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GEMOLOGICAL ANALYSIS OF SOME RARE GEMSTONES FROM MOGOK AREA, MANDALAY REGION

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Abstract. *Mogok has long been noted as a supplier of various gemstones over the past decades. The principal gemstones are ruby, sapphire and spinel. Nowadays, fabulous rare gemstones from Mogok are being sold in foreign markets. This area is mainly composed of igneous and metamorphic rocks. Exceptionally rare gemstones are also discovered and they are johachidolite, poudretteite, thorite, etc. The fantastic occurrences of rare gemstones provoke attraction and well attention to mineralogists and gemmologists. Most of the rare gemstones in the present research work are studied from gems dealers from Mogok. Other rare samples are recorded and studied in the favor of the gems collectors. The data on primary occurrence of these rare gemstones are still uncertain and further investigation should be required. In the Mogok area, these rare minerals are recovered from alluvial, eluvial, residual deposits along the riverside, hill slope, flat plains and low-lying area. Economically, rare gemstones are highly important for both local and foreign gem markets. Some gemstones are important economically as well as technologically for its composition, such as thorite and beryl, which are used in space and aeronautical purposes. Most of the rare gemstones are valuable for its rarity and collected as museum pieces and collector's stones. Thus, they are invaluable.*
Keywords: Mogok, Rare gemstones, Residual deposits, Flat plains, Rarity

1. **Introduction.** In worldwide today, there are about 200 varieties of natural gemstone including the world's precious gems such as diamond, ruby, sapphire, and emerald. Among them, Asian countries produce many of the best quality gemstones in the world. In particular, Myanmar (Burma) offers the highest quality, most desirable Ruby stones and sapphires from Mogok in Mandalay region. Admirably, this Mogok area is called "The Valley of Rubies" due to its glittering treasures of exceptional purity and hue, such as the famed "pigeon's blood" deep bluish-red rubies. Moreover, Myanmar has the reserve of high quality Jade stones. In addition, Myanmar produces some rare stones such as Chrysoberyl, Spinel, Iolite, Sapphire, Peridot, Zircon, Topaz and Amethyst. It is worthwhile, to mention about one of the rarest gemstones found in Mogok area named Myanmar mineralogist U Kyaw Thu, "Kyawthuite" as seen in Figure 1. According to the mineralogists, it is the first in the world. It is not found in other countries. Therefore, our survey team headed to the area, which is located at about (545) miles north from Yangon. It is situated in Mogok Township, Mandalay Region, and Central Myanmar.

Automobiles from the Yangon through Mandalay can access the study area. The road between Mandalay and Mogok-Kyatpyin is rough and twisted. The topographic features in the study area occur in the rugged and hard accessible territories of the hilly regions.

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Figure 1. Kyawthuite was found in Mogok, Mandalay region. Photo: Supplied

These hilly regions are covered with dense vegetation and bamboo forest. This area is mainly composed of igneous and metamorphic rocks namely Kabaing granite, leucogranite, syenite, marble and gneiss.

The research works presented in this paper is based on our field studies carried out by a geological academic team composed of university students and teachers from the Department of Geology in the university. The significant aspect of this research is by not only academic point of views but also the young student point of views. On the other hand, the findings are more accurate than some previous works in the literature. In the following we briefly describe some related works and our works.

2. **Some Related Works.** There has been a tremendous amount of research works concerning with gemstones attempting to understand how they have formed [1]. Among them, the pioneer work of the eminent Swiss gemologist Dr. Edward J. Gübelin had made the first systematic classification of inclusions in natural gem minerals, and his research demonstrated the importance of these internal features in determining a gem's identity as well as its country of origin [2]. In addition, the research work in [3-5] presents a complete gemological description of a rare gemstone from the Mogok Valley and furthers the characterization of this mineral by advanced spectroscopic and chemical analytical techniques. Moreover, several researchers work on inclusions in Burmese gemstones [6-10] and some are working on Burmese gemstones in general [11-14]. In particular, the specific features of gemological points of view are also focused by the researchers [15-17].

In this paper, we present our research works based on the field studies in the Mogok gem tracks. The purpose of the study is to analyze some rare gemstones from gemology perspectives. Detailed gemological observations were done in the field lasted about two weeks. In the field periods, detailed investigations were done to cover up available data on some rare gemstones. Some rare samples were collected whereas other rarer samples were studied and recorded systematically by the collectors.

3. **Materials and Methods.** The overview of the gemological analysis of some rare gemstones is described in Figure 2. The system consists of three phases. In Phase I, the study team collected prospective gemstones and the detailed gemological preliminary observations are performed. Then the potential sample stones are brought for further analysis in the university laboratory to be carried out as Phase II in which research processes are performed, for example, (i) some diagnostic inclusions were photographed under the stereo zoom gemmolite, (ii) perform the process of the values of SG of the rare gemstones by using hydrostatic weighing method, (iii) search RI, DR and optical characteristics of the rare gemstones by using refractometer, (iv) observe fluorescence of certain rare gemstones which were carried out under both LWUV and SWUV, and (v) make spectral analysis which was conducted by diffraction grating spectroscope. In Phase III, the research findings are summarized and statistical analysis is performed.

4. **Gemology Experimental Results for Some Rare Gemstones.** In this section, we present the gemological aspects of experiments carried out on some rare gemstones samples collected from Mogok region. The research findings describe the key characteristics of rare gemstones so that it will be very beneficial to identify some new ones. We

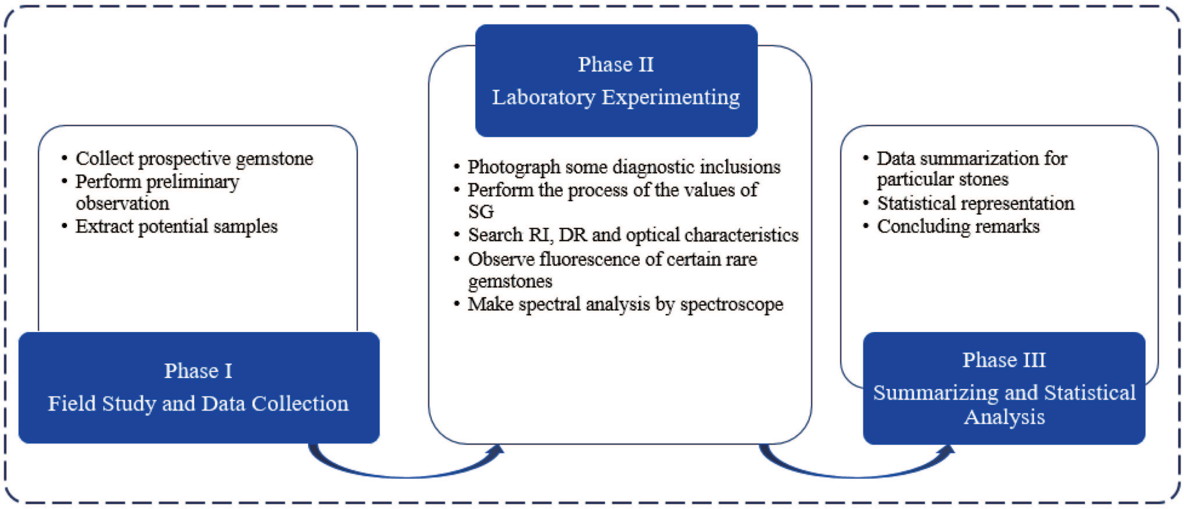


FIGURE 2. Overview of gemological analysis of some rare gemstone

have investigated six rare gemstones namely: Chrysoberyl, Hambergite, Herderite, Painite, Poudretteite and Thorite. The detailed specifications for each stone are described in respective figures. Among them, only rare stone Chrysoberyl has the characteristic of Twinning and the characteristics of Streak belong to two gemstones Chrysoberyl, and Thorite. The remaining characteristics are common in all investigated samples with different contents.

Principal Component Analysis. We obverse that in all sample gemstones there are four characteristics, which are measured in numerical values. They are SG, Hardness, RI and DR properties. In this aspect, it is worthwhile to make the statistical analysis to explain these variables in terms of a smaller number of variables, called principal components, with a minimum loss of information.

Principal component analysis is a statistical technique that is used to analyze the interrelationships among a large number of variables by using only small number of variables. From this analysis, which characteristic is the most important and which is least important so that not all characteristics are necessary to make laboratory testing. In order to do, we first collect the numerical measures of the four characteristics for all six sample rare gemstones. Table 1 shows the measures for six sample stones.

TABLE 1. Numerical measures for characteristics

Gem.	SG	Hardness	RI	DR
Chrys.	3.7	8.5	1.7445	0.009
Hamb.	2.35	7.5	1.593	0.072
Herde.	3	5	1.609	0.03
Paint.	4	8	1.8015	0.029
Poudr.	2.527	5.625	1.5215	0.021
Thorite	4.6	4.75	1.7	0.04

Correlation Matrix =

	SG	Hardness	RI	DR
SG	1	-0.03776	0.798669	-0.31939
Hardness	-0.03776	1	0.515841	-0.07089
RI	0.798669	0.515841	1	-0.27625
DR	-0.31939	-0.07089	-0.27625	1

We then compute the correlation matrix among the four characteristics. In practice, we usually compute to standardize the sample scores. This will make the weights of the four criteria equal. This is equivalent to using the correlation matrix.

Let $C = [c_{ij}]$, where c_{ij} is the correlation between the characteristic i and characteristic j.

Note that all the values on the main diagonal are 1, as we would expect since the variances have been standardized. We next calculate the eigenvalues for the correlation matrix using basic linear algebra equations. The corresponding Eigen values and Eigen vectors are shown in Table 2. We then rearrange the Eigen values in descending order and calculate the amount of variances per value. The results are shown in Table 3.

Table 2. Eigen values and Eigen vectors

	$\lambda 4$	$\lambda 3$	$\lambda 2$	$\lambda 1$
E-value	0.031077	0.799513	1.077403	2.092007
	↓	↓	↓	↓
E-vector	21.57159	0.449823	−1.10047	−1.61837
	14.27415	−0.26754	2.2997	−0.88509
	−25.0954	0.274335	0.401961	−1.85472
	1	1	1	1

Table 3. Variance accounted for by each Eigen value

E-values	%	Cumulative
2.092	52.3	52.3
1.0774	26.935	79.235
0.7995	19.9875	99.2225
0.0311	0.7775	100
4	100	

The values in column E-value are simply the eigenvalues listed in the first row of Table 2, with last row producing the value 4 as expected. Each row in column (%) contains the percentage of the variance accounted for by the corresponding eigenvalue. Therefore, we see that 52.3% of the total variance is accounted for by the largest eigenvalue. The last column simply contains the cumulative frequencies, and so we see that the first two eigenvalues account for 79.235% of the variance. We decide the two largest eigenvalues can explain well and more significant characteristics. Using Excel's charting capability, we can plot the values in column % of Table 3 to obtain a graphical representation, called a scree plot as shown in Figure 3.

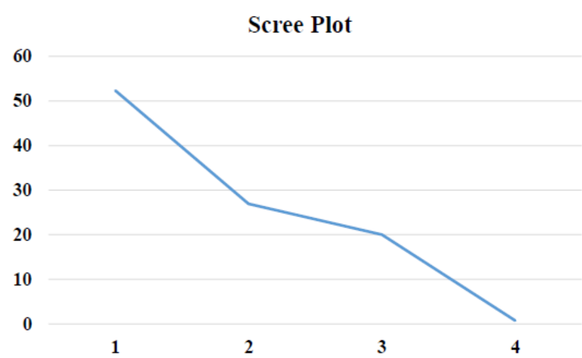
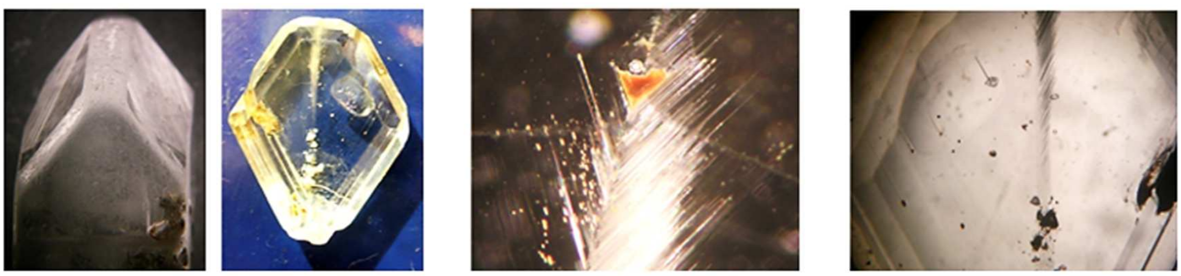


Figure 3. Scree plot

In particular, we have investigated six rare gemstones namely: Chrysoberyl (Figure 4), Hambergite (Figure 5), Herderite (Figure 6), Painite (Figure 7), Poudretteite (Figure 8), and Thorite (Figure 9). The detailed specifications for each stone are described in respective figures.

Chrysoberyl

- Chemical composition - $BeAl_2O_4$ (Beryllium aluminium oxide)
- Crystal system - Orthorhombic system
- Habit - Generally tabular, pseudo hexagonal
- Twinning - Common, often repeated, to give pseudo-hexagonal crystals
- SG - 3.7
- Hardness - 8.5
- Cleavage - Prismatic, poor
- Fracture - Uneven to conchoidal
- Colour and transparency - Various shades of green and yellow: transparent to translucent: used as a gemstone when transparent; the variety alexandrite is emerald green but red by artificial light.
- Streak - White
- Luster - Vitreous
- RI and DR - 1.740-1.749 and 0.009
- Optical character - Biaxial (+) ve
- Distinguishing features - Colour and hardness; crystals tabular, in contract to the prismatic habit of beryl. May be confused with olivine.
- Occurrence - Occur in granitic rocks and pegmatities, also in mica schists. It is frequently found in alluvial sands and gravels.
- Inclusions - Stepped twin planes inclusions and two-phase inclusions with opaque triangular mineral
- Locality - Kyauksin, Ohn Bin villages
- Name derivation - Taken from the Greek and alludes to the golden yellow colour. Alexandrite was named for Tsar Alexander II of Russia.



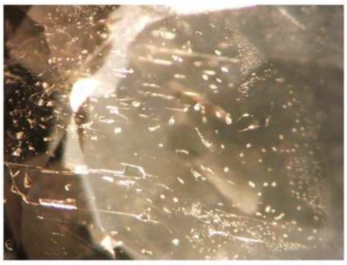
(a) Chrysoberyl crystals (b) Stepped twin planes inclusions (40X) (c) Two-phase inclusions with opaque triangular mineral (75X)

Figure 4. Chrysoberyl

Hambergite

- Chemical composition - Be_2BO_3 (OH, F) (Beryllium borate)
- Crystal system - Orthorhombic system
- Habit - Prismatic and flattenedSG-2.35
- Hardness - 7.5
- Cleavage - One perfect cleavage
- Colour and transparency - Colourless, white, grayish white: transparent to translucent
- Luster - Vitreous to dull
- RI and DR - 1.557-1.629 and 0.072
- Optical character - Biaxial (+) ve
- Distinguishing features - Low SG and high DR
- Occurrence - Occur in syenite pegmatites and alkali pegmatites
- Inclusions - Liquid feather inclusions and tube-like inclusions
- Locality - Khatchae village
- Name derivation - Derived from Axel Hamberg, Swedish mineralogist

(a) Hambergite crystal



(b) Loquid feather inclusions (40X)

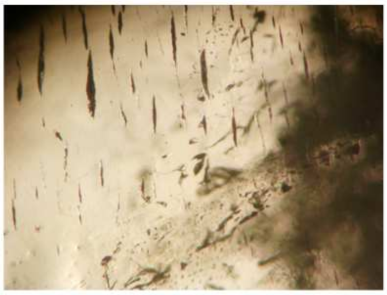
(c) Tube-like inclusions (40X)

FIGURE 5. Hambergite

Herderite

- Chemical composition - CaBe (PO_4) (OH, F) (Calcium beryllium fluo-phosphate)
- Crystal system - Monoclinic system
- Habit - Prismatic and tabular
- SG - 3.0
- Hardness - 5
- Cleavage - Interrupted prismatic, brittle
- Colour and transparency - Pale green: transparent to translucent
- Luster - Greasy to glassy
- RI and DR - 1.594-1.624 and 0.030
- Optical character - Biaxial (-) ve
- Distinguishing features - The crystals are too soft for wear, slightly etched and, if large enough, have a distinctive and recognizable rounded, greasy look.
- Occurrence - Occur in granite pegmatites
- Inclusions - Brown flakes inclusions and two-phase inclusions
- Locality - Sakangyi village
- Name derivation - Derived from Saw Von Herder, a mining official in Freiburg Germany


(a) Herderite crystal


(b) Brown flakes inclusions (40X)

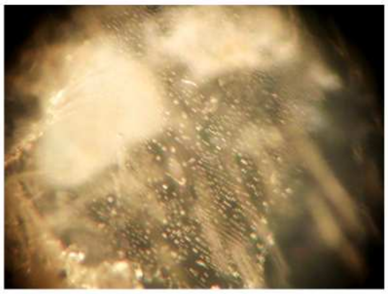

(c) Two-phase inclusions (30X)

Figure 6. Herderite

Painite

- Chemical composition - $Ca_4Al_{20}BSiO_{38}$ (Calcium aluminium boron silicate)
- Crystal system - Hexagonal system (Pseudo-orthorhombic)
- Habit - Crystals usually prismatic and pseudo-orthorhombic
- SG - 4
- Hardness - 8
- Cleavage - Not determined
- Colour and transparency - Dark red (garnet like in hue): translucent to opaque
- Luster - Vitreous
- RI and DR - 1.787-1.816 and 0.029
- Optical character - Uniaxial (-) ve
- Distinguishing features - Faint Chromium spectrum
- Occurrence - Occur in 1951 and identified in 1957 as a new mineral at Mogok Stone Tract. Also recently found in Wetlu area in Mogok Township.
- Inclusions - Straight colour zoning
- Locality - Thurein Taung, Wetlu, Bawlongyi and Ohn Gaing villages
- Name derivation - Derived from A. C. D Pain, the discoverer


(a) Painite crystal


(b) Straight colour zoning (30X)

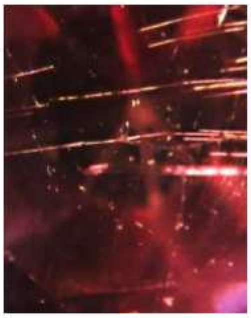
Figure 7. Painite

5. **Conclusions.** Based on the data presented in this paper, we feel that such inclusion studies can help distinguish Mogok gemstones from those of other sources worldwide and therefore contribute to the origin determination of ruby in gemological laboratories. We expect that further studies of gemstones characteristics in the future will add to this knowledge. Moreover, most of the rare gemstones in the present research work are studied from gems dealers of Mogok. Other rare samples are recorded and studied in the favor of the gems collectors. Rare gemstones are highly important for both local and foreign gem

Poudretteite

- Chemical composition - $KNa_2Be_3Si_{12}O_{30}$ (Silicate of potassium, sodium and beryllium)
- Crystal system - Hexagonal system
- Habit - Bipyramidal habit
- SG - 2.527
- Hardness - Not tested
- Cleavage - -
- Colour and transparency - Colourless, purplish-pink; transparent, translucent to nearly opaque
- Luster - Vitreous
- RI and DR - 1.511-1.532 and 0.021
- Optical character - Uniaxial (+) ve
- Distinguishing features - A/S (a faint broad band at 530 nm)
- Occurrence - Occur in marble xenoliths within a nepheline syenite
- Inclusions - Hollow tube-like inclusions
- Locality - Painpyit village
- Name derivation - Come from the Poudrette family (1987) who owned and operated the quarry (Rouville County, Quebec, Canada) that produced the crystals

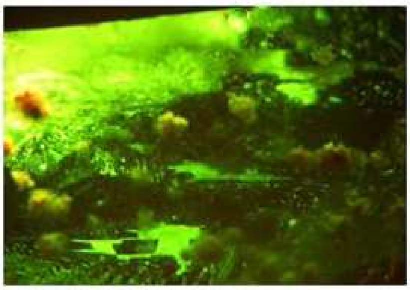
(a) Poudretteite crystal



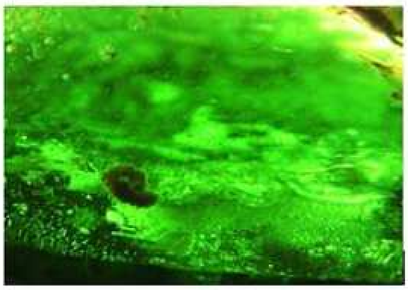
(b) Hollow tube-like inclusions (30X)

Figure 8. Poudretteite

(a) Thorite crystal



(b) Oxidized grains and some solid crystals (40X)



(c) Oily colour distribution (40X)

Figure 9. Thorite

Thorite

- Chemical composition - $ThSiO_4$ (Thorium silicate)
- Crystal system - Tetragonal system
- Habit - Prismatic and dipyramidal habit
- SG - 4.4-4.8
- Hardness - 4.5-5
- Cleavage - Indistinct
- Colour and transparency - Greenish-yellow, brownish green: transparent to translucent, occasionally nearly opaque
- Streak - Brown, orange-yellow
- Luster - Vitreous
- RI and DR - 1.68 - 1.72 and 0.04
- Optical character - Uniaxial (+) ve
- Distinguishing features - Highly radioactive, sometimes admixed with uranium; soluble in hydrochloric acid
- Occurrence - As large crystals in the syenite-pegmatites
- Inclusions - Oxidized grains and some solid crystals and oily colour distribution
- Locality - Ohn Gaing, Le U villages
- Name derivation - Derived from thorium element

markets. Generally, the rare gemstones are valuable for its rarity and collected as museum pieces and collector's stones. Actually, this research work is not the end of the story of the rare gemstones of Mogok Gemstone Tract. Some more concealed rare gemstones must be definitely discovered in the near future by gems collectors and gemologists. Thus, Mogok (Ruby Land) will always attract gemologists, mineralogists, geologists, gems dealers and gems collectors.

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REFERENCES

[1] E. J. Gübelin, The ruby mines in Mogok in Burma, *Journal of Gemmology*, vol.9, no.12, pp.411-426, 1965.
[2] R. E. Kane, E. W. Boehm, S. D. Overlin, D. M. Dirlam, J. I. Koivula and C. P. Smith, A gemological pioneer: Dr. Edward J. Gübelin, *Gems & Gemology*, vol.41, no.4, pp.298-327, 2005.
[3] C. Smith, G. Bosshart, S. Graeser, H. Hänni, D. Günther, K. Hametner and E. Gübelin, A rare gem species from the Mogok valley, *Gems & Gemology*, no.39, pp.24-31, 2003.
[4] A. Cooper and Z. Sun, Lab notes: Spinel inclusion in spinel, *Gems & Gemology*, vol.50, no.4, pp.293-301, 2014.
[5] E. B. Hughes, Beyond octahedra: Inclusions in spinel, *Journal of the Gemmological Association of Hong Kong*, vol.38, pp.41-44, 2017.
[6] K. Thu and K. Zaw, Gem deposits of Myanmar, in *Myanmar: Geology, Resources and Tectonics*, A. J. Barber, K. Zaw and M. J. Crow (eds.), London, UK, Geological Society London Memoirs, https://doi.org/10.1144/M48.23, 2017.
[7] M. Thein, Modes of occurrence and origin of precious gemstone deposits of the Mogok stone tract, *Journal of the Myanmar Geosciences Society*, vol.1, no.1, pp.75-84, 2008.
[8] T. Themelis, *Gems & Mines of Mogok*, Self-published, 2008.
[9] V. Pardieu, S. Sangsawong, W. Vertriest and Raynaud, Gem news international: "Star of David" spinel twin crystal with multiphase inclusions from Mogok, *Gems & Gemology*, vol.52, no.1, pp.100-101, 2016.

[10] A. Peretti, J. Mullis, L. Franz and D. Günther, Spinel formation by sulphur-rich saline brines from Mansin (Mogok area, Myanmar), *The 15th Swiss Geoscience Meeting*, Davos, Switzerland, pp.149-150, 2017.

[11] W. Vertriest and V. Reynaud, G&G Micro-World: Complex yellow fluid inclusions in red Burmese spinel, *Gems & Gemology*, vol.53, no.4, p.468, 2017.

[12] V. Pardieu, Hunting for "Jedi" spinels in Mogok, *Gems & Gemology*, vol.50, no.1, pp.46-57, 2014.

[13] A. S. Sofianides and G. E. Harlow, *Gems & Crystal: From the American Museum of Natural History (Rocks, Minerals and Gemstones)*, 1991.

[14] B. Krause, *Mineral Collector's Handbook*, GIA, 1996.

[15] *Diploma Course in Gemmology*, Text Book from GAGTL, London.

[16] H. L. Aung, *Systematic Gemmological Study of Rare Stones of the Mogok Area, Mandalay Division*, M.Sc Thesis, Dept. of Geology, Yangon University, 2005.

[17] H. L. Aung, *Mineralogy and Chemical Composition of Some Rare Stones from the Mogok Gemstones Tract, Northern Myanmar*, M.Res Thesis, Dept. of Geology, Yangon University, 2006.