# Petrochemistry of Igneous Rocks exposed in Saga-Mindaw Area, Salingyi Township, Sagaing Region, Myanmar

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## Abstract

The study area lies between north latitude 21˚ 56′ N to 21˚ 59′ N and east longitude E 95˚ 03′ E to 95˚ 08′ E, in one inch topographic map 2195_01. It is located northern part of the Central Volcanic Line and southern part of the Chindwin Basin. The study area is composed of Igneous, metamorphic and sedimentary rocks. Igneous rocks, diorites, rhyolites, granites, gabbro are exposed in the study area. Radiometric dates of the igneous rocks are diorite (106±7 m.y), granite (103±4 m.y) and gabbro (91±8 m.y). Salingyi Complex lies in the Central Volcanic Line (CVL) and which are mostly calc-alkaline series with some tholeiitic series. This indicates that the igneous rocks of the study area are formed by the partial melting of subducted oceanic crust of the Indian Plate beneath the Eurassian Plate. The petrochemical data indicate the various igneous rocks of the study area are I-type magmatic source, peralkaline, and strongly fractionated from magma. They are derived by partial melting of a mafic- mantle derived igneous source material probably of a sub-crustal underplate.

**Key words:** Salingyi Complex, Central Volcanic Line, I-type, peralkaline, strongly fractionated, mantle-derived

## Introduction

The study area, Saga-Mindaw is situated in Salingyi Township, Sagaing Region. It is covering about 66.74 square kilometers and lies between latitudes 21°56′ N to 21°59′ N and longitudes 95°03′ E to 95 °08′ E. The north – south extend is about 7.1 km long and east-west extend is about 9.9 km wide. It occupies in UTM map of 2195_01. The study area can be reached all year round. From Monywa to the study area, firstly we will across the Chindwin River by boat and reach to Naungbingyi, which is located in the western bank of Chindwin River. Then, we will travel to Salingyi, Saga-Mindaw by mean of car or motorcycle. The Monywa-Pakokku-Magwe Highway passes along the western part of the area. The location map of the study area is shown in figure (1).

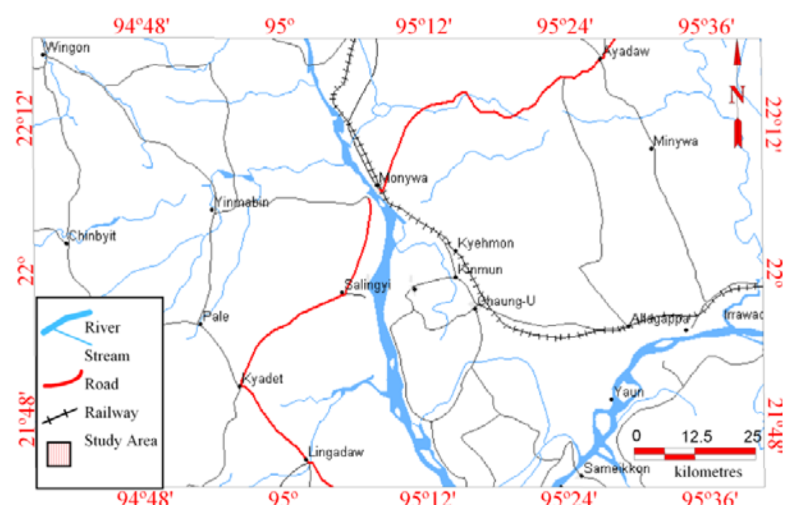


Figure (1). Location map of the study area (source: MIMU, 2010)

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## Purpose of Study

This paper attempts to find out the temporal and spatial relationship of the igneous activities, and their tectonic regime, which is responsible for the emplacement of the acidic rocks and basic rocks into the present position.

The purpose of study is to know the various igneous rocks in Salingyi complex and its surrounding rocks. This paper primarily focuses on the mode of occurrences of igneous rocks employing combination of field investigation, petrographic studies and geochemical studies.

## Materials and Methods

Rock samplings were made for petrological and geochemical analysis studies. Systematic sample collection of rocks in some individual rock types. Thirteen samples were collected from several locations for geochemical analysis. Bulk rock chemistry was analyzed by using Spectro Xepos XRF Spectrometer in SPECTRO X-LAB of Defence Service Academy to contribute the petrochemistry and mineral chemistry.

ED-XRF analyses of igneous rocks were aimed to determine the major, minor and trace elements composition, which are useful in defining the rock types, their affinity and tectonic setting as well as their source origin.

## GENERAL GEOLOGY

Three rock types; viz, igneous, sedimentary and metamorphic are found altogether in the study area (Table 1 and Fig. 2). They are exposed with differing areal coverage. Among them, igneous and sedimentary units are shared nearly equal exposure of the study area. The metamorphic rocks occur as xenoliths in igneous rocks. Dykes and veins of apalite and quartzofeldspathic veinlets are commonly occurred in the various igneous bodies.

Table (1). Stratigraphic Succession of Saga-Mindaw Area.

| STRATIGRAPHIC UNIT | AGE |
|---|---|
| **SEDIMENTARY ROCKS** | |
| Alluvium | Holocene |
| Pyroclastic Rocks | Pleistocene |
| Magyigon Formation | Late Miocene-Pliocene |
| Damapala Formation | Middle Miocene |
| **IGNEOUS ROCKS** | |
| Gabbro and Hornblendite | Late Cretaceous (91±8 m.y)* |
| Granites | Late Cretaceous (103±4 m.y)* |
| Diorites | Late Cretaceous (106±7 m.y)* |
| Rhyolite and Dacite | Early Cretaceous |
| METAMORPHIC ROCKS | |
| Gneiss and Amphibolite Schist | Pre-Cretaceous |

*Source: UNDP, 1979

In the study area, rhyolites are found at the western part of the Salingyi complex. Gabbro and Hornblendite (Late Cretaceous) are intruded in the southwestern part of rhyolitic body. Medium to coarse-grained diorite pluton is found to be covered nearly a quarter of the area. Granites are situated in the northern part of the complex and southwest of the Saga. Gabbro and Hornblendite are intruded in rhyolite and diorite body. Most pyroclastic materials are found at the northern part.

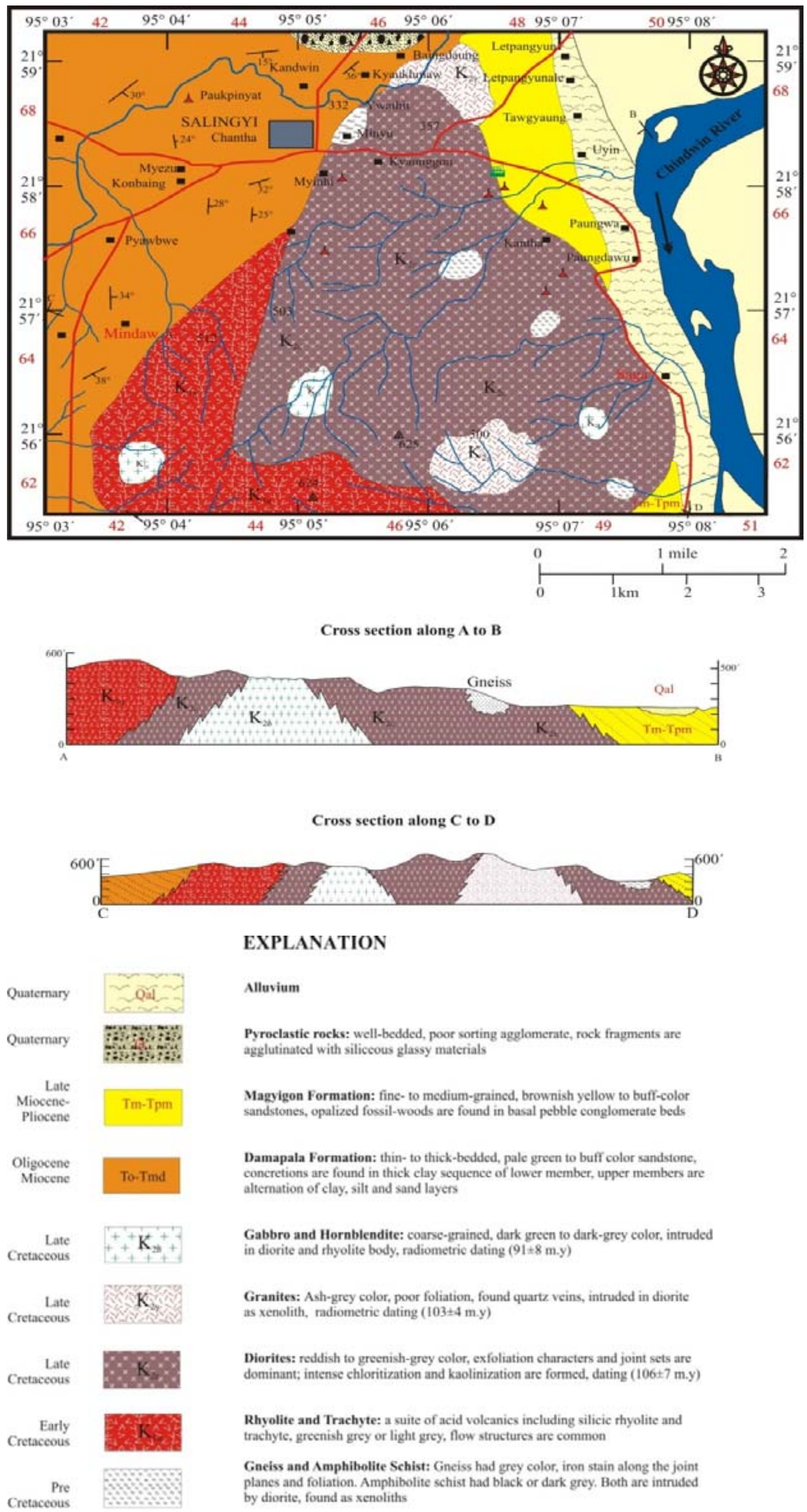



Figure (2). Geological map of the Saga-Mindaw Area, Salingyi Township.

## Petrochemistry of Igneous Rocks

Thirteen analytical data were made for rhyolites, diorites, granites and gabbro (Table 3). Geochemical data are used to aid definition and characterization of the lithologic units of igneous rocks, petrographic analysis in the identification of lithologies. In addition, this chemical classification scheme is supplemented by petrographic analysis and hand specimen examination in this study (Table 3).

Table (2). Chemical Composition of Igneous Rocks.

| | Granites | | | Gabbro | | Diorites | | | | Dacites | | Rhyolites | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Gr 1** | **Gr 2** | **Gr 3** | **Gb 1** | **Gb 2** | **Di 1** | **Di 2** | **Di 3** | **Di 4** | **Dc 1** | **Dc 2** | **Ry 1** | **Ry 2** |
| $SiO_2$ | 75.38 | 71.26 | 76.48 | 42.18 | 43.51 | 57.86 | 56.08 | 52.4 | 47.72 | 67.2 | 68.54 | 74.86 | 74.62 |
| $Al_2O_3$ | 13.57 | 17.03 | 11.65 | 22.7 | 24.69 | 17.8 | 16.78 | 16.68 | 16.87 | 13.57 | 13.87 | 13.21 | 12.65 |
| $Fe_2O_3$ | 0.77 | 3.28 | 1.7 | 11.83 | 1.55 | 10.54 | 10.76 | 8.14 | 5.86 | 7.78 | 7.48 | 3.03 | 4.78 |
| FeO | 0 | 0 | 0.66 | 0 | 4.73 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 |
| MnO | 0 | 0.03 | 0.02 | 0.15 | 0.1 | 0.16 | 0.18 | 0.13 | 0.08 | 0.06 | 0.18 | 0.06 | 0.09 |
| MgO | 0.25 | 1.16 | 0.3 | 14.55 | 7.38 | 4.9 | 5.5 | 9.35 | 5.81 | 2.83 | 2.3 | 0.6 | 0.23 |
| CaO | 0 | 2.04 | 4.7 | 6.05 | 15.18 | 4.13 | 5.91 | 8.37 | 10.71 | 4.56 | 1.82 | 0.43 | 0.29 |
| $Na_2O$ | 4.32 | 2.7 | 2.8 | 1.69 | 0.96 | 2.84 | 3.36 | 2.63 | 1.63 | 2.97 | 3.71 | 6.68 | 6.35 |
| $K_2O$ | 4.92 | 0.55 | 0.45 | 0.1 | 0.24 | 0.29 | 0.62 | 0.27 | 0.16 | 0.08 | 0.09 | 0.19 | 0.17 |
| $TiO_2$ | 0 | 0 | 0.57 | 0 | 0.55 | 0 | 0 | 0 | 2.54 | 0 | 0 | 0 | 0 |
| $P_2O_5$ | 0.13 | 0.21 | 0.32 | 0.18 | 0.18 | 0.07 | 0.21 | 0.01 | 0.17 | 0.16 | 0.18 | 0 | 0.24 |
| $SO_3$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.13 | 0 |
| $H_2O$ | 0 | 0 | 0.33 | 0 | 0.95 | 0 | 0 | 0 | 1.03 | 0 | 0 | 0 | 0 |
| L.O.I | 0.28 | 1.36 | 0 | 0.14 | 0 | 0.78 | 0 | 1.26 | 0 | 0.18 | 1.16 | 0 | 0 |
| Total | 99.62 | 99.62 | 99.98 | 99.57 | 100.0 | 99.37 | 99.4 | 99.24 | 99.58 | 99.39 | 99.33 | 99.19 | 99.42 |
| ASI | 1.46 | 3.21 | 1.46 | 2.89 | 1.5 | 2.45 | 1.69 | 1.48 | 1.34 | 1.78 | 2.46 | 1.8 | 1.85 |
| F.I | 1 | 0.614 | 0.408 | 0.228 | 0.073 | 0.431 | 0.402 | 0.257 | 0.143 | 0.4 | 0.67 | 0.94 | 0.95 |
| M.I | 2.43 | 15.08 | 5.07 | 51.65 | 49.66 | 26.38 | 27.17 | 45.85 | 28.39 | 20.71 | 16.93 | 5.71 | 1.99 |
| L.I | 29.79 | 21.1 | 20.28 | -6.44 | -12.5 | 10.59 | 7.9 | 0.01 | 7.45 | 15.09 | 18.81 | 24.11 | 24.52 |

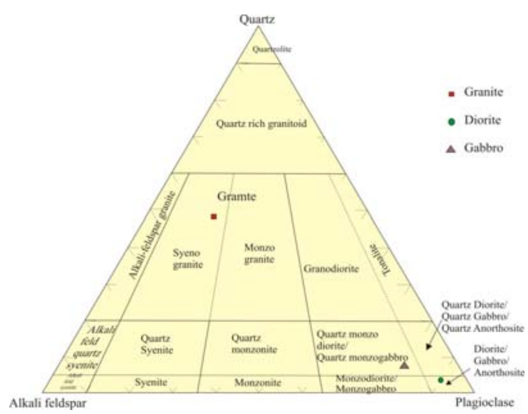
ASI = $Al_2O_3$/ ($CaO$+$Na_2O$+$K_2O$)
F.I =$Na_2O$+$K_2O$ /($Na_2O$+$K_2O$+$CaO$)
M.I =100MgO/(MgO+FeO+$Fe_2O_3$)
L.I= 1/3 $SiO_2$+$K_2O$-(Fe+ MgO+ CaO)

Classification of aphanetic rocks are done by using ($Na_2O$ + $K_2O$) vs. $SiO_2$ diagram (Fig. 4). This figure shows two falls in the rhyolite field and another falls in the dacite field. Igneous rock is controlled by the chemical composition of the source: the pressure, temperature and degree of partial melting. Moreover, it is also controlled by the nature, and extent of subsequent assimilation and differentiation processes.

Harker variation diagram is used for the classification of igneous rocks of the study area. Figure (4) shows the variation diagrams of major oxides such as $Al_2O_3$, $Fe_2O_3$, $K_2O$, $Na_2O$, MgO, CaO, versus $SiO_2$.

Table (3). Modal Composition of Igneous Rocks (Petrographic Examination)

| Rock Type / Mineral | Rhyolite | Diorite | Granite | Gabbro |
|---|---|---|---|---|
| Quartz | 30 | 4 | 38 | 2 |
| K-Feldspar | 28 | 12 | 32 | - |
| Plagioclase | 5 | 46 | 13 | 59 |
| Hornblende | 2 | 32 | 6 | 20 |
| Biotite | - | 3 | 1 | - |
| Pyroxene | - | 2 | - | 13 |
| Serpentine | - | - | - | 2 |
| Olivine | - | - | - | 4 |
| Opaque mineral | 3 | 1 | - | - |
| Ground mass | 32 | - | - | - |
| | 100 | 100 | 100 | 100 |



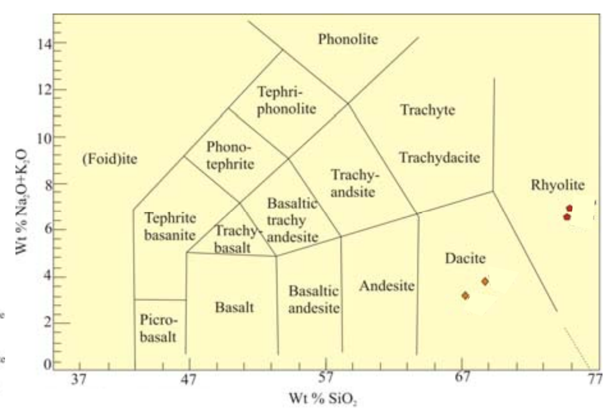




Figure (3). QAP igneous classification of the phaneratic rock based on IUGS (2006)

Figure (4). A chemical classification of volcanics based on total alkalis vs. silica (Winter, 2001 & reference therein).

The contents of other oxides except $Al_2O_3$, $Fe_2O_3$, MgO and CaO are negatively correlated with the $SiO_2$ in variation diagrams. However, $K_2O$ and $Na_2O$ contents providing positive correlation. 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-undersaturated, whereas subalkaline rocks are silica-saturated to oversaturated. If the series are indeed unique, they should be distinguished by their evolutionary patterns of variation diagrams (Winter 2001).

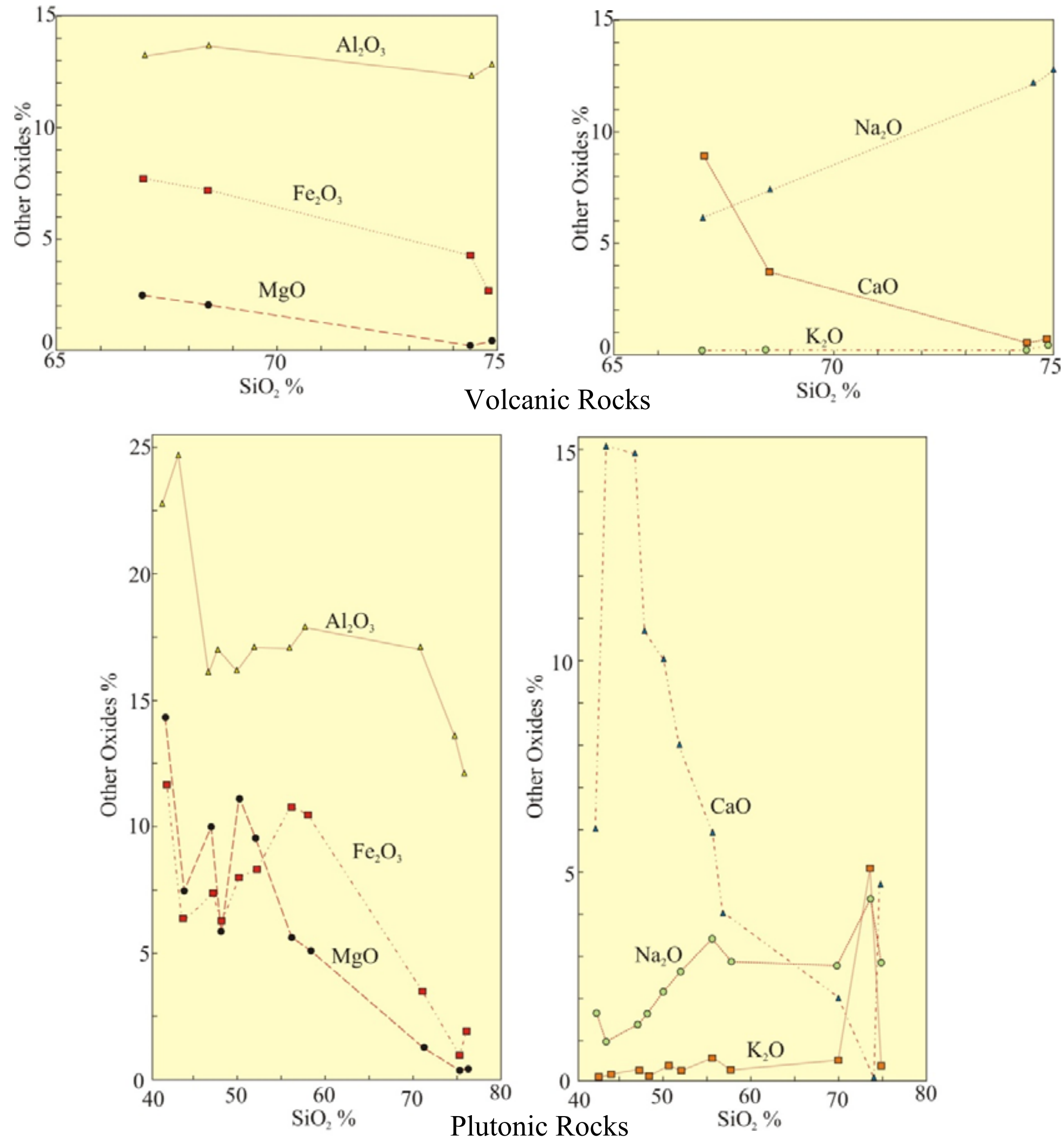



Figure (5). Harker variation diagrams of major oxides vs. $SiO_2$ for igneous rocks

In the study area, calc-alkaline types dominate over tholeiitic, but there are also alkali-calcic and alkaline varieties when using the criteria of Peacock (1931). He used a plot of CaO and ($Na_2O$ + $K_2O$) vs. $SiO_2$ (Fig. 6) to somewhat arbitrarily distinguish for chemical classes of igneous rocks. Here the igneous rocks of the study area yield alkali-lime indices of ~ 68.5. Therefore, the igneous rocks of the study area fall in calcic class when using Peacock index.

In the study area, the igneous rocks are peralkaline rocks (Fig. 7 A). In the $Al_2 O_3$ + CaO / $Fe_2 O_3$ + $Na_2O$ + $K_2O$ vs. 100 (MgO + $Fe_2 O_3$+ $TiO_2$) / $SiO_2$ binary diagram, most of the igneous rocks of the study area show close to the highly fractionated calc-alkaline series and falls in the alkaline series (Fig. 7 B).

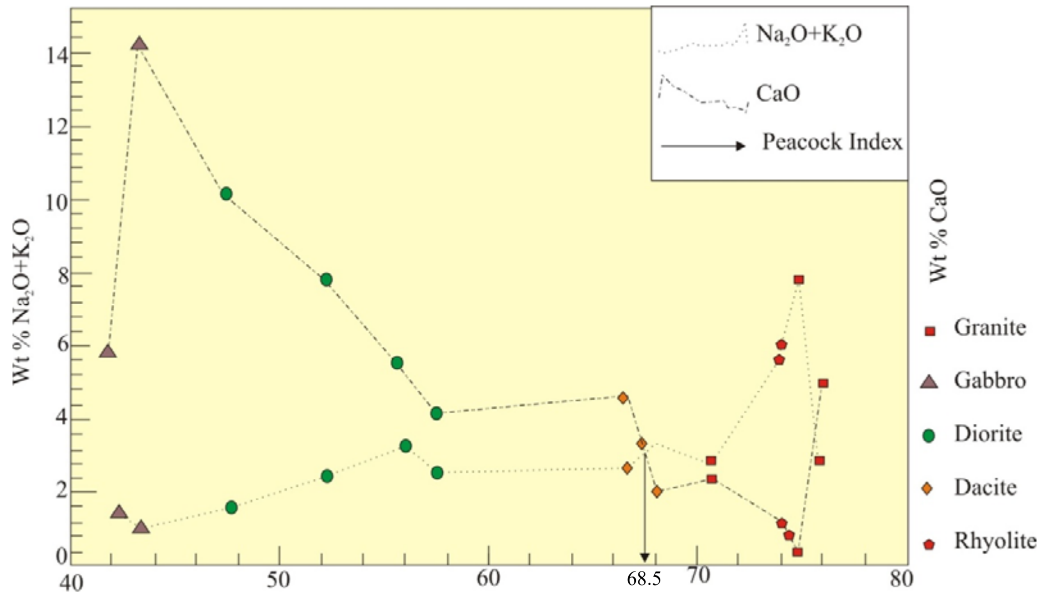



Figure (6). Plot of CaO and Na2O + K2O vs. $SiO_2$ in igneous rocks of the study area

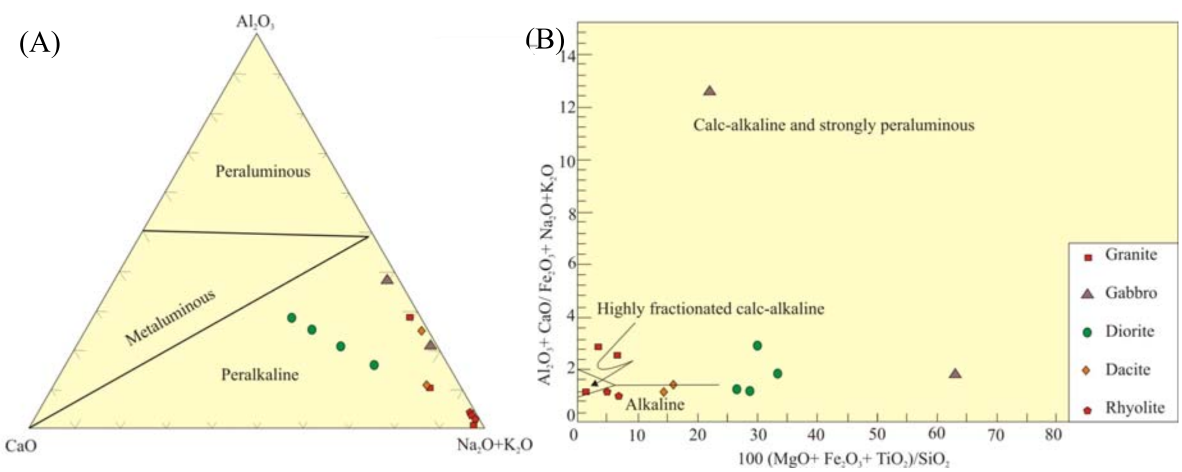



Figure (7). (a) A/(C+N+K) ternary diagram for alumina saturation indices (Shand, 1927) with analyses of the all are peralkaline rock types; (b) Major element discrimination of igneous rocks of the study area supposed to be subduciton-related igneous rocks (after Sylvester, 1989).

There are numerous attempts to classify the diverse spectrum of igneous rocks. Of course, a simple mineralogical classification may be readily approached and is useful in naming hand specimen, but tells little about their nature.

The indication that granitoid chemical composition reflects their source and setting suggests that an alternative classification based on genetic criteria can be developed. Field relationships also refined such an approach.

In ACF ternary plot, all igneous rocks are fallen in the I-type field (Fig. 8). I-type granitoid has higher $SiO_2$ than S-type but $K_2O/Na_2O$ is low. A/(C+N+K) ratio is low (peralkaline) in I-type.

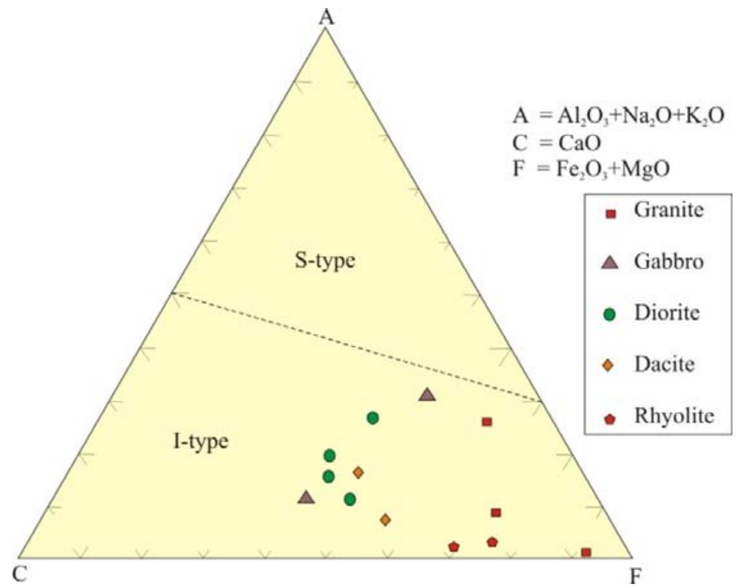



Figure (8). ACF diagram determining S-type granitoids and single I-type granitoid of the study area (after Hyndman, 1985)

Therefore, igneous rocks of the study area are I-type and the chemical composition suggests that they are derived by partial melting of a mafic- mantle derived igneous source material probably of a sub-crustal underplate.

As a conclusion, the results show all igneous rocks have been fallen in calc-alkaline series. In term of mafic index, rhyolites ranges between approximately 2 to 20; diorite is fairly constant in value of about 27 excluding meladiorite of 45; and gabbros vary within 49 to 53. This suggests that these rocks are possibly generated at subduction related setting.

## Conclusions

The petrochemical data indicate the various igneous rocks of the study area are I-type magmatic source, peralkaline, and strongly fractionated from magma. All of the igneous rocks are formed in Cretaceous. Rhyolite and dacite volcanism and other three different age of plutonism had been mentioned. On the basis of field relationship and radiometric dating (UN, 1979), the sequences of emplacement of igneous activity can be summarized as follow:

Metamorphic rocks of pre-Cretaceous gneiss and amphibolite schists are exposed on the surface and extruded by rhyolite and dacite volcanism in Early Cretaceous. Dacite contemporaneously erupted with rhyolite by means of magmatic contamination. The major emplacement of igneous rocks within the area was ended up by the intrusion of gabbro (91± 8 million years) in Late Cretaceous. The Pleistocene pyroclstic materials were deposited by means of siliceous volcanism.

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