Burmese Sapphire from Mogok: its Inclusions and Country of Origin Determination

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Extended abstract

Introduction

Among sapphires from different localities in the world, Burmese sapphire is renowned for its exceptional and unbeatable royal blue color. For centuries, in addition to the world-best-quality ruby and spinel, blue sapphire and some fancy sapphires have also been mined in Mogok, Myanmar.

Burmese sapphires from different localities along Mogok Stone Tract display not only a very attractively intense, slightly violetish blue hue, but they also inherit some unique inclusions that could be used as an important criterion for designating the country of origin of the stones. It is therefore the purpose of this article to communicate and emphasize the importance of this aspect.

Geology of Mogok in brief

Mogok gem deposits are located 200 kilometers from north east of Mandalay city in the Mandalay province. Geologically, the Mogok Stone Tract lies in what geologists described as the Mogok metamorphic belt which covers an area of more than 1450 km long and 40 km-wide as shown on the geologic map of Mogok (Figure 1).

Figure 1: Geologic map of Mogok area (modified after Themelis, 2008)
A brief description of the geology of Mogok is summarized as follows. The belt comprises a variety of andalusite and sillimanite-bearing metamorphic rocks, pre-collisional granites and granodiorites, and post-collision garnet-tourmaline-bearing leucogranites (Searle et al., 2007). Via phlogopite inclusions, the Mogok marble emplacement has been dated at approximately 18.7 million years (Garnier et al., 2006). In the Mogok area there are also intercalating schist beds and quartz veins cutting across the marble units. Another important rock type is the so-called Mogok gneiss, which is composed mainly of sillimanite-garnet gneiss intercalated with patches of calc-silicate rock. Ultramafic rocks also found in Mogok include dunite and harzburgite, both featuring chromite. Pegmatite veins and graphic granite dykes cut into these ultramafic rocks (Mitchell et al., 2007). Intrusive igneous rocks in Mogok are predominantly nepheline syenite.

It is interesting to note that the geology of the Mogok area is extremely complex, with formation processes including metamorphism, igneous intrusion and skarn reactions. Such processes have produced ruby-bearing marbles, sapphire-bearing pegmatites, nepheline syenites, and a host of other rocks.

**Blue sapphire deposits in Mogok**

Many deposits of blue sapphire have been reportedly mined in Mogok area. Burmese sapphire roughs have been un-earth from the ground in both primary and secondary (alluvial) deposits (Figures 2 and 3). Some localities host only sapphire while other sites host both ruby and sapphire such as at the Baw Mar mine (pers. comm. with Mr. Tint Lwin, the mine owner).

![Figure 2: Ruby and sapphire mining in a primary deposit in Mogok area](image1)

![Figure 3: Ruby and sapphire mining in a secondary deposit in Mogok area](image2)

Ruby and sapphire in those primary deposits are mainly hosted in white marble intercalated with other meta-sediments of the Mogok metamorphic belt. The formation processes including metamorphism, igneous intrusion (pegmatite, granite, leucogranite, syenite), and skarn. Such processes have produced sapphire-bearing rocks (Figure 4), ruby-bearing marble (Figure 5), including a host of other gemstones.
Those sapphire deposits were formed because of metasomatic processes. Small-scale metasomatism mostly involved desilication reactions between silico-aluminous rocks (pegmatites, gneisses, etc.) and silica-poor rocks (ultramafites, meta-carbonates), that led to the formation of limited-size deposits (Simonet et al., 2008). In fact, the formation of many blue sapphires in Mogok is a result of the desilication process at the contact zone of pegmatite veins and leucogranite dykes (Figures 6 and 7) that cut into these ultramafic and meta-carbonate rocks.

**Material and methods**

Thirty-three samples of blue sapphire (Figure 8) collected from eleven different localities in Mogok Stone Tract were used in this study. Those blue sapphires were mined from both primary and secondary deposits. Those eleven localities from west to east of Mogok are Thit Sien Kone, Kyauk-nyat-atay-nyant, Gwebin, Baw-lon-gyi, Pingu-taung-nyant, Baw mar, Kyauk-sin, Win-hta-yan, Kyauk-poke, Chaung-gyi-ah-le-ywa and Ko-miles-le-taw (Figure 9). The aim of this study is to illustrate the variation of inclusion features in Mogok sapphire that can be used as a clue for origin determination purpose.
**Figure 8:** Cut and rough samples of sapphires from eleven different mines along the Mogok Stone Tract used in this study.

**Figure 9:** Mogok routes illustrating the mine location names from west to east under this investigation (modified after Themelis, 2008)

The external and internal features in those stones were observed under a gemological microscope. All photomicrographs were taken by using a gem microscope with Canon EOS 7D camera attached. In
addition, some inclusions in those samples were also identified by a Ranishaw inVia Raman spectroscopy with a green laser 532 nm excitation at the Gem and Jewelry Institute of Thailand.

**Microscopic feature**

Based on the classic work published in the *Photoatlas of Inclusions in Gemstones* by Prof. Dr. Edward J. Gübelin & John I. Koivula (1997), we have classified inclusions found in sapphires from Mogok into 3 main groups, i.e., protogenetic, syngenetic and epigenetic inclusions. A similar method of study was previously being employed by Atichat and Sriprasert (2014).

**(I) Protogenetic Inclusions** are those formed before the host crystal. Logically, they are mostly solid inclusions that appear rounded or corroded crystals as a result of having been partially dissolved in the environment that produced the host. In our study, the candidates being categorized to this group of inclusions are isolated somewhat corroded solid inclusions of mica (Figure 10a) and colorless crystal (apatite?) (Figure 10b) found in Mogok sapphires.

![Rounded mica crystal](image1.jpg)  
**Figure 10:** Different kinds of protogenetic inclusions in sapphires from different mines in Mogok area.

**(a) Rounded mica crystal (identified by Raman), Win-hta-yan mine (50X)  
(b) Colorless crystal, Win-hta-yan mine (50X)**

**(II) Syngenetic Inclusions** are those formed at the same time as the host crystal. Fundamentally, they could be generally sharp and angular solid crystals that occur in equilibrium (presumably at the same time) with the host crystal. Of course, primary or pseudo-secondary fluid inclusions such as, negative crystal, two phase inclusion, also belong to this group because they are cavities formed during crystal growth that have been filled with liquid, liquid plus gas, or even liquid, gas, and solids. Actually, other syngenetic features are twinning, color zoning and color banding that are certainly forming during crystal growth.

Hence, in our study, the internal features falling into this group include primary fluid inclusion or negative crystal containing CO₂ (Figure 11a), two-phase inclusions of possibly primary or pseudo-secondary origin (Figure 11b), subtle color zoning (Figure 11c), tube along twinning plane (Figure 11d) and polysynthetic twinning (Figure 11e and 11f) in sapphires from Mogok.
(a) Primary fluid inclusion or negative crystal containing CO2 (confirmed by Raman), Win-hta-yan mine (50X)

(b) Two-Phase inclusions, Thit-seint-kone mine (50X)

(c) Subtle color zoning, Chaung-gyi-ah-le-ywa mine (12.5X)

(d) Tube along twinning plane, Baw-lon-gyi mine (12.5X)

(e) Polysynthetic Twinning, Chaung-gyi-ah-le-ywa mine (40X)

(f) Twinning plane, Baw-lon-gyi (32X)

**Figure 11:** The different kinds of syngenetic inclusions in sapphires from various mines in Mogok area

(III) **Epigenetic Inclusions** are those formed after the host crystal. Literally, these may be any features formed by post-crystallization chemical alteration, such as healed fissure or the so-called “fingerprint” including secondary fluid inclusions trapped along such healed fissure and crystallization product from enclosed inclusion liquid, exsolution phase(s) from the host crystal during crystal cooling. Basically, these also include the penetration of material into cracks and fissures and structural damage by radioactive emanations. However, it should be mentioned here that any artifacts or damages caused by artificial enhancement of the stone are excluded from this group as they are not the natural features.

Based on these facts, the features being classified into this group are needles or silk-like inclusions as a result of exsolution (Figure 12a-d), fingerprint inclusions caused by fissure healing (Figure 12e and 12f), fracture-filled iron stain (Figure 12g), clouds of pinpoint inclusions resulting from exsolution (Figure 12h) and highly reflective thin-film inclusions due to the healing of liquid-filled flat fissure (Figure 12i) in sapphires from Mogok.
Figure 12: The different kinds of epigenetic inclusions in sapphires from several mines in Mogok area.

Conclusion

In this investigation, we have described inclusions selected from the sapphire samples collected from various mines in Mogok, namely, Thit Sien Kone, Kyauk-pyat-that-atay-pyant, Gwebin, Baw-lon-gyi, Pingu-taung-pyant, Baw mar, Kyauk-sin, Win-hta-yan, Kyauk-poke, Chaung-gyi-ah-le-ywa and Ko-miles-le-taw, etc. We have also demonstrated that inclusions found in Mogok sapphires do belong to different genetic modes of formation. Protogenetic inclusions are mica, colorless crystal (possibly apatite). For the syngenetic inclusions, they are negative crystal containing CO₂, two-phase inclusions, color banding, growth band and twining. Last stage of formation, the epigenetic inclusions are fingerprints, short intact needles lying in a plane in association with thin-film platelets. Therefore, the inclusion features in this study reveals many similarity from different mines and this could suggest their close genetic geological condition of blue sapphire formation at different localities throughout the Mogok Stone Tract.
In the opinion of the authors, the internal features found in blue sapphires from Mogok draw attention to a somewhat possible way for providing guideline to origin determination. In fact, when chemical fingerprinting could not help discriminate the exact origin of the gemstone, types of inclusions, and its assemblage could be useful as criterion for indication of gem locality. Therefore, the following inclusion features of Mogok's blue sapphire that could be locality-specific are fine silk-like inclusions usually containing short needles and thin-film, cluster of highly reflective thin-film inclusions along a plane, negative crystal containing CO₂, patchy cloud inclusions, folded fingerprint, and subtle color banding and set of parallel flat tubes along twin plane.

References