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PETROGRAPHY AND PETROCHEMICAL CHARACTERISTICS OF SKARN AROUND MONBINZON VILLAGE AND MINBON TAUNG AREA, THAZI TOWNSHIP, MANDALAY REGION

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Abstract

The study area falls 24.3 km southeast of Thazi at Mandalay Region that covers two types of rocks; igneous and metasedimentary rocks. Meta-sedimentary rocks consist calc-silicate rocks and skarn. Calc-silicate rock occurred as roof-pendant, visible ridges and furrows nature. Skarn are exoskarn that subdivided into garnet skarn and garnet-clinopyroxene skarn. It contains garnet, diopside, plagioclase, quartz and tremolite. According to petrochemical study, the massive garnet-clinopyroxene skarn exhibit much flatter profiles in Chondrite-normalized REE patterns that indicating the garnet may preferentially concentrate HREE. In Harker variation diagrams, SiO_2, TiO_2 and K_2O show a systematic decrease from diorite to skarn and FeOt display general increase to skarn rocks due to mass transfer during metasomatism. Cu, Zn and Y enrichment in skarn is relative to granite. Sr exhibits a perceptible decline in the direction of exoskarn.

Keywords: exoskarn, garnet skarn, garnet-clinopyroxene skarn

Introduction

The study area is situated about at the Monbinzon village and Minbon Taung in Thazi Township, Mandalay Region. It is about 24.3 km southeast of Thazi, situated along the Thazi-Taunggyi motor road. It is lying between latitude 20˚ 41′ 30″ N &20˚ 45′ 0″ N and longitude 96˚ 14′ 0″ E & 96˚ 17′ 0″ E as shown in Figure 1. Physiographic feature of the area is typically expressed by roughly parallel ridges with relatively relief, especially in the southern part of the area. The general trend of the area is running in a northeast - southwest direction with respect to the regional strike trend.

The area is located in the eastern part of the Thazi-Pyawbwe plain which lies in the western part of the Shan Plateau which had become a stable block since the close of the Mesozoic. Granitic and metamorphic rocks within the study area are located within the Mogok Metamorphic Belt (Searle and Ba Than Haq, 1964). The area consists of igneous complex which was emplaced into a belt of low to medium grade metamorphism (of originally lower Paleozoic age) in the western part and sedimentary (Mesozoic age) in the eastern part. The granitic rock of the study area belongs to Payangazu granitoids and in central grantoids belt.

The study area can roughly be divided into mountainous region in the eastern part and the lowland region in the northwestern part. The highest-peak is Minbon Taung (704 m). The area is located at the western marginal part of the Shan-Plateau. Kyawme Chaung and Kywegya Chaung are main drainage of this area. They are flowing from east-west direction. In the whole area, drainage pattern is coarse dendritic pattern. All rocks can be traced along the mountain ranges but the mountain ranges are covered with highly weathered outcrops and spare vegetation. Thus most of the rocks units can be observed along the stream channels.

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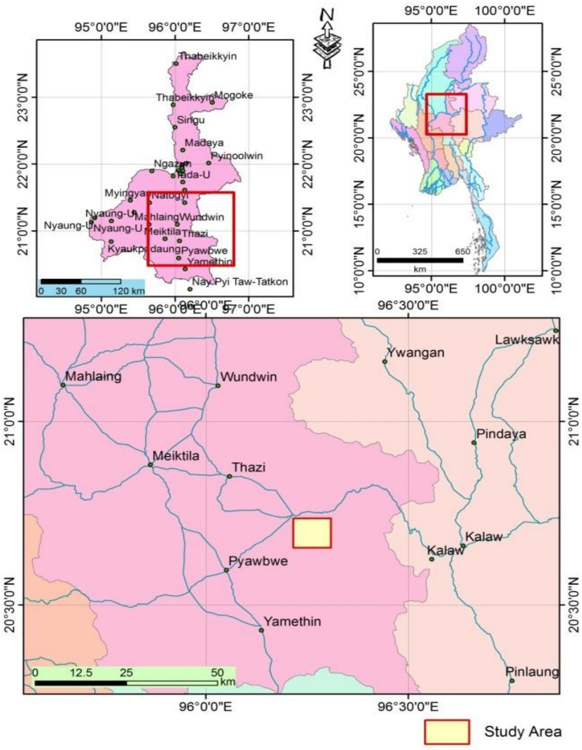


Figure 1 Location map of the area

Good exposures are noticed along Monbinzon at the northern part and Minbon Taung and Imagyi village at the southern part of the area. The study area is mainly composed of the igneous rocks and meta-sedimentary rocks. Igneous rocks are namely diorite, hornblendite, meladiorite, microdiorite, biotite granite, rhyolite, and dykes and veins (leucogranite, microgranite, pegmatite, aplite, quartz and quartzofeldspartic veins). Metasedimentary rocks mainly consists calc-silicate rock and skarn as shown in Figure 2.

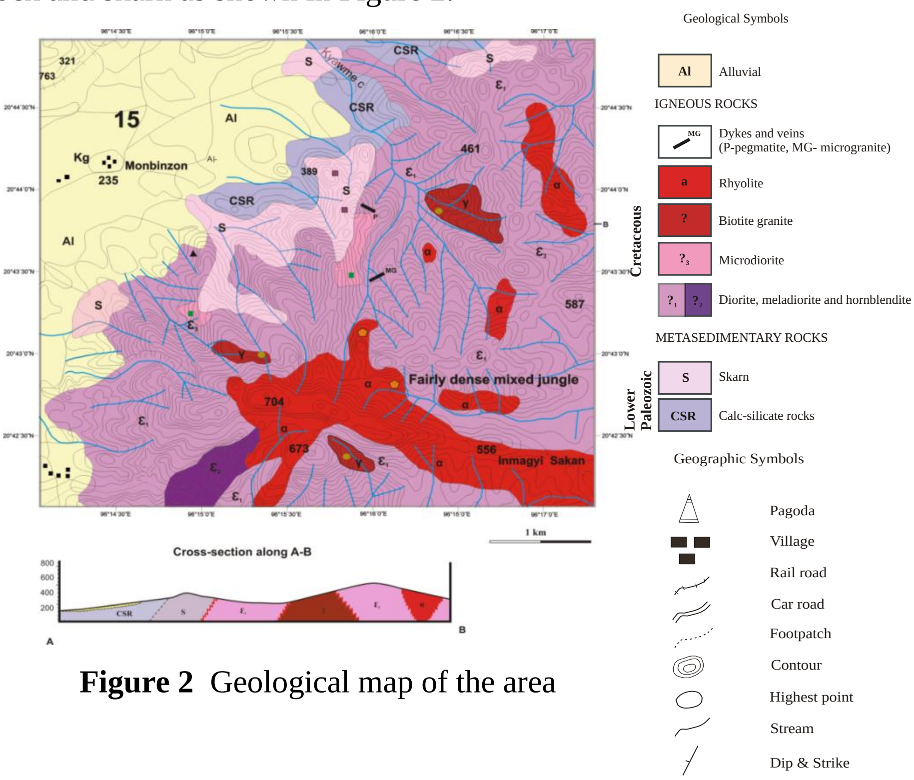


Figure 2 Geological map of the area

Nature of Skarn

The intrusion of diorite into impure limestone has recrystallized, part of the limestone to form a marble and the introduction of elements from the pluton has formed a skarn. Due to the effect of contact metamorphism to calcareous rocks, skarn have been observed on the southern part of Monbinzon village and south of Kywedatson car road. It occurs at the contact between diorite bodies and calc-silicate rocks and well exposed as a massive body.

As a result of contact metamorphism, the calc-silicate rocks become coarse-grained and show colour banding of greenish and reddish brown, the width of these colour bands vary. Skarn contain grossularite, tremolite and diopside. This rock is knotted, due to differential weathering of grossulariteand calcite. The dominant constituent minerals are diopside, tremolite, grossularite, epidote, calcite and quartz.

It is generally consider that the existing geological structures are some related to the movement of the tectonically significant Sagaing fault. The granitoid rocks and meta-sedimentary rocks are most widespread study area. The metasedimentary unit so far encountered is in the form of roof pendentin Figure 3(a).

Skarn is medium grained texture, fresh color dark green and weather color dark grey. It contains garnet, diopside and tremolite. These rocks are coarse-grained and occasionally associated with quartzite bands as shown in Figure 3(b). This skarns is exoskarn and present adjacent to the diorite emplaced into skarn. Garnet-clinopyroxene skarn is dark green in clinopyroxene-rich and purplish brown in garnet-rich skarn occurred southern part of Monbinzon village.

(a)

(b)

Figure 3(a) Roof pendant at southeastern part of Monbinzon village
(b) Skarn at south eastern part of Monbinzon village

Garnet skarn

The contact between the diorite and garnet skarn, where observed, is sharp and garnet skarn generally grades outwards into garnet-pyroxene skarn away from the pluton. Pea sized and larger brown or dark reddish brown euhedral garnet crystals are very common in areain Figure 4(a). Coexisting garnet and vesuvianite are common near the contact see in Figure 4(b) and far from diorite intrusion, medium to coarse-grained pale brown garnet with or without brown coloured vesuvianite.

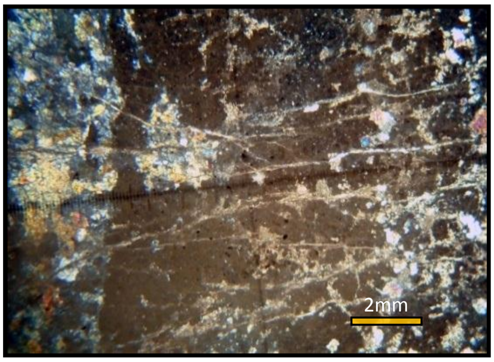
Garnet skarn is a coarse- to medium-grained, honey yellow to brown rock with a crude granoblastic to poikiloblastic texture in Figure 5(a).Epidote grains occur as inclusions in garnet andeuhedral garnet with pyroxene and zoisite mineral in skarn as shown in Figure 5(b). Minor variable amounts of calcite, quartz,biotite, amphibole, chlorite, and magnetite are present.

Vesuvianite is present as columnar aggregates. It occurs as crystals and has neutral colour under P.P.L. It gives straight extinction, has a high relief and anhedral crystals. Quartz shows strain effect. Accessories are apatite and large euhedral sphene which has acute rhombic shape.

(a) (b)

Figure 4 (a) Garnet knots on skarn at south eastern part of Monbinzon village

(b) Outcrop nature of skarn (garnet with vesuvinite) at southern part of Monbinzon village



(a) (b)

Figure 5(a) Poikiloblastic form of garnet with calcite and clinopyroxene

(b) Zoisite and garnet in skarn under XN

Garnet-clinopyroxene skarn

Garnet-clinopyroxene skarn is mainly composed of quartz, plagioclase, diopside, garnet, and tremolite and characterized by the absence of hornblende and biotite in Figure 6(a).Accessory minerals are apatite, and magnetite. Clinopyroxene is commonly associated with garnet in garnet-clinopyroxene skarn. These two minerals are generally approximately equal or pyroxene is slightly greater in proportion to garnet in Figure 6(b).

Hypidiomorphic granular texture of garnet-pyroxene skarn is composed mainly of quartz, plagioclase (An 40-45),and poikiloblastic orthoclase enclosing euhedral-subhedral pale green clinopyroxene (diopside) seen in Figure 7.

Clinopyroxene (diopside) is subhedral and basal section shows two sets of pyroxene cleavage. It is colourless or pale green and non-pleochroic. Grossularite garnet is anhedral and it contains inclusions.

Magnetite occurs mostly interstitially to pyroxene, although inclusions of this phase are observed in both clinopyroxene, and rarely garnet. Additionally, magnetite occurs along fractures and in veinlets.

(a) (b)

Figure 6(a) Garnet-clinopyroxene skarn at southern part of Monbinzon village
(b) Clinopyroxene mineral in skarn at south eastern part of Monbinzon village

Tremolite has a columnar form and is colourless in Figure 8(a). Interstices between garnet and clinopyroxene contain calcite, quartz or both, with or without k-feldspar and rare plagioclase.

Epidote forms as anhedral aggregates, giving high relief and strong birefringence and occurs usually as inclusions in larger garnet grains. Epidote is present interstitially to clinopyroxene grains. Accessory minerals are apatite, and magnetite. Sericite, pyrite, chlorite and calcite are common alteration products in Figure 8(b).

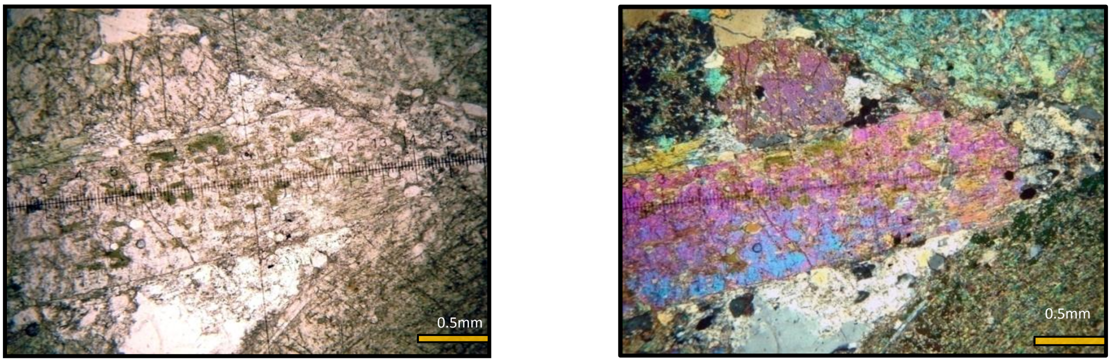
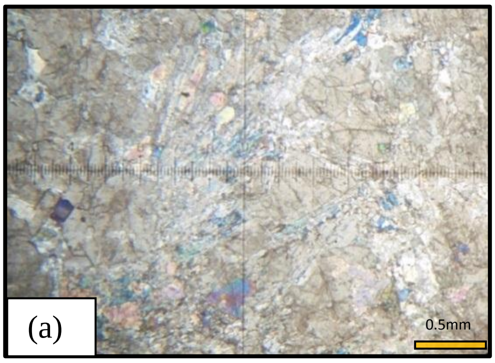


Figure 7 Clinopyroxene and garnet minerals in skarn under PPL and between XPL



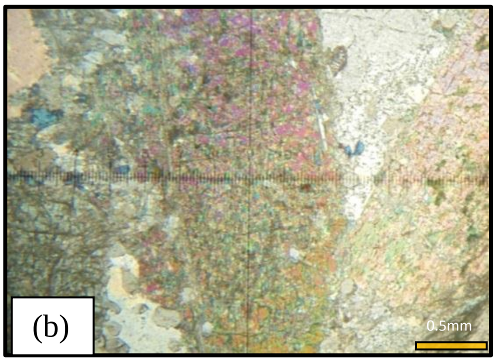


Figure 8 (a) Columnar aggregates of tremolite minerals in garnet-clinopyroxene skarn
(b) Clinopyroxene altered to chlorite in skarn

Distinguishing feature of garnet skarn and garnet-clinopyroxene skarn are shown in Table (1) and mineral assemblages are seen in Table (2).

Table 1 Distinguishing feature of garnet skarn and garnet-clinopyroxene

	Garnet Skarn	**Garnet-clinopyroxene skarn**
Grain size	**Medium to coarse-grained**	**Medium to coarse-grained**
Mineralogy	Garnet, Quartz, Plagioclase (An32-45), Hornblende, Biotite, Orthoclase, Magnetite	Pyroxene, Garnet, Quartz, Orthoclase(perthite), plagioclase (An20-34), Magnetite
Alteration	Sericite, e pidote, chlorite, calcite	Sericite, chlorite, actinolite
SiO_2	41.15	32.92
Na_2O	2.04	2.93
A/CNK	0.19	1.82
CaO	29.89	0.36
Sr	91	18

Coexisting garnet and clinopyroxene exhibit the following textural relationship:

(i) Clinopyroxenes are xenoblastic and form granoblastic and vermicular aggregates with less abundant garnet grains.

(ii) In garnet rich domains, massive garnet contains inclusions of calcite and clinopyroxene in poikiloblastic arrangement and

(iii) Garnet-clinopyroxene domains with a crude granoblastic texture

Table 2 Mineral assemblages in recrystallized calc-silicate rocks, garnet skarn, garnet-clinopyroxene skarn and diorite.

Rock type	Mineral assemblage	Microstructure	Retrograde assemblages
CSR	Garnet + epidote + quartz ± k- feldspar ± plagioclase	Crude granoblastic, anhedral garnet in with minor subhedral epidote inclusions. Anhedral-subhedral K-feldspar and plagioclase.	
Garnet Skarn	Garnet + calcite + quartz ± magnetite	Crude granoblastic, zoned-garnet with minor subhedral epidote with minor plagioclase as cavity fillings or interstitial to garnet grains. Subhedral-euhedral magnetite normally associated with cavity fillings of amphibole prims.	Some fine grained garnets replaced by calcite. Magnetite weathered to hematite.
Clino-pyroxene Skarn	Clinopyroxene+ garnet + calcite + quartz ± epidote ± K-feldspar ± plagioclase	Crude granoblastic, intergrowths of garnet and clinopyroxene. Xenoblastic calcite and quartz with minor K-feldspar and plagioclase. Some subhedral amphibole is long and normally aggregates. Subhedral idioblastic magnetite along clinopyroxene planes and with or without amphibole.	Clinopyroxene replaced by calcite plus magnetite and altered to amphibole. Isotropic garnet altered to calcite and magnetite.
Diorite	Hornblende + plagioclase + quartz + biotite + magnetite	Hypidiomorphic granular with euhedral quartz and anhedral-subhedral K-feldspar and plagioclase. Subhedral-euhedral epidote as inclusions large hornblende grains.	Hornblende altered epidote

Petrochemical Characteristic of Skarn

The analytical data of major and trace elements composition of skarn rocks are shown in Table (3). All of the samples were analyzed by XRF and ICP-MS analysis.

Table 3 Major oxide (wt %) and trace elements (ppm) abundances of theskarns

Type	Garnet skarn	Pyroxene skarn
SiO2	41.13	32.92
TiO2	0.33	0.2
Al2O3	6.39	7.14
Fe2O3	19.67	29.55
MnO	0.89	0.69
MgO	0.64	28.45
CaO	29.89	0.36
Na2O	2.04	2.93
K2O	0.85	0.62
P2O5	0.13	0.12
Cr2O3	2.04	2.93
LOI	0.51	1.08
Total	100.43	100.5

Type	Garnet skarn	Pyroxene skarn
Sr	91	18
Nb	n.d	6
Y	90	19
Zn	37	93
Ti	0.3	<0.1
Zr	103	53
Rb	20	16
Ni	3	3
La	57.1	27.4
Ta	0.5	0.4

Major Element Based Classification

The plots in Harker's variation diagramsas shown in Figure 9 indicate that SiO_2,$TiO_2$and K_2O show a systematic decrease from diorite to skarn in Figure 9(a). FeO_t display a similar distribution, general increase to skarn Figure 9(b).These distribution profiles are consistent with mass transfer during metasomatism.

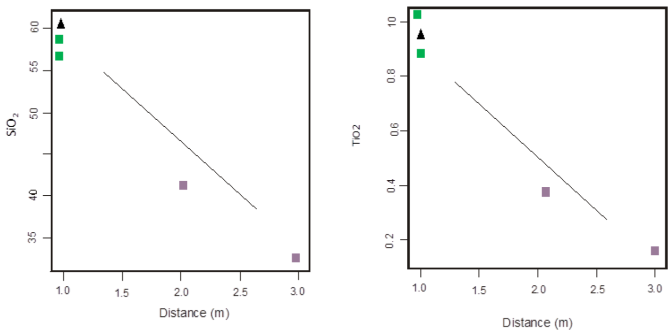


Figure 9(a) Harker'svariation diagrams by using major element

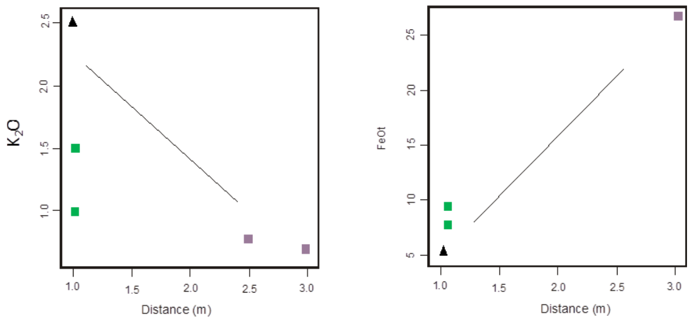


Figure 9(b) Harker' svariation diagrams by using major element

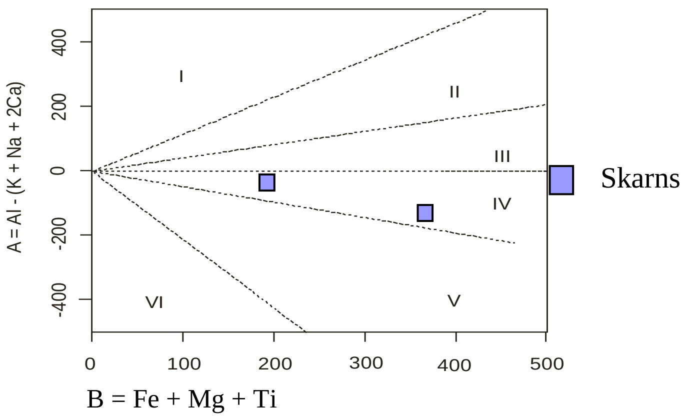


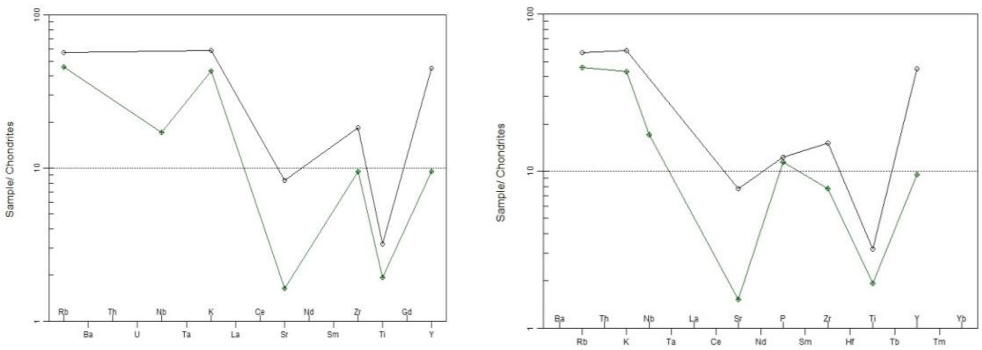
Figure 10 Mineral characteristic diagrams for the granitoid after Debon and Le Fort, 1983.

- Sector I = Muscovite alone/muscovite biotite
- Sector II = Biotite muscovite
- Sector III = Biotite alone
- Sector IV = Variety of characteristic minerals (biotite, hornblende, orthopyroxene, clinopyroxene, primary epidote and sphene)
- Sector V = High proportion of clinopyroxene and/or primary epidote and/or sphene
- Sector VI = only igneous rocks with very exceptional composition

Debon and Le Fort (1983) used a diagram based on two parameters. The character of skarns is analyses into sectors IV plot in Figure 10.

Type of Skarn

Cu, Zn and Y enrichment in skarn is relative to granite. Sr exhibits a perceptible decline in the direction of exoskarn. This decline again reflects geochemical decoupling is a reflection of crystal chemical controls on the ease of atomic substitution of Sr in garnet and pyroxene which form the exoskarn in this suite of samples. Zr concentration is much lower in adjacent exoskarn. Slightly enrichment in HREE (Y) is normally garnet rich. Strontium is decline in exoskarn due to forming of garnet and pyroxene because Sr can substitute in the lattice of garnet and pyroxene in Figure 11 (a).According to Thompson (1982) Chondrite normalized plots, the massive garnet-clinopyroxene skarn exhibit much flatter profilesin Figure 11 (b), suggesting that LREE/HREE enrichment is less pronounced, and indicating that garnet (see also Clark,1984) may preferentially concentrate HREE.



(a) (b)

Figure 11(a) Chondrite-normalized REE patterns by Sun et al. (1980)
(b) Chondrite-normalized REE patterns by Thompson (1982)

Mass transfer studies conducted by other workers, during the evolution of skarn, numerous chemical components, including Si, Ti, Al, Fe, Mn, Mg, Zn, Nb, Cu and zr are generally added and CaO, CO_2 and Sr are removed from the system. Of fundamental importance to an understanding of the process of skarn formation is how elements may be mobilized and finally incorporated in skarn.

Types of Metamorphism

The mineral assemblages indicated that the area had been subject to three types of metamorphism. They are regional metamorphism, localized contact metamorphism and cataclastic metamorphism.

Regional metamorphism is characterized by the formation of calc-silicate rocks. It is obvious that these rocks had low grade metamorphic minerals of chlorite reached up to Greenschist facies.

Regional metamorphism was superimposed by contact metamorphism by the emplacement of igneous intrusions, especially diorite intrusion. The skarn rocks are observed at the contact of diorite and adjacent metasedimentary rocks. Skarn rocks are the evidence of the existence of contact metamorphism. Contact metamorphism is indicated by the occurrence of skarn containing grossularite, diopside, tremolite and vesuvianite; therefore, the study area had taken place under "Pyroxene hornfels facies".

Cataclastic metamorphism is observed at or near the contact of igneous intrusion and adjacent metasedimentary rocks regarded by the occurrence of the bent twin bands of feldspar, the strain effect, cataclastic effect and highly brecciated nature of pegmatite.

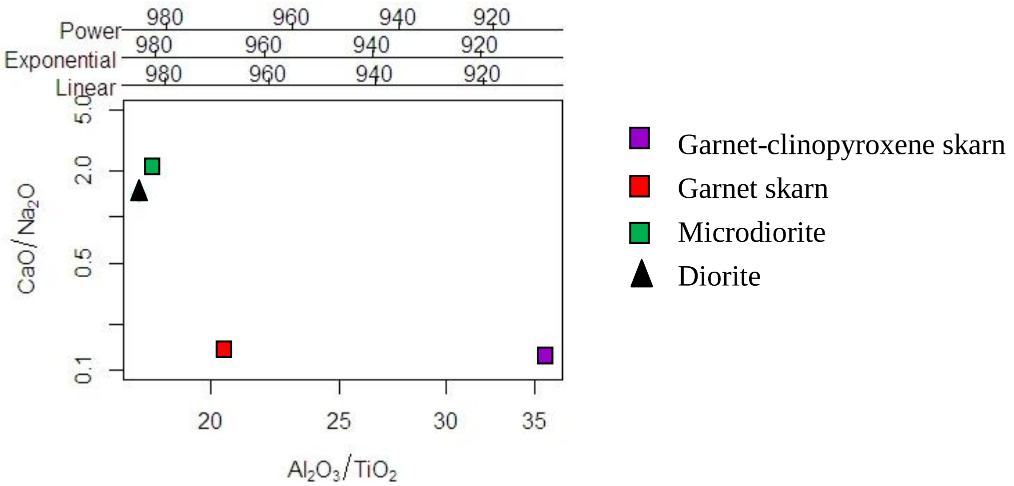


Figure 12 Temperature (˚C) after Jung and Pfander (2007)

According to the CaO/Na_2O vs Al_2O_3/TiO_2 diagram after Jung and Pfander (2007), the temperature of diorite is slightly more than microdiorite and decrease to garnet skarn (~ 970°C) and garnet-clinopyroxene skarn (not more than 920°C) as shown in Figure 12.

Mechanism and Depth of Emplacement

The possible mechanism of emplacement of intrusion is considered to be of forceful injection that the foliations are generally parallel to the contact between the intrusion and the country rock.

According to Winter (2013), the probable depth of emplacement of granitic rocks based on the evidences, petrographic studies and petrochemical studies are as follow:

1. The igneous rocks may show partially concordant and discordant contacts.
2. The contacts with the country rocks are sharp.
3. Roof pendent of metasedimentary rocks are formed over the pluton.
4. The country rocks are medium to high grade regional metasedimentary rocks.
5. A contact metamorphic aureole is typically well developed. And there exists a skarn zone.
6. Achill zone is locally present along the contact.
7. Presence of contact migmatite.
8. Fibrous in the pluton are commonly foliated or lineated near the contact.
9. Pegmatite dykes and quartz veins are common.

The above mentioned evidence shows that the igneous rocks of the study area are emplaced at the upper level of mesozone to catazone to the metasedimentary rocks and forming skarns.

Summary and Conclusion

The study area is situated about 24.3 km southeast of Thazi Township, Mandalay Region. Physiographic feature of the area is typically expressed by roughly parallel ridges with relatively relief, especially in the southern part of the area. The western part is lowland and the eastern part is a mountainous region. The highest-peak of the area is Minbon Taung 704m which exposed the skarn.

The study area is located in the eastern part of the Thazi-Pyawbwe plain which lies in the western part of the Shan Plateau which had become a stable block since the close of the Mesozoic. Two major fault zones, the Sagaing Fault in the West and Shan scarp fault in the East.

The area composed of different lithologic units such as igneous rocks and meta-sedimentary rocks. The igneous rocks of are emplaced at the upper level of mesozone to catazone to the metasedimentary rocks and form as skarn.

In the area, skarn consist predominantly of garnet-rich skarn and garnet-clinopyroxene skarn, with respect to increasing distance from the pluton. Garnet-clinopyroxene skarn crops out as greenish brown coarse- to medium-grained rocks. On the side of calc-silicate rocks, it is clinopyroxene rich and becomes garnet rich along the pluton contact.

Skarn is medium to coarse grained. In garnet rich domains, massive garnet contains inclusions of calcite and pyroxene in poikiloblastic texture. In garnet-pyroxene domains, pyroxenes are xenoblastic and form granoblastic texture.

Geochemically, the distribution profiles of Harker's variation diagramsare consistent with mass transfer during metasomatism due to SiO_2, TiO_2 and K_2O decrease from diorite to skarn and FeO_t increase to skarn.

Cu, Zn and Y enrichment in skarn and Sr exhibits a perceptible decline in the direction of exoskarn. This decline again reflects geochemical decoupling is a reflection of crystal chemical controls on the case of atomic substitution of Sr in garnet and pyroxene which form the exoskarn in this suite of samples. Zr concentration is much lower in adjacent exoskarn. Slightly enrichment in HREE (Y) is normally garnet rich. Strontium is decline in exoskarn due to forming of garnet and pyroxene. In Chondrite-normalized REE patterns, LREE/HREE enrichment is less pronounced, and indicating that garnet may preferentially concentrate HREE in skarns.

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