Rare Fancy Sapphires from Bo Phloi Gem Field, Kanchanaburi, Western Thailand

Thanong Leelawatanasuk, Tasnara Sripoonjan*, Namrawee Susawee, Pornsawat Wathanakul and Visut Pisutha-Arnond

The Gem and Jewelry Institute of Thailand (Public Organization), Bangkok 10500 Thailand; *Email: stasnara@git.or.th

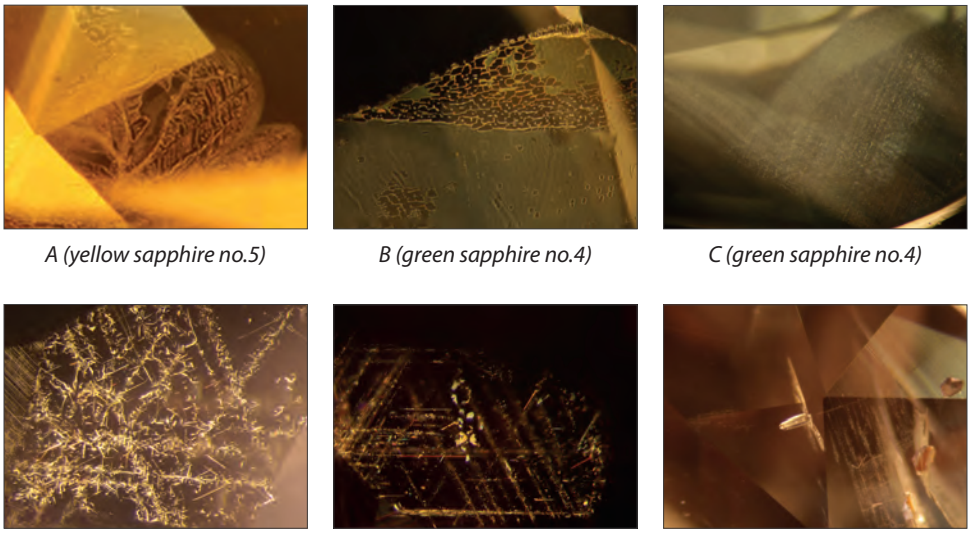
Introduction

Over the past few decades, the Bo Phloi gem field of Kanchanaburi province in the western Thailand was one of the important sources of blue sapphires supplied to the world market. Blue sapphires from Kanchanaburi have long been well known for their deep blue colour and large variations in sizes. Those sapphires occur in subsurface gem-bearing gravel beds of a secondary alluvial deposit. The sapphire gravels were derived from a weathered alkaline basalt nearby. As of the present days, the production has dramatically been decreased due to the depletion of the resources in the areas. In the past decades, however, the very rare and less well-known varieties of fancy sapphires were also collected by a mine owner during the active mining activity. Those materials are pink, violet-purple, yellow, green and parti-colour varieties of sapphires that allowed to be used for this study by the owners. In this study, 10 representative samples (Figure 1) were selected from the owner's collection (totally 15 stones). The stones' gemological properties were collected by basic gem equipment and various advanced instruments, such as UV-Vis-NIR, FTIR, Raman and EDXRF spectroscopy.

Figure 1. Fancy sapphire samples from Bo Phloi gem field, Kanchanaburi, Thailand: (1) violet, 7.65 ct; (2) pale green, 0.78 ct; (3) parti-colour, 2.60 ct; (4) green, 1.39 ct; (5) yellow, 2.72 ct; (6) pale pink, 9.38 ct; (7) pink, 6.35 ct; (8) pink, 1.07 ct; (9) purple, 0.71 ct; (10) pink, 2.99 ct. Photo by T. Sripoonjan.

Gemological Properties

The stones had the RI of 1.760-1.770, SG of 3.92-4.01 and mostly were inert to moderate orangey red under LWUV radiation and mostly inert under SWUV radiation. Microscopic observation revealed that the most common internal features were fingerprint-like inclusions which were sometimes filled with orange-brown iron oxides (Figure 2A, B). Almost all the samples contained cloud-like inclusions as well as brown silks identified by Raman spectroscopy as hematite (Figure 2C, D). Some samples showed iridescent platelets (Figure 2E) and mineral inclusions such as a nepheline also by Raman spectroscopy (Figure 2F).



A (yellow sapphire no.5) *B (green sapphire no.4)* *C (green sapphire no.4)*

D (violet sapphire no.1) *E (purple sapphire no.9)* *F (pink sapphire no.8)*

Figure 2. Microscopic features of inclusions in fancy sapphires from Bo Phloi, Kanchanaburi (see text for further details) Photos by T. Sripoonjan.

Advanced spectroscopy

UV-Vis-NIR spectra (Figure 3) clearly showed different absorption bands diagnostic of colour varieties as well as peaks at 378, 387 and 450 nm due to Fe^{3+} appeared in all varieties. Cr^{3+}- related absorption bands were usually observed in violet-purple and pink varieties, whilst Fe^{2+}/Ti^{4+} IVCT absorption bands were commonly present in blue and green stones (as suggested by Burn, 1993; Fritsch and Mercer, 1993). The spectra in Mid-IR region displayed absorption peaks related to AlOOH (Bowersox et al., 2000) at 3360, 3090, 2622 and 2416 cm^{-1} (see Figure 4). EDXRF analyses (Table 1) gave high iron content in all colour varieties (av. 0.54 wt.% Fe_2O_3). High titanium contents are found in green and parti-colour samples (av. 0.02 wt.% TiO2), whereas high chromium contents appeared in violet, purple and pink varieties (av. 0.03 wt.% Cr_2O_3). Gallium and vanadium contents typically averaged 0.02 wt.% Ga_2O_3 and 0.01 wt.% V_2O_3.

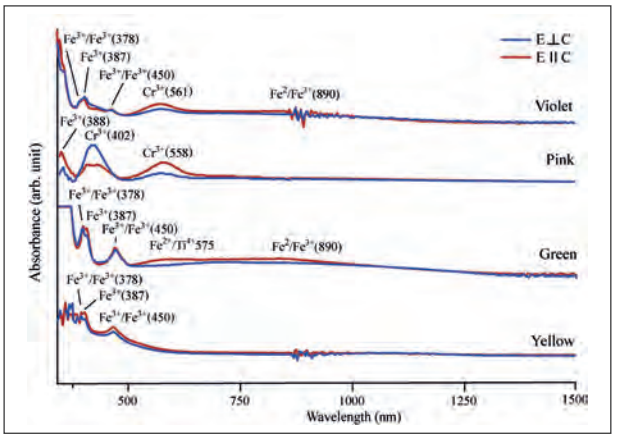


Figure 3. UV-Vis absorption spectra of various coloured sapphires from Bo Phloi gem field.

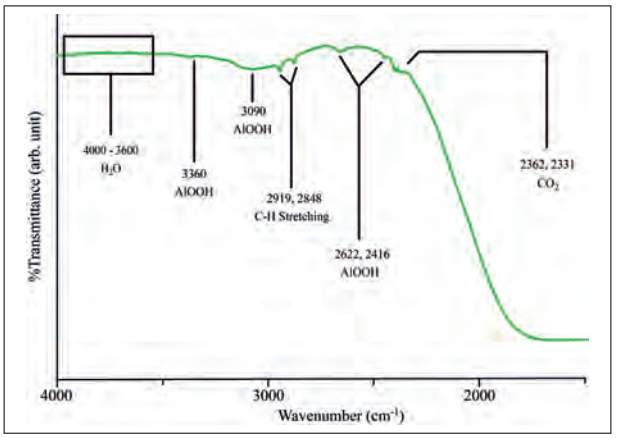


Figure 4. FTIR spectrum of a representative fancy sapphire showing absorption peaks related to AlOOH.

Table 1. EDXRF analyses of fancy sapphires from Bo Phloi, Kanchanaburi (wt.%).

Oxides\Colours	Pink (4)	Yellow (1)	Green (2)	Violet-Purple (2)	Parti (1)
TiO_2	0.007-0.018	0.008	0.018-0.025	0.014-0.023	0.017
V_2O_3	0.004-0.016	0.010	0.003-0.029	0.007-0.013	0.040
Cr_2O_3	0.015-0.033	0.010	0.002-0.006	0.024-0.088	0.089
Fe_2O_3	0.055-0.428	0.093	0.935-0.937	0.358-0.410	0.438
Ga_2O_3	0.013-0.021	0.027	0.026-0.026	0.021-0.025	0.022

Discussion and Conclusion

The colors of fancy sapphires from Bo Phloi, Kanchanaburi are related well to the amounts of their trace element constitutes; (1) the pink hue is caused mainly by the Cr^{3+}-related absorption that correspond well to its high Cr but low Ti contents; (2) the yellow hue is due mainly to Fe^{3+} transitions that correspond well to its high Fe but low Ti and Cr contents (3) the violet-purple hue is caused by the combination of the blue coloration from Fe^{2+}/Ti^{4+} and Fe^{2+}/Fe^{3+} IVCT plus pink from the Cr^{3+}-related absorption that correspond well to its high Cr, Fe and Ti contents; (4) the green hue is caused by the combination of the blue coloration from Fe^{2+}/Ti^{4+} and Fe^{2+}/Fe^{3+} IVCT plus yellow from Fe^{3+} transitions that correspond well to its high Fe and Ti but low Cr contents. Moreover, the high Ga contents (130-252 ppm) of our pink-violet-purple samples are comparable to those (170-310 ppm) of the rare alluvial ruby–sapphire transition megacrysts found in Australia; thus, the chemical data obtained from this study may suggest that the pink-violet-purple sapphires could involve in a magmatic-related metasomatic process as proposed by Sutherland et al. (2017). It is noteworthy that the presence of the nepheline inclusion in the pink sapphire also supports a model that the Bo Phloi fancy sapphires was likely to originate from a syenetic-melt as suggested by Khamloet et al. (2014).

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