Geology and Gems of Mogok Area, Pyin Oo Lwin District, Mandalay Region

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Abstract

Mogok area is situated about 200 km north of Mandalay and 148 km northeast of Shwebo. The study area is bounded by N latitude 23˚15'-22˚52' and 96˚10'-96˚45' E longitude. Mogok can be easily accessed by car in 5-6 hours drive from Mandalay, depending on the weather conditions. Geologically, the Mogok gems mining area is situated within the Mogok Metamorphic Belt (MMB). The MMB is a mid-Cenozoic orogenic belt that has suffered significant erosion due to weathering. It is comprised of steeply dipping, deformed, medium to high grade metamorphic rocks consisting mainly of mica schists, marbles, calc-silicate rocks, gneiss and a smaller amount of quartzites. They are often intruded by igneous rocks, such as syneite, leucogranite, biotite microgranite (Kabaing Granite), peridotite-dunite, as well as pegmatite dykes. Mogok gems are born in metamorphic, igneous and in skarn-contact zone rocks involving complex metasomatic, magmatic and pegmatitic processes. Mogok and other villages nearby have been famous since ancient times for its gemstones, especially ruby and sapphire, but semi-precious stones such as lapis lazuli, garnet, moonstone, peridot and chrysoberyl are also found. Most gems are found in alluvial marble gravels by means of panning, tunneling and digging pits by hand. Some are found as insitu in marble, gneiss and skarn rocks. Those insitu gems are extracted by tunneling. Gems are sold in markets in Mogok . 90 % of the world's rubies come from Myanmar, Mogok. The Mogok gems are noted as the world's finest "pigeon's blood" rubies and the world's most beautiful "royal blue" sapphire.

Key words. Mogok Metamorphic Belt

I. Location and Size

The study area is situated about 200 km N of Mandalay and 148 km NE of Shwebo. Politically, Mogok belongs to Pyin Oo Lwin District in the Mandalay Region. Northern boundary of the study area is located along the Momeik Fault running roughly parallel to 23˚ 15' whereas southern boundary is about 3 km S of the municipality of Mogok at about 22˚ 52' N. The Eastern boundary lies about 4 km E of Pein-pyit village at about 96˚ 45' E and western boundary is defined at the far western end of Mogok, west of the village of shwe-naung-bin to include the mining area of

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On-dan at about 96˚ 10' E. It can be easily accessed by car in 5-6 hours drive from Mandalay, depending on the weather condition. The location map of the study area is shown in figure 1.

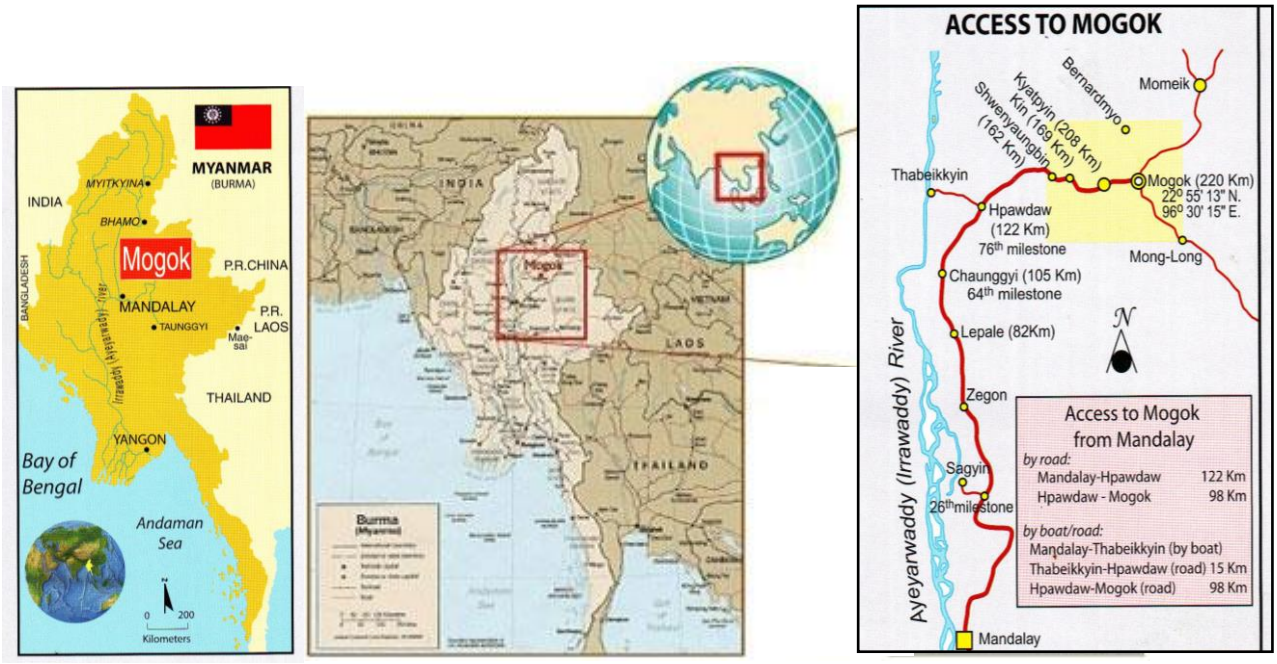

Figure 1. Location map of Mogok Area

II. Main Objectives

Main objectives of the study are as follow,

1. To reinvestigate the general geology of Mogok area,
2. To conduct in detail the gem-bearing rocks of the study area,
3. To study the important geological events and features of the study area,
4. To know the gem mining process and
5. To focus the Myanmar famous gems, especially ruby and sapphire.

III. Geomorphology

The general area of Mogok is rugged and mountainous region with steep slopes covered by dense forest forming the western border of the Shan Plateau. The panoramic view of Mogok area is shown in figure 2. The area is dissected by numerous rivers and streams, such as, Kin-chaung, Chaung-gyi-chaung, Yebu-chaung, Yeni-chaung, Nam-peik-chaung, and Pan-taw-chaung. The elevation of the

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Mogok gem mining area ranges from about 600 meters above sea level at the gem mines at Kin to 1,900 meters at Zalat-taung.

Mogok is characterized by basins, those surface depressions formed when the roof of a cavern collapses as a result of subterranean erosion and dissolution, typical of Karst topography. Other basins are situated at Ohn-bin-ye-htwet, Shwe-pyi-aye, Baw-lon-gyi, Sin-the-gyant and elsewhere. Sinkholes are common in some karst areas at Mogok. They are forming a basin with very small channels that allow only the water to escape. Depending on the topography, water descends below ground to the water table, forming networks of underground rivers. The gem-bearing alluvium deposited at the floor of a sinkhole may be flushed via the narrow channels and deposited in the passages or on the floor of the caves. On suitable topography, the alluvium may travel further via underground rivers and be deposited in a relatively distant area. The underground rivers at Mogok were known since the British times. At this time access to these underground rivers is prohibited by the authorities and to this day, they have not been fully explored. The landsat image is shown in figure 3.

Mogok is inhabited by various ethnic groups such as Lisus, Burmas, Palaungs, Shans, Nepali-Gurkhas and Sino-Shan ethnic tribes.

Figure 2. Panoramic view of Mogok Area,

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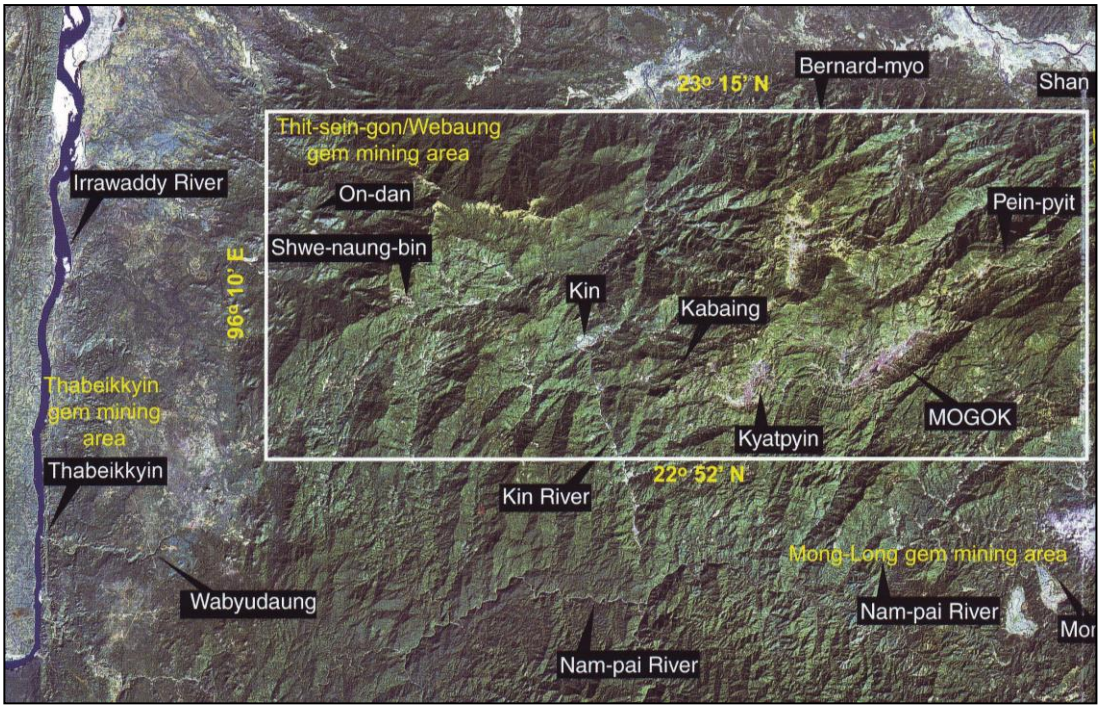

Figure 3. Landsat image of Study Area

IV. Geology of the Mogok Area

Mogok's geological evolution is attributed to six significant events occurred during a period of over 200 million years, as follow ;(in figure 4)

1. sedimentation
2. drifting
3. convergence
4. continental plate collision
5. post collision extension
6. uplift and erosion .

Hundreds of millions of year ago the area of Mogok was under the sea. Sandstones, shales and lenses of limestone accumulated and deposited on the basin floor. After the sedimentation process, the first magmatic event was formed with the intrusion of granitic rocks into the sedimentary sequence in a span of time between ~200 and ~150Ma. And then, a tectonic convergence process of crustal plates is started involving an oblique subduction of Indian plate and Burma microplate along the Sunda Trench. The eastward-dipping subduction caused great lateral

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compressional stress, "sequeezing" and metamorphosing the laid down sedimentary sequence and the intrusions of the first magmatic cycle.

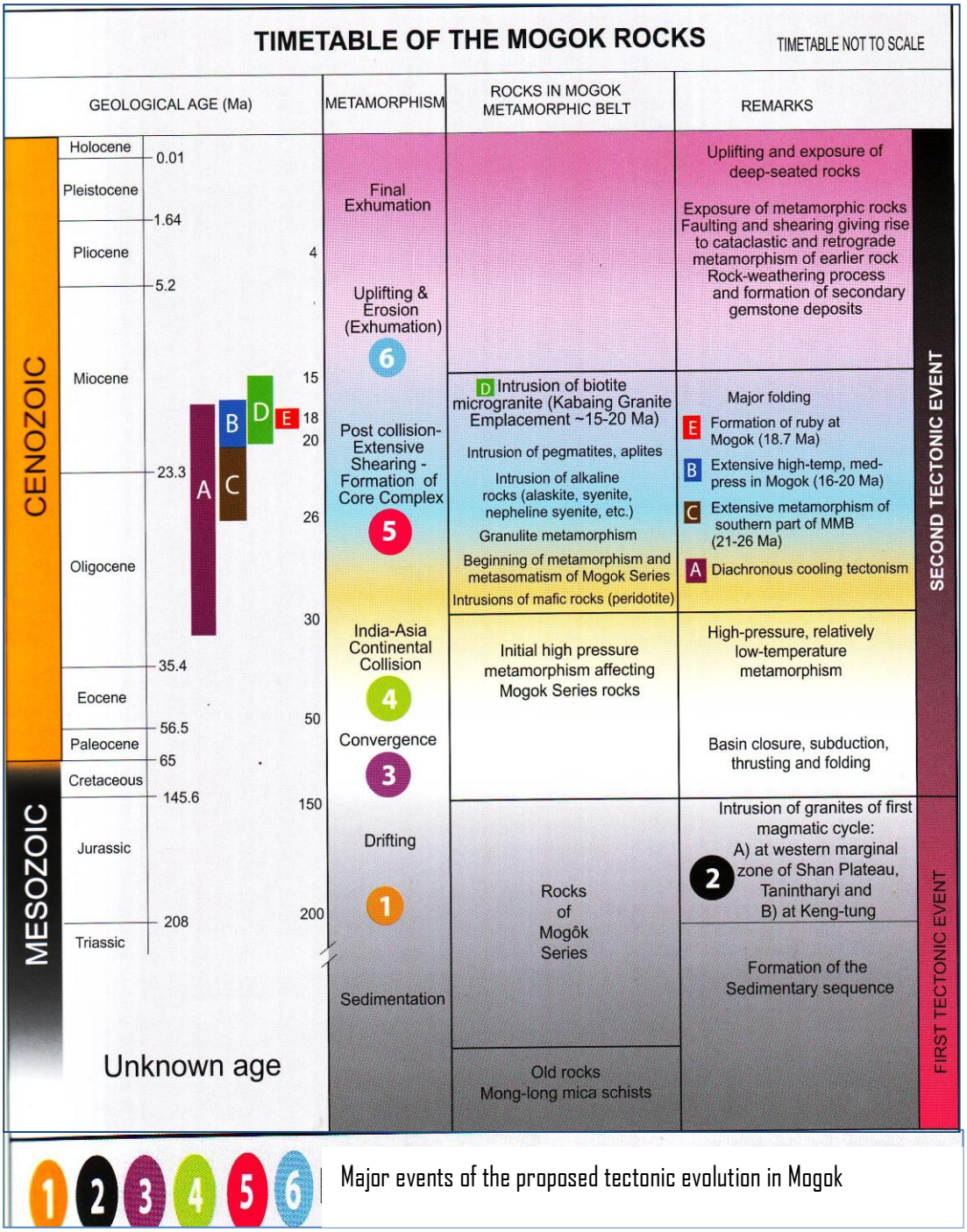

Figure 4. Proposed timetable of the evolution of the mogok rocks showing the geological evolution of the region.

A post collisional extension (relaxation, plate rebound) period followed with intrusions of the deep-seated rocks (Fig 4). Gradually, the temperature increased

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(maximum 750˚ C), while the pressure decreased (up to 7-8 kilo bars) resulting in metamorphism and metasomatism in the Mogok rocks. Granite emplacements (syenite and granodiorite intrusions together with pegmatitic segregate), due to melting of the crustal rocks at depth, occurred between ~20 and 15 Ma. During this period rubies were formed at ~18.7 Ma and most likely all other gemstones found in Mogok under different genetic environments. Exhumation (uplifting) was relatively slow in the last ~4Ma and still continues today. Weathering processes modeled the mountains and valleys leading to the formation of the present-day topography of Mogok. Moreover, these recent erosive processes produced the residual, colluvial, alluvial and other gemstone deposits.

Metamorphism played an important role in the evolution of the rock sequences in Mogok, particularly important in the formation of the great variety of gemstones found in the region. At Mogok, metamorphism occurred in (a) extensive (regional metamorphism) and (b) local scale (contact metamorphism) (Fig. 5&6). Geologically, the Mogok gems mining area is situated within the Mogok Metamorphic Belt (MMB) (Fig.7). This relatively narrow , elongated, sigmoidal zone is generally oriented N-S , adjacent to the N- trending Sagaing fault in the west, and Shan fault scarp in the east . It is a mid-Cenozoic orogenic belt that has suffered significant erosion due to weathering. The MMB is comprised of steeply dipping, deformed, medium to high grade metamorphic rocks consisting mainly of mica schist, marbles, calc- silicates, gneiss and a smaller amount of quartzite. These metamorphic rocks were collectively referred to as “Mogok Series”. They are often intruded by igneous rocks, such as syenite , leucogranite , biotite microgranite (Kabaing Granite), peridotite-dunite , as well as pegmatite dykes. Geological map of Mogok Area is shown in figure 8.

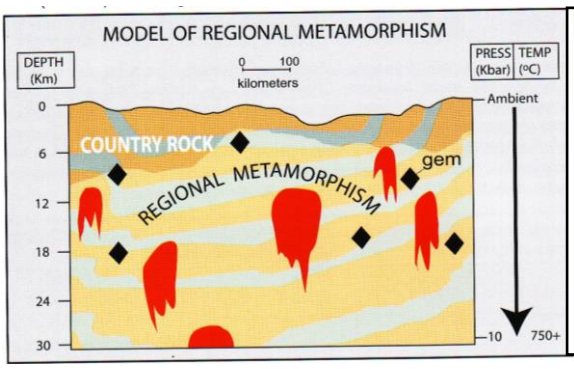

Figure 5. Model of regional metamorphism in Mogok

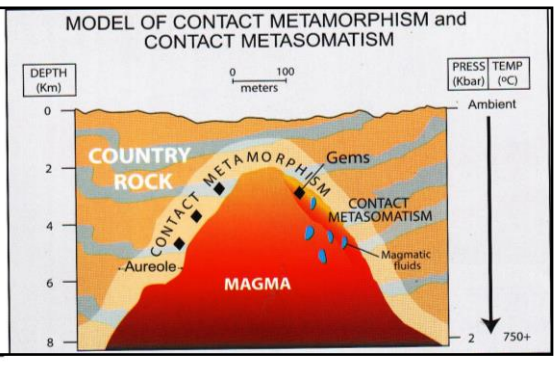

Figure 6. Model of contact metamorphism associated with metasomatism

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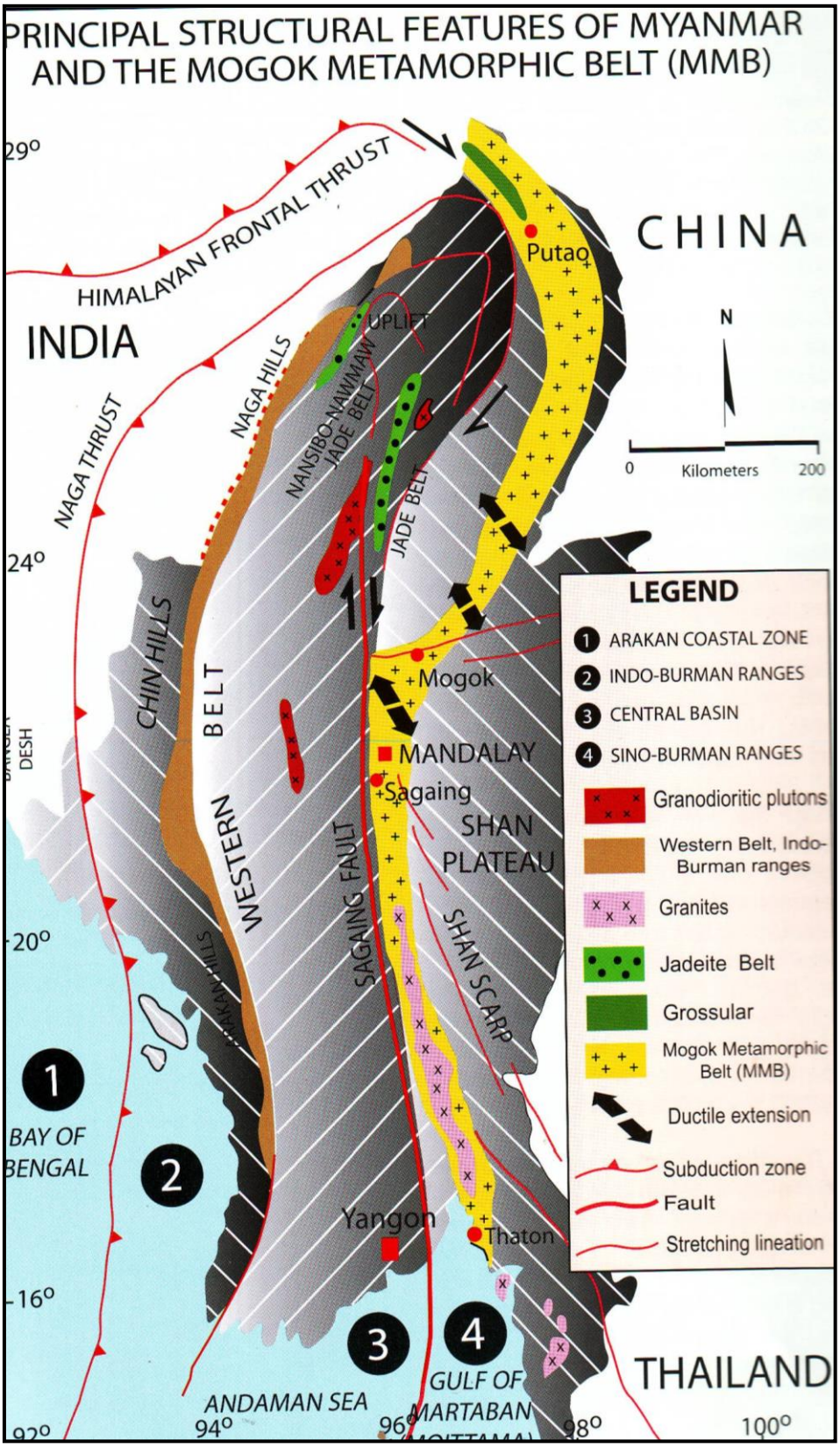

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Figure 7. Principal geological features of Myanmar and Mogok Metamorphic Belt (MMB)

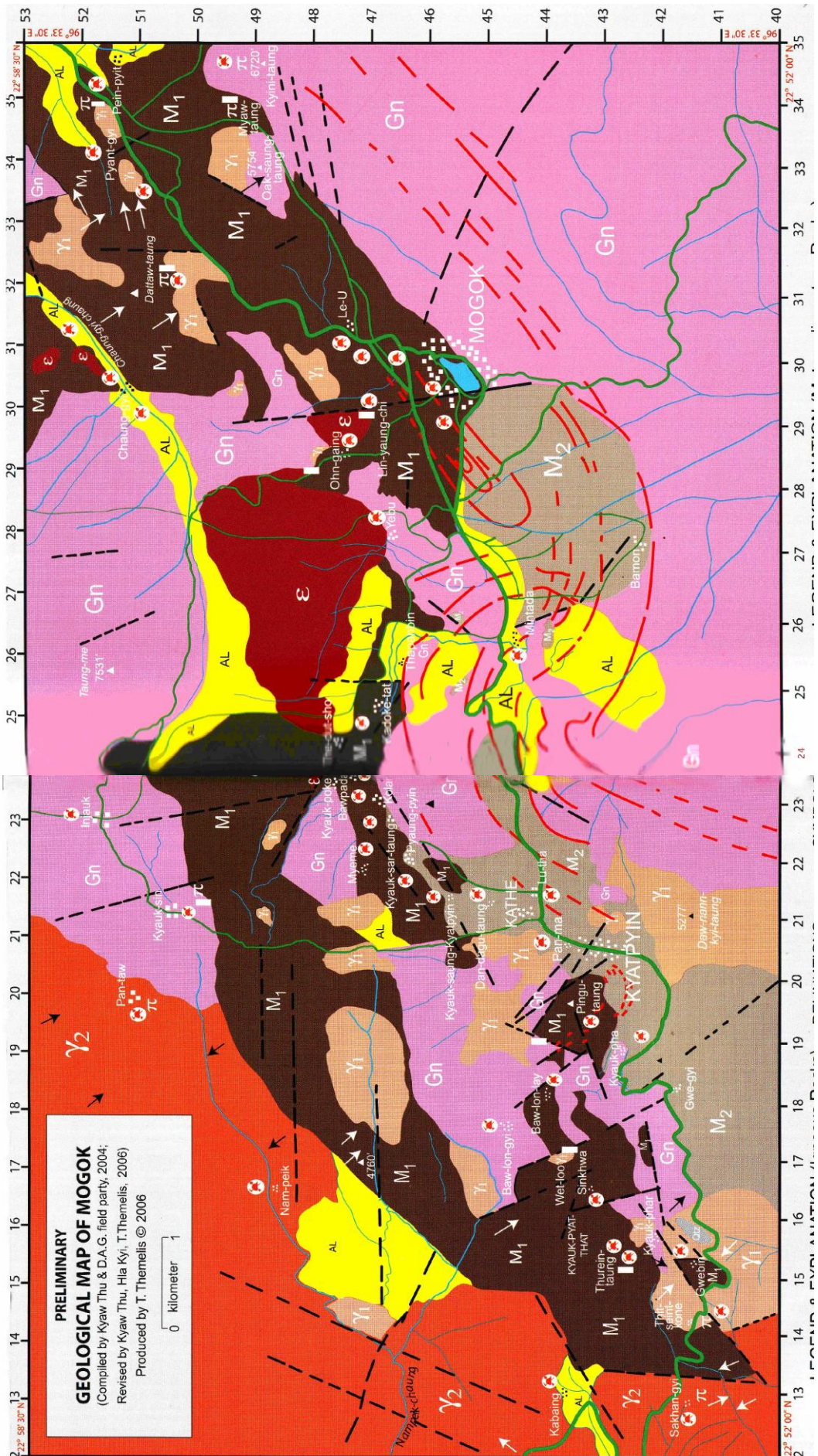


Figure 8. Geological Map of Mogok Area

LEGEND & EXPLANATION
(Igneous Rocks)

Alluviaium

Leucogranite. Coarse-grained, composed mainly of alkali- feldspar and quatz with black tourmaline, garnet and biotite.

Biotite microgranite (Kabaing granite). Medium-grained with uniform texture, Composed mainly of quartz,alkali-felspar, biotite with accessory apatite and zircon.

Syenitic rocks: Coarse-grained mainly nordmarkite (quartz-bearing alkali Syenite and minor sapphire-bearing feldspathoidal syenites.

Pegmatite. Localized veins intruded into microgranite, bearing topaz, quartz, beryl , and muscovite.

(Metasedimentary Rocks)

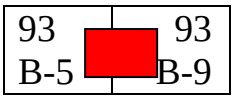
Quartzite. Fine-grained, greyish to bluish , often light pink , sparsely exposed.

Marble (M1) . Ruby-bearing marble, ruby-sphene-diopside marble, spinel-bearing marble, spinel-chondrodite marble,spinel-graphite-phlogopite - chondrodite marble, spinel-chondrodite-phlogopite marble, scapolite marble, pyrite-scapolite-diopside marble, diopside marble.

Marble (M2). Graphite marble, white marble & graphite-phlogopite marble, white marble, yellow marble & calc-silicate rock , apatite-phlogopite marble, graphite-phlogopite marble, graphite-phlogopite-forsterite-marble, diopside marble &calc-silicate rock, spinel-graphite-phlogopite marble, phlogopite-forsterite marble, forsterite-garnet-chondrodite marble.

Gneiss.Garnet-biotite gneiss and leucogneiss; also , limited exposures of sillimanite-gneiss and cordierite-gneiss.

SYMBOLS



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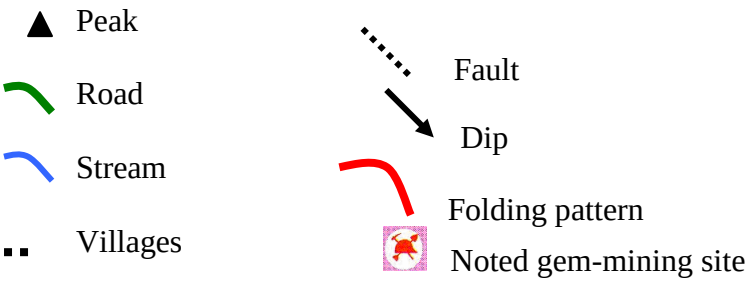

V. The Rocks of Mogol

Due to a succession of major events in the region the geology and the rocks of Mogok varied. The most important rocks of Mogok are igneous and metamorphic grouped as follows:

IGNEOUS ROCKS

Granite pegmatite

Biotite microgranite (Kabaing Granite)

Leucogranite (Alaskite suite)

Augite granite

Diorite

Syenite

A. Quartz-bearing alkali syenite (nordmarke)

B. Hornblende syenite

C. Nepheline syenite

D. Alkali feldspar syenite pegmatite

MANTLE ROCKS

Ultramafic rocks

A. Dunite and peridotite

B. Serpentinite

METAMORPHIC ROCKS

Marble

Group M1 (Gem-bearing marble):

Scapolite marble, ruby-bearing marble, ruby-titanite-diopside marble, spinel-bearing and forsterite spinel marble, diopside marble, spinel-clinohumite-phlogopite

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marble and chondrodite-phlogopite-graphite marble, forsterite-grossular-clinohumite marble, apatite-phlogopite-diopside marble, pure (white) marble

Group M2 (Non-gem bearing marble):

Graphite marble, graphite-phlogopite marble, phlogopite-forsterite marble

Calc-silicate rocks

Quartzite

Gneiss

Granite Pegamatite

The most important and largest pegmatite bodies in Mogok are situated at the SW part of Sakhan-gyi village, while a smaller pegmatite body is found at Thit- seint-kone. Many gem minerals are also found in the altered contact zone surrounding the pegmatite body (Fig. 9).

Syenite

Syenite is a rock of intermediate silica content. Exfoliated syenite boulders are found near Chaung- gyi village and elsewhere. Sapphire, often of gem quality, is found only in nepheline syenite and in alkali–syenite pegmatite. Other gems found in syenite are orthoclase, adularia moonstone, sanidine, almamdine, labradorite, spessartite and hematite. The common occurrences in Mogok are near the village of On-dan, Yadana-kaday-kadar, Thurein-taung, Ohn-gaing, and Lay-tha (East of Bernardmyo)(Fig 10&11).

Dunite and Peridotite

Dunite and peridotite (fig. 12) have essentially very similar characteristics. They are occurred in Pyaung-gaung (Mya-sein-taung mine), Zalat-taung and Bernardmyo. Chatoyant hornblende, peridot, enstatite and chrysoprase-gem minerals are found.

Marbles

There are two groups in marbles. They are (1) gems-bearing marbles and (2) non-gem bearing marbles. Most marbles at Mogok are composed mainly of calcite, fewer are of dolomitic composition, and other marbles are of mixed composition. Gem minerals in the marble include ruby, spinel, zircon, apatite and others. The gem bearing marbles consist mostly of calcite, with traces of chromium, titanium,

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manganese, iron and other impurities. Most marbles are concentrated in the so-called Mogok Marble Ark. Red to crimson-red rubies, pink sapphires may be present in marbles at Bawpadon, Kolan, Lin-yaung-chi, Dattaw, On-dan and elsewhere.

Gneiss

Garnet- biotite gneiss (fig. 13), garnet-sillimanite gneiss and cordierite-gneiss are found at Mogok mostly in highly weathered exposures, often altered to kaolin, a clay mineral. Occurred gem minerals are almandine, iolite and fibrolite.

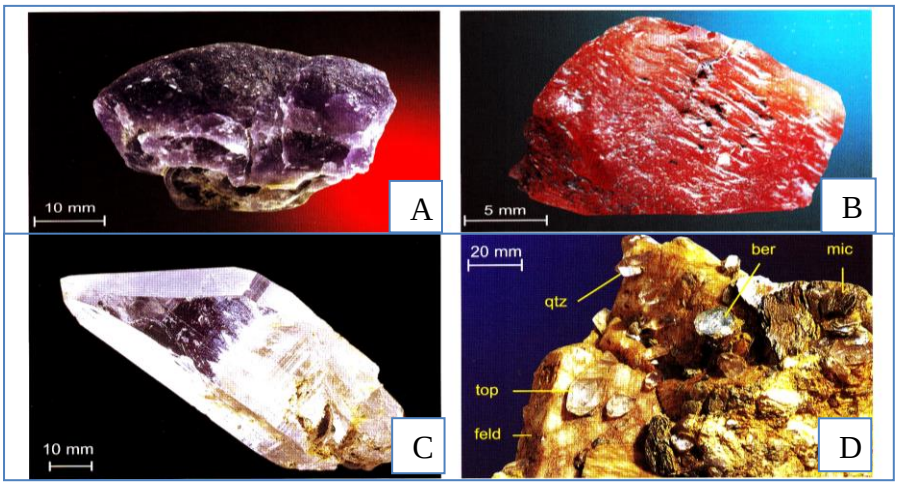

Figure 9. Pegmatitic Minerals of Mogok Area- A. purple blue fluorite, B. transparent orange sheellite, C. quartz, and D. feldspar, topaz, mica, beryl and quartz

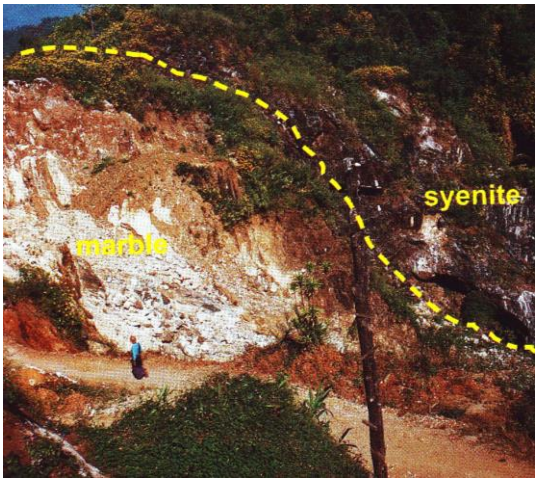

Figure 10. Marble and syenite exposures at Yadanar-kaday-kadar mine. Fine quality and large sapphies are found in

Figure 11. Syenite boulders at the Nga-yant –inn mine

Figure 12. Highly jointed peridotite show blocky cracks and sheeted rodingite at Mya-sein-taung.

Figure 13. Garnet-biotite gneiss in Chaung-Gyi

In Mogok, the gems are born in metamorphic, igneous and in skarn-contact zone rocks involving complex metasomatic, magmatic and pegmatitic process. Not surprisingly, many of the world's finest and largest rubies, sapphires, spinels, peridots and other gems come from Mogok. Mogok gems are classified into 1. Gems of metamorphic origin, 2. Gems of igneous origin and 3. Gems of skarn-contat zone (fig. 14).

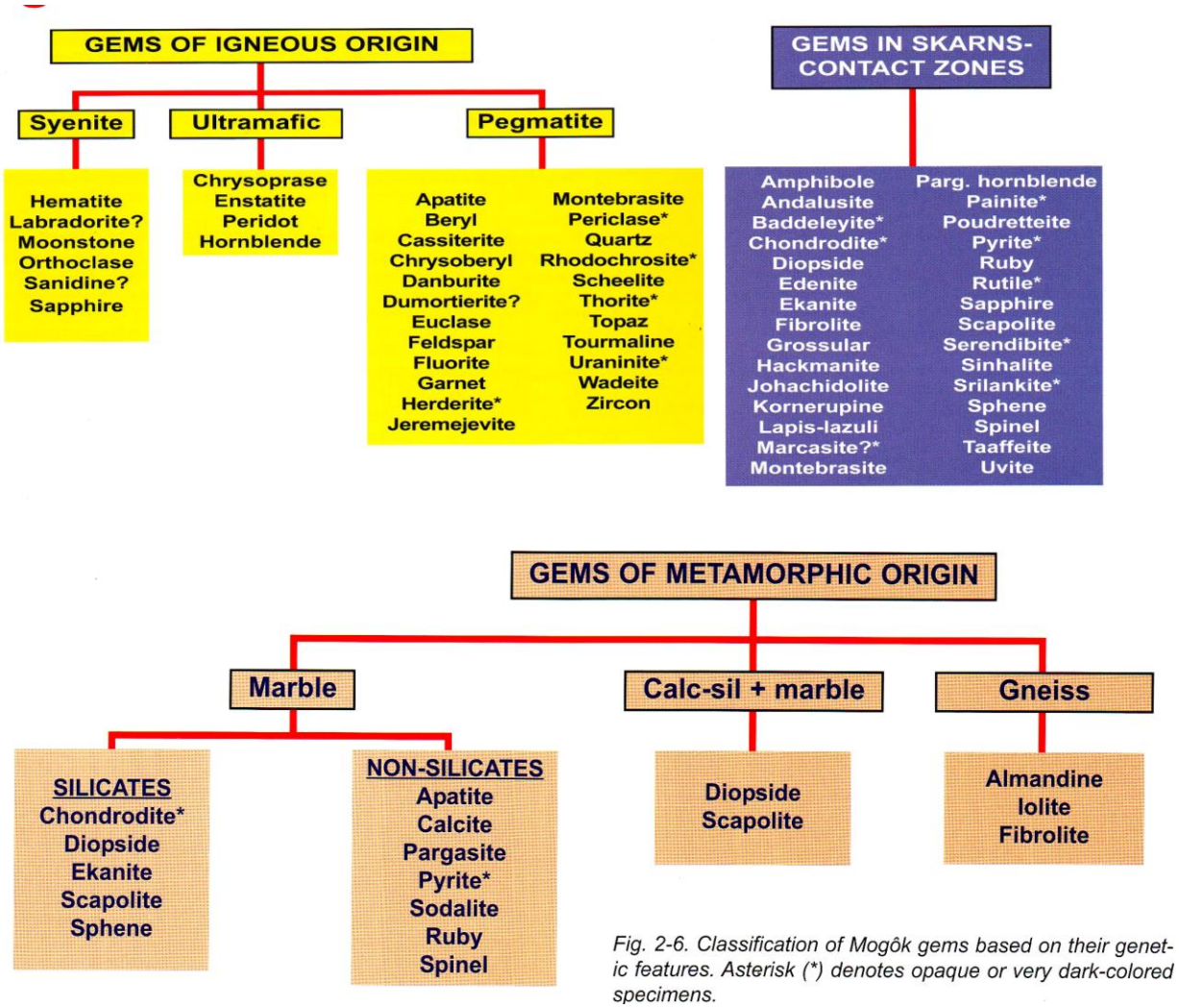

Fig. 2-6. Classification of Mogôk gems based on their genetic features. Asterisk (*) denotes opaque or very dark-colored specimens.

Figure 14. Classification of Mogok Gems based on their genetic features.

VII. Distribution of Gems in Mogok

In Mogok, the same gem species may be found in different genetic environments. All types of gemstones may be found in the alluvium throughout the Mogok region (fig. 15).

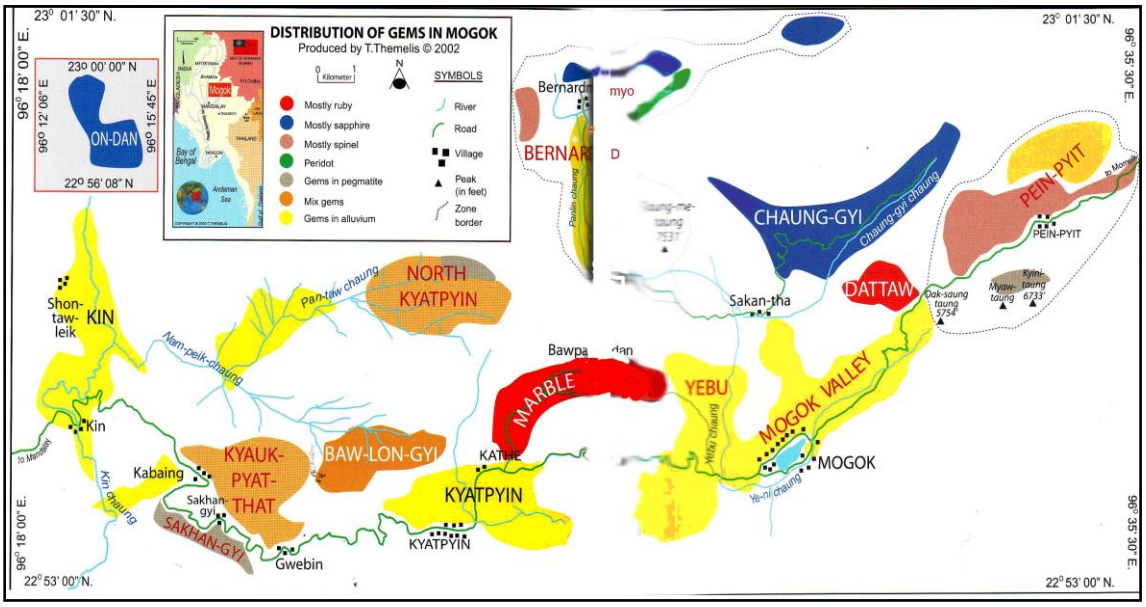

Figure 15. Distribution of Gems in the Mogok general area

VIII. Gem Mining in Mogok

Gem mining in Mogok is evidenced during prehistoric times, but most historians speculate that gem mining started around 1044 AD when the Pyus (Early Burmans) settled at Tagaung and subsequently at Momeik and then Mogok. Most gems are found in alluvial marble gravels by means of panning, tunneling and digging pits by hand. Some are found insitus in marble, gneiss and skarn rocks.

In Mogok, gems are recovered in all seasons of the year, utilizing different mining methods depending on the type of deposit, topography, climatic conditions, logistic support, cost of mining and other considerations. The following gem mining methods are employed:

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-Twinlon or lebin-dwin (sinking shafts to byon layer)

-Myaw-dwin (sluicing)

-Quarries (Open-pit mining)

-Loo-dwin (twisted holes)

-Letkya –dwin (cavity filled deposits)

-Gwe- dwin (tunneling).

The gems mines of Mogok are shown in figure 16. They are 1.Bernardmyo, 2.Chaung-gyi, 3.Pein-pyit, 4. Mogok Valley, 5. Marble Ark, 6. Kathe (South), 7. Kyatpyin (Central), 8. Kyatpyin (North), 9. Kyauk- pyat-that, 10. Kin, and 11.On-dan.

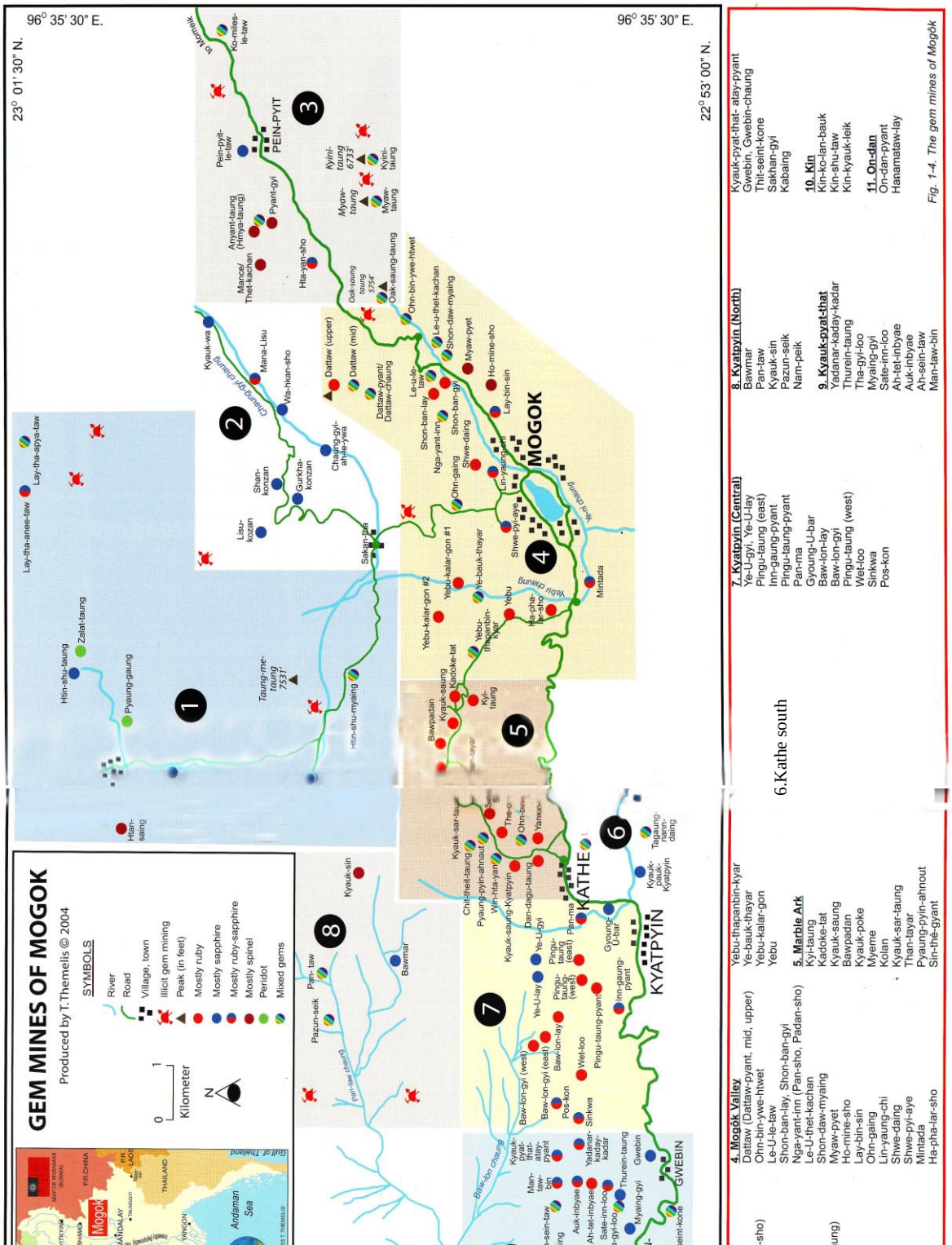

Figure 16. Gem Mines of Mogok Area

IX. The Mogok Gems

More than 60 gemstone varieties have been found in Mogok. Mogok and other villages nearby have been famous since ancient times for its gemstones, especially ruby and sapphire, but semi-precious stones such as lapis lazuli, garnet, moonstone, peridot and chrysoberyl are also found. Among them, the famous gems of Mogok (ruby, and sapphire) are discussed in this research.

X. Ruby and Sapphire

Myanmar has long been known to be the source of superfine ruby and it still ranks as the principal source of world's supply of finest ruby. Myanmar produces more beautiful and valuable rubies than are found in any part of the world.

Although a red ruby and a blue sapphire bear no outward resemblance to each other when cut as gemstone, they are both colour varieties of the same mineral corundum. Its chemical formula is Al_2O_3. So, ruby and sapphire are members of the mineral corundum. Red-coloured corundum is called ruby; any other coloured corundum is called sapphire. The colour of the ruby is due to chromium and the colour of blue sapphire is due to iron and titanium. The Mogok gems are noted as the world’s finest “Pigeon’s blood rubies" and the world’s most beautiful “royal blue" sapphire. In Mogok, ruby is found in-situ, in marbles, in detrital, in fracture-filled and alluvial deposits. Sapphire occurs in igneous rocks, often associated with plumasite syenite rocks (On- dan). Mogok rubies are prisms, pinacoids, often a combination of pyramids and prisms. They may show tabular habit with rhombohedral faces.

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Common crystal forms in Mogok sapphires include prism and pinacoid, pyramids and prisms. Pinacoid faces may show trigons. Some ruby and sapphire gems displaying asterism are known as “Star” and these can be highly prized. Star ruby and sapphire exists in six ray star, though twelve ray stars are also known (fig. 17).

These gems are used in all forms of jewelry, including bracelets, necklaces, rings and earings. It is used both as centerpiece gemstone in pendants and rings, as well as a secondary stone to complement other gemstones such as diamonds. Star Ruby is polished as cabochons and if clear, can be extremely valuable. Some people use and believe ruby is the birthstone for July and sapphire is the birthstone of September.

In the Mogok stone tract (fig. 18), two very important modes of occurrence of ruby and sapphire are: (1) as thin (generally 2 – 4 inches thick) gem-bearing bands in marbles (primary) ;(2) as alluvial placers (known as byon layers) deposited in river valleys and wide depressions (secondary). Three less important , but quite productive modes of occurrences are: (1) as skarns in the contact zones between the marbles and syenite, syenite prgmatite or urtite (primary) ; (2) as fissure-filled deposits (known as let-kya-byon) (secondary); (3) as cavern – and sinkhole – filled deposits (known as lu) (secondary). Important factors favouring and controlling the primary formation of ruby and sapphire may be grouped under two headings, namely , lithologic factors and high-grade metamorphic conditions (both regional and contact metamorphism were involved).The favourable lithologic factors are (1) presence of aluminous (kaolinitic or bauxitic ?) clay bands in the original carbonate sequence (probably Plateau Limestone), (2) excess alumina from syenitic and related intrusions , and (3) probable nearby source of Ti , Cr, and Fe from syenitic, basic and ultramafic rocks. The controlling high-grade metamorphic conditions are (1) general T-P range 500˚ - 600˚ C and 2-5 kb (mainly upper amphibolite facies) in the case of regional metamorphism, and (2) general T-P range 550˚-700˚ C and 1-2 kb (mainly pyroxene hornfels facies) in the case of contact metamorphism.

Figure 17. Crystal forms and Habits of Mogok Rubies and Sapphires

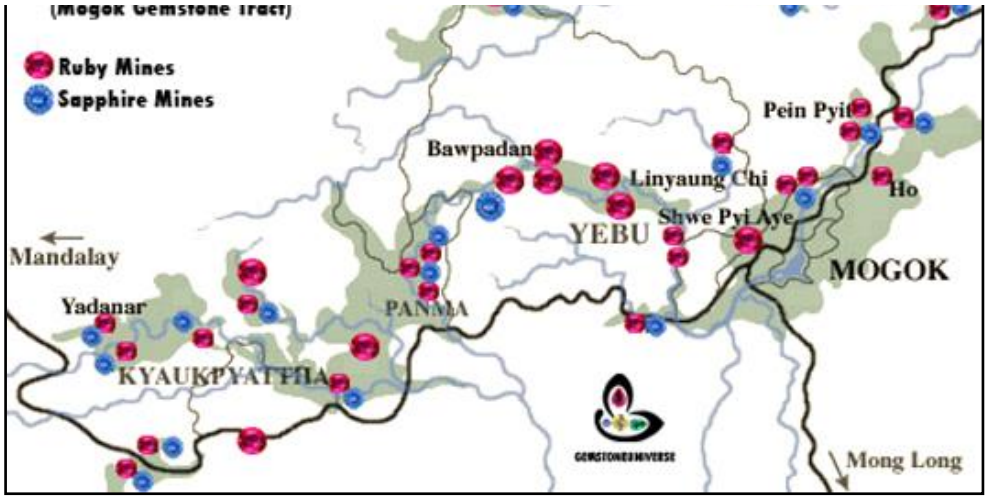

Figure 18. The occurrence of ruby mine and sapphire mine in Mogok area.

X. The Treatment of Mogok Gems

The treatment of Mogok gemstones and minerals are known for many decades. In Mogok, dyeing and heating are the most commonly applied treatments. Chemical and oiling is considered by most gem traders part of gem's fashioning, not a treatment. Rubies are often heat treated to improve colour as well as burn out certain inclusions. It is common industry practice to heat treat Rubies, and untreated Rubies with excellent natural can be exceptionally valuable. The center of Ruby gemstone trade is in Bangkok and Thailand.

Summary and Conclusion

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The study area is situated about 200 km N of Mandalay and 148 km NE of Shwebo, Pyin Oo Lwin District in the Mandalay Region. The general area of Mogok is rugged and mountainous region with steep slopes characterized by basins and Karst topography. Mogok's geological evolution is attributed to six significant events occurred during a period of over 200 million years. Metamorphism played an important role in the evolution of the rock sequences in Mogok, particularly important in the formation of the great variety of gemstones found in the region. At Mogok, metamorphism occurred in (a) extensive (regional metamorphism) and (b) local scale (contact metamorphism). Geologically, the Mogok gems mining area is situated within the Mogok Metamorphic Belt (MMB). Mogok gems are classified into 1. gems of metamorphic origin, 2. gems of igneous origin and 3. gems of skarn-contat zone. Important factors favouring and controlling the primary formation of ruby and sapphire may be lithologic factors and high-grade metamorphic conditions (both regional and contact metamorphism were involved).The favourable lithologic factors are (1) presence of aluminous (kaolinitic or bauxitic ?) clay bands in the original carbonate sequence (probably Plateau Limestone), (2) excess alumina from syenitic and related intrusions , and (3) probable nearby source of Ti , Cr, and Fe from syenitic, basic and ultramafic rocks. In Mogok, gems are recovered in all seasons of the year, utilizing different mining methods depending on the type of deposit, topography, climatic conditions, logistic support, cost of mining and other considerations. The gems mines are 1.Bernardmyo, 2.Chaung-gyi, 3.Pein-pyit, 4. Mogok Valley, 5. Marble Ark, 6. Kathe (South), 7. Kyatpyin (Central), 8. Kyatpyin (North), 9. Kyauk- pyat-that, 10. Kin, and 11.On-dan. More than 60 gemstone varieties have been found in Mogok. The Mogok gems are noted as the world’s finest “Pigeon’s blood rubies" and the world’s most beautiful “royal blue" sapphire. These gems are used in all forms of jewelry, including bracelets, necklaces, rings and earings.

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