LAB UPDATE

"GEM-QUALITY GRANDIDIERITE FROM MADAGASCAR"

By GIT-Gem Testing Laboratory

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INTRODUCTION

In September 2016, GIT-GTL received 6 rough bluish green stones claimed to be "Grandidierite" from Madagascar (Figure 1). Unfortunately, the dealer did not have any information about the mining activity and location where the stones were collected. Basically, it is known that grandidierite is one of the rarest minerals of the world (Laurs, 2016). Mineralogically, it is the magnesium end member in the solid-solution series with ominelite as the iron end member (Bruyère *et al*., 2016). Grandidierite occurs in a bluish green to greenish blue mineral in an orthorhombic crystal system with the formula $(Mg,Fe^{2+})Al_3(BO_3)(SiO_4)O_2$. It was named after the French Naturalist and explorer, Alfred Grandidier (1836-1912), an authority on the natural history and geography of Madagascar. It was described in 1902 in Southern Madagascar (Vertriest *et al*., 2015). Even though this mineral has been reportedly found in many countries such as Algeria, Antarctica, Canada, the Czech Republic, India, Italy, Malawi, New Zealand, Norway, Suriname, the United States and other localities, the gem-quality grandidierites larger than a millimeter can only be found in Madagascar and Sri Lanka (Bruyère *et al*., 2016).

What follows is a discussion of method of study, some gemological characteristics and key identifying features of these gem-quality grandidierite samples.

SAMPLES AND METHODS

Those 6 samples are rough materials weighing from 0.41-1.24 cts (Figure1). In this study, standard gemological equipment were used for recording basic gemological properties, such as Refractive Indices (RI), Specific Gravity (SG), Pleochroic colors. The external and internal features were observed under a gemological microscope. All photomicrographs were taken by using a gem microscope with Canon EOS 7D camera attached. Fluorescence reaction was observed by using a gemological ultraviolet lamp in both long-wave (365 nm) and short-wave (254 nm) ultraviolet light. For the spectroscopic analyses, we used a Thermo Nicolet 6700 Fourier-transform infrared (FTIR) spectrometer to record IR absorption spectra in the Mid-IR

range (4,000-400 cm^{-1}) with a resolution of 4.0 cm^{-1} and 128 scans. The UV-Vis-NIR absorption spectra of samples were taken with PerkinElmer Lambda 950 spectrophotometer in the range 300-800 nm with the sampling interval of 3.0 nm and scan speed of 441 nm per minute. A Ranishaw inVia Raman spectroscopy with a green laser 532 nm excitation was also used to verify those samples and record photoluminescence (PL) spectrum. The chemical analysis was carried out by an Energy-dispersive X-ray Fluorescence (EDXRF) spectroscopy of Eagle III system.

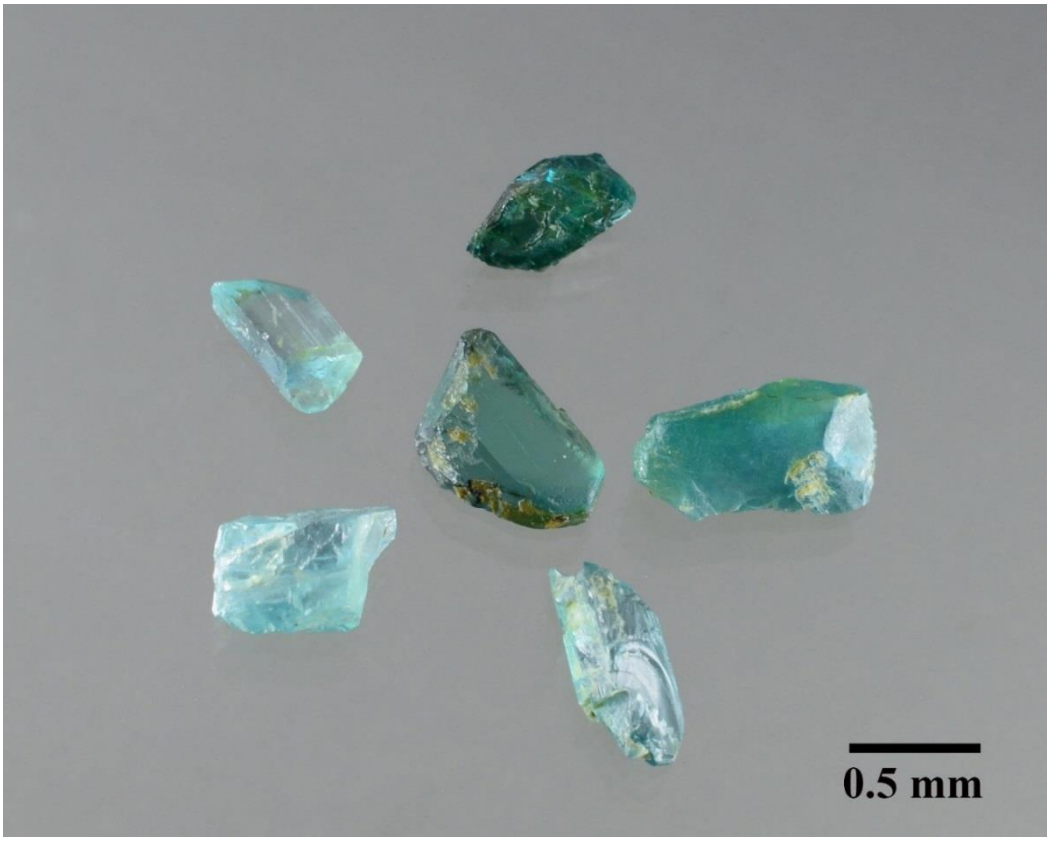
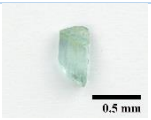


Figure 1: *Six rough bluish green grandidierites from Madagascar, weighing from 0.41 to 1.24 cts. (Photo by P. Ounorn)*

GENERAL PROPERTIES

In general, those 6 rough crystals display prismatic habits with straight striations on crystal faces and conchoidal fractures on the broken surface. They possess vitreous luster and semi-transparent to semi-translucent clarity. The colors of stone appear as light bluish green to intense bluish green. The stones also show obvious trichroic colors of light bluish green to bluish green, light yellow to colorless and greenish blue. Basic gemological tests revealed an average refractive index (RI) of 1.568-1.670, birefringence 0.035-0.050, double refraction-biaxial (DR-Bi), specific gravity (SG) of 2.88-2.92 (2.90) and inert under either long- or short-wave UV fluorescence. All gemological properties of the samples recorded in this study (Table 1) are consistent with the properties of grandidierite.

Table 1: *Gemological properties of rough grandidierite samples*

Properties/ Sample	 Sample 1	 Sample 2	 Sample 3	 Sample 4	 Sample 5	 Sample 6
Weight (ct)	0.41	1.00	0.67	1.24	0.89	0.55
Size (mm)	6.3 x 3.1 x 2.3	6.8 x 5.1 x 4.3	8.4 x 3.7 x 3.5	9.3 x 5.3 x 4.3	8.5 x 5.1 x 2.5	6.4 x 3.8 x 3.4
Color	Light bluish green	Bluish green	Bluish green	Bluish green	Bluish green	Intent bluish green
Pleochroism	Light bluish green/ Colorless / Greenish blue	Light bluish green/ Light yellow/ Greenish blue	Light bluish green/ Light yellow/ Greenish blue	Bluish green/ Light yellow/ Greenish blue	Bluish green/ Colorless/ Greenish blue	Bluish green/ Light yellow/ Greenish blue
Transparency	STL	STL	STL	STL	STP	STL
RI (bire)	~1.60	~1.61	~1.62	~1.58	1.568 – 1.670 (0.035-0.050)	~1.61
SG	2.92	2.89	2.90	2.90	2.90	2.88
UV fluorescence (LW and SW)	Inert	Inert	inert	inert	inert	inert

MICROSCOPIC FEATURES

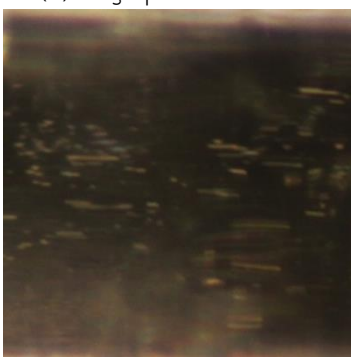
Under a microscope these stones showed internal features, namely, crystal inclusions, fingerprint inclusions, parting plane, fractures, minute particles and needle- like inclusions (Figure 2).

(a) Crystal inclusions

(b) Fingerprint inclusions

(c) Parting plane

(d) Fractures



(e) Minute particles

(f) Needle-like inclusions

Figure 2: *The microscope features of the grandidierite specimens. Dark Field (DF) 50x (Photo by M. Maneekrajangsaeng)*

ADVANCED TESTING

UV-Vis-NIR spectroscopy

The UV-Vis-NIR spectra of grandidierite samples revealed small absorption peaks at 355 and 386 nm in the UV, 441, 460 and 489 nm in the blue and broad absorption band center at around 735 nm (Figure 3).

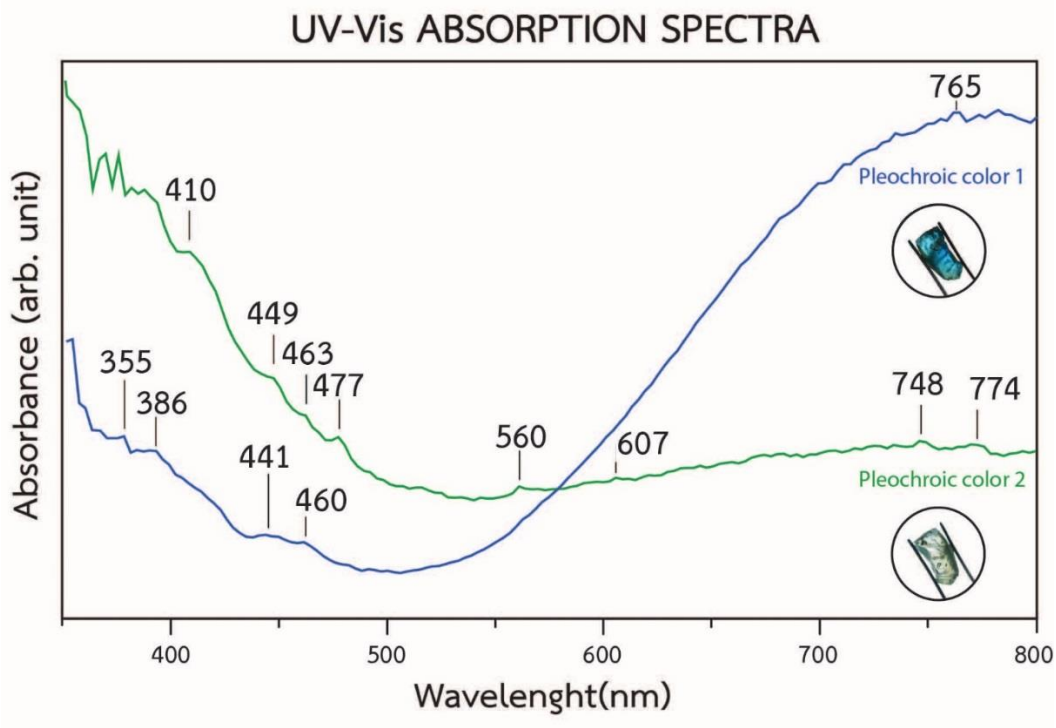


Figure 3: *Representative polarized UV-Vis-NIR spectra of a grandidierite sample*

FTIR spectroscopy

The infrared spectrum collected in the range of 2,000-4,000 cm^{-1} showed several absorption peaks of grandidierite (Figure 4).

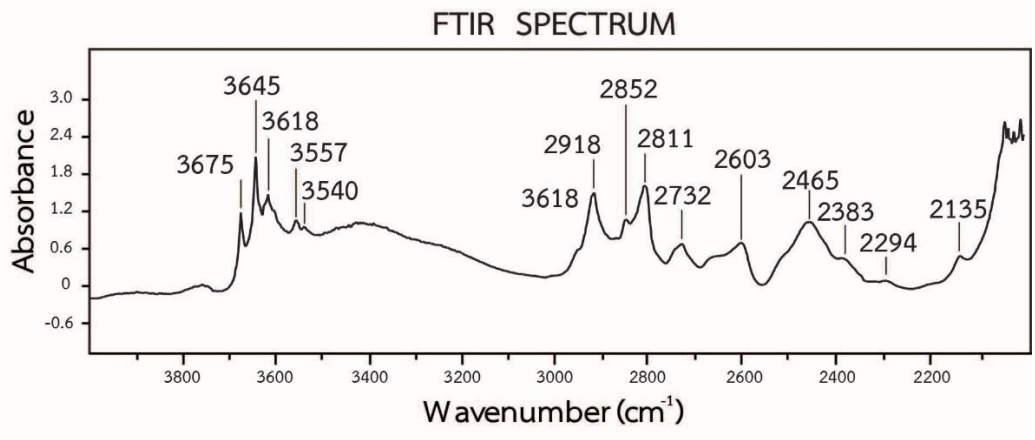


Figure 4: *Representive Mid-IR spectrum of a grandidierite sample*

Raman spectroscopy

The Raman spectrum collected in the range of 200-1,600 cm-1 exhibited several peaks that are matched very well with the reference grandidierite material (Figure 5).

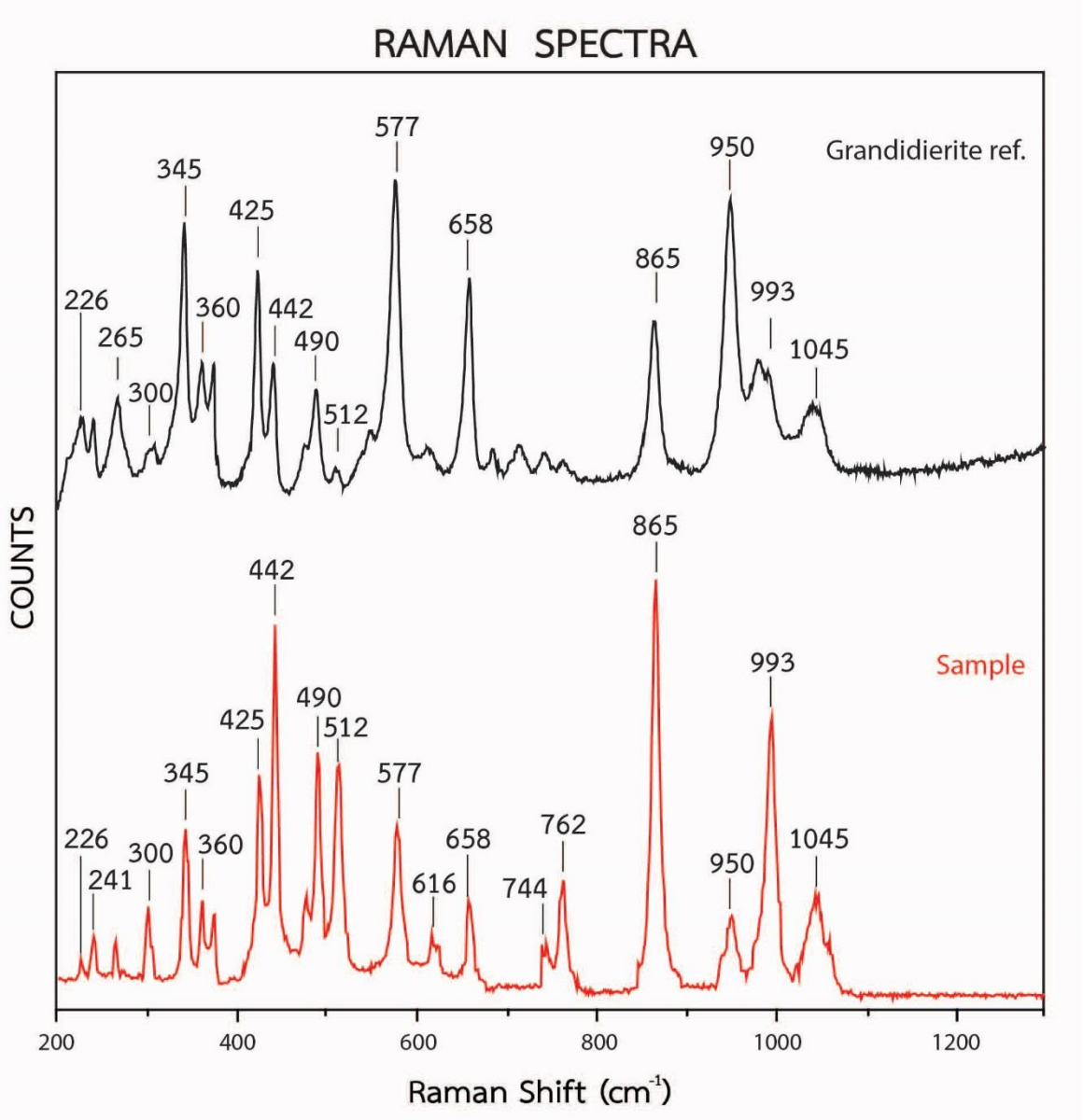


Figure 5: *Representive Raman spectrum of grandidierite sample (red) as compared to reference spectrum from RRUFF database (black).*

The photoluminescence (PL) spectrum, using a 532 nm laser in the range of 550 – 900 nm showed several emission board bands and peaks at 687, 697, 710, 717 and 725 nm (Figure 6).

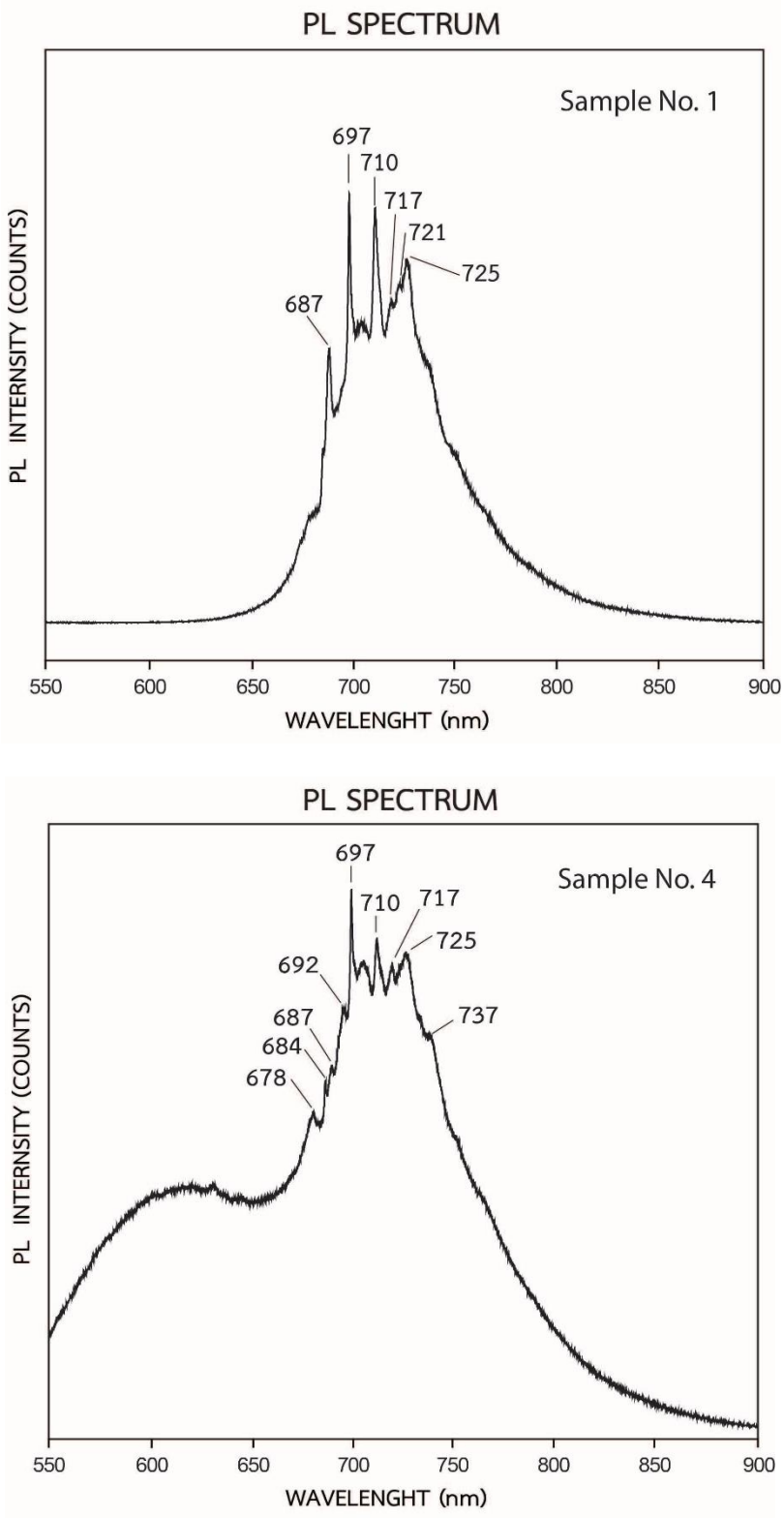


Figure 6: *Two representive PL spectrums of grandidierite samples.*

Chemical composition

Chemical compositions of the six samples analyzed by EDXRF (Table 2) gave Mg, Al Si and Fe as their major element compositions that are consistent with the grandidierite chemical formula, $(Mg,Fe^{2+})Al_3(BO_3)(SiO_4)O_2$, in which some iron have substituted magnesium in its structure (Schmetzer *et al*., 2003).

Table 2 : *Chemical composition of a gem-quality grandidierite samples by EDXRF analysis.*

Element Oxides (wt%)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
MgO	12.93	11.58	11.98	15.76	11.15	11.05
Al_2O_3	51.91	64.80	56.30	34.78	66.83	66.31
SiO_2	34.34	23.12	30.76	47.77	21.35	21.80
CaO	0.22	0.09	0.09	0.74	0.04	0.07
TiO_2	0.04	0.02	0.02	0.08	0.01	0.01
V_2O_5	0.05	bdl	0.03	0.02	0.01	0.02
Cr_2O_3	0.02	bdl	0.01	bdl	0.01	0.02
MnO	0.01	0.01	0.01	0.01	0.01	0.01
Fe_2O_3	**0.48**	**0.38**	**0.80**	**0.81**	**0.59**	**0.71**
ZnO	bdl	bdl	bdl	0.03	bdl	bdl

bdl = below detection limit

CONCLUSIONS

Based on the aforementioned data, it can be concluded that these stones are definitely grandidierite samples. These specimens show the color range from light bluish green to intense bluish green with strong pleochroism. Some distinct microscopic features include crystal inclusions, parting plane, minute particle inclusions and parallel needle-like inclusions. The PL spectra reveal several absorption board band peaks at 687, 697, 710, 717 and 725 nm. Their chemical compositions suggest that the depth of green color in the samples seem to be related to its iron contents. In fact, the properties obtained from this study are consistent with the properties previously reported on similar material from Madagascar (Vertriest *et al*., 2015).

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Pimtida Bupparenoo and Marisa Maneekrajangsaeng

GIT -Gem Testing Laboratory

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