‘‘BLUE JADE’’: A Rare Jadeite-Jade

Introduction

Jadeite-jade is one of the most sought-after gemstones that are rich in cultural and historical background. In Chinese culture jade has been considered the stone-of-heaven for centuries. Jadeite is characterized by its transparent to opaque, close-packed fibrous aggregate structure, resulting in its high toughness suitable for carving. The stone can be found in various colors ranging from white, green, lavender (purple or violet), brown, blue and black. Among those, the green and lavender are the most famous hues, while the blue is considered the rarest variety of this jade. There are only a few deposits of gem quality jadeite, such as Myanmar, Japan and Guatemala. Blue jadeites and their characteristics were reported from Quebrada Seca area of Guatemala (Harlow,1994; Hargett, 1990), Ohmi-Kotaki area of Japan (Chihara, 1971) and Sorkhan area of Iran (Oberhänsli *et al.*, 2007; Abduriyim *et al.*, 2017; Hargett, 1990).

Recently, GIT Gem Testing Laboratory (GIT-GTL) received two greenish blue to blue-green stones for testing as shown in figure 1.

Figure 1. Two semi-translucent blue-green stones, 6.24 ct oval cabochon (left) and 18.09 ct Buddhist image (right), were submitted to the GIT-GTL for testing. Photos by C. Kamemakanon and W. Krajaejan

Sample and Methods

The two stones we examined were an oval-shaped cabochon, weighed 6.24 ct and measured 13.24 x 9.95 mm (Figure 1, left), and a Buddhist image, weighed 18.09 ct and measured 32.40 x 19.94 mm (Figure 1, right). Both samples are greenish blue to blue-green and semi-translucent.

Standard gemological instruments were used for obtaining the stone properties. External and internal features were observed with a high magnification gemological microscope, and the photos of all inclusions were taken by using the attached Canon EOS 7D camera. The standard light source of the D50 Daylight (5000° Kelvin) lamp was used for observing the stone colors. Fluorescence effects of the stones were observed using standard ultraviolet lamps, long-wave (365 nm) and short-wave (254 nm). In addition, fluorescence images were taken by using the DiamondView™ instrument.

The Raman spectra were collected with a Renishaw inVia spectrometer using 532 nm laser excitation in the range 200 – 1500 Raman shift (cm^{-1}). The chemical compositions were collected with EDXRF Eagle II. The Mid-Infrared (IR) spectral (6500 - 400 cm^{-1}) features of the stones were collected by a Thermo Nicolet 6700 Fourier-Transform Infrared (FTIR) spectrometer. The Ultraviolet-Visible-Near Infrared (UV-Vis-NIR) spectra were recorded by a PerkinElmer Lambda 1050 spectrophotometer in the range 250 - 1500 nm.

Gemological properties

Both stones, oval cabochon and Buddhist image, showed similar refractive indices (RI) of 1.65-1.66 (spot reading) and specific gravity (SG) values of 3.30 -3.32. that are typical for jadeite.

Microscopic Features

When examined the samples with the gem microscope, the oval cabochon exhibited a coarse fibrous aggregate structure (Figure 2). The Buddha image, by contrast, displayed a somewhat finer fibrous aggregate structure (Figure 3 left) with minor associated white minerals (Figure 3 right). No color concentration was observed along grain boundary and fissures in both samples.

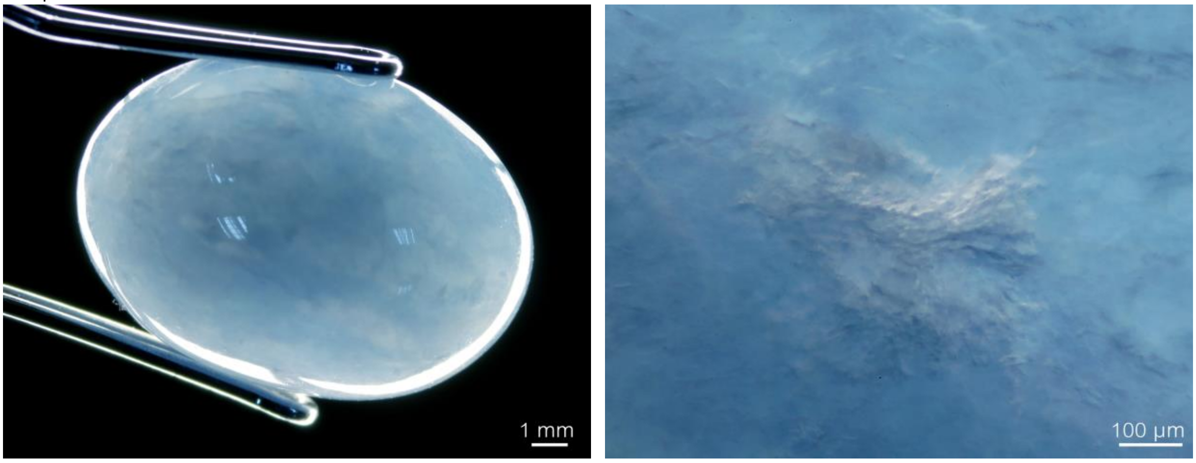

Figure 2. Top view of the cabochon sample showing semi-translucent blue body color (left), and a coarse fibrous aggregate structure (right). Photomicrographs by S. Saengbuangamlam

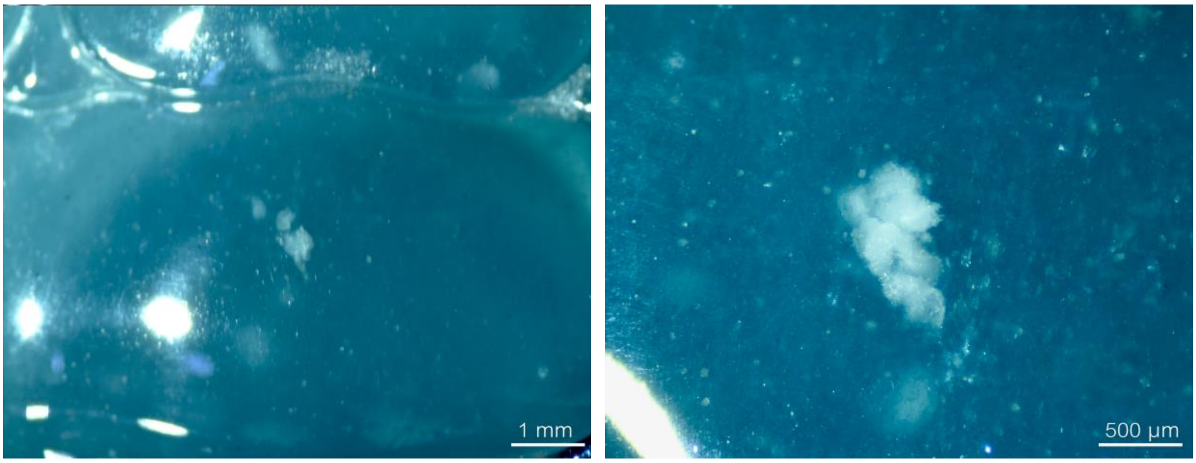

Figure 3. The Buddhist image sample showing a fine fibrous aggregate structure (left) with minor associated white minerals (right). Photomicrographs by S. Promwongnan

The DiamondView™ photos clearly revealed weakly to moderately bluish green fluorescence of the coarse fibrous aggregate grains of the cabochon sample and very weakly green fluorescence of the fine fibrous aggregate grains in the Buddhist image sample (Figure 4). No reddish fluorescence, however, was observed in both samples, probably due to the very low manganese content (see Table 1). Both stones also were inert to standard long- and short-wave UV lights.

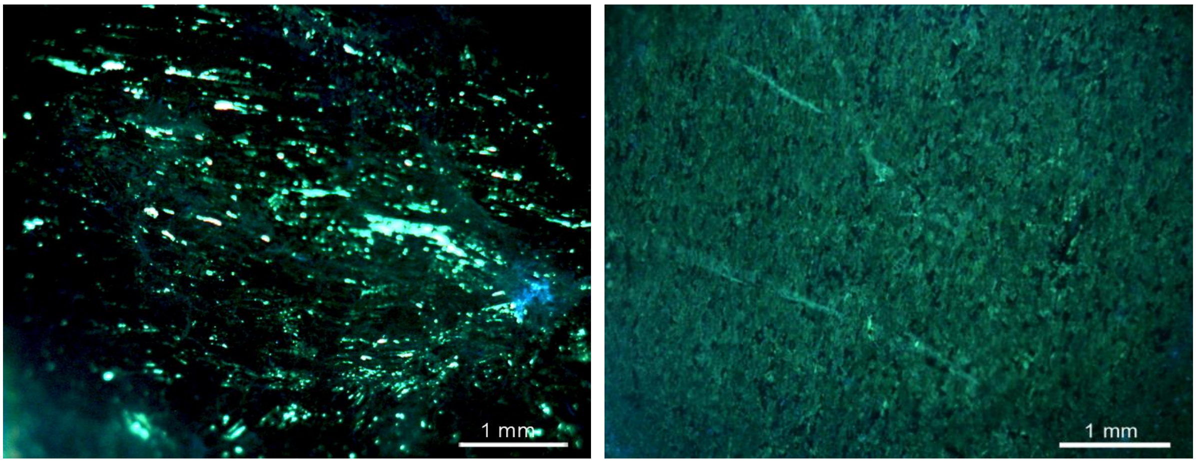

Figure 4. DiamondView™ photos show weakly to moderately bluish green fluorescence of the coarse fibrous aggregate grains in the cabochon sample (left) and very weakly green fluorescence of the fine fibrous aggregate grains in the Buddhist image sample (right). The fluorescent lines in the right photo are the artifact from scratching. Photomicrographs by S. Promwongnan.

Advanced Instrumental Analyses

Raman spectroscopy analysis

The Raman spectra of the blue mineral grains in both samples showed dominant peaks (Raman shifts) at approximately 375, 641, 1040 cm^{-1} and several other smaller peaks that were perfectly matched the jadeite reference spectrum from the RRUFF database (Figure 5).

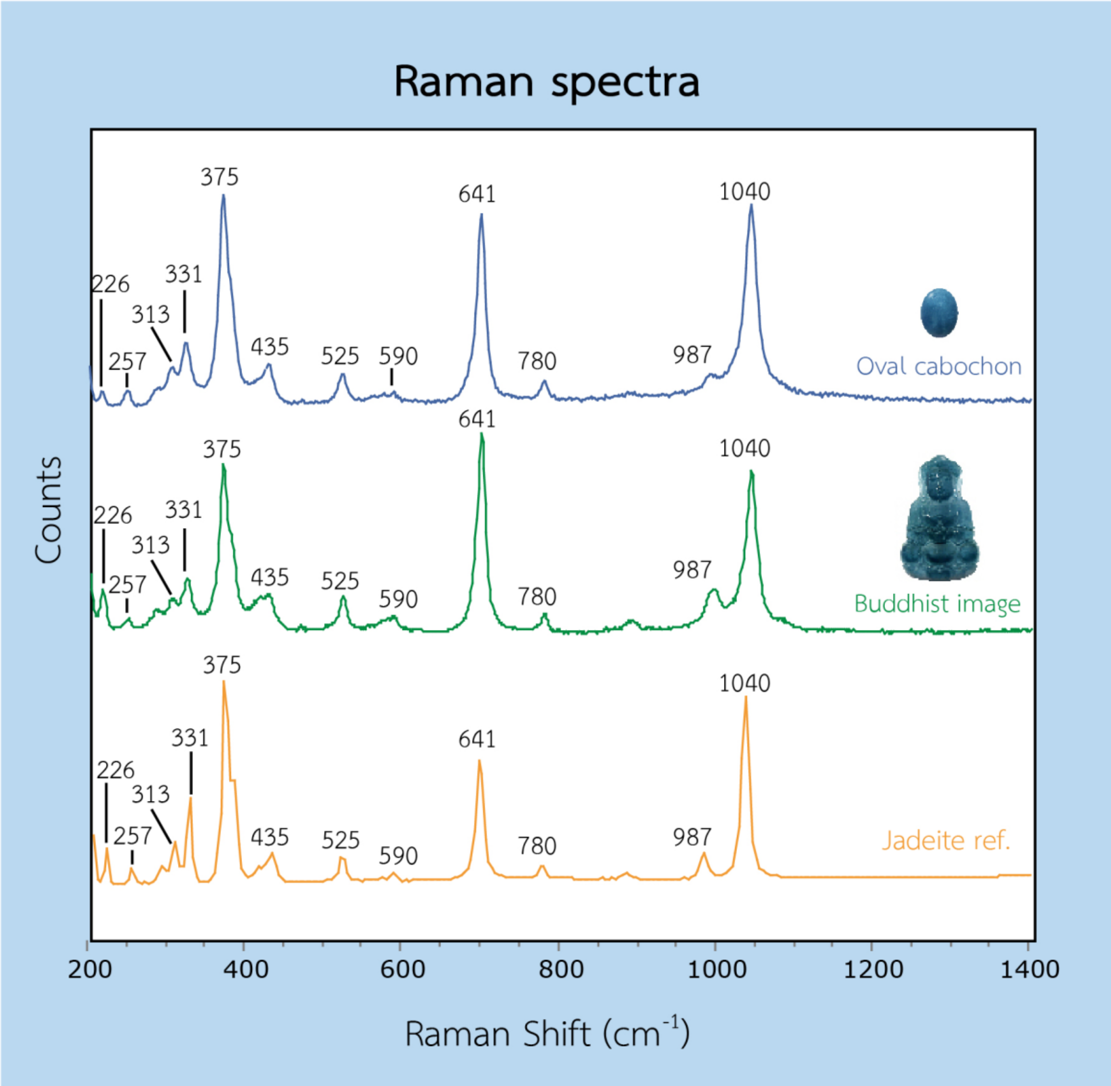

Figure 5. Raman spectra of the cabochon and Buddhist image samples (blue and green lines, respectively) show the Raman shift features that are perfectly matched the jadeite reference spectrum from the RRUFF database (orange line).

Chemical Composition

The semi-qualitative chemical analyses of these two stones by EDXRF revealed the major contents of Si and Al, minor amounts of Na, Ca, Mg and Fe, and traces of Ti, Cr and Mn (Table 1). Overall, these chemical data, which were normalized to 100%, are consistent with the composition of jadeite. Among the important chromophores--- Ti, Cr, Mn and Fe, both samples similarly contain significant amounts of Ti and Fe that are responsible for the blue coloration of the stones (see Figure 7).

Table 1. Chemical contents measured by EDXRF.

Element Oxides (wt.%)	Na_2O	MgO	Al_2O_3	SiO_2	CaO	TiO_2	Cr_2O_3	MnO	Fe_2O_3
Oval cabochon	6.56	1.28	20.94	66.24	3.35	0.36	0.03	ND	1.24
Buddhist image	7.15	2.27	22.36	63.93	3.06	0.22	ND	0.02	0.98

ND = Not Detected

Mid-Infrared Absorption Spectra

The mid-IR spectra clearly indicated no polymer impregnation treatment in these samples. However, weak absorption at 2849 and 2916 cm^{-1} were detected due to the presence of wax in the Buddhist image sample (Figure 6).

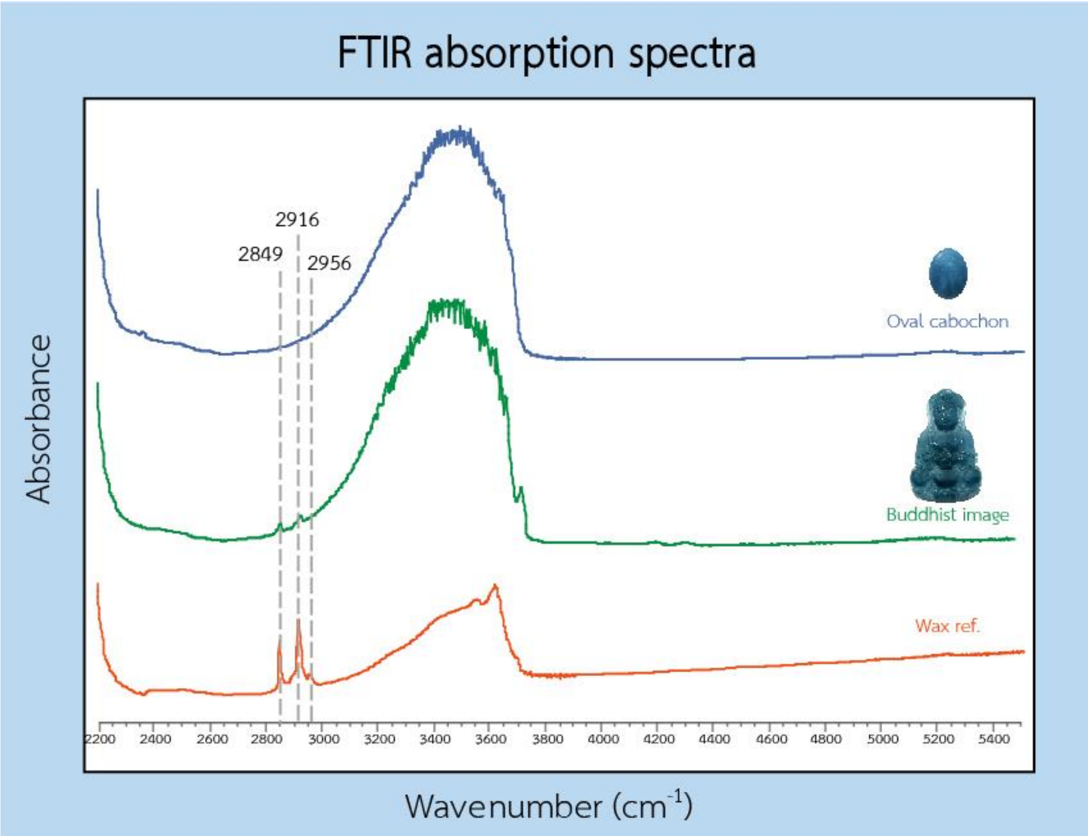

Figure 6. Mid-IR spectra of the cabochon and Buddhist image samples (blue and green lines, respectively) as compared with the wax reference spectrum (red line).

UV-Visible Absorption Spectra

The UV-Vis spectra of both samples (Figure 7) similarly showed the characteristic peak at 437 nm (attributed to Fe^{3+}), a broad band centered around 620 nm (due to the intervalence-charge-transfer—IVCT-- of Ti^{4+}-Fe^{2+} pair) and a small hump around 540 nm (probably related to Mn^{3+}; Abduriyim *et al.*, 2017). These absorption features allow the transmission window in the blue region, thus giving rise to the blue coloration of the stones.

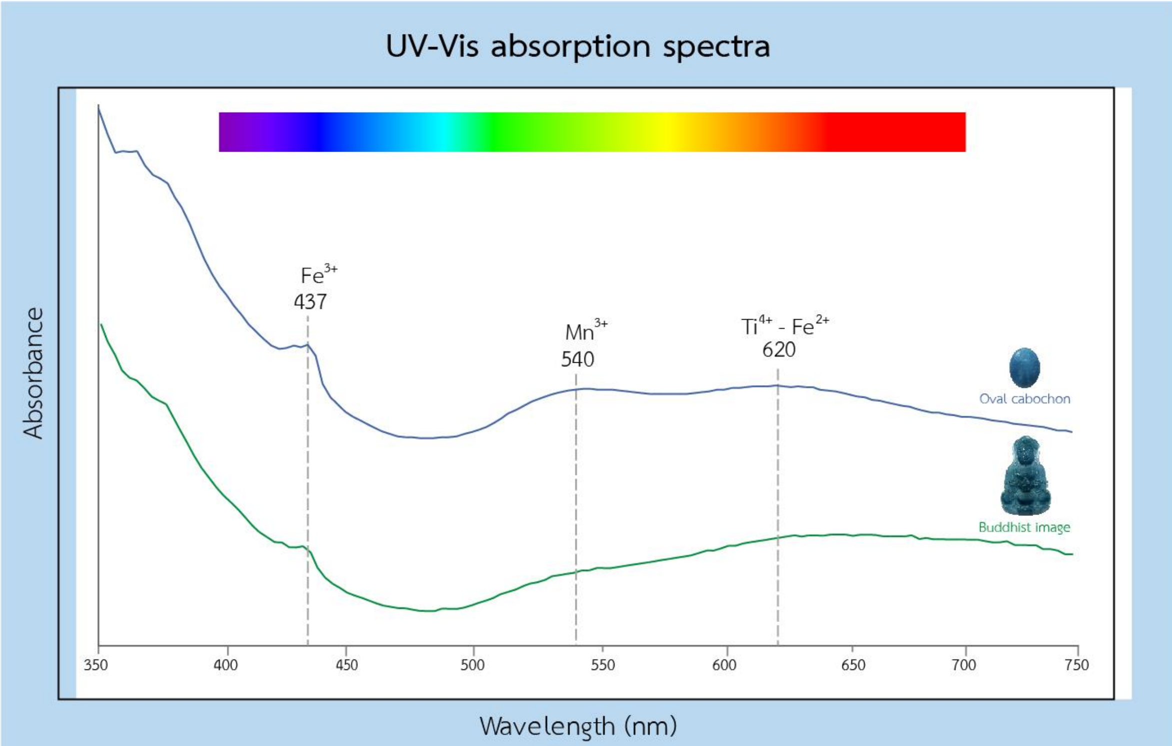

Figure 7. UV-Vis absorption spectra of the two blue stones show an Fe^{3+}-related peak at 437 nm, a Ti^{4+}-Fe^{2+} IVCT broad band around 620 nm and a small Mn^{3+} hump around 540 nm.

Conclusions

Based on the above evidences, i.e., RI--1.65-1.66 (spot reading), SG--3.30-3.32, their specific Raman shifts and the fibrous aggregate features without color concentration, it is obvious that these two stones are the untreated natural blue jadeite-jade, aka A-Jade. The UV-Vis- absorption spectra showed the characteristic peak at 437 nm that was attributed to Fe^{3+}, the broad band centered around 620 nm due to the Ti^{4+}-Fe^{2+} IVCT and the small hump around 540 nm to Mn^{3+} (Abduriyim *et al.*, 2017). These data are consistent with significant contents of Ti and Fe found in both stones by the EDXRF analyses.

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