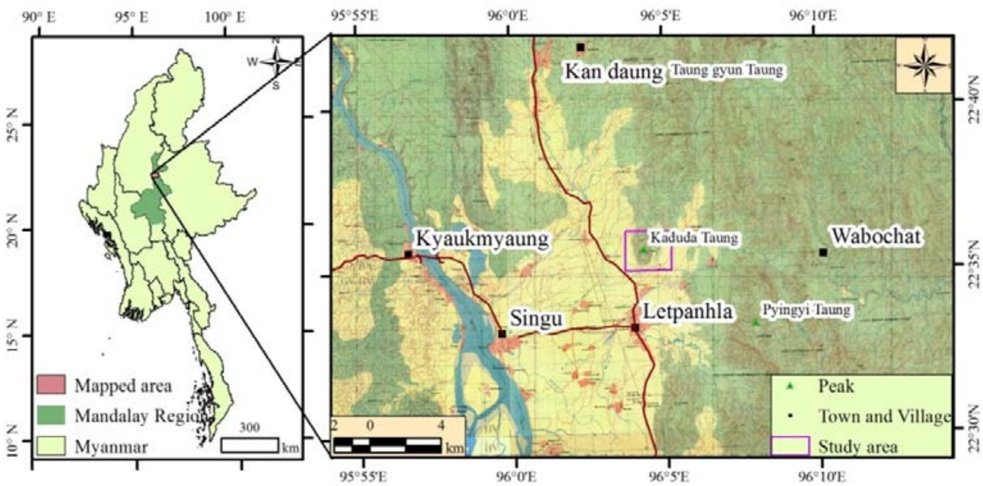


Figure (1). Location map of the study area (source: MIMU, 2010)

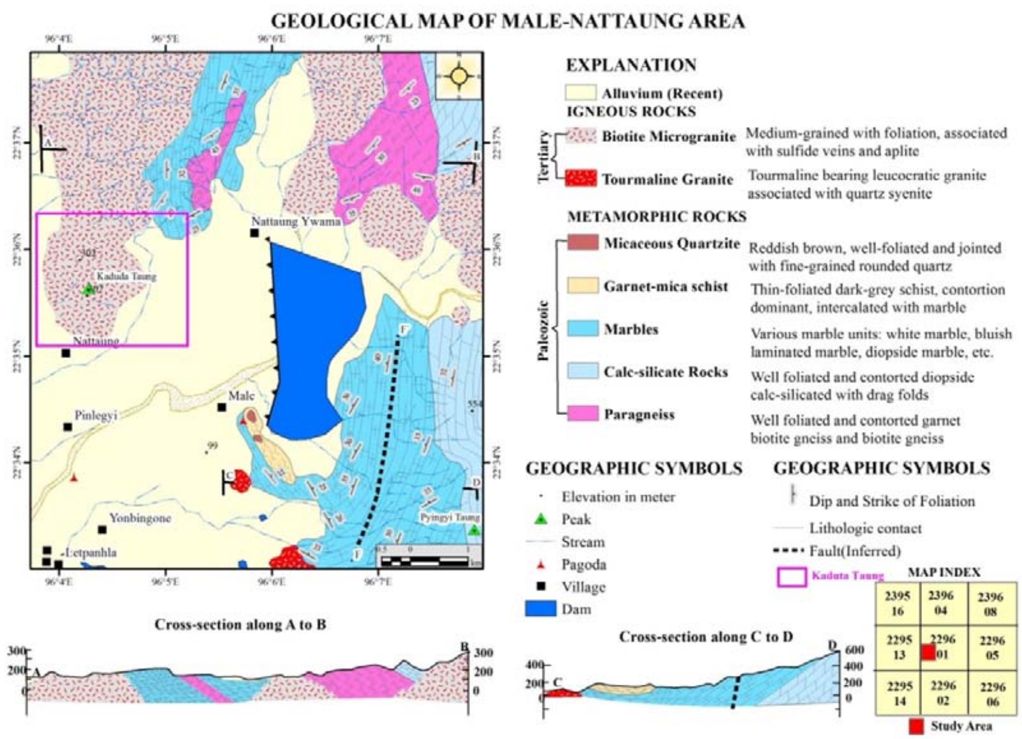


Figure (2). Geological map of the study area and its environs

The use of the aluminum saturation index (ASI) which is expressed in the micas and minor minerals in the rock is becoming popular as it is related to the magma sources and the conditions of melting. The alumina saturation index (ASI) defined by molecular ratio Al_2O_3/Na_2O+K_2O+CaO has been used to classify the granitic rocks as peraluminous and as S-type rock. Rocks can be characterized by the abundance of the major oxodes within them. Low concentrations of CaO, MgO, Fe_2O_3, as well as low ratio of Na_2O/K_2O are attributes of peraluminous rocks (Cerry, *et al.,* 1981 and Longstaff, 1982). Similarly, when the ratio of

Na_2O+K_2O+CaO/Al_2O_3 is less than unity (ratio<1), it confirms the peraluminous character of the rock (Pearce *et al*., 1984). These attributes have been applied in the classification of Kaduda Granites.

Materials and Methods

Field Study

The field data Table (1) indicates the physical study of the rock and the data comprising the coordinates, colour, texture, and mineralogy. The texture of the granite varies from fine- medium to coarse grains. The colour differences also occur among the granites according to the mineral content.

Analytical Methods

Chemical whole rock analyses have been used to classify the granitiods rocks and to evaluate crustal evolution in the study area. The chemical composition of selected granitoids is presented in Table (2). Major and some trace element (Rb, Sr, Zr, Ba, Ti,W) concentrations were analysed by XRF from pressed powder pellets in the geological laboratory of Mandalay University. Thin sections prepared from the representative samples are studied under the research- type petrographic microscope to yield the information on petrogenetic consideration.

Table (1) Field Data Collections

Sample Number	Coordinates	Colour	Texture	Mineralogy
8L-3	N 22° 35´ 15´´ E 96° 04´ 15´´	Grey, black and white	Porphyritic	K-feldspar, biotite, muscovite and quartz
8L-4	N 22° 35´ 42´´ E 96° 04´ 27´´	Dark grey and white	Coarse	Biotite, quartz and feldspar
8L-7	N 22° 35´ 37´´ E 96° 04´ 15´´	Pink, black and white	Coarse	K feldspar, biotite, muscovite and quartz
8L-11	N 22° 35´ 20´´ E 96° 04´ 15´´	Pink, black and white	Porphyritic	K feldspar, biotite, muscovite and quartz
15L-2	N 22° 35´ 25´´ E 96° 04´ 15´´	Grey, black and white	Fine	Feldspar, biotite, quartz
15L-7	N 22° 35´ 46´´ E 96° 04´ 15´´	Pink, black and white	Porphyritic	K feldspar, biotite, muscovite and quartz
15L-9	N 22° 35´ 40´´ E 96° 04´ 15´´	Pink, grey and black	Fine	K feldspar, biotite, muscovite and quartz
15L-10	N 22° 35´ 35´´ E 96° 04´ 19´´	Pink, white and black	Coarse	K feldspar, biotite, muscovite and quartz
15L-13	N 22° 35´ 20´´ E 96° 04´ 15´´	Pink, grey and black	Coarse	K feldspar, biotite, muscovite and quartz

Table (2). Chemical Composition of the Granitoid Rocks.

Sample	On Graph	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
8L-3	1	67.30	0.09	20.80	0.60	0.01	0.28	0.91	7.15	2.64	0.06	99.80
8L-4	2	66.40	0.05	21.20	0.37	0.01	0.27	0.62	7.81	3.07	0.04	99.91
8L-7	3	68.20	0.03	20.30	0.24	0.01	0.00	0.43	7.70	3.02	0.01	99.95
8L-11	4	66.80	0.07	21.40	0.52	0.02	0.20	0.83	7.45	2.58	0.04	99.79
15-2	5	66.80	0.04	21.20	0.34	0.03	0.17	0.91	7.72	2.62	0.00	99.83
15L-7	6	67.00	0.03	21.70	0.23	0.01	0.09	0.61	7.08	3.16	0.00	99.54
15L-9	7	66.40	0.09	21.00	0.45	0.01	0.30	0.63	8.04	2.95	0.04	99.85
15L-10	8	68.00	0.06	20.30	0.42	0.01	0.18	0.70	7.51	2.64	0.03	99.85
15L-13	9	67.20	0.04	20.40	0.40	0.01	0.19	0.63	8.02	2.95	0.03	99.52

Petrography

The thin sections of the granites show the various mineral grains of quartz, feldspar (microcline and plagioclase), biotite, opaque minerals and rarely hornblende. Microcline and quartz occur as large porphyritic crystals. Biotite content is low (3.56-5.82) compared to quartz (7.10-13.82) and plagioclase feldspar (62.93-70.89) Table (3). They occur in different orientations with mineral alignment poorly developed. Plagioclase is seen in large crystals with its characteristic features of twinning in some of the samples. Accessory mineral like hornblende (a ferromagnesian mineral) is observed. Quartz and feldspar (plagioclase, mica and microcline) alone constitutes over 70% of the rock while minerals such as garnet and magnetite constitute the opaque minerals. The minerals contained in Kaduda granite are as shown in Table (3).

Table (3). Mineral Composition of the Kaduda Granite.

Sample	Quartz	Microcline	Plagioclase	Hornblende	Biotite	Opaque	Sum
8L-3	13.83	14.96	64.62	0.74	5.59	0.03	99.77
8L-4	8.01	17.52	68.90	0.46	4.89	0.02	99.79
8L-11	11.93	14.79	66.89	0.61	5.60	0.03	99.85
15-2	9.92	15.09	69.84	0.34	4.57	0.06	99.81
15L-7	12.42	18.47	62.93	0.23	5.82	0.02	99.89
15L-9	7.11	16.74	70.89	0.54	4.52	0.02	99.83
15L-10	12.80	15.19	66.82	0.49	4.48	0.02	99.80
15L-13	7.99	17.00	70.79	0.47	3.57	0.02	99.84

The feldspar are large, well-formed crystals of both microcline and plagioclase with carls-bard twinning (Fig. 3 A & B). They are subhedral to anhedral form. Connective texture from growth of alkali feldspar with quartz (granophyric and micro-graphics texture) can be found in some samples. The plagioclase crystals can also be seen as polysynthetic twin (Fig. 4 A & B) and zoning (Fig. 5 A & B).

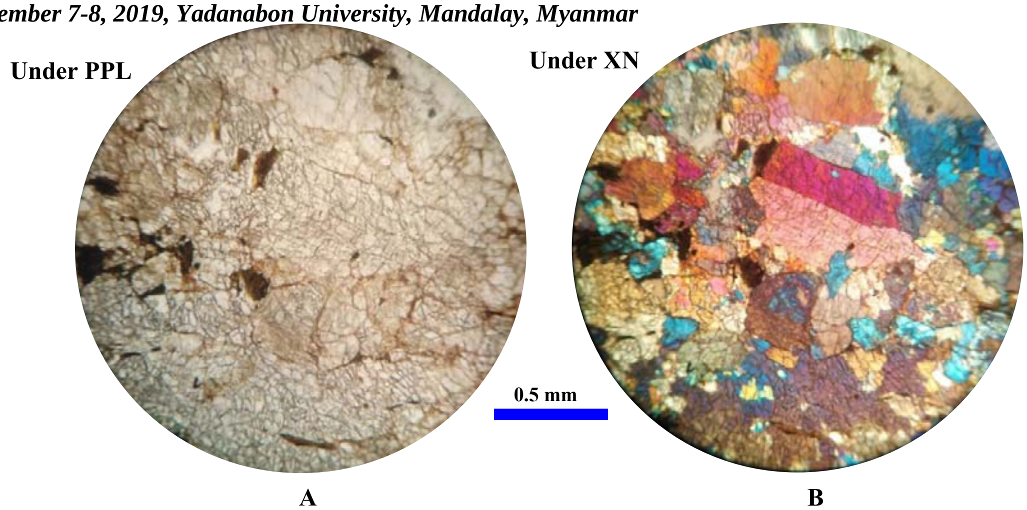


Figure (3). Photomicrographs showing (A) reddish brown biotite flakes embedded in the well-cleaved feldspars and fractured quartz under PPL, and (B) the Carlsbad twinning of plagioclase under XN

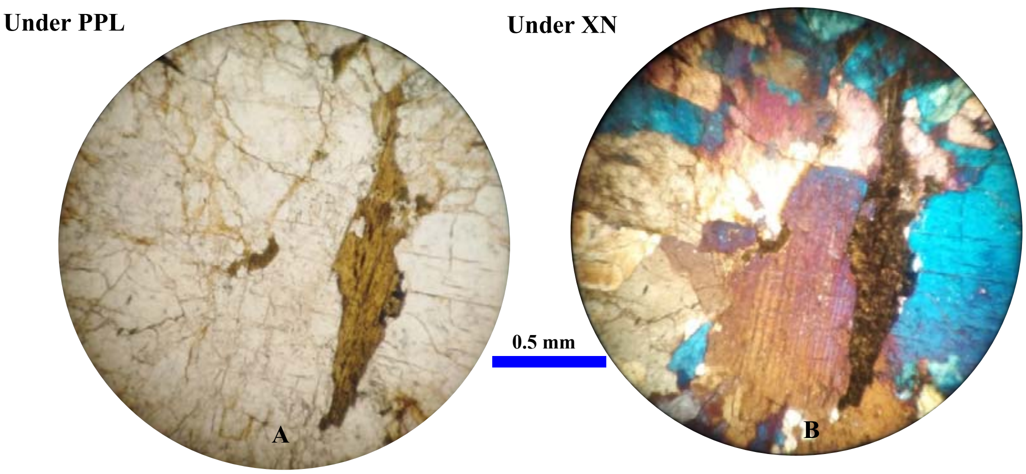


Figure (4). Photomicrographs showing (A) second order interference colour of biotite under PPL, and (B) the polysynthetic twinning of plagioclase under XN

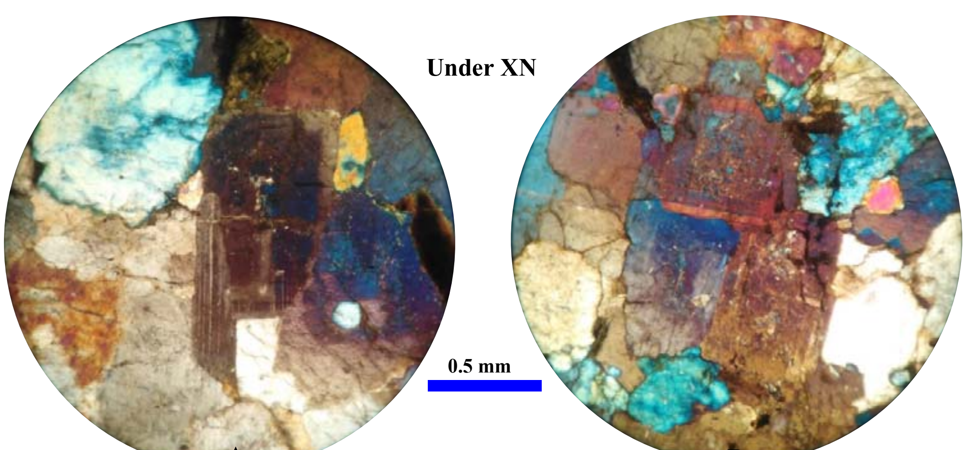


Figure (5). (A) & (B) Photomicrographs showing various colour zoning of plagioclase under XN

Quartz occurs as irregular masses of colourless and unaltered grains. In most cases, they have filled the space between the large crystals of plagioclase and alkali feldspar. Based on quartz crystals changes from angular, uniform to ridge in almost all the photomicrographs. Quartz form the dominant mineral followed by the feldspar. All the quart grains display low first order interference colour.

The hornblende content in the granite is low. Biotite is mainly the green and brown colored minerals with medium relief. Biotite displays the anomalous red colour interference when viewed under the microscope.

In general, in granitiods rocks, the presence of plagioclase, alkali feldspar and quartz with a porphyritic and granular texture are indicative of a slow cooling condition and in balance with the environment. But creating the granophyric and micrographic texture and also zoning in plagioclase indicate the formation of non-equilibrium conditions in the crystallization environment. Presence of these textures may be the result of magma mixing.

Results and Discussion

Geochemical Characteristic

The major element composition (in wt. oxide) of the representative granitiods from the study area and the CIPW normative mineral assemblages are in table (2). All the rocks samples analysed have SiO_2 content ranging from 66.%4 to 68.2%, TiO_2 from 0.02% to 0.09%, Al_2O_3 from 20.3% to 21.7%, total iron as Fe_2O_3 from 0.22% to 0.0.60 %, MnO from 0.0075 to 0.0.0159 %, MgO from 0.17% to 0.29%, CaO from 0.43% to 0.91%, (Na_2O+K_2O) content of 9.8 to 10.9 , and Na_2O/K_2O ratio from 2.24 to 2.95 and P_2O_5 from 0.01% to 0.05% and the A/CNK (molecular Al_2O_3/CaO+ Na_2O+K_2O) ranges from 1.75% to 1.94%.

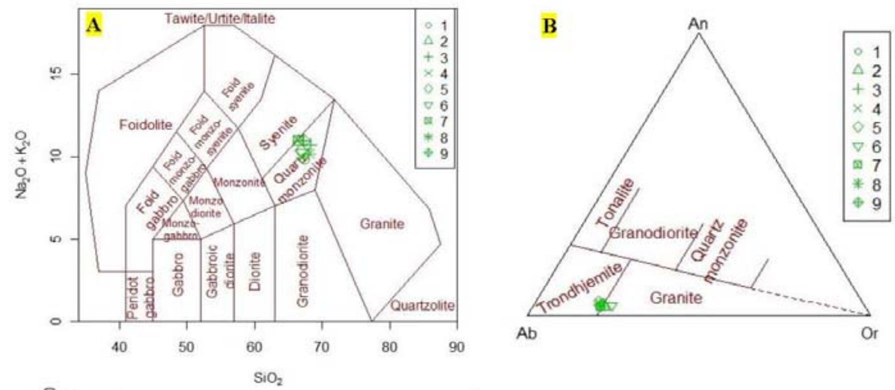
According to the classification of plutonic rocks based on the SiO_2 vs. (Na_2O+K_2O) diagram (Fig. 6 A), the granitic rocks are classified as quartz monzonite except one sample fall in syenite field. Quartz monzonite or adamellite is an intrusive, felsic, igneous rock that has an approximately equal proportion of orthoclase and plagioclase feldspar. It is typically a light coloured phaneritic (coarse-grained) to porphyritic granitic rock.

In the ternary An-Ab-Or diagram (O' Connor, 1965) (Fig. 6 B), the rock samples are classified as granite and trondhjemite. The rock samples in the study area fall within the scope of syenite and quartz syenite (Fig. 6 C) with respect to R_1-R_2 plot diagram (De La Roche *et al*. 1980).

These rocks are in the range of calc-alkaline series to determine the magmatic series according to the figure (7 A) and figure (7 B). In the K_2O vs. SiO_2 diagram, the granitic rocks fall in high -K Calc- alkaline series and Calc-alkaline series (Fig. 7 C).

The alumina saturation index (ASI) defined by molecular ratio Al_2O_3/Na_2O+K_2O+CaO is greater than unity (one) in all the rock samples by values ranging from 1.7589 to 2.000 wt. % implying that the granitic rocks are peraluminous. Rocks can be characterized by the abundance of the major oxides within them. Low concentrations of CaO, MgO , Fe_2O_3 are attributes of peraluminous rocks (Cerny, *et al* : 1981 and Longstaff, 1982).

Rocks which have the above characteristics are rich in albite ($NaAlSi_3O_8$), potassium feldspar ($KAlSi_3O_8$) and quartz (SiO_2). In peraluminous or alumina- oversituated rocks, excess alumina is accommodated in micas, especially muscovite, in addition to Al-rich biotite, and in aluminous accessory minerals such as cordierite, sillimanite, tourmaline, corundum and topaz. Zen (1988) equally pointed that rocks which have ASI >1 are corundum-normative, meaning that they have more Al than can be accommodated in feldspars and that they must have another aluminous phase present, in which case in the more strongly peraluminous granite, the phase can be muscovite, cordeirite, garnet or an Al_2SiO_5 ploymorph. The minerals microcline, plagioclase, biotite, and mica as well as moderate silica are all characteristics features of a peraluminous and S type granitic rock.



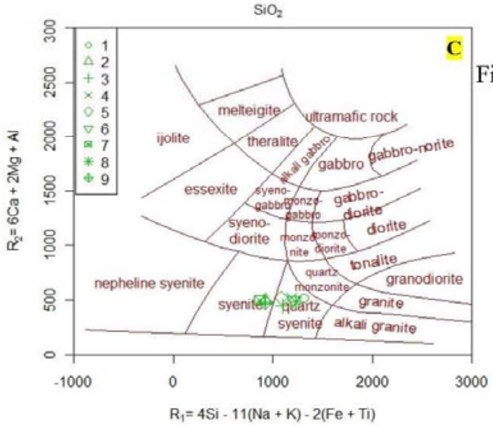
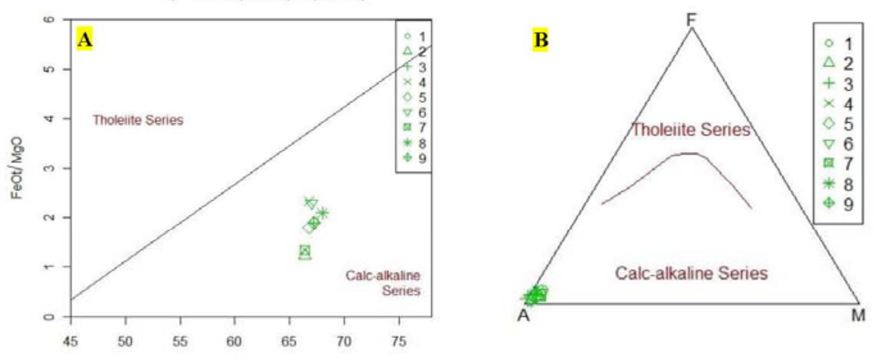


Figure (6). Classification of granitoid rocks of the Kaduda Taung Area: (A) based on TAS diagram of Middlemost, 1985; (B) Feldspar triangle of O'Connor, 1985, and R1-R2 plot of De la Roche *et al. 1980.*



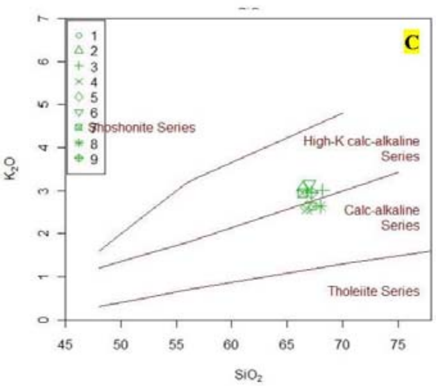


Figure (7). Magmatic series of granitoid rocks of the Kaduda Taung Area: (A) SiO_2-FeOt/MgO plot of Miyashiro, 1974; (B) AFM plot of Irvine and Baragar, 1971, and SiO_2-K_2O plot of Peccerillo and Taylor, 1976.

The plot of $Al_2O_3/(Na_2O+K_2O)$ versus $Al_2O_3/(Na_2O+K_2O+CaO)$ of Shand(1943) shows that the granitic rocks plot mainly in the Peraluminous field (Fig. 8 A). According to the triangular diagram (Al_2O_3-Na_2O-K_2O), the granitoid rock samples plot in peraluminous field. (Fig. 8 B) Wilson (1991) postulated that peraluminous granites contain crustal or sedimentary materials in their original magma.

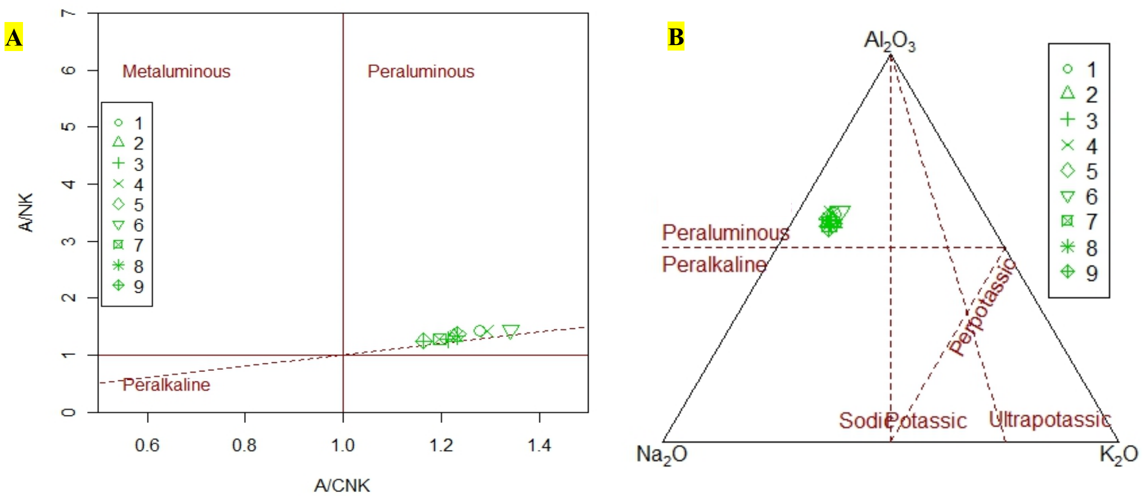


Figure (8). Alumina situation of granitoid rocks of the Kaduda Taung Area: (A) A/CNK-A/NK plot of Shand, 1943; (B) Molar Al_2O_3-Na_2O-K_2O plot showing peraluminous field of granitoid rocks.

In the $Al_2O_3/(Na_2O+K_2O+CaO)$ versus SiO_2 diagram, the granitic rocks fall in S-type field (Fig. 9 A). Similarly, in triangular diagram (Hyndman, 1985) the granitoid rock samples plot within the S-type field (Fig. 9 B). S- type granitoids are derived from the partial melting of sedimentary and metasedimentary rock and they are more common in collision zones. However, Chappell& White (1974) strongly pointed out that peraluminous melts may have formed by melting of biotite-bearing metaluminous felsic rocks or even by water excess melting of mafic rocks. And that they are also formed from a sedimentary source.

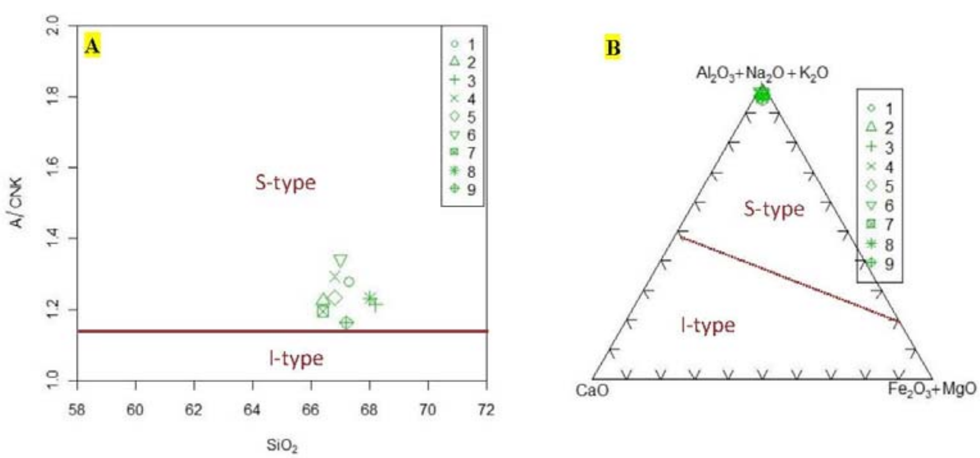


Figure (9) Types of granitoid rocks of the Kaduda Taung Area: (A) A/CNK-SiO_2 plot; (B) ACF plot showing peraluminous field of granitoid rocks (after Hyndman, 1985)

Using the plot of Na_2O+K_2O-CaO against SiO_2 of Frost *et al*., (2001), the granitic rock samples fall only in alkalic field (Fig. 10). This point indicates that the granitic rocks may have been derived from same source of materials in the magma that formed the rock.

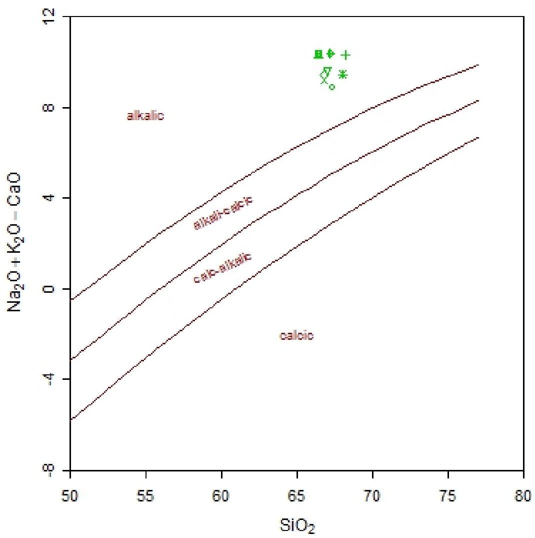


Figure (10) Plot of Na_2O+K_2O-CaO against SiO_2 showing granite tectonic discrimination, Frost *et al*., (2001)

The tectonic discrimination of granitoids rocks of the study area is mainly based on the major element chemistry. According to the Maniar and Piccoli (1989), K_2O vs. SiO_2 diagram indicate that the granitoid rocks plot within the field of IAG+CAG+CCG+RRG+CEUG environment (Fig. 11 A). FeOt/(FeOt+MgO) vs. SiO_2 diagram (Fig. 11 B) and F/ACF vs. C/ACF diagram (Fig. 11 C) classify that the granitic rocks fall into IAG+CAG+CCG and POG environments. Based on the tectonic discrimination diagrams, the granitic rocks from the study area fall in the orogenic granitoid environment.

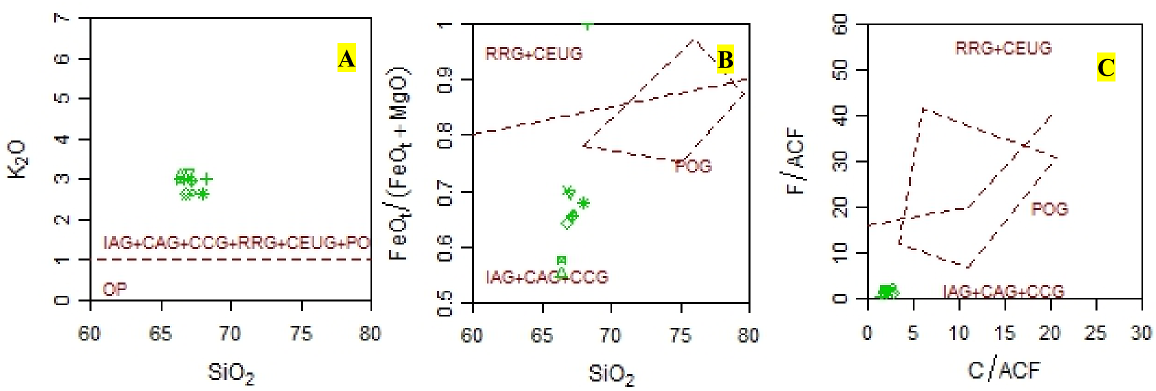


Figure (11) Granite tectonic discrimination of the Kaduda Taung Area: (A), K_2O vs. SiO_2 diagram; (B) FeOt/(FeOt+MgO) vs. SiO_2 diagram, and (C) F/ACF vs. C/ACF diagram showing orogenic granitoid environment (Maniar and Piccoli, 1989)

Conclusions

The granite from Kaduda indicates a strong crystallization from a peraluminous melt. TiO_2, MgO and CaO contents are low due to their removal during crystallization of mafic minerals. Na_2O is also lost during the alteration of feldspar to clay mineral. Low concentrations of CaO, MgO and Fe_2O_3 are attributes of peraluminous rocks (Cerny, *et al*; 1981 and Longstaff, 1982). Similarly, when the ratio of Al_2O_3/Na_2O+K_2O+CaO is greater than unity (ratio>1), it confirms the peraluminous character and S-type of Kaduda granite. The mineralogy reflects the major element compositions. The mineral compositions of the granite comprise muscovite, microcline, plagioclase, biotite and ilmenite. The geochemical characteristics of peraluminous granites control their mineralogy. Ilmenite is the opaque phase characteristic of S-type rocks. White and Chappell (1977), Flood & Shaw (1975) and Green (1976) have implied that some aspects of the mineralogy of S-Type granites are inherited from the magma's source rock. The plot of $Al_2O_3/(Na_2O+K_2O)$ versus $Al_2O_3/(Na_2O+K_2O+CaO)$ of Shand (1943) confirms the peraluminous and S-type class of the Kaduda granite. Wilson (1991) postulated that peraluminous granites contain crustal or sedimentary materials in their original magma derived from partial melting of sedimentary and metasedimentary rock. According to the tectonic discrimination diagrams, the granitic rocks in IAG+CAG+CCG and POG environments. These features suggest that a mixture of magma inputs and depositions. John and Wooden, 1990; Miller *et al*., 1990 pointed out that granitoids rarely come from single source, but instead are mixtures of mantle-derived mafic melts and melts of crustal rocks that may or may not contain metasedimentary components, Miller,(1985) however, stated that similar granitic compositions can be produced by partial melting of a variety of sources.

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