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An Historical Alexandrite from the Mineralogy Museum of Paris School of Mines

Eloïse Gaillou, Stefanos Karampelas, Ugo Hennebois, Annabelle Herreweghe, Farida Maouche, Bérengère Meslin Sainte Beuve, Didier Nectoux and Aurélien Delaunay

ABSTRACT: A spectacular 42.54 ct faceted alexandrite belonging to the collection of the Mineralogy Museum of Paris School of Mines was non-destructively characterised for this report. This historical gem was exhibited in at least one exposition in Paris during the late 1870s and/or in 1880 before it was donated to the museum by lapidary Henri Garreaud in 1882. However, its geographic origin was not stated, and its gemmological properties have not been examined until now. Our study reveals that the gem's microscopic, chemical and spectroscopic characteristics are similar to those of alexandrite from Sri Lanka.

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A 42.54 ct alexandrite belonging to the Mineralogy Museum of Paris School of Mines (Mines Paris – PSL; Figure 1) is exceptional in several ways: it is historical, very rare, shows a distinct change of colour and is quite large for its species (particularly with this colouration). The only larger faceted alexandrites that we know of in other museums are two stones in the collection of the Smithsonian Institution (Washington DC, USA) weighing 48.20 and 65.70 ct, and a 43.18 ct alexandrite in the Natural History Museum, London. All three of these gems are reportedly from Sri Lanka. To the best of our knowledge, no scientific studies have been published on any of them.

Until recently, the 42.54 ct stone that is the subject of this article was stored in the vault at Mines Paris – PSL since its donation in 1882, but it is now on public display in a temporary exhibit titled 'Collectible Minerals' (6 September 2023–9 March 2024; see *The Journal*, Vol. 38, No. 7, 2023, p. 644). For this occasion, Mines Paris – PSL partnered with the Laboratoire Français de Gemmologie

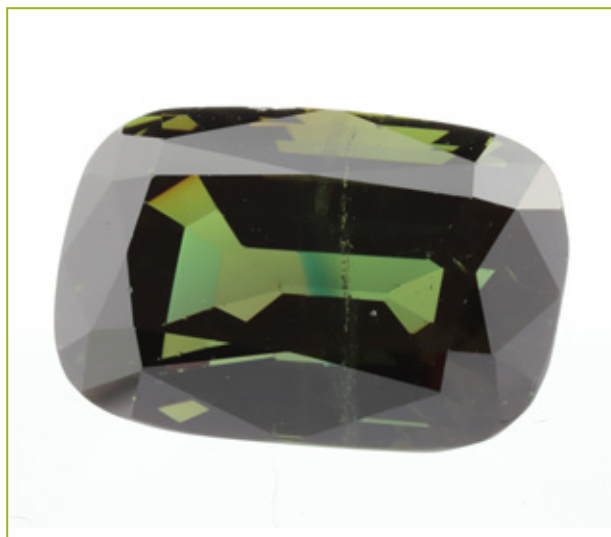


Figure 1: This 42.54 ct alexandrite (23.15 × 15.95 × 12.31 mm) belongs to the collection of Paris School of Mines (Mines Paris – PSL). It was donated in 1882 by French lapidary Henri Garreaud, with the only note of its origin being the 'Indies'. It is shown here under 5500 K illumination. Photo by E. Gaillou; © Mineralogy Museum, Mines Paris – PSL (sample no. ENSMP 69873).

(LFG) to conduct a scientific examination of the stone (Gaillou *et al.* 2022; Karampelas *et al.* 2023). This article chronicles its history and describes its gemmological and chemical properties in order to infer its probable geographical origin.

HISTORICAL BACKGROUND

Although the museum has owned the alexandrite for approximately 140 years, until now very little was known about it, other than what was written in the museum’s catalogue (Figure 2). The gem was reported to be a faceted alexandrite, also known as *cymophane*, weighing 41½ ct and presenting a distinctive internal pattern, as illustrated in a sketch of the stone in the catalogue (again, see Figure 2). The catalogue entry mentions that it was donated in 1882 by H. Garreaud, a lapidary and expert for the French government. The catalogue also states that Emile Bertrand, a mineralogist and former student of the School of Mines, suggested that the alexandrite came from the ‘Indies’.

The donation of this alexandrite to the museum was important enough to be reported in several press articles (e.g. Weiss 1883). We were able to trace the donor back to Henri Garreaud, who died in Paris in 1892. Garreaud had a boutique of gemstones and *objets d’art* made of gem materials. He exhibited on several occasions at national and international world fairs. For example, he won a gold medal for his gemstone display at the 1878 Exposition Universelle in Paris (Gonse & de Lostalot 1890, p. 444), and in 1876 and 1880 he received silver

medals at the Exposition des Beaux-Arts appliqués à l’Industrie. It is most likely that the 1880 fair is the one mentioned in the ‘Observations’ column of the museum’s catalogue, as it was the last one to take place before Garreaud donated the stone in 1882.

The reason Garreaud gave the stone to the School of Mines is not known. However, it is interesting to note that the organisers of the 1878 Exposition Universelle decided to unite the Fine Arts and the Industrial Arts sections under the same exhibit, in which the School of Mines played a role. Indeed, the School of Mines encouraged its professors and engineers to participate in these international fairs as organisers, jury members or exhibitors, and acquired many of the samples presented at the fairs for its collection. A meeting between Garreaud and School of Mines personnel was likely, possibly leading to the donation.

Garreaud’s name and skills were forgotten after he died in 1892, leaving his entire shop of gems and lapidary *objets d’art* to be sold at auction (Anonymous 1893). No other French museums seem to have acquired any of Garreaud’s other pieces.

METHODS

For this study, Mines Paris – PSL provided the alexandrite to LFG on a very short-term loan (eight hours) for scientific characterisation by strictly non-destructive methods. It was examined with a Zeiss Stemi 508 binocular microscope equipped with crossed polarisers, and also with a Chelsea Colour Filter. Its RIs

| NUMERO DE L'ÉCHANTILLON | DESCRIPTION DÉTAILLÉE DE L'ÉCHANTILLON NATURE – LOCALITÉ, etc. | DÉTERMINATION D'INVENTAIRE | LOCALITÉ | PAYS | REVENU DES ANCIENS CATALOGUES | OBSERVATIONS |
|-------------------------|---|----------------------------------|--------------------------------|-------------------------------------|----------------------------------|--|
| 440 | Alexandrite taillée La pierre a un défaut 41 ½ carats | Cymophane n.7 Cymophane no. 7 | Indes (d'après M. Bertrand) | Indes (according to Mr Bertrand) | | (au coffre fort le 15 juin 1891) d. p. de H. Garreaud Lapidier Expert du Gouvernement Hors concours à l'Exposition des Beaux-Arts appliqués à l'Industrie 67. rue de Richelieu Paris (in the vault June 15 1921 insured) Donated by Mr H. Garreaud lapidary Government Expert Standout at the Exhibition of Fine Arts applied to Industry 67. rue de Richelieu Paris |

Figure 2: The alexandrite was documented in entry no. 4410 of the museum’s catalogue. Photo by E. Gaillou; © Mineralogy Museum, Mines Paris – PSL.

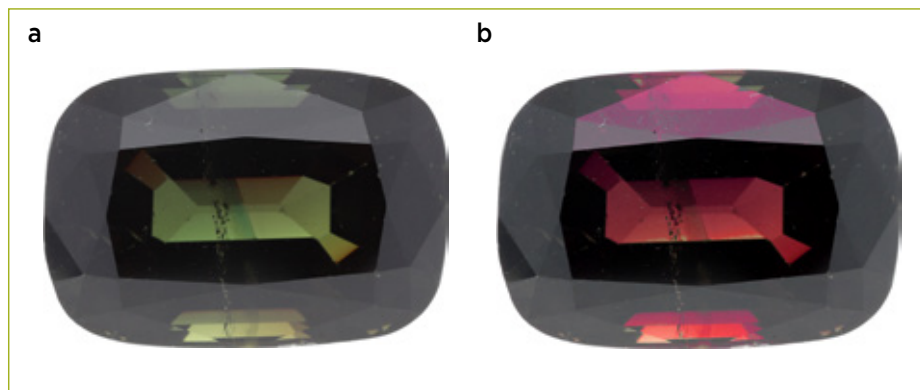


Figure 3: The 42.54 ct alexandrite appears (a) brownish green in daylight-equivalent light (6500 K) and (b) brownish-reddish purple in incandescent light (2856 K). Photos by Thiala Magalhaes/LFG; © Mineralogy Museum, Mines Paris – PSL.

were measured with a refractometer and its SG was determined hydrostatically. The stone's luminescence was tested with a 6 W UV lamp (Vilber Lourmat VL-6. LC) equipped with long-wave (365 nm) and short-wave (254 nm) radiation, in a Vilber CN-6 darkroom with a distance of 10 cm between the sample and the lamp.

Raman and photoluminescence (PL) spectra were acquired using a GemmoRaman-532SG spectrometer with 532 nm laser excitation and a spectral resolution of 11 cm^{-1} . Raman spectra were collected in the $200\text{--}2000\text{ cm}^{-1}$ range (1 s exposure time and four accumulations), and PL spectra were obtained in the $540\text{--}760\text{ nm}$ range (0.3–0.4 s exposure time and 30 accumulations). Raman and PL spectra were also acquired for the gem—as well as its inclusions—with a Renishaw inVia spectrometer coupled with an optical microscope and 514 nm excitation from a diode-pumped solid-state laser. Raman spectra covered the range of $250\text{--}1250\text{ cm}^{-1}$ (30 s exposure time and ten accumulations); the laser power on the sample was 40 mW and the spectral resolution was about 2 cm^{-1} . PL spectra spanned $500\text{--}900\text{ nm}$ (10 s exposure time and one accumulation) with a laser power of 0.1 mW. Both spectrometers were calibrated using the 1331.8 cm^{-1} Raman peak of diamond.

Fourier-transform infrared (FTIR) spectra were obtained in the range of $400\text{--}8000\text{ cm}^{-1}$ using a Nicolet iS5 spectrophotometer with 4 cm^{-1} resolution and 500 scans. Ultraviolet-visible-near infrared (UV-Vis-NIR) spectra were acquired over $365\text{--}1000\text{ nm}$ using a GemmoSphere spectrometer (0.05–0.10 s acquisition time and 50 accumulations) equipped with an integrating sphere. In addition, UV-Vis spectra were obtained using a Jasco V-630 spectrophotometer from 250 to 850 nm, with a data interval and spectral bandwidth of 2 nm and a scan rate of 210 nm/min. All of the acquired spectra were unpolarised.

Chemical analysis was performed using a Thermo Scientific ARL Quant'X energy-dispersive X-ray fluorescence (EDXRF) spectrometer with an aperture of 5 mm diameter. Specific sets of parameters for filters and

voltages were optimised for the most accurate analysis of chrysoberyl (no filter/4 kV, cellulose/8 kV, aluminium/12 kV, thin palladium/16 kV, medium palladium/20 kV, thick palladium/28 kV and thick copper/50 kV), with an acquisition time of about 20 minutes for each measurement. Measured iron was calculated as FeO, and BeO was fixed at 18.7%.

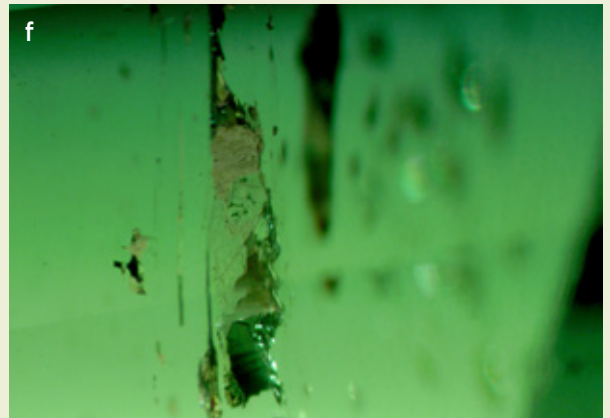
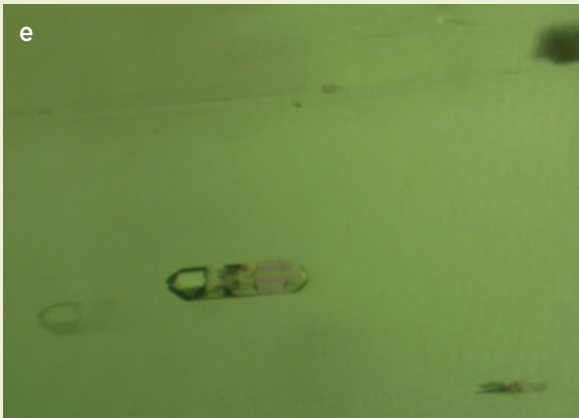
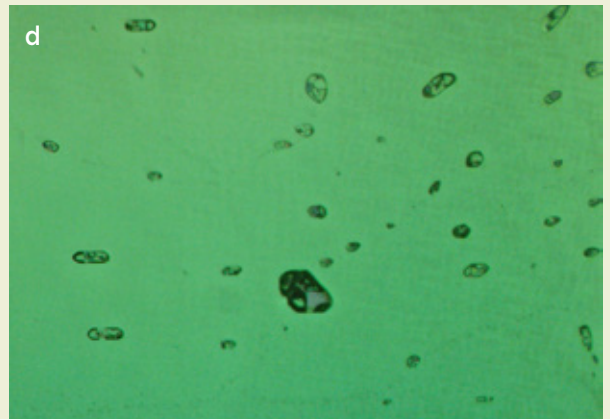
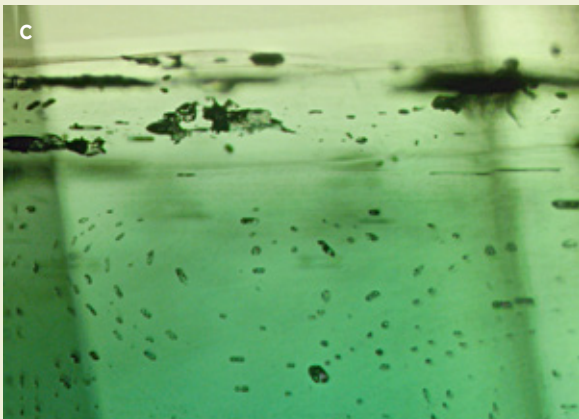
RESULTS AND DISCUSSION

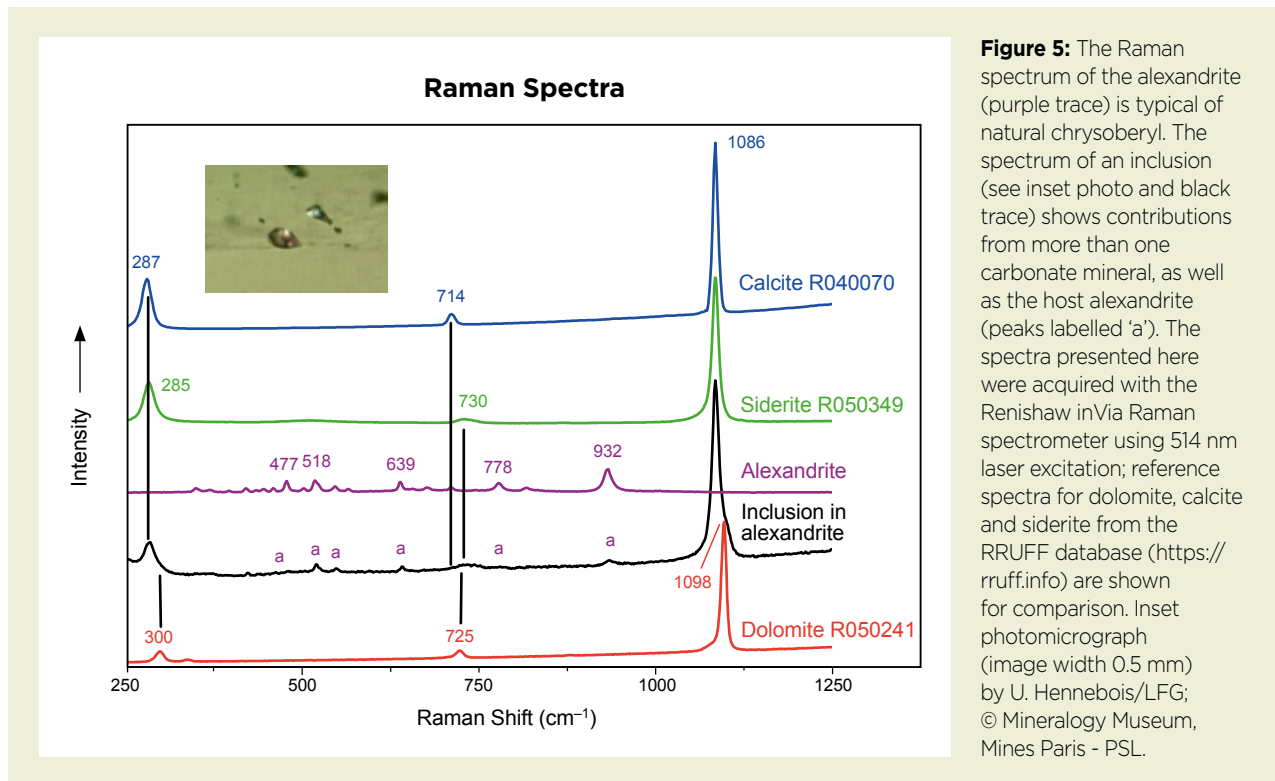
Gemmological and Chemical Characteristics

The alexandrite was faceted as a cushion-shaped mixed-cut gemstone that measured $23.15 \times 15.95 \times 12.31\text{ mm}$ and weighed 42.54 ct (vs $41\frac{1}{2}$ ct recorded in the museum catalogue). The gem displayed a pronounced colour change, from brownish green in daylight-equivalent light (6500 K; Figure 3a) to brownish-reddish purple in incandescent light (2856 K; Figure 3b). The RIs were 1.745–1.755 and the SG value was 3.72. The stone showed strong pleochroism from yellow to green to purple (Figure 4). It appeared red with the Chelsea filter, and was inert to long- and short-wave UV radiation. These characteristics are consistent with the typical properties of alexandrite (cf. Webster & Anderson 1983).

The stone contained an eye-visible twin plane through its centre (Figures 1, 3 and 4a, b)—which

Figure 4: (a, b) A twin plane in the alexandrite appears more distinct when viewed with different orientations of the polariser in transmitted light. The sample's strong pleochroism is also evident in these images. (c–h) Several types of internal features are present within the linear array of inclusions that is seen crossing the stone in Figures 1 and 3, including multiphase inclusions of various shapes and sizes (c–g)—some with rounded outlines—as well as fingerprints and feathers (f–g), and also particles and short needles (h). Photomicrographs by U. Hennebois/LFG; © Mineralogy Museum, Mines Paris – PSL; image widths (a, b, d, e) 1.4 mm, (c, g) 2.2 mm, (f) 4.5 mm and (h) 3.5 mm.





is also shown in the museum catalogue sketch in Figure 2—and this plane is accompanied by colour zoning. A linear array of inclusions crossing the stone could also be observed with the unaided eye when viewed table up (again, see Figures 1 and 3). This zone contained various internal characteristics consistent with a natural origin, such as multiphase inclusions of various sizes and shapes, ‘fingerprints’ and feathers

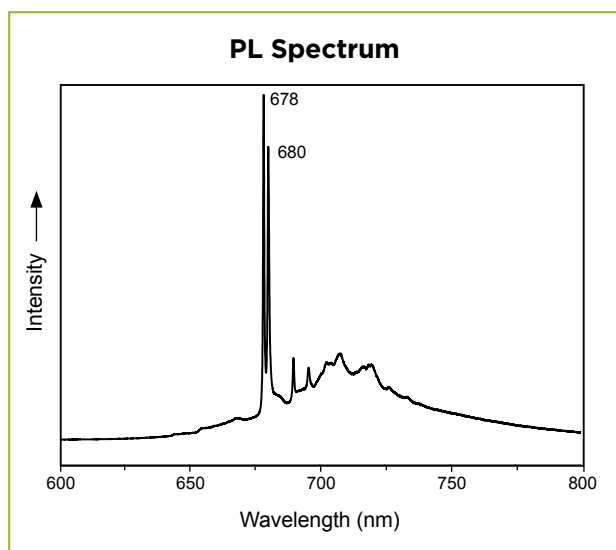


Figure 6: The PL spectrum of the alexandrite displays bands characteristic of Cr³⁺ in natural chrysoberyl. The spectrum was acquired with the Renishaw inVia Raman spectrometer using 514 nm laser excitation.

(Figure 4c–g), as well as particles and short needles (Figure 4h). This inclusion scene is similar to that observed in some alexandrite gems from Sri Lanka (Gunawardene & Rupasinghe 1986; Sun *et al.* 2019).

Raman spectra of the alexandrite displayed bands at approximately 477, 518, 639, 778 and 932 cm⁻¹ (e.g. Figure 5, purple trace) due to Be-O and Al-O vibrations of chrysoberyl (Rybnikova *et al.* 2023). It was not possible to acquire Raman spectra from most of the inclusions, but we did obtain the spectrum of one of them (Figure 5, inset and black trace). Its main Raman band was at around 1086 cm⁻¹ with a shoulder at 1098 cm⁻¹, along with less intense bands at about 285 and 735 cm⁻¹. These features correspond to the lattice modes and internal modes, respectively, of carbonates. This series of bands appears to represent a combination of signals from more than one carbonate mineral, such as dolomite, calcite and siderite (cf. Rividi *et al.* 2010; Kim *et al.* 2021).

The PL spectrum of the alexandrite (Figure 6) showed a doublet at 678 and 680 nm along with a series of other bands that are linked to Cr³⁺ in the chrysoberyl structure (Powell *et al.* 1985; Suchocki *et al.* 1987).

The FTIR spectrum of the alexandrite revealed a series of bands above 2800 cm⁻¹, centred at around 2840, 3130, 3230 and 4140 cm⁻¹ (Figure 7). These bands are characteristic of natural alexandrite, and are related to OH defects and vacancies in chrysoberyl (Bauerhansl

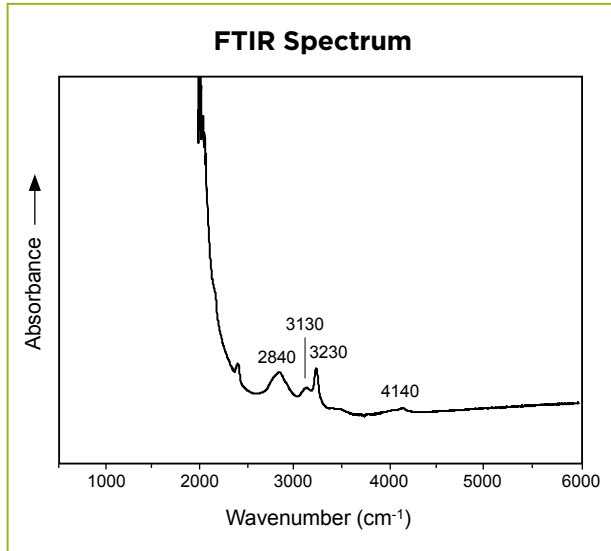


Figure 7: The FTIR spectrum of the alexandrite exhibits features characteristic of natural chrysoberyl.

& Beran 1997; Malsy & Armbruster 2012).

The Vis-NIR absorption spectrum of the alexandrite (Figure 8) showed a Cr³⁺-related absorption (with a possible contribution from V³⁺) centred at around 575 nm, and a cutoff at around 450 nm. The doublet seen at around 680 nm in the PL spectrum is also visible, but as a single peak. Also present is a continuum that gradually decreases in intensity towards the NIR range, possibly due to the presence of iron (Farrel & Newnham 1965; Powell *et al.* 1985; Suchocki *et al.* 1987).

EDXRF chemical analysis revealed about 9460 ppmw

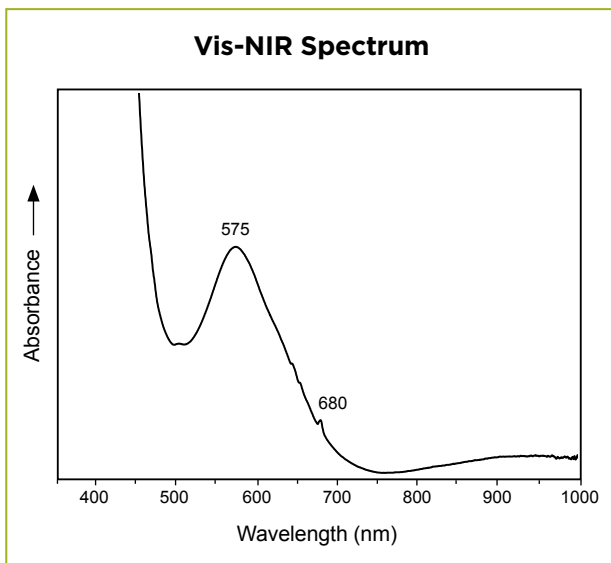


Figure 8: The Vis-NIR spectrum of the alexandrite (acquired with the GemmoSphere spectrometer) reveals absorptions at 575 and 680 nm associated with Cr³⁺, as well as a gradually decreasing continuum towards the NIR range, possibly linked to iron.

Fe, 925 ppmw Ga, 885 ppmw Cr, 430 ppmw V and 190 ppmw Ti; all other trace elements were below the detection limit of the instrument. Such a combination of enriched Fe and Ga in gem-quality alexandrite has been reported only for material from Sri Lanka (Sun *et al.* 2019).

Inferred Sri Lankan Origin

Chrysoberyl is commonly associated with Be-rich and pegmatitic rocks, and the presence of alexandrite reflects a rare combination of enriched Be and Cr in the formation environment. In Sri Lanka, alexandrite is mined from secondary (placer) deposits (Marshall & Walton 2014) derived from the weathering of various host rocks. Most Sri Lankan gem deposits originally formed by contact metamorphism of mafic intrusions (producing charnockite) and the intrusion of Be-enriched pegmatitic fluids into highly aluminous metasediments of the Highland Group (2200 to 3000 million years [Ma] ago, with high-grade metamorphism occurring at 1100 and 550 Ma), producing beryl, chrysoberyl, taaffeite and other Be-bearing minerals (Rupasinghe *et al.* 1984). A reaction between marble and pegmatitic fluid has been postulated for the Elahera gem field (Rupasinghe & Dissanayake 1985; Dissanayake *et al.* 2000), which is consistent with the presence of a carbonate inclusion in the studied alexandrite, although there are different types of Sri Lankan alexandrite showing particular inclusion scenes and geochemical signatures (Schmetzer 2010; Sun *et al.* 2019).

Russia has commonly been considered the only source of alexandrite during the nineteenth century, and little information was available about alexandrite from Sri Lanka until the early 1920s (Sun *et al.* 2019). However, the first mention of alexandrite from Sri Lanka can be found in a Russian textbook on gems published in 1888 (Pylyaev 1888), where it was acknowledged that these stones had already been available in Russia for seven years. One can therefore assume that Sri Lankan alexandrite arrived in Russia around 1880 or before (Schmetzer 2010). Early in the twentieth century, various authors reported alexandrite of exceptional quality and size (up to 131 ct, possibly rough) coming from Morawaka (sometimes with a slightly different spelling), a town in Sri Lanka's Southern Province (Day 1904; Stokes 1908; Bauer 1909; Bingham 1923).

Additionally, there is evidence of fine alexandrite coming from Sri Lanka prior to 1880, which is consistent with the 42.54 ct stone being donated to the Mineralogy Museum of Paris School of Mines in 1882. In 1873, the Natural History Museum in London purchased a

43.18 ct alexandrite from Sri Lanka (Hansen 2022). This suggests that early production of alexandrite from Sri Lanka—and the quality and size of the stones—might have been much better than previously thought. Thus, not all alexandrite found in nineteenth-century (e.g. Victorian) jewellery necessarily originated in Russia; some could have come from Sri Lanka.

CONCLUSIONS

We examined an exceptional, historical 42.54 ct faceted alexandrite belonging to the collection of the Mineralogy Museum of Paris School of Mines (Figure 9). It was donated to the museum in 1882 by French lapidary Henri Garreaud. All characteristics of the sample are consistent with those of natural alexandrite. It shows a pronounced colour change from brownish green in daylight to brownish-reddish purple in incandescent light. The inclusion scene (e.g. needles, multiphase inclusions of various shapes and feathers), as well as chemical composition (e.g. relatively high Fe and Ga content), suggest a Sri Lankan origin. The presence of this and another large historical alexandrite gemstone in London's Natural History Museum collection further indicate that during the nineteenth century, fine



Figure 9: The studied historical alexandrite is shown here in incandescent light (2800 K). Photo E. Gaillou; © Mineralogy Museum, Mines Paris – PSL.

alexandrite came from Sri Lanka as well as Russia.

Until recently, the 42.54 ct alexandrite had not been exhibited to the public since the late 1870s or 1880, but it is on display (through 9 March 2024) in a temporary exhibit titled 'Collectible Minerals,' at the Mineralogy Museum of Mines Paris – PSL. Accompanied by the information in this article, this noteworthy stone is enriched by further knowledge of its history and a thorough gemmological characterisation.

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