The Journal of Gemmology

Volume 35 / No. 5 / 2017

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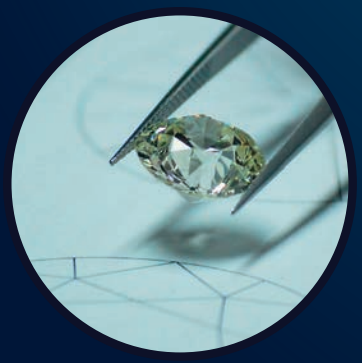
ORIGIN DETERMINATION · TREATMENT DETECTION

DIAMOND GRADING · PEARL TESTING

EDUCATION · RESEARCH



THE SCIENCE OF GEMSTONE TESTING

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COLUMNS

Cover Photo:

High-quality rubies, sapphires and emeralds are typically accompanied by geographical origin reports from gemmological laboratories, as discussed on pp. 416–423 of this issue. Shown in this composite photo are matched pairs of Colombian emeralds, Kashmir sapphires and Burmese rubies (total weights approximately 10, 7 and 4 ct, respectively). Courtesy of Joseph Ambalu, Amba Gem Corp., New York, New York, USA.


p.386
Klaus Schollenbruch photo


p. 388
Jeff Scovil photo

ARTICLES

Feature Articles

Gemmological Briefs

The Journal is published by Gem-A in collaboration with SSEF and with the support of AGL and GIT.

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SSEF SCHWEIZERISCHES GEMMOLOGISCHES INSTITUT SWISS GEMMOLOGICAL INSTITUTE INSTITUT SUISSE DE GEMMOLOGIE
AGL AMERICAN GEMOLOGICAL LABORATORIES
The Gem and Jewelry Institute of Thailand (Public Organization)

ISSN: 1355-4565, http://dx/doi.org/10.15506/JoG.2017.35.5

The Journal of Gemmology

Content Submission
The Editor-in-Chief is glad to consider original articles, news items, conference/excursion reports, announcements and calendar entries on subjects of gemmological interest for publication in *The Journal of Gemmology*. A guide to the various sections and the preparation of manuscripts is given at www.gem-a.com/index.php/news-publications/publications/journal-of-gemmology/submissions, or contact the Production Editor.

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The Journal of Gemmology is published quarterly by Gem-A, The Gemmological Association of Great Britain. Any opinions expressed in *The Journal* are understood to be the views of the contributors and not necessarily of the publisher.

Printed by DG3 (Europe) Ltd.

ISSN: 1355-4565

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Registered Charity No. 1109555
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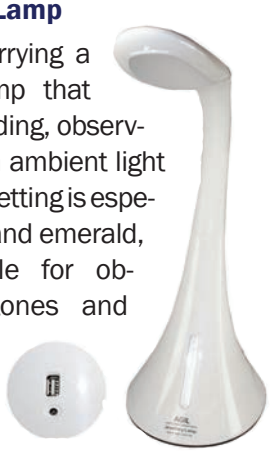
Understanding Gems™

What's New

INSTRUMENTATION

Multi-Colour-Temperature Lamp



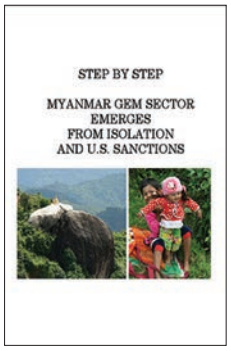
The Gem-A Shop is now carrying a multi-colour-temperature lamp that can be used for diamond grading, observing colour change, and as an ambient light source. The 3,700–3,900 K setting is especially useful for viewing jade and emerald, 4,200–4,500 K is suitable for observing most coloured stones and 5,000–5,500 K is ideal for diamonds and blue sapphires. The lamp has eight levels of brightness controlled by a touch-sensitive slide. The flexible head folds for storage. The unit comes with a 100/240 V adaptor and a USB-powered connector. To order, email instruments@gem-a.com. *CMS*

PL-Inspector

Gemetrix Pty Ltd released its new PL-Inspector instrument in May 2016 at the Mediterranean Gem and Jewellery Conference in Spain. It contains a portable UV light source, weighing only 300 g, that provides both short-wave (255 nm) and long-wave (365 nm) radiation for the observation of fluorescence and phosphorescence in gems (particularly diamond). An optional battery pack makes the unit suitable for travel. Visit http://gemetrix.thediamondpages.com/PLinspector.html; for North American orders, go to www.gemconference.com/store and for European orders visit www.iglcert.gr. *CMS*

NEWS AND PUBLICATIONS

AGTA Report on Myanmar Gem Sector



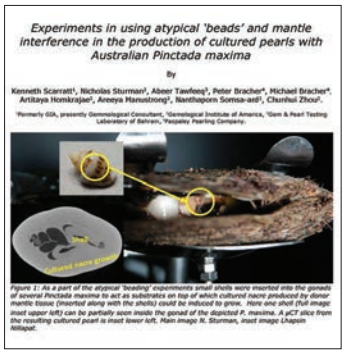
In October 2016, the American Gem Trade Association led a visit to Myanmar that included a delegation of American gem industry representatives. In January 2017, AGTA released a white paper titled 'Step by Step: Myanmar Gem Sector Emerges from Isolation and U.S. Sanctions' that gives the background and outcome of that visit. The report describes several mines visited and the local supply chain, along with recommendations for the ethical support of the gem sector of Myanmar. To download the report, go to http://agta.org/info/docs/burmawhitepaper2016.pdf. *CMS*

ASEAN Gem & Jewelry Review

Issue 1, 2017, of this English-language gem and jewellery trade publication for the Association of Southeast Asian Nations (ASEAN) focuses on the coloured stone trade between Thailand and Myanmar, e-commerce opportunities in Thailand and ASEAN, the jewellery manufacturing industry in Vietnam, major sources of gems and precious metals in ASEAN, and more. To download the issue, go to www.git.or.th/2014/thai/info_center/trade_review/2017/2017_ASEAN_Gem_Review.pdf. *CMS*

Atypical Pearl Culturing Experiments in *P. maxima*

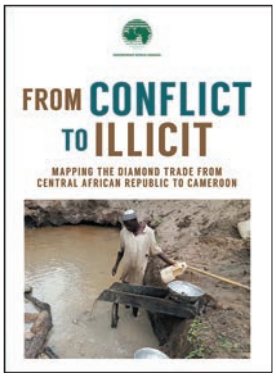
In February 2017, GIA's online Research News section posted a report titled 'Atypical "Beading" in the Production of Cultured Pearls from Australian *Pinctada maxima*'. It describes experiments using low-quality natural pearls and other materials as beads for producing cultured pearls in


Experiments in using atypical 'beads' and mantle interference in the production of cultured pearls with Australian Pinctada maxima

P. maxima. Most of the resulting bead-cultured pearls could be readily identified using either real-time X-ray imaging or X-ray computed micro tomography. Download the report at www.gia.edu/gia-news-research/atypical-beading-production-cultured-pearls-australian-pinctada-maxima. *CMS*

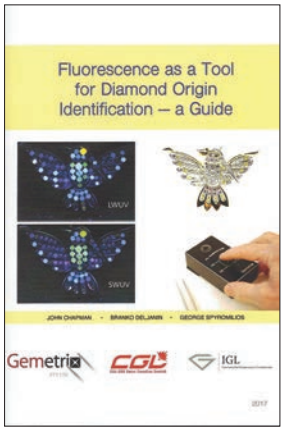
Conflict Diamonds and Cameroon

Partnership Africa Canada released its report 'From Conflict to Illicit: Mapping the Diamond Trade from Central African Republic to Cameroon' in December 2016. It describes the failure of the Kimberley Process to prevent conflict diamonds from CAR from reaching the international diamond market via adjacent Cameroon. The report includes recommendations to the Kimberley Process, the government of Cameroon and the diamond industry to control the flow of conflict diamonds from CAR. Download the report at http://pacweb.org/images/PUBLICATIONS/from-conflict-to-ilicit-eng-web.pdf. *CMS*



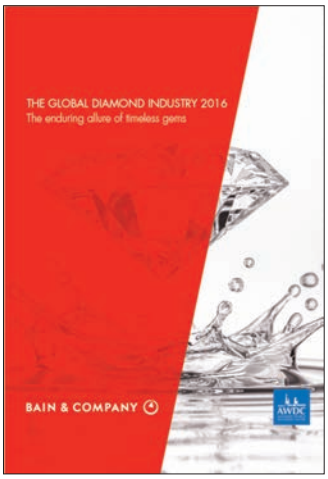
Fluorescence as a Tool for Diamond Origin Identification—a Guide

In January 2017, this 19-page booklet was released by Gemetrix Pty Ltd, CGL-GRS Swiss Canadian Gemlab Inc. and Independent Gemological Laboratory to provide a photographic reference for the luminescence behaviour of colourless and coloured diamonds. Numerous images show typical fluorescence (to long- and short-wave UV radiation) and phosphorescence reactions for untreated and treated natural and synthetic diamonds. Also included is a brief review of diamond type classification, causes of colour, treatments, and synthetics and their detection. The booklet closes with a short article, 'Identification of CVD-Grown Diamonds on the Greek/EU Market with Standard and Advanced Gem Instruments', by G. Spyromilios, B. Deljanin, M. Åström and J. Chapman, followed by a reading list. The booklet is available for US$25.00 plus shipping and handling from www.gemconference.com/store/books/fluorescence-as-a-tool-for-diamond-origin-identification-a-guide. *BML*

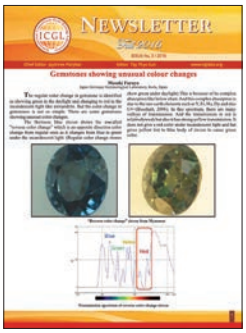


Global Diamond Industry 2016

Released in December 2016, the 6th annual report on the global diamond industry prepared by the Antwerp World Diamond Centre and Bain & Company is titled 'The Global Diamond Industry 2016: The Enduring Allure of Timeless Gems'. The paper reviews recent developments in the diamond industry and then describes rough diamond production, the cutting and polishing industry, retail jewellery sales and how the 'millennial generation' perceives diamonds and diamond jewellery. It concludes with discussions of the current challenges to the industry and an updated model of supply and demand. Download the report at www.bain.com/Images/bain_diamond_report_2016.pdf. *CMS*



ICGL Fall 2016 *Newsletter*



The International Consortium of Gem-Testing Laboratories' Fall *Newsletter* (No. 3, 2016) was released in December 2016, and features gems with unusual colour changes, similar-appearing serendibite and sapphirine gems, a new ornamental material from

Pakistan called 'Sannan Skarn' and sphene from India. Visit http://icglabs.org to download this and previous issues. *CMS*

Journal of the Gemmological Society of Japan Online

All issues of this journal, published from 1974 (Vol. 1) through 2016 (Vol. 32), were made available online in January 2017. Most of the content is in Japanese, but articles commonly contain an English abstract. PDF files are freely downloadable for all but the most recent issue, **32**(1–4), for which access to articles and short notes requires a subscriber login. Visit www.jstage.jst.go.jp/browse/gsjapan. *CMS*

Raman Spectrometer Sensitivity

In November 2016, TSI Inc. posted online an application note titled 'Simple Method for Sensitivity Comparison of Raman Spectroscopic

Instruments', which describes a technique using the 1082 cm^{-1} feature of a calcium carbonate standard to measure the sensitivity of Raman spectrometers. Download the three page report at http://tinyurl.com/zqlfq9s. *CMS*

World Gold Council's Gold Demand Trends 2016

This annual report on the gold industry was released in February 2017 and includes extensive data analysis of changes in demand for the year 2016 compared with previous years. Due to high gold prices, annual jewellery demand for gold declined to a seven-year low. The report can be viewed online at www.gold.org/supply-and-demand/gold-demand-trends/back-issues/gold-demand-trends-full-year-2016, which also has links to download the complete report, data spreadsheets and charts, and infographics. *CMS*

OTHER RESOURCES

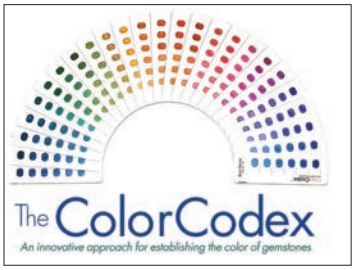
2016 Agate Expo DVDs

Released in September 2016, this set of four DVDs contains extensive information from the 2016 Agate Expo held 8–10 July 2016 in Cedarburg, Wisconsin, USA. Included on the DVDs are all 12 symposium presentations, 10 additional speaker presentations, the opening ceremony, highlights from the 128 show displays, vendor interviews and more. To order the set, visit https://thegemshop.com/collections/publications-1/products/2016-agate-expo-dvd-complete-set-pre-order. *CMS*

AGTA 2017 Tucson Seminars

Held from 31 January to 5 February 2017, the American Gem Trade Association (AGTA) GemFair in Tucson, Arizona, USA, featured numerous educational presentations covering a broad range of gem, jewellery and industry topics. Approximately 26 of the seminars are available (as audio synchronized with the presenters' PowerPoint slides) on a flash drive that is available to AGTA non-members for US$50.00. (AGTA members can freely access the seminars through AGTA's eLearning online program.) To view a list of topics/presenters and place an order, visit www.agta.org/education/seminars.html. *CMS*

ColorCodex Color Referencing System



Released in early 2017, the ColorCodex is a set of colour-range cards designed for gem colour description. Each card has six textured colour images for a specific hue that range from lighter to darker and more saturated, with even numbers (to permit communication of interpolated appearances) that correspond to each image. The system is designed for use with both mounted and unmounted gems. Visit www.color-codex.com. *CMS*

GemeSquare and MyGemewizard Apps

Released in February 2017 by Gemewizard Ltd., the free GemeSquare and MyGemewizard apps make it possible to use a smartphone or tablet to communicate gem colours. The GemeSquare app enables users to select the gem's colour from a base palette of 31 master hues modified by tone and saturation, and translate it into other colour coordinates such as Munsell, CIE L*a*b* and CMYK. The MyGemewizard app enables users to save records of gems of interest (e.g. at shows or in suppliers' offices), enabling them to capture their images, analyse and record their colours and save other information, such as their properties, prices, vendor information and more. The apps can then be used to share the gem's information via email and social media. Visit www.gemeapps.com for additional information and links to download iOS and Android versions. *CMS*

Gemewizard Monitor Colour Calibration Kit

In February 2017, Gemewizard Ltd. released a specially designed kit enabling users to calibrate their computer monitor to display accurate gem colours. The kit contains a row of six faceted pieces of terbium glass representing all of the hues needed for calibrating an LCD/LED screen: blue, red, magenta, green, cyan and yellow. The kit is placed under a standard 6,500 K (D65) fluorescent lamp next to the monitor displaying the Gemewizard calibration page at www.gemewizard.com/calibration, and the user adjusts the monitor settings until the colours most closely resemble those shown by the glass samples. The kit will soon be available for US$10.00, and will be included at no extra charge with subscriptions to GemePrice. To order, email sales@gemewizard.com. *BML*

MISCELLANEOUS

Fabergé Online

The Virginia Museum of Fine Arts in Richmond, Virginia, USA, possesses one of the world's outstanding collections of Fabergé works, including five Imperial Easter Eggs and more than 170 additional pieces, donated in 1947 by Lillian Thomas Pratt. VMFA now offers the ability to search the collection online, as well as a website dedicated to the story of the collection, and an app for iOS and Android smartphones and tablets that was launched in October 2016. Visit https://vmfa.museum/collections/faberge. *CMS*

Reopening of The Lapworth Museum of Geology

In September 2016, the University of Birmingham opened its extensively redeveloped Lapworth Museum of Geology. The Museum's exhibits cover 3.5 billion years, including rocks, fossils and dinosaurs. The mineralogy collection contains approximately 12,000 specimens, many from British mining areas that are now closed, as well as historical displays about famous British mineralogists and collectors. For more information about the Museum and its collections, visit www.birmingham.ac.uk/facilities/lapworth-museum/index.aspx. *CMS*

What's New provides announcements of new instruments/technology, publications, online resources and more. Inclusion in What's New does not imply recommendation or endorsement by Gem-A. Entries were prepared by Carol M. Stockton (CMS) or Brendan M. Laurs (BML), unless otherwise noted.

Moonstone Mystery

Alan Hodgkinson

The three cabochons in Figure 1a each show an aspect that may be seen in moonstone: chatoyancy, asterism and adularescence (from left to right). The stones on the left and right are in fact moonstones, easily confirmed by their spot RI of 1.53 and their biaxial interference figure (e.g. Figure 2). However, no such figure was obtainable with a polariscope from the cabochon in the centre. It was handed to the author at the 2016 Scottish Gemmological Association conference by a regular Norwegian attendee, Stig Sundin, with the question, "Just what exactly is the identity?"

Exposure of the three samples to short-wave UV radiation revealed the faintest pinkish red luminescence in the two moonstones, but striking 'sky'-blue fluorescence in the other cabochon (Figure 1b). The mystery sample also exhibited various combinations of asterism depending on the angle of light and viewing, ranging from four, five, six or even seven rays as the cabochon was manoeuvred (e.g. Figure 3). Lapidary Martin Donoghue polished the base of the cabochon, and this enabled a clear single RI reading of 1.727 on an Eickhorst refractometer. The test results confirmed synthetic spinel, but what was the mechanism that formed the stars?

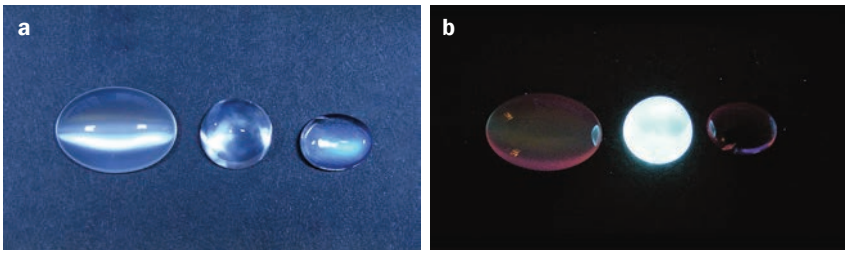
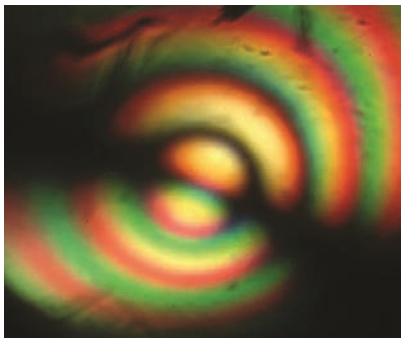


Figure 1: (a) The moonstone on the left (6.14 ct) displays chatoyancy, while the moonstone on the right (2.40 ct) shows bluish adularescence. The moonstone simulant in the centre (6.08 ct), which proved to consist of heat-treated synthetic spinel, exhibits asterism with various numbers of rays depending on the orientations of the light source and the cabochon. (b) Exposure of these cabochons to short-wave UV radiation revealed faint pinkish red fluorescence in the two moonstones, whereas bright 'sky'-blue luminescence is shown by the synthetic spinel. Photos by A. Hodgkinson.

Cross-polarized light revealed the 'tortured' interior of the cabochon as a random birefringence pattern (Figure 4), which could be due to strain or the exsolution of a second phase. This suggested that this moonstone simulant was originally grown as a Verneuil colourless synthetic spinel that was then subjected to heat treatment. The heating caused a segregation or exsolution within the structure of this flame-fusion synthetic spinel (Eppler, 1943; Saalfeld and Jagodzinski, 1957). Unlike corundum, since it is difficult to grow synthetic spinel by the Verneuil technique, the alumina-to-magnesia ratio was increased by as much as five times of that contained in natural spinel to facilitate growth of a product with minimal internal stress (Nassau, 1980).

The high temperature may have caused lamellae of aluminium oxide to partially segregate, with the resultant appearance of an adularescent moonstone. Such cabochons were in fact posed as star moonstone simulants, but there was little market for such products when moonstones themselves from Sri Lanka cost very

Figure 2: A biaxial interference figure in the polariscope is useful for confirming the identity of moonstone. Photo by A. Hodgkinson.



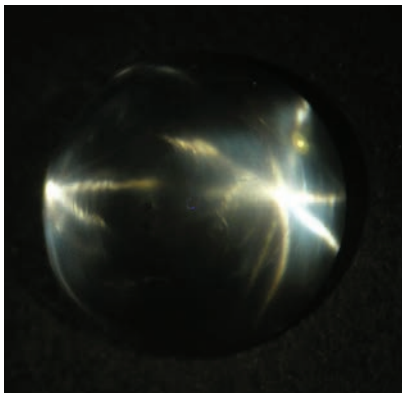


Figure 3: Various numbers of rays are shown by the asterism in the 6.08 ct heat-treated synthetic spinel. Photo by A. Hodgkinson.

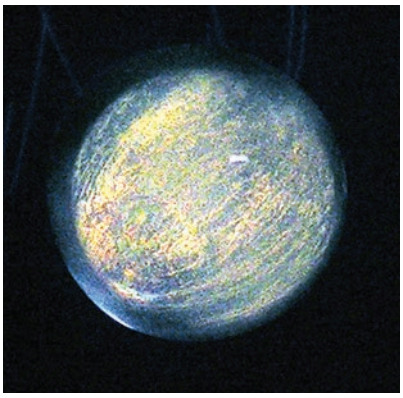


Figure 4: A random birefringence pattern, possibly due to strain or the exsolution of a second phase, is seen when the 6.08 ct synthetic spinel cabochon is viewed with cross-polarized light. Photo by A. Hodgkinson.

little during that period in the late 1940s–50s.

The variable-ray stars in such products may be the result of the exsolved lamellae of an aluminium-rich phase within the synthetic spinel host. This created multi-random reflective mechanisms, and so, as the light source and/or specimen is manoeuvred, the light paths within the specimen will reflect. The cabochon cut then acts as a convex lens to focus the reflections in various directions to the dome surface, hence the random and unpredictable nature of the star formations.

Readers may wonder why valuable crystal-growth resources would be targeted toward simulating such an inexpensive gem as moonstone. During World War II, Germany was nearly starved of the crucial commodity of industrial diamond, essential to keep the wheels of war turning. The friction obstacle found in all bearings—especially those deployed in aircraft—required very hard and tough materials to offset wear and abrasion. This resulted in much effort and expense that was funded primarily by the German Luftwaffe (air force). Central to the German effort, Prof. W. Eppler at the University of Strasbourg experimented with heat/annealing processes to increase the wear resistance of both synthetic spinel and synthetic sapphire (Steindorff, 1947). To test this, he devised a sandblast wear-resistance and hardness test, based on loss of weight of a standard polished sample. Incredibly, in some cases he was able to increase the wear resistance of synthetic spinel to a greater factor than that of synthetic sapphire. The benefit of this to Germany was immense, as it minimized the need for industrial diamond powder.

The point of interest here is that the experiments involved controlled heating sequences. Apart from the successes of such work, there would have been experiments that did not yield the desired results for hardening the heated material, and it is fair to assume that such items would be rejected. By chance, Prof. Eppler was also head of the Technical Gem Cutting School at Idar-Oberstein, and it is therefore understandable that such reject material would find its way onto their faceting laps and, in the case of cabochons, the by-product had a moonstone appearance with the bonus of also having asterism.

To put this article in some perspective, it should be mentioned that one of the two factories charged with growing such synthetic spinels, Wiedes Carbidwerk at Freyung, produced 4,000,000 carats of synthetic spinel per month (Anonymous, 1948). It is little wonder that such moonstone imitations should now turn up on occasion! However, they are straightforward to identify with standard gemmological instruments—and a knowledge of their existence.

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Gem Notes

COLOURED STONES

Red Beryl in Matrix, Cut as Cabochons

It is always interesting to see innovative uses of gemstone raw materials, particularly for high-value gem varieties. During the 2017 Tucson gem shows, this author saw one such example—for red beryl from the Wah Wah Mountains of southwest Utah, USA. The Ruby Violet mine was the only commercial source of gem-quality red beryl, but it closed several years ago, making this very rare beryl variety even rarer.

Figure 1: These cabochons (8 × 6 mm each) are cut from red beryl interspersed with its associated altered rhyolite matrix. Photo by Jeff Scovil.

At the booth of Robert and Patricia Van Wagoner (Beija-flor Wholesale, Haiku, Hawaii, USA), there were dozens of calibrated cabochons cut from red beryl in matrix (e.g. Figure 1). Various patterns were displayed by the light-coloured, altered rhyolite matrix against the deep red-to-pink beryl, ranging from random-appearing intergrowths to linear patterns that resulted from the crystallization of the red beryl along thin veinlets in the host rock (see, e.g., Figure 9 of Shigley et al., 2003). The cabochons were cut in various shapes (round, pear and oval), and ranged from 4 mm in diameter to 9 × 7 mm. Although it is common for red beryl to be clarity enhanced, these cabochons reportedly were untreated.

Brendan M. Laurs FGA

Reference

Shigley J.E., Thompson T.J. and Keith J.D., 2003. Red beryl from Utah: A review and update. *Gems & Gemology*, **39**(4), 302–313, http://dx.doi.org/10.5741/gems.39.4.302.

Ceruleite from Chile

Ceruleite is a blue hydrous copper aluminium arsenate, $Cu_2Al_7(AsO_4)_4(OH)_{13} \cdot 12(H_2O)$, that is rarely encountered as a gemstone. Although originally described in 1900 from Chile, gem-quality ceruleite was first documented from Bolivia by Schmetzer et al. (1978). Subsequently, gem-quality material from Chile was mentioned by Schmetzer et al. (1983). Like turquoise, ceruleite is typically polished as cabochons. At the 2016 Tucson gem shows, we encountered ceruleite from Chile that was faceted and contained various impurities. The stones were offered by Mauro Pantò (The Beauty in the Rocks, Sassari, Italy), who had approximately 20 pieces weighing 1.0–2.5 ct. Pantò indicated the rough material came from Mina El Guanaco in the Taltal area of the Antofagasta Region, Chile. He kindly donated a 1.45 ct stone to Gem-A, and it was examined by authors CW and BW.

The gem was cut in a modified octagonal shape and measured 7.15 × 6.90 × 5.02 mm (Figure 2). It was opaque and showed an overall intense blue colour (World of Color 5B 7/8), with some dark brown, white and green areas corresponding to impurities. The RIs could not be obtained, probably due to the stone's poor polish. The hydrostatic SG was 2.69, which is lower than the value of 2.80

Figure 2: This 1.45 ct stone consists of intense blue ceruleite with dark brown, white and green impurities. Gift of Mauro Pantò; photo by B. Williams.

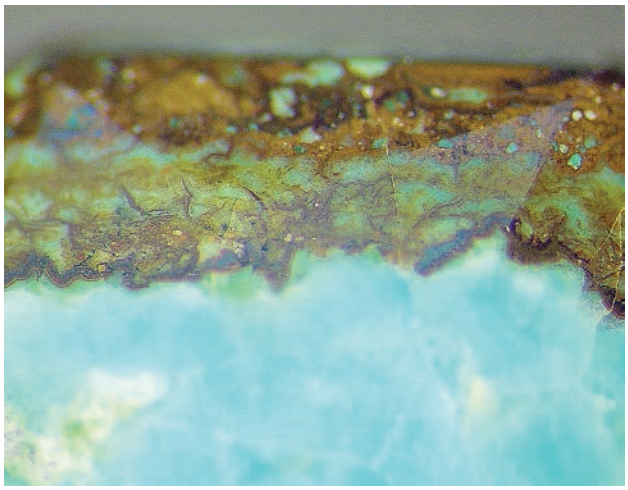

Figure 3: This closer view of the pavilion side of the stone in Figure 2 shows the veined appearance of the iron staining and associated matrix material, as well as the green and white impurities in the ceruleite. Photomicrograph by C. Williams; magnified 50×.

typically reported for ceruleite, but is similar to the SG of 2.70 determined by Schmetzer et al. (1978) on polycrystalline mater-ial. The blue areas of the sample were confirmed as ceruleite using an Enwave 785 Raman spectrometer, by comparing the spectra to the RRUFF database.

Microscopic observation of the blue areas revealed a polycrystalline texture, while the dark brown areas showed vein-like patterns (e.g. Figure 3) that resembled the iron-stained matrix commonly seen in turquoise and the white areas locally contained tiny open vugs. According to analytical work done by German mineralogist Gunnar Farber, the green inclusions consist of schlossmacherite, a sulphate mineral of the alunite group with the formula $(H_3O)Al_3(SO_4)_2(OH)_6$.

The reported hardness of 5–6 on the Mohs scale makes ceruleite sufficiently durable for cutting and use in jewellery. Like turquoise, however, it may be sufficiently porous to require stabilization. Schmetzer at al. (1983) documented plastic-impregnated ceruleite, which was easily identified because its SG was distinctly lower (2.58) than that of untreated material, and infrared spectroscopy showed a diagnostic absorption band at 1725 cm^{-1}, as seen in stabilized turquoise.

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Yellow Danburite from Namalulu, Tanzania: Gemmological Properties and Chemical Composition

Danburite is a calcium borosilicate [$CaB_2(SiO_4)_2$] that is an uncommon collector's stone. It typically ranges from colourless to light brown or light yellow, although less commonly it can exhibit intense yellow coloration. In early 2008, significant amounts of gem-quality yellow danburite entered the market, mined from granitic pegmatites in the Morogoro region of central Tanzania (Chadwick and Laurs, 2008). A few years later, another deposit of yellow danburite was discovered near

Figure 4: These two vivid yellow danburites (8.72 and 7.86 ct) are from the Namalulu area of north-east Tanzania. Courtesy of the Somewhere In The Rainbow Collection; photo by Bilal Mahmood, AGL.

Namalulu village in north-east Tanzania. According to a Tanzanian supplier of this material to gem dealer Werner Radl (Mawingu Gems, Niederwörresbach, Germany), mining of the Namalulu deposit began in 2012, and production consisted of hundreds of kilograms of mainly tumble- and cabochon-grade material, as well as several kilograms of facet-grade rough.

Since 2014, one of the authors (CPS) has examined a number of the vivid yellow danburites from Namalulu, ranging from less than 1 ct to more than 18 ct (e.g. Figure 4). Their standard gemmological properties were: RIs—n_α = 1.628–1.629, n_β = 1.631–1.634 and n_γ = 1.634–1.637; birefringence—0.006–0.008; hydrostatic SG—2.97–3.01; and fluorescence—inert to both long- and short-wave UV radiation. These data for Namalulu danburite are consistent with the material from Morogoro reported by Chadwick and Laurs (2008). Microscopic features consisted of small colourless crystals, pinpoint particles, series of fine etch tubules, open fractures with a frosted surface appearance and partially healed fissures. (The absorption spectra and colour stability of Namalulu danburite are described in the following Gem Note entry.)

We measured the chemical composition of three samples of faceted yellow danburite from Namalulu, as well as three faceted yellow danburites from Myanmar for comparison. Energy-dispersive X-ray fluorescence (EDXRF) spectroscopy was performed on one sample each from Tanzania and Myanmar with a Thermo Scientific Quant'X instrument, using a series of seven excitation energies from 4 to 50 kV (SSEF silicate routine). Laser ablation inductively coupled plasma mass spectroscopy (LA-ICP-MS) was performed on all samples with a GeoLas 193 nm excimer laser, coupled with a PerkinElmer Elan 6100 DRC mass spectrometer (see Table I footnote for details of the procedure).

EDXRF spectroscopy revealed the expected major elements Si and Ca; B could not be measured due to limitations of the technique for detecting light elements. In addition, low concentrations of Sr were detected in samples from both Tanzania and Myanmar. The trace-element data obtained by LA-ICP-MS are shown in Table I; overall, the analysed specimens had similar compositions. Rare-earth elements (REE) were present in all the samples, with a general enrichment of light REEs (La, Ce, Pr, Nd and Sm), as also found by Huong et al. (2016) in danburite samples from Tanzania, Vietnam and Mexico. Our data for the Namalulu danburites were similar to the selected elements reported by Chadwick and Laurs (2008). However, our Tanzanian danburites contained higher concentrations of heavy REEs (including Y) compared to the samples from Myanmar.

Due to the fact that elements with even atomic numbers are naturally more abundant than those with odd atomic numbers (so-called Oddo-Harkins rule), REE data are often plotted in a diagram normalized to a chondrite standard (stony meteorite; data from Anders and Grevesse, 1989). This diagram for our samples clearly shows the higher abundance of heavy REEs in danburite from Tanzania compared to the Burmese samples (Figure 5). The so-called europium anomaly, a deficiency or enrichment of Eu relative to the other REEs^{3+}, is a common feature in minerals and rocks, and is linked to the fact that this element can be found in two valence states: Eu^{3+} and Eu^{2+} (Weill and Drake, 1973). The danburites from Tanzania were characterized by a distinct negative Eu anomaly, whereas two of the three Burmese samples showed no such anomaly. However, the presence of an Eu anomaly in one of the Burmese samples precludes the use of this element for separating danburites from these two localities.

*Table I: Average trace-element concentrations in danburite analysed by LA-ICP-MS.**

Origin	Tanzania			Myanmar		
Weight	**2.10 ct**	**2.93 ct**	**3.01 ct**	**1.50 ct**	**1.60 ct**	**1.70 ct**
Element						
Be	188 (5)	169 (4)	136 (1)	81.3 (22.3)	29.8 (4.2)	202 (11)
Na	11.8 (0.2)	13.5 (0.1)	10.1 (0.4)	164 (56)	24.2 (1.4)	156 (8)
Mg	4.56 (0.43)	5.55 (0.58)	4.60 (0.22)	5.38 (0.32)	4.91 (0.18)	4.98 (0.46)
Al	178.8 (0.6)	129.3 (0.4)	146.9 (1.0)	89.6 (20.5)	474 (53)	82.9 (1.4)
P	29.3 (5.0)	36.8 (3.0)	28.2 (0.7)	39.8 (0.9)	31.3 (5.0)	36.5 (6.2)
K	<2.0	<1.4	<1.5	1.60 (0.12)	<2.5	5.5 (0.9)
Sc	0.66 (0.08)	0.78 (0.04)	0.39 (0.12)	0.80 (0.12)	0.68 (0.10)	0.49 (0.03)
Ti	<18	<6.0	14.8 (1.5)	<6.3	<20	<19
Mn	1.35 (0.19)	0.50 (0.08)	<0.6	<0.45	1.56 (0.12)	<0.8
Fe	25.7 (3.8)	26.5 (2.1)	21.3 (3.0)	31.3 (3.4)	23.1 (3.2)	25.2 (3.9)
Ga	5.89 (0.62)	10.07 (0.22)	4.07 (0.38)	2.19 (0.27)	4.60 (0.12)	5.08 (0.70)
Ge	7.38 (0.24)	6.75 (0.46)	7.07 (0.17)	2.14 (0.17)	3.42 (0.28)	2.48 (0.31)
Sr	343 (2)	203 (1)	181 (2)	612 (38)	226 (20)	1037 (12)
Y	19.2 (0.3)	13.04 (0.09)	14.68 (0.23)	1.48 (0.14)	5.99 (0.81)	2.11 (0.03)
Sn	2.05 (0.15)	1.63 (0.13)	2.00 (0.14)	1.44 (0.26)	2.33 (0.60)	2.01 (0.09)
Ba	<0.22	<0.14	<0.20	1.75 (0.32)	<0.25	9.89 (0.74)
La	192 (3)	333 (1)	99 (2)	84 (6)	157 (26)	234 (5)
Ce	297 (4)	475 (1)	203 (3)	95 (8)	229 (19)	266 (4)
Nd	68.6 (0.8)	91.0 (0.3)	62.4 (0.6)	24.7 (1.6)	42.7 (1.7)	57.4 (2.3)
Eu	0.84 (0.03)	0.61 (0.02)	0.56 (0.03)	0.74 (0.13)	0.26 (0.01)	1.32 (0.03)
Gd	7.33 (0.20)	6.00 (0.12)	5.91 (0.14)	1.19 (0.21)	2.47 (0.32)	2.10 (0.07)
Dy	3.17 (0.04)	2.16 (0.08)	2.58 (0.09)	0.40 (0.01)	1.00 (0.10)	0.55 (0.07)
Er	0.96 (0.09)	0.65 (0.01)	0.83 (0.01)	0.077 (0.002)	0.32 (0.04)	0.10 (0.01)
Yb	0.50 (0.09)	0.32 (0.02)	0.52 (0.03)	<0.08	0.12 (0.03)	<0.14
Lu	0.055 (0.003)	0.035 (0.004)	0.062 (0.007)	<0.01	<0.02	<0.02
Pb	8.34 (0.11)	11.04 (0.09)	19.16 (0.46)	6.12 (0.51)	7.26 (0.27)	5.82 (0.06)
Th	1.39 (0.08)	0.438 (0.012)	0.54 (0.015)	0.009 (0.004)	<0.007	0.024 (0.003)

* Three analyses were done on the polished girdle of each sample, using a 60 µm spot size. Values are shown in parts per million by weight, and standard deviations are given in parentheses. The raw data were standardized using NIST 610 glass as an external standard and Si as an internal standard. Before each analysis, a short pre-ablation was performed with the laser to avoid surface contamination effects. The concentration calculation of the transient LA-ICP-MS signals was carried out with SILLS data reduction software (Guillong et al., 2008). The isotopes were carefully selected to ensure there were no interferences, and special care was taken in the data processing to correct for any artefact (spike) or contamination (surface or inclusions). The following elements were analysed but were below the detection limits: Li, V, Cr, Co, Ni, Cu, Zn, Rb, Zr, Nb, Mo, Sb, Hf, Ta, W, Bi and U; not analysed were the REEs Pr, Sm, Tb, Ho and Tm.

Nevertheless, the analysed samples from Myanmar and Tanzania could be effectively distinguished by plotting the concentrations of the elements Gd, Dy and Ge (Figure 6).

Acknowledgements: The authors thank Prof. Dr Christoph A. Heinrich and Dr Markus Wälle from the Institute of Geochemistry and Petrology at the Federal Institute of Technology, ETH Zurich, Switzerland, for the LA-ICP-MS analyses. For the loan of samples, the authors thank Dudley Blauwet (Dudley Blauwet Gems, Louisville, Colorado, USA), Bill Barker (Barker & Co., Scottsdale, Arizona, USA) and Shelly Sergent (Somewhere In The Rainbow Collection, Scottsdale). Useful background information on Tanzanian danburite was provided by Bill Barker and by Werner Radl.

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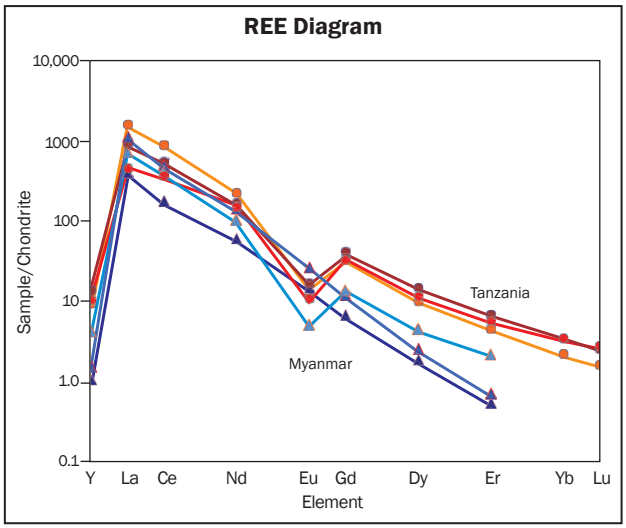

Figure 5: This chondrite-normalized REE diagram of the danburite samples analysed by LA-ICP-MS reveals their general enrichment in light REEs (La to Sm). The three specimens from Tanzania show distinctly higher amounts of heavy REEs (Gd to Lu) than the Burmese samples. All but two of the samples (from Myanmar) show a negative Eu anomaly.

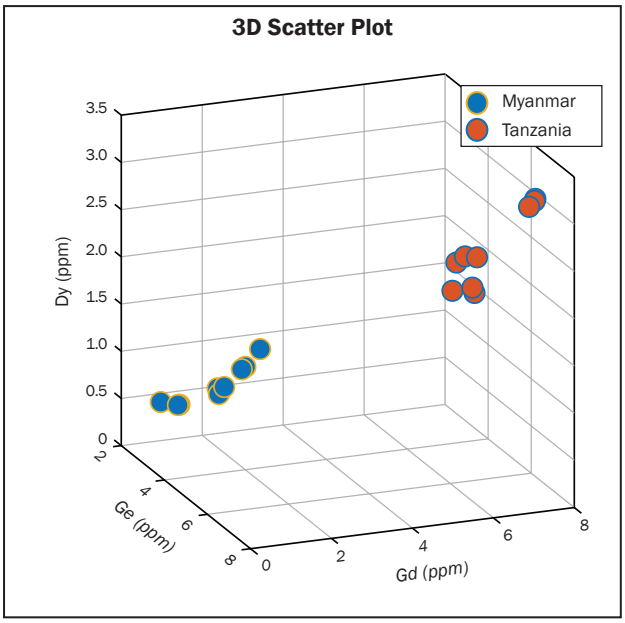

Figure 6: The analysed danburites from Myanmar and Tanzania are clearly distinguished in this three-dimensional scatterplot of germanium, gadolinium and dysprosium.

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Yellow Danburite from Namalulu, Tanzania, and Myanmar: Origin of Colour and Its Stability

The origin of the yellow colour in danburite is not fully known. However, some researchers have speculated that it may be due to didymium, a name referring to a mixture of light REEs including praseodymium (Pr) and neodymium (Nd), and sometimes cerium (Ce). These and other REEs can replace Ca^{2+}.

When viewed with a desk-model spectroscope, typically no absorption features were observed for yellow danburites from Tanzania and Myanmar (see preceding Gem Note for sample descriptions). However, in the larger and more intensely coloured samples, a very faint line at approximately 584 nm could be seen. Using a Perkin-Elmer Lambda 950 spectrometer, several weak bands were recorded in the visible region at approximately 525, 567, 577, 584, 732, 744 and 792 nm, as well as two dominant bands in the UV region positioned at approximately 275 and 315 nm (Figure 7).

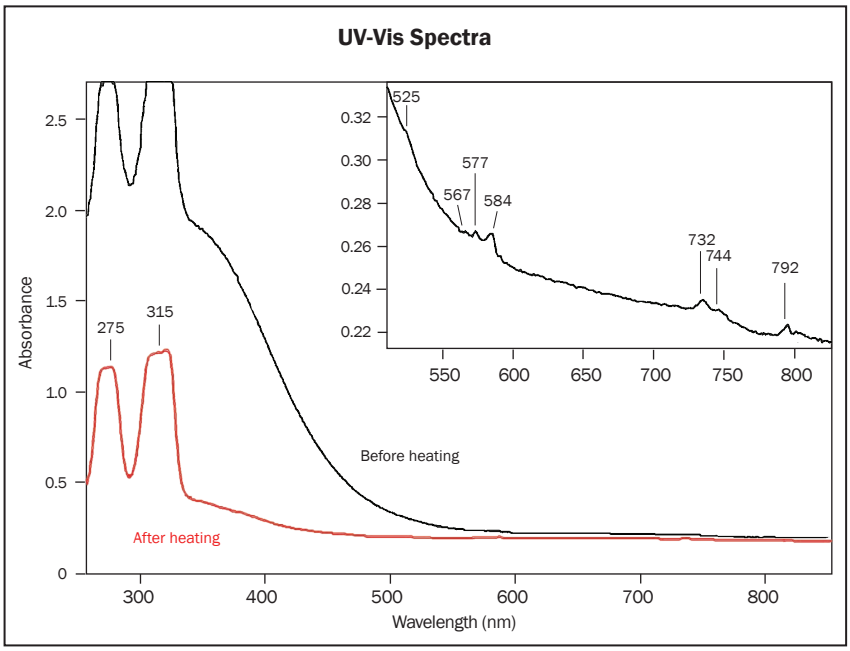

Figure 7: UV-Vis-NIR spectra (5.4 mm path length) are shown for a rough sample of Namalulu danburite, before and after heating. The spectrum before heating shows a general increase in absorption beginning just below 600 nm, as well as two dominant bands in the UV region positioned at approximately 275 and 315 nm. After heating, the yellow sample became colourless with a corresponding decrease in absorption from the visible to the UV region of the spectrum; the bands in the UV region remained unchanged. A series of weak absorption bands positioned at approximately 525, 567, 577, 584, 732, 744 and 792 nm (see inset) appeared to be unaffected by heating.

Although we assume that lanthanides (REE with atomic numbers 57–71) are responsible for the colour of these danburites, we could not find a direct correlation between the yellow colour saturation and the REE concentration in the studied samples from Tanzania and Myanmar. The colour intensity may therefore be linked to variable ratios of the valence states of certain lanthanides (e.g. Ce^{2+}, Ce^{3+}, Ce^{4+}), in addition to their concentration.

To test the colour stability of yellow danburite, one of the authors (CPS) heated one rough sample each from Tanzania (Figure 8a) and Myanmar to 500°C for four hours, and both showed a complete loss of colour (e.g. Figure 8b). The samples were then heated further to 950°C for a period of 24 hours, but they remained colourless. Ultraviolet-visible-near infrared (UV-Vis-NIR) absorption spectroscopy was performed on the samples before and after heating. In their unheated state, the yellow danburites showed a significant rise in general absorption from roughly 550 nm leading into the UV region of the spectrum (again, see Figure 7). After heating, this absorption was greatly reduced. The mid-infrared spectra (taken with a Thermo Scientific Nicolet 6700 spectrometer) were virtually unaffected by heating, although a band at 3588 cm^{-1} did appear slightly diminished. Additionally, no apparent changes were noted in Raman or photoluminescence spectra (recorded with a Renishaw InVia spectrometer equipped with a 514 nm Ar-ion laser) in the samples after heating.

We did not perform experiments specifically to restore the yellow colour in the danburite

Figure 8: A rough yellow danburite from Namalulu, Tanzania, (a) was heated to 500 °C for four hours, resulting in a complete loss of colour, and the sample remained colourless after further heating to 950 °C for 24 hours (b). For another test, one bead of Namalulu danburite was kept as a reference sample, while another bead was exposed to a tensor lamp for eight hours (c, left and right samples, respectively). After three hours, the bead exposed to the lamp darkened and became more brownish. Photos by Bilal Mahmood (a, b) and C. P. Smith (c).

samples, but exposure of Burmese danburite to X-rays is known to induce a yellow or 'golden' brown colour (Webster, 1953); the stability of the induced colour was not reported.

Gem dealers who have handled danburite from the two localities in Tanzania (Morogoro and Namalulu) have noted a significant difference in their colour stability to sunlight. While the Morogoro material appears stable, Namalulu danburite develops a darker brownish yellow coloration after exposure to sunlight (Werner Radl and Menahem Sevdermish, pers. comm., 2016). To test this, author CPS exposed a yellow danburite from Namalulu to a tensor lamp (positioned 15 cm from the stone) for eight hours and checked hourly for any changes in colour. After approximately three hours, its colour had become slightly more saturated, yet distinctly more brownish (Figure 8c). After the full eight hours, its colour did not change further. No experiments were performed in an attempt to restore the original coloration, but according to Radl this change in colour is permanent and irreversible under normal conditions of display or wear. He added that mining for the Namalulu danburite has stopped in recent years due to lack of commercial interest as a result of the susceptibility to develop a brownish coloration.

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New Production of Emerald from Ethiopia

Ethiopia has been known as a source of emerald for many years, but recently it produced some high-quality material (see, e.g., Figure 9 and Renfro et al., 2017) and some fine stones were displayed by various dealers during the 2017 Tucson gem shows. One vendor, Mahesh Agarwal (Stone International, Jaipur, India), reportedly obtained approximately 1,000 carats of faceted stones (150–200 pieces) that ranged up to 21.70 ct. The emeralds were cut from selected pieces of a parcel weighing several kilograms that was mined since September 2016 in the Shakiso region of southern Ethiopia. In addition, Agarwal has obtained ~300 kg of low-to-medium quality rough material. He indicated that the faceted stones were untreated except for light oiling (with mineral oil), as is typically done for coloured stones after they are cut in Jaipur.

Figure 9: These emeralds (total weight 23.60 carats) reportedly were produced recently from Ethiopia and were on display at one of the 2017 Tucson gem shows. Courtesy of Mahesh Agarwal; photo by B. M. Laurs.

Figure 10: A miner searches for emeralds in a narrow shaft in the Kenticha area of Ethiopia. Photo by Dr Klaus Schollenbruch, © Gübelin Gem Lab.

According to gem dealer Hussain Rezayee (Rare Gems & Minerals, Los Angeles, California, USA), the recent emerald production took place in the Kenticha area, which is located approximately 40 km south of Shakiso. A series of shallow pits and shafts (up to a few metres deep; e.g. Figure 10) have been dug by about 500 miners in search of emerald. Production from the area

Figure 11: Amde Zewdalem holds a large emerald crystal that he indicated was mined recently in Ethiopia. The sample was previously sliced in two places to extract facetable areas, so the original crystal was somewhat longer. Photo by B. M. Laurs.

has averaged 30–40 kg of mine-run emerald per week, and about 5% of it is gem quality.

The gemmological and chemical properties of these schist-hosted emeralds were described by Renfro et al. (2017), who reported that they could be separated from those of Zambia and Brazil by their trace-element contents (i.e. Cs, Li, Rb, Sc and Rb, analysed by LA-ICP-MS). In addition, Cevallos et al. (2012) documented the gemmological and chemical properties of earlier Ethiopian emerald production, reportedly from the Dubuluk' area, which is ~70 km south-west of Kenticha. Cevallos et al. (2012) mentioned that during a buying trip to Ethiopia in 2011, gem dealer Farooq Hashmi (Intimate Gems, Glen Cove, New York) was told that the Dubuluk' area has produced emeralds for a few years. More recently, in September 2013, Hussain Rezayee informed one of us (BML) about some additional production of emeralds from the Shakiso region, including some large crystals—although they contained only small areas that were transparent enough for faceting. During the 2017 Tucson gem shows, Amde Zewdalem, an Ethiopian gem dealer living in Jacksonville, Florida, USA, indicated that some large stones likewise have been produced during the most recent mining (i.e. Figure 11).

The area hosting emerald deposits in southern Ethiopia appears quite extensive, and it seems likely that additional commercially significant production will take place there in the future.

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Vivid Purplish Pink Fluorite from Illinois, USA

The Illinois-Kentucky Fluorspar District in the east-central USA was a famous producer of beautiful specimens of fluorite and associated minerals from the early 1800s until 1995, when the last operating mine was closed (Goldstein, 1997). Fluorite from this area shows a wide variety of colours, with the most common being purple, yellow and colourless (often as zoned crystals); blue and green are less common, and pink is rare (Smath, 2010).

It was surprising, therefore, to encounter vivid purplish pink fluorite from Illinois (e.g. Figure 12) at the 2017 Tucson gem shows. The stones were offered by Paul Cory (Iteco Inc., Powell, Ohio, USA), who had 90 gems cut from a single large piece of rough that was mined some years ago near Cave-In-Rock, Hardin Co., Illinois. They ranged from 4 mm in diameter up to ~150 ct, with ~20 stones weighing >1 ct. Although the largest stone was rather included, the next

largest (52.85 ct; Figure 12) was relatively clean, with few eye-visible inclusions. Cory plans to have two more larger-size stones cut from the remaining rough material.

While pink is an unusual colour for fluorite from this famous mining area, such a vivid purplish pink coloration is notable for fluorite from any locality. Cory decided to have the stones cut on occasion of the theme of the 2017 Tucson Gem and Mineral Show®, which was 'Mineral Treasures of the Midwest'; Illinois is one of the states in the American Midwest.

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Figure 12: This 52.85 ct fluorite from Illinois, USA, is notable for its saturated purplish pink colour. It was faceted by Jay Medici (Fredericktown, Ohio). Photo by Jeff Scovil.

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Colourless Forsterite from Vietnam

Gem-quality colourless fosterite (the Mg-rich end member of the olivine group) was recently found in the Luc Yen region in northern Vietnam. Previously, colourless forsterite was described in gem quality only from the Pyaung Gaung (Themelis, 2008) and Dattaw (Krzemnicki and Groenenboom, 2008) mining areas of Myanmar, and from Kukh-i-Lal in the south-western Pamir Mountains of Tajikistan (Kondo, 2008); it is also known from the Embilipitiya region of Sri Lanka (Gamini Zoysa, pers. comm., 2016).

The Vietnamese forsterite occurrence was discovered in July 2016 by a local miner and author RH at the Cong Troi mine near the village of An Phu. This region was influenced by the tectonic movements of South-East Asia during the closing of the Palaeo-Tethys ocean and subsequent Himalayan orogeny. The area consists mainly of metamorphic rocks, including mica schist, marble and granulite gneiss. The marble layers in the Luc Yen area are quite thick (up to 500 m), and locally contain pargasite, sulphides, chlorite minerals and gem-quality spinels of various colours (Chauviré et al., 2015), which are mined from both primary and secondary deposits.

The colourless forsterite described here was found in coarse-grained white marble together with clinohumite, pink spinel, green pargasite and mica. Two pieces of transparent forsterite were separated from the rock and faceted into oval cuts with dimensions of 5.44 × 4.68 × 3.64 mm (0.54 ct) and 5.17 × 4.61 × 3.27 mm (0.44 ct; Figure 13). They had RIs of 1.638–1.670, a birefringence of 0.032 and a hydrostatic SG of 3.25. The identity of both samples was confirmed by Raman spectroscopy (with peaks at 964, 917, 856, 824, 752, 591, 542, 430, 410, 372, 328, 304 and 226 cm^{-1}). Microscopic examination revealed tiny fluid inclusions and two white anisotropic solid inclusions (probably carbonates) in one of the

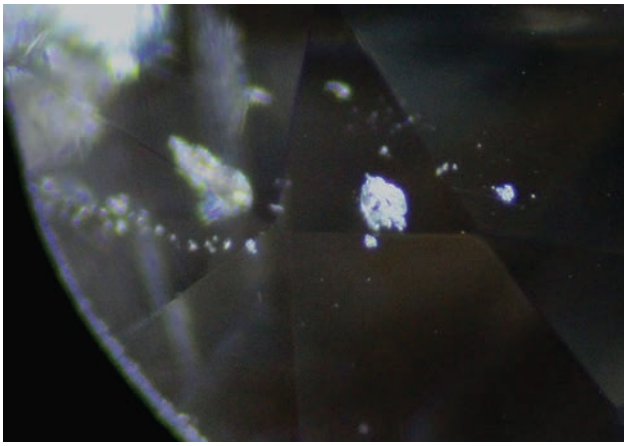
Figure 13: Weighing 0.44 and 0.54 ct, these colourless forsterites are from Cong Troi in the Luc Yen region of northern Vietnam. Photo by R. Hanus and J. Štubňa.

samples (Figure 14). Both stones were inert to long-wave UV radiation and fluoresced weak violet to short-wave UV.

The typical green-yellow colour of peridot (a solid solution between the end members forsterite [Mg_2SiO_4] and fayalite [Fe_2SiO_4]) is caused by Fe^{2+} in octahedral coordination. The colourless appearance of the present forsterite gems is consistent with its Mg-rich end-member composition, which is also indicated by the RI and SG values (cf. Deer et al., 1982). UV-Vis-NIR spectroscopy revealed absorption bands at 645, 668 and 740 nm (Figure 15). By comparison, the typical absorption spectrum of green peridot shows three distinct bands due to iron in the blue region of the spectrum at 453, 473 and 493 nm (O'Donoghue, 2006), which were absent from the colourless forsterite.

This is the first documented occurrence of colourless forsterite in the Luc Yen area of northern

Figure 14: The 0.44 ct forsterite contains colourless crystals and fluid inclusions. Photomicrograph by R. Hanus and J. Štubňa; magnified 90×.



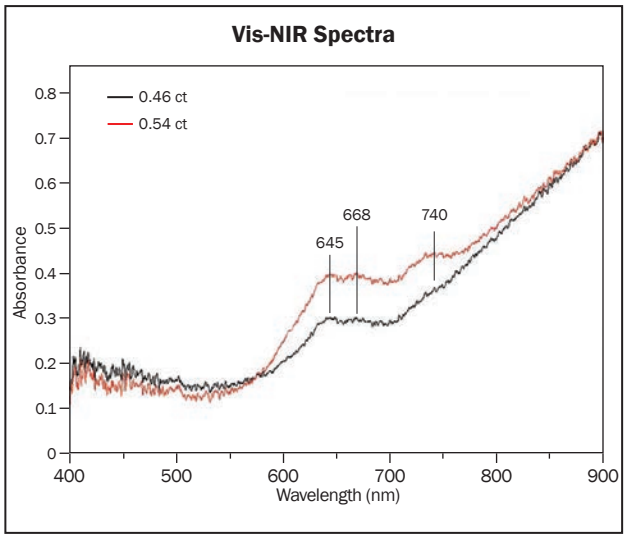


Figure 15: UV-Vis-NIR spectra of the two Vietnamese forsterite samples show absorptions at 645, 668 and 740 nm, but lack the features typically seen in green peridot at 453, 473 and 493 nm.

Vietnam that is known to the authors. It is possible that such forsterite may have been inadvertently sold on the local gem market as microcline, topaz, colourless spinel or quartz. It seems likely that more of this colourless forsterite will be mined in the future.

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New Sapphires from Ambatondrazaka, Madagascar

Madagascar, an island of many gem treasures, saw in recent months another gem 'rush' after the discovery of a new sapphire deposit at Bemainty, located about 35 km east of the small town of Ambatondrazaka (Perkins and Pardieu, 2017). With about 50,000 artisanal miners working the gravels of this alluvial deposit, this new site has so far reportedly produced an impressive amount of mainly blue sapphires, including some large stones up to 30 g of exceptional quality and additionally some orangey pink sapphires. These stones are currently arriving in the gem market in significant quantities, and some of them have been heated to improve their colour and clarity.

SSEF recently analysed a number of sapphires reportedly from this new source ranging from 1.3 ct to 34 ct (Figure 16). Most of the stones showed a rather pure moderately strong to strong blue colour, sometimes with a slight greyish to greenish tint. UV-Vis spectroscopy (Figure 17) showed that they can be separated into two categories, both of metamorphic origin. One group exhibited only small features due to Fe^{3+} that are reminiscent of sapphires from Sri Lanka and Kashmir with slight turbidity. The other group consisted of mostly dark, saturated blue stones with rather distinct Fe^{3+}-related absorption features, as also seen in Burmese sapphires.

Many of the studied specimens exhibited a slight to marked milkiness due to sub-microscopic fine particles in zones and bands (Figure 18a), but only occasionally did they have small rutile needles. Some of these sapphires also showed patches and crossed stripes of coarser particles and very fine kinked dust lines (Figure 18b), somehow reminiscent of Kashmir sapphires. We also observed characteristics found in gem-quality sapphires from other metamorphic-related deposits in

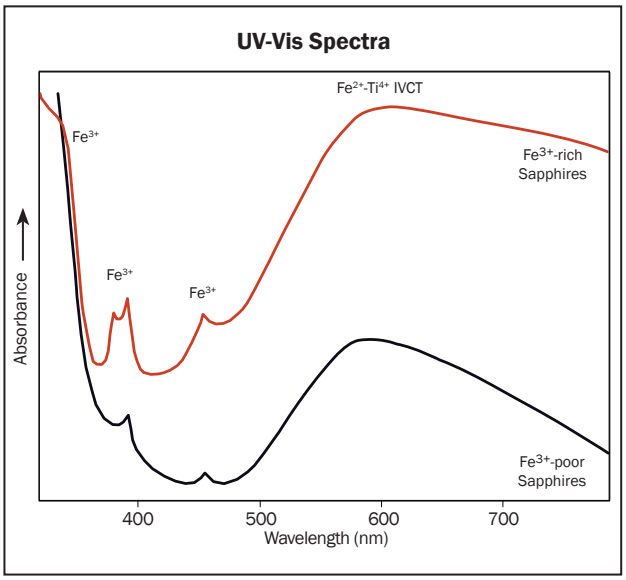

Figure 17: Absorption spectra are shown for the o-ray (i.e. beam oriented perpendicular to the c-axis) of blue sapphires from the new Ambatondrazaka deposit. The spectra were recorded with a portable UV-Vis spectrometer developed by SSEF.

Figure 16: These blue (~1.3–34 ct) and orangey pink (~30 ct) sapphires are representative of some of the stones that were recently studied by SSEF from a new deposit near Ambatondrazaka in Madagascar. Photo by Julien Xaysongkham, SSEF.

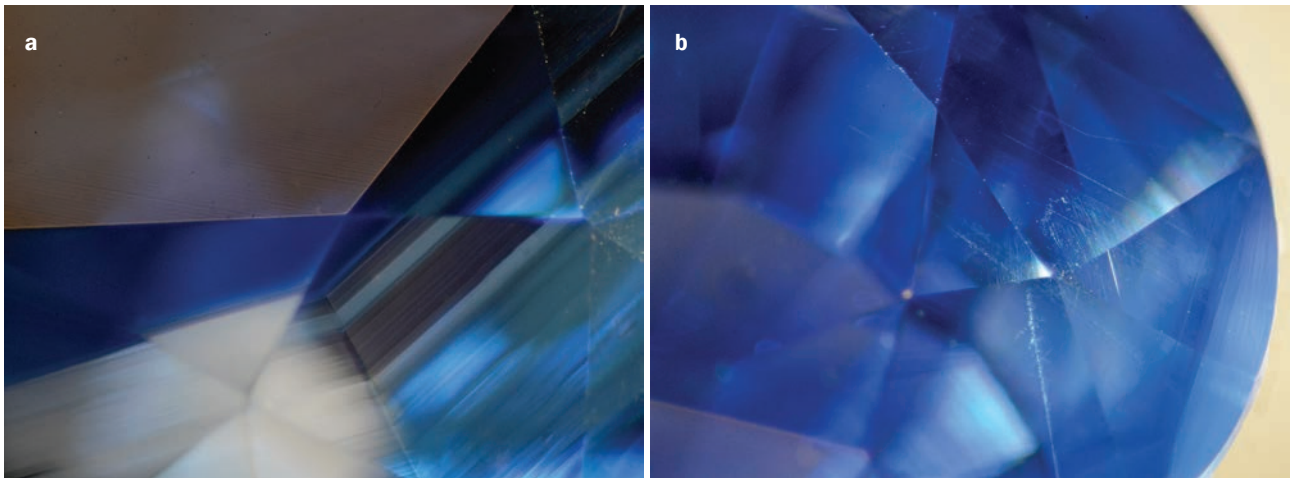

Figure 18: These sapphires from the Ambatondrazaka area contain fine milky banding due to minute particles (a, magnified 35×), as well as crossed stripes of coarser particles and very fine kinked dust lines (b, magnified 45×). Photomicrographs by M. S. Krzemnicki.

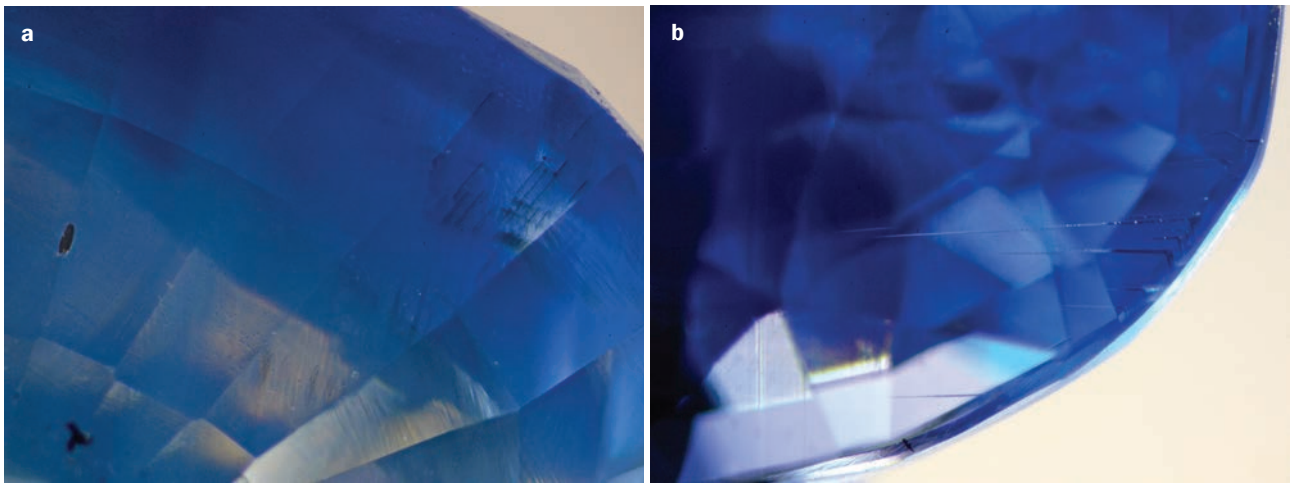

Figure 19: Also seen in the Ambatondrazaka sapphires are: a dense 'chaotic' pattern of growth lines with greyish colour effects (a, magnified 30×) and fine etched hollow channels that emanate from a stone's girdle (b, magnified 50×). Photomicrographs by M. S. Krzemnicki.

Madagascar (e.g. Andranondambo and Ilakaka), such as distinct and narrow growth zoning. This zoning also can produce a 'chaotic' three-dimensional pattern, occasionally showing brownish or greyish colour effects when viewed with transmitted light (seen with brightfield illumination, due to slight variations in refractive index; Figure 19a). A few samples also contained hollow channels that appeared to be etched (Figure 19b). Other features consisted of small colourless prismatic zircon inclusions surrounded by tension fissures and a black flake (presumably graphite) with small comet-like dust trails.

Although the visual appearance of some of these sapphires may resemble those from Kashmir, we did not find in our samples any of the highly characteristic inclusions of Kashmir sapphires, such as pargasite needles, short-prismatic tourmaline and corroded long-prismatic zircon. The dark sapphires rich in Fe^{3+} from this new source were often quite clean, sometimes with zones of short rutile needles associated with irregular platelets. Many of the dark blue sapphires we examined also showed small milky bands and zones, in contrast to Burmese sapphires that typically contain no such features.

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Colour-Change Scorodite from Tsumeb, Namibia

Scorodite is a hydrous iron arsenate with the formula $Fe^{3+}AsO_4 \cdot 2H_2O$. The mineral was first described by Breithaupt (1818), who named it after the Greek word 'scorodion', which means 'garlic' because of the smell of the arsenic vapours produced when heating or grinding the material. The type locality of scorodite is the Asser pit in Langenberg, Saxonia, Germany. Scorodite is a secondary mineral originating from the weathering of arsenopyrite and other arsenic minerals. A significant source of scorodite is the Tsumeb mine in Namibia. This deposit is well-known to geologists, mineralogists and mineral collectors, and of the 288 minerals known from there, it is the type locality for 72 of them (www.mindat.org/loc-2428.html). Mining of the deposit began in 1907, primarily for Cu-Pb-Zn-Ag-Ge-Cd ores. In 1996, when the mine closed, a final depth of 1,000 m had been reached.

Facetable scorodite from Tsumeb was described by Gübelin (1976). Scorodite has a Mohs hardness of only 3½–4 and is rarely found in gem quality, so it is typically considered a collector's stone. In addition, scorodite loses all of its water upon heating to 200–220°C (Gübelin, 1976), which could cause unintended colour and/or stability alterations. Furthermore, the mineral is soluble in various strong acids and in some weak basic solutions (Weiß, 2000).

The authors investigated a translucent, faceted scorodite (6.99–7.07 × 4.36 mm; 1.41 ct), from Tsumeb that attracted attention because of its unusual colour behaviour, which has not been described previously in a faceted sample. Viewed with a daylight-equivalent lamp (6,774 K), the stone appeared dark green (Figure 20a), but it changed to dark greenish blue under a 3,400 K halogen lamp (Figure 20b). With an incandescent lamp or candlelight, the colour changed to violetish red. This change appeared strongest with transmitted incandescent light (Figure 20d). For comparison, Figure 20c shows the greenish blue appearance of the stone in transmitted light from the halogen lamp.

The SG was determined with a hydrostatic balance as 3.29. This is consistent with literature data for scorodite (3.29–3.31). The refractive indices of scorodite are reported as n_x = 1.738–1.786, n_y = 1.742–1.796 and n_z = 1.765–1.814, with a biaxial positive optic character (cf. Henn, 2012). However, it was not possible to determine the RIs of the investigated sample with a standard refractometer because of poor surface polish attributed to its low hardness. Therefore, the identity of the stone was confirmed by Raman spectroscopy. Microscopic observation revealed fissures, partially healed fractures and colourless doubly-refractive mineral inclusions. Qualitative chemical analysis by EDXRF spectroscopy revealed the major elements Fe and As, as well as traces of Al.

In general, the absorption spectra of colour-change minerals show two transmission minima around 476–507 and 625–666 nm, as well as a strong absorption maximum in the 561–578 nm region. Stones that are green in daylight usually change to red in artificial light, while bluish green and blue ones typically change to reddish violet (Schmetzer et al., 1980). An unpolarized absorption spectrum of the 1.41 ct scorodite was recorded with a MAGI GemmoSphere spectrometer. The visible-range spectrum (Figure 21) was characterized by three absorption bands at ~430, 570 and 800 nm caused by Fe^{3+} (Lehmann, 1978); the 430 nm band is not completely visible in Figure 21 because the signal overwhelmed the detector. The 570 nm band is responsible for the colour change; transmission windows on either side of this strong band (located at 480 and 688 nm) correlate to the sample's colour (Figure 20b–d), depending on the spectral composition of the light source. When measured with the daylight-equivalent lamp as the light source, the transmission window located at 480 nm shifted

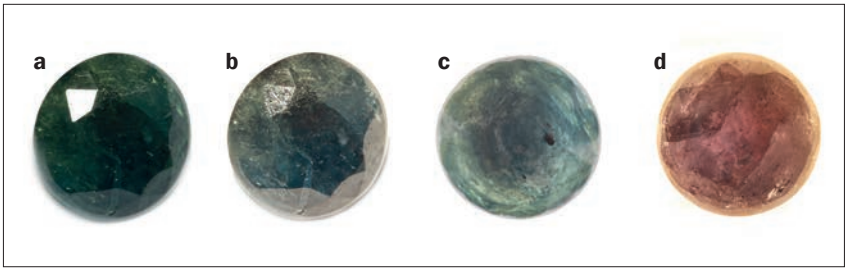

Figure 20: This 1.41 ct scorodite displays different colours in (a) artificial daylight-equivalent light (6,774 K), (b) halogen light (3,400 K), (c) transmitted halogen and (d) transmitted incandescent light (the yellowish hue close to the girdle is an artefact of the light source). Photos by T. Stephan.

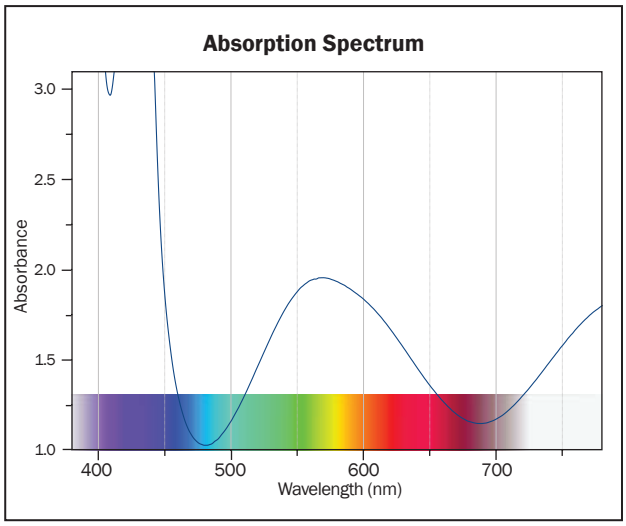

Figure 21: The visible-range absorption spectrum of the investigated scorodite (here, illuminated with an approximately 3,400 K light source) displays distinct transmission windows at 480 and 688 nm that account for the colour change.

to 500 nm, causing the dark green colour shown in Figure 20a.

Usually Cr^{3+} and V^{3+} (and less commonly REEs) are described in the literature as the causes of a colour change in gems (e.g. Schmetzer et al., 1980; Hänni, 1983). The scorodite described here revealed no traces of Cr^{3+} or V^{3+} in EDXRF analyses; also no bands associated with these elements were recorded in the absorption spectrum. Therefore, it appears that Fe^{3+} (and its associated strong absorption band at 570 nm) is the sole cause of the colour change in this scorodite.

Gebhard (1999) also mentioned colour-change scorodite from Tsumeb, and Weiß (2000) described it from Hemerdon in south-west England. Gebhard (1999) described the colour change as greenish blue to blue-green, while the samples documented by Weiß (2000) changed from intense blue in sunlight to grey-blue or grey-yellow in 'artificial' light, pale green in 'neon' light and bright yellowish green in the light of an 'energy-saving' lamp.

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Stichtite as a Gem Material

Stichtite, $Mg_6Cr_2CO_3(OH)_{16} \cdot 4H_2O$, is an attractive purplish pink to purple mineral of the hydrotalcite group that is very soft, with a Mohs hardness of just 1½–2. Nevertheless, because of its attractive colour, this material is sometimes polished as a collector's stone. Such gems commonly are sourced from Tasmania, Australia, and typically consist of compact aggregates of stichtite that form in association with serpentinite, producing striking colour combinations of purple and yellow-green (e.g. Laurs, 2012). Less frequently encountered are nearly monomineralic stichtite gems (e.g. Koivula et al., 2003).

At the 2016 Tucson gem shows, rare-stone dealer Mauro Pantò had approximately 50 nearly monomineralic faceted stichtites (~1.0–2.5 ct) from South Africa. Two regions in South Africa are known to produce stichtite, in Limpopo

and Mpumalanga Provinces (www.mindat.org/min-3784.html); the particular origin of Pantò's stones is unknown. He kindly donated to Gem-A a 1.70 ct faceted hexagon (Figure 22), and it was characterized for this report by authors CW and BW.

The stone was opaque with a pinkish purple colour and a waxy lustre. A faint RI was recorded at approximately 1.54 and SG was measured hydrostatically as 2.11; these values are similar to those reported by Koivula et al. (2003). The sample was inert to both long- and short-wave UV radiation. Microscopic observation revealed a polycrystalline oolitic structure with tiny pearlescent cleavage reflections similar to those commonly seen in amazonite. In addition, small black inclusions were distributed throughout the stone.

Raman analysis with an Enwave spectrometer (789 nm laser) confirmed its identity as stichtite. Chemical analysis with an Amptek X123-SDD EDXRF spectrometer showed major amounts of Cr and also some Fe (possibly present within the dark inclusions). Raman analysis of areas containing the dark inclusions was inconclusive, but the presence of Fe combined with the stone's significant magnetic susceptibility suggested magnetite or chromite; similar-appearing inclusions were identified as chromite in the sample examined by Koivula et al. (2003).

While the low hardness of stichtite does not allow for its common use in jewellery, when cut as a cabochon it may be suitable for pendants and other items that receive gentle wear. Such a pendant was submitted to Stone Group Laboratories in mid-2016, in which stichtite was set with various quartz gems (Figure 23).

Figure 22: This stichtite (1.70 ct) was faceted from material that was mined in South Africa. The low lustre and rounded facet junctions visible at the lower right are consistent with the low hardness of stichtite. Gift of Mauro Pantò; photo by C. Williams.

Figure 23: This pendant containing a 13 × 18 mm-wide cabochon of stichtite was submitted to Stone Group Laboratories in mid-2016. It also is set with pale amethyst, CVD-coated colourless quartz and black onyx, in sterling silver. Photo by B. Williams.

Cara Williams FGA, Bear Williams FGA and Brendan M. Laurs FGA

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DIAMONDS

A Zoned Type IaB/IIa Diamond of Probable 'Superdeep' Origin

Few zoned-type diamonds have been documented, and most are type IIa/IIb (see, e.g., Reinitz and Moses, 1993; Hall and Moses, 2000; Breeding, 2005; Chadwick, 2008). Sunagawa (2001) illustrated a positive image of micro-diamonds on a photographic plate exposed to 253.7 nm (short-wave UV) radiation, and reported that the black-appearing stones corresponded to type IaA diamond (opaque to SWUV), the transparent ones to type II (transparent to SWUV) and the grey samples to mixed types I and II. However, no additional spectroscopic investigations were done on those zoned-type diamonds to confirm their nature.

The Laboratoire Français de Gemmologie (LFG) in Paris recently examined a notable zoned-type 7.28 ct round brilliant diamond. It was graded K colour and VS_2 clarity due to clouds that extended through two-thirds of the stone (Figure 24). The portion that was free of clouds was situated near the culet. Observation of the diamond between crossed polarizing filters revealed parallel graining in most of the sample (Figure 25), while a 'tatami' pattern was seen in the area near the culet. The latter pattern is specific to type II diamonds. The two portions of the sample also differed in luminescence with the DiamondView. A dislocation network typical of type II diamond was visible near the culet, while yellow-emitting graining was seen on a background of blue luminescence in the rest of the stone. The difference in plasticity between the two zones could be seen near their contact (Figure 26); the absence of graining in the type II portion caused it to appear less 'rigid' than its counterpart.

The infrared spectrum taken in transmission through the girdle of the stone showed the presence of type IaB diamond with hydrogen. Photoluminescence spectra taken with 325 and 514 nm excitations at liquid-nitrogen temperature showed marked differences between the two zones (Figure 27). The type IIa zone contained more N-V and GR1 defects than the type IaB zone. In addition, the IaB zone contained 536 and 576 nm defects, which are linked to B-aggregates. The 491 nm centre was detected in the same region, and is often observed in plastically deformed diamonds with the 406 and 423 nm centres (also present here; cf. Collins, 2001; Nadolinny et al., 2009).

This is the first time that a diamond composed of a mixture of types I and II has been documented at LFG. However, Dr Ulrika D'Haenens-Johansson of the Gemological Institute of Amer-

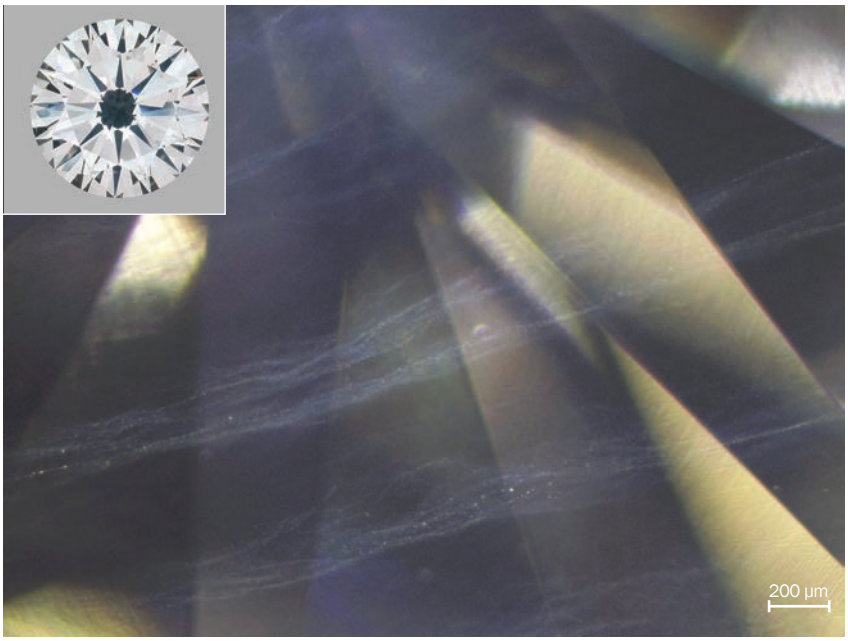


Figure 24: The 7.28 ct diamond (see inset) contains clouds that account for its VS_2 clarity; they are restricted to the type IaB zone of the stone. Photomicrograph by A. Delaunay, © Laboratoire Français de Gemmologie.

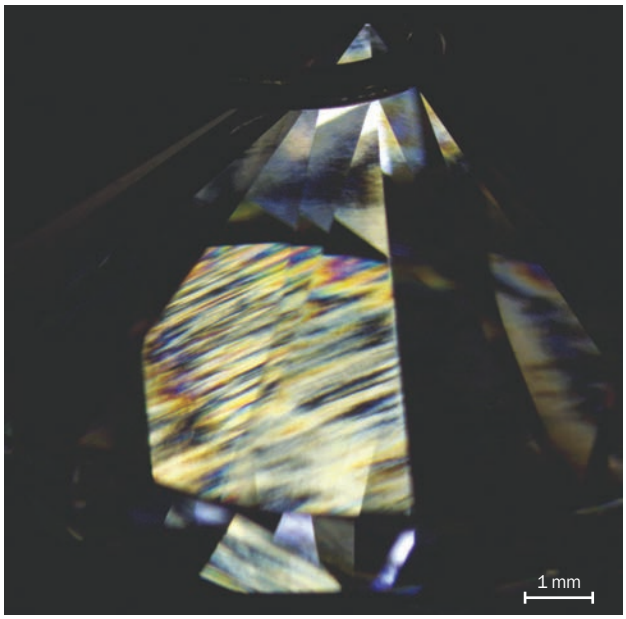


Figure 25: A sharp contrast in anomalous birefringence is seen between the main portion of the diamond, which exhibits parallel graining, and the culet area of the stone. Photomicrograph by A. Delaunay, © Laboratoire Français de Gemmologie.

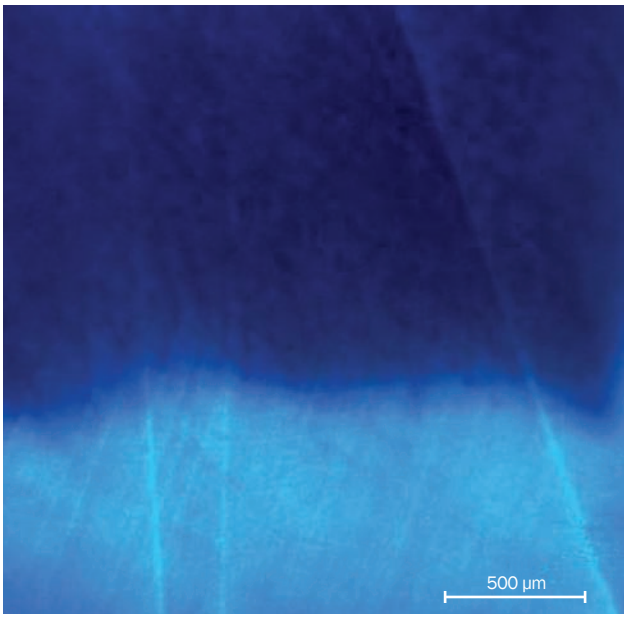
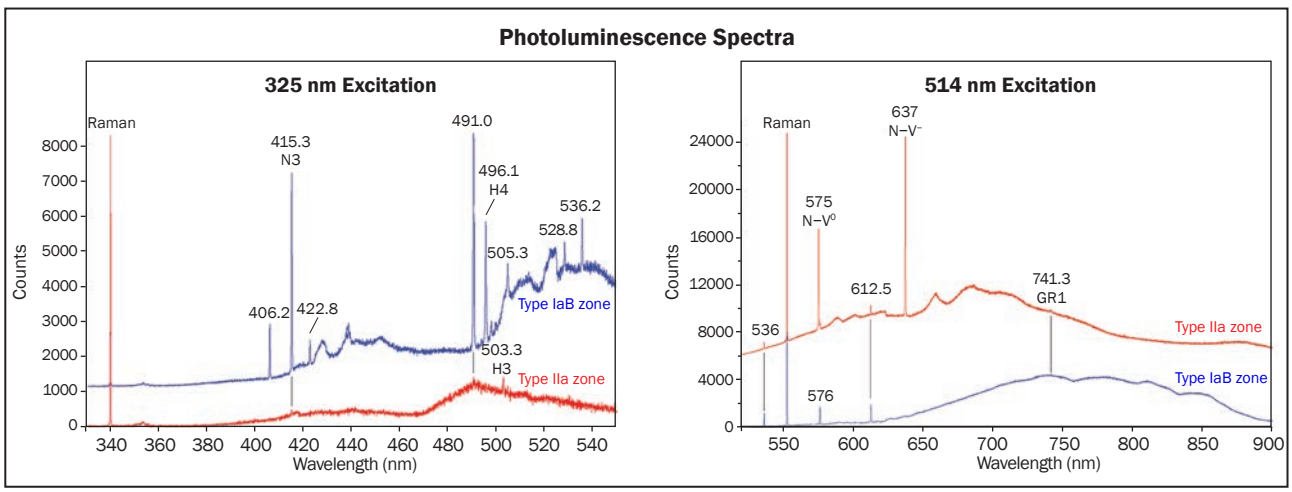


Figure 26: The DiamondView image of the contact between the type IaB and IIa zones of the diamond illustrates how the graining seen in the type IaB portion (bottom) seems to dissolve into the type IIa zone (top). Image by A. Delaunay, © Laboratoire Français de Gemmologie.

ica's New York laboratory indicated to these authors that she has encountered such zoning two or three times (pers. comm., October 2016), but since they were client stones, there was no time for a detailed study. The presence of such zoning proves that the formation conditions of type IIa and IaB diamonds may be similar, such that they can occur in a single crystal. This is also consistent with correlations in the behaviour of type IIa and IaB diamonds, for example, in terms of UV transparency and high-pressure, high-temperature treatment (the rare type IaB diamonds are transparent to SWUV and can be HPHT treated to improve their colour; Deljanin and Fritsch, 2001). Furthermore, the association of type IaB diamond with low-nitrogen type IIa

Figure 27: Liquid-nitrogen temperature photoluminescence spectra of the two zones of the diamond with 325 and 514 nm laser excitation show that the type IaB zone contains numerous defects, such as the 406.2 nm, N3 (415 nm), 491 nm, H4 (496.1 nm), 536 nm, 576 nm, 612 nm and a very weak GR1 (741 nm) centre, whereas the type IIa zone contains only very weak emissions of the N3, H4 and H3 (503.3 nm) centres, a trace of the GR1 (741.3 nm) defect, weaker emissions of the 536 and 612 nm centres, and N-V$^-$ and N-V^0 features (637 and 575 nm, respectively).



diamond showing a high level of nitrogen aggregation, formed under high pressure and temperature conditions, is consistent with 'super-deep' diamonds—those derived from the base of the lithosphere down to about 600 km (see, e.g., Burnham et al., 2016)—rather than about 150 km, where most diamonds form.

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SYNTHETICS

Synthetic Star Ruby with an Unusual Production History

The process for manufacturing synthetic asteriated ruby and sapphire was invented by researchers J. N. Burdick and J. W. Glenn in the late 1940s and was patented by the Linde Air Products Company (Schmetzer et al., 2015). Grown by the Verneuil technique, early samples frequently showed—after annealing to form rutile precipitates—an inhomogeneous distribution of colour and inclusions between the cores and the rims of the boules. In such samples, this zoning of colour and rutile precipitates often caused the resulting six-rayed stars on their surface to appear broken or partially absent in areas where the zoning had depleted the cabochon of titanium (Schmetzer et al., 2015).

In examining historical samples of synthetic asteriated corundum from various collections, one of the authors (KS) recently observed a synthetic star ruby that likewise displayed pronounced zoning but which differed from the more common scenario just described. The sample had been kept in the teaching and reference collection of author LR for several decades, but the original producer is unknown. The cabochon, weighing 4.20 ct, was examined with fibre-optic illumination and in immersion in transmitted light using a gemmological microscope (up to 100× magnification), and at higher magnification (up to 1,000×) with a Leitz Ortholux II Pol-BK polarizing microscope.

In reflected light, the sample showed a typical six-rayed star on its surface and displayed a rather milky appearance (Figure 28a). Conversely, the base of the cabochon consisted entirely of transparent synthetic ruby material, without any milkiness (Figure 28b). Between crossed polarizers and in a view parallel to the optic axis (i.e. approximately perpendicular to the base of the cabochon), the

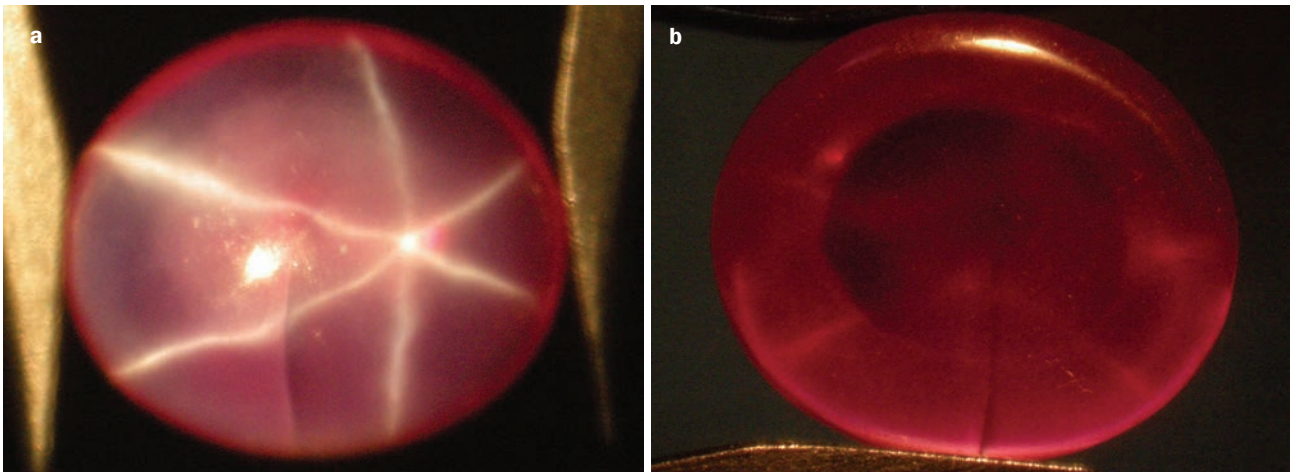


Figure 28: This 4.20 ct synthetic star ruby is shown in two views: (a) toward the milky, translucent dome of the cabochon, and (b) toward the transparent base of the cabochon. The photo of the dome side is focused slightly above the cabochon's surface, where the star appears sharpest. Fibre-optic illumination; photos by K. Schmetzer.

sample showed a series of parallel striations, referred to as 'Plato lines' in gemmological literature (Figure 29). These striations represent glide planes parallel to the second-order hexagonal prism $\{11\bar{2}0\}$ and are caused by internal stress generated during the Verneuil process used for crystal growth.

In views nearly parallel to the base of the cabochon, it became apparent that the sample consisted of two principal parts. The outer portion, comprising the dome of the cabochon, showed a curved structure of sequential shell-like layers. These layers generally followed the external form of the dome. In contrast, the central part of the cabochon, including the central part of the base, revealed curved growth striations that were oblique to the boundary between the core and rim of the sample (Figure 30). Within the rim, but close to the core of the sample, an almost opaque zone with a high concentration of inclusions, mostly in the form of non-transparent, irregularly shaped particles, was present. A further inclusion feature was a fracture that extended through the cabochon from the base to the dome.

At higher magnification, three sets of needle-like precipitates, forming angles of 60° with one another, were visible in the milky rim (Figure 31). The transparent red core was free of such needles.

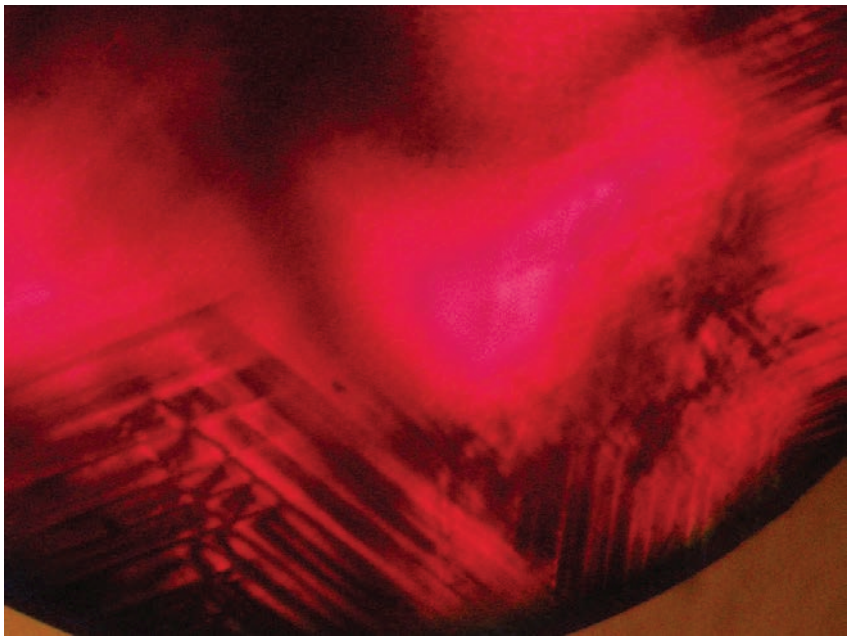


Figure 29: Between crossed polarizers, three series of parallel striations are visible in a view parallel to the optic axis of the synthetic star ruby. These striations (Plato lines) represent glide planes parallel to the second-order hexagonal prism. Immersion, field of view 4.6 × 3.4 mm; photomicrograph by K. Schmetzer.

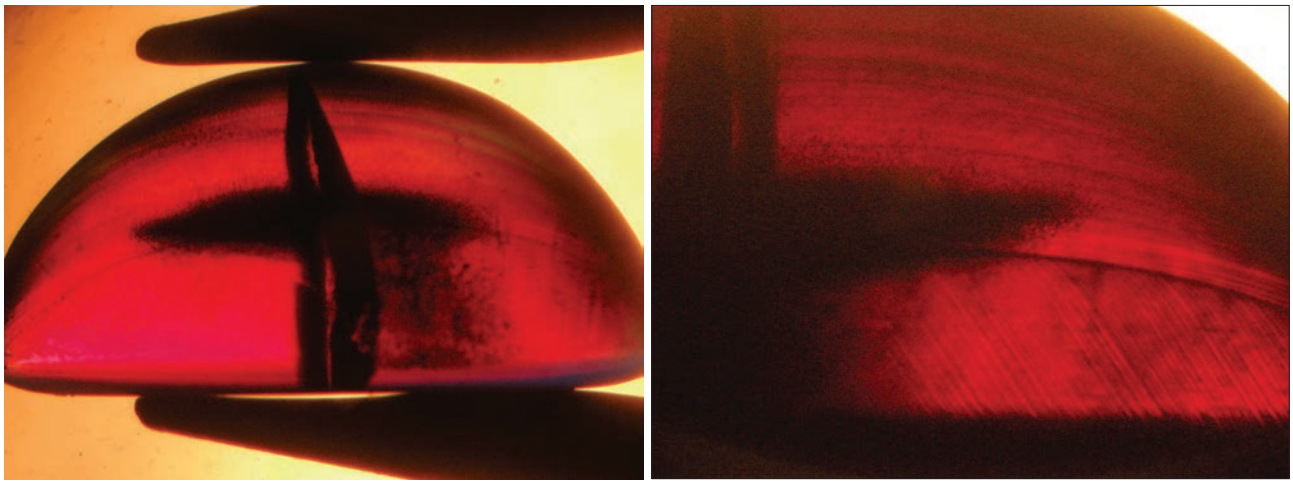
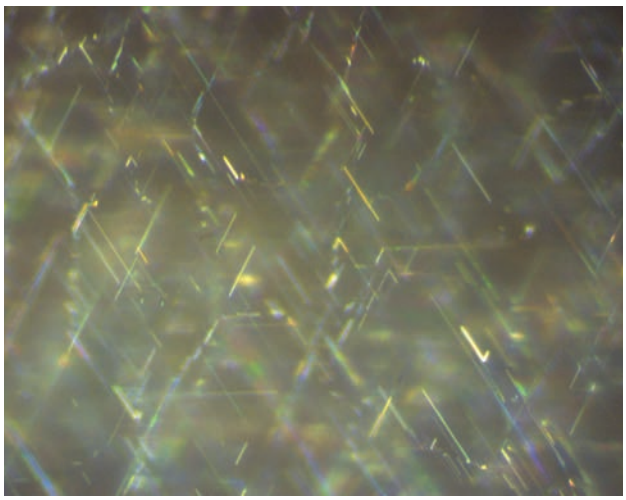


Figure 30: In these views nearly parallel to the base of the synthetic ruby cabochon, the sample can be seen to consist of two principal parts: a Verneuil-grown core of transparent synthetic ruby without rutile needles, and a Verneuil-grown somewhat milky rim of synthetic ruby containing rutile precipitates. In the rim, shell-like layers approximately follow the external form of the cabochon; in the core, curved Verneuil striations are oriented obliquely to the core-rim boundary. Within the rim, close to the core, an almost opaque zone with a high concentration of inclusions is seen. In addition, a fracture runs vertically through the stone. Immersion, field of view 8.8 × 6.5 mm (left) and 7.8 × 5.9 mm (right); photomicrographs by K. Schmetzer.

The foregoing observations thus established that production of this star sample began from a cabochon of transparent Verneuil-grown ruby. That cabochon was used as a seed for the growth of a Verneuil crystal with high Ti concentration, thereby enabling formation of rutile precipitates upon subsequent annealing. Such an approach is analogous to the classical method for manufacturing star corundum, but normally small seeds of oriented natural or synthetic ruby or sapphire are used. The small seeds are then removed when asteriated cabochons were cut for jewellery purposes.

Figure 31: Three sets of rutile needles in the synthetic star ruby cabochon are responsible for the reflection and scattering of light that generates asterism. Reflected light, oil immersion, field of view 92 × 69 µm; photomicrograph by H.-J. Bernhardt.



Oriented seeds are necessary for control of crystal orientation in the Verneuil process, a particularly important factor when the aim is to produce star material. This technique was invented independently in Germany and in the United States in the 1940s (see again, Schmetzer et al., 2015). Without such oriented seeds, the orientation of the Verneuil-grown synthetic ruby and sapphire crystals is unpredictable, and consequently, each crystal must be individually examined to find the optic axis for cutting cabochons with well-centred stars.

In the present case, use of a synthetic ruby cabochon for the seed also explained the high concentration of non-transparent, irregularly shaped inclusions near the boundary between the core and rim portions. These inclusions were trapped at the dome of the seed cabochon at the beginning of crystal growth, before more stable growth conditions were achieved.

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Synthetic Emeralds Grown by W. Zerfass: Historical Account, Growth Technology and Properties

Karl Schmetzer, H. Albert Gilg and Elisabeth Vaupel

Rough and faceted synthetic emeralds were produced by W. Zerfass in Idar-Oberstein, Germany, between 1963 and 1973. The synthesis process was developed in cooperation with the chemist G. H. Jaeger; experiments started in 1952 and led to samples of facetable size in the early 1960s. Microscopic examination and chemical analysis of rough and cut Zerfass samples indicate that crystal growth took place on oriented seed plates cut from synthetic emerald crystals within a molybdate melt. Only chromium was added to the nutrient as a colour-causing trace element. Although the growth method was similar to that developed by H. Espig in the 1930s and applied by the IG Farben company, the process used by Zerfass and Jaeger was developed independently and, contrary to certain statements in the gemmological literature, did not involve anyone who had formerly worked with Espig at the IG Farben plant in Bitterfeld, Germany.

The Journal of Gemmology, **35**(5), 2017, pp. 404–414, http://dx.doi.org/10.15506/JoG.2017.35.5.404

Introduction

In 1963, a new synthetic emerald grown by W. Zerfass in Idar-Oberstein, Germany, was introduced to the market. The production technique, however, was not disclosed. Several descriptions of the material followed shortly after its introduction (Schlossmacher, 1963; Eppler, 1964; Gübelin, 1964a,b). Schlossmacher mentioned that the samples, especially in small sizes, were of high quality, resembling Colombian emeralds in colour (e.g. Figure 1). No information was offered regarding the chemical compounds used for crystal growth, and he did not speculate as to the production technology. The latter topic was instead taken up by subsequent writers. Eppler concluded, based on the form and distribution of inclusions, that the synthetic emeralds were grown through a flux-melt process. In contrast, Gübelin assumed a hydrothermal origin, deduced from the presence of inclusions formed by tapered conical channels with small crystals attached to their wider ends (commonly called 'nail-head spicules'). Further work by E. M. Flanigen and colleagues at the Linde division of Union Carbide Corp. (Flanigen et al., 1965, 1967) then considered the available evidence, but without the benefit of directly examining samples produced by Zerfass. Comparing different types of hydrothermal and flux-grown synthetic emeralds, they noted that nail-head spicules could be formed by both growth methods,

Figure 1: Shown here are faceted and rough synthetic emeralds grown by W. Zerfass in Idar-Oberstein, Germany, in the 1960s. The faceted samples weigh 0.24–1.02 ct, and the crystals are 0.23 and 0.40 g; the faceted sample on the upper left measures 6.4 × 6.4 mm and weighs 1.02 ct. Photo by K. Schmetzer.

provided the seed plates used had been cut at an incline to the beryl crystal faces. Therefore, taking into account the relatively low SG and RI values (as reported by previous researchers), they concluded that the Zerfass synthetic emeralds had been created through flux-melt growth. However, in the absence of any published chemical data, the production method remained a matter of discussion (O'Donoghue, 1980).

In addition to the foregoing focus on the production technique, and despite the relative rarity of the material in the marketplace (see Crowningshield, 1970), details about the individuals involved were also of continuing interest. In the early papers describing the new synthetic emerald, an unnamed 'inventor' or 'co-worker' was mentioned along with Zerfass (Schlossmacher, 1963; Eppler, 1964). Later, Nassau (1976a,b) offered the following based upon an unpublished interview with Zerfass conducted by R. Crowningshield: "The Zerfass emeralds were grown for a time in small quantities by one of Espig's I.G.-Farben co-workers after he left the firm and worked for Walter Zerfass of Idar-Oberstein, Germany, from about 1964 on, undoubtedly using the I.G.-Farben process."

Given the apparent logic, the explanation offered by Nassau was widely accepted (see, e.g., Sinkankas, 1981; O'Donoghue, 2005, 2006). In addition to H. Espig, the inventor of the process for growing IG Farben AG synthetic emerald (Igmerald), there would have been a number of people involved in the routine production of Igmerald in Bitterfeld, Germany, from 1935 to 1942. Such individuals, in turn, would have had internal knowledge of the process and could have moved to West Germany after World War II.

During a recent re-evaluation of the growth process applied by IG Farben at Bitterfeld and of the properties of Igmeralds (Schmetzer et al., 2016a), the present authors also examined synthetic emeralds grown by R. Nacken in the 1920s (Schmetzer et al., 2016b) and by Zerfass. These investigations were prompted by reports that the Nacken and Zerfass material had been grown by processes similar to those used for Igmeralds and/or that various people or companies involved might have collaborated. Thus, efforts were undertaken to delve into historical facts and to correlate the properties of faceted and rough samples with knowledge about the growth techniques applied.

Collaboration by W. Zerfass and Dr G. H. Jaeger

Walter Zerfass[1] (Figure 2) was a gem cutter in Idar-Oberstein leading a small, independently owned company. His son, chemist Dr Torsten Zer-

[1] W. Zerfass (1911–1995) was trained as an agate cutter and worked in that profession in the 1920s and 1930s. He was employed first in the family firm and later, in the 1930s, founded his own company in Hintertiefenbach, now part of Idar-Oberstein, Germany. After World War II, he augmented his work by cutting and polishing hard materials for technical applications, such as jewel bearings for watches or water meters. Subsequently, in the early 1950s, he developed processes for manufacturing layered glasses used as a substitute for banded agate, leading to German patents published in 1951 and 1952. Also, in the early 1950s, Zerfass met G. H. Jaeger (see footnote 2), and the two collaborated on several projects during that era. For instance, they cooperated in developing cutting and polishing methods for technical ceramic products, an endeavour related to Jaeger's work at that time for Degussa AG. They similarly began in the early 1950s to partner on experiments for synthetic emerald growth at Hintertiefenbach. After implementing their own production process, in 1963 they presented the first synthetic emeralds resulting from these long-running efforts to the public. Other activities by Zerfass included cutting and polishing hard metal tools (e.g. knives for microtomes).

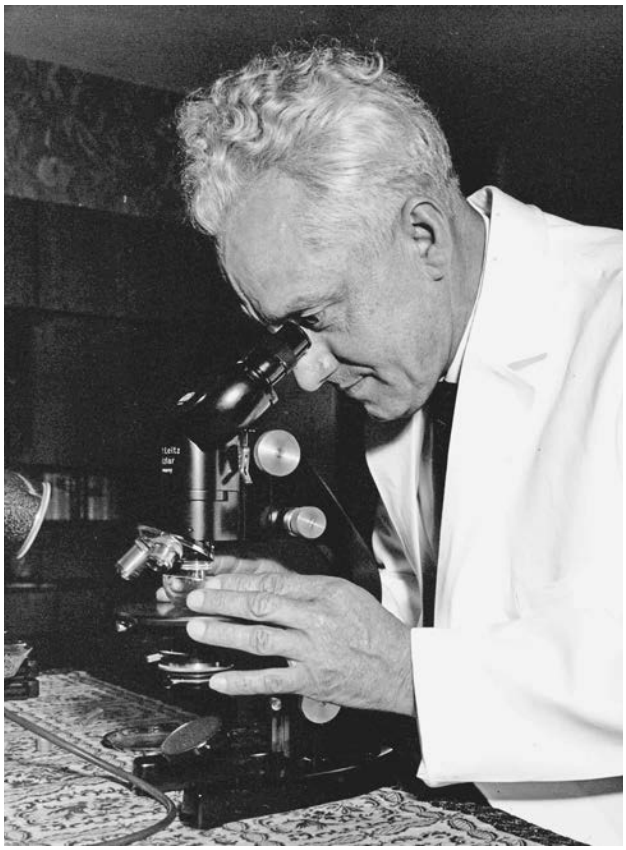


Figure 2: W. Zerfass developed a method for emerald synthesis over the course of a decade, from approximately 1952 to 1962, and presented his first faceted synthetic emeralds to the public in 1963. Production of Zerfass synthetic emeralds continued in the 1960s and early 1970s on a small scale. Photo taken in approximately 1970; courtesy of T. Zerfass.

Figure 3: Dr G. H. Jaeger, who worked with W. Zerfass in developing a synthesis technique for emerald, was an inorganic chemist involved in the 1930s with beryllium ore processing and metallurgy. Later he focused on the development and production of oxide ceramics for Degussa AG, now part of Evonik Industries AG. Photo taken in approximately 1953–1954; © Evonik Industries AG.

fass (hereinafter T. Zerfass), continues to reside in Idar-Oberstein and was interviewed by one of the authors (KS) in the course of this study. T. Zerfass identified his father's partner in developing the emerald synthesis technique as Dr Gustav Heinrich Jaeger[2] (Figure 3). Jaeger was a chemist living in Neu-Isenburg, near Frankfurt, Germany.

Zerfass and Jaeger met by chance and thereafter cooperated for approximately two decades (1952–1973) in the synthetic emerald project. Zerfass was the practical partner, building the different devices used in the experiments. Jaeger was the scientist, developing the various recipes for the fluxes and nutrients used to grow the synthetic emeralds (T. Zerfass, pers. comm., 2015, 2016).

Corroborating this association, an internal document from the Walter Zerfass gem-cutting company, dated 1971, also named Jaeger as a partner in developing the process for synthetic emerald growth (D. Jerusalem, pers. comm., 2015).

[2] G. H. Jaeger (1901–1974) studied natural sciences, especially chemistry, at the University of Frankfurt, Germany, from 1920 until graduating in 1924 with a dissertation on the analytical chemistry of nitrogen-bearing compounds. In the curriculum vitae accompanying his thesis, he mentioned R. Nacken as one of his academic advisors. Nacken and Jaeger also collaborated in the mid-1920s in Frankfurt, and filed a patent application dealing with improvements to gemstone synthesis by the Verneuil technique. Based on this invention, German and British patent documents by Nacken et al. were published in 1926 and 1927. Jaeger joined Degussa AG (**De**utsche **G**old- **u**nd **S**ilber-**S**cheide**a**nstalt, now part of Evonik Industries AG) in Frankfurt in 1928, and eventually he left the company in 1959 because of health problems. From 1932 to 1938, he led operations at the branch of the company responsible for beryllium metallurgy and technology. Later he headed production at Degussa of various technical ceramics, such as the so-called 'Degussit'. Numerous German and international patents involving beryllium refinement and technology, dated in the 1930s and 1940s, named Jaeger as the inventor. From his involvement with Degussa, he developed extensive expertise in the fields of beryllium chemistry and the processing of Be minerals.

Materials and Methods

The present study is based on the examination of five faceted samples (0.24–1.02 ct) and two crystals (0.23 and 0.40 g) of Zerfass synthetic emeralds. Four samples came from the reference collection of the German Gemmological Association, Idar-Oberstein, and three were loaned by T. Zerfass.

Refractive indices were measured on the faceted synthetic emeralds using a Topcon refractometer, and the SG values of all seven rough and faceted samples (e.g. Figure 1) were measured hydrostatically. All samples were examined with a gemmological microscope (magnification up to 100×), with and without immersion; also used was a Leica DM LM polarizing microscope, with a transmitted light source and magnification up to 1,000×. Photographic documentation of inclusions at high magnification was accomplished with an Olympus DP25 digital camera with Olympus Stream Motion software (version 1.6.1).

All seven Zerfass synthetic emeralds were chemically analysed by energy-dispersive X-ray fluorescence (EDXRF) spectroscopy using a Bruker Tracer III-SD portable unit equipped with an Rh anode (40 kV, 30 µA), a yellow filter (12 mil Al + 1 mil Ti) and a 10 mm² peltier-cooled XFlash SDD system. The counting time was 30 s.

Results

Crystal Morphology

Of the two crystals examined (Figure 4), the larger one showed a short prismatic to thick tabular habit consisting of a 12-sided prism and two basal faces. First- and second-order hexagonal prisms **m** $\{10\bar{1}0\}$ and **a** $\{11\bar{2}0\}$ were present in combination with the basal pinacoid **c** {0001}. Tiny polycrystalline material, most likely small synthetic emerald crystals grown by spontaneous nucleation, covered the prism faces. A groove traversed all prism faces, encircling the crystal (Figures 4 and 5).

The smaller crystal also had a short prismatic form, with six dominant prism faces and one basal pinacoid. The six-sided prism also showed some smaller additional prism faces that would correspond to a 12-sided prism if fully developed. The prism faces were again covered with small prismatic synthetic emerald crystals (Figure 6), but these were somewhat larger than those seen on the other rough sample. Likewise present was a deep groove surrounding the crystal, as also seen in the larger crystal (see again Figure 4). The smaller sample, however, had been sawn at a short distance from the groove, presumably to remove half of the piece for cutting.

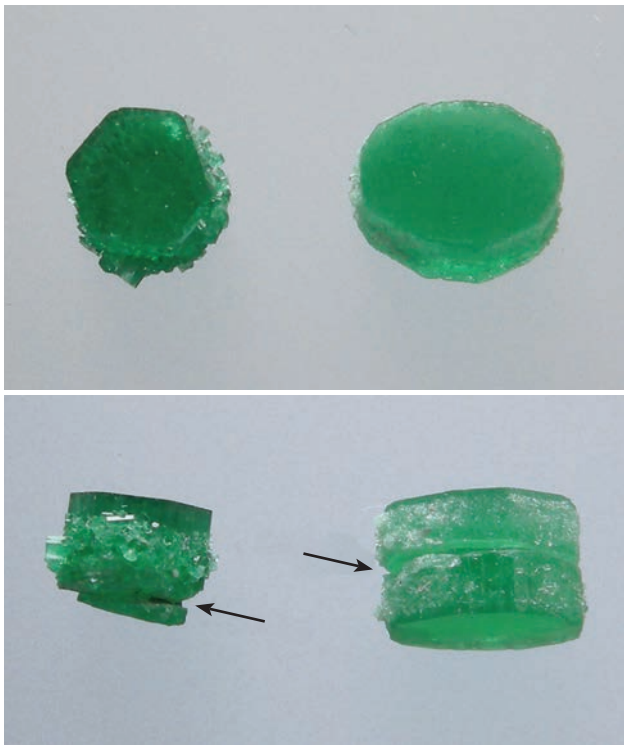


Figure 4: These two Zerfass synthetic emerald crystals were grown using small seed plates of synthetic emerald that were suspended with gold wires in a special holder within a lithium molybdate flux. After the gold wires were removed from the crystals, grooves where the wires originally rested remained on the surface of the crystals (see arrows); the lower half of the left crystal was sawn off for cutting purposes. Views are shown almost parallel to the c-axis of the crystals (above) and almost perpendicular to the c-axis (below). The left crystal measures approximately 6.0 mm in diameter on the basal face and 4.6 mm along the c-axis, and it weighs 0.23 g; the right crystal measures about 6.8 × 5.7 mm on the basal face and 4.8 mm along the c-axis, and it weighs 0.40 g. Photos by K. Schmetzer.

Gemmological Properties

The synthetic emeralds were slightly bluish green in colour, displaying pleochroism of blue-green parallel to the c-axis and green to slightly yellowish green perpendicular to the c-axis. The RIs of the faceted samples ranged from 1.558 to 1.559 for n_e and from 1.562 to 1.563 for n_o, with a birefringence of 0.004. The SG values were between 2.65 and 2.66. These data are consistent with information generally reported for flux-grown synthetic emerald from various produc-

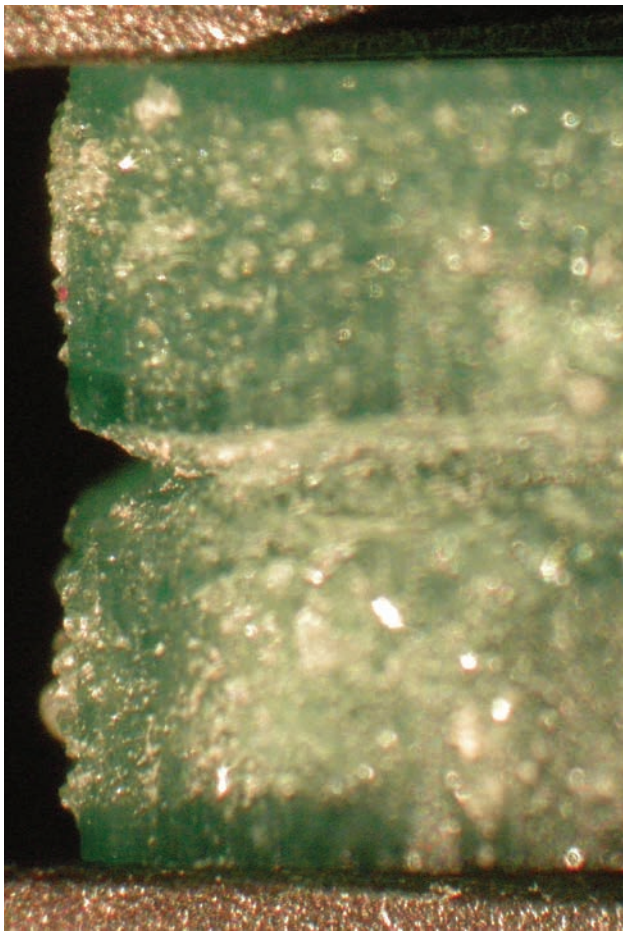


Figure 5: The larger Zerfass synthetic emerald crystal is viewed here perpendicular to the c-axis. The prism faces are covered with tiny synthetic emerald crystals. The groove in the centre circumscribing the prism faces was left by a gold wire; the wire had been used to suspend a small seed plate of synthetic emerald in the lithium molybdate flux. The c-axis runs vertically, and the length of the crystal along the c-axis is 4.8 mm. Photomicrograph by K. Schmetzer.

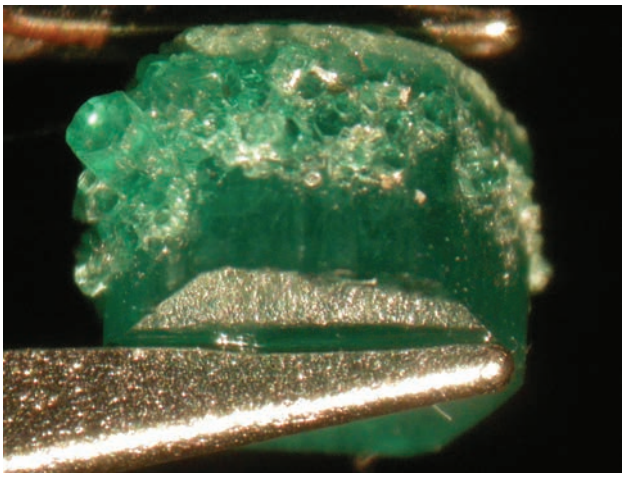
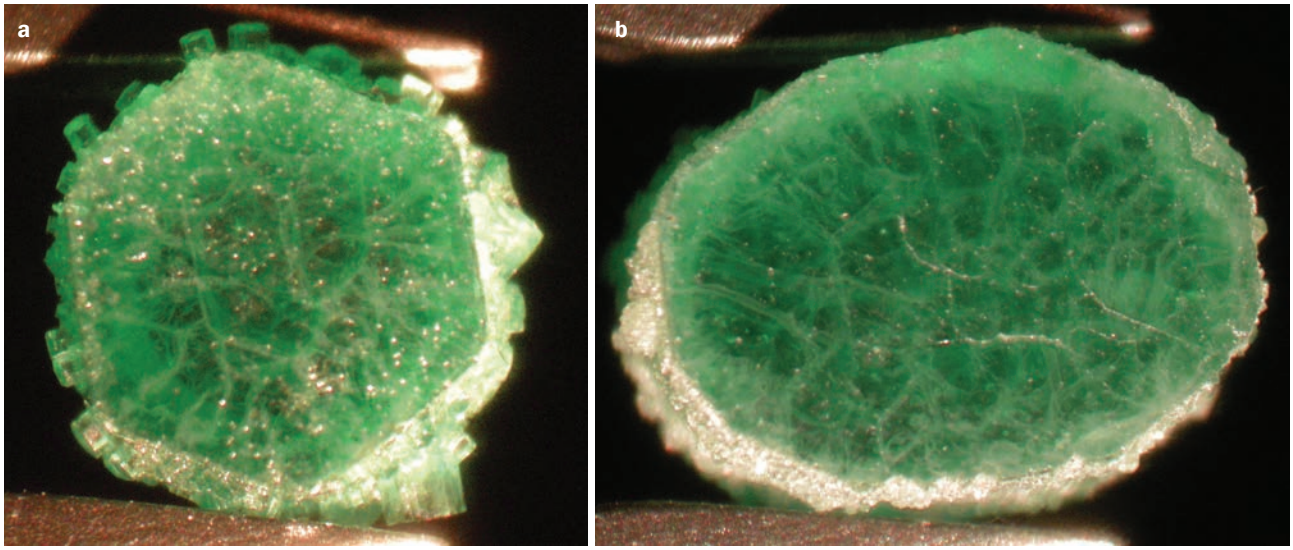


Figure 6: The smaller Zerfass synthetic emerald crystal is viewed here almost perpendicular to the c-axis. The prism faces are covered with small prismatic synthetic emerald crystals. The c-axis is almost vertical, and the length of the crystal along the c-axis is 4.6 mm. Photomicrograph by K. Schmetzer.

ers (see, e.g., Flanigen et al., 1967; Sinkankas, 1981; Henn, 1995).

When the crystals and cut samples were viewed parallel to the c-axis with a microscope, a cellular pattern of residual flux was observed (e.g. Figure 7). This created a honeycomb-like structure formed by residual flux concentrated along planes running through the synthetic emeralds in a direction parallel to the c-axis. When examined in immersion (Figure 8), the three-dimensional extension of the honeycomb pattern was evident. The individual cells of the pattern varied from nearly hexagonal to completely ir-

Figure 7: A cellular web-like pattern of residual flux is seen parallel to the c-axis of the Zerfass synthetic emerald crystals. The samples have diameters of approximately (a) 6.0 mm and (b) 6.8 × 5.7 mm. Photomicrographs by K. Schmetzer.



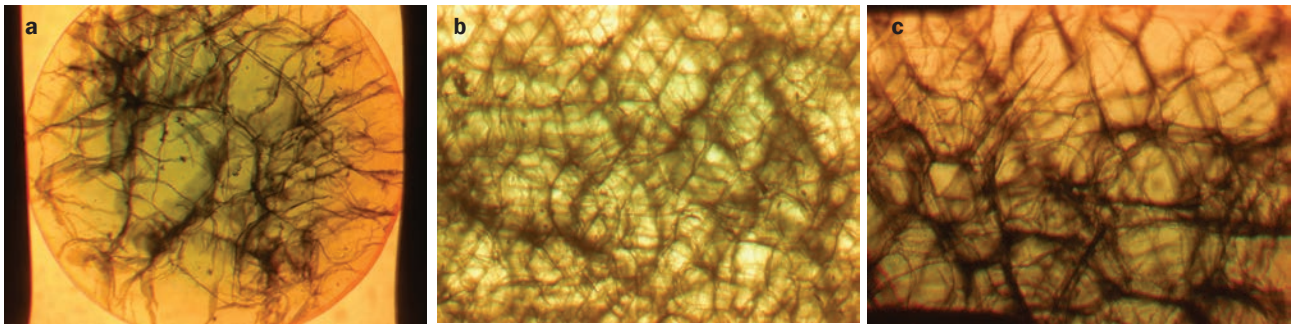


Figure 8: Cellular honeycomb-like structures are formed by residual flux concentrated on planes traversing the synthetic emeralds in a direction parallel to the c-axis. Such structures were seen in all the faceted Zerfass synthetic emeralds, with the cells forming patterns that show a variety of sizes and shapes. Immersion; view parallel to the c-axis; field of view (a) 4.6 × 3.5 mm, (b) 3.5 × 2.6 mm and (c) 3.2 × 2.4 mm; photomicrographs by K. Schmetzer.

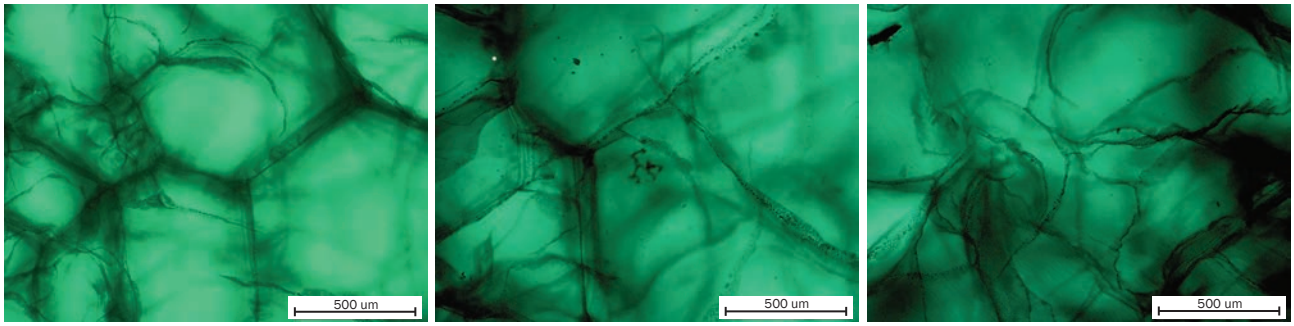


Figure 9: These images show details of the honeycomb-like structures observed in the Zerfass synthetic emeralds. These patterns are formed by tiny flux particles concentrated in various forms, ranging from almost planar faces running parallel to the c-axis to wispy veils with an entirely irregular arrangement. Transmitted light; view parallel to the c-axis; photomicrographs by H. A. Gilg.

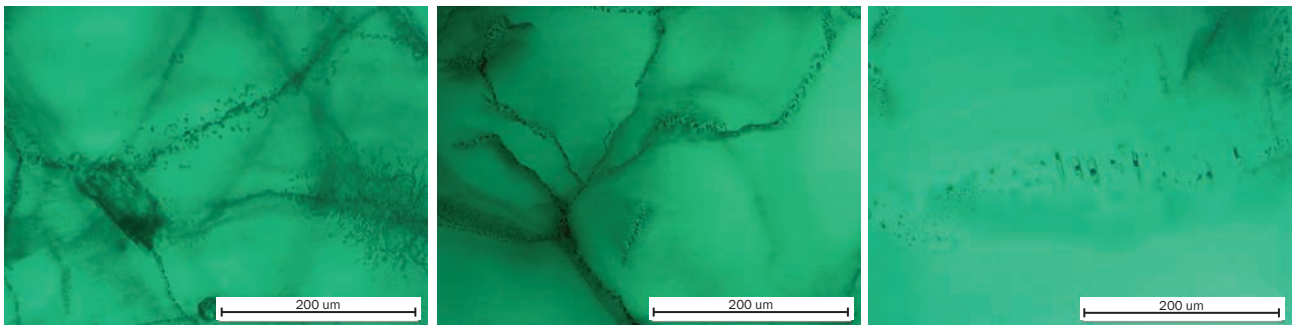


Figure 10: At higher magnification, the tiny particles of residual flux in the Zerfass synthetic emeralds are shown to be formed by two-phase inclusions consisting of contraction bubbles and various components of the flux. Transmitted light; photomicrographs by H. A. Gilg.

regular in shape (Figure 9). At higher magnification, the tiny particles of residual flux that formed the pattern could be resolved (Figure 10), and minute two-phase inclusions (residual flux with contraction bubbles) were frequently apparent.

When the rough and faceted samples were viewed perpendicular to the c-axis, a layered structure was observed with distinct boundaries that were more-or-less parallel to the basal plane (Figure 11). The boundaries were not always exactly planar and could even be slightly inclined to one another. Strong colour zoning was observed between the different growth layers. The honeycomb pattern of six-sided to irregularly shaped cells formed by particles of residual flux caused the two crystals and some of the faceted samples to appear only translucent when viewed perpendicular to the c-axis (again, see Figure 11), notwithstanding their rather good transparency when viewed parallel to the c-axis.

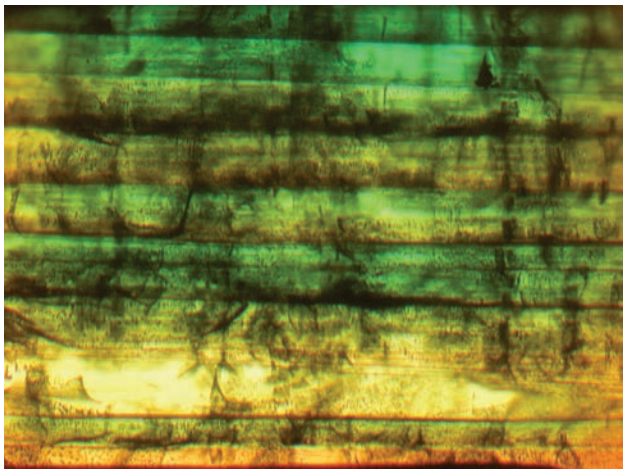


Figure 11: Growth zoning combined with colour zoning is seen parallel to the basal pinacoid in a faceted Zerfass synthetic emerald. Immersion; view perpendicular to the c-axis, with the c-axis vertical; field of view 3.9 × 2.9 mm; photomicrograph by K. Schmetzer.

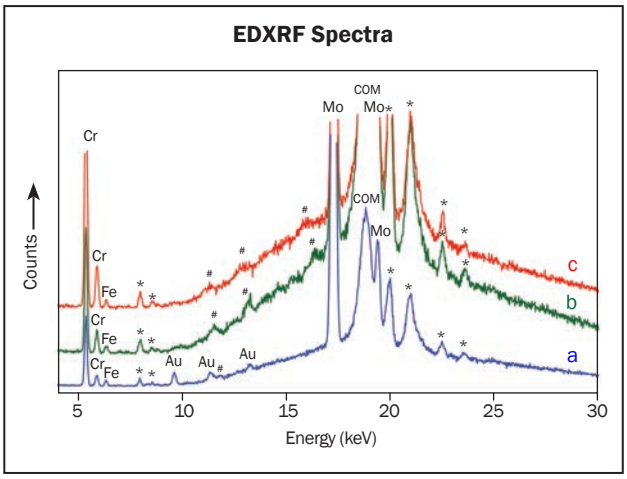


Figure 12: EDXRF spectra of Zerfass synthetic emeralds are shown for: (a) a crystal with the X-ray beam directed toward the prism faces, (b) the same crystal with the X-ray beam directed toward a basal face and (c) a faceted sample. The spectra indicate Cr as the main colour-causing trace element, with traces of Fe, and also Mo as the main component of the flux. In addition, the lower spectrum (a) shows signals for Au, derived from a gold wire (now removed) that was originally used to suspend the seed plate for crystal growth. The peaks labelled with an asterisk (*) are related to the X-ray tube (Rh) or to interactions with the instrument (Pd, Cu and Zn). Diffraction peaks are labelled #, and COM refers to the inelastic scattering of the incident radiation (Compton scattering).

Chemical and Spectroscopic Properties

The trace elements revealed by EDXRF spectroscopy showed a homogeneous pattern in all seven samples (e.g. Figure 12). Chromium was the main colour-causing trace element, with small traces of Fe also present. No V or Ni was detected.

Molybdenum peaks in the EDXRF spectra indicate that the synthetic emeralds were grown from a Mo-bearing flux. Unexpectedly, characteristic X-ray lines for Au were recorded for both rough samples, but only when analysed with the X-ray beam aimed toward the prism faces and incorporating the surface grooves. Gold was not detected when the beam was directed toward the basal faces of the two crystals, nor was it found in any of the faceted samples.

Ultraviolet-visible absorption spectra of several previously examined Zerfass synthetic emeralds (unpublished data of author KS) showed the typical Cr^{3+} spectrum of emerald without any remarkable features. This is consistent with chemical data of the present study, showing Cr as the dominant colour-causing trace element.

Discussion and Conclusions

Connections Between IG Farben and Zerfass

Although similarities might exist between the process used by IG Farben for growing synthetic emerald and the method later employed by Zerfass and Jaeger, all historical evidence indicates that technical developments made by the latter team occurred independently. No person from the IG Farben staff involved either in developing the Igmerald growth process (from 1929 to 1935) or in subsequently producing Igmeralds at Bitterfeld (from 1935 to 1942) could be identified as a potential co-worker of Zerfass. While documentation does show that G. H. Jaeger had contact with Nacken during his years in Frankfurt in the 1920s, no such connections to IG Farben staff members at Bitterfeld have been demonstrated.

Nonetheless, consideration of the existing facts suggests a possible explanation for the erroneous information published by Nassau (1976a,b): It appears that Nassau might have misinterpreted what was said in the interview of Zerfass by Crowningshield. In the 1930s, when the breakthrough in emerald synthesis at Bitterfeld was announced (see Jaeger and Espig, 1935), Dr Max Jaeger was the director of the IG Farben chemical plant, including the gemstone branch at Bitterfeld. The first description of the 'German synthetic emerald' by the Gemological Institute of America (Anonymous, 1935) likewise mentioned the names 'Jaeger' and 'Espig'. Thus, operating on the premise that the name Jaeger was given correctly

by Zerfass to Crowningshield, we might conclude that a conflation of family names could have led to the now largely discredited assumptions.[3]

Production Technology

From the results described above, it can be concluded that the production process applied by Zerfass in Idar-Oberstein, which he developed between 1952 and 1963 together with Jaeger, was based on flux-growth technology. Given the outcome of our examinations, we could establish that synthetic emerald plates sliced parallel to the basal face were used as seeds and suspended in a Mo-bearing flux for crystal growth. The combination of the grooves seen traversing the prism faces of the crystals and the traces of gold detected by EDXRF spectroscopy indicate that circumscribing gold wires were used to suspend the seed plates in the flux. With that technique, the crystals could grow freely in both directions parallel to the c-axis of the crystal, but only limited growth was observed perpendicular to the c-axis. The only colour-causing trace element identified was chromium. The growth zoning parallel to the basal face suggests that several interruptions took place in the growth process.

All of the foregoing conclusions drawn from observations of the rough and faceted samples were confirmed by T. Zerfass, who has in-depth knowledge about the growth technology applied by his father and developed together with Jaeger. T. Zerfass also added further details about the growth process, as revealed in the following paragraphs, many of which were not deducible directly from the samples themselves.

Similar to the IG Farben process, crystal growth was performed in platinum crucibles, with the nutrient subdivided into two parts. Compounds of Al, Be and Cr were placed in the bottom of the crucible, and natural quartz crystals floated on top of the lithium molybdate melt. No colour-causing trace elements other than Cr (such as V or Ni) were ever added by Zerfass and Jaeger to the nutrient. The method did not involve the use of a temperature gradient within the crucible. The first experiments, performed in about 1952–1953, started by reproducing the emerald synthesis described by French scientists in the late 19th century (Hautefeuille and Perrey, 1888, 1890). By 1956, Zerfass and Jaeger had altered their process to one that involved using seed plates and separating the nutrient into two components, with quartz floating on top of the lithium-molybdate melt. Notably, they made these adjustments independently of other scientists dealing with emerald synthesis who adopted similar approaches, such as those formerly at IG Farben in Bitterfeld.[4]

A special holder for the suspended seed plates was placed between the ingredients at the bottom of the crucible and the quartz floating on top of the melt. During early experiments, natural aquamarine or natural emerald was used to make seed plates. Such samples were not examined in the present study, but a Zerfass synthetic emerald described by Gübelin (1964a,b) containing nail-head spicules may represent this early work. The primary production of the 1960s and 1970s, however, was performed using oriented seeds cut from synthetic emerald crystals obtained in the earlier growth experiments. With the crucible arrangement mentioned, especially the orientation and suspension of seed plates, crystal growth was mainly in a direction parallel to the c-axis. A special furnace was used that was able to heat several platinum crucibles at the same time.

In contrast to the IG Farben process, in which nutrient was added to the bottom of the crucible every 2–3 days, the Zerfass process was performed without interruption for a period of about 2–3 weeks. Only then were the synthetic emeralds temporarily removed, and another run with additional flux and nutrient was prepared. This separation of the growth process into 2- to 3-week intervals was reflected in the zoning of the synthetic

[3] Since Dr M. Jaeger (1869–1938) and Dr G. H. Jaeger (1901–1974) were both born in the city of Frankfurt on the Main, the authors initially wondered whether they could be related (e.g. father and son or uncle and nephew). However, invest-igations of various birth registers preserved at the Institut für Stadtgeschichte in Frankfurt failed to reveal any such familial relationship. Thus, there remains no proven connection, either professional or familial, between these two chemists involved in the development of emerald synthesis.

[4] Because Zerfass and Jaeger started their work by following the techniques described by Hautefeuille and Perrey (1888, 1890), rather than by undertaking experiments based on the successful work by Nacken (T. Zerfass, pers. comm., 2016), it is unlikely that Jaeger had obtained any information regarding Nacken's emerald synthesis experiments of the mid-1920s. Nonetheless, it is possible that Nacken could have shown Jaeger examples of those flux-grown crystals. (For more details about Nacken's work, see Schmetzer et al., 2016b.)

emeralds parallel to the basal faces. A proprietary technique was used to avoid variable concentrations of Cr in the melt within a single growth cycle. In the final years of their partnership, Zerfass and Jaeger also performed experiments aimed at reducing the concentration of trapped flux particles and obtaining larger and cleaner material.

Hence, the chronological history of the Zerfass production can be summarized as follows. Experiments in crystal growth took place from approximately 1952 to 1962, and the first faceted synthetic emeralds were presented to the public in 1963. Production continued on a small scale during the 1960s and early 1970s, and then terminated in ~1973.

Comparison of the Processes Used for Emerald Synthesis by Nacken, Espig (IG Farben) and Zerfass

The historical development of flux-grown synthetic emerald in Germany occurred over the course of six decades and involved three principal producers: Nacken , IG Farben and Zerfass. The story can be traced from about 1910 or 1911, when a precursor company of IG Farben performed the first experiments in Bitterfeld, to 1973, when Zerfass ceased production in Idar-Oberstein.

Sources of direct information (i.e. provided by the producers) evidencing these developments is varied but limited. Certain aspects of IG Farben's process for Igmerald production were published by Espig in the early 1960s, and further information was contained in internal IG Farben reports dated 1930, 1945 and 1946, likewise penned by Espig, that have recently come to light (for details, see Schmetzer et al., 2016a). Nacken himself never published regarding his emerald synthesis, and only fragmentary accounts can be found in Allied government documents generated from 'interviews' with German scientists in 1945 and 1946 by American and British investigators after World War II (for details, see Schmetzer et al., 2016b). Zerfass also did not formally document his work, but unpublished information was disclosed to his son T. Zerfass (reported in this article).

Insights into growth technologies derived from the foregoing sources proved to be consistent with the examination of respective synthetic emerald samples. Results of the authors'

*Table I: Growth of synthetic emeralds by R. Nacken, IG Farben and W. Zerfass.**

Production	Nacken Type 1	Nacken Type 2	IG Farben	Zerfass
Reference	Schmetzer et al. (2016b)		Schmetzer et al. (2016a)	This paper
Time of production	Mid-1920s		1935–1942	1963–1973
Flux	Molybdate	Molybdate-vanadate	Molybdate	
Crucible	Gold		Platinum	
Nutrient for SiO_2	Quartz pieces, distributed in the melt		Silica plates, floating on the melt	Quartz plates, floating on the melt
Nutrients for BeO and Al_2O_3	Distributed in the melt		At the bottom of the crucible	
Chromophore(s)	Cr-bearing compound		Cr- and Ni-bearing compounds, alleged yttrium oxide	Cr-bearing compound
Type of seed	Irregularly shaped natural beryl		Synthetic emerald plate, cut parallel to the basal face	
Suspension of seed plate	No suspension, seed freely distributed in the melt		Seeds placed below platinum baffles	Seeds suspended in the melt with gold wires and an additional holder
Growth cycles	Several growth cycles		Several growth cycles of about 1 month with addition of nutrient every 2–3 days	Several growth cycles of 2–3 weeks each without addition of nutrient during the cycle

* Only the primary variants of the processes as finally developed are given. All of the techniques used a homogeneous temperature (no temperature gradient).

work on rough and faceted synthetic emeralds from all three producers are summarized in Table I. On a conceptual level, each producer employed a process for growing synthetic emerald based upon dividing the nutrient into two components. Specifically, BeO, Al_2O_3 and colour-causing ingredients were added to the melt separately from SiO_2 (quartz or vitreous silica).

All three producers started with employing natural colourless beryl as seed material, but only IG Farben and Zerfass transitioned to using synthetic emerald plates for seeds. The seeds were suspended in a molybdate or molybdate-vanadate flux, primarily in gold or platinum crucibles. For all three manufacturers, growth then proceeded through multiple cycles. In the IG Farben process, additional nutrient was added to the bottom of the crucible every 2–3 days. This method, however, had the disadvantage of frequently interrupting the process and causing different equilibria and concentrations of nutrient within the melt. Further developments instigated by Zerfass avoided this problem, but the details of the technique have not been disclosed by his son to the present authors.

Nacken and Zerfass used only Cr-bearing compounds as colour-causing trace elements. Espig, in contrast, added nickel carbonate to the melt, and this component was responsible for the desired slightly yellowish green colour of the Igmeralds, as compared to natural and synthetic emeralds without Ni. Although yttrium oxide was also added by Espig as a purported colour-causing ingredient, any potential influence on colour remains unclear; samples showing traces of Y by EDXRF spectroscopy and those without any detectable Y did not display any noticeable difference in colour. For those Nacken synthetic emeralds grown from vanadate-molybdate fluxes, V may make a small contribution to the otherwise Cr-based colour, similar to that exhibited by natural emeralds from various sources, such as those from Colombia.

With IG Farben's announcement in 1935, it became public knowledge that growing synthetic emeralds of facetable size was possible. Although details of the growth technology used by IG Farben were not disclosed until the early 1960s, the mere presentation of these first faceted samples may have stimulated interest within the research community. A similar effect was created some years later by the presentation of the first faceted synthetic emeralds produced in the USA by Chatham in the early 1940s, and any such interest would have been augmented by various discussions after 1945 involving Nacken's experiments in emerald synthesis.

These various announcements may have encouraged other researchers, such as the team working at Linde's research and development department, to grow synthetic emeralds. Being informed in principle about the success in emerald growth by IG Farben and Nacken in Germany and the production by Chatham in the USA, Zerfass and Jaeger can be seen as following the same tradition.

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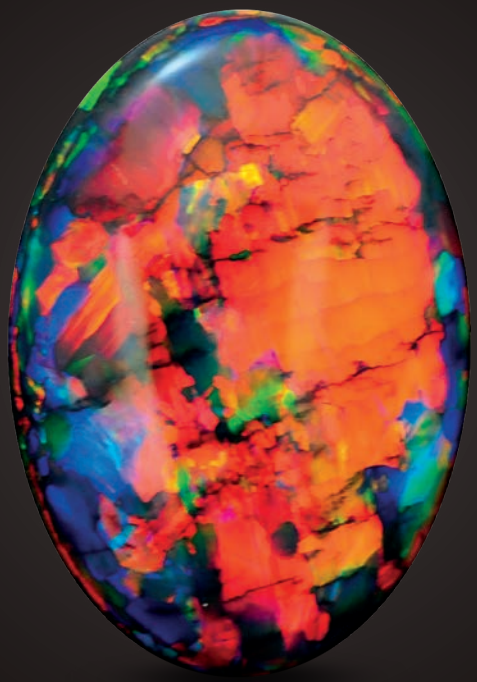
Acknowledgements

The synthetic emeralds grown by W. Zerfass in cooperation with G. H. Jaeger were kindly loaned by Dr T. Zerfass and by Dr U. Henn (German Gemmological Association). T. Zerfass also provided valuable information about the history and production technology of his father's emerald synthesis. We also appreciate the assistance of D. Jerusalem of Idar-Oberstein in providing historical insights.

The Fire Within

"For in them you shall see the living fire of the ruby, the glorious purple of the amethyst, the sea-green of the emerald, all glittering together in an incredible mixture of light."

– Roman Elder Pliny, 1st Century AD



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Rethinking Laboratory Reports for the Geographical Origin of Gems

Jack M. Ogden

The proliferation of gemmological laboratory reports and the need for transparency to best protect against litigation suggest that some gem-testing laboratories should consider changes in the wording and content of their geographical origin reports. Based on the author's recent broader study of the legal aspects of the opinions provided by experts in the field of art and antiques, the main proposals presented here are that statements of opinion rather than fact should be clearly expressed as such where they are presented on a report, rather than relegating all mention of 'opinion' to the 'terms and conditions', and that the basic nature of the observational or analytical evidence on which any opinions are based should be noted. In addition, a laboratory might usefully provide some indication of the level of confidence in its opinion.

The Journal of Gemmology, **35**(5), 2017, pp. 416–423, http://dx.doi.org/10.15506/JoG.2017.35.5.416

Introduction

In a recent law journal article, the present author considered opinions in the art and antique world from a legal perspective and suggested how the rather woolly concept of 'opinions' might be made more objective and therefore more useful to those who rely on them, including the courts (Ogden, 2016). This article looks more briefly at opinions provided in gemmological testing and grading reports, and proposes some ways to improve their helpfulness and transparency. This is written from the point of view of someone with recent experience in art law[1], and who has had a long association with gem labs as an observer—from being on the committee overseeing the lab run by the Diamond, Pearl and Precious Stone Section of the London Chamber of Commerce (the forerunner of the Gem-A laboratory) in the early 1970s to being in the unenviable position of having to action the closing of Gem-A's lab in 2008 when he was CEO of Gem-A. Those wanting more of the legal background are directed to Ogden (2016).

Numerous authors in the past have considered the challenges that confront gemmological laboratories issuing reports and their need to balance scientific prudence with the demands of the gem trade, particularly with regard to geographical origin determination (e.g. Hänni, 1994; Nyfeler, 2006; Krzemnicki, 2007; Rossman, 2009). In addition, the actual processes and procedures of gem testing within a laboratory have been described at length in this and in other gemmological journals.

Origin reports have become a prominent part of the gem trade, particularly for high-end stones (e.g. cover of this issue and Figure 1). They aim to provide support for the seller and reassurance for the buyer, and, as is often observed, some gems seem to be sold as much on the basis of their accompanying paperwork as on their appearance (Figure 2). Against this background, it is timely

[1] The author has had a long-term interest in art law and was awarded a Diploma in Art Profession Law and Ethics (with distinction) by the Institute of Art Law, London, in 2014.

Figure 1: This ring with a 30.08 ct sapphire was sold at auction (Bonhams, London, 30 April 2014, lot 186) and was accompanied by three lab reports that gave two different geographical origin opinions—Sri Lanka and Burma (Myanmar). Photo © Bonhams, used with permission.

to consider whether the uncertainty often inherent in such reports is always presented clearly enough to those who rely on them. This is particularly important with 'origin' reports, which can have a huge impact on prices. Some laboratories are scrupulously cautious here with their wording and its prominent placing; others are less so.

This article discusses the nature of opinions on geographical origin reports, the objective and subjective factors leading to an expression of opinion of origin—and the levels of confidence in that opinion—and then considers extended liability and trade expectations before giving recommendations for initial steps toward improving the transparency and usefulness of such reports by proposing changes in their wording and content.

The Nature of Opinions

Gemmological laboratories are usually careful to state that their reports present opinions. This provides a level of protection against litigation for the lab but can be of limited comfort to the user of the report because of the lack of precision. There has been some education of laboratory users about the way in which labs reach their conclusions, such as SSEF's *Standards & Applications for Diamond Report/Gemstone Report/Test Report* (1998), but little to help the user gauge how much confidence the laboratory might have in its report. A laboratory report offering the opinion that a particular sapphire is from Kashmir (e.g. Figure 3), say, could imply anything from the lab's absolute conviction that it is from that cherished source to a consensus among lab employees that on balance it is more likely to be Kashmir than not (e.g. Hänni, 1990). A consensus approach such as this is not unusual, particularly with diamond grading. If two employees in a lab have slightly different views, they will typically ask a third for their opinion and go with the majority. It is essential that the nature of a lab report as an opinion must be made absolutely clear to all who are likely to rely on it, but if we accept that laboratories would be delusional to assert that they were equally confident in all their opinions, do the users of their reports have some right to know how convinced those labs are about their opinion?

Opinions presented in gem-testing reports are of course nothing more nor less than educated guesses or a consensus of educated guesses. If they were more than educated guesses they would be facts. Referring to details on gem lab reports, particularly origin statements, as educated guesses is not a new thing; a previous example is mentioned in an editorial in *Gems & Gemology* (Liddicoat, 1990). The education for the guesses is provided by a range of factors—from precise and replicable scientific analysis to experience and even gut feelings—and so, if the report presents an opinion rather than a provable fact, it will be based on a combination of objective and subjective elements. For as long as there is a subjective element, then report conclusions necessarily will not be constant from one laboratory to another. This is not a new observation. For example, Hainschwang and Notari (2015) pointed out that where lab reports are based to some extent on "the opinion of the analyst and not only on scientific evidence…the results of a specific stone may vary to a certain degree from laboratory to laboratory".

Objective and Subjective Elements

In the interests of transparency for the user of the report and for protection against litigation for its issuer, it is reasonable to suggest that the

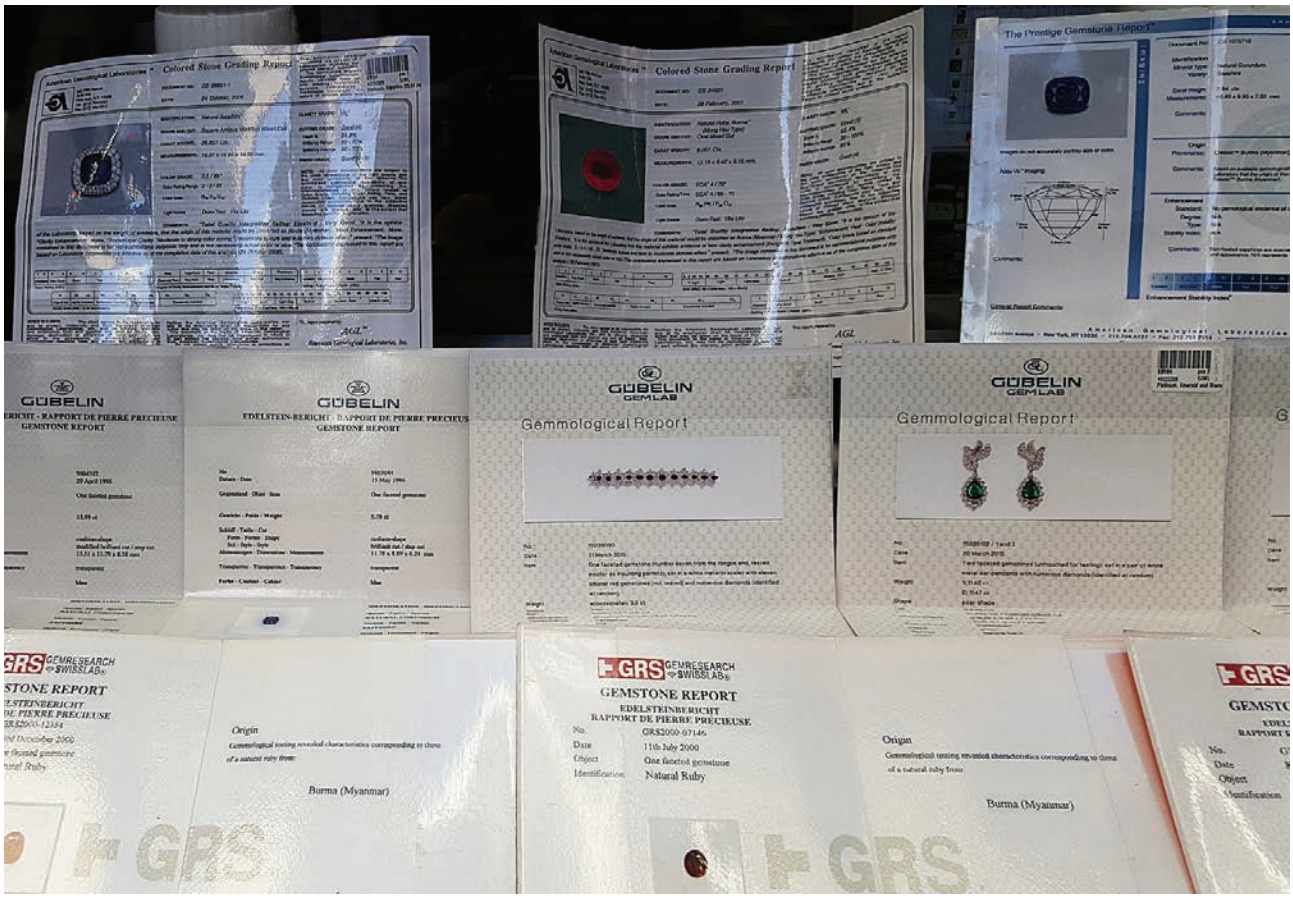


Figure 2: A shop window in New York's jewellery district demonstrates the significance currently given to lab reports. Photo by J. M. Ogden, November 2016.

objective facts and the subjective interpretations derived from them should be distinguished in the report. Even this is not as simple as it sounds. Some aspects are obviously facts, such as the weight and shape of a gem, but even here names of shapes or the classifications of girdle thicknesses, say, are not standardized any more than is colour terminology. The treatment of a gem may be an observable fact (a visible laser drill hole in a diamond, for example) or a subjective inference based on observation or analysis. Nevertheless, it should be possible to distinguish between the objective aspects that could be checked and replicated by another laboratory, and the deductions by the laboratory from observation or inferred on the basis of past experience or defined using non-standardized terminology.

Figure 3: Two examples are shown of the sections on 'Origin' on gemmological laboratory reports, for a 10.33 ct sapphire sold by Christie's in Hong Kong in 2015. The Christie's catalogue described both reports as "stating that the 10.33 carat sapphire is of Kashmir origin". The sapphire fetched $2.5 million.

Origin	Gemmological testing revealed characteristics consistent with those of sapphires originating from: Kashmir
Condition	No indications of heating (NTE).
Comments	See Information Sheet(s). Important notes and limitations on the reverse.

Comments:	The analysed properties confirm the authenticity of this transparent sapphire. No indications of heating. Origin: Kashmir

This suggestion of a distinction between the objective and the subjective is not a novel proposal; it is already laid down for the handful of gemmological laboratories that are accredited under International Standard ISO/IEC 17025 (2005). International Standards lack legal weight in most jurisdictions, but they would usually be taken to represent best practice. This particular standard is aimed primarily at testing laboratories where the data collected are measurable facts, but it recognizes that reports may include opinions based on those facts, and so in Section 5.10.5 it states that "Opinions and interpretations shall be clearly marked as such in a test report." It goes on to

say that "When opinions and interpretations are included [in a report], the laboratory shall document the basis upon which the opinions and interpretations have been made." It could be argued that this latter clause means that the laboratory should retain this documentation in its files and not necessarily pass it on to the client, but in the interest of transparency there are good reasons to suggest that in addition to distinguishing between the analyses or measurements a laboratory has made on a gem and the deductions it has derived from these, it should provide some indication on the report of how the latter were inferred from the former.

Indeed, in the UK at least, we can find some legal support for this. In a very different sort of context, Lord Justice Stuart-Smith stated: "I do not think guesswork, educated or otherwise, is sufficient to discharge the burden of proof, especially when he [the expert] does not indicate what evidence he relies upon as educating his guess" (Vernon v Bosley, 1996). As things stand, a sapphire might be sold at a very high price as 'Kashmir' on the basis of evidence less persuasive than would be needed to convict someone of stealing it. This practice of including the data on which the opinion is based in a laboratory report has been termed a "justified report" (Segura et al., 2015). Justification in this way, as defined in the International Standard 17025 cited above, is particularly applicable to opinions of origin for gems where, in the words of Bui et al. (2012), "origin determination is sometimes more akin to branding than science", although they ignore the point that 'science' is itself a combination of experiment, observation, interpretation and theory.

Clear Expression of Opinion

In the spirit of International Standard 17025, and thus again arguably best practice, it would make things clearer if all gem labs clearly stated that opinions are simply opinions where they are presented in a report, and not relegated to some generality about it all being an opinion in the typically small print of the 'terms and conditions', sometimes even on the reverse of the report. This means stating something like, 'Based on the chemical constituents of the sapphire, the measured spectral features and its internal characteristics, it is this laboratory's opinion that it comes from Kashmir', rather than simply saying 'Origin: Kashmir' with a generalized disclaimer about 'opinions' tucked away on the side or back. One only needs to leaf through the files of photocopies of lab reports at any major jewellery auction preview, viewed by public as well as trade buyers, to realize that it is time for more up-front—literally—transparency and honesty. We can note that in its recent formal request for public views on 'terms and conditions' relating to consumer products, the UK government has expressed its view that the key terms in such conditions should be 'upfront and bold' (Department for Business Innovation & Skills, 2016). One cannot argue that the 'opinion' nature of a lab report is not a key aspect.

It is growing practice for gemmological laboratories to accompany a report on an important gem with supplementary documentation that can range from a letter to a glossy book. Such an offering about an emerald, say, might praise its size, quality and Colombian origin, but among the glossy photos of sunsets over Muzo, comparisons with the green in a Renoir painting and stories of Cleopatra and conquistadors, there might be little sign of a clear statement that the Colombian origin of the gem in question is merely an opinion. As a side note, this author repeats a plea made before (Ogden 2012a): that labs should apply the same level of academic rigour to these glossy dossiers as they would to the publication of their gemmological research.

Levels of Confidence

Even if lab reports start becoming more open about the opinions they provide, along the lines of the wording proposed for the Kashmir sapphire example above, they still will not have solved the problem of the inherent fuzziness of the word 'opinion'. Some gems are trickier than others to characterize and some easier, all for a wide variety of reasons: from the individual nature of the gem, to laboratory experience or rigour of the stone reference database, to fortuitous availability of up-to-date published research. So, would it be reasonable for the user of a report to have some indication as to how much confidence a laboratory has in its opinion? From the report user's point of view—or the lawyer's, if a dispute ever came to court—a useful question to the report's signatory would be, "Are you personally convinced that the gem is from Kashmir (say) or merely believe that it is probably so?"

Quantification of overall confidence that the sapphire is from Kashmir is problematic. Courts must often undertake such assessment to apportion blame or damages on the balance of

probability, sometimes quoted as a percentage, when confronted by conflicting evidence with no means of determining the truth. Court pragmatism is different from market reality, however, and besides, laboratories could not consistently calculate overall likelihood. But just because numerical quantification of a lab's overall confidence in an opinion is unrealistic, it does not mean that all quantification is unwarranted. When there is clear, objective data from a gem, such as trace-element ratios and a large and robust database of comparisons, deductions can be made. Plotted charts can give a graphical indication of groupings and overlaps (e.g. Figure 8 of Wang et al., 2016, at www.gem-a.com/component/edocman/3233-wang-additional-plots-to-accompany-figure-8/download?Itemid=), although these are commonly constrained to two dimensions with two or three variables, while multivariate statistics can generate probabilities expressed in percentages with definable margins of error.

There is a good parallel here with the Antique Plate Committee of the Worshipful Company of Goldsmiths, London, which has been operating for nearly 80 years. A piece of antique silver submitted to this committee for verification is analysed, the results are compared with a huge database of analyses, and the likelihood of a certain date range is expressed as percentages. Thus, the computations might show that a purported Georgian silver coffee pot has an 84% likelihood of being pre-circa 1830, an 11% likelihood of being between 1830 and 1899, and a 5% chance of being 20th century or later. No one pays top price for a Georgian coffee pot with a 16% chance it is fake, so the Antique Plate Committee mulls over the analysis implications in the light of their expertise and experience regarding style, technique, patina and so on, and then states its overall opinion—alongside noting the 84% probability as generated by the statistical calculations of the analysis results.

This author is not aware of published information about multivariate statistics being used this way in gem labs, although it is hard to imagine they are not. This would be ideal where the results of chemical analysis could be compared with a robust database of reference material. There are good arguments for statistical results, whether expressed numerically or graphically, to be noted on a gem report as part of the supporting evidence for a stated opinion.[2] If the trace-element ratios indicate an 85% chance that a sapphire is from Kashmir, it seems fair—and certainly in the spirit of International Standard 17025—for the end-user to be told. It helps explain one of the criteria by which the lab justifies its final opinion. Chemical analysis is seldom the sole criterion; various internal characteristics will help identify origin, sometimes fairly conclusively, and often colour will give clues. A combined approach will typically provide a more certain indication of origin than chemical analysis alone, but even so can the user of a report claim a right to be told if the objective analytical data, in effect, showed a 15% chance that the gem was not from Kashmir (see Ogden, 2012b)?

Of course, there is a further layer here: the confidence a laboratory has in the database or reference collection upon which it relies. The Gemological Institute of America (GIA) classifies its laboratory reference collection according to the confidence it has in the given origin, ranging from certainty with gems collected in the mine by their own employees to the far less reliability of the stated origin of gems purchased in the market (Pardieu, 2009). Only a few laboratories, however, have the resources to build rigorous sample databases. 'Objective' statistics based on factors such as trace-element ratios are only as reliable as the comparative data to which the lab has access.

Extended Liability

The growing profusion of supplementary documentation aimed at the ultimate buyer says a lot about who the labs see as their end-user, even though reports might state that they are solely for the commissioning client—usually a gem dealer, auction house or jeweller. Labs know that consumers often rely on reports and, in a wider context, might work with consumer protection agencies to help safeguard the public. They also have some legal responsibilities further down the line, certainly in the UK. If the lab knows or should reasonably be expected to know that their report will be relied upon by a third party, their liability will generally extend to that party. There is UK case law on this, although nothing specific to

[2] The challenge of providing useful information in reports without disclosing intellectual property has been noted by the author (Ogden, 2016). There can be a balance, noting sufficient background to show due diligence without revealing proprietary methods. The situation if a dispute comes to court can be more problematic, especially since those best able to gauge the validity of an approach are the very competitors from whom a lab may wish to hide it.

gems, but for equivalent situations such as property surveys and company valuations (Ogden, 2016). Labs are potentially liable to third parties or classes of third party that they know, or should reasonably expect, are likely to rely on their report. Whatever the original intention of lab reports, labs now know full well that their reports often will play a significant role in both marketing and purchasing decisions. Some of the dossiers and other supplementary documents issued by gem labs are so blatantly an endorsement for a gem that this author wonders if they might even be subject to advertising legislation.

We have talked about the evidence that suggests what a gem is. What about contrary evidence? There is legal support, in the UK anyway, to the view that if the seller is aware of any significant negative opinions about a gem, the buyer should be advised of this. (For a case involving negative opinions on antique porphyry vases, see Thomson v. Christie Manson & Woods Ltd and others, 2005.) This probably means that if the laboratory is aware of negative or less-than-wholly-supportive aspects of their opinion, the user of the report might have a right to be told. On this basis, the user of the report probably has a right to know if the data or observations leading to a 'Burma' origin for a sapphire left room for significant doubt, or if two of the gemmologists in the lab thought it was from Myanmar but another indicated Sri Lanka.

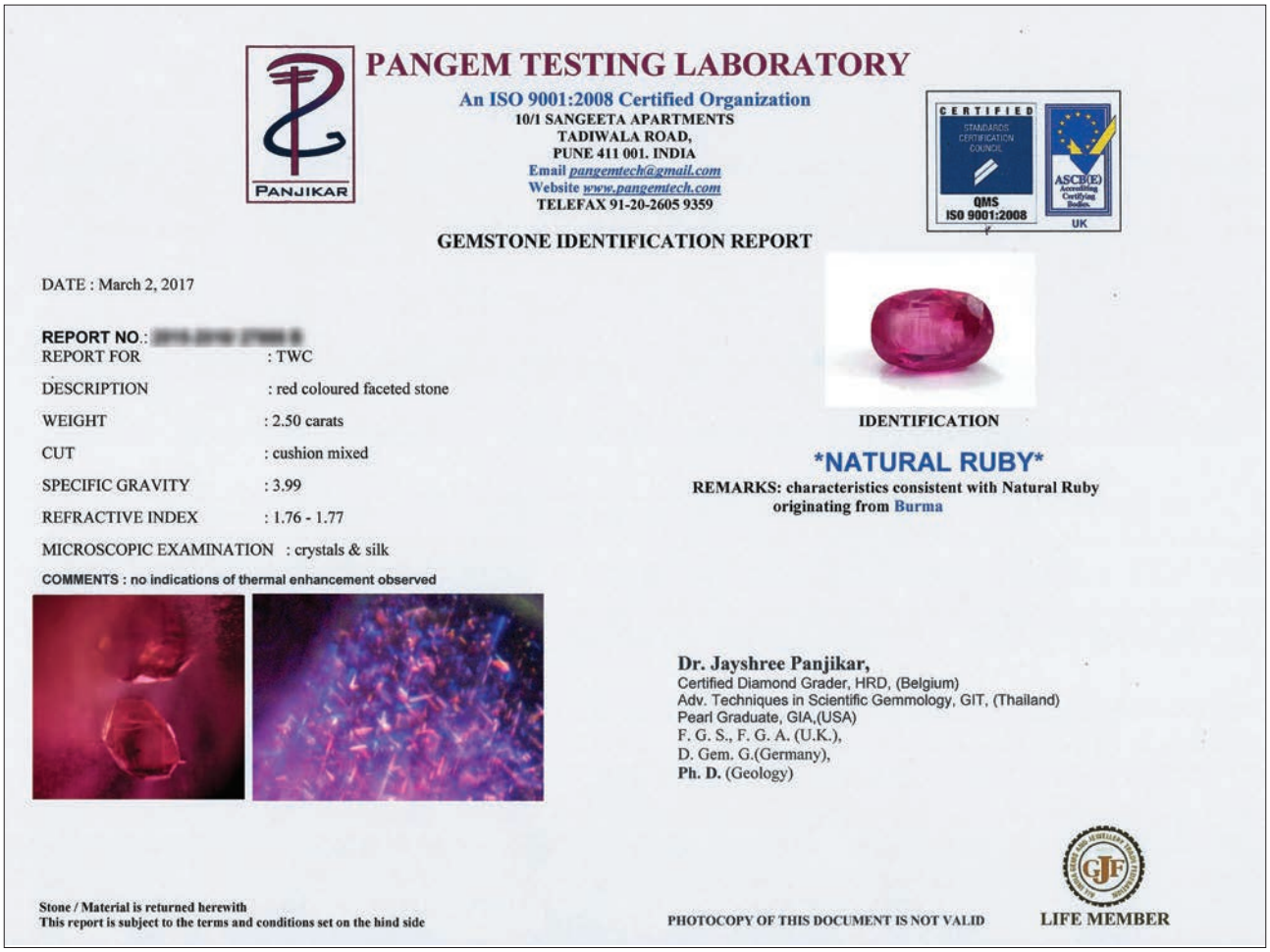
Also, the not-uncommon practice for a dealer to get more than one lab report for the origin of a sapphire, say, and retain any that say Kashmir and dispose of the rest, is likely to be illegal rather than just unethical. This selective presentation of lab reports in the trade has been countered by the growing practice for major auction houses to list the findings of different gem labs in their catalogues, even if they disagree. For example, an auction of fine jewellery held in London in 2014 included a ring set with an important sapphire weighing 30.08 ct (again, see Figure 1; Bonhams, 2014). It was accompanied by reports from SSEF and The Precious Stone Laboratory (London) giving a Sri Lankan origin, as well as a report from the Gübelin Gem Lab expressing the opinion that it was from Burma. This openness in providing all three reports is the result of legal advice and an indication of the sort of transparency, realism and honesty that buyers should be able to expect from all in the trade. How buyers might be expected to know how much confidence they can place in the individual laboratories is a problem and a matter for ongoing discussion. Labs differ in the equipment and experience they have, and one might be far more accomplished with one type of gem than another.

Trade Expectations

The gem trade's use of lab reports brings us back to the practicalities. There is no scientific reason not to be more open and transparent about lab reports being an educated guess, and likewise there is no reason for them not to include something about the data and reasoning that formed the basis of the stated opinion. There are strong ethical and probably even legal reasons why they should. The main obstacle is the trade. Those who commission the reports ideally want black-and-white answers: the origin of the sapphire, say, stated as unequivocally as possible. Just consider the indignation, even anger, that can greet an 'undeterminable' lab verdict on a stone. However, if a lab is to be genuinely independent and aware of its responsibilities to all who are likely to rely on the report, it should not let its scientific principles be subverted by the unrealistic expectations of the gem trade. Modern gemmology is deeply complex and must attempt to keep its head above the waters of the flood of gem treatments, synthetics and origin challenges.

But laboratories tread a difficult path. As one former lab director has said, if gem laboratories are too cautious in their reports, they lose customers; if they are overconfident, they lose credibility (H. A. Hänni, pers. comm., 2017). Labs are businesses and costly to run, so there must be a balance, but the overriding factor must surely be the best interests of those who rely on the reports. The boards that run the labs might also be warier about expressing uncertainty than those working in them, but times are changing.

Every industry today is awash with the need for laboratory reports, from contaminants in baby powder to ancient Greek gold wreaths. In the art and antique world, perhaps closest in concept to gem lab reports, it is increasingly normal for reports to include tables of analyses, details of methods of manufacture and signs of age, often with photomicrographs and, of course, the relevant expert's overall view, which necessarily includes the input of his or her 'experienced eye'. With a carefully thought-out workflow, the addition of analytical data and photos (e.g. Figure 4) does not greatly increase the time taken to pro-



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GEMSTONE IDENTIFICATION REPORT

DATE : March 2, 2017

REPORT NO.:

REPORT FOR	: TWC
DESCRIPTION	: red coloured faceted stone
WEIGHT	: 2.50 carats
CUT	: cushion mixed
SPECIFIC GRAVITY	: 3.99
REFRACTIVE INDEX	: 1.76 - 1.77
MICROSCOPIC EXAMINATION	: crystals & silk

COMMENTS : no indications of thermal enhancement observed

IDENTIFICATION

NATURAL RUBY

REMARKS: characteristics consistent with Natural Ruby originating from Burma

Dr. Jayshree Panjikar,
Certified Diamond Grader, HRD, (Belgium)
Adv. Techniques in Scientific Gemmology, GIT, (Thailand)
Pearl Graduate, GIA,(USA)
F. G. S., F. G. A. (U.K.),
D. Gem. G.(Germany),
Ph. D. (Geology)

Stone / Material is returned herewith
This report is subject to the terms and conditions set on the hind side

PHOTOCOPY OF THIS DOCUMENT IS NOT VALID

LIFE MEMBER

Figure 4: This lab report provides an example of including photomicrographs to support an opinion of a stone's geographical origin—in this case, a Burmese ruby. Courtesy of Dr Jayshree Panjikar.

duce a report. After all, the lab is keeping these records anyway.

However, with a more 'justified' gem lab report, this author is not suggesting documenting every inclusion, say, but rather providing an overview of the range of observations or tests that were significant in reaching the conclusions presented, along with a statistical representation of data where relevant. This sort of report will not necessarily give sufficient detail for the reader to gauge how much confidence he or she should place in the report, but it should be worded in a way to indicate broadly how confident the lab is in its opinion. More justified laboratory reports might not reduce the issuing of conflicting reports by different labs, but they might better allow the users of those reports to understand why different conclusions were reached.

Conclusions

A serious discussion of a way forward in the context of gemmological lab reports, and their value for and impact on the trade is long overdue. There are various industry bodies that could spearhead this, and even a new International Standard is perhaps not unrealistic. With the growing use of reports and the legal liabilities of labs, such discussions are surely essential. This author suggests two initial steps:

- When conclusions presented in a lab report are opinions, not facts, they should be clearly expressed as such at the point where they are presented.
- Reports should briefly explain the nature of the observations and analyses on which their conclusions are based, where possible including relevant photomicrographs, analyses or statistical information.

Another step would be to realize that use of the word 'probably' in a report can be a sign of wisdom rather than weakness.

It might well be that some gemmological laboratories decide their future is best served as the marketing arm of the gem trade. That is their

choice; there is nothing wrong with the gemmologist as poet, but they cannot then pretend to the trade, and the trade cannot pretend to their customers, that they represent an independent, detached service. If all gem lab reports become more open about the inherent uncertainties behind many opinions, fine gems might begin again to be sold on the basis of their beauty and individuality rather than on the basis of paper. A wider and more realistic understanding of the subjective content of lab reports would mean also an understanding that labs should be able to change their opinions without this being viewed as a sign of incompetence or ignorance. Information, experience and technology develop. As the 18th century moralist Joseph Joubert said: "Those who never retract their opinions love themselves more than they love truth."

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Acknowledgements

The author is grateful to Prof. Dr Henry A. Hänni (GemExpert, Basel, Switzerland) for many helpful suggestions for improvements to this article, to the other anonymous reviewers of its first draft, and to Dr Daniel Nyfeler (Gübelin Gem Lab, Lucerne, Switzerland) for useful conversations on this subject.

Fake Pearls Made from *Tridacna gigas* Shells

Michael S. Krzemnicki and Laurent E. Cartier

Five non-nacreous 'pearls' that allegedly came from *Tridacna gigas* (giant clams) were studied for this report. Our observations revealed that none of them were pearls, but instead they had been manufactured from *Tridacna* clam shell. The identification of such imitations is in most cases straightforward, and is mainly based on their characteristic layered structure observed in reflected light and with transmitted fibre-optic illumination. Our results are compared with recent reports of other such fake pearls that are often wrongly described as being genuine natural pearls.

The Journal of Gemmology, **35**(5), 2017, pp. 424–429, http://dx.doi.org/10.15506/JoG.2017.35.5.424

Introduction

Pearls inspire the imagination of mankind, as they have represented status, good fortune and wealth since historic times. Therefore, it is no surprise that, even today, exceptionally large pearls attract much interest among the public (even though they are not nacreous). Occasionally reports on such objects appear in popular news media, in which they are commonly and correctly described as formations from the *Tridacna* clam (e.g. *Tridacna gigas*). A single account from a local newspaper may be multiplied by press agencies, so that a story based on just one pearl is then covered in many newspapers and websites, thus making its way into worldwide headlines.

Due to such recent media coverage, the authors' laboratory is being confronted with numerous requests to analyse similar non-nacreous 'giant pearls'. This article documents the results of our testing on five such items at SSEF (Figure 1), all of which proved to be fake pearls that had been cut and polished from *Tridacna* clam shell.

Tridacna Clams and Their Pearls

Tridacna clams (Tridacninae subfamily) are among the largest living bivalve molluscs, with a shell diameter up to 110 cm (Sarasin, 1904; Rosewater, 1965). Inhabiting shallow coastal waters of the Indo-Pacific region (Rosewater, 1965), these species are nowadays among the most endangered clams and are protected by the Convention on International Trade in Endangered Species (CITES, 2016). Their white shell is massive and thick, and shows a characteristic and attractive wave-like cross-section. As such, the shell has been used for adornment in native cultures and historically as fonts (vessels containing holy water) in Catholic churches throughout Europe (e.g. Saint Sulprice in Paris, France: Figuier, 1868, p. 148; Kunz and Stevenson, 1908, p. 76).

The presence of symbiotic single-celled dinoflagellate algae (zooxanthellae) in the mantle tissue of *Tridacna* clams not only results in a colourful appearance of the living animal, but also is regarded as the reason for the growth of the

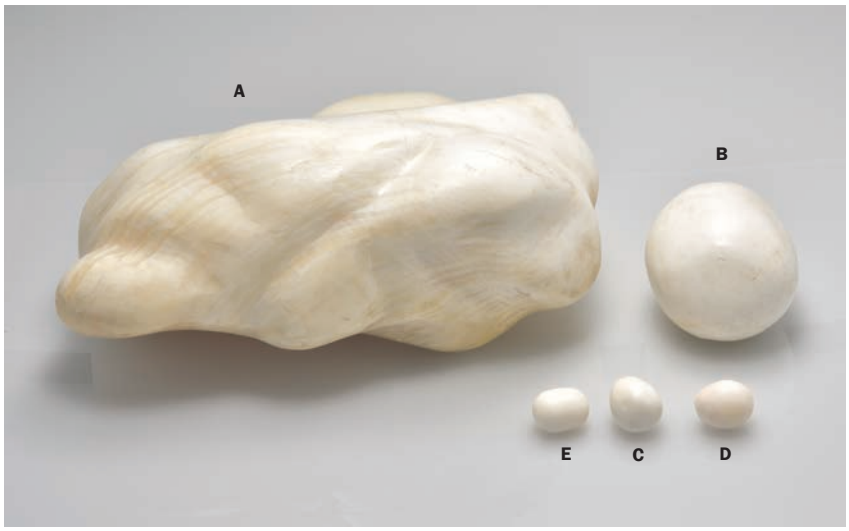


Figure 1: These five fake pearls (samples A–E), all cut from the shell of giant clams, were studied for this report. The largest item is 27 cm in diameter and weighs 6.8 kg. Photo by V. Lanzafame, © SSEF.

massive calcium carbonate shells of these species (Dame, 2011).

Pearls, blister pearls (i.e. those attached to the inner wall of a shell) and blisters (i.e. internal protuberances of the shell caused by the intrusion of foreign bodies between the mantle and the shell) from *Tridacna* clams are known in the trade (e.g. Kunz and Stevenson, 1908; Bari and Lam, 2010; Singbamroong et al., 2015; see also www.pearl-guide.com/forum/content.php?76), but due to their often rather dull whitish appearance and baroque shape (e.g. Figure 2) they have not gained much interest so far, except among a few pearl collectors. The shell material of *Tridacna* clams consists of regularly and densely interwoven aragonite fibres, similar to *Strombus gigas* (queen conch: Osuna-Mascaró et al., 2014) and many other gastropods. This partially results in fine 'flame structures' when viewed in reflected light (Hänni, 2010). As a consequence, both natural pearls and polished shell pieces from *Tridacna* clams often show such flame structures on their surface. However, not all non-nacreous white natural pearls claimed to be from *Tridacna* clams (Lai, 2014; Singbamroong et al., 2015) necessarily originate from the Tridacninae subfamily. They may also be the beautiful products of other mollusc species—misnamed as *Tridacna* clam pearls, since there is currently no method for the species identification of such non-nacreous white pearls. This is very much in contrast to nacreous pearls, which currently can be separated genetically (Meyer et al., 2013), and also in some cases by UV-Vis-NIR reflectance and Raman spectroscopy.

Samples and Methods

For this study, we investigated five samples (specimens A–E, Figure 1) submitted to SSEF by one client who reported them to be *Tridacna* pearls originating from Palawan, an island in the eastern Philippines. The samples ranged in weight from 6.8 kg (A) to 18.4 g (E) and in maximum length from approximately 27 to 2.6 cm. The large size and weight of some of the samples precluded our normal pearl testing procedure, so we based our conclusions mostly on careful observation of surface textures with the unaided eye and the microscope (Eickhorst LED Leica Gemmaster). In addition, for sample E we performed Raman spectroscopy with a Renishaw InVia microscope and chemical analysis by energy-dispersive X-ray fluorescence (EDXRF) spectroscopy using a Thermo

*Figure 2: A large hollow natural blister is shown attached to the inside of a giant clam shell (*Tridacna gigas*). A loupe is shown for scale; the shell measures approximately 26 cm wide. Photo by Luc Phan, © SSEF.*

Scientific Quant'X instrument. Also, X-radiography was performed on the three smaller samples (C, D and E) using a Yxlon Cougar digital X-ray setup.

Visual and Microscopic Observations

We divided the study specimens into two categories according to their shape (again, see Figure 1). The largest sample (A) displayed a baroque shape, visually somewhat reminiscent of the wave-like form of *Tridacna* shell. The remaining specimens (B–E) were oval to slightly baroque, and thus were more typical of the shapes exhibited by pearls.

Viewed with reflected light, all five specimens showed distinct curved, layered structures across their entire surfaces. These structures had no direct correlation to the shapes of the specimens, but were consistent with the undulating layered structures of *Tridacna* clam shell. Sample B exhibited a complex curved and folded structure (Figure 3) that appeared to represent the hinge of the clam; this area possesses the thickest accumulation of calcium carbonate in *Tridacna* shells.

Close examination of all the samples further revealed distinct polish marks in random orientations (e.g. Figure 4), as would be expected from items worked into a roundish shape. The low-quality polish, suggesting a rushed 'production' of these items, contrasts with the highly polished specimens

Figure 4: Distinct polish marks on the surface of fake pearl sample C result in a low-quality polish. Photo by M. S. Krzemnicki, © SSEF; image width 10 mm.

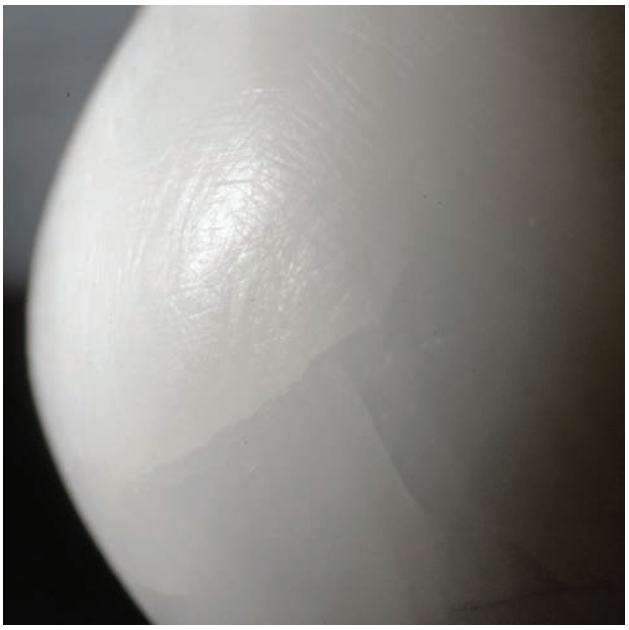


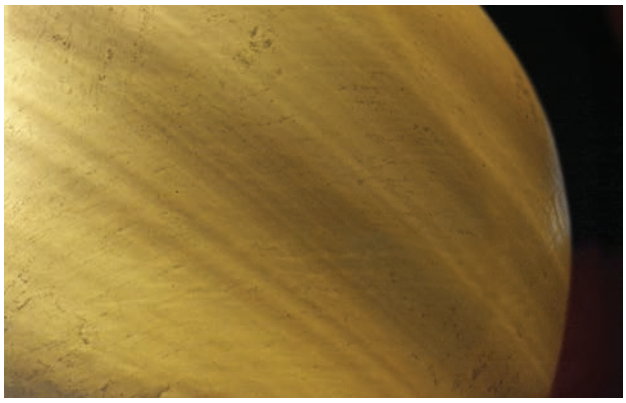
Figure 3: The surface of specimen B (8.6 cm long), cut and polished from Tridacna *shell, exhibits distinct curved lines representing seasonal growth layers. Photo by V. Lanzafame, © SSEF.*

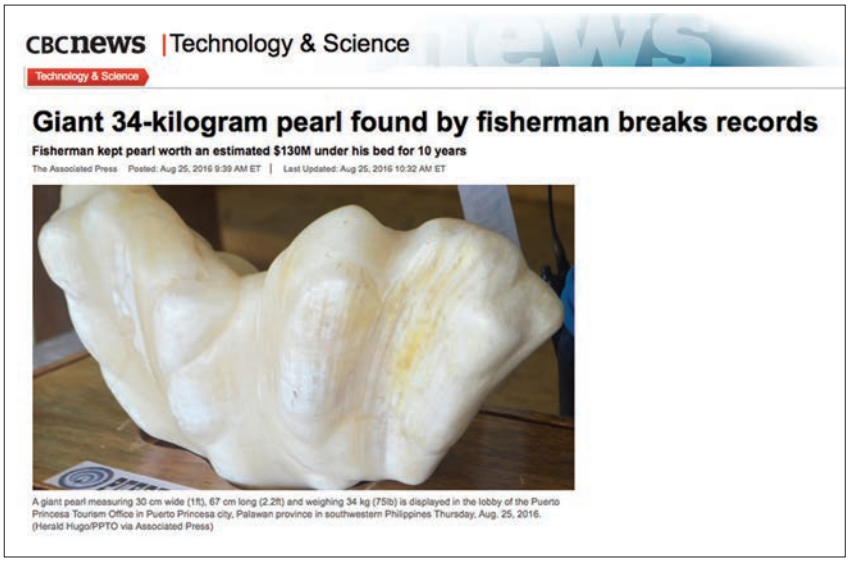
of manufactured shell material that have been previously examined at SSEF (e.g. Krzemnicki, 2006).

Using a strong transmitted fibre-optic light source, it was possible to investigate the internal structure of the five study samples. All showed distinct and sharply defined internal layering (Figure 5), representing the seasonal calcium carbonate precipitation layers of the shell in *Tridacna* species. Such features are not commonly observed in pearls, which form by precipitation of concentric spherical layers within the pearl sac of a mollusc.

Although surface- or subsurface-related striae in genuine *Tridacna* pearls might occasionally produce a somewhat layered appearance with transmitted fibre-optic illumination (Lai, 2014),

Figure 5: Viewed with transmitted fibre-optic illumination, this close-up of specimen D (22.5 g) reveals the layered structure of the Tridacna *shell from which it was cut. Photo by M. S. Krzemnicki, © SSEF; image width 11 mm.*

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Giant 34-kilogram pearl found by fisherman breaks records

Fisherman kept pearl worth an estimated $130M under his bed for 10 years

The Associated Press Posted: Aug 25, 2016 9:39 AM ET | Last Updated: Aug 25, 2016 10:32 AM ET

A giant pearl measuring 30 cm wide (1ft), 67 cm long (2.2ft) and weighing 34 kg (75lb) is displayed in the lobby of the Puerto Princesa Tourism Office in Puerto Princesa city, Palawan province in southwestern Philippines Thursday, Aug. 25, 2016. (Herald Hugo/PPTO via Associated Press)

Figure 6: A reported 'giant pearl' weighing 34 kg provides a recent example of a fake pearl that made its way into worldwide headlines via the Associated Press in August 2016. The shape, layered structure and poor surface polish provide strong combined evidence that this object has been manufactured from Tridacna *shell.*

the present samples did not show any such striae, but rather only a badly polished surface.

The complex and sharp banding exhibited by the present samples (e.g. Figures 3 and 5) is also very different from the weak circling bands occasionally observed in non-nacreous white pearls from various molluscs, such as *Spondylus* spp. (Ho and Zhou, 2015) and *Fusinus* spp. (Bari and Lam, 2010, p. 75). These circles (seen as parallel bands when viewed from the side) are due to growth heterogeneities aligned by the rotation of the pearl during its formation (Gueguen et al., 2015). Typically these bands are rather broad and diffuse, and are visible either as a sub-surface effect when illuminated with a strong light source or at the surface (i.e. in nacreous pearls), where they may negatively affect the quality of a pearl. Such pearls commonly show a distinct rotational shape (button to long-prismatic oval) and occasionally reveal distinct flame structures radially emanating from rotational axis points at their top and bottom.

Viewed with the microscope, some of the five study samples revealed weak and fine flame structures perpendicular to the layering, similar to those described by Hänni (2010), but no flame structures were seen radially emanating from a distinct (rotational axis) point.

Based on these observations, we concluded that all five study specimens were fake pearls that had been cut and polished from the massive shells of *Tridacna* clams. Such imitations—typically of rather small size—have been manufactured since historic times (mostly then from *Unio* freshwater mussel shells) and have been described in detail by Kunz and Stevenson (1908, pp. 361, 494 and 497).

Advanced Testing

Raman spectroscopy of sample E revealed that it consisted of aragonite, as expected for *Tridacna* clams (Hänni, 2010). EDXRF analysis of this sample showed the expected major amounts of Ca along with traces of Sr (0.25 wt.% $SrCO_3$), but with Mn below the detection limit, clearly supporting a formation of the biogenic calcium carbonate in marine waters. X-radiography of samples C, D and E revealed no discernible internal structures such as layers or internal cavities in any of these specimens. This result is very common for non-nacreous pearls or shells (or beads made from such shells) that consist completely of densely interwoven aragonite fibres.

Further Cases of Fake Pearls from *Tridacna* Clams

From time to time, the authors' laboratory is asked to analyse 'giant pearls', and these objects are often accompanied by dubious identification and appraisal documents. Since the international media highlighted such a 'giant pearl' in August 2016 (e.g. Figure 6), the number of such requests has increased steadily. Although the authors have not personally studied the 'giant pearls' claimed to originate from *Tridacna* clams that have recently appeared in the media, we are convinced that most—if not all—of them are in fact fakes that were manufactured from the shell of *Tridacna* clams. This opinion is based on their apparent similarity in shape, layered structure and surface polish to the study samples we described above.

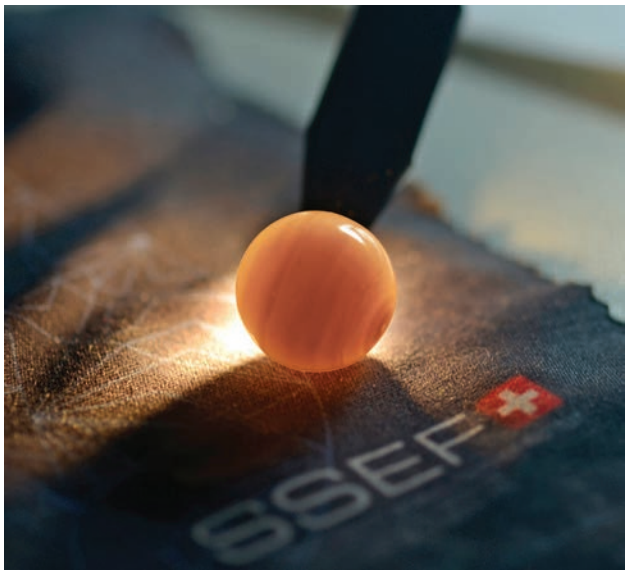

Figure 7: This 'pearl' (18.6 mm in diameter) is actually a bead cut from Tridacna *shell. The shell layers are distinctly visible when illuminated with fibre-optic lighting. Photo by M. S. Krzemnicki, © SSEF.*

Figure 8: This polished Tridacna *shell bead (~23 × 16 mm or 63 ct) was dyed to imitate a Melo pearl. Note the well-developed flame structure, as would be expected for a genuine Melo pearl. Photo by M. S. Krzemnicki, © SSEF.*

Still, the media hype about such 'giant pearls' is worth highlighting, as it reveals the context in which modern urban myths are presented to the general public. For those who have read about several such 'giant pearl' discoveries, the themes sound very familiar. The stories include emotions such as greed and tragedy (a diver dies as he is trying to remove the 'pearl' from the giant clam but is stuck in the closing shell), unexpected discoveries but ignorance of their value (a poor fisherman finds the 'pearl' and keeps it as a personal item without knowing its 'true' value) and fairy-tale endings that involve achieving wealth and fortune and, hopefully, happiness (finally the 'giant pearl' is appraised by some unknown source as being of enormous value—for example, US$100 million—with an open ending as to how much money the poor fisherman will actually obtain). Although such stories may be entertaining and intriguing, the same themes have been used and repeated with great detail since historic times (Kunz and Stevenson, 1908, p. 144), mostly to create illusion and interest in such exotic 'oddities'.

Unnoticed by the media, but occasionally encountered in the laboratory and reported in the gemmological literature, are smaller fake pearls that most probably have been cut and polished from *Tridacna* clams (Disner and Notari, 2015). In the past few years, SSEF has analysed a few such specimens, cut into roundish shapes and sizes typical for gastropod pearls (e.g. Figure 7). They were polished with great care to display their fine flame structure and perfectly shaped to fit into jewellery. As such, they have been mistakenly bought as non-nacreous natural pearls, even by knowledgeable pearl dealers. Moreover, these manufactured 'pearls' may be dyed orange to imitate Melo pearls (Wentzell, 2006; Sturman et al., 2011; Figure 8). Raman spectroscopy of one such Melo imitation showed no peaks at 1134 and 1527 cm^{-1} characteristic of the natural-colour pigment in Melo (and conch) pearls, but did reveal three broad features at 1519, 1499 and 1363 cm^{-1} that closely matched the broad Raman peaks of organic dye (possibly red eosin; Krzemnicki, 2006).

Conclusions

Based on our observations and analyses, the five specimens submitted as 'pearls' reportedly originating from giant clams were identified unambiguously as beads cut and polished from *Tridacna* shell. The main criterion for the detection of all these fake pearls was the presence of distinctly discernible shell layers (sometimes overprinted by fine flame structures).

Considering the similarity of these specimens to numerous other items on the Internet or in pictures sent to us, we assume that most of these others also are fakes, and as such have essentially no commercial value. This is very much in contradiction to media reports or dubious appraisal documents, which unfortu-

nately are too often reproduced and relinked by reputed news sources without question.

It is also important to reiterate that *Tridacna* clams are endangered species listed in Appendix II of CITES (2016) and therefore are protected. Any international trade of shells or pearls from *Tridacna* requires an official permit before export. As such, trade organizations actively have banned the use of *Tridacna* shell beads in jewellery or as beads for pearl cultivation in recent years (Zhou and Zhou, 2015).

And, finally, this study reminds us of the ingenuity of mankind to create illusion and garnish fraud with an appealing myth. The authors hope that with this article, the chapter on the so-called 'giant pearls' from *Tridacna* clams can be closed, at least in the gemmological community.

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Large 12-Rayed Black Star Sapphire from Sri Lanka with Asterism Caused by Ilmenite Inclusions

Thanh Nhan Bui, Pascal Entremont and Jean-Pierre Gauthier

A large (112.64 ct) black star sapphire of probable Sri Lankan origin that exhibits 12-rayed asterism was studied for this report. As in other 12-rayed star sapphires, its phenomenal appearance is due to the presence of oriented needle-like inclusions that produce two superimposed six-rayed stars that are rotated 30° relative to one another. However, Raman spectroscopy combined with optical microscopy unexpectedly revealed that the inclusions responsible for both stars consist of the same mineral, ilmenite. By contrast, 12-rayed star sapphires from Thailand typically contain separate inclusion sets of rutile and hematite-ilmenite series minerals corresponding to the two six-rayed stars.

The Journal of Gemmology, **35**(5), 2017, pp. 430–435, http://dx.doi.org/10.15506/JoG.2017.35.5.430

Introduction

Asterism is an optical phenomenon that occurs in gemstones containing oriented needle-shaped inclusions. In corundum, due to the three-fold rotational symmetry of the basal pinacoid, networks of needles are oriented in three different crystallographic directions that intersect at 120°. As a consequence, typical asterism in corundum consists of a six-rayed star composed of three intersecting branches. The exsolved acicular inclusions, with the same rotational symmetry, may be oriented along two different hexagonal prisms of the host crystal. As a general rule, rutile needles are oriented parallel to the growth zoning and the second-order hexagonal prism of the host corundum, while needles of hematite-ilmenite series minerals are oriented perpendicular to these features (Hughes, 1997, p. 94). When both orientations of acicular inclusions are present in the same corundum host, they result in a 12-rayed star.

In the gemmological literature, there is a lack of systematic identification of minerals leading to asterism in corundum and, more generally, in asteriated gemstones. In this article, we use Raman spectroscopy to analyse both networks of needle inclusions in a large 12-rayed black star sapphire reportedly from Sri Lanka, as well as in smaller samples from the same source and from Thailand for comparison.

Materials and Methods

The large star sapphire (Figure 1) weighs 112.64 ct and was purchased in Colombo, Sri Lanka, by author PE in approximately 1985. No information concerning the exact origin of the stone was available. Named 'Ceylon Stars', it is the largest 12-rayed star sapphire from Sri Lanka that is known to the authors. It resembles another large 12-rayed star sapphire (70.79 ct), also from Sri Lanka, that is very dark blue and mounted in a ring in the National

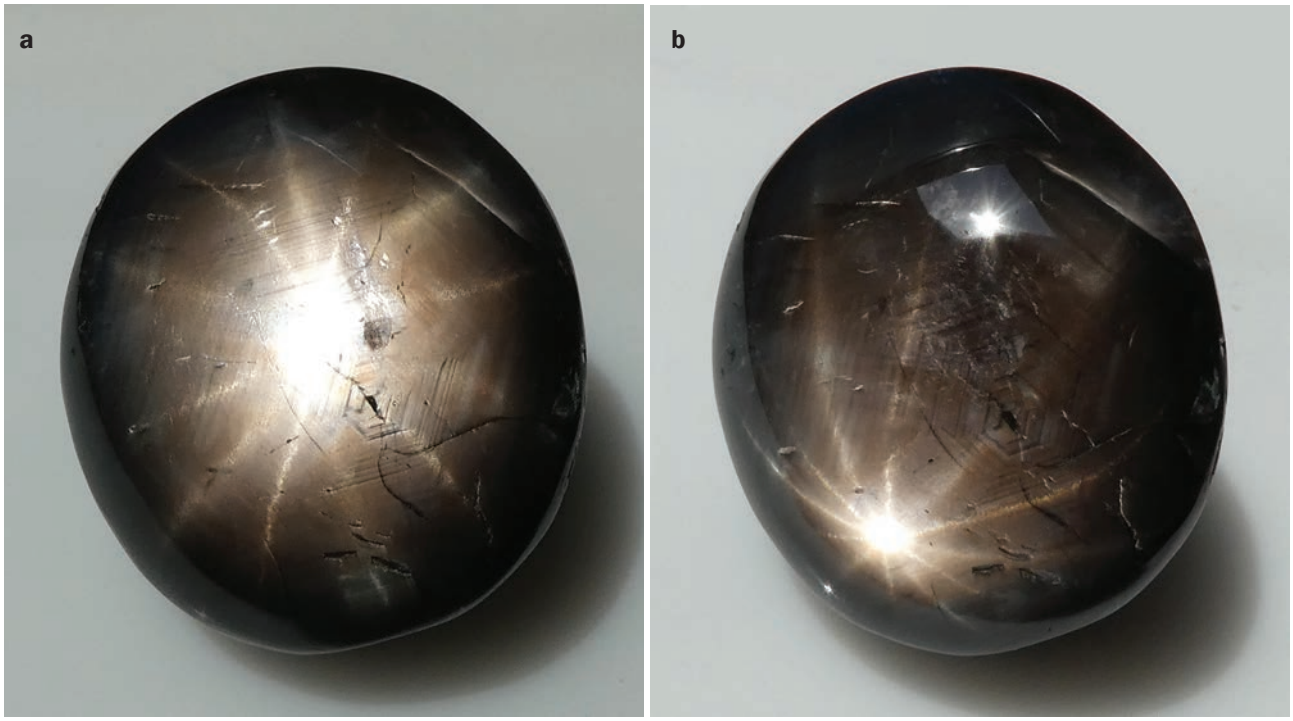


Figure 1: The 112.64 ct 'Ceylon Stars' sapphire, from the collection of P. Entremont, displays 12-rayed asterism, as shown here with pinpoint illumination positioned (a) over its centre and (b) obliquely. Photos by P. Entremont.

Gem Collection of the Smithsonian National Museum of Natural History (http://geogallery.si.edu/index.php/10002721).

For comparison, five other 12-rayed star sapphires from Sri Lanka (Figure 2A–E)—all weighing less than 5 ct and obtained by author PE at the same time as the 112.64 ct stone—also were examined, as well as a 12-rayed star sapphire from Thailand (Figure 2F) weighing 8.05 ct that was recently obtained by author TNB in Chanthaburi, Thailand.

All samples were observed with a binocular microscope in reflected light at magnifications of 15×–1,000× to examine their acicular inclusions. The inclusions in all samples were then identified using a Horiba LabRAM 800HR micro-Raman spectrometer. Calibration was performed on a silicon substrate (first-order Raman peak of 520.7 cm^{-1}). A green laser (514 nm) was used to excite the samples, and the power (6.6 mW) was modulated at 50% and 100%. The acquisition time for each spectrum ranged from 1 to 2 minutes, and each spectral acquisition was performed twice. Due to the very small size of the inclusions (a few micrometres wide), we used an optical magnification of 1,000×. In order to plot several curves in the same graph, the spectra were normalized according to the most intense Raman peak. The background was not subtracted from the spectra.

Results and Discussion

Large Sri Lankan Black Star Sapphire

When illuminating the cabochon at its centre (Figure 1a) or obliquely (Figure 1b) with pinpoint illumination, we readily observed the 12-rayed star. Growth zoning was seen as bands along three crystallographic directions in the basal plane of the pinacoid of the corundum host. The hexagonal growth bands were off-centre relative to the dome of the cabochon. This is probably due to weight optimisation during cutting, as supported by the backside of the cabochon being kept in its rough state. The body colour of the sapphire was difficult to discern due to the dense concentration of acicular inclusions. Nevertheless, strong transmitted illumination revealed that its body colour was mainly dark blue with some areas showing a more violet hue.

The 12-rayed star was composed of two six-rayed stars rotated 30° relative to one another. This seems consistent with the usual exsolution of inclusions in this type of corundum, in which one set of needles (perpendicular to the growth bands in the corundum) consists of hematite-ilmenite minerals, and the other set (parallel to the growth bands) consists of rutile (cf. Bui et al., 2016). These latter inclusions typically appear white and are thinner in dimension, producing

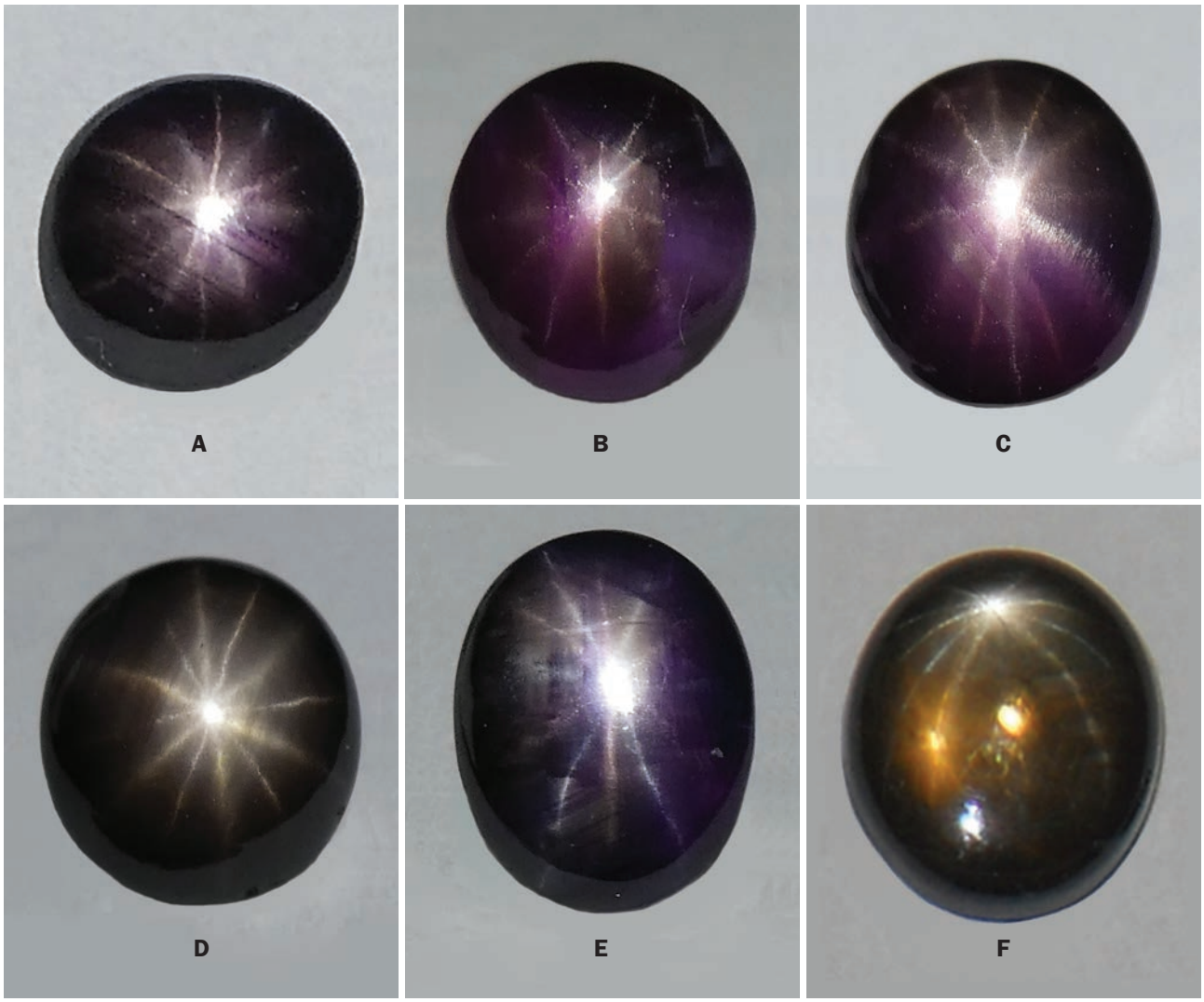


Figure 2: Several additional 12-rayed star sapphires were studied for comparison, including five others from Sri Lanka (A–E; 1.53–4.19 ct) and one from Thailand (F; 8.05 ct). The Sri Lankan samples range from purple to violet, except one that can be considered black (D). The Thai stone (F) is also a black star sapphire. In samples A–D, all rays of the stars are brownish, while samples E and F have both brownish and whitish rays corresponding to differences in the inclusions responsible for their stars. Photos by T. N. Bui (A–E) and J.-P. Gauthier (F).

sharp asterism, whereas the former are darker and wider, giving broader rays. However, in the present stone, the needles of the two stars were similar in colour. For this reason, we decided to examine this 12-rayed sapphire more carefully to determine the exact nature of its inclusions.

Close inspection by optical microscopy at high magnification near the surface of the cabochon revealed some details about the microstructure of the growth bands. Networks of oriented needles and platelets—in three different orientations intersecting at 60°/120°, typical of the three-fold rotational symmetry of corundum—were present within the basal plane. Compared to the growth bands, most of the acicular inclusions were oriented perpendicular and oblique at 30° (e.g. Figure 3a), or parallel and oblique at 60° (e.g. Figure 3b). From these relative orientations of the acicular inclusions compared to the growth bands, we expected to attribute the inclusions in Figure 3a to the hematite-ilmenite series and those in Figure 3b to rutile. However, the density and the width of inclusions varied in different areas of the stone. Also, the average width of the inclusions oriented perpendicular to the growth bands of the host corundum was narrower than the inclusions oriented parallel to the growth bands. This explains the difference in sharpness between the two six-rayed stars constituting the 12-rayed asterism.

Figure 4a illustrates a dark-coloured region that was depleted of acicular inclusions. Instead, it contained a lower density of somewhat larger

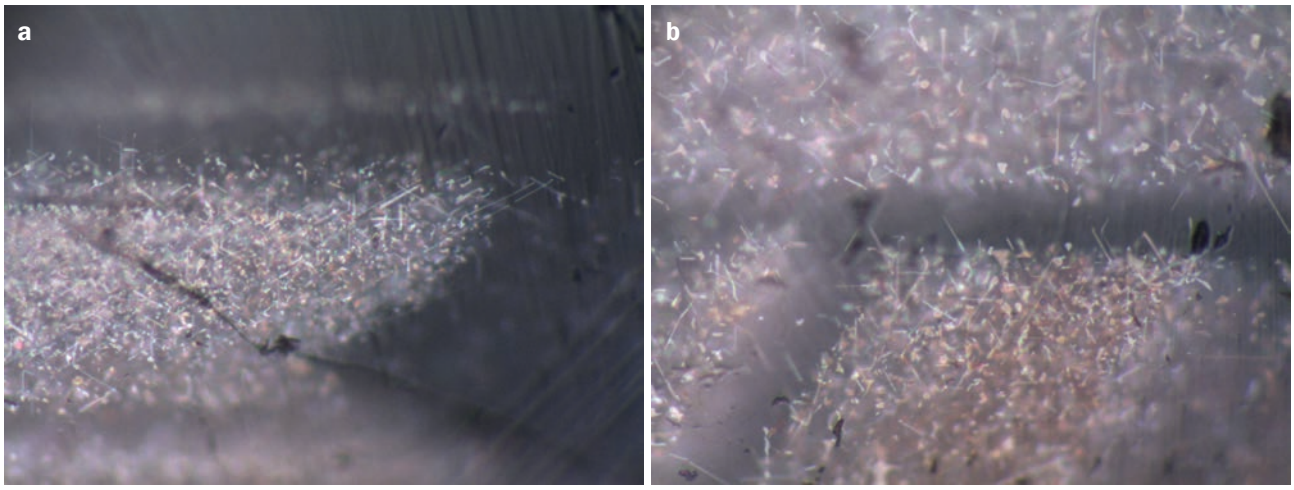


Figure 3: Two networks of needles constitute the growth zoning in the large 12-rayed sapphire, oriented perpendicular (a) and parallel (b) to the growth bands in the host corundum. The corundum growth bands are horizontal in both of these images. Photomicrographs by T. N. Bui in brightfield illumination; field of view 400 × 300 µm.

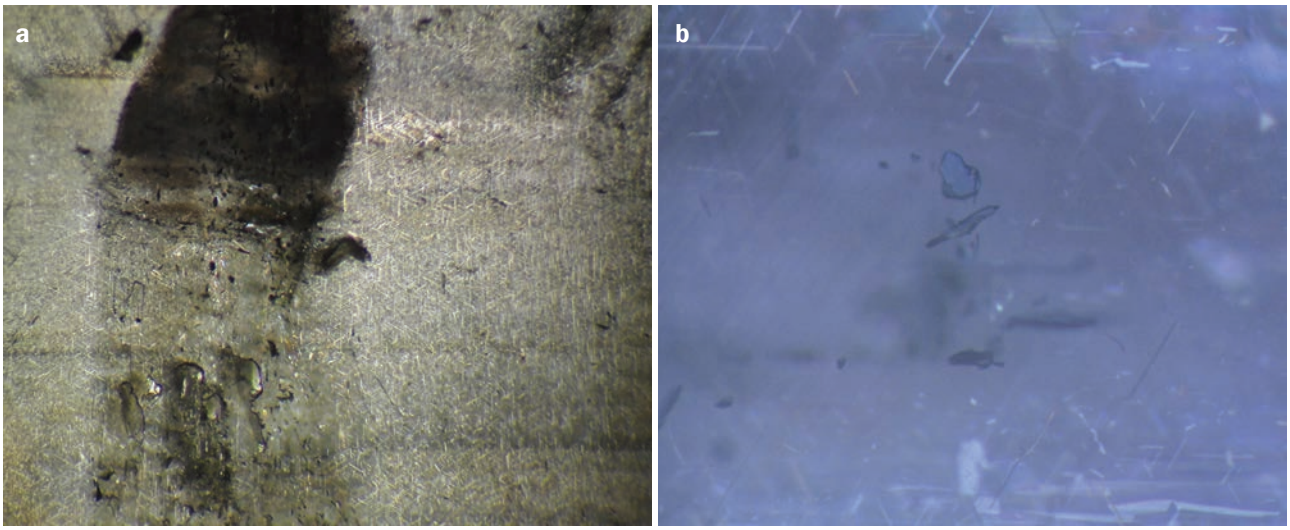
black inclusions. High magnification revealed their plate-like shape (Figure 4b), with edges parallel or perpendicular to the acicular inclusions. Their appearance was similar to the magnetite inclusions found in 'Gold Sheen' sapphires (see Figure 13 in Bui et al., 2015). In the present case, however, these black inclusions were isolated from the networks of acicular inclusions.

In agreement with previous studies (e.g. Palanza et al., 2008; Bui et al., 2015), Raman spectra of the inclusions consisted of superimposed signals from both the host sapphire and the tiny inclusions. Figure 5a illustrates the spectrum of sapphire (α-Al_2O_3 corundum), including peaks at 379, 418, 430, 449, 576 and 750 cm^{-1}. Surprisingly, both networks of acicular inclusions, as well as the black inclusions, were identified as ilmenite ($FeTiO_3$); no hematite or rutile inclusions were found. Typical Raman spectra for the ilmenite inclusions were characterized by a strong band at 678 cm^{-1}, as depicted in Figure 5 (spectra b–d). The other vibration modes for ilmenite were 162, 194, 221, 256, 291, 329, 374, 451 and 597 cm^{-1}. The obtained spectra are in good agreement with natural ilmenite (e.g. Rull et al., 2004, 2007; Bui et al., 2015) and pure synthesized ilmenite (e.g. Sharma et al., 2009; Guan et al., 2013).

Thai Black Star Sapphires

Black star sapphires, including those displaying 12 rays, are usually attributed to the Ban Kha Cha

Figure 4: Near the surface of the large sapphire is an area that is free of inclusions that contribute to the asterism; this area appears dark and contains black inclusions (a: field of view 3.25 × 2.60 mm). A closer view of the black inclusions reveals their plate-like shape with edges that are parallel or perpendicular to the acicular inclusions (b: field of view 400 × 300 µm). Photomicrographs by T. N. Bui in brightfield illumination.



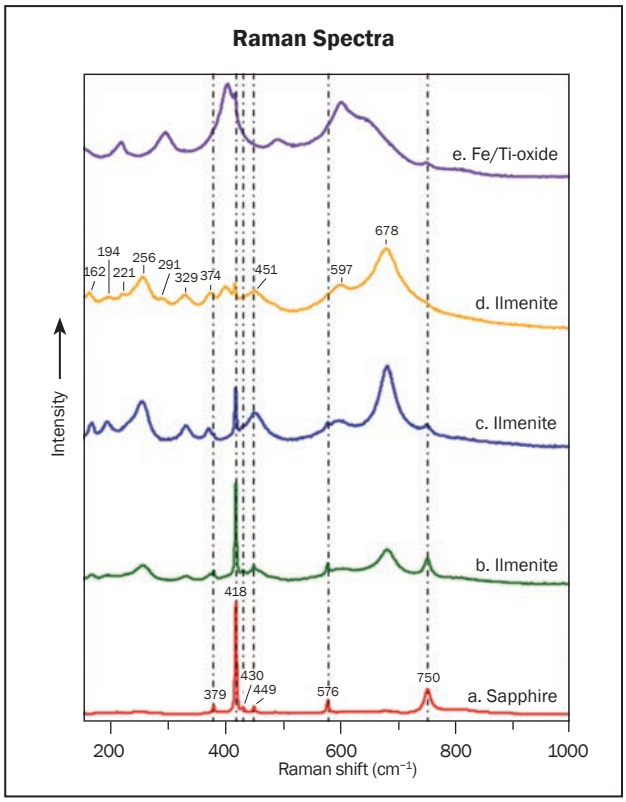


Figure 5: For the large sapphire, Raman spectra are shown for the host corundum (a); the inclusions responsible for the 12-rayed star, identified as ilmenite, present as narrow (b) and thick (c) needles and/or platelets; and for black inclusions of ilmenite that are not related to the asterism (d). The ilmenite spectra are distinct from those of Fe/Ti-rich oxide acicular inclusions in black star sapphires from Thailand (e). The vertical dashed lines indicate the Raman peaks of corundum superimposed on those of the analysed inclusions.

mine in Thailand, based on their physical and chemical characteristics. The acicular inclusions forming the classic six-rayed black star sapphires have been reported as an exsolution of hematite (Weibel and Wessicken, 1981) or both hematite and ilmenite (Gübelin and Koivula, 2008, p. 214). It was later demonstrated by scanning electron microscopy with energy-dispersive X-ray spectroscopy (Moon and Phillips, 1984) and by electron microprobe analysis (Saminpanya, 2001) that the inclusion exsolution is of the same chemical composition (Fe/Ti-rich oxides) but not pure hematite or pure ilmenite. In 12-rayed star sapphires from Thailand, the additional network of needles—parallel to the second hexagonal prism of the corundum host and producing the second six-rayed star at 30° with respect to the first one—is typically attributed only to rutile (Schmetzer and Glas, 2001). To our knowledge, there are no reports in the literature containing Raman spectra of Fe/Ti-rich oxides from acicular inclusions in black star sapphires, and therefore no identification of their exact mineralogy.

Figure 5 demonstrates the difference between a typical Raman spectrum of Fe/Ti-rich oxide inclusions in our 12-rayed black star sapphire from Thailand (Figure 2F) and those found in the large Sri Lankan gem (Figure 1). Further characterization of the mineralogical nature of the Fe/Ti-rich oxide acicular inclusions in the Thai sample is beyond the scope of the present study. We also confirmed the presence of rutile inclusions in this stone by Raman spectroscopy (not plotted in Figure 5).

Our 12-rayed black star sapphire from Thailand (Figure 2F) had the same appearance as the one reported by Schmetzer and Glas (2001). While one six-rayed star was brownish, the other was whitish, which was not the case for the large Sri Lankan sample in this study. Moreover, the branches of the whitish star in 12-rayed black star sapphires from Thailand were sharper than those of the brownish star, due to the narrower width of the rutile needles. In the large Sri Lankan sample, the six-rayed star parallel to the growth zoning was sharper than the other rays seen in this stone. The fact that it contains only ilmenite inclusions is consistent with its Sri Lankan origin, which is distinctive from the inclusion assemblage found in Thai stones.

Sri Lankan Star Sapphires

The smaller 12-rayed star sapphires that were studied for comparison had body colours ranging from purple to violet (Figures 2A–C and 2E) and black (Figure 2D). In each sample, the acicular inclusions parallel to the first-order hexagonal prism were identified by Raman spectroscopy as ilmenite. Ilmenite also constituted the second set of acicular inclusions—as for the 112.64 ct stone—except for one sample (Figure 2E), in which the second network consisted exclusively of rutile needles, which was consistent with the whitish colour of its corresponding six-rayed star.

Twelve-rayed stars are quite rare among Sri Lankan sapphires (Hughes, 1997, p. 406). By analysing the pattern of the growth zoning (formed by exsolved inclusions of epigenetic ilmenite) in our samples, we can deduce a relatively constant input of fluids rich in Ti and Fe during crystal growth. The lack of notable variation in fluid composition was suitable for ilmenite growth along both the first- and second-order hexagonal prisms in all but one of our samples. Microscopic observation of all the Sri Lankan samples demonstrated that the width of acicular ilmenite inclusions was narrower

for those oriented perpendicular to the growth bands in the corundum. This explains the sharpness difference between the two six-rayed stars constituting the 12-rayed asterism. In addition, the presence of the same mineral—ilmenite—causing both six-rayed stars in all but one Sri Lankan sample is consistent with the uniform brownish colour observed in all 12 rays of those samples (Figures 1 and 2A–D). However, both a brownish and whitish appearance of the rays may be shown by some Sri Lankan 12-rayed star sapphires (see Figure 2E and http://geogallery.si.edu/index.php/10002721/corundum-var-star-sapphire) and also in 12-rayed black star sapphires from Thailand (Schmetzer and Glas, 2001; Figure 2F), which contain inclusion networks of both the hematite-ilmenite series and rutile.

Conclusion

The presence of a single mineral—ilmenite—as the cause of 12-rayed asterism in sapphire was documented here for the first time in the largest such gem known to the authors, a 112.64 ct black star sapphire of probable Sri Lankan origin. For comparison, we examined five smaller star sapphires from Sri Lanka and one star sapphire from Thailand, all of which displayed 12-rayed asterism. Visual observation and optical microscopy showed a similar appearance for both networks of inclusions (i.e. both perpendicular and parallel to the growth bands of the host corundum). Raman spectroscopy confirmed that both sets of inclusion networks in all but one of the Sri Lankan sapphires consisted of ilmenite, which caused both six-rayed stars that constitute the 12-rayed asterism. By contrast, the 12-rayed asterism in Thai star sapphires is attributed to separate networks of hematite-ilmenite minerals and rutile. In addition, separate networks of ilmenite and rutile were confirmed in one of our Sri Lankan samples.

The identity of the mineral(s) causing the asterism in 12-rayed star sapphires can be inferred from the colour of the branches of each six-rayed star: ilmenite corresponds to brownish rays, and rutile produces whitish rays. The sharpness of the rays correlates to the width of the inclusions, regardless of the identity of the mineral that causes them.

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GIT 2016 Pre-Conference Field Trip to Mogok, Myanmar

November 2016

Tasnara Sripoonjan, Saengthip Saengbuangamlam and Thanong Leelawatanasuk

The Gem and Jewelry Institute of Thailand (GIT) organized a field trip to Mogok, Myanmar, to accompany the 5th GIT International Gem and Jewelry Conference, which was held 14–15 November 2016 (see report on pp. 445–447 of this issue). This 9–13 November pre-conference excursion was attended by 15 overseas participants from various fields related to gems and jewellery (i.e. gemmologist, mineralogist, journalist, gem retailer, gem wholesaler, gem collector and retail jeweller): Marcelo E. Souza (Brazil), Dr Geng Li (China), Ioannis Alexandris (Germany), Arent and Helene Heilmann (Greenland), Mary Ng (Hong Kong), Meenu Brijesh Vyas (India), Kentaro Emori (Japan), Yoko Okubo (Japan), William Wold (Netherlands), Sang Phil Oh (South Korea), Young Soo Chung (South Korea), Yuanchan Chaiyawat (Thailand), Chen Shen (USA) and Cynthia Unninayar (USA). The group was led by Aung Naing Thun, a representative of the Myanmar Gem and Jewellery Entrepreneurs Association, as well as three GIT gemmologists (the authors).

The goal of the five-day trip was to examine gem deposits, active mining operations and stone trading in Mogok. Participants had many opportunities to learn about the geology, mining and recovery techniques, as well as ruby and sapphire production. Other attractions included visits to educational facilities, gem markets and several historical pagoda sites.

***En Route* to Mogok:** The group flew from Bangkok to Mandalay and then boarded a van. Our first stop was the Werawsana Jade Pagoda near Amarapura Township, about 20 km from the airport. The pagoda is decorated with several varieties of jadeite jade, including 'ice', green and lavender types. We then visited a gemmological laboratory and school in Mandalay, where we stayed overnight before proceeding to Mogok early the next morning.

Our route followed the Mandalay–Myitkyina highway, passing through an immigration checkpoint near Pyin Oo Lwin in the

Editor's note: This report gives a description of the Mogok area just before it was closed to foreigners by Myanmar's government in December 2016. For two previous Excursions reports on Mogok, see *The Journal*, **34**(1), 2014, 55–67.

A panoramic view of 'Ruby Land' greets visitors to the Mogok valley. Photo by T. Sripoonjan.

Shan Highland, some 67 km east of Mandalay. The trip to Mogok took around six hours on good pavement alternating with dirt road, often quite winding. Upon our arrival, we checked into the King Bridge Hotel and then visited a viewpoint on the main road to the east of the gem mining region. It provided a panoramic vista of the Mogok Valley with numerous villages flanked by forested mountains.

Mogok Monasteries: We visited three pagodas in the Mogok area. At the Phaung Daw Oo temple, a white marble Buddha is flanked on both sides by sacred gilded Buddhas. The Buddhas are brought out for worship and placed on gem-studded, gold-and-silver plinths for one day each year. The plinths are decorated with various gemstones, including ruby, sapphire, jadeite and others. The stones were mainly donated by gem dealers and local people, notably a former governor, and kept as one of the secret treasures of Mogok. Our group was fortunate to see these plinths, which are rarely displayed for visitors.

Chan Thar Gyi is another famous temple in Mogok. It is situated on the hill of Minn Phaya in Shansu Quarter. Like Phaung Daw Oo, this temple contains white marble Buddhas, along with cabinets displaying innumerable gemstones donated by local people. The gems and jewellery on display there are a sign of the cultural affluence and respect for the Buddha by the Burmese people.

The Daw Nan Kyi temple is located in a spectacular setting at around 1,520 m (5,000 ft) elevation, above the western side of Mogok. From there, we could see the town of Kyat Pyin and surrounding hillsides comprising the Mogok Stone Tract.

EN ROUTE *TO MOGOK*

(A) The beautiful Werawsana Jade Pagoda near Amarapura is decorated with jadeite of various colours. (B) Thousands of tons of jadeite slabs are cemented to the surface of the pagoda. (C) U Tommy Thein (left) introduces his gemmological school in Mandalay. Photos by T. Sripoonjan (A–B) and S. Saengbuangamlam (C).

MONASTERIES IN MOGOK

(A) The former governor of Mogok and his son showed us treasures of the Phaung Daw Oo temple. (B) Chan Thar Gyi temple contains a collection of valuable gemstones and antique jewellery. (C) The Daw Nan Kyi Monastery affords an excellent view of the Mogok Stone Tract. Photos by T. Sripoonjan.

Bernardmyo Peridot Deposits: Fine peridot is mined from the Pyaunggaung area near Bernardmyo, located in the northwest part of Mogok. The deposits in this area are well-known for producing peridot from veinlets and pockets within a fine-grained peridotite rock. Although many of the mines are run by the government, we visited a private operation owned by Purify Co. The authors climbed down a shaft on traditional wooden ladders, where we saw active drilling using pneumatic hammers. There also was a small shaft used to transport equipment and mined material. Near this peridot mine is a military station and sanatorium established after the Third Anglo-Burmese War. A cemetery there dates back more than 120 years, based on the years 1888–1898 that were inscribed on headstones of British soldiers.

Baw Mar Sapphire Mine: Located northwest of Kyat Pyin Township, about 18 km west of Mogok, is a well-known blue sapphire mine called Baw Mar. We accessed the site in four-wheel-drive pickup trucks provided by the mine owners. The geology of the area is complex, consisting mainly of regionally metamorphosed rocks, especially calc-silicates and graphitic marble, often with weathered gneiss, and is locally intruded by syenite or pegmatite veins. The mine is operated with heavy machinery, and excavators initially remove up to 20 m of overburden to reach secondary deposits containing the sapphires. The miners use water cannons to wash the gravels from the pit, and the material is then routed to a washing plant.

We had an opportunity to discuss the mine operation with the owners at their home. Our hosts gave us a warm welcome and took our group to view the gem-sorting process. The mine recently has produced blue sapphire in relatively large siz-

PYAUNGGAUNG PERIDOT MINING AREA

(A) The entrance of the Purify Company's peridot mine is located in the mountains of the Bernardmyo area. (B–C) The Purify mine is accessed by a traditional wooden ladder, and a rope is attached to a winch for transporting mining equipment. (D) This view shows the typical underground workings in the Purify peridot mine. (E) Graves of British soldiers from the late 19th century are located near the peridot mines. Photos by T. Sripoonjan.

BAW MAR MINE

(A) The large open pit at Baw Mar is mined for blue sapphire. (B) Miners use water cannons to mobilize gravels in the pit. (C) Sorting of rough blue sapphires is done on-site. (D) U Ye Min Tun (left), one of the owners of the Baw Mar mine, displays some rough and faceted blue sapphires. Photos by T. Sripoonjan (A–B) and S. Saengbuangamlam (C–D).

es (up to 3+ cm in diameter) in low-to-moderate qualities. Fine gem-quality sapphire is occasionally found, and additional production consists of spinel of various colours.

Yadana Shin Ruby Mine: One of the most famous ruby mines of Mogok, Yadana Shin, is located approximately 4 km north-west of the town of Mogok. Yadana Shin is a relatively modern operation that is exploited underground as well as in open pits. Miners access the underground workings using a series of ladders. Ruby mineralization is hosted by fine-grained marble with some brown mica. The ruby-bearing marble pieces are placed in secure bags and transported to the surface using a cable pulley system. All the material then passes into jaw crushers, and the fragments are washed into jigs using water jets. The jigs are hand-picked for ruby, spinel and other gems, and the rejected material is further sorted by workers with metal blades before it is transported to the tailings pile outside the mine, where local people are allowed to go through it. Most of the mine's ruby production is not of high quality, but only a few good stones are needed to make the operation viable.

Ruby Dragon Mine: This mine is located near Yadana Shin in the Bawpadan area. Operated by Ruby Dragon Jade and Gems in a joint venture with the Myanmar government, this is one of the largest ruby mines in the Mogok area. The best overall ruby production occurred in 2012, yielding approximately 450,000 carats. By comparison, in 2016 the mine produced around 100,000 carats of ruby. At the time we visited, mining took place almost 400 m below the surface in a complex network of tunnels following the ruby-bearing marble layers. However, most of the ruby-rich layers were found at around 90 m depth. The mine manager used a scale model of the workings to explain the sophisticated operation. The manager also took us to visit the mine entrance, but unfortunately visitors were prohibited from entering. The gem material (faceted pieces averaging 2–3 ct; exceptionally up to 10 ct) is sorted on-site into various qualities, and the least transparent stones are reportedly heated to improve their clarity.

YADANA SHIN MINE

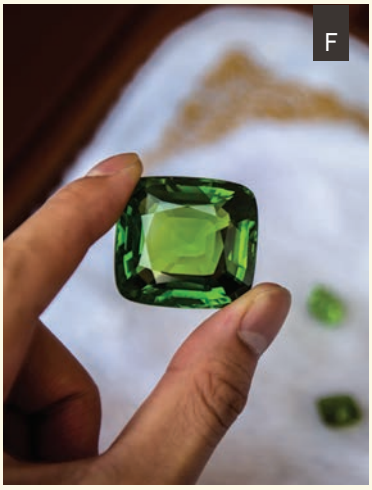
(A) Yadana Shin is one of the most well-known ruby mines in Mogok. (B) The mine workings are accessed by shafts, (C) which contain wooden ladders and timbering. (D) The mined material is passed through jaw crushers and then into jigs. (E) Workers sort the crushed rock by hand to recover the rubies. Photos by S. Saengbuangamlam (A, C) and T. Sripoonjan (B, D–E).

RUBY DRAGON MINE

(A) The Ruby Dragon mine is surrounded by steep, forested slopes. (B) An elevator is used to access this Ruby Dragon shaft. (C) The mine manager shows a scale model of the underground workings. (D) The air in the shaft is hazy from the mining activities below. (E) Ore carts are used to bring the mined material to the surface. Photos by T. Sripoonjan (A–D) and S. Saengbuangamlam (E).

MOGOK GEM MARKETS

(A) Many kinds of rough samples, faceted stones and some jewellery are offered at the Cinema Lane market. (B) This old cinema gives the gem market its name. (C) Gem traders enthusiastically offer their stones to prospective buyers. (D) A strong torch is an indispensable tool for gem trading. (E–F) Faceted rubies and peridots were available during our visit to Mogok. (G) The gem-trading atmosphere is busy at the so-called blue umbrella market. Photos by T. Sripoonjan.



Our international group of participants gathered together at the Mogok Valley viewpoint. Photo courtesy of T. Sripoonjan.

Gem Markets in Mogok: There are two notable gem markets in the town of Mogok, as well as several smaller markets scattered throughout the Mogok area. At these open-air markets, mostly low- to medium-quality rough and cut rubies, sapphires and other gems are traded among the locals. The Yoke Shin Yone gem market (also known as the 'crystal market', or Cinema Lane since it is located within sight of the old cinema) operates daily in the morning. It occupies both sides of the street for about 100 m. Some of the minerals and rough gem parcels there were reasonably priced. Also present were ornamental rocks and less-common specimens, including shells and fossils. A small amount of imitations and synthetics was noted at this market.

We then visited the Panchan (or 'blue umbrella') gem market, the largest in Mogok, which opens from 1:00 pm to around 4:00 pm. In addition to Burmese traders, it is frequented by people of Indian, Chinese and other ethnic backgrounds, along with some Thais. The buyers sit at tables under numerous blue umbrellas and are offered gems by local dealers or brokers. We saw energetic dealers buying and selling gemstones enthusiastically. Interestingly, we encountered some of the same dealers that we saw at the morning gem market, offering us the same stones. The sellers especially focused on foreigners once anyone showed interest in buying, and negotiating the prices was a long, painstaking process. We saw various qualities of ruby, sapphire, spinel and peridot, particularly as rough stones. Nevertheless, the prices seemed relatively high. We were not offered any obvious synthetics or imitations in this market.

Conclusions: The gem town of Mogok has retained its charm as one of the most desirable places for gem enthusiasts to visit. There are several active mining operations in the area, mainly for ruby and sapphire, and mechanized techniques are commonly used. However, the production of fine-quality ruby and sapphire is scarce. We hope that Mogok will once again be open to visits by foreigners in the future.

Acknowledgements

The authors thank GIT's director, Dr Pornsawat Wathanakul, for her advice. Thanks also to academic advisors Dr Visut Pisutha-Arnond and Wilawan Atichat for their valuable comments and kind review of this article.

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Conferences

AGA Tucson Conference

The 2017 Accredited Gemologists Association Conference in Tucson, Arizona, USA, took place 1 February, with the theme 'Cutting Edge Gemology to Keep You in the Loupe'. Attended by 125 people, the event was moderated by AGA president Stuart Robertson and featured eight presentations.

Christopher Smith (American Gemological Laboratories Inc., New York, New York, USA) reviewed various systems for communicating colour in gemmology (i.e. Gem Dialogue, Color Scan, Color Master, GemSet, Gemewizard and World of Color), and then introduced his ColorCodex Color Referencing System (Figure 1). Consisting of a set of colour-range cards, each with six textured foils for a specific hue that range from lighter to darker and more saturated, the ColorCodex provides an intuitive, observer-based system for referencing (not grading) colour in loose or mounted gems.

Elise A. Skalwold (Cornell University, Ithaca, New York, USA) gave two presentations. Her first one reviewed her work, together with Dr William Bassett (retired professor of geology, Department of Earth and Atmospheric Sciences, Cornell University), on various mineralogical and gemmological projects involving mineral physics. Perhaps most intriguing was an investigation to identify a blue inclusion in a macle-twinned diamond that turned out to be olivine; the reason for its anomalous colour is still unknown. Skalwold's second presentation examined the possible use of iolite or calcite as navigation aids by Viking seafarers. Referred to as 'sunstones', the Vikings purportedly looked though them to find the location of the sun through the fog that commonly blanketed the cold seas in the Scandinavian region.

Warren Boyd (R.T. Boyd Ltd, Oakville, Ontario, Canada) profiled two gem materials from the western USA: Montana sapphires and 'Apache Blue stone' from Arizona. A mechanized mining operation by Potentate Mining LLC at the West Fork of Rock Creek in Montana is producing sapphires in a variety of hues, and most are heat-treated to improve their colour and clarity. Apache Blue stone has a turquoise-like appearance and was recovered recently in cooperation with a copper-mining company at a deposit located <1 km from the Sleeping Beauty turquoise deposit near San Carlos, Arizona. It appears to be primarily composed of chrysocolla, along with multiple minerals that formed through supergene processes; most of the material is stabilized before cutting by impregnating it with resin.

Yianni Melas (Limassol, Cyprus) described 'Aquaprase', a relatively new bluish green chalcedony from Africa. The rough material is hand-mined from an open pit, and approximately 80% is processed locally. Chemical analysis has revealed traces of various chromophoric elements in Aquaprase, including Cr, Ni and Cu.

Gary Roskin (International Colored Gemstone Association [ICA], New York, New York) provided some interesting background information on ICA, and then noted various trends in coloured stones that he had

Figure 1: Christopher Smith discusses the fundamentals of colour space before introducing his ColorCodex Color Referencing System. Photo by B. M. Laurs.

seen during the previous few days at the 2017 Tucson gem shows. Among the items he mentioned were irradiated and heated morganite showing brownish pink to orangey pink coloration that was available in relatively large sizes (10–40 ct), blue sapphires from a new deposit in Madagascar (see pp. 391–392 of this issue for more on this material) and an abundance of Cu-bearing tourmaline from Mozambique that showed good colour saturation but was fairly included.

Art Samuels (EstateBuyers.com and Vivid Diamonds & Jewelry, Miami, Florida, USA) described how gemmological knowledge has helped make him money when dealing with diamonds, including faceting the girdle of a 6.4 ct round brilliant to improve its colour grade from H to G; buying brown type IIa diamonds that can be decolourized through high-pressure, high-temperature treatment, so they can be sold (with disclosure) for more money; and requesting that a laboratory recheck a diamond that had received a borderline I_1 clarity grade, resulting in a considerably more valuable SI_2 grade.

Dr Jeffrey Post (Smithsonian Institution, Washington DC, USA) chronicled the history of the Hope diamond, a 45.52 ct type IIb blue diamond at the Smithsonian Institution, and then described his scientific research on this famous gem. Although it shows no fluorescence to UV radiation, it displays long-lasting intense orange phosphorescence (for approximately one minute). Recent analysis of the diamond with time-of-flight laser ablation inductively coupled plasma mass spectrometry showed that it contains an average of only 0.5 ppm boron, which is enough to produce its deep blue colour.

The conference ended with the announcement of a new Hanneman Award for contributions to the literature of gemmology. **William Hanneman** (Monterey, California, USA) announced that the award is being given to two recipients, **John I. Koivula** (Gemological Institute of America [GIA], Carlsbad, California) and **Alan Hodgkinson** (Ayrshire, Scotland). The AGA Gala took place later that evening, where The Antonio C. Bonanno Award for Excellence in Gemology was presented to **Al Gilbertson** (GIA, Carlsbad). This honour recognized Gilbertson's many contributions to gemmology, which included authoring the book titled *American Cut—The First 100 Years*. Published in 2007, it recently became available for free download at https://archive.org/details/AmericanCut--theFirst100YearsTheEvolutionOfTheAmericanCutDiamond.

Brendan M. Laurs FGA

GIT 2016

The Gem and Jewelry Institute of Thailand's 5th International Gem and Jewelry Conference, GIT 2016, was held in Pattaya, Thailand, 14–15 November 2016. It included a pre-conference field trip to Mogok, Myanmar (see report on pp. 436–443 of this issue), and a post-conference excursion to the Chanthaburi-Trat area of Thailand. The conference was well attended, with 306 participants that included 185 Thai nationals and 121 others from 33 countries. There were 84 presenters (e.g. Figure 2) consisting of four keynote speakers, four invited speakers and 30 others who delivered oral presentations over two days in two parallel sessions, as well as 46 poster presenters. Those oral presentations that the authors attended are reported here, and abstracts of all the presentations are available in the conference proceedings volume, which can be downloaded at www.git.or.th/download/GIT2016.pdf.

GIT's Chairman of the Board of Directors **Siripol Yodmuangcharoen** and Director **Dr Pornsawat Wathanakul** delivered brief welcoming speeches to open the conference. Gem-cutting specialist **Victor Tuzlukov** (Moscow, Russia) gave the first keynote

Figure 2: GIT 2016 conference organizers and presenters gather for a group photo. Courtesy of GIT.

speech, titled 'The fourth "C": Today and tomorrow', in which he described changes in the gem-cutting market. Modern gem-cutting techniques are becoming more and more precise (down to the micrometre). Tuzlukov described in detail the judging criteria of the United States Faceters Guild and showed photos of beautifully faceted topaz, spessartine, amber, kunzite, tanzanite and a 219 ct amethyst with 705 facets. **Cynthia Unninayar** (*Jewelry Showcase Magazine*, New York, New York, USA) gave the second keynote lecture titled 'The dozen dominant design directions for fine jewelry in 2017', in which she described the trending design directions as: Mesmerizing Multicolors, Nature's Glory, Lusciously Lacy, All About Anglez, Circular Momentum, Gothic Chic, Evolving Earwear, Fun Finger Fashion, Trendy Tassels & Fringe, Wristeria, Long & Layered and Eco-Jewels. She also discussed Pantone's prediction of 2017 fashion colours and the corresponding gem varieties. For the third keynote lecture, **Dr Gaston Giuliani** (Institute of Research for Development, Vandœuvrelès-Nancy, France) gave detailed information about the geological environment, timing and geographical distribution (in terms of paleogeography and modern geography) for the most important ruby and sapphire deposits. This fundamental research provides important background knowledge for country-of-origin determinations. The fourth keynote speech was delivered by **Rupak Sen** (Gemfields, Mumbai, India), who provided a detailed historical account of a shift in popularity from diamonds to coloured stones and the passion for them in Asian countries. He emphasized the fact that not only are celebrities taking the lead in this change, but people are now saying 'I do' with coloured stones. He then updated the delegates on Gemfields' projects and initiatives around the globe, including an ethical mining and marketing policy to help ensure the future of the coloured stone industry.

Among the invited speakers, **Didier Giard** (Association Française de Gemmologie, Paris, France) described a shift in the paradigm of the gem and jewellery trade from being more production oriented toward an emphasis on sustainable development. He also proposed an idea for a United Nations 'International day for the sustainable management of the gem mines and pearl farms', which would focus on the traceability of products, energy efficiency and mining regulation. He continued with three more proposals, for the establishment of a 'rainbow passport', an international platform for exchange, as well as possible financial actions. **Francis Errera** (Francis Errera Ltd., Hong Kong) summarized the pricing and marketing of coloured diamonds from the 1970s to 2010s. In 1976, coloured diamonds were cheaper than colourless diamonds. The market changed after 1986 when the Argyle mine in Australia started production. Certainly, consumer awareness also propelled the value of coloured diamonds over the past 40 years. **George Lu** (CIBJO Coral Commission and Chii Lih Coral Co., Taipei, Taiwan) pointed out that the coral used as a gem material is not the same as the coral reefs where most people go snorkelling. The gem corals come from much deeper waters, ranging from several hundred metres to 1,800 m. He went on to describe the taxonomy of corals from various localities and included some amazing images of coral carvings and jewellery from various cultures around the world. **Dr Pornsawat Wathanakul** described GIT's many years of research on the colour grading of ruby and sapphire. She presented GIT's Masterstone sets for 'pigeon's blood' ruby, 'royal blue' sapphire and 'cornflower blue' sapphire in terms of the Munsell system, as well as displaying the Masterstone sets on site during the conference. She also described the importance of a standard lighting system used in the colour-grading environment.

The contributed papers were organized into six sessions: Gem Deposits and Identification; Diamonds; Corundum and Others; Pearls and Others, Innovation and Instrumentation; and Jewelry Trend and Design. **Dr Lore Kiefert** (Gübelin Gem Lab, Lucerne, Switzerland) described the results of her lab's country-of-origin study on demantoid. She specified the two major geological environments in which these garnets formed: serpentinite-related and skarn-related. She went on to characterize the corresponding differences in inclusions, spectral features and chemical composition, and provided further details about demantoid from specific localities, as well as the heat treatment of Russian material. **Tasnara Sripoonjan** (GIT) reported on purple rhodolite from Mozambique, including inclusion features, spectral characteristics and the cause of colour. **Adesoji Adesugba** (Gemstones Miners and Marketers Association of Nigeria, Abuja) described the gem deposits and investment incentives in Nigeria. **Dr Ahmadjan Abduriyim** (Tokyo Gem Science and Kyoto University, Japan) highlighted jadeite from Itoigawa, Japan, and reported the textural, chemical and spectral characteristics in comparison with jadeite from Myanmar, Guatemala and Russia. **Prof. Guanghai Shi** (China University of Geosciences, Beijing) described the geology of placer nephrite deposits in the southern Xinjiang area. He then compared the 'shan' (primary) material and 'zi' (placer) material in terms of the appearance and the price of the finished products. **Dr Visut Pisutha-Arnond** (GIT) gave a presentation for **Dr Henry Hänni** (GemExpert, Basel, Switzerland) on the gemmological properties of 'Sannan Skarn' from Pakistan, a relatively new gem material that resembles mawsit-sit. **Arent Heilmann** (Ministry of Mineral Resources, Nuuk, Greenland) explained the occurrence, colour

and tenebrescence, fluorescence and mining of tugtupite from Greenland. **Dr Jayshree Panjikar** (Panjikar Gem Research & Tech Institute, Pune, India) reported her study of sphene from Mettur Taluk, southern India.

John Chapman (Gemetrix, Perth, Australia) examined how the details of lighting, viewing angle, cutting and colour zoning can affect the colour grading of coloured diamonds. **Seung Kwon Lee** and **Jo Eun Ok** (Wooshin Gemological Institute of Korea, Seoul, South Korea) reported their research on coated-colour diamonds and identification techniques for near-colourless melee-sized synthetic diamonds.

Dr Dietmar Schwarz (Federated International GemLab, Bangkok) and **Saengthip Saengbuangamlam** (GIT) both provided insights into determining the geographic origin determination of blue sapphires. **Thanong Leelawatanasuk** (GIT) described 'golden sheen' and non-sheen sapphires from Kenya, highlighting the gemmological characteristics and microscopic features. **Nguyen Ngoc Khoi** (Hanoi University of Science, Vietnam) provided an update on ruby and sapphire from Vietnam, and classified them into marble, gneiss and basalt types. **Hyunmin Choi** (Hanmi Gemological Institute & Laboratory, Seoul) described blue sapphires before and after high-pressure, high-temperature enhancement, as well as the use of Fourier-transform infrared spectroscopy for identifying this treatment. **Thitikorn Na Nan** (Chiang Mai University, Thailand) described blue lead-glass-filled sapphires. **Dr Tobias Häger** (Centre for Gemstone Research, Johannes Gutenberg-University of Mainz, Germany), characterized strontium aluminate that shows strong phosphorescence and has been sold as apatite.

Nicholas Sturman (GIA, Bangkok) used real-time X-ray microradiography and X-ray computed microtomography to characterize non-bead cultured pearls from the Mergui Archipelago of Myanmar. **Kook Whee Kwak** (Wooshin Gemological Institute of Korea) described the identification of dyed golden South Sea cultured pearls using ultraviolet-visible and photoluminescence spectroscopy. **Geng Li** (School of Gems, China University of Geosciences, Beijing) explained the cultivation and the market for Chinese freshwater cultured pearls, covering both historic and current production. **Sutas Singbamroong** and **Aisha Rashid Almazrooei** (Gemstone and Precious Metal Laboratory, Dubai Central Laboratory, United Arab Emirates) presented the microradiographic structures of natural non-nacreous pearls from *Tridacna* species.

Dr Andreas Burkhardt (Zollikon-Zürich, Switzerland) covered state-of-the-art energy-dispersive X-ray fluorescence instruments and techniques for chemical analysis. **Dr Ewa Wagner-Wysiecka** (Gdansk University of Technology, Poland; Figure 3) reviewed infrared spectral features that can help separate copal from amber. **Dr Nirawat Thammajak** (Synchrotron Light Research Institute, Nakhon Ratchasima, Thailand) covered the radiation treatment of cultured pearls and the use of synchrotron X-ray absorption spectroscopy for gemmological applications. **Dr Chatree Saiyasombat** (Synchrotron Light Research Institute) described a multiple-X-ray-techniques beamline that he is developing for gemmological research applications.

Figure 3: Dr Ewa Wagner-Wysiecka discusses how infrared spectral features can help separate copal from amber. Courtesy of GIT.

Although presentations from the poster session are not covered here, three posters received special recognition in a poster competition: (1) **Meenu Brijesh Vyas** (Gem Testing Laboratory, Jaipur, India) described green spinel from Afghanistan, (2) **Sungjae Kim** (Hanyang University, Seoul) presented a colour-origin study of various beryls and (3) **Charuwan Khowpong** (GIA, Bangkok, Thailand) described the diversity of rubies from Kenya.

Conference attendees celebrated the Festival of Loy Krathong, where prayers and wishes were set afloat in 'krathongs' made with banana leaves and decorated with flowers, candles and incense. The celebration took place on the night of the 'super moon', the closest full moon to Earth since 1948, which was the inspiration for the conference theme of 'The Fullmoon of GEMUnity'.

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Bangkok, Thailand

Jewelry Industry Summit 2017

The second Jewelry Industry Summit—The Open Forum on Sustainability & Responsible Sourcing in the Jewelry Industry was held in Tucson, Arizona, USA, 29–30 January 2017, just prior to the AGTA GemFair. This year's conference brought together 125 attendees (Figure 4) from many industry groups, including miners, gem dealers, designers, appraisers, retailers, gemmological educators, laboratory personnel, government representatives and members of non-governmental organizations. Holding the Summit just prior to the Tucson gem shows allowed for a diverse representation from many sectors of the industry.

A vision was developed at the first Jewelry Industry Summit (held in March 2016; see *The Journal,* **35**(1), 71–73) that merged ideas from all the participants, and can be summarized into four categories:

1. Procure products in a manner that protects and sustains the environment and respects and benefits the people and communities where these products are found.
2. Use business methods and engage in actions designed to promote and sustain growth and development of the people and communities where products are sourced, manufactured, traded and sold.
3. Continue to take affirmative steps towards ensuring legal compliance, transparency and open and legitimate business practises by actively engaging in and managing everyday actions through the business supply chain.
4. Commit to existing international standards including the *UN Guiding Principles on Human Rights* and *OECD Guidelines for Multinational Enterprises*.

The primary objective of the second summit was to continue to collaborate and collectively engage with members of all sectors of the industry to help further the vision principles outlined above. The four main goals were:

1. Generate broad-based awareness of facts related to the jewellery industry supply chain and responsible sourcing, and explore what works and what does not.
2. Learn about and review progress on current industry-wide initiatives and developments related to sustainable business practises and responsible sourcing.
3. Develop shared visions for key segments of the jewellery-industry supply chain that support the broader industry vision for sustainable business and responsible sourcing.
4. Design prototypes of tools and strategies that enable businesses in the supply chain to make progress through continuous improvement.

To effectively explore and reach the objectives, the firm Innovation Partners International was hired to help guide participants. After an initial interview session, attendees were asked to form groups to discuss what they felt was working and gather examples within or outside our industry that may be beneficial for others to hear. The next task was to identify the biggest challenges each segment of our industry faces regarding sustainability and responsible sourcing. Finally, participants were asked what they could do within their control that would have a ripple effect on their personal segment of the industry.

Throughout the Summit, several speakers provided tangible examples of efforts other industries were employing to address sustainability and corporate responsibility. **Lisa Manley** (Cone Communications, Boston, Massachusetts, USA), who served six years as global sustainability communications director for The Coca-Cola Company, described her work as a sustainability consultant for clients such as Converse, CVS, Hilton, Mars, Quaker, Target, Timberland, U.S. Bank, Wrigley and others. She emphasized that it is okay for businesses to take an advocacy stance, and millennials expect companies to adhere to ethical business practices.

Figure 4: The second Jewelry Industry Summit brought together 125 attendees from various industry groups. Photo by Mariana Photiou.

She cited sustainable business trends such as transparency, collaboration, human rights initiatives, recycling, etc. She challenges her clients to be conscientious, connected to communities where they source and sell, and be radically inclusive and inspiring. Tangible examples include water stewardship, sustainable packaging, climate protection and supporting sustainable communities through women's economic empowerment and active, healthy living. **Thea Polancic** (Clear Space, Chicago, Illinois, USA) gave a passionate presentation on 'Conscious Capitalism' to relay the power of business to create prosperity, beauty and happiness in the world. The Conscious Capitalism movement was popularized by John Mackey, CEO of Whole Foods, and is dedicated to elevating humanity through business. This movement has gained ground rapidly, and Polancic runs the Chicago chapter, which has grown to 1,100 members in 18 months. The main tenets of the movement are to focus on a higher purpose, create value for all stakeholders, encourage caring and passionate leadership, and create healthy and value-based cultures.

Participants were then asked to gather in small groups to create compelling visions for the future of our industry and to identify real actions we could take to bring those visions to fruition (e.g. Figure 5). Each group then presented their visions to the entire audience. The end of the first day concluded with a cocktail reception and poster session, which featured more than 20 presenters.

The second day of the Summit began with a presentation by **Bob Mitchell** (Electronic Industry Citizenship Coalition [EICC], Alexandria, Virginia, USA). Mitchell is a 16-year veteran of Hewlett Packard with more than 10 years in sustainability. He was most recently the Director of Global Social & Environmental Responsibility at Hewlett Packard Enterprise, where he led a team of professionals in human rights, supply-chain responsibility and conflict minerals. Mitchell shared examples of his experiences at Hewlett Packard and the EICC mission and values of a responsible global electronics supply chain. The EICC consists of more than 100 electronics companies, has a combined revenue of more than US$4.75 trillion and directly employs more than 6 million people. Their primary focus is on ethical and conflict-free sourcing of raw materials and labour.

The attendees were then asked to identify action possibilities that they could personally explore and implement. The author's group was inspired by one of the poster presentations—by **Dr Girma Woldestinsae** (Ministry of Mines, Petroleum and Natural Gas, Addis Ababa, Ethiopia)—to provide basic resources and education to students in rural areas, in order to help them learn about and identify potential local natural resources. In his presentation, Dr Woldestinsae enthusiastically shared his experiences educating and encouraging rural school children to look for minerals and gems on their way to and from school. Teachers are asked to form science and coloured-stone clubs through which they can integrate their teaching curricula to educate their students about the characteristics and properties of the rocks and minerals they find. They also focus on stories that encourage thinking about creating added value and turning raw materials into useful products. To assist his project, we proposed providing gemmological training and instrumentation, as well as translating into local languages the Gemological Institute of America's new guide to gem rough booklet that has already been introduced to rural mining communities in Tanzania.

Figure 5: Summit participants broke into small groups to discuss visions for the future of the jewellery industry and to identify actionable tasks to bring those visions to reality. Here, Dr Girma Woldestinsae and Anna Barker review notes from their group. Photo by E. Boehm.

Along with new ideas, a number of initiatives initially introduced at the first Summit were reintroduced for update and further review. For example, **Eric Braunwart** (Columbia Gem House, Vancouver, Washington, USA) and his committee shared developments on eliminating silicosis. His initiative proposes education and use of equipment designed to reduce exposure to ultra-fine particulates from mining and cutting that are known to cause silicosis. His committee presented several possible technological developments that would reduce exposure during the cutting and polishing of beads. Another initiative from the first Summit focuses on mining of rutilated quartz in a remote region of Bahia, Brazil. This responsible sourcing initiative aims to create a model artisanal and small-scale (ASM) mining community that would serve as a guide for other ASM communities. **Brian Cook** (Nature's Geometry, Tucson) proposed empowering the rural rutilated-quartz-mining community by constructing a processing warehouse and lapidary school. He also plans to help the miners and their families create greater food security through the development of organic farming.

Five new initiatives were introduced along with the eight initiatives from the first Summit, so participants divided into 13 teams. Attendees were encouraged to migrate to the initiatives that interested them most to hear their goals and provide input. Group leaders gave brief presentations and conducted discussions with teammates and those who joined in. Participants were encouraged to visit as many different groups as possible and focus on how to overcome challenges and obstacles. This process allowed further refinement of each initiative's goals and helped each group gain additional support and create a prototype that the group could confidently present to the entire Summit. The initiatives and their descriptions, progress, next steps, challenges and resources needed, will be shared via the Jewelry Industry Summit's website www.jewelryindustrysummit.com, Facebook page jewelryindustrysummit and on Instagram at #ResponsibleJewelryStories.

Edward Boehm FGA (edward@raresource.com)
RareSource, Chattanooga, Tennessee, USA

Letters

Comment on the Apparent Anomalous Reflectance of a Sumitomo Synthetic Diamond

In the previous issue of *The Journal*, Hodgkinson (2016) reported observations that he and a colleague had made on a Sumitomo high-pressure, high-temperature (HPHT) synthetic diamond using a Hanneman Diamond Eye reflectance meter. The reading obtained from that sample was much higher than that obtained from a control sample of natural diamond. We show below that this 'anomalous behaviour' has its origin in the different geometries of the natural and synthetic diamonds used in that investigation. The former was faceted as a round brilliant, whereas the Sumitomo sample was a thin polished plate.

The reflectance R in air from the polished surface of an optical material is approximately given by $R = (n - 1)^2/(n + 1)^2$, where n is the refractive index of the material. For diamond $R = 0.172$ at the 'sodium D' wavelength (589.3 nm). Consider a thin pencil of light incident normally on the table of a round brilliant. Approximately 17% of the light is reflected back along the path defined by the incident illumination. The rest of the light enters the diamond where it is refracted and reflected in numerous directions. Very little, if any, of that light travels back along the path defined by the incident illumination.

For a thin plate of diamond, with near-parallel polished top and bottom faces, approximately 17% of the incident illumination is reflected from the top surface. The rest of the light enters the diamond, and about 17% of the light that reaches the rear surface is also reflected. The reflected light from both the top and bottom faces travels back along the path defined by the incident illumination. For a colourless diamond, the total intensity of the reflected light is about 29% of the incident intensity. (This value is obtained by taking into account the multiple reflections that occur within the diamond plate.) If the diamond is coloured, as with the HPHT synthetic studied by Hodgkinson (2016), some light will be absorbed internally, and there is a smaller contribution from the rear surface; however, the total intensity of the reflected light will still be much greater than that observed from the table of a round brilliant. That is why, in Hodgkinson's investigation, "the indicator needle [of the Hanneman reflectance meter] raced across the scale beyond 'diamond' to the extremity of the instrument".

Prof. Alan T. Collins
Department of Physics, King's College London

Reference

Hodgkinson A., 2016. Anomalous behaviour of a Sumitomo synthetic diamond on the reflectance meter. *Journal of Gemmology*, **35**(4), 274–275, https://doi.org/10.15506/jog.2016.35.4.274.

Gem-A Notices

GIFTS TO THE ASSOCIATION

The Association is most grateful to the following for their gifts and donations for research and teaching purposes:

Meg Berry, Fallbrook, California, USA, for pieces of green garnet from Ethiopia.

Guy Borenstein FGA, Gemewizard, Ramat Gan, Israel, for Gemewizard monitor calibration kit containing six faceted pieces of terbium glass.

Dr Marco Campos Venuti, Seville, Spain, for a faceted pollucite with polylithionite inclusions from Pakistan.

Jeffrey Bergman, Primagem, Bangkok, Thailand for two trapiche ruby specimens from India consisting of a hexagonal flat cabochon and a crystal.

Farooq Hashmi, Glen Cove, New York, USA, for two antigorite cabochons from Pakistan.

Syed Iftikhar Hussain, Syed Trading Co., Peshawar, Pakistan, for four chrysoprase cabochons from Australia, and a faceted quartz with actinolite needles from Pakistan.

Marc Jobin, New York, New York, USA, for three spheres of rainbow moonstone from Madagascar.

Mona Khan, Vista Gems, Skillman, New Jersey, USA, for a cabochon of 'Passion amethyst' from Minas Gerais, Brazil.

National Association of Jewellers, London, for a box of paste replicas of famous diamonds, three sets of fashion diamond imitations displaying different shapes and sizes, and four teaching sets of NAJ education stones containing more than 200 various rough and cut specimens.

Mauro Pantò, The Beauty in the Rocks, Sassari, Italy, for a buff-top quartz with chlorite inclusions from Brazil.

Werner Radl, Mawingu Gems, Niederwörresbach, Germany, for one quartz sphere with inclusions from Kongwa District, Tanzania.

Helen Serras-Herman FGA, Gem Art Center, Rio Rico, Arizona, USA, for a 'Mohave Purple turquoise' composite stone.

Leonardo Silva Souto, Cosmos Gems, Minas Gerais, Brazil, for a quartz cabochon with pyrite inclusions from Minas Gerais, Brazil.

Steve Ulatowski, New Era Gems, Grass Valley, California, USA, for a Cr-bearing dravite crystal from Tanzania.

Charles Vargas, Apache Gems, San Carlos, Arizona, USA, for three pieces of rough 'Apache Blue stone' from the Apache Nation, Arizona.

Tak Yi Yung FGA, Shau Kei Wan, Hong Kong, for a monetary donation.

OBITUARY

Evelyn (Eve) Rosemary Symes FGA DGA (D.2002 and 2007), Bath, Somerset, passed away on 6 December 2016. Eve was Treasurer of the South West Branch of Gem-A for a number of years.

Learning Opportunities

CONFERENCES AND SEMINARS

44th Rochester Mineralogical Symposium
20–23 April 2017
Rochester, New York, USA
www.rasny.org/minsymp

Scottish Gemmological Association Conference
28 April–1 May 2017
Stirling, Scotland
www.scottishgemmology.org/conference

3rd Mediterranean Gemmological and Jewellery Conference
11–14 May 2017
Syracuse, Italy
www.gemconference.com
Note: The conference theme is coloured diamonds, and the programme will include several speakers, a round table discussion, pre-conference workshops and a poster competition.

5th Annual New England Mineral Conference
12–14 May 2017
Newry, Maine, USA
www.nemineralconference.org/nema

The 31st Annual Santa Fe Symposium
21–24 May 2017
Albuquerque, New Mexico, USA
www.santafesymposium.org

2017 Society of North American Goldsmiths Conference
24–27 May 2017
New Orleans, Louisiana, USA
www.snagmetalsmith.org/events/conferences

11th International Conference on New Diamond and Nano Carbons
28 May–1 June 2017
Cairns, Queensland, Australia
http://ndnc2017.org

JCK Las Vegas
5–8 June 2017
Las Vegas, Nevada, USA
http://lasvegas.jckonline.com/en/Events/Education
Note: Includes a seminar programme.

Association for the Study of Jewelry and Related Arts (ASJRA) Annual Conference
9–10 June 2017
Boston, Massachusetts, USA
www.jewelryconference.com

Compiled by Angharad Kolator Baldwin and Brendan Laurs

The Gemmological Society of Japan Conference
10–11 June 2017
Tokyo, Japan
www.gakkai.ac/gsj/english

XVIèmes Rendez-Vous Gemmologiques de Paris
12 June 2017
Paris, France
www.afgems-paris.com/rdv-gemmologique

PEG2017—8th International Symposium on Granitic Pegmatites
13–15 June 2017
Kristiansand, Norway
www.nhm.uio.no/forskning/aktuelt/arrangementer/konferanser-seminarer/peg2017/

Scandinavian Gem Symposium 2017
17–18 June 2017
Kisa, Sweden
http://sgs.gemology.se

Sainte-Marie-aux-Mines 54th Mineral & Gem Show
22–25 June 2017
Sainte-Marie-aux-Mines, France
www.sainte-marie-mineral.com/english/modules/cultural-activities
Note: Includes a symposium and lectures.

Tourmaline 2017
23–28 June 2017
Nové Město na Moravě, Czech Republic
www.tourmaline2017.cz

Swiss Gemmological Society Conference and European Gemmological Symposium 2017
29 June–1 July 2017
Zermatt, Switzerland
http://gemmologie.ch/en/current/messages/central-course-egs-2017.php

Northwest Jewelry Conference
11–13 August 2017
Seattle, Washington, USA
www.nwjcon.com

48th ACE© IT Annual Mid-Year Conference
12–15 August 2017
Indianapolis, Indiana, USA
www.najaappraisers.com/html/conferences.html

Dallas Mineral Collecting Symposium
25–27 August 2017
Dallas, Texas, USA
www.dallassymposium.org

28th International Conference on Diamond and Carbon Materials (DCM 2017)
3–7 September 2017
Gothenburg, Sweden
www.diamond-conference.elsevier.com

Hong Kong Jewellery & Gem Fair
13–19 September 2017
Hong Kong
http://tinyurl.com/hbn8y56
Note: Includes a seminar programme.

Denver Gem & Mineral Show
15–17 September 2017
Denver, Colorado, USA
www.denvermineralshow.com
Note: Includes a seminar programme.

IRV Loughborough Conference
16–18 September 2017
Loughborough
www.jewelleryvaluers.org/Loughborough-Conference

11th International Kimberlite Conference
18–22 September 2017
Gaborone, Botswana
www.11ikc.com
Note: Pre- and post-conference field trips will visit diamond deposits in Botswana and neighbouring countries.

World of Gems Conference V
23–24 September 2017
Rosemont, Illinois, USA
http://gemguide.com/events/world-of-gems-conference
Note: Includes a poster session, and pre- and post-conference workshops.

ASA 2017 International Appraisers Conference
7–10 October 2017
Houston, Texas, USA
www.appraisers.org/education/conferences

200th Anniversary Meeting of the Russian Mineralogical Society
10–13 October 2017
Saint Petersburg, Russia
www.minsoc.ru/2017
Session of interest: Natural Stone in History of Civilization (Including Gemology)

Friends of Mineralogy Pacific Northwest Chapter 43rd Annual Symposium: Minerals of the Pacific Northwest
13–15 October 2017
Kelso, Washington, USA
www.pnwfm.org/symposium

Canadian Gemmological Association Conference
20–22 October 2017
Toronto, Canada
www.canadiangemmological.com/index.php/com-virtuemart-menu-configuration/conferences-and-special-events

ICA Congress
21–24 October 2017
Jaipur, India
www.gemstone.org (to be announced on new website)

Geological Society of America Annual Meeting
22–25 October 2017
Seattle, Washington, USA
www.geosociety.org/GSA/events/GSA2017
Session of interest: Gemological Research in the 21st Century: Characterization, Exploration, and Geological Significance of Diamonds and Other Gem Minerals.

9th International Congress on the Application of Raman Spectroscopy in Art and Archaeology
24–28 October 2017
Évora, Portugal
www.raa2017.uevora.pt

The Munich Show
27–29 October 2017
Munich, Germany
www.munichshow.com/en
Note: Includes a seminar programme.

Gem-A Conference
4–5 November 2017
London
www.gem-a.com

EXHIBITIONS

Asia

Treasures of the Natural World: Best of London's Natural History Museum
Until 11 June 2017
National Museum of Nature and Science, Tokyo, Japan
http://treasures2017.jp/outline/english_index.php

Mastery of an Art: Van Cleef & Arpels: High Jewelry and Japanese Crafts
29 April–6 August 2017
National Museum of Modern Art, Kyoto, Japan
http://highjewelry.exhn.jp

Europe

Across Art and Fashion
Until 7 April 2017
Museo Salvatore Ferragamo, Florence, Italy
www.ferragamo.com/museo/en/usa/exhibitions

De Vroomen: Harmony in Colour and Form
12 April–26 July 2017
Goldsmiths' Hall, London
www.thegoldsmiths.co.uk/company/today/events/2017/de-vroomen-harmony-colour-and-form

Warrior Treasures: Saxon Gold from the Staffordshire Hoard
Until 23 April 2017
Bristol Museum & Art Gallery, Bristol
www.bristolmuseums.org.uk/bristol-museum-and-art-gallery/whats-on/warrior-treasures

Authentically Inauthentic?—Jewellery from Pforzheim's Industrial Production
21 May–10 September 2017
Municipal Museum, Pforzheim, Germany
www.schmuckmuseum.de/flash/SMP_en.html

Must-haves—Jewellery Created by Greats of the Craft and **Must-sees—Jewellery in the Arts**
21 May–10 September 2017
Schmuckmuseum, Pforzheim, Germany
www.schmuckmuseum.de/flash/SMP_en.html

Tone Vigeland. Jewelry–Object–Sculpture
Until 11 June 2017
The Design Museum, Munich, Germany
http://dnstdm.de/en/tone-vigeland-schmuck-objekt-skulptur-2

Stone of Heaven. HRH Prince Henrik's Collection of Oriental Jade
Until 27 August 2017
Museet på Koldinghus, Kolding, Denmark
www.koldinghus.dk/uk/exhibitions-2017/stone-of-heaven.html

Vanity: Stories of Jewelry in the Cyclades
Until September 2017
Archaeological Museum of Mykonos, Mykonos, Greece
http://odysseus.culture.gr/h/4/eh41.jsp?obj_id=23576

Jewellery—From Decorative to Practical
Ongoing
Nordiska Museet, Stockholm, Sweden
www.nordiskamuseet.se/en/utstallningar/jewellery

North America

Bijoux Parisiens: French Jewelry from the Petit Palais, Paris
Until 14 May 2017
The Taft Museum of Art, Cincinnati, Ohio, USA
www.taftmuseum.org/cur_exhib

Playa Made: The Jewelry of Burning Man
Until 4 June 2017
Fuller Craft Museum, Brockton, Massachusetts, USA
http://fullercraft.org/event/playa-made-burning-man-jewelry

Spectacular! Gems and Jewelry from the Merriweather Post Collection
10 June 2017–1 January 2018
Hillwood Estate, Museum & Gardens, Washington DC, USA
www.hillwoodmus eum.org/Spectacular-Gems-and-Jewelry

Past Is Present: Revival Jewelry
Until 19 August 2019
Museum of Fine Arts, Boston, Massachusetts, USA
www.mfa.org/exhibitions/past-is-present-revival-jewelry

The Wonderful World of Opals
Until December 2017
New Mexico Museum of Natural History & Science, Albuquerque, New Mexico, USA
www.nmnaturalhistory.org/exhibits/temporary-exhibits/wonderful-world-opals

Gilded New York
Ongoing
Museum of the City of New York, New York, USA
www.mcny.org/exhibition/gilded-new-york

Mightier than the Sword: The Allure, Beauty and Enduring Power of Beads
Ongoing
Yale Peabody Museum of Natural History, New Haven, Connecticut, USA
http://peabody.yale.edu/exhibits/mightier-sword-allure-beauty-and-enduring-power-beads

Australia and New Zealand

Australian Opal Exhibition
3–4 August 2017
Surfers Paradise, Queensland, Australia
www.austopalexpo.com.au

The House of Dior: Seventy Years of Haute Couture
27 August–7 November 2017
The National Gallery of Victoria, Melbourne, Australia
www.ngv.vic.gov.au/exhibition/the-house-of-dior

OTHER EDUCATIONAL OPPORTUNITIES

Gem-A Workshops and Courses
Gem-A, London
www.gem-a.com/education/courses

Gem-A Midlands Branch
Fellows Auctioneers, Birmingham
Email Georgina@fellows.co.uk

- 21 April 2017 (*please note the change in date*)
  Elizabeth Goring—Suffragette Jewellery

DUG Advanced Gemology Program (in English)
6 November–8 December 2017
Nantes, France
www.gemnantes.fr/en

Gemstone Safari to Tanzania
8–25 January 2018
Morogoro, Umba, Arusha, Longido, Merelani and Lake Manyara, Tanzania
www.free-form.ch/tanzania/gemstonesafari.html
Note: Includes options for a lapidary class and/or a private trip to visit ruby mines near Morogoro and Mpwapwa (including Winza).

Lectures with The Society of Jewellery Historians
Society of Antiquaries of London, Burlington House, London
www.societyofjewelleryhistorians.ac.uk/current_lectures

- 27 June 2017
  Andrew Prince—Sparkling Times and My Work So Far
- 26 September 2017
  (*40th Anniversary Lecture*)
  Paulus Rainer—Benvenuto Cellini's Salt Cellar: Some New Thoughts, Some New Discoveries
- 24 October 2017
  Lynne Bartlett—The Rise and Fall of the Chatelaine
- 28 November 2017
  Judy Rudoe—Cartier Gold Boxes: A Visionary Patron and a Bet with Ian Fleming

Gem-A

THE GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

SAVE THE DATE

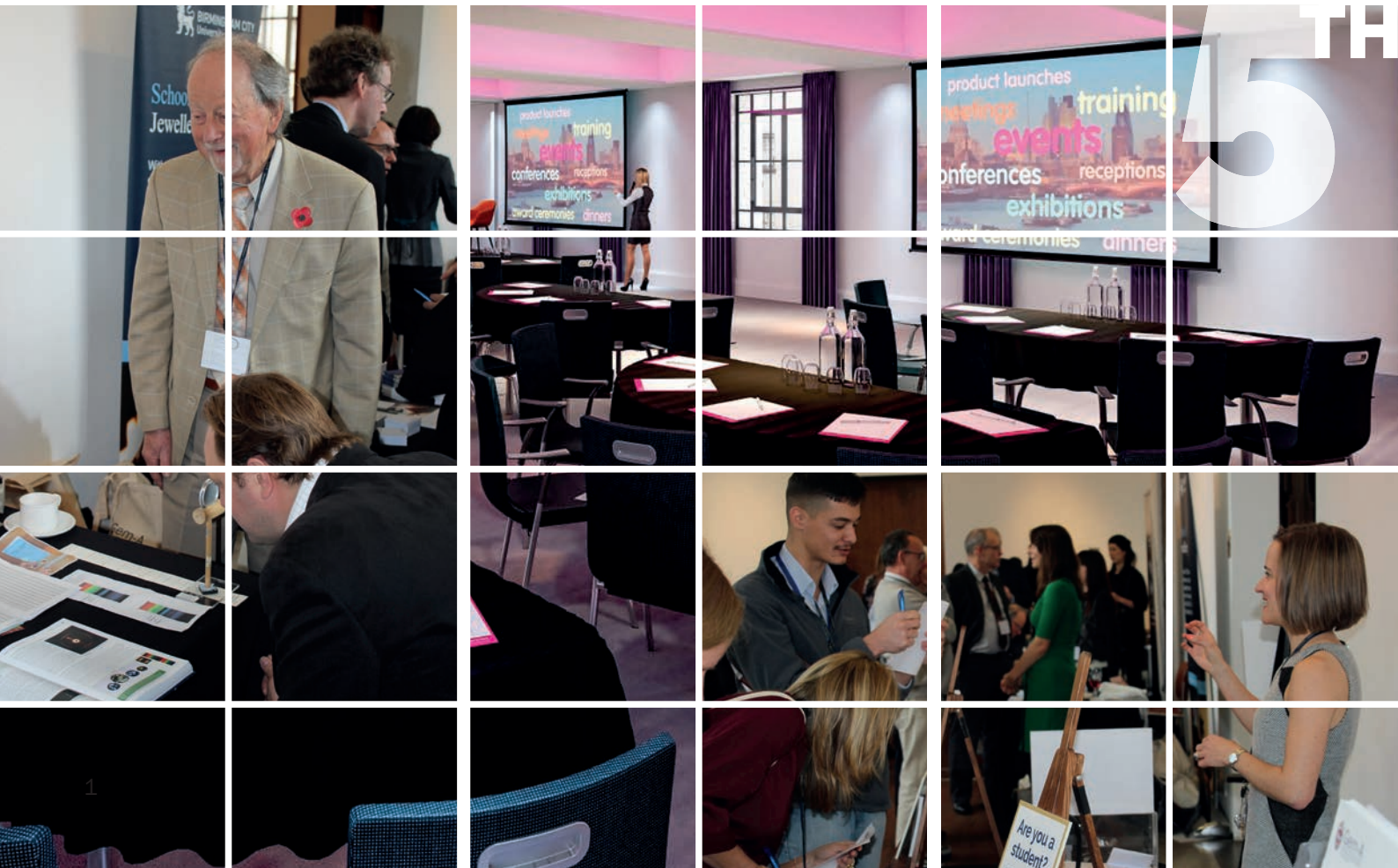
Gem-A Conference 2017

Saturday 4 and Sunday 5 November

etc.venues County Hall, Westminster Bridge, London

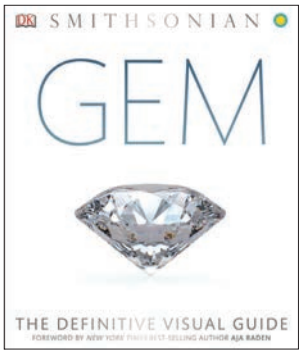
4TH

5TH



New Media

Gem—The Definitive Visual Guide



2016. Dorling Kindersley Ltd, London, in connection with Smithsonian Books, Washington DC, USA, www.dk.com/us/9781465453563-gem, 440 pages, illus., ISBN 978-1465453563. £25.00 hardcover.

Beware of a book with multiple editors and no recognized authors. (Five contributors, listed in the acknowledgments, are presumably responsible for the text of this large volume; but the masthead lists 13 editors, exclusive of additional editor named on the cover.) With no single person responsible, but many people 'in charge', facts and meanings can get lost.

In a book review, it is traditional to indicate whether the reviewer liked or disliked the book. I wanted to like this book, but it pains me to note that this guide to gems, while beautiful, is by no means definitive. Instead, it is fraught with errors and mischaracterizations.

There are three main aspects to such a guide book: its organization, its words and its images. All three have problems, as well as some positive aspects.

I have several comments on the book's organization. The book alternates gem characterization pages (or two-page spreads) with descriptive pages about jewellery history or specific jewels. This is a strong positive feature, since the jewellery pages are anything but boring and are profusely illustrated. As jewellery and its history are not areas of my expertise, I am not competent to find errors on these pages and they read very well for me. The characterization pages, however, tended to catch my eye for their errors, inconsistencies or odd placement. These pages are divided into the following categories: Native Elements, Gemstones, Organic Gems, and Rock Gems and Rocks. This is an unfortunate way to slice up the 'gem universe', since the only non-metallic native element considered is diamond, and the ordering scheme (which follows the Dana system) does not start with the most important gems, but with rather insignificant ones. (If you were looking in a gem book for the characteristics of diamond, would you look after copper and before pyrite?) Minerals are defined by their chemical compositions *and their structures*. The book neglects even the mention of structure, so the reason for organizing gem minerals by the Dana system—by anions and not cations, rather than, say, considering all copper minerals together—is not obvious. There are also errors with how some minerals are categorized. For example, variscite, an aluminium phosphate, is listed out of order on page 104 with the carbonates.

Regarding the book's words, these are found in several blocks on the characterization pages: main text, characterization box, figure captions, figure labels and a pithy quote. Among my issues with the words:

- Regarding the treatments mentioned on page 31, laser drill holes in diamonds are much likelier to be filled with a high-RI glass than with epoxy resin.
- Page 23: Absorption spectra depend not only on specific (chromophore) elements, but also their local environment (chromium causes different spectra in ruby, red spinel and red garnet, not to mention green emerald). And there are other causes for absorption besides chromophores, such as the structural defects in pink diamonds.
- Pages 44 and 48: For some reason, RI values are given for platinum and copper. Since metals are opaque (except in very thin sections), it would be more meaningful to provide reflectivity, or to omit such values entirely.
- Page 71: Sapphire does not have adamantine lustre, but rather vitreous.
- Page 88: Cassiterite localities are listed in two places and the lists do not match.
- It is unlikely that synthetic topaz was used in the restoration of the Patiala Necklace (page 91), as this was not yet a commercially significant material in gem quality, and natural (and treated) topaz was both plentiful and inexpensive.
- Page 98: When stating, "Calcite has the largest number of different crystal structures of any mineral…", it should say crystal *habits* here. Calcite has only one crystal structure.
- There is an error in transcribing ancient Greek on page 117: 'γονια' (*gonia*) means angle, not 'gouia'.
- Page 157: 'Black onyx' is not onyx, which is striped; it is instead heat-treated porous chalcedony.

The publisher DK has done its usual excellent job of finding images. However, I have some issues with the figures (mainly their captions and labels), among them:

- The size (or at least weight) of most objects in the images is not indicated.

- If a gem is photographed in diffuse lighting, it will generally not display 'fire' (which instead is seen when the edge of a light ray is partly refracted, leading to a flash of spectral colour). The caption for a colourless 'cut taaffeite gemstone' on page 87 asserts that fire is visible, but none is seen in the photograph.
- The causes of 'fire' should be discussed. Double refraction is not the primary cause of fire, although it can help. The same is true of a high RI. The main cause of fire in gemstones is *dispersion*, the tendency of rays at the opposite end of the visual spectrum—i.e. red and blue/violet—to take different paths through a gem because of their different refractive indices.
- Page 14: The example provided for carbonates is chrysocolla (a silicate, not a carbonate), with a label pointing to chrysocolla and saying it is 'blue azurite'. There is azurite (a carbonate) on the specimen, but it looks black, not blue, here.
- Page 21: Unless African orange sapphires are included in the term 'padparadscha', I question whether these gemstones are as affordable as indicated on the figure.
- Pages 24–25: This list of sources for the various gem varieties, while helpful, is not exhaustive.
- Page 66: The 'modified crystals' of pyrite show cube and pyritohedral faces, not cube and octahedral faces.
- On page 72, the bipyramidal 'colourless rough' crystal is described as having prismatic shape. And the so-called padparadscha looks instead like a pink sapphire, possibly with some rust staining.
- The Timur Ruby is not discernible in the famous portrait of Queen Elizabeth II on page 78.
- Page 88: The example labelled 'Specular Hematite | Rough' does not show specular hematite, which forms in flat plates.
- On page 114, lapis lazuli is given as the anniversary gem for both the 9th year (caption title) and the 7th year (text of caption).
- The 'traditional triangular step cut' on page 116 has a four-sided profile, not a three-sided one. I would call it a lozenge shape instead.
- In the amethyst images/text on page 136, an apparent flaw is visible in the upper left corner of the 'internally flawless' step cut, and colour zoning is still visible in the mixed cut, which was supposedly fashioned to minimize this effect.

Various additional examples of mistakes or mischaracterization have not been mentioned here. So, why these many problems? As alluded to above, this book has no single responsible author and more than a dozen editors. But with a 'critical mass' of editors, the result can be a massive game of 'telephone'. An urgent deadline and easy access to the Internet may lead the unwary to create a product that is 'good enough'…but not, in this case, definitive.

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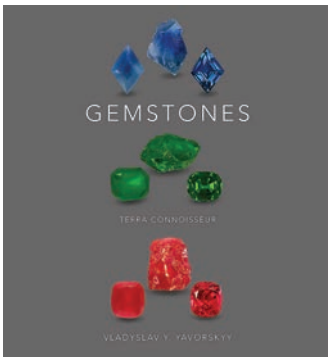
Gemstones—Terra Connoisseur



By Vladyslav Y. Yavorskyy, 2017. Yavorskyy Co. Ltd, New York, New York, USA, http://ivynewyork.com/gemstonesbook, 235 pages, illus., ISBN 978-0692784990. US$88.00 hardcover.

This is the third book in the *Terra* series, after spinel and garnet, and it follows the style of previous *Terra* works: colourful and beautiful. They have been created by a true artist: Yavorskyy loves nature, is a fine photographer and has travelled the world in search of his passion—rough gem materials.

There is very little text in *Gemstones*, with most pages being full of colour. Like a kaleidoscope, photos are often practically stacked upon each other, creating a somewhat different look from the usual gem book. The pages often show ethereal photos from the area of the gem being featured, with mining shots, miners, rough stones and finished gems telling a story within that page. Maps have been used throughout from antique prints, with colourful groups of gems and rough on each corner (which, as an antiquarian map lover, I found a bit unnecessary).

The book's contents are highlighted on pages 7–8, and even these two pages have gem photos peeking out. Portions of the text are listed that have been authored by various experts and friends. The first 40 pages cover several topics, including the author's forward, the history of gemstones, gem cutting and lighting. The history section, while succinct in its eight pages, hit many highlights with photos reproduced from various museums that are credited. The gem cutting section is basic, but well done in 10 pages, mostly consisting of photos of gems and a few lapidaries shown cutting as well as the related machinery. I particularly liked this statement: "...so the essence of the craft lies in the preforming stage; this is when the destiny of a gem is shaped". The lighting chapter consists of two pages showing the different looks achieved in white vs. somewhat yellow light, with tips that might be use-

ful for interested readers trying their hand at gem photography.

The next 44 sections cover specific gemstones that Yavorskyy has been involved with, ranging from diamond to fluorite in no particular order. His stated favourite gemstone is spinel, which is covered in seven of the 44 sections (categorized as: rare, blue, mauve, grey, lavender, red and pink). This gives the author many pages to feature various stories from Sri Lanka, Tanzania, Burma and Vietnam. Most of these are two pages long, but the red spinel chapter is 20 pages! Each of the gem sections show extraordinary cut stones, photos of nearby areas (often at sunset) and the local people involved with gems. The hundreds of gems photographed—most with their carat weight listed—may seem a bit like a fancy catalogue of the author's inventory, but with that said the gems are beauties. Repeated on most of these pages featuring the cut stones is printed "all [gem name] in these pages are natural and untreated". Although a bit redundant, it highlights the importance to the author of untreated gems.

The final dozen pages briefly cover other gem materials and gem properties, how to be successful in the gem business, gem shows and gemstones of the future, with an index of gem varieties on the final page.

The inside front and back covers are the same: a group photo of several hundred gemstones. Many are used throughout the book in various places, and some are seen more often than others.

In this reviewer's opinion, most anyone interested in gems will enjoy this book. Several friends saw the book as I was reviewing it, and expressed interest in acquiring a copy. They felt it was a good 'coffee table' book to page through with an abundance of beautiful colour photos that anyone would enjoy. Not all gem books are this beautiful.

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OTHER BOOK TITLES

Coloured Stones

Asterism—Gems with a Star
By Martin P. Steinbach, 2017. Self-published, 900 pages, ISBN 978-3000504945. US$199.00 hardcover.

Ruby & Sapphire: A Gemologist's Guide
By Richard W. Hughes, 2017. Lotus Publishing, Bangkok, Thailand, 816 pages, ISBN 978-0964509719. US$200.00 hardcover.

Diamond

Botswana Diamond Jewellery
By Michael C. Brook, 2016. Self-published, 136 pages, ISBN 978-9996804182. US$75.00 hardcover.

Diamond—The Ultimate Gemstone (MINERAL Monograph No. 19)
Ed. by Jeff W. Harris and Gloria A. Staebler, 2017. Lithographie Ltd, Arvada, Colorado, USA, 152 pages, ISBN 978-0983632351. US$40.00 softcover.

Fancy Color Diamonds: The Pricing Architecture
By Eden Rachminov, 2016. Self-published, 200 pages. US$240.00 hardcover.

Kohinoor: The Story of the World's Most Infamous Diamond
By William Dalrymple and Anita Anand, 2016. Self-published using Juggernaut, 264 pages, ISBN 978-9386228086. US$32.95 hardcover.

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By Michael D. Cowing, 2017. Amazonas Gem Publications, Palma, Mallorca, Spain, 138 pages, ISBN 978-0998483702. US$19.95 ebook.

Compiled by Angharad Kolator Baldwin and Brendan Laurs

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Silver, Freiberg, Erzgebirge,
Saxony, Germany
Specimen courtesy of
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Minerals, Inc.
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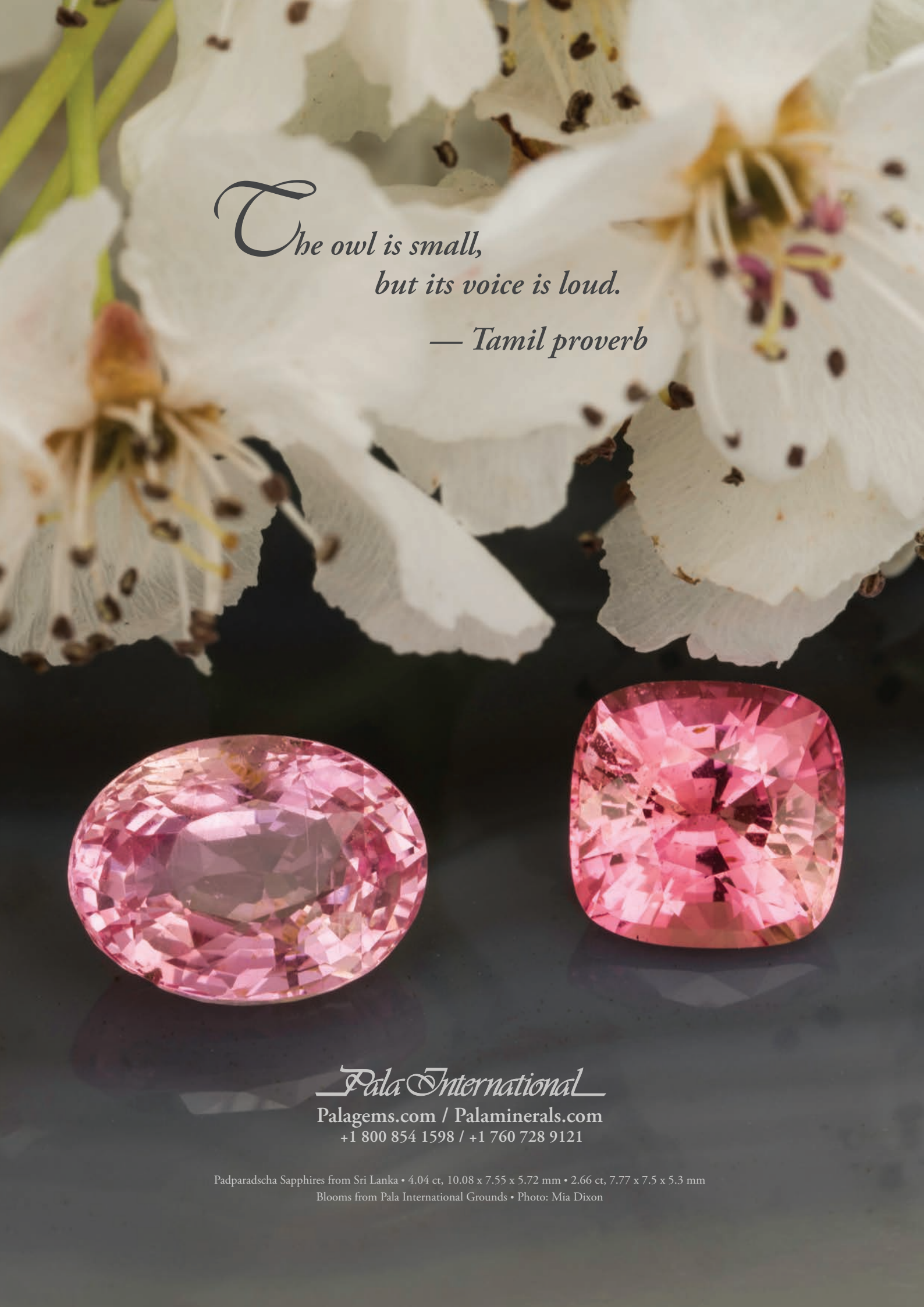

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Padparadscha Sapphires from Sri Lanka • 4.04 ct, 10.08 x 7.55 x 5.72 mm • 2.66 ct, 7.77 x 7.5 x 5.3 mm

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