ศิลาเคมีของหินต้นกำเนิดพลอยคอรันดัมในเวลลาวายา ประเทศศรีลังกา

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PETROCHEMISTRY OF CORUNDUM-BEARING ROCK IN WELLAWAYA, SRI LANKA

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หัวข้อ (ภาษาไทย)	**ศิลาเคมีของหินต้นกำเนิดพลอยคอรันดัมในเวลลาวายา ประเทศศรีลังกา**
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บทคัดย่อ

การศึกษาศิลาเคมีของหินในบริเวณเวลลาวายา ซึ่งมีลักษณะเฉพาะที่สัมพันธ์กับการกำเนิดพลอยคอรันดัม เพื่อสืบค้นกระบวนการแปรสภาพและการเกิดของพลอยคอรันดัมในพื้นที่ โดยได้แบ่งหินตัวอย่างโดยใช้องค์ประกอบและเนื้อหินสามารถแบ่งได้เป็น 2 กลุ่มคือ กลุ่มหินแปรที่มีพลอยคอรันดัมฝังปะอยู่และกลุ่มหินไมก้าชีท โดยเน้นศึกษาไปที่กลุ่มหินแปรที่มีพลอยคอรันดัมฝังปะอยู่ซึ่งสามารถแบ่งย่อยได้เป็น 2 กลุ่ม คือกลุ่มหินแปรมีริ้วลายและกลุ่มหินแปรไม่มีริ้วลาย จากการศึกษาศิลาวรรณาพบว่ากลุ่มหินแปรที่มีพลอยคอรันดัมฝังปะอยู่ทั้งสองกลุ่ม มีแร่องค์ประกอบและลักษณะเนื้อหินที่ใกล้เคียงกัน ประกอบด้วยแร่อัลคาไลเฟลด์สปาร์และแร่แพลจิโอเคลสแบบผลึกไร้หน้าขนาดเท่ากันเกิด Triple junction มีองค์ประกอบแร่ แพลจิโอเคลส 50-55% แร่อัลคาไลเฟลด์สปาร์ 25-30% แร่ไบโอไทต์ 10-15% และแร่คอรันดัม 1-5% แร่คอรันดัมมักพบเป็นผลึกดอกแปรรูปร่างสมบูรณ์ล้อมรอบด้วยเนื้อหินผลึกเม็ด โดยลักษณะทางศิลาเคมีแสดงถึงการแปรสภาพขั้นสูง อย่างไรก็ตาม พบว่าส่วนที่เป็นเฟลสิกในกลุ่มหินแปรไม่มีริ้วลายอาจเป็นส่วนของหินแปรมีริ้วลาย ผลวิเคราะห์ธรณีเคมีของแร่ในแต่ละกลุ่มมีความแตกต่างกันน้อยมากในส่วนขององค์ประกอบ ไม่สามารถแบ่งกลุ่มได้ชัดเจน องค์ประกอบที่แตกต่างกันนั้น อาจมีสาเหตุมาจากการแปรสภาพ และสามารถจัดกลุ่มของการอิ่มตัวด้วยอลูมิน่าที่สูงมาก ผลการศึกษาเคมีแร่พบว่ากลุ่มหินแปรที่มีพลอยคอรันดัมฝังปะทั้งสองกลุ่มมีค่าเคมีแร่คอรันดัม แร่อัลคาไลเฟลด์สปาร์ แร่แพลจิโอเคลส แร่เซอร์คอน และแร่ไบโอไทต์ คล้ายคลึงกัน โดยมีการตกผลึกระหว่างที่มีค่าความสมดุลของการแปรสภาพสูงสุด โดยแร่คอรันดัมมีการเกิดในสภาวะอุณหภูมิสูงและความดันที่กว้างระหว่างการแปรสภาพแบบไพศาลที่สมดุลย์กับแร่ไบโอไทต์ แพลจิโอเคลส และอัลคาไลเฟลด์สปาร์ หินต้นกำเนิดก่อนการแปรสภาพควรมีองค์ประกอบของอลูมิน่าสูงก่อนเกิดการแปรสภาพขั้นสูงระดับ granulite facies

PETROCHEMISTRY OF CORUNDUM-BEARING ROCK IN WELLAWAYA, SRI LANKA

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Abstract: This study is aimed to characterize corundum-bearing rocks in Wellawaya. Petrochemistry and mineral chemistry of rock samples were then investigated prior to reconstruction of metamorphism of the area. Rock collection can be divided, based on petrographic description, into 2 types including corundum-bearing rock and mica schist. Moreover, corundum-bearing samples, the main focus of this study, can also be divided into 2 types which are obvious foliated rock and non-foliated rocks. All corundum-bearing rock samples have similar mineral composition and microscopic texture characterized by alkali feldspar and plagioclase which usually form granoblatic grains with well-developed triple junctions. Essential minerals contain about 50-55% plagioclase, 25-30% alkali feldspar, 10-15% biotite and 1-5% corundum. Corundums have been found as granoblastic and porphyroblastic grains that usually formed as very large crystals in both sample groups. These petrographic features indicate high-grad metamorphism. However, non-foliated samples appear to have occurred as a part of felsic layer in foliated rocks. Whole-rock geochemistry shows somewhat difference within these rocks. All corundum-bearing rocks are classified as peraluminous rocks on the basis of alumina saturation. Mineral chemistry shows similarity of assemblages observed in both corundum-bearing groups. They have similar mineral chemistry of corundum, alkali feldspar, plagioclase zircon, and biotite. Corundum may have crystallized during the peak metamorphism equilibrated with biotite, plagioclase and alkali feldspar. Corundum forms at high temperature conditions with a wide range of pressure conditions during regional metamorphism. Their protoliths would be alumina rich provenance prior to high grade metamorphism belonging to granulite facies.

Keyword: Petrochemistry, Corundum, Granulite, Sri Lanka, Mineral Chemistry

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Special thanks are sincerely expressed to all member staffs at Chulalongkorn University for their help and assistance including advises during research for all analytical equipment used in this project.

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Chapter I

INTRODUCTION

1.1 General Statement

Sri Lanka is an island country situated in the India Ocean close to the southeastern Indian continent. Geographically, the island is mostly occupied by mountain ranges of highland lining from north to south, particularly in the central and southern parts of the island. Sri Lanka is a part of Precambrian craton and the supercontinent Gondwanaland, connected to the craton of the Indian subcontinent. It had been separated from the Indian plate since Precambrian (Katz, 1999). Regarding to metamorphism, it appears to have originated continuously and comparably to metamorphic belts in India, eastern Africa, Kenya, Tanzania, Madagascar and eastern Antarctica which this particular belt is called "Mozambique belt". There are evidences indicating the significant events of high grade metamorphism in this island. Based on metamorphic lithology and geologic setting, Sri Lankan metamorphic belt can be subdivided into 3 major lithotectonic units, Wanni Complex (WC), Highland Complex (HC), Vijayan Complex (VC) and Kaduganwa Complex (KC) (Tennakoon et al., 2005 cited in Kroner et al., 1991).

Wellawaya is located in the southeastern part of Sri Lanka. The area is geologically situated near the boundary between Highland Complex and Vijayan Complex in which is considered as destructive type area (Pathirana, 1980). Its wide variety of gemstones is dominated by corundum, chrysoberyl, garnet, spinel, tourmaline, zircon etc (Fernando et al., 2005). However, these deposits can be grouped into two main types including *in-situ* and elluvial deposits. Tipprasert (2006) reported a primary corundum deposit discovered in high grade metamorphic rock of Wellawaya; besides, these stones have potential for heat treatment.

However, origin of corundum and metamorphism has not yet been carried out. This information is quite important and could lead to further exploration of metamorphic corundum deposits of the country and throughout the Mozambique belt in those mentioned above.

1.2 Objectives

This study is aimed to characterize corundum-bearing rocks in Wellawaya, Sri Lanka. Therefore, the main objectives are set below.

1.) To investigate petrochemical characteristics of the rock samples.

2.) To analyze mineral chemistry of major assemblage in these rock samples.

1.3 Theoretical Background and Relevant Research

Katz (1999) reported that geotectonic process in India and Sri Lanka was controlled by Precambrian faulting. Shear zone appears to be suturing between subcontinents; besides, it may be controlled by mantle seated. Sri Lanka had moved away from India in Jurassic to early Cretaceous and continuously kept tracking northwards during Paleocene until the island has arrived the recent position since Pleistocene. This is recognized as a result of the significant event of tectonic movement of African plate away from Pacific plate. Consequently, Sri Lanka still remains rock formations comparable to those in east Africa as well as southern India, particularly charnockitic mobile belt lining in NNE direction.

Over 90 % of the whole island, Sri Lanka is occupied by Precambrian metamorphic rocks which have been divided into 3 major lithotectonic units named as Wanni Complex (WC), Highland Complex (HC) and Vijayan Complex (VC); in addition, Kaduganwa Complex (KC) was grouped separately later by Tennakoon et al. (2005, cited in Kroner et al., 1991).

Sri Lanka has long been known as a world major source of gem variety with high quantity. Wellawaya is also one of those gem potential area; it is situated in the southern region of Sri Lanka Island. Geologically, it is located near the boundary between Highland Complex and Vijayan Complex which is suspected as a destructive type (Pathirana, 1980). Northwest and north northeast of the area contain rock units of Highland Complex as trending in the middle of island. Tectonism and high graded metamorphism as well as weathering process appear to have modified the different landforms such as mountain and plain in the area.

Regarding the regional rock formation, Highland Complex rocks are suspected to have metamorphosed from igneous and sedimentary rocks (Tennakoon et al., 2005). Most of these metamorphic rocks are classed as upper amphibolite to granulite facies. Vijayan Complex rocks contain mainly hornblende-biotite orthogneiss with granitic to granodioritic composition which belong to amphibolite facies. Boundary zone of Highland Complex and Vijayan Complex is interpreted as a flat-lining thrust zone. The distribution of serpentinite is also an indicator of discontinuity as well as different origin and structure including metamorphic histories of subcontinental plate distinguished in some particular areas. Moreover, deep-seated thrust zone indicating obducted ophiolite belt which have been formed by high grade metamorphism and deformation during collision of subcontinents has been also discovered along the boundary between both complexes.

Simonet et al. (2008) divided gem corundum both ruby and sapphire, deposits in the world into primary deposits and secondary deposits. Primary deposits are typically involved by igneous and metamorphic processes. However, igneous gem corundum deposits are quite rare; there are some cases such as sapphire-bearing syenite in Kenya. In this regard, it is still a result from metasomatic processes mostly being small-scale process involving desilication reactions between silica-aluminous rocks and silica-poor rocks. For large scale metamorphism, it is usually more difficult to characterize and therefore is not separated from isochemical metamorphism in this classification. In metamorphic deposits, gem corundum is generated from transformation of an Al-rich and Si-poor protolith; such as ruby-bearing gneisses and mafic granulites, ruby-bearing metalimestone and sapphire-bearing gneisses and granulites. Secondary deposits assemble sedimentary and volcanic occurrencesin which gem corundums appear to have originated in other lithologic units before erosion and deposition in sedimentary basins or being picked up as xenocrysts by basaltic magma rising up to the surface.

Tsunogae and Santosh (2003) studied sapphirine and corundum-bearing granulite from Karur in Madurai Block, two new locations of sapphirine-bearing rocks from Lachmanpatti and Malappatty block in southern India. The new occurrences of shapphirine and corundum-bearing granulite are intercalated within orthogneisses. Hornblende biotite gneiss is the major lithology of the area. The shapphirine-bearing aluminous layers at Lachmannapatti occur as coarse-grained biotite-rich metasediments. The samples, sapphirine, occur as symplectite with cordierite and corundum, which are in turn surrounded by cordierite and biotite, intergrowth with corundum. Sapphirine occurs as fine-grained subhedral mineral. Sapphirine and cordierite should form in the low pressure side of the reaction. This study has importance bearing on the ultrahigh-temperature metamorphism as well as on the tectonic evolution of the continental deep crust in Southern India.

1.4 Scope of work

Petrochemistry of corundum-bearing rock samples from Wellawaya, Sri Lanka was carried out under this study. Petrography was described under polarizing microscope prior to mineral chemistry analysis using Electron Probe Micro-Analyzer (EPMA). Moreover, whole-rock geochemical analysis was taken place using X-ray Fluorescence (XRF) Spectrometer for major and minor compositions.

1.5 Expected Outputs

1) Petrochemical data of corundum-bearing rocks from Wellawaya, Sri Lanka.
2) Petrogenesis and corundum occurrence in Wellawaya, Sri Lanka.

Chapter II

METHODOLOGY

Methods of study can be divided into 6 steps as summarized in the schematic diagram (Fig.2.1) and detail is described below.

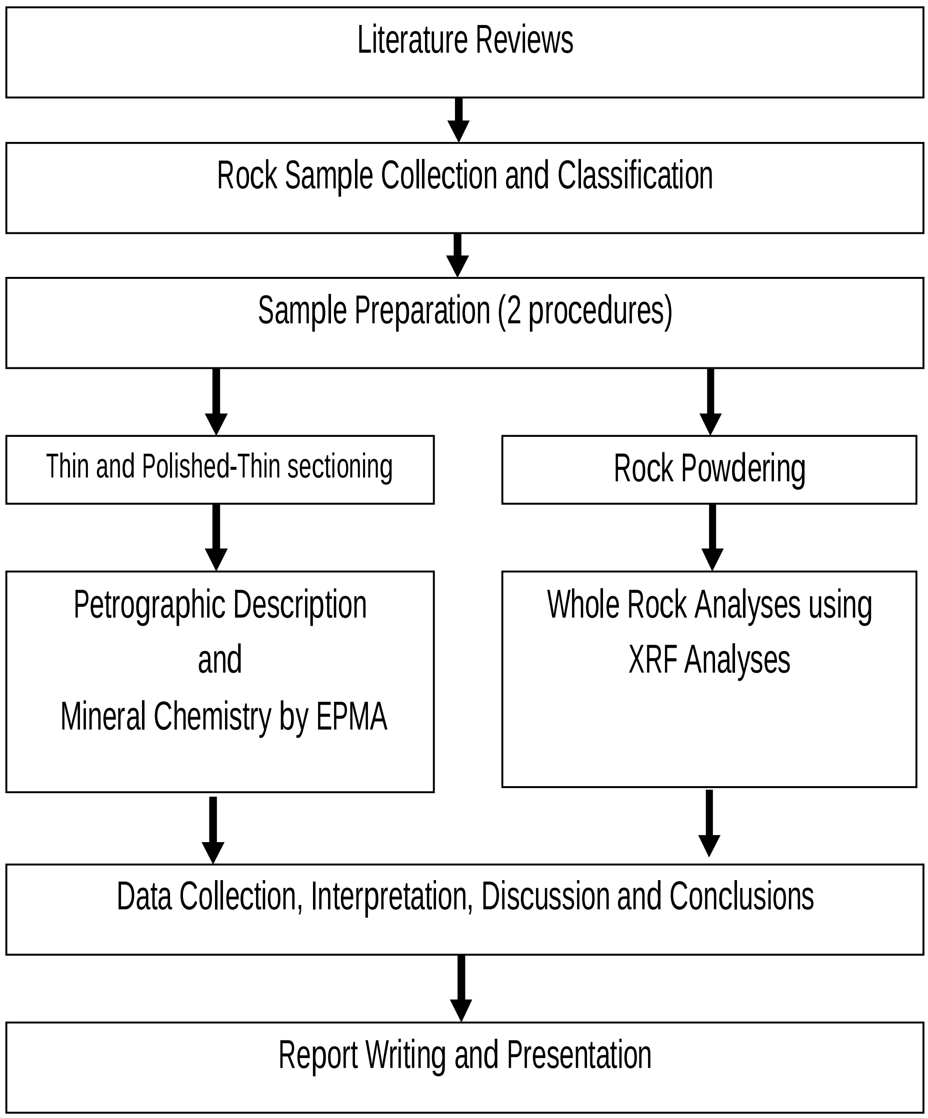


Fig.2.1 Schematic diagram showing study steps of the research project.

1) *Literature Reviews:* were taken place to receive some general idea to initiate this research work. Previous researches and geological reports related to corundum deposits and metamorphism in Sri Lanka were reviewed to guide for interpretation and discussion.

2) Rock Samples Collection and Classification: all rock samples were provided by The Gem and Jewelry Institute of Thailand (Public Organization) (GIT). All rock samples were roughly identified and grouped for analytical preparation.

3) Sample Preparation: included two procedures including thin sectioning and rock powdering. Thin sections and polish-thin sections were used for petrographic description and mineral chemical analysis. Rock powder samples were analyzed for whole-rock geochemical analysis. All equipments for sample preparation are based at the Geology Department, Faculty of Science, Chulalongkorn University.

4*) Analytical Techniques:* contain three main steps, i.e., petrography, whole-rock geochemistry and mineral chemistry. Petrographic description was carried out initially using thin sections and polished-thin sections under polarizing microscope. Texture and mineral composition were investigated and photomicrographs were taken for most particular features. Mineral assemblages were summarized with crystallization order. Selective mineral grained were analyzed chemically using Electron Probe Micro-Analyzer (EPMA; Model JEOL JXA-8100 ELECTROC PRORE MICROANALYZER) for detailed mineral chemistry. Mineral and pure oxide standards were calibrated using focused beam (<1 μm in diameter) with operating condition of 15kV and about 2 μA. Whole rock geochemistry were carried out by X-ray Fluorescence (XRF) Spectrometer. These quantitative analyses of whole-rock composition were operated at Bruker axs S4 PIONEER with 220/380 v. use, 50 Hz, 8 kvA. Internal standards were used for calibration. All analytical instruments used in this study are based at Faculty of Science, Chulalongkorn University.

5) Data Collection, Interpretation, Discussion and Conclusions: finally, all analytical results were collected for interpretation of petrogenesis and origin of corundum. Discussion on geologic setting and metamorphism related to corundum genesis were also worked out prior to conclusions in some particular aspects.

6) Report Writing and Presentation: research report was wrapped up and submitting to the Geology Department to fulfill requirement of the Bachelor of Science (BSc) in Geology program. Presentation of the study was also given in the department seminar. In addition, short technical paper may be prepared for publication.

Chapter III

GENERAL GEOLOGY, GEM DEPOSIT IN SRI LANKA AND WELLAWAYA

3.1 General Geology

The metamorphic basement of Sri Lanka is an important key to understand the evolution of the Gonwanaland supercontinent. Geologically, Precambrian high-grade metamorphic rocks are dominant in Sri Lanka and can be divided, on the basis of lithotectonic, into four major units, Wanni Complex (WC), Highland Complex (HC), Vijayan Complex (VC) and Kaduganwa Complex (KC) (Fig. 3.1) (Cooray, 1994: cited in Dissanayake, 2000). The geological structure of Sri Lanka is mainly a thick sequence of Archean metamorphic rocks at the southern boundary of the Indostan crystalline shield. The lower part of sequence is orthogneiss and paragneiss of the Vijayan group, which are overlain quartzite, crystalline schist and marble of Highland group in the central part of the island.

The Highland Complex is the largest unit formed above the Precambrian bedrock. A variety of igneous intrusion, predominantly granitoid composition (Kroner et al.,1991: cited in Dissanayake, 2000). The Highland Complex rocks were metamorphosed under granulite facies condition.

The Vijayan Complex is located in the eastern Highland Complex. It is mainly composed of biotite-hornblende gneiss and scattered bands of metasediment and charnockitic gneiss which were metamorphosed in the amphibolite facies (Kroner et al., 1991: cited in Dissanayake, 2000). Milisenda et al. (1991) described the gneissose granitoids of the Vijayan Comlex as tonality toleucogranitic in composition.

The Wanni Complex, composed of granitiod gneisses, charnockitic gneisses and granites, were metamorphosed within amphibolite and granulite facies. Their initial compositions are predominated by pelitic and semipelitic rocks. The Wanni rocks are relatively younger than the Highland rocks based on age dating data of zircon in metapilite (Milisenda et al., 1991: cited in Dissanayake, 2000).

Fig.3.1 Geological map of Sri Lanka, the star showing the location of Wellawaya. Legends and symbols are present in Fig. 3.2 (modified from www.library.wur.nlisrickaartorigineelLK).

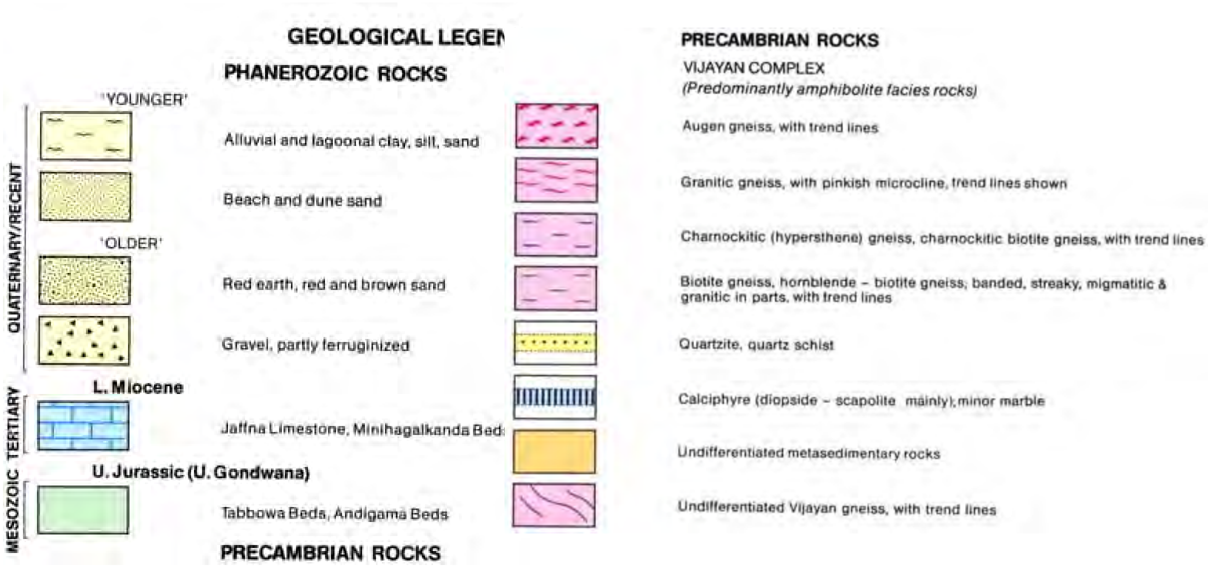
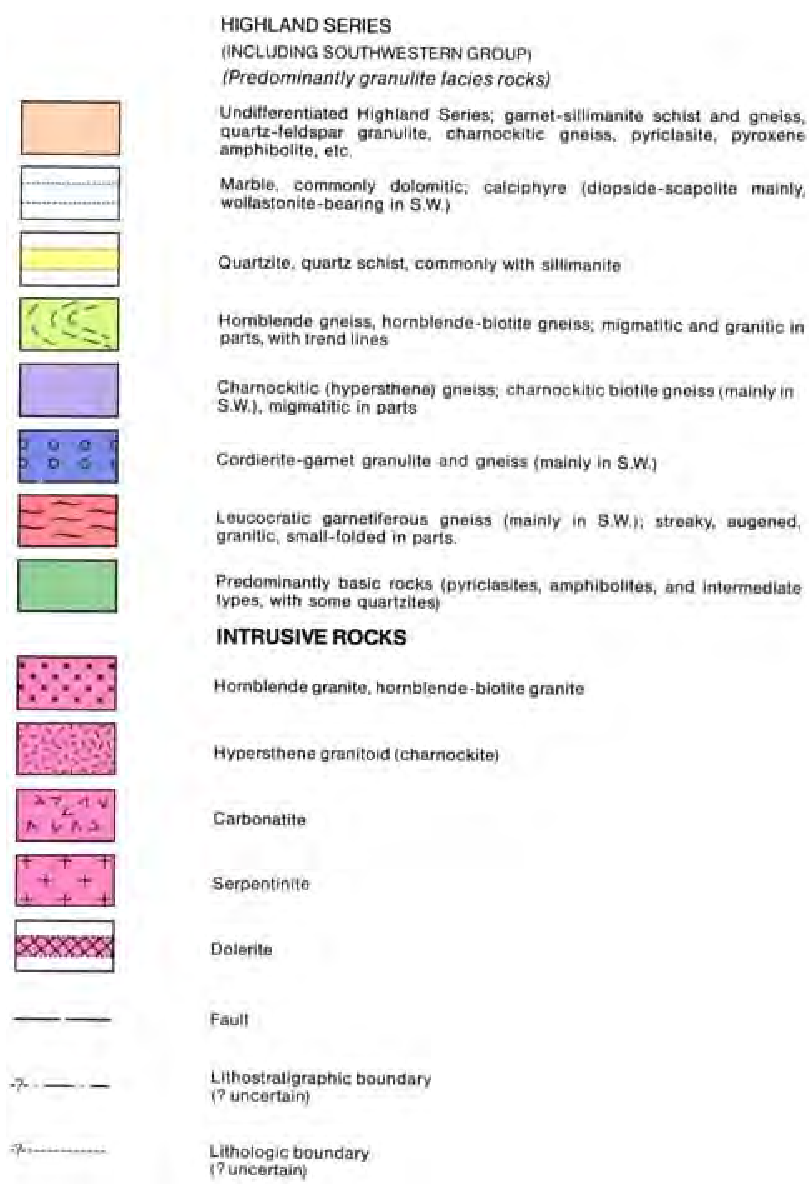


Fig.3.2 Legends and symbols of the geological map of Sri Lanka in Fig. 3.1.



3.2 Gem Deposits

Sri Lanka has been known as the “island of gems” for century. Variety of gem which include blue, yellow and orange shapphire, alexandrite, chrysoberyl (cat’s eye), spinel, zircon, garnet (e.g., pyrope, almandine, spressartine and hessonite), peridot, topaz, tourmaline, beryl, amethyst, smoky and colorless quartz have been discovered from complex placer deposits on the island (Hughes, 1977). The blue sapphires from Sri Lanka are known as Ceylon sapphire. Ceylon sapphires are quite unique in color, clarity and luster compared to blue sapphires from elsewhere.

Sri Lanka is a famous source of high quality gemstone, particularly corundum. Most stones are mined from alluvial gravels that occur as lens or bands in the riverbeds and stream valley. Most of the gem fields in Sri Lanka are located mainly in the south-east region and partly in the northern regions. Gem minerals are missing in the Vijayan Complex which has not pyroxene and garnet-gearing assemblages. A major gem fields in Sri Lanka usually lie in the Highland Complex (Fig. 3.4). High-grade metamorphic rocks of granulite facies appear to have characteristics of gem-bearing rocks (Tennakoon et al., 2006). Gemstones found within the Vijayan domain may have transported via river system flowing from Highland Complex. The source rocks of gem minerals are significantly characterized by skarns, marbles, pegmatite, garnetiferouse gneiss and charnockite (Dissanayake and Rupasinghe, 1995: cited in Dissanayake, 2000)

Gem-bearing alluviums occur crucially in the central and southern parts of Sri Lanka. Residual deposits are mainly found in flood plains along rivers and streams. The metamorphic type of gem deposit is main constitute (up to 90%) in Sri Lanka. Ratnapura is the most famous gem deposits of the country and its name means “city of gems”. Most of corundums found around placer deposit. Although, complex gem placer deposits are widely distributed in this area as well as throughout Sri Lanka island; the primary sources of most deposits have not been discovered yet (Silva and Siwardene, 1988: cited in Hughes, 1977).

Dissanaryake and Rupasinghe (1995) classified gem deposits in Sri Lanka, based on initial rock types, into 3 groups including sedimentary, igneous and metamorphic types. Dahanayake et al. (1980) suggested that the sedimentary gem deposits are by far the most importance of Sri Lanka gem fields which include residual, elluvial and alluvial deposits. The specific types and details of each gem deposit groups are summarized and shown in Fig. 3.3.

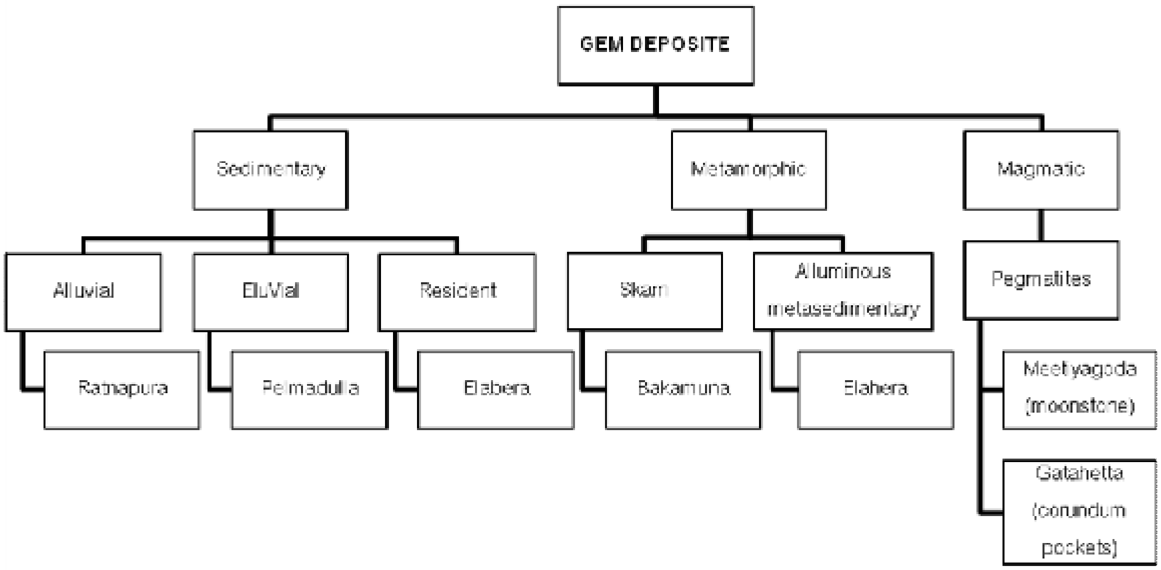


Fig.3.3 Schematic diagram showing classification of gem deposits in Sri Lanka with examples of locations of different types (modified from Dissanayake and Rupasinghe, 1995).

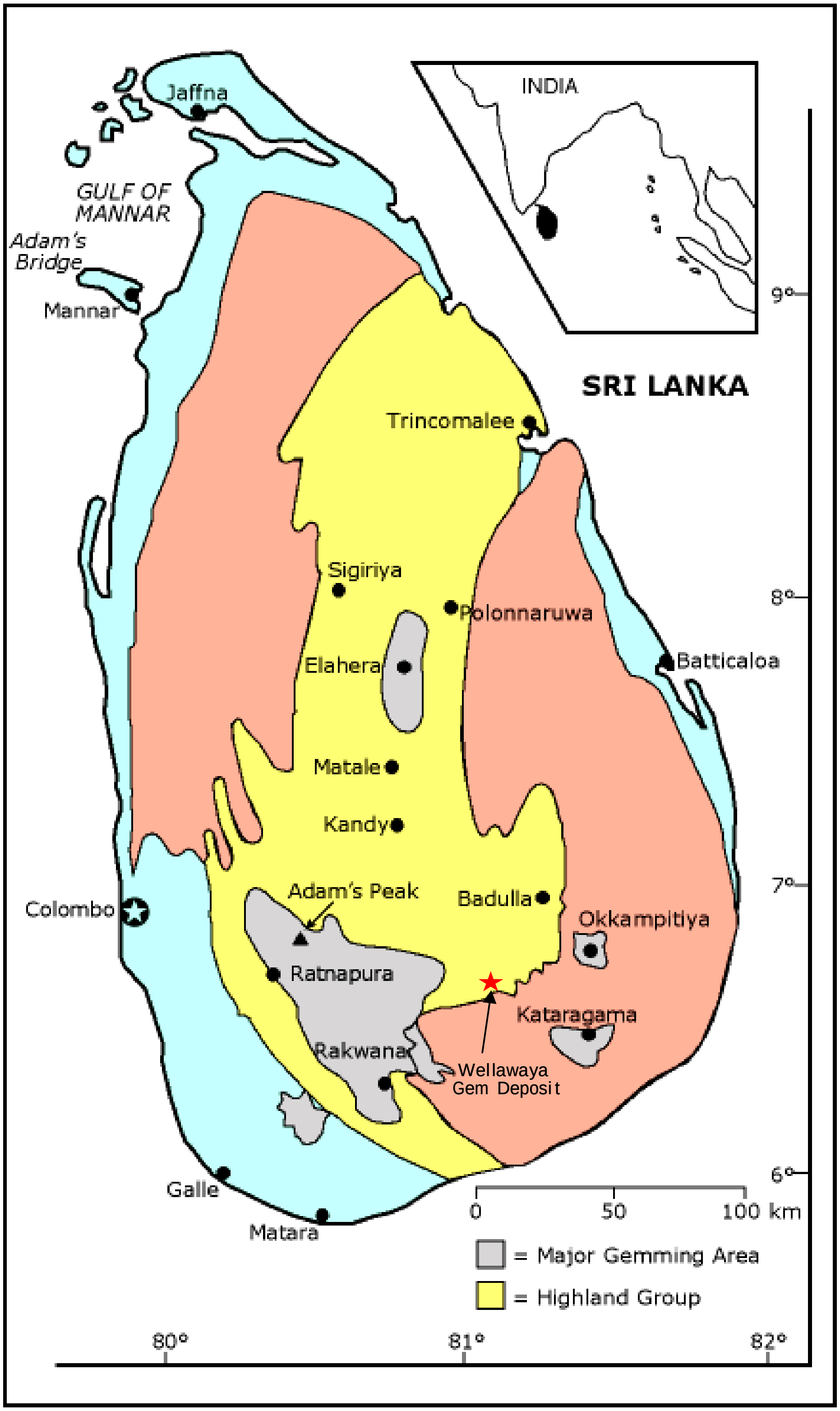


Fig.3.4 Map of Sri Lanka (Ceylon) showing the location of important cities, distributions of main gem mining areas and their related-high land complex as well as Wellawaya gem field under this study (modified from www.palagems.com/ceylon_sapphire_bancroft.htm).

3.3 Wellawaya Gem Deposit

Wellawaya is located in the southwestern Sri Lanka (Figs. 3.4 and 3.5). In the West-North and Northern ends of the Wellawaya valley, a series of hill are lying in the Highland. During tectonics and high grade metamorphism and subsequent erosion, many hills with different heights have been developed. It has been observed that the front short hills have corundum mineralization comprising of large idiomorphic crystals. Gampaha, Galbokka, Gampanguwa, Bubulugama and Bulula, located about 8-10 km from the boundary, are some of the village where such crystals could be found. Good gem quality transparent crystals have not been found but pink and blue translucent idiomorphic crystals are available. Some of the crystals could be heat treated to obtain a bluish color and which can then be used for preparation of ornament (Tennakoon et al., 2005; Tipprasert 2006).

Wellawaya area is not economically high gem deposit but it is a probable gem bearing locality. The most common gem found in Wellawaya is garnet; besides, corundum gems such as yellow sapphires and geuda are occasionally recorded. They are found far downwards the Wellawaya town. Paleoalluvial gravels of Kirindi Oya have been recognized as the main occurrence. Recently, there are some *in-situ* gem occurrences in the particular area. The identified *in-situ* corundum deposits are located about 6-8 km away from the boundary zone of the Highland Complex and Vijayan Complex, the underlying rock, being mainly charnockitec gneiss. The elluvial corundum deposits are found on west of the Highland-Vijayan thrust boundary (Tennakoon et al., 2005).

The first *in-situ* corundum deposit is found about 6 km northeast of Wellawaya town at a village called “Gampanguwa”. Corundum-bearing residual overburden soil is found on the mountain top. Savanna grass and some large trees such as “Nelli” –*Phyllanthus emblica* and “Gammalu” – Pterocarpus marsupium are occasionally seen covering this mountain. These trees are mostly fire resistant and useful as timber and highly valuable for indigenous medicine. The deposit is under a protected area of the deposit is part cover by Dry-Mixed Evergreen forest and Savanna grassland.

On the way to the deposit, large boulders of mobilized marble are prominent, containing angular and sub-round rock fragments. Migmatised biotite gneiss and garnet rich biotite gneiss are also frequent while some rocks have graphite as an accessory mineral. The overburden consists of well-developed corundum crystals. The rock is partially weathered and easily breakable. Breaking of source rock results in the release of corundum crystals. The crystals are well-developed and most crystals are of bluish color. The others are grey, white, pink, and reddish crystals. Most crystals are translucent to opaque.

The second *in-situ* corundum deposit is found about 9 km northeast of the Wellawaya town at a village called 'Bubulagama'. Corundum-bearing residual overburden soil is found on the mountain top. Bubulagama corundum deposits are about 3 km away from the Gampanguwa deposits, but on the light bluish, pinkish color, with smaller crystals as compared to those seen at Gampanguwa but with a large number of crystals (Tennakoon et al., 2005).

The *in-situ* corundum-bearing rocks are hammered and broken by the traditional miners. These are then fragmented and the corundum with well developed crystal faces are collected and sold as lots. The rock fragment is rich with corundum crystals and therefore the buyers have more interest on rock fragment than on individual corundum crystals.

The first Elluvial corundum deposit is found 5 km northwest of Wellawaya town, on the west of the Highland-Vijayan Boundary. The area is known as 'Galbokka', which had been a village but is now abandoned. Here the source rock is not exposed and the corundum crystals which have retained the crystal shape are found in the overburden of soil transported due to early landslides. Therefore, it is being categorized as an elluvial deposit. The soil among the moved boulders are extracted and panned in water in order to collect corundum crystals the topsoil of the hills is rich in spinel crystals with octahedral shape, and are blue and green but semi-translucent to translucent.

The second Elluvial corundum deposits are located at 8-10 km away from the Wellawaya town towards Beragala. The area is known as Makuldeniya and Gampaha and the gem bearing regions are also terrains of early landslides. The region is rich in corundum crystals. They are Gampaha corundum deposits are about 5-8 km away from the Galbokka deposits. According to the geologic and topographic maps, these deposits are situated in the same geological trend (Tennakoon et al., 2005).

In-situ and elluvial corundum-bearing area have produced valuable corundum minerals due to ideal pressure, temperature and chemical conditions during regional metamorphism. Good gem quality corundum has not been found yet. However, heat treatable corundums are rich in this mineral belt. It is suggested to explore the real extension of the corundum belt and grade the quality of corundum (Tennakoon et al., 2005).

Fig.3.5 Geologic map showing a series of *in-situ* corundum occurrences have been found in the region around Wellawaya. This area lies near the boundary between the Highland and Vijayan Complexes (Kievlenko, 2003).

Fig.3.6 A natural outcrop of the study area.

Fig.3.7 Euhedral corundum crystals are found in the host rock and residual deposits; they have pinkish and bluish colors.

Fig.3.8 Corundum-bearing mafic granulite with a large pinkish corundum crystal.

Fig.3.9 Corundum-bearing felsic granulite found in the area.

Chapter IV

RESULTS

4.1 Sample Collection

Corundum-bearing rock samples were collected from Wellawaya area by gemologists and geologists of the Gem and Jewelry Institute of Thailand (GIT) in 2006. Wellawaya gem-bearing samples are mostly exposed in the hilly area containing various rocks such as gneiss and migmatite series. In general, they appear to have formed as mica-rich gneiss, felsic granite and mafic granulite. Corundum-bearing gravel is sometimes found along the stream. Folding and migmatitic structures are usually observed in these rocks that clearly indicate high-grade metamorphism. Many pink and blue sapphires with good crystal shape are found in the host rock samples (e.g., SLK 1, SLK 3, SLK 6, SLK 9, SLK 10, SLK 11, SLK13 and SLK 18). Moreover, many samples also contain huge crystals including corundum crystal such as sample nos.SLK 14, SLK 15, SLK 16 and SLK 19.

All rock samples in this collection can be divided into 2 main types including mica schist without corundum occurrence and corundum-bearing rocks. Moreover, corundum-bearing samples, the main focus of this study, can also be subdivided into 2 types which are obviously foliated rock and non-foliated rock as summarized in the diagram (Fig. 4.1) below.

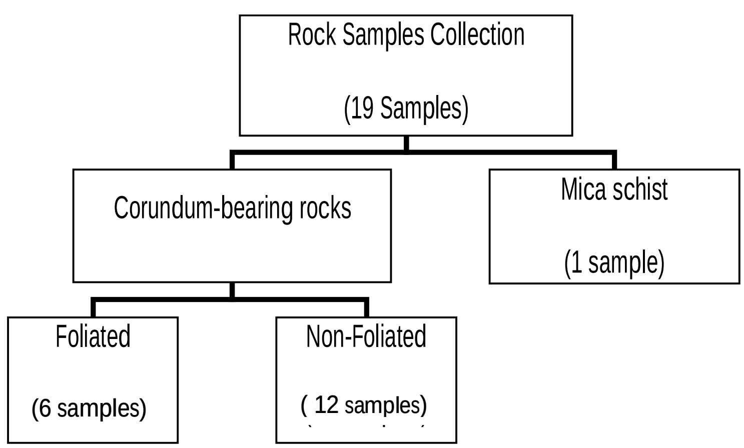


Fig.4.1 Diagram showing classification of rock samples under this study.

4.1.1 Mica Schist

Mica (biotite) rich rock, likely mica schist, was collected nearby the study area. Figure 4.2 shows sample No.SLK 2 of mica schist which has flat band leading to smooth slab. Calcite is hardly observed in hand specimen.

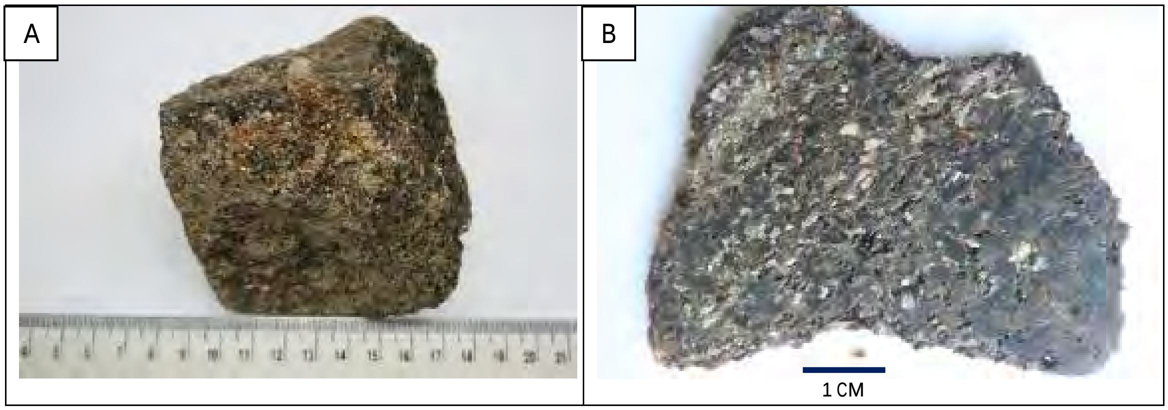


Fig.4.2 Hand specimen sample SLK2 (A) and its slab sample of mica schist without corundum (B).

4.1.2 Corundum-Bearing Rocks

Corundum-bearing rock samples are the main focus of this study. Therefore, many samples were collected. They are mainly composed of biotite forming slightly preferred orientation with some unclearly separated dark bands. However, some samples show obvious foliation. Huge corundum crystals are clearly observed within these samples. They are bluish or purplish colors. As shown in Fig. 4.3 A of sample nos. SLK 15, they show clearly foliations whereas sample SLK 5 (Fig. 4.3 B) has unclear foliation but still shows feature of mafic granulite. Crystals of corundum are clearly observed with bluish to pinkish colors. In Fig. 4.3 C and D of samples SLK14 and SLK11 show non-foliation in felsic granulite; besides, sample SLK 11 (Fig. 4.3 D) also shows large corundum crystal with pinkish color in felsic granulite texture.

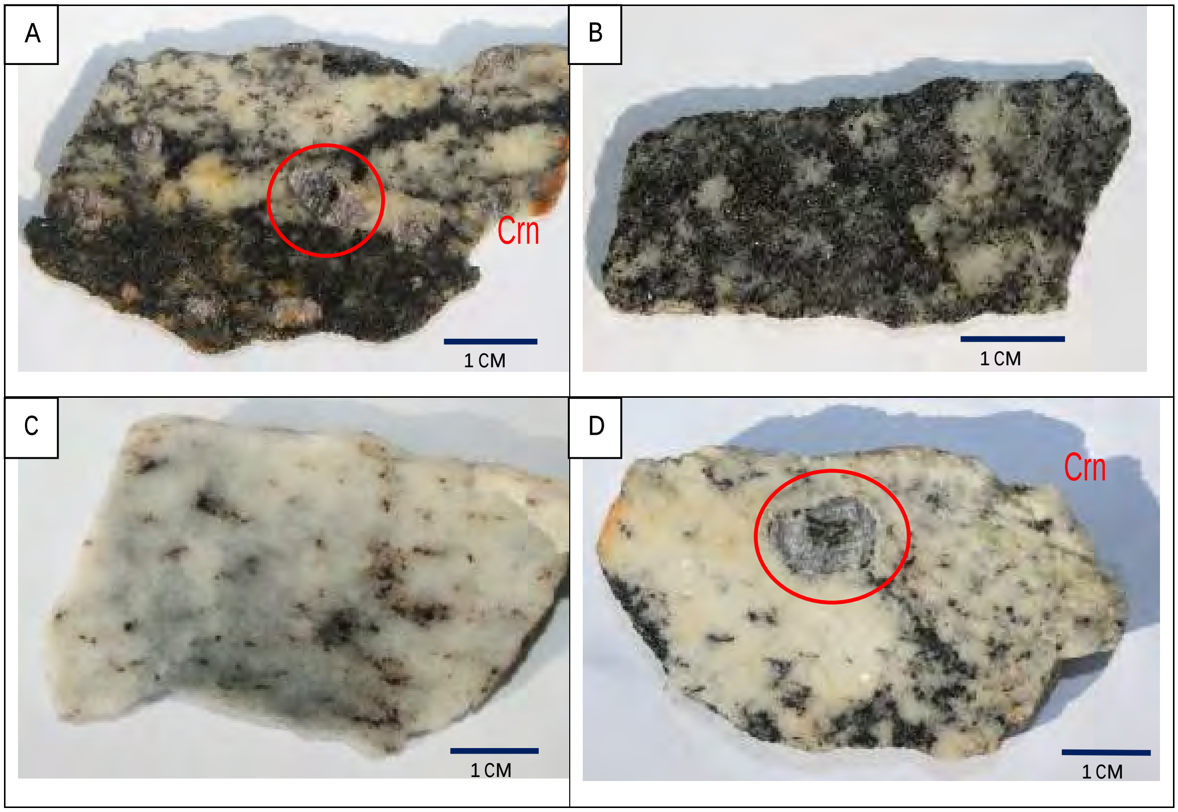


Fig.4.3 Rock slabs of corundum-bearing samples, slab sample SLK15 (A) with clear foliation shows feature of corundum-bearing felsic granulite; sample SLK 5 (B) also shows mafic granulite feature with unclear foliation. Slab sample SLK14 (C) shows unclearly foliation of felsic granulite with lenticular mafic layers and sample SLK11 (D) also contain corundum crystals.

4.2 Petrography

4.2.1 Mica Schist

Only one sample of mica schist without corundum was collected from adjacent area. It was studied to compare with corundum-bearing rocks. Rock sample is composed essentially of mica and calcite forming thin parallel-banded or foliated structure yielding smooth slab (Fig. 4.4 A). Calcite is unclearly and hardly to find in hand specimen. This mica schist is dark brown to black and moderately weathered and clearly present lepidoblastic biotite crystals oriented in a particular direction (Fig. 4.4 B-D). These biotites are subhedral shape with size ranging from 0.5 to 2 mm. Apart from the main composition of biotite, calcite appears to be minor component which forms subhedral grains with size of 0.5 to 1 mm. The other minerals are rarely observed. It is content about 65-70 % biotite, 20-25% calcite and 5% other minerals.

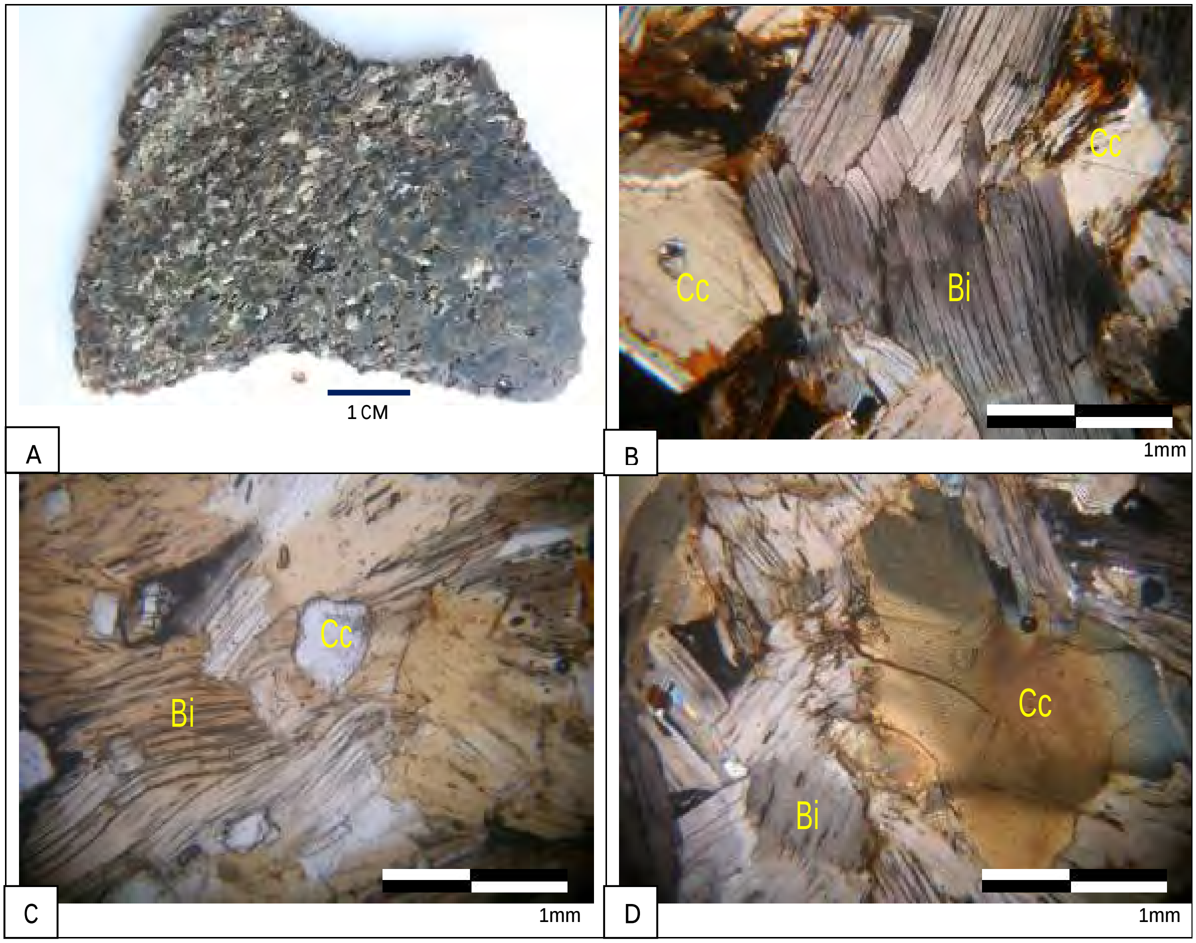
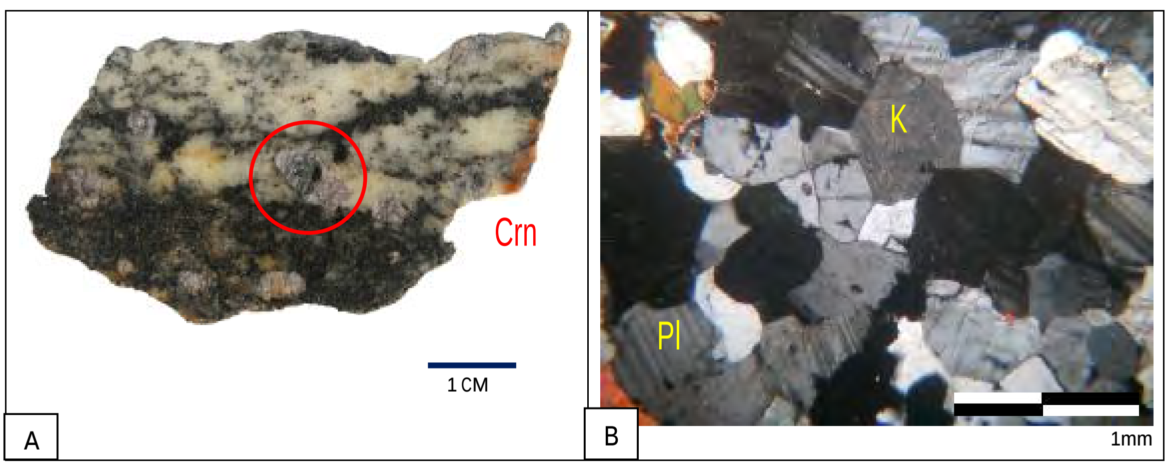


Fig.4.4 Slab sample SLK 2 (A) of mica schist without corundum; B to D are photomicagraphs showing lepidoblastic texture of large biotite more than 2 mm in size and granoblastic calcite.

4.2.2 Foliated corundum-bearing rock

These rocks have alternate layers between white and dark bands. White bands are mainly characterized by plagioclase and alkali feldspar whereas dark bands are predominately composed of biotite. Specimens SLK 15 shows clearly foliations and pinkish crystals of corundum (Fig. 4.5 A). These samples are composed essentially of granoblastic plagioclase and alkali feldspar which usually forms polygon grains with triple junctions (Fig. 4.5 B), besides, perthitic texture is also observed in some alkali feldspar grains. Corundum porphyroblasts are often recognized in mafic bands. Corundum typically forms euhrdral crystals with size ranging from 0.5 to 1 mm (Fig. 4.5 D). Biotite is characterized by high birefringence and also stippled birdeye extinction; its size ranges from 0.5 to 1 mm forming lepidoblastic crystals oriented in particular direction (Fig. 4.5 C). Essential minerals are composed of 45-50% plagioclase, 20-25% alkaline feldspar, 15-20% biotite wheras corundum appears to be minor component of about 1-3%.



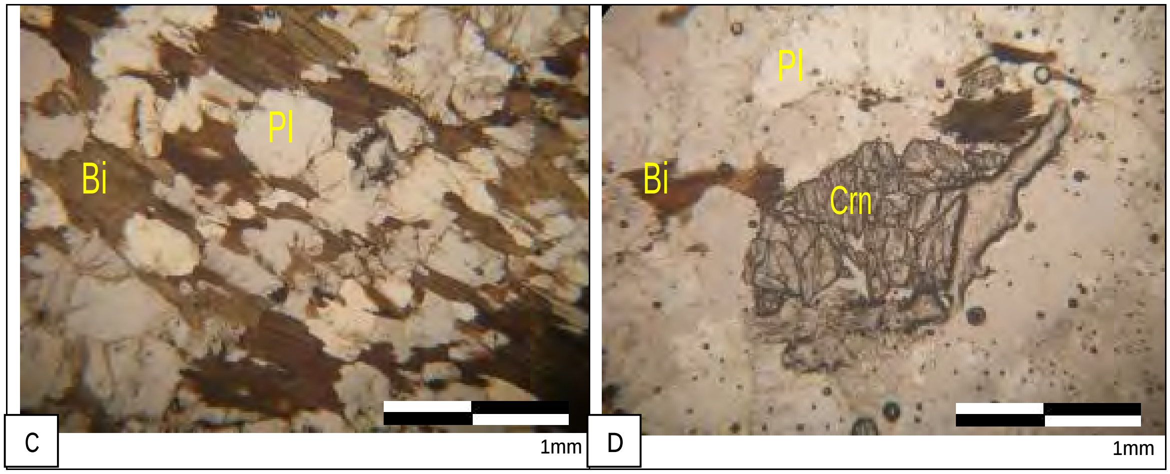


Fig.4.5 Slab sample SLK 15 (A) of foliated corundum-bearing rock; Photomicrograph of samples SLK9 (B) showing granoblastic texture of plagioclase (Pl) and alkali feldspar (K) XPL; lepidoblastic biotite (Bi) and granoblastic plagioclase (Pl) in sample SLK9 (C) (PPL); euhrdral porphyroblastic corundum (Crn) surrounded by plagioclase (Pl) and biotite (Bi) (D) in sample SLK3 (PPL).

4.2.3 Non-foliated corundum-bearing rock

These rocks show no foliation with present of corundum. Corundums are pinkish euhedral crystals (Fig. 4.6 A). Granoblastic texture of plagioclase and alkali feldspar are forming polygon grain with triple junction and ranging in size from 0.1 to 0.5 mm (Fig. 4.6 B). Poikilitic texture of plagioclase, zircon and corundum embedded large alkali feldspar (Fig. 4.6 C) can also be observed in some parts. Corundum porphyroblast ranging in size from 0.1 to 0.5 mm is usually intergrowth with plagioclase and biotite crystals ranging in size from 0.5 to 1 mm (Fig. 4.6 D). Essential mineral composition contains about 55-60% plagioclase, 20-25% alkali feldspar and 5-10% biotite whereas corundum appears to be minor component of about 1-3%.

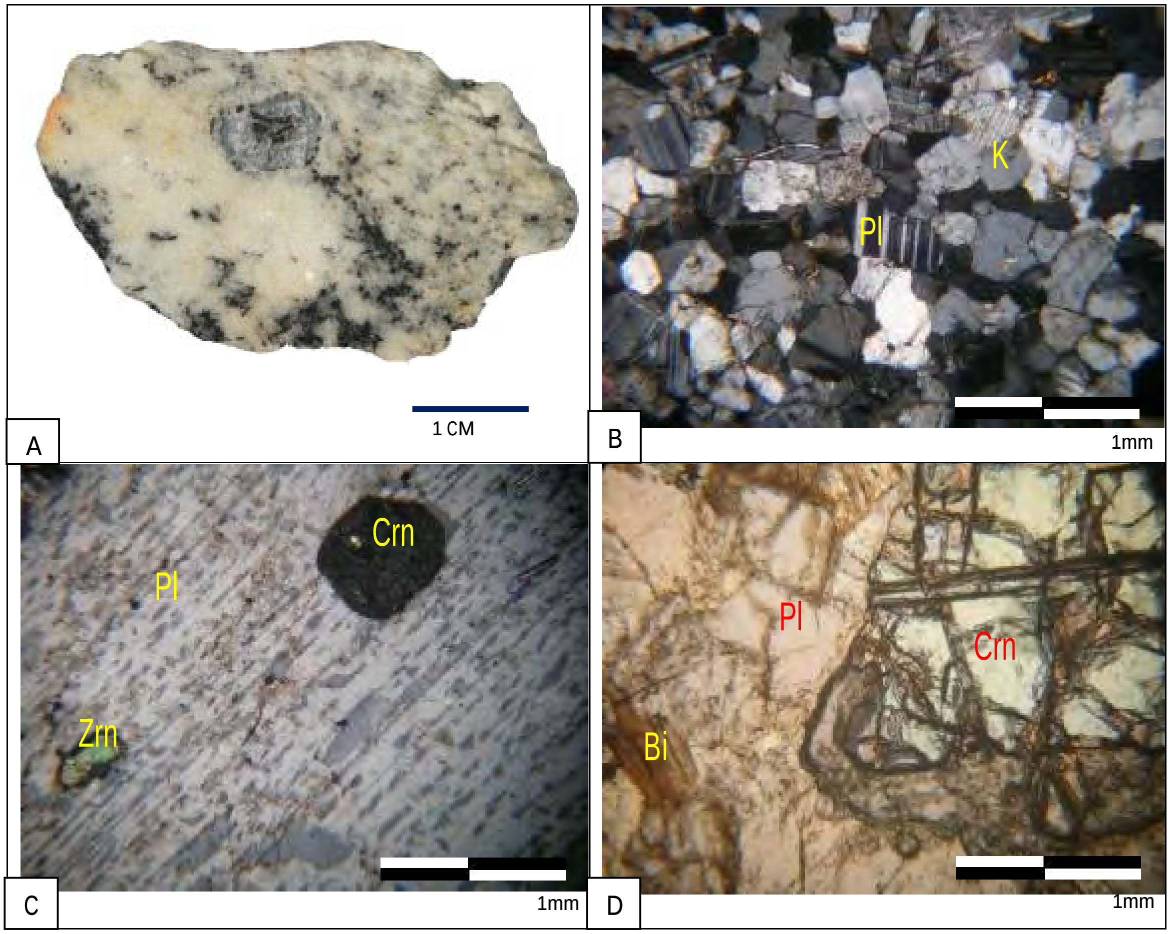


Fig.4.6 Slab sample SLK 11 (A) of non-foliated corundum-bearing rocks; photomicagraph showing granoblastic texture of plagioclase (Pl) and alkali feldspar (K) (B) in sample SLK7 (XPL); poikilitic tecture of plagioclase (Pl), tiny zircon (zrn) and corundum (Crn) embedded in a big alkali feldspar crystal in sample SLK7 (C; XPL); corundum porphyroblast associated with plagioclase (Pl) and biotite (Bi) in sample SLK18 (D; PPL).

4.3 Whole Rock Geochemistry

Whole-rock geochemical analysis was taken place using X-ray Fluorescence Spectrometer (XRF) for major and minor element compositions including SIO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, K_2O, Na_2O and P_2O_5. All analyses of each rock type are present in Table 4.1. Geochemical study is crucial result to support and to understand the nature of rock. . SIO_2 contents range from 39.91% in mica schist to 50.59-51.53% in foliated corundum-bearing rock and 51.86-59.85% in non- foliated corundum-bearing rock. TiO_2 contents are about 2.05% in mica schist, 1.26-1.50% foliated corundum-bearing rock and 0.08-0.63% in non-foliated corundum-bearing rock. Al_2O_3 contents are 16.00% in mica schist, 21.30-21.99% in foliated corundum-bearing rock and 21.59—27.96% in non-foliated corundum-bearing rock. Total iron analyzed in form of Fe_2O_3 contents range 2.30% in mica schist to 3.70-4.24% in foliated corundum-bearing rock and 0.33-1.53% in non- foliated corundum-bearing rock. MnO contents are quite low and not much different ranging from 0.02% in mica schist to 0.02-0.2% in foliated corundum-bearing rock and 0.01% in non-foliated corundum-bearing rock. MgO contents yield clearly different between each rock types containing 22.59% in mica schist, 5.48-6.25% in foliated corundum-bearing rock and 0.51-3.77% non- foliated corundum-bearing which is clearly caused by biotite assemblage. CaO contents vary from 1.50% in mica schist to 3.18-3.75% in foliated corundum-bearing rock and 3.05-7.75% in non- foliated corundum-bearing rock. K_2O contents have narrow ranges of 11.95% in mica schist; 7.88-8.37% foliated corundum-bearing rock and 3.61-6.32% in non- foliated corundum-bearing rock. Na_2O contents are 0.42% in mica schist, 2.74-3.06% in foliated corundum-bearing rock and 3.61-6.32% in non- foliated corundum-bearing rock. P_2O_5 present with small contents of 1.19% in mica schist, 0.09-0.15% in foliated corundum-bearing rock and 0.05-0.28% in non- foliated corundum-bearing rock.

The results were then taken for comparison and interpretation using Harker-type variation diagrams. SiO_2 versus other major and minor oxides are present in Fig 4.7. For non-foliated and foliated corundum-bearing rocks show no deference of Al_2O_3 trend. TiO_2, Fe_2O_3, MnO, MgO and P_2O_5 in foliated corundum-bearing group are higher than those of non-foliated corundum-bearing rock which indicates that foliated samples containing more amount of biotite. Besides, non-foliated samples may have occurred as a part of felsic layer in foliated rocks. Trends of CaO, Na_2O and K_2O of non-foliated group are higher than those of the foliated group.

This may be caused by more contents of plagioclase and alkali feldspar in non-foliated rocks. Regarding to Mg# variation diagrams versus major oxides (Fig. 4.8), they show no difference of trending, particularly, Al_2O_3 values fall within the same range that may represent the same provenance. All of rocks sample can be classified on the basic of alumina saturation as peraluminous and silica saturation from ultrabasic to intermediate are present in Table 4.2.

Table 4.1 Major and minor oxides (in weight %) of the studied rock samples using XRF analysis.

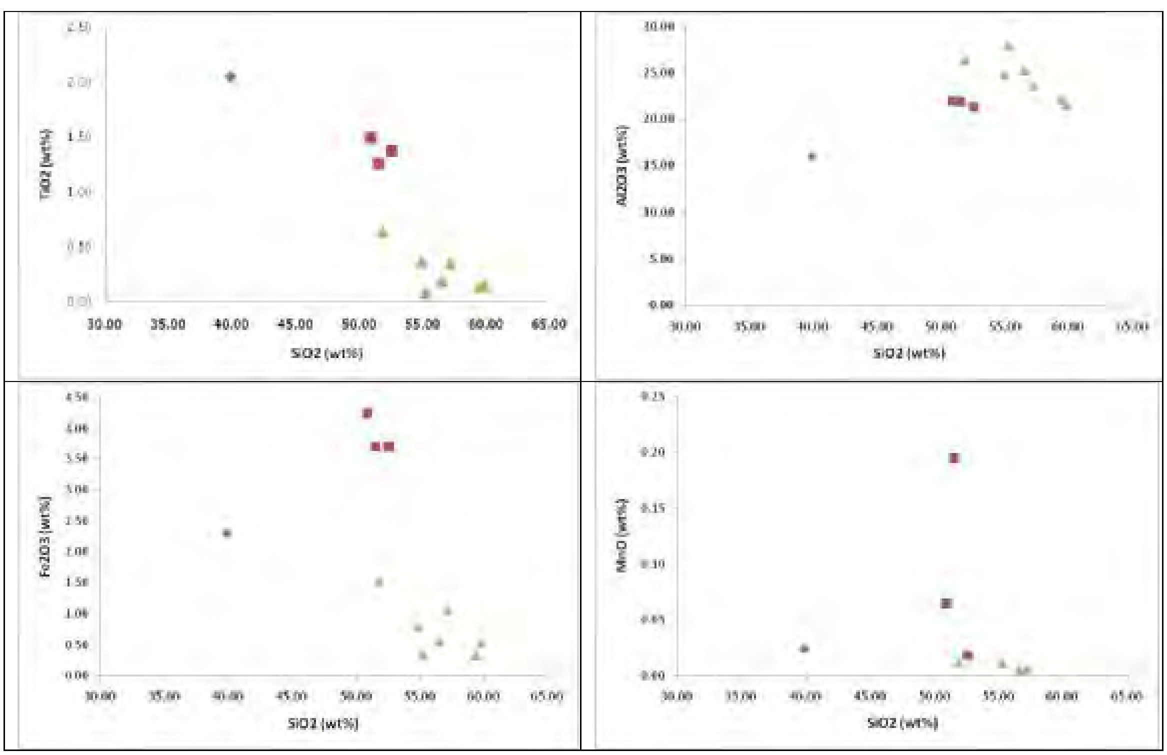
	Mica Schist	Foliated Crn-bearing Rocks		
Sample No.	SLK-2	SLK-1	SLK-5	SLK-18
SiO_2	39.91	50.92	52.59	51.86
TiO_2	2.05	1.50	1.38	0.63
Al_2O_3	16.00	21.99	21.30	26.37
Fe_2O_3	2.30	4.24	3.70	1.53
MnO	0.02	0.06	0.02	0.01
MgO	22.59	6.25	5.48	3.77
CaO	1.50	3.18	3.75	6.91
K_2O	11.95	8.37	8.13	3.86
Na_2O	0.42	2.74	3.00	4.30
P_2O_5	1.19	0.09	0.12	0.09
LOI	0.54	1.02	0.85	0.68
Total	97.94	99.34	99.46	99.34

Table 4.1 (cont.)

	Non-foliated Crn-bearing Rocks						
Sample No.	SLK-8	SLK-10	SLK-14	SLK-17	SLK-19	SLK-4	SLK-6
SiO_2	54.92	57.19	55.24	59.85	56.54	59.41	51.53
TiO_2	0.36	0.35	0.08	0.14	0.19	0.13	1.26
Al_2O_3	24.91	23.60	27.96	21.59	25.28	22.18	21.94
Fe_2O_3	0.80	1.07	0.35	0.54	0.56	0.33	3.70
MnO	0.00	0.01	0.01	0.00	0.01	0.00	0.20
MgO	2.42	1.55	0.46	0.51	1.02	0.62	6.03
CaO	7.63	5.33	7.67	3.05	7.75	3.62	3.57
K_2O	3.06	4.46	1.54	9.64	2.37	9.59	7.88
Na_2O	5.24	5.85	6.32	3.84	5.89	3.61	3.06
P_2O_5	0.17	0.28	0.05	0.23	0.08	0.09	0.15
LOI	0.81	0.91	0.21	1.02	0.76	0.64	1.68
Total	99.52	99.68	99.67	99.39	99.69	99.59	99.31

Table 4.2 Chemical classification of alumina and silica saturations.

	Sample No.	Na_2O+K_2O	Na_2O+K_2O+CaO	Al_2O_3	Alumina Saturation	Silica Saturation
Mica schist	SLK-2	12.37	13.88	16.00	Peraluminous	Ultrabasic
Foliated Crn-bearing rocks	SLK-1	11.11	14.29	21.99	Peraluminous	Basic
	SLK-5	11.13	14.88	21.30	Peraluminous	Intermediate
	SLK-18	8.16	15.07	26.37	Peraluminous	Basic
Non-foloated Crn-bearing rocks	SLK-8	8.30	15.94	24.91	Peraluminous	Intermediate
	SLK-10	10.31	15.64	23.60	Peraluminous	Intermediate
	SLK-14	7.86	15.52	27.96	Peraluminous	Intermediate
	SLK-17	13.48	16.53	21.59	Peraluminous	Intermediate
	SLK-6	10.94	14.50	21.94	Peraluminous	Basic
	SLK-19	8.27	16.02	25.28	Peraluminous	Intermediate
	SLK-4	13.20	16.83	22.18	Peraluminous	Intermediate



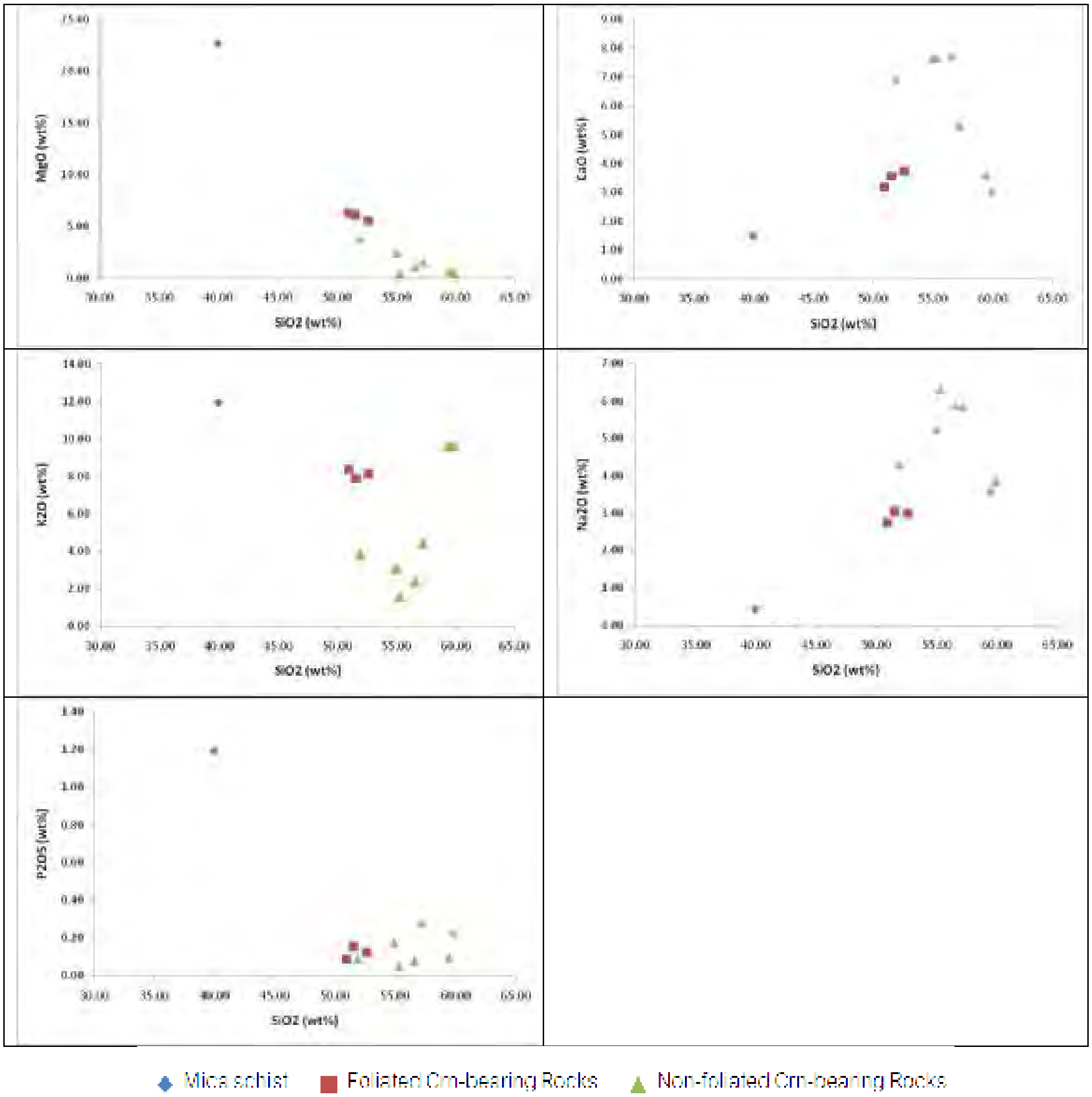
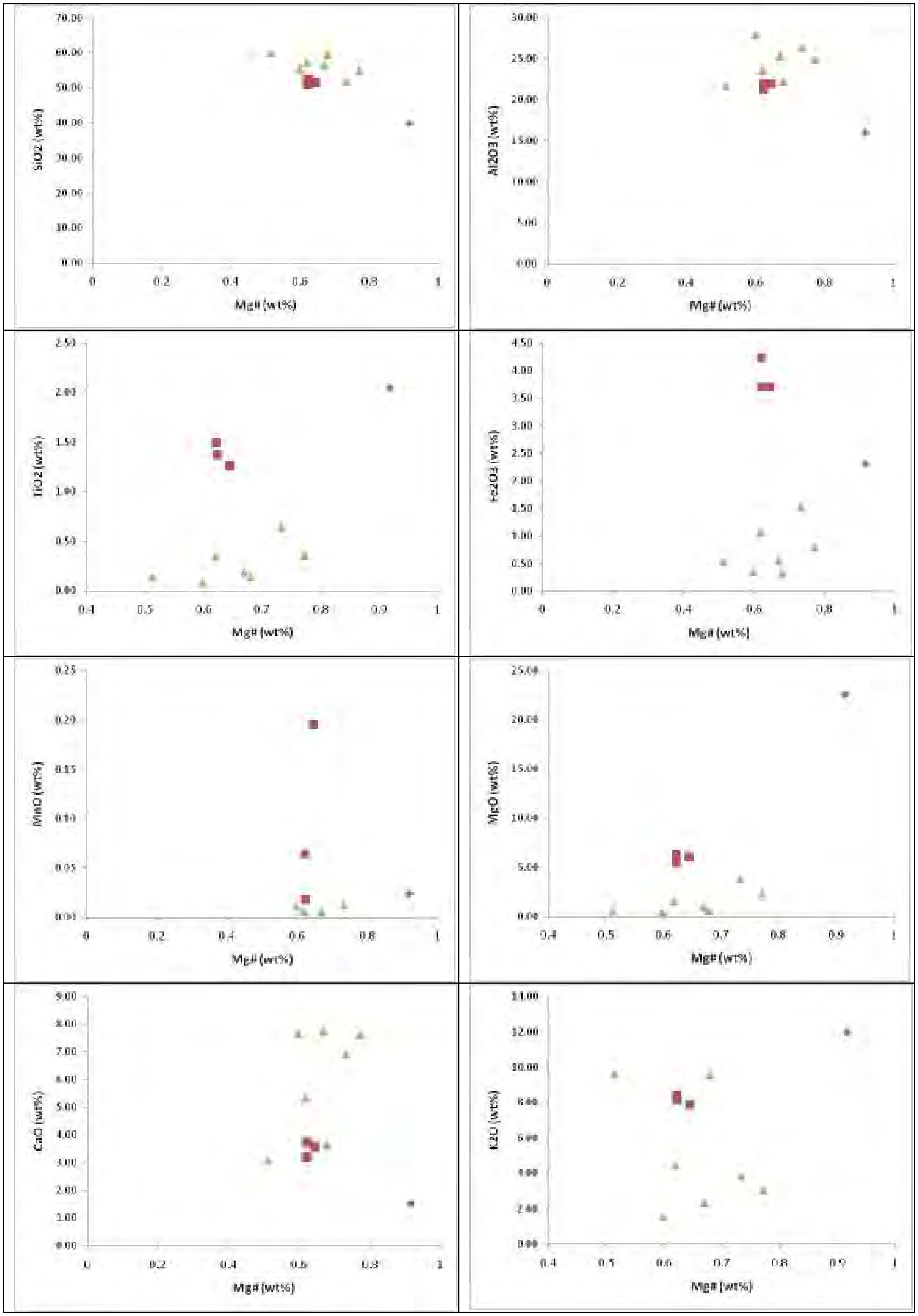


Fig.4.7 Harker-type variation diagram of wt% SiO_2 versus major and minor oxides for mica schist corundum-bearing rocks both foliated and non-foliated groups.



SiO2 (wt%)
Mg# (wt%)
Al2O3 (wt%)
Mg# (wt%)
TiO2 (wt%)
Mg# (wt%)
Fe2O3 (wt%)
Mg# (wt%)
MnO (wt%)
Mg# (wt%)
MgO (wt%)
Mg# (wt%)
CaO (wt%)
Mg# (wt%)
K2O (wt%)
Mg# (wt%)

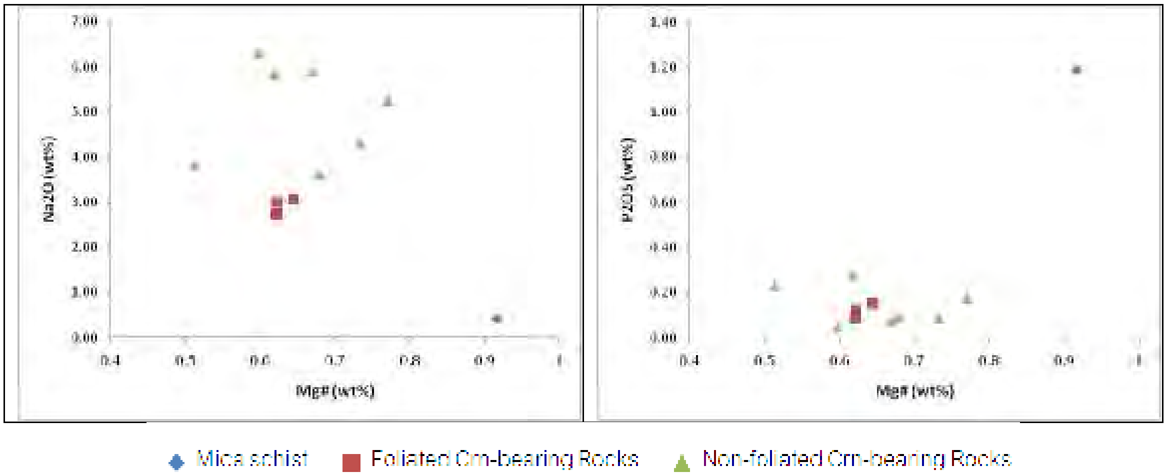


Fig.4.8 Variation diagram of wt% Mg number (Mg#) versus major and minor oxides of all rock types [Mg# = MgO/ (FeO+MgO)].

4.4 Mineral Chemistry

Electron Probe Micro-Analyzer (EPMA) was engaged to analyze chemical composition of mineral (mineral chemistry) of main components present in each rock sample group. Seven samples consist of 1 mica schist sample, 3 foliated corundum-bearing samples and 3 non-foliated corundum-bearing samples. Consequently, six minerals, i.e., corundum, plagioclase, alkali feldspar, biotite, calcite and zircon, have been analyzed and taken into consideration. Their analyses are summarized in Tables 4.3 to 4.8. All analyses are collected in Appendix A.

Corundum: found in both foliated and non-foliated rocks contains similar chemical composition (Table 4.3). Based on 3(O) formula, corundum's in foliated group consist 1.994-1.996 Al, 0.002-0.003 Fe^{3+} per formula unit (pfu.) whereas those in non-foliated group consist of 1.997-1.998 Al, 0.000-0.001 Fe^{3+} pfu. The other cations are not significant composition.

Zircon: is found in both types of corundum-bearing rock. Their chemical compositions are close to the idea zircon formula ($ZrSiO_4$) (see Table 4.4). In foliated group zircon analyses consist of 0.993-1.023 Zr and 0.955-1.005 Si pfu. Whereas those yielded from non-foliated group consist of 0.899-0.980 Zr and 0.969-1.011 Si p.u.

Alkali feldspar: The main component of corundum-bearing rocks both foliated and non-foliated types. Regarding to their chemical compositions, alkali feldspar of both groups fall within the same range of 0.528-0.861 K and 0.100-0.369 Na per 8 oxygen basis (Table 4.5).

Plagioclase: The other main assemblage of both corundum-bearing groups. Their chemical compositions plagioclase are quite similar and vary in a narrow range of 0.007-0.386 Ca and 0.369-0.843Na per 8 oxygen basis (Table 4.6).

Biotite: is the most important mineral for comparison between corundum-barren schist and corundum bearing rocks of the study area. Their chemical compositions are clearly different between corundum-barren and corundum-bearing rocks (Table 4.7). In mica schist, they consist of 0.749-0.888 K, 0.082-0.095 Fe^{2+}, and 0.517-0.677 Mg pfu. On the other hand, biotites in corundum-bearing rocks of both foliated and non-foliated groups consists similar composition of 3.724-5.807 K, 0.470-0.633 Fe^{2+}, 1.473-1.925 Mg with higher total cations pfu.

Calcite: is found only in mica schist. Its chemical composition consists of almost pure calcite (99.09 -100%) with very low dolomite (0.0 – 0.09%) component (Table 4.8).

Table 4.3 Representative major and trace analyses of corundum by Electron Probe Micro-Analyzer.

	Corundum							
	foliated Crn-bearing rocks					non-foliated Crn-bearing rocks		
Comment	1p1crn1	1p1crn1-2	3crn1-3	3crn2	3crn2-2	4p5crn1	4p5crn1	4p5crn2
SiO2	0.05	0.00	0.01	0.00	0.00	0.01	0.04	0.02
TiO2	0.01	0.05	0.04	0.04	0.00	0.01	0.03	0.01
Al2O3	98.26	99.30	96.95	96.01	95.50	99.15	98.45	99.54
Cr2O3	0.01	0.05	0.20	0.03	0.05	0.00	0.00	0.00
FeO	0.14	0.22	0.14	0.15	0.12	0.10	0.11	0.09
MnO	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01
MgO	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00
ZnO	0.03	0.01	0.00	0.38	0.11	0.04	0.03	0.06
CaO	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Na2O	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00
K2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	98.54	99.67	97.37	96.68	95.82	99.32	98.69	99.76
Formula 3(O)								
Si	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Ti	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000
Al	1.997	1.996	1.995	1.994	1.997	1.998	1.997	1.998
Cr	0.000	0.001	0.003	0.000	0.001	0.000	0.000	0.000
Fe3+	0.002	0.003	0.002	0.002	0.002	0.001	0.002	0.001
Fe2+	-	-	-	-	-	-	-	-
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zn	0.000	0.000	0.000	0.005	0.001	0.000	0.000	0.001
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Na	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total*	2.001	2.001	2.001	2.003	2.001	2.001	2.000	2.001

Table 4.4 Representative major and trace analyses of zircon by Electron Probe Micro-Analyzer.

	Zircon							
	foliated Crn-bearing rocks				non-foliated Crn-bearing rocks			
Comment	12Zrn1	12Zrn1-2	12Zrn1-3	3Zrn6	6 Zr1	6 Zrn1-2	6 Zrn2	6 Zrn2-2
SiO2	31.00	31.30	31.96	32.00	28.93	26.89	27.18	29.94
TiO2	0.00	0.03	0.04	0.00	0.03	0.04	0.00	0.04
ZrO2	67.68	68.24	67.63	66.84	58.56	51.19	52.39	58.51
Al2O3	0.02	0.22	0.97	0.00	0.42	2.06	2.11	0.37
Cr2O3	0.00	0.01	0.00	0.00	0.03	0.06	0.01	0.00
FeO	0.42	0.43	0.34	0.01	0.33	1.05	0.77	0.19
MnO	0.05	0.06	0.02	0.00	0.02	0.08	0.04	0.00
MgO	0.03	0.03	0.05	0.03	0.01	0.03	0.11	0.01
ZnO	0.00	0.20	0.00	0.08	0.01	0.00	0.02	0.04
CaO	0.54	0.79	0.08	0.01	0.42	2.32	2.15	0.54
Na2O	0.00	0.00	0.00	0.00	0.02	0.07	0.07	0.05
K2O	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00
Total	99.74	101.31	101.08	98.99	88.76	83.80	84.85	89.69
Formula 4(O)								
Si	0.961	0.955	0.968	1.005	0.993	0.969	0.967	1.011
Ti	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.001
Zr	1.023	1.016	0.999	0.993	0.980	0.899	0.909	0.963
Al	0.001	0.008	0.035	0.000	0.017	0.088	0.088	0.015
Cr	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000
Fe3+	-	-	-	-	-	-	-	-
Fe2+	0.011	0.011	0.009	0.000	0.009	0.032	0.023	0.005
Mn	0.001	0.001	0.000	0.000	0.001	0.003	0.001	0.000
Mg	0.001	0.001	0.002	0.001	0.001	0.002	0.006	0.001
Zn	0.000	0.004	0.000	0.002	0.000	0.000	0.000	0.001
Ca	0.018	0.026	0.002	0.000	0.015	0.089	0.082	0.019
Na	0.000	0.000	0.000	0.000	0.002	0.005	0.004	0.003
K	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Total*	2.016	2.024	2.016	2.002	2.019	2.089	2.082	2.019

Table 4.5 Representative major and trace analyses of alkali feldspar by Electron Probe Micro-Analyzer.

	Alkali feldspar							
	foliated Crn-bearing rocks			non-foliated Crn-bearing rocks				
comment	5feld2	5feld31	5feld33	12feld8	12feld9	12feld10	6feld1	6feld6
SiO2	63.48	65.43	66.42	63.10	63.44	63.10	62.24	61.28
TiO2	0.05	0.00	0.04	0.04	0.03	0.03	0.08	0.03
Al2O3	20.17	18.52	18.75	20.19	19.91	20.71	18.17	20.61
Cr2O3	0.00	0.01	0.00	0.03	0.02	0.01	0.00	0.03
FeO	0.02	0.08	0.06	0.06	0.03	0.00	0.02	0.00
MnO	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00
MgO	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
ZnO	0.03	0.04	0.03	0.00	0.00	0.01	0.00	0.00
CaO	0.13	0.13	0.12	0.75	0.40	0.92	0.13	2.31
Na2O	1.79	2.02	1.93	1.90	2.11	1.12	1.59	4.07
K2O	14.31	8.91	9.01	12.70	12.64	13.26	14.23	8.86
Total	99.98	95.13	96.35	98.79	98.59	99.17	96.52	97.18
Formula 8(O)								
Si	2.923	3.052	3.056	2.921	2.939	2.911	2.972	2.865
Ti	0.002	0.000	0.001	0.001	0.001	0.001	0.003	0.001
Al	1.095	1.018	1.017	1.102	1.087	1.126	1.023	1.135
Cr	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.001
Fe3+	0.001	0.003	0.002	0.002	0.001	0.000	0.001	0.000
Fe2+	-	-	-	-	-	-	-	-
Mn	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Zn	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Ca	0.006	0.006	0.006	0.037	0.020	0.045	0.007	0.115
Na	0.160	0.183	0.172	0.171	0.190	0.100	0.147	0.369
K	0.841	0.530	0.529	0.750	0.747	0.780	0.867	0.528
Total*	5.028	4.795	4.784	4.986	4.985	4.965	5.020	5.015

Table 4.6 Representative major and trace analyses of plagioclase by Electron Probe Micro-Analyzer.

	Plagioclase																
	foliated Crn-bearing rocks									non-foliated Crn-bearing rocks							
Comment	1p3plg1	1p4plg11	3plg1	3plg1-2	3plg5	5plg3	5plg4	5plg1	5plg5	6plg1	6plg5	6 plg5-2	6plg6	6plg7	6 plg8	12plg4	12plg4-2
SiO2	59.55	59.67	59.17	58.84	59.45	57.26	57.91	61.50	61.23	59.46	57.59	57.98	58.15	58.15	61.28	60.88	61.32
TiO2	0.03	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.03	0.01	0.02
Al2O3	24.91	25.01	24.52	24.37	23.28	26.05	25.89	25.11	25.05	23.29	24.74	24.13	24.24	24.46	20.61	23.09	22.28
Cr2O3	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.01	0.00	0.03	0.00	0.00
FeO	0.05	0.10	0.09	0.01	0.00	0.00	0.00	0.08	0.00	0.04	0.06	0.00	0.00	0.00	0.00	0.03	0.04
MnO	0.00	0.01	0.00	0.00	0.02	0.02	0.03	0.00	0.02	0.03	0.02	0.00	0.00	0.02	0.00	0.00	0.01
MgO	0.01	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
ZnO	0.03	0.03	0.00	0.00	0.02	0.01	0.00	0.17	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.00
CaO	6.66	6.67	6.24	6.35	6.22	8.44	7.96	6.81	6.69	6.16	6.51	6.32	6.35	6.40	2.31	6.99	7.13
Na2O	7.51	7.46	8.29	8.21	8.13	6.53	6.94	7.09	6.90	8.22	7.99	8.03	8.13	8.26	4.07	9.74	9.74
K2O	0.00	0.00	0.16	0.15	0.22	0.12	0.13	0.15	0.16	0.22	0.19	0.19	0.29	0.26	8.86	0.14	0.12
Total	98.78	99.01	98.49	97.96	97.39	98.42	98.86	100.91	100.06	97.44	97.15	96.77	97.21	97.69	97.18	100.88	100.67
Formula 8(O)																	
Si	2.681	2.680	2.680	2.680	2.721	2.602	2.618	2.706	2.710	2.720	2.650	2.676	2.673	2.664	2.865	2.711	2.737
Ti	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.001
Al	1.322	1.324	1.309	1.308	1.255	1.395	1.380	1.302	1.307	1.256	1.342	1.313	1.313	1.320	1.135	1.212	1.172
Cr	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Fe3+	0.002	0.004	0.003	0.000	0.000	0.000	0.000	0.003	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.001	0.002
Fe2+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000
Mg	0.000	0.002	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Zn	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Ca	0.321	0.321	0.303	0.310	0.305	0.411	0.386	0.321	0.317	0.302	0.321	0.312	0.313	0.314	0.115	0.334	0.341
Na	0.655	0.649	0.728	0.725	0.722	0.575	0.608	0.605	0.592	0.729	0.713	0.719	0.725	0.733	0.369	0.841	0.843
K	0.000	0.000	0.009	0.009	0.013	0.007	0.007	0.008	0.009	0.013	0.011	0.011	0.017	0.015	0.528	0.008	0.007
Total*	4.984	4.982	5.034	5.033	5.019	4.991	5.000	4.950	4.937	5.023	5.041	5.032	5.041	5.049	5.015	5.107	5.102

Table 4.7 Representative major and trace analyses of biotite by Electron Probe Micro-Analyzer.

	Biotite															
	mica schist Crn-barren					foliated Crn-bearing rocks						non-foliated Crn-bearing rocks				
Comment	2p5bt2	2p5bt4	2p5apt1	2p5bt7	2p5crn6	1p1bt1	3 bt1	3 bt3	5bt2	5bt5	5bt5-2	6 bt4	6 bt5	6 bt6	12bt1	12bt1-2
SiO2	41.17	41.84	41.54	40.81	40.40	35.18	34.25	33.09	36.55	49.79	48.96	36.39	36.27	36.31	32.58	32.17
TiO2	1.16	0.95	1.12	1.21	1.54	3.05	3.14	2.50	3.10	2.99	2.23	3.26	3.50	3.18	2.84	2.93
Al2O3	14.63	13.46	13.71	14.09	15.34	17.58	15.73	15.79	17.18	16.36	17.47	17.94	18.04	18.09	15.74	15.30
Cr2O3	0.00	0.04	0.00	0.03	0.00	0.04	0.09	0.07	0.06	0.09	0.06	0.05	0.05	0.03	0.03	0.00
FeO	1.51	1.31	1.30	1.50	1.48	8.73	8.33	7.32	8.18	8.51	8.75	10.25	10.40	10.64	6.52	6.40
MnO	0.00	0.00	0.01	0.00	0.02	0.01	0.05	0.04	0.08	0.04	0.03	0.08	0.04	0.00	0.09	0.05
MgO	23.13	23.81	23.39	22.21	22.27	14.61	15.18	15.30	14.90	15.24	14.68	16.30	16.76	16.11	13.42	13.24
ZnO	0.01	0.00	0.00	0.06	0.00	0.06	0.00	0.02	0.05	0.04	0.01	0.02	0.00	0.06	0.00	0.00
CaO	0.02	0.01	0.06	0.05	0.07	0.06	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Na2O	0.32	0.26	0.28	0.28	0.28	0.03	0.05	0.09	0.11	0.12	0.10	0.09	0.07	0.10	0.09	0.09
K2O	0.09	0.11	0.11	0.10	0.10	0.10	5.50	5.26	6.03	5.63	2.81	10.02	6.33	6.50	4.27	4.12
Total	82.04	81.79	81.52	80.34	81.49	79.45	82.34	79.49	86.28	98.81	95.11	94.42	91.46	91.04	75.58	74.29
	Formula 11(O)															
Si	3.100	3.155	3.143	3.135	3.063	2.859	2.805	2.792	2.844	3.285	3.297	2.689	2.704	2.724	2.852	2.862
Ti	0.065	0.054	0.064	0.070	0.088	0.186	0.193	0.159	0.182	0.148	0.113	0.181	0.196	0.180	0.187	0.196
Al	1.298	1.196	1.222	1.275	1.371	1.684	1.518	1.570	1.575	1.272	1.387	1.562	1.585	1.599	1.624	1.604
Cr	0.000	0.002	0.000	0.002	0.000	0.002	0.006	0.005	0.004	0.005	0.003	0.003	0.003	0.002	0.002	0.000
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe2+	0.095	0.083	0.082	0.096	0.094	0.593	0.571	0.517	0.532	0.470	0.493	0.633	0.648	0.667	0.478	0.476
Mn	0.000	0.000	0.000	0.000	0.001	0.000	0.004	0.003	0.005	0.002	0.002	0.005	0.003	0.000	0.007	0.004
Mg	2.596	2.677	2.639	2.543	2.517	1.770	1.853	1.925	1.729	1.499	1.473	1.795	1.863	1.802	1.752	1.757
Zn	0.001	0.000	0.000	0.004	0.000	0.004	0.000	0.001	0.003	0.002	0.001	0.001	0.000	0.003	0.000	0.000
Ca	0.001	0.001	0.005	0.004	0.005	0.005	0.000	0.000	0.003	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Na	0.047	0.038	0.041	0.042	0.040	0.005	0.008	0.014	0.017	0.015	0.012	0.013	0.010	0.015	0.015	0.016
K	0.859	0.749	0.749	0.888	0.857	5.794	5.615	5.239	4.979	3.724	3.985	5.621	5.807	6.014	5.024	5.089
Total*	8.063	7.955	7.946	8.059	8.037	12.903	12.571	12.225	11.873	10.422	10.766	12.503	12.818	13.007	11.940	12.003

Table 4.8 Representative major and trace analyses of calcite by Electron Probe Micro-Analyzer.

	Calcite									
	mica schist Crn-barren									
Comment	2p5cc4	2p4cc1	2p5cc1	2p1cc2	2p5cc10	2p5cc11	2p5cc5	2p5cc7	2cc8	2p5cc7
SiO2	0.29	0.14	0.32	0.12	0.22	0.23	0.10	0.17	0.25	0.22
TiO2	0.00	0.00	0.00	0.00	0.07	0.03	0.01	0.00	0.00	0.02
ZrO2	0.11	0.09	0.09	0.18	0.08	0.00	0.09	0.07	0.11	0.01
Al2O3	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.00	0.00	0.02
Cr2O3	0.01	0.00	0.00	0.03	0.00	0.03	0.00	0.00	0.00	0.00
FeO	0.02	0.02	0.00	0.00	0.00	0.07	0.04	0.05	0.00	0.00
MnO	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.01	0.03	0.02
MgO	0.03	0.04	0.04	0.04	0.04	0.03	0.02	0.03	0.01	0.02
ZnO	0.02	0.02	0.00	0.00	0.04	0.01	0.00	0.09	0.05	0.00
CaO	53.39	53.19	52.99	49.66	53.16	52.95	53.20	53.21	48.39	53.16
Na2O	0.04	0.09	0.05	0.09	0.08	0.10	0.04	0.06	0.11	0.08
K2O	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	53.91	53.59	53.49	50.15	53.73	53.48	53.53	53.68	49.00	53.54
Formula 1(O)										
Si	0.005	0.002	0.005	0.002	0.004	0.004	0.002	0.003	0.005	0.004
Ti	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Zr	0.001	0.001	0.001	0.002	0.001	0.000	0.001	0.001	0.001	0.000
Al	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe3+	-	-	-	-	-	-	-	-	-	-
Fe2+	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.000
Zn	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.000
Ca	0.986	0.991	0.985	0.988	0.986	0.986	0.992	0.989	0.985	0.989
Na	0.001	0.003	0.002	0.003	0.003	0.003	0.001	0.002	0.004	0.003
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total*	0.995	0.998	0.995	0.997	0.996	0.997	0.998	0.997	0.996	0.997
%Cc	99.932	99.901	99.885	99.888	99.906	99.921	99.950	99.916	99.960	99.958
%Dol	0.068	0.099	0.115	0.112	0.094	0.079	0.050	0.084	0.040	0.042

Chapter V

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Petrochemistry Genesis

Rocks collection can be divided based on petrographic description, into 2 main types including corundum-bearing rock and mica schist. Moreover, corundum-bearing samples, the main focus of this study, can also be subdivided into 2 types which are obvious foliated rock and non-foliated rocks. However, non-foliated samples appear to have occurred as a part of felsic layer in foliated rocks. They apparently belong to granulite forming preferred orientation which is clearly developed by lepidoblastic biotite. Non-foliated rocks contain less amount of biotite leading to unclear foliation. In addition, the main assemblage of corundum-bearing rock is similarly characterized by alkali feldspar and plagioclase which usually form granoblatic grains with well-developed triple junctions. Corundums have been found as granoblastic and porphyroblastic grains that usually formed as very large crystals in both sample groups. These petrographic features indicate high grad metamorphism.

On the other hand, mica schist is characterized clearly by different texture and mineral assemblage which mainly contains large lepidoblastic biotite and granoblastic calcite. These are obviously different from the corundum-bearing rocks. Whole-rock geochemistry shows somewhat difference within these rocks. Although all mica schist and corundum-bearing rocks are classified as peraluminous rocks on the basis of alumina saturation, Al_2O_3 content of mica schist is lower than those of the corundum-bearing rocks. Based on silica saturation, mica schist appears to fall within ultrabasic composition whereas both groups of corundum-bearing rocks have lower silica saturation falling within basic to intermediate ranges.

Mineral chemistry shows similarity of assemblages observed in both corundum-bearing groups. They have similar chemical compositions of corundum, zircon, alkali feldspar, plagioclase and biotite. On the other hand, biotite yields different composition between corundum-bearing rocks and mica schist which corundum-bearing groups have higher amounts of K and Mg atoms per formula unit maybe caused by effect of hydrous and other anions. Regarding to corundum composition, these corundum analyses yielded from the host rocks are quite similarly to *in situ* corundum found within the area as reported by Tipprasert (2006).

5.2 Corundum Formation

Corundum is the common gems found as residual or in situ deposits as well as alluvial occurrences in the particular areas. Corundum-bearing rocks are found on the mountain top which their overburden soil consists of well-developed corundum crystals

The corundum-bearing samples under this study belong to granulite facies containing more mafic layer yielding well developed foliation and more felsic layer presenting non-foliation. However, they have similar mineral assemblage with slightly different proportion; moreover, corundum porphyroblasts appear to have crystallized with less nucleuses yielding large size. Corundum occurs as medium- to very coarse-grained euhedral crystal, but can also be partly to completely irregular in shape which has grown within plagioclase, alkali feldspar and biotite. They may have crystallized during the peak metamorphism equilibrated with biotite, plagioclase and alkali feldspar. Corundum forms at high temperature conditions with a wide range of pressure conditions, during regional metamorphism. The protolith of these rocks would be alumina rich provenance prior to high grade metamorphism belonging to granulite facies as previously reported (Tsunogae and Santosh, 2003).

5.3 Recommendations

Due to limited time of this study, there are some works could not be completed. Mineral chemistry of mineral is not really good quality; therefore, reanalysis would be concerned prior to improve the work. Thermobarometry can also be carried out in some particular cases such as ternary feldspar, solvus pertithic feldspar, and biotite chemistry. In addition, triangular plots, e.g., ACF and AFM diagrams, would be taken into account for further interpretation.

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APPENDIX A

Table I Representative major and trace analyses of corundum by Electron Probe Micro-Analyzer.

	Corundum												
	foliation corundum-bearing								non-foliation corundum-bearing				
Comment	1p1crn1	1p1crn1-2	3crn1-3	3crn2	3crn2-2	3crn3	3crn4	3 crn5	4p5crn1	4p5crn1	4p5crn2	6 crn1	6 crn3
SiO2	0.05	0.00	0.01	0.00	0.00	0.01	0.00	0.04	0.01	0.04	0.02	0.01	0.02
TiO2	0.01	0.05	0.04	0.04	0.00	0.02	0.04	0.07	0.01	0.03	0.01	0.04	0.01
Al2O3	98.26	99.30	96.95	96.01	95.50	90.01	91.65	91.59	99.15	98.45	99.54	90.08	89.54
Cr2O3	0.01	0.05	0.20	0.03	0.05	0.06	0.13	0.02	0.00	0.00	0.00	0.03	0.12
FeO	0.14	0.22	0.14	0.15	0.12	0.11	0.21	0.21	0.10	0.11	0.09	0.17	0.14
MnO	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
MgO	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.00
ZnO	0.03	0.01	0.00	0.38	0.11	0.00	0.00	0.00	0.04	0.03	0.06	0.00	0.01
CaO	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Na2O	0.00	0.01	0.00	0.01	0.00	0.03	0.00	0.02	0.00	0.00	0.00	0.01	0.00
K2O	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Total	98.54	99.67	97.37	96.68	95.82	90.28	92.06	92.01	99.32	98.69	99.76	90.35	89.89
	Formula 3(O)												
Si	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000
Ti	0.000	0.001	0.001	0.001	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.000
Al	1.997	1.996	1.995	1.994	1.997	1.997	1.995	1.995	1.998	1.997	1.998	1.996	1.996
Cr	0.000	0.001	0.003	0.000	0.001	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.002
Fe3+	0.002	0.003	0.002	0.002	0.002	0.002	0.003	0.003	0.001	0.002	0.001	0.003	0.002
Fe2+	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Zn	0.000	0.000	0.000	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Na	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total*	2.001	2.001	2.001	2.003	2.001	2.001	2.001	2.001	2.001	2.000	2.001	2.001	2.001

Table II Representative major and trace analyses of zircon by Electron Probe Micro-Analyzer.

	Zircon								
	foliation corundum-bearing					non-foliation corumdum-bearing			
Comment	1p3Zrn3	12Zrn1	12Zrn1-2	12Zrn1-3	3Zrn6	6 Zr1	6 Zrn1-2	6 Zrn2	6 Zrn2-2
SiO2	29.63	31.00	31.30	31.96	23.74	28.93	26.89	27.18	29.94
TiO2	0.00	0.00	0.03	0.04	0.00	0.03	0.04	0.00	0.04
ZrO2	58.87	67.68	68.24	67.63	48.08	58.56	51.19	52.39	58.51
Al2O3	0.02	0.02	0.22	0.97	0.00	0.42	2.06	2.11	0.37
Cr2O3	0.00	0.00	0.01	0.00	0.00	0.03	0.06	0.01	0.00
FeO	0.00	0.42	0.43	0.34	0.01	0.33	1.05	0.77	0.19
MnO	0.00	0.05	0.06	0.02	0.00	0.02	0.08	0.04	0.00
MgO	0.01	0.03	0.03	0.05	0.02	0.01	0.03	0.11	0.01
ZnO	0.00	0.00	0.20	0.00	0.06	0.01	0.00	0.02	0.04
CaO	0.04	0.54	0.79	0.08	0.01	0.42	2.32	2.15	0.54
Na2O	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.07	0.05
K2O	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Total	88.59	99.74	101.31	101.08	71.93	88.76	83.80	84.85	89.69
Formula 4(O)									
Si	1.015	0.961	0.955	0.968	1.005	0.993	0.969	0.967	1.011
Ti	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.001
Zr	0.983	1.023	1.016	0.999	0.993	0.980	0.899	0.909	0.963
Al	0.001	0.001	0.008	0.035	0.000	0.017	0.088	0.088	0.015
Cr	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000
Fe3+	-	-	-	-	-	-	-	-	-
Fe2+	0.000	0.011	0.011	0.009	0.000	0.009	0.032	0.023	0.005
Mn	0.000	0.001	0.001	0.000	0.000	0.001	0.003	0.001	0.000
Mg	0.000	0.001	0.001	0.002	0.001	0.001	0.002	0.006	0.001
Zn	0.000	0.000	0.004	0.000	0.002	0.000	0.000	0.000	0.001
Ca	0.001	0.018	0.026	0.002	0.000	0.015	0.089	0.082	0.019
Na	0.000	0.000	0.000	0.000	0.000	0.002	0.005	0.004	0.003
K	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Total*	2.001	2.016	2.024	2.016	2.002	2.019	2.089	2.082	2.019

Table III Representative major and trace analyses of alkali feldspar by Electron Probe Micro-Analyzer.

	Alkali feldspar											
	foliation		non-foliation corundum-bearing									
Comment	5feld12	5feld33	6feld1	6feld3	6feld1	6feld6	6 feld8	12feld3	12feld8	12feld9	12feld10	12 feld3
SiO2	64.93	66.42	55.54	59.10	62.24	61.28	55.19	62.76	63.10	63.44	63.10	54.49
TiO2	0.00	0.04	0.03	0.04	0.08	0.03	0.02	0.03	0.04	0.03	0.03	0.01
Al2O3	18.53	18.75	16.37	17.34	18.17	20.61	16.64	18.24	20.19	19.91	20.71	15.62
Cr2O3	0.00	0.00	0.00	0.02	0.00	0.03	0.01	0.00	0.03	0.02	0.01	0.01
FeO	0.00	0.06	0.14	0.05	0.02	0.00	0.02	0.00	0.06	0.03	0.00	0.01
MnO	0.04	0.00	0.00	0.00	0.01	0.00	0.02	0.03	0.02	0.00	0.00	0.01
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00
ZnO	0.00	0.03	0.02	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.01	0.07
CaO	0.29	0.12	0.04	0.15	0.13	2.31	0.10	0.07	0.75	0.40	0.92	0.06
Na2O	1.74	1.93	1.14	1.69	1.59	4.07	1.16	1.71	1.90	2.11	1.12	0.98
K2O	8.82	9.01	8.02	7.98	14.23	8.86	7.68	9.11	12.70	12.64	13.26	6.46
Total	94.35	96.35	81.33	86.39	96.52	97.18	81.05	92.01	98.79	98.59	99.17	77.71
Formula 8(O)												
Si	3.051	3.056	3.034	3.033	2.972	2.865	3.023	3.035	2.921	2.939	2.911	3.074
Ti	0.000	0.001	0.001	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Al	1.026	1.017	1.054	1.049	1.023	1.135	1.074	1.040	1.102	1.087	1.126	1.038
Cr	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.001
Fe3+	0.000	0.002	0.006	0.002	0.001	0.000	0.001	0.000	0.002	0.001	0.000	0.001
Fe2+	-	-	-	-	-	-	-	-	-	-	-	-
Mn	0.002	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.001	0.000
Zn	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.003
Ca	0.015	0.006	0.003	0.008	0.007	0.115	0.006	0.004	0.037	0.020	0.045	0.003
Na	0.159	0.172	0.120	0.168	0.147	0.369	0.123	0.160	0.171	0.190	0.100	0.107
K	0.528	0.529	0.559	0.523	0.867	0.528	0.536	0.562	0.750	0.747	0.780	0.465
Total*	4.780	4.784	4.778	4.786	5.020	5.015	4.768	4.805	4.986	4.985	4.965	4.692

Table IV Representative major and trace analyses of plagioclase by Electron Probe Micro-Analyzer.

	Plagioclase																	
	foliation corundum-bearing																	
Comment	1p4plg1 -2	1p4plg3	1p4plg2	1p4plg6	1p4plg7	1p4plg8	1p3plg1	1p3plg2	1p3plg1	1p4plg3	1p1plg1	1p4plg11	3 plg1	3plg1	3plg1-2	3plg5	5plg3	5plg4
SiO2	57.81	54.38	54.96	55.59	55.52	55.18	59.55	54.86	56.94	56.27	56.37	59.67	54.97	59.17	58.84	59.45	57.26	57.91
TiO2	0.04	0.00	0.00	0.02	0.02	0.00	0.03	0.02	0.02	0.03	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.00
Al2O3	24.06	22.66	23.49	22.99	23.02	22.96	24.91	22.87	23.80	23.93	24.09	25.01	23.76	24.52	24.37	23.28	26.05	25.89
Cr2O3	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
FeO	0.01	0.03	0.00	0.07	0.01	0.00	0.05	0.01	0.02	0.02	0.00	0.10	0.04	0.09	0.01	0.00	0.00	0.00
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.02	0.02	0.03
MgO	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00
ZnO	0.00	0.00	0.05	0.05	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.02	0.01	0.00
CaO	5.80	5.23	5.48	5.42	5.23	5.31	6.66	5.25	5.80	5.73	6.03	6.67	5.36	6.24	6.35	6.22	8.44	7.96
Na2O	7.64	7.63	7.59	7.57	7.62	7.53	7.51	7.47	7.46	7.63	7.37	7.46	8.28	8.29	8.21	8.13	6.53	6.94
K2O	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.17	0.16	0.15	0.22	0.12	0.13
Total	95.36	89.94	91.57	91.70	91.45	90.99	98.78	90.49	94.07	93.63	93.88	99.01	92.60	98.49	97.96	97.39	98.42	98.86
Formula 8(O)																		
Si	2.691	2.688	2.669	2.694	2.695	2.692	2.681	2.691	2.688	2.672	2.669	2.680	2.651	2.680	2.680	2.721	2.602	2.618
Ti	0.001	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Al	1.320	1.320	1.345	1.313	1.317	1.321	1.322	1.323	1.324	1.339	1.344	1.324	1.350	1.309	1.308	1.255	1.395	1.380
Cr	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Fe3+	0.000	0.001	0.000	0.003	0.000	0.000	0.002	0.000	0.001	0.001	0.000	0.004	0.002	0.003	0.000	0.000	0.000	0.000
Fe2+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Mg	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.002	0.000	0.000
Zn	0.000	0.000	0.002	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000
Ca	0.289	0.277	0.285	0.281	0.272	0.278	0.321	0.276	0.294	0.291	0.306	0.321	0.277	0.303	0.310	0.305	0.411	0.386
Na	0.689	0.732	0.715	0.711	0.717	0.713	0.655	0.711	0.683	0.702	0.676	0.649	0.774	0.728	0.725	0.722	0.575	0.608
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.011	0.009	0.009	0.013	0.007	0.007
Total*	4.992	5.018	5.016	5.005	5.004	5.004	4.984	5.002	4.991	5.008	4.997	4.982	5.066	5.034	5.033	5.019	4.991	5.000

	Plagioclase																
	foliation corundum-bearimg																
Comment	5plg1	5plg5	5plg2	5plg3	5plg4	5plg5	5plg4	5plg4-2	5plg4-3	5plg28	5plg13	5plg13-2	5plg10	5feld11	5plg2-2	5plg3	5plg3-2
SiO2	61.50	61.23	57.64	57.98	58.94	57.82	56.40	57.58	53.31	56.79	57.38	58.48	58.35	52.15	56.61	62.39	61.32
TiO2	0.00	0.00	0.00	0.01	0.03	0.00	0.03	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00
Al2O3	25.11	25.05	23.88	23.62	24.34	23.77	23.28	23.85	22.21	23.25	23.79	23.87	23.72	21.49	23.18	25.45	24.86
Cr2O3	0.00	0.01	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.03	0.03	0.04	0.00	0.00	0.01	0.02
FeO	0.08	0.00	0.00	0.02	0.04	0.00	0.11	0.06	0.08	0.00	0.04	0.00	0.01	0.00	0.01	0.00	0.00
MnO	0.00	0.02	0.01	0.02	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.01	0.00	0.02	0.00
MgO	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.01	0.02	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00
ZnO	0.17	0.00	0.00	0.00	0.05	0.00	0.09	0.00	0.00	0.00	0.13	0.00	0.02	0.00	0.00	0.07	0.02
CaO	6.81	6.69	6.00	5.99	5.72	5.93	5.77	6.27	5.43	5.66	6.22	6.04	5.77	4.74	5.88	6.81	6.47
Na2O	7.09	6.90	10.46	10.12	9.92	9.36	9.63	9.86	9.41	9.64	9.72	9.85	9.99	9.35	9.61	10.11	10.10
K2O	0.15	0.16	0.09	0.07	0.15	0.15	0.14	0.14	0.10	0.12	0.11	0.11	0.12	0.12	0.11	0.18	0.24
Total	100.91	100.06	98.11	97.83	99.18	97.29	95.44	97.78	90.56	95.50	97.41	98.39	98.28	87.84	95.39	105.06	103.02
Formula 8(O)																	
Si	2.706	2.710	2.648	2.665	2.666	2.665	2.658	2.651	2.649	2.669	2.652	2.669	2.669	2.666	2.666	2.668	2.674
Ti	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Al	1.302	1.307	1.293	1.280	1.297	1.292	1.293	1.294	1.301	1.288	1.295	1.284	1.279	1.294	1.287	1.282	1.277
Cr	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.000	0.000	0.000	0.001
Fe3+	0.003	0.000	0.000	0.001	0.001	0.000	0.004	0.002	0.003	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Fe2+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn	0.000	0.001	0.001	0.001	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.000	0.001	0.000
Mg	0.000	0.000	0.000	0.000	0.000	0.014	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Zn	0.005	0.000	0.000	0.000	0.002	0.000	0.003	0.000	0.000	0.000	0.004	0.000	0.001	0.000	0.000	0.002	0.000
Ca	0.321	0.317	0.295	0.295	0.277	0.293	0.291	0.309	0.289	0.285	0.308	0.295	0.283	0.260	0.296	0.312	0.302
Na	0.605	0.592	0.931	0.902	0.870	0.837	0.880	0.880	0.907	0.879	0.871	0.871	0.886	0.926	0.877	0.838	0.854
K	0.008	0.009	0.005	0.004	0.009	0.009	0.008	0.008	0.006	0.007	0.006	0.006	0.007	0.007	0.006	0.010	0.013
Total*	4.950	4.937	5.174	5.147	5.123	5.111	5.139	5.146	5.157	5.129	5.139	5.127	5.137	5.154	5.132	5.114	5.121

	Plagioclase																				
	non-foliation corundum-bearing																				
Comment	4p4plg2	4p5plg7	4p5plg4	6plg1	6 plg1-2	6plg4	6 plg4	6plg5	6plg5	6plg6	6plg7	6plg8	6 plg9	6plg10	6plg11	12plg1	12plg74	12plg2	12plg4	12plg4-2	12plg5
SiO2	53.46	49.45	49.95	59.46	57.29	55.10	55.59	57.59	57.98	58.15	62.24	58.15	61.28	54.94	53.57	51.10	55.16	52.61	60.88	61.32	57.07
TiO2	0.03	0.00	0.04	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.08	0.03	0.03	0.00	0.00	0.02	0.00	0.00	0.01	0.02	0.03
Al2O3	24.36	22.20	22.76	23.29	23.47	23.09	23.35	24.74	24.13	24.24	18.17	24.46	20.61	23.02	19.88	21.65	22.98	22.77	23.09	22.28	23.36
Cr2O3	0.00	0.00	0.02	0.02	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
FeO	0.04	0.00	0.00	0.04	0.02	0.00	0.00	0.06	0.00	0.00	0.02	0.00	0.00	0.01	0.10	0.02	0.00	0.00	0.03	0.04	0.05
MnO	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.02	0.00	0.01	0.02	0.00	0.01	0.02	0.00	0.01	0.00
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.01	0.01	0.02	0.00	0.00	0.01
ZnO	0.00	0.03	0.03	0.00	0.08	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.05	0.02	0.04	0.04	0.09	0.00	0.00	0.00
CaO	6.66	5.59	5.81	6.16	5.98	6.51	5.60	6.51	6.32	6.35	0.13	6.40	2.31	5.46	5.10	5.08	5.69	6.33	6.99	7.13	6.46
Na2O	6.67	6.42	6.38	8.22	8.20	7.66	7.98	7.99	8.03	8.13	1.59	8.26	4.07	7.77	7.76	8.76	9.10	9.48	9.74	9.74	9.39
K2O	0.00	0.00	0.00	0.22	0.27	0.07	0.21	0.19	0.19	0.29	14.23	0.26	8.86	0.29	0.08	0.09	0.08	0.10	0.14	0.12	0.14
Total	91.23	83.69	84.99	97.44	95.32	92.44	92.76	97.15	96.77	97.21	96.52	97.69	97.18	92.33	86.54	86.78	93.07	91.41	100.88	100.67	96.51
Formula 8(O)																					
Si	2.613	2.631	2.618	2.720	2.685	2.664	2.673	2.650	2.676	2.673	2.972	2.664	2.865	2.677	2.757	2.645	2.659	2.604	2.711	2.737	2.660
Ti	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.003	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.001
Al	1.403	1.392	1.406	1.256	1.297	1.316	1.323	1.342	1.313	1.313	1.023	1.320	1.135	1.322	1.206	1.321	1.306	1.328	1.212	1.172	1.283
Cr	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe3+	0.002	0.000	0.000	0.001	0.001	0.000	0.000	0.002	0.000	0.000	0.001	0.000	0.000	0.001	0.004	0.001	0.000	0.000	0.001	0.002	0.002
Fe2+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.001
Zn	0.000	0.001	0.001	0.000	0.003	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.002	0.001	0.001	0.001	0.003	0.000	0.000	0.000
Ca	0.349	0.319	0.326	0.302	0.300	0.337	0.288	0.321	0.312	0.313	0.007	0.314	0.115	0.285	0.281	0.282	0.294	0.336	0.334	0.341	0.322
Na	0.632	0.662	0.648	0.729	0.745	0.718	0.743	0.713	0.719	0.725	0.147	0.733	0.369	0.734	0.774	0.879	0.850	0.909	0.841	0.843	0.848
K	0.000	0.000	0.000	0.013	0.016	0.005	0.013	0.011	0.011	0.017	0.867	0.015	0.528	0.018	0.005	0.006	0.005	0.006	0.008	0.007	0.008
Total*	5.000	5.005	5.001	5.023	5.047	5.040	5.042	5.041	5.032	5.041	5.020	5.049	5.015	5.038	5.030	5.136	5.116	5.189	5.107	5.102	5.126

Table V Representative major and trace analyses of biotite by Electron Probe Micro-Analyzer.

	Biotite														
	mica schist corundum-barren												foliation corundum-bearing		
Comment	2p5bt1	2p5bt1-2	2p5bt2	2p5bt3	2p5bt4	2p5bt2	2p5bt6	2p5bt6-2	2p5bt6 -3	2p5bt7	2p5bt13	2p5bt14	1p3bt1	1p1bt1	1p4bt7
SiO2	40.72	41.54	41.17	39.10	41.84	41.51	32.22	40.40	40.76	40.81	40.02	40.75	37.19	35.18	37.22
TiO2	1.26	1.12	1.16	1.11	0.95	1.11	0.54	1.54	1.27	1.21	1.45	1.43	3.74	3.05	3.72
Al2O3	15.12	13.71	14.63	14.11	13.46	13.79	11.47	15.34	14.92	14.09	15.29	15.56	18.29	17.58	18.04
Cr2O3	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.03	0.03	0.00	0.01	0.09	0.04	0.08
FeO	1.57	1.30	1.51	1.31	1.31	1.24	0.64	1.48	1.62	1.50	1.44	1.76	10.94	8.73	10.85
MnO	0.01	0.01	0.00	0.01	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00
MgO	22.91	23.39	23.13	22.90	23.81	22.77	20.27	22.27	23.07	22.21	21.54	21.93	14.73	14.61	14.58
ZnO	0.00	0.00	0.01	0.01	0.00	0.00	0.07	0.00	0.06	0.06	0.00	0.00	0.01	0.06	0.04
CaO	0.08	0.06	0.02	0.00	0.01	0.00	0.06	0.07	0.02	0.05	0.00	0.02	0.01	0.06	0.00
Na2O	0.29	0.28	0.32	0.30	0.26	0.31	0.29	0.28	0.31	0.28	0.36	0.32	0.07	0.03	0.09
K2O	0.10	0.11	0.09	0.09	0.11	0.11	0.07	0.10	0.11	0.10	0.10	0.11	0.10	0.10	0.11
Total	82.05	81.52	82.04	78.95	81.79	80.86	65.66	81.49	82.18	80.34	80.19	81.89	85.16	79.45	84.72
Formula 11(O)															
Si	3.069	3.143	3.100	3.063	3.155	3.161	3.036	3.063	3.071	3.135	3.079	3.076	2.847	2.859	2.863
Ti	0.071	0.064	0.065	0.066	0.054	0.064	0.038	0.088	0.072	0.070	0.084	0.081	0.215	0.186	0.215
Al	1.343	1.222	1.298	1.303	1.196	1.238	1.273	1.371	1.324	1.275	1.386	1.384	1.650	1.684	1.636
Cr	0.000	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.002	0.002	0.000	0.000	0.005	0.002	0.005
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe2+	0.099	0.082	0.095	0.086	0.083	0.079	0.051	0.094	0.102	0.096	0.092	0.111	0.700	0.593	0.698
Mn	0.000	0.000	0.000	0.001	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mg	2.574	2.639	2.596	2.674	2.677	2.586	2.847	2.517	2.591	2.543	2.470	2.467	1.681	1.770	1.671
Zn	0.000	0.000	0.001	0.001	0.000	0.000	0.005	0.000	0.003	0.004	0.000	0.000	0.000	0.004	0.002
Ca	0.007	0.005	0.001	0.000	0.001	0.000	0.006	0.005	0.002	0.004	0.000	0.001	0.001	0.005	0.000
Na	0.042	0.041	0.047	0.045	0.038	0.046	0.053	0.040	0.045	0.042	0.053	0.047	0.010	0.005	0.013
K	0.894	0.749	0.859	0.809	0.749	0.724	0.573	0.857	0.925	0.888	0.853	1.005	6.441	5.794	6.450
Total*	8.099	7.946	8.063	8.047	7.955	7.897	7.884	8.037	8.137	8.059	8.019	8.174	13.551	12.903	13.553

	Biotite															
	foliation corundum-bearing								non-foliation corundum-bearing							
Comment	3 bt1	3 bt3	5bt2	5bt1	5bt1-2	5bt1-3	5bt11	5bt12	4p5bt4	12 bt1	12bt1-2	6 bt2	6 bt3	6 bt4	6 bt5	6 bt6
SiO2	34.25	33.09	36.55	35.88	34.67	34.75	30.81	33.79	30.92	34.15	36.54	34.21	34.16	36.39	36.27	36.31
TiO2	3.14	2.50	3.10	2.99	2.98	3.39	3.11	2.55	2.18	3.30	3.42	3.09	3.68	3.26	3.50	3.18
Al2O3	15.73	15.79	17.18	17.67	17.24	16.56	15.78	16.28	16.55	16.55	17.20	17.38	17.16	17.94	18.04	18.09
Cr2O3	0.09	0.07	0.06	0.00	0.08	0.00	0.08	0.08	0.00	0.03	0.00	0.10	0.08	0.05	0.05	0.03
FeO	8.33	7.32	8.18	8.82	8.58	8.90	8.77	8.48	5.42	9.36	9.91	9.16	9.19	10.25	10.40	10.64
MnO	0.05	0.04	0.08	0.06	0.05	0.05	0.01	0.03	0.02	0.07	0.07	0.03	0.04	0.08	0.04	0.00
MgO	15.18	15.30	14.90	14.28	14.18	14.06	14.48	14.27	15.58	14.74	15.44	15.48	14.80	16.30	16.76	16.11
ZnO	0.00	0.02	0.05	0.00	0.00	0.00	0.00	0.05	0.04	0.00	0.00	0.09	0.00	0.02	0.00	0.06
CaO	0.00	0.00	0.03	0.01	0.03	0.01	0.02	0.00	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Na2O	0.05	0.09	0.11	0.06	0.12	0.06	0.10	0.10	0.07	0.16	0.11	0.06	0.06	0.09	0.07	0.10
K2O	5.50	5.26	6.03	5.63	5.56	5.64	5.64	5.53	0.10	5.47	5.47	9.16	5.64	10.02	6.33	6.50
Total	82.34	79.49	86.28	85.40	83.49	83.40	78.80	81.16	70.90	83.84	88.17	88.77	84.82	94.42	91.46	91.04
	Formula 11(O)															
Si	2.805	2.792	2.844	2.822	2.795	2.811	2.670	2.809	2.780	2.761	2.799	2.675	2.728	2.689	2.704	2.724
Ti	0.193	0.159	0.182	0.177	0.181	0.206	0.203	0.159	0.148	0.201	0.197	0.182	0.221	0.181	0.196	0.180
Al	1.518	1.570	1.575	1.637	1.638	1.579	1.611	1.595	1.754	1.576	1.552	1.602	1.615	1.562	1.585	1.599
Cr	0.006	0.005	0.004	0.000	0.005	0.000	0.006	0.005	0.000	0.002	0.000	0.006	0.005	0.003	0.003	0.002
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe2+	0.571	0.517	0.532	0.580	0.579	0.602	0.636	0.589	0.407	0.632	0.634	0.599	0.614	0.633	0.648	0.667
Mn	0.004	0.003	0.005	0.004	0.003	0.003	0.000	0.002	0.002	0.005	0.005	0.002	0.002	0.005	0.003	0.000
Mg	1.853	1.925	1.729	1.675	1.705	1.696	1.871	1.768	2.088	1.776	1.763	1.805	1.763	1.795	1.863	1.802
Zn	0.000	0.001	0.003	0.000	0.000	0.000	0.000	0.003	0.003	0.000	0.000	0.005	0.000	0.001	0.000	0.003
Ca	0.000	0.000	0.003	0.001	0.003	0.001	0.002	0.000	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Na	0.008	0.014	0.017	0.009	0.018	0.009	0.016	0.016	0.012	0.025	0.016	0.009	0.009	0.013	0.010	0.015
K	5.615	5.239	4.979	5.481	5.605	5.852	6.619	5.887	4.400	6.144	5.839	5.627	5.893	5.621	5.807	6.014
Total*	12.571	12.225	11.873	12.386	12.531	12.759	13.634	12.834	11.596	13.123	12.808	12.513	12.850	12.503	12.818	13.007

Table VI Representative major and trace analyses of calcite by Electron Probe Micro-Analyzer.

	Calcite								
	Mica schist corundum-barren								
Comment	2p5cc1	2p5cc2	2p5cc5	2p5cc4	2p4cc1	2p5cc1	2p1cc1	2p1cc2	2p5cc10
SiO2	0.23	0.27	0.34	0.29	0.14	0.32	0.09	0.12	0.22
TiO2	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.07
ZrO2	0.09	0.18	0.00	0.11	0.09	0.09	0.02	0.18	0.08
Al2O3	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.01
Cr2O3	0.00	0.02	0.00	0.01	0.00	0.00	0.01	0.03	0.00
FeO	0.01	0.06	0.03	0.02	0.02	0.00	0.05	0.00	0.00
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.01
MgO	0.05	0.01	0.03	0.03	0.04	0.04	0.00	0.04	0.04
ZnO	0.00	0.00	0.05	0.02	0.02	0.00	0.00	0.00	0.04
CaO	49.09	53.30	39.81	53.39	53.19	52.99	48.11	49.66	53.16
Na2O	0.10	0.08	0.05	0.04	0.09	0.05	0.10	0.09	0.08
K2O	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Total	49.57	53.92	40.35	53.91	53.59	53.49	48.41	50.15	53.73
	Formula 1(O)								
Si	0.004	0.005	0.008	0.005	0.002	0.005	0.002	0.002	0.004
Ti	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Zr	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.002	0.001
Al	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe3+	-	-	-	-	-	-	-	-	-
Fe2+	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Mn	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
Mg	0.001	0.000	0.001	0.001	0.001	0.001	0.000	0.001	0.001
Zn	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001
Ca	0.986	0.985	0.980	0.986	0.991	0.985	0.993	0.988	0.986
Na	0.004	0.003	0.002	0.001	0.003	0.002	0.004	0.003	0.003
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total*	0.997	0.995	0.993	0.995	0.998	0.995	1.000	0.997	0.996
%Cc	99.867	99.974	99.909	99.932	99.901	99.885	100.000	99.888	99.906
%Dol	0.133	0.026	0.091	0.068	0.099	0.115	0.000	0.112	0.094