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<th>Diamond Diploma</th>
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<td>Price: £3,150</td>
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</tr>
</tbody>
</table>

**Understanding Gems**
647 Editorial

COLUMNS

648 What’s New

652 Practical Gemmology
The Kerez effect in green tourmaline

654 Gem Notes
Apatite from Mozambique | Chondrodite from Tanzania | Purple garnets from East Africa | Green prase opal from Tanzania | Trapiche ruby from Myanmar | Sapphires from Kenya | Shattuckite and bisbectite from the DRC | Purple tourmaline from Mozambique | Tourmaline slices from Myanmar | Wurtzite from Tanzania | Star zircon | Amber processing in Lithuania | Shungite | Gem-set cultured pearls

Cover Photo: This 5.86 ct intense reddish purple garnet was cut by Jeff White from rough material that was mined in Mozambique; see Gem Note on pp. 656-658. Photo by Jeff White.

ARTICLES

678 From Exsolution to ‘Gold Sheen’: A New Variety of Corundum
By Thanh Nhan Bui, Katerina Deliousi, Tanzim Khan Malik and Katrien De Corte

692 Age Determination of Zircon Inclusions in Faceted Sapphires
By Klemens Link

702 Identification of a CVD Synthetic Diamond with a ‘Tree Ring’ Growth Pattern
By Yan Lan, Rong Liang, Taijin Lu, Yong Zhu, Tianyang Zhang, Xuan Wang, Jian Zhang, Hong Ma and Zhonghua Song

712 Conferences
Canadian Gemmological Association | First World Emerald Symposium | Gem-A | Geological Society of America

721 Gem-A Notices

735 Learning Opportunities

738 New Media

743 Literature of Interest

746 Volume Index

The Journal is published by Gem-A in collaboration with SSEF and with the support of AGL.
Good News for The Journal!

For more than 60 years, *The Journal of Gemmology* has been one of the top scientific journals in gemmology. Receiving *The Journal* is an important Gem-A membership benefit, and it provides a useful means of continuing education for all gemmologists, in keeping with Gem-A’s mission and values. The scientific standing of scholarly publications such as *The Journal* rests heavily on their selection for coverage by the international research platform known as the Web of Science. Formerly known as the ISI (Institute for Scientific Information) Web of Knowledge, this online subscription-based service is maintained by Thomson Reuters and provides comprehensive access to multiple databases covering the sciences, social sciences, arts and humanities.

I am pleased to report that in November 2015, *The Journal* joined the Web of Science (WoS) when it was accepted into Thomson Reuters’ new Emerging Sources Citation Index (ESCI) database. Journals in ESCI are indexed like those in other databases within WoS, but they do not receive an impact factor (a measure of how often recent articles are cited in WoS journals). As *The Journal* continues to be evaluated for Thomson Reuters’ impact-factor science database (Science Citation Index Expanded), it should benefit greatly from the exposure provided by ESCI. Additional exposure is provided by *The Journal*’s inclusion in databases that are maintained by other indexing services and journal aggregators (e.g. Scopus, EBSCO, ProQuest and GeoRef) that are commonly subscribed to by university libraries and research institutions worldwide.

*The Journal*’s inclusion in WoS is good for our authors, for our readers and for gemmology in general. *The Journal* will now be in a better position to attract articles from researchers at top universities who are required to publish in WoS journals, and our readers will benefit from this cutting-edge research. In addition, *The Journal*’s coverage by WoS will certainly help raise awareness of gemmology in the global scientific community. Being part of WoS will not change the direction or scope of *The Journal*, as gemmology will continue to be the core foundation of its content.

On another subject, thanks to the efforts by consultant Carol Stockton, I am pleased to announce the completion of *The Journal*’s Cumulative Index that covers all issues from 1947 to 2013 (Volumes 1–33). This index is available as a free downloadable PDF file on *The Journal*’s website, and early in 2016 it will be updated to include all issues through 2015.

Coming soon (also scheduled for early 2016), Gem-A will unveil a new website, and this will give Gem-A members free access to the entire archive of *The Journal* as searchable PDF files. In addition, non-members will be able to purchase PDFs of individual articles/sections, as well as complete issues. The availability of the entire journal archive, combined with the Cumulative Index, will provide a comprehensive gemmological reference tool.

*Brendan Laurs*
*Editor-in-Chief*
What’s New

INSTRUMENTS AND TECHNIQUES

Gemlogis Taupe Diamond Segregator

Gem laboratories are more commonly receiving mixed parcels of natural and synthetic diamonds for identification. At this author’s lab, colourless to near-colourless diamonds weighing >0.50 ct are subjected to advanced testing, while smaller stones (i.e. 0.02–0.49 ct) are segregated using a Gemlogis Taupe Diamond Segregator (www.gemlogisusa.com/gemlogis-taupe-diamond-lab-created-tester.htm), which is manufactured by Jubilee Diamond Instrument Ltd., Hong Kong, and was released in May 2014. The instrument is compact and portable, and has a short-wave UV beam that is focused on the sample. Sensors detect the transmission of the UV beam through the sample to identify type II diamonds, thereby flagging potentially CVD- or HPHT-grown synthetics, or natural diamonds that may have been HPHT treated.

The sample is placed table-down on the instrument and the lid is shut for the analysis. Within seconds of pressing the ‘test’ button, a green light will indicate the diamond is type I (and therefore probably natural), while a yellow-orange light identifies the need for further testing. An advantage of the instrument is that small diamonds down to 0.02 ct can be segregated. For best results, the instrument should be regularly calibrated using known melee-sized CVD- and HPHT-grown synthetic diamonds.

There is an increasing need for such instruments that are affordable and can segregate small potentially synthetic diamonds from natural ones. Although the instrument does not specifically identify synthetic or HPHT-treated diamonds, it is helpful for separating type II gems for further examination.

Jayshree Panjikar (jayshreepanjikar@gmail.com)
Pangem Testing Laboratory (Pangemtech)
Pune, India

M-Screen Automatic Melee Screening Device

In September 2015, HRD Antwerp released the M-Screen device, which rapidly screens melee parcels (0.01–0.20 ct) to separate natural from potentially synthetic/treated diamonds and simulants. The desktop instrument automatically feeds, screens and sorts colourless and near-colourless (D–J) round brilliant diamonds at a rate of 2–5 stones per second (7,200–18,000 per hour). Also, starting in November 2015, HRD Antwerp began offering a rapid (24-hour turnaround time) melee screening service using the M-Screen. Visit www.hrdantwerp.com/en/product/m-screen.

Presidium Synthetic Diamond Screener

In September 2015, Presidium debuted a new device for screening colourless and near-colourless (D–J) diamonds and flagging type IIa stones. The instrument measures 13.0 × 10.0 × 6.5 cm, weighs 210 g and can be operated using AAA batteries or via a USB connection. Samples ranging from 0.1 to 10 ct that are loose or mounted (with an open-back setting) can be tested, and the measurement takes approximately 6 seconds. Visit http://presidium.com.sg/psdproduct/synthetic-diamond-screener-sds.

Spekwin32 Spectroscopy Software

In October 2015, Dr Friedrich Menges released an updated version of the spectroscopy software Spekwin32. New capabilities of interest to gemmologists include ‘Spectroscope View’—which renders a spectrum collected using a spectrometer.
ICGL Newsletter

The International Consortium of Gem-Testing Laboratories has released the Fall 2015 issue of their newsletter (No. 3/2015), available at http://icglabs.org. It features articles on small HPHT-grown octahedral colourless and blue synthetic diamonds produced using an even-temperature method, heat-treated amber beads, amber in the collection of the Pangem Testing Laboratory (Pune, India) and a proposal to include...
certain spectroscopic data on diamond reports to aid in the detection of fraudulent replicas of loose or mounted stones.

ISO Standards for Diamonds
In July 2015, the International Organization for Standardization released a new standard (ISO 18323:2015) for diamond nomenclature: ‘Jewellery – Consumer Confidence in the Diamond Industry’. The document is designed to be understood by the consumer, and covers nomenclature and disclosure of diamonds—natural, treated, synthetic, composite and imitation—as well as a glossary. The standard is available for purchase at www.iso.org/iso/catalogue_detail.htm?csnumber=62163.

The Journal of Gemmology Cumulative Index
In December 2014, Gem-A released The Journal’s Cumulative Index, covering all issues from 1947 to 2013 (Volumes 1–33). In early 2016, it will be updated to include Volume 34 (2014–2015). The contents are listed by subject, and the PDF file is searchable, so entries by specific authors also can be located. The Cumulative Index is available in electronic format only as a free download from The Journal’s website at www.gem-a.com/publications/journal-of-gemmology.aspx.

Rare Book Scanning by GIA Library
The Gemological Institute of America’s Richard T. Liddicoat Gemological Library and Information Center is in the process of digitizing its collection of rare and historically significant books, and many titles are available for free download at https://archive.org/details/@gia_library. As of December 2015, 101 books had been uploaded, with more being added weekly. Brief descriptions of each item can be seen in list view; most were taken from Gemology: An Annotated Bibliography compiled by the late John Sinkankas in 1993.

Responsible Business Practices and Jewellery Consumption
A November 2015 presentation delivered at the ESRC Festival of Social Science by Prof. Marylyn Carrigan of Coventry University on preferences by UK jewellery consumers who shop in the Birmingham Jewellery Quarter is available for free download from the National Association of Jewellers’ website at http://tinyurl.com/zz6j3qb.

RJC 2015 Progress Report

What’s New
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 are prepared by Brendan Laurs unless otherwise noted.
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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The Kerez Effect in Green Tourmaline

Andrew Fellows

The Kerez effect refers to an optical behaviour that is very rarely shown by green tourmaline. Since it is so uncommon, it often goes unreported in gemmology textbooks.

Originally discovered by Dr C. J. Kerez (Read, 1982), this optical effect was apparently first described by Mitchell (1967) in two very unusual Brazilian tourmalines. He wrote: “To all outward appearances they are quite normal stones. Refractometer readings, however, reveal the inexplicable fact that the stones each give four distinct shadow edges...the twin ordinary ray readings remain stationary while the other two move as the stone is rotated.” Such additional shadow edges, ranging from two to four pairs (four to eight lines in total), also have been referred to as satellite readings (Schiffmann, 1972, 1975). The multiple shadow edges can understandably create confusion for gemmologists.

According to everything that this author has been taught, this optical effect should not happen—and this prompted the author’s search for such specimens. Eight years (and many tourmalines) later, an elusive multi-RI stone was found. It consisted of a 1.39 ct oval cut (Figure 1) that produced eight individual shadow edges in the refractometer (Figure 2). The two groups of four edges could easily be differentiated using a polarizing filter, giving the four sets of readings that are shown in Table I (which also gives the results from other visually similar green tourmalines that were studied for comparison). Each set of shadow edges corresponded to the ordinary and extraordinary rays, but interestingly they were not equally spaced, although the birefringence was constant for all four sets.

For stones showing the Kerez effect, the ‘true’ RI values were shown by Schiffmann (1975) to correspond to the lowest reading of each of the sets of shadow edges. He proved this after repolishing such a stone, which resulted in a single set of readings that were normal for tourmaline. Therefore, the correct RI range for the 1.39 ct stone examined by this author

Table I: RI readings of green tourmalines in this study.

<table>
<thead>
<tr>
<th>Stone</th>
<th>Weight (ct)</th>
<th>Shape</th>
<th>RI readings</th>
<th>Birefringence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.39</td>
<td>Oval</td>
<td>1.622–1.649</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.627–1.654</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.629–1.656</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.634–1.661</td>
<td>0.027</td>
</tr>
<tr>
<td>2</td>
<td>0.67</td>
<td>Emerald cut</td>
<td>1.620–1.640</td>
<td>0.020</td>
</tr>
<tr>
<td>3</td>
<td>2.74</td>
<td>Emerald cut</td>
<td>1.621–1.638</td>
<td>0.017</td>
</tr>
<tr>
<td>4</td>
<td>0.53</td>
<td>Emerald cut</td>
<td>1.618–1.640</td>
<td>0.022</td>
</tr>
<tr>
<td>5</td>
<td>0.53</td>
<td>Oval</td>
<td>1.621–1.640</td>
<td>0.019</td>
</tr>
<tr>
<td>6</td>
<td>0.54</td>
<td>Oval</td>
<td>1.622–1.641</td>
<td>0.019</td>
</tr>
<tr>
<td>7</td>
<td>2.54</td>
<td>Round</td>
<td>1.624–1.642</td>
<td>0.018</td>
</tr>
</tbody>
</table>

Figure 1: Of the green tourmalines shown here (0.53–2.74 ct), only one (no. 1) showed the Kerez effect in the refractometer. See Table I for RI data corresponding to each stone. Photo by Henry Mesa.
should be inferred as 1.622–1.649.

The Kerez effect is thought to result from the cutting and polishing process, when over-enthusiastic polishing causes a build-up of heat due to friction from the cutting wheel (Schiffmann, 1975). This creates thermal damage that penetrates slightly below the stone's surface.

To check whether the Kerez effect could purposely be created during the cutting process, this author enlisted the help of a fellow gemmologist and local lapidary. Two individual sections of a dark green tourmaline were subjected to heavy polishing, with sufficient speed and pressure used to build up heat within the stones. However, compared to a 'normally' polished section of the same stone, there were no differences seen in the RI readings, and no additional shadow edges were created by the aggressive polishing. It is therefore difficult to see how a lapidary could inadvertently create the Kerez effect, and perhaps there is more than just heat involved.

The exact cause of the Kerez effect, and why it appears restricted to green tourmaline, is still unknown. It is hoped that increasing the awareness of this interesting phenomenon will enable other gemmologists to recognize the effect in tourmalines that they may rarely encounter.

Acknowledgement: The author thanks Sam Lloyd FGA for help with polishing the tourmaline samples, and for independently checking the results.

References

Andrew Fellows FGA DGA is the online distance learning tuition manager, and a gemmology and diamond tutor, at Gem-A in London. Email: andrew@gem-a.com

Figure 2: Refractometer readings of the 1.39 ct tourmaline displayed the Kerez effect in four sets of shadow lines corresponding to the ordinary (left) and extraordinary (right) rays. Photos by A. Fellows.
Apatite from Mozambique

In January 2014, gem dealer Dudley Blauwet (Dudley Blauwet Gems, Louisville, Colorado, USA) obtained a 600 g parcel of rough apatite that his African supplier indicated was from Nhamatanda, Mozambique. In July 2014, cutting of six pieces weighing 236.7 g yielded 55 gemstones with a total weight of 264.44 carats. The largest stones (up to 39 ct) contained parallel arrays of eye-visible platelet inclusions, and some also contained fibrous needles. To decrease the visibility of the platelets, the gems were cut so the inclusions were oriented perpendicular to the table facet. Blauwet loaned two apatites to the American Gemological Laboratories (AGL) for examination, and they were characterized by this author: a 3.88 ct triangle and a 10.61 ct cushion (Figure 1).

The yellowish green colour combined with an excellent polish made these stones quite attractive. Standard gemmological testing of both gems revealed RIs of 1.630–1.635 (birefringence 0.004–0.005) and a hydrostatic SG value of 3.17. These properties confirmed the samples were apatite (cf. O’Donoghue, 2006). They were inert to long-wave UV radiation and exhibited a weak yellow fluorescence to short-wave UV.

Microscopic examination revealed various internal features. Parallel star-like oriented cross-hatch inclusions formed one of the most interesting types (Figure 2a). The stones also contained several high-relief disc-like fissures (Figure 2b). Additionally present were parallel growth tubes with reflective platelets and particles (Figure 2c), as well as minute unidentified crystals with parallel needle-like tubes (Figure 2d).

Semi-quantitative chemical analysis using a Thermo Electron Corp. ARL Quant’X energy-dispersive X-ray fluorescence (EDXRF) spectrometer showed the expected major amounts of Ca and P, as well as minor Mg (~0.7 wt.%) and Mn (~0.2 wt.%), and traces of Fe (~0.07 wt.%).

Gem-quality apatite is known from several localities. It is possible that the inclusion assemblage shown by these Mozambique apatites is unique to their specific locality, but more research would be needed to confirm this.

Monruedee Chaipaksa
(mchaipaksa@aglgemlab.com)
American Gemological Laboratories
New York, New York, USA

Reference
Chondrodite reportedly from Tanga, Tanzania

Chondrodite, (Mg,Fe²⁺)(SiO₄)₂(F,OH)₂, is an uncommon gem material that is known from various localities, including two places in Tanzania: Sumbawanga in the west-central part of the country (Fritz et al., 2007) and Mahenge in south-central Tanzania (Overton, 2011). A broad range of colour has been documented for Tanzanian chondrodite (‘Uncommon minerals as gemstones…’, 2007), although the most common colour appears to be ‘golden’ yellow. In September 2014, gem dealer Dudley Blauwet obtained a parcel of rough from his East African supplier that was represented as chondrodite from a different locality in Tanzania: the Tanga region, in the north-western part of the country. Cutting of 16 pieces of rough weighing 14.78 g yielded 45 gems ranging from 0.15 to 1.96 ct.

Blauwet loaned five of the faceted stones (0.52–1.96 ct; Figure 3) to AGL for examination, and the following gemmological properties were recorded: colour—brownish yellow to yellow, except for one sample that was orangey yellow; no obvious pleochroism; RI—1.592–1.623; birefringence—0.028–0.029; SG—3.12–3.20; fluorescence—inert to long-wave UV and weak-to-moderate yellow to short-wave UV radiation; and no features were visible with the desk-model spectroscope. All of these properties are consistent with data reported for chondrodite by O’Donoghue (2006). Microscopic examination revealed small zones of coarse particles and ‘fingerprints’ in most of the stones. One sample contained small, parallel needle-like inclusions (Figure 4). EDXRF spectroscopy of the five chondrodite samples showed traces of Al, Mn, Ca, Ti, Na and K, consistent with the results presented by Fritz et al. (2007) for material from Sumbawanga (no chemical data were reported for the chondrodite from Mahenge).

The gemmological properties of these samples are comparable with chondrodite from both Sumbawanga and Mahenge. If the Tanga location can be confirmed, it represents the third location in Tanzania for this unusual gem material.

Bryan Clark (bclark@aglgemlab.com)
American Gemological Laboratories
New York, New York, USA

References
Uncommon minerals as gemstones from Tanzania, 2007. SSEF Facette, 14, 6.
Purple Garnets from East Africa

During the June 2015 JCK gem and jewellery show in Las Vegas, Nevada, USA, news circulated about some attractive new purple garnets from East Africa. Gem dealer Geoffrey Watt (Mayer & Watt, Maysville, Kentucky, USA) had an intense purple 3.87 ct cushion (Figure 5, centre), which was one of two faceted purple garnets that he bought from a Sri Lankan cutter at the 2015 Tucson gem shows. The cutter said he had purchased the rough material in Tanzania. Later, shortly before the JCK show, a 5.86 ct intense purple garnet was faceted by Jeff White (J.L. White Fine Gemstones, Kingsport, Tennessee, USA; see cover of this issue). Subsequently White cut nine more of these garnets, ranging from ~2 ct to 13.31 ct. He purchased the rough from Steve Ulatowski (New Era Gems, Grass Valley, California, USA), who obtained the material in March–April 2015 while on a buying trip to Arusha, Tanzania. His supplier initially told him that the source was Tanzania, but he subsequently confirmed that the material actually came from Catandica, Mozambique. (This also may apply to the origin of Watt’s garnet.) Ulatowski noted that the pieces appeared alluvial and were irregularly shaped with a pitted surface texture. After several buying trips to Arusha and Bangkok through October 2015, Ulatowski obtained a total of 1 kg of this garnet (only selecting the better-quality material), commonly in pieces weighing around ½ g each.

Ulatowski also mentioned encountering a different type of purple garnet since December 2014, represented as ‘rhodolite’ from Salima, Malawi. This material also appeared alluvial but had better shape (like ‘gumdrops’) and smoother surfaces, and it was available in larger sizes, though stones exceeding 10 g appeared over-dark; he obtained 5–6 kg of this garnet. According to Bill Barker (Barker & Co., Scottsdale, Arizona, USA, the shape of this garnet enables a good cutting yield; he attained 40% from a 1 kg parcel, with individual stones weighing up to 10 ct. Dudley Blauwet also acquired some of the Malawi garnet from an East African supplier, and from 10 pieces of rough weighing 26.4 g, he cut 10 stones (49.96 carats total weight) ranging from 1.47 to 10.60 ct; he loaned two of the more purple gems for examination. They were gemmologically characterized by three of the authors (CW, BW and DH), along with the 3.87 ct cushion from Geoffrey Watt (Figure 5).

The gemmological properties of the three samples are summarized in Table I. They are consistent with those reported for pyralspite garnets by Stockton and Manson (1985), and the RI values of all three samples fall within the ranges expected for both pyrope-almandine (rhodolite) and pyrope-spessartine, with or without some grossular (cf. Jackson, 2006). The magnetic data measured for the 1.47 and 3.87 ct garnets further indicated a pyrope-almandine composition with Pyr>Alm for both gems (cf. Hoover, 2008).

EDXRF spectroscopy using an Amptek X123-SDD instrument with a DP5 preamplifier showed a major amount of Fe, present in approximately equal amounts in all three stones. A small amount of Ca was detected in the three garnets, with slightly more in the 1.47 ct sample; that stone also contained a significant amount of Mn and Cr. (Note: Although Mg was not seen, it is only marginally detectable with this instrumentation.) UV-Vis spectroscopy of the 3.87 and 1.47 ct samples using an Ocean Optics USB4000 instrument showed slightly greater absorption in the ~420 nm region of the 1.47 ct sample. This created a more pronounced transmission window in the violet range for the 3.87 ct stone, corresponding to its more intense purple colour.

Ultraviolet-visible–near infrared (UV-Vis-NIR) absorption spectra also were collected on two
additional samples by one of us (GRR), merging data from three spectrometers: an OceanOptics UV CCD, a silicon-diode array visible spectrometer and a Nicolet iS50 near-infrared unit (Figure 6). Both samples consisted of doubly-polished slabs. Sample 3237 was prepared from a piece of Mozambique rough material supplied by Jeff White (e.g. see border region of cover photo) that was originally obtained from Steve Ulatowski, and sample 3235 was a slightly less intense purple garnet supplied by Ulatowski from a much earlier find that occurred in Tanga, Tanzania. Both pieces had nearly identical spectra, except 3235 showed greater absorption in the violet range (near 400 nm). The more intense purple sample 3237 had less absorption in that region, producing increased transmission. Manganese (Mn$^{2+}$) is responsible for absorption in the 400–440 nm region of the spectrum (Manning 1967), and chemical analysis (Table II) showed that sample 3235 had >20% more Mn than 3237. The additional manganese absorption in sample 3235 removed more of the violet light, causing it to appear less purple than 3237. An additional factor contributing to the

---

### Table I: Properties of the faceted purple garnets from East Africa.$^a$

<table>
<thead>
<tr>
<th>Locality</th>
<th>Tanzania/Mozambique?</th>
<th>Salima, Malawi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Watt</td>
<td>Blauwat</td>
</tr>
<tr>
<td>Weight (ct)</td>
<td>3.87</td>
<td>2.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.47</td>
</tr>
<tr>
<td>Colour</td>
<td>Vivid slightly reddish purple</td>
<td>Moderate purplish pink, shifting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to a moderate slightly purplish</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pink in incandescent light</td>
</tr>
<tr>
<td>RI</td>
<td>1.765</td>
<td>1.749</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.748</td>
</tr>
<tr>
<td>SG</td>
<td>3.89$^a$</td>
<td>3.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.73</td>
</tr>
<tr>
<td>Magnetic data$^c$</td>
<td>$18.01 \times 10^4$ SI</td>
<td>Not determined</td>
</tr>
<tr>
<td>Internal features</td>
<td>Many parallel needles, some</td>
<td>Clusters of small, colourless,</td>
</tr>
<tr>
<td></td>
<td>appearing as broken lines and</td>
<td>iridescent, crumb-like inclusions</td>
</tr>
<tr>
<td></td>
<td>others corresponding to growth tubes</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ None of the garnets showed any reaction to the Chelsea filter or UV radiation.

$^b$ A cavity on the pavilion appeared to be filled with a polishing medium, and it is possible that it may have slightly lowered the SG value.

$^c$ Volume magnetic susceptibility measurements were performed by author DH using the method described in Hoover (2008).

---

Figure 6: UV-Vis-NIR absorption spectra of two purple garnet slabs from Tanzania (sample 3235) and Mozambique (sample 3237) show nearly identical patterns until the violet range, where 3235 has greater absorption. The more pronounced transmission window in this region for 3237 corresponds to its slightly more intense purple colour. Both samples were scaled to plot as 1.0 mm thick.
The colour of 3237 is the absence of Fe$^{3+}$, that both by itself and through interactions with Fe$^{2+}$ would absorb light in the blue region of the spectrum.

Table II: Electron microprobe analyses of purple pyrope-almandine garnets from Tanzania and Mozambique.*

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>3235</th>
<th>3237</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Tanga, Tanzania</td>
<td>Catandica, Mozambique</td>
</tr>
<tr>
<td>Oxides (wt.%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SiO$_2$</td>
<td>40.40</td>
<td>40.23</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>22.95</td>
<td>23.01</td>
</tr>
<tr>
<td>FeO</td>
<td>22.17</td>
<td>24.03</td>
</tr>
<tr>
<td>MgO</td>
<td>13.36</td>
<td>12.72</td>
</tr>
<tr>
<td>CaO</td>
<td>1.35</td>
<td>0.77</td>
</tr>
<tr>
<td>MnO</td>
<td>0.25</td>
<td>0.21</td>
</tr>
<tr>
<td>Total</td>
<td>100.48</td>
<td>100.97</td>
</tr>
<tr>
<td>Ions per 12 oxygens</td>
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<tr>
<td>Si</td>
<td>3.002</td>
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<tr>
<td>Al</td>
<td>2.010</td>
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<tr>
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<tr>
<td>Ca</td>
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<td>0.061</td>
</tr>
<tr>
<td>Mn</td>
<td>0.016</td>
<td>0.013</td>
</tr>
</tbody>
</table>

* Average of five analyses per sample. Cr and Ti were analysed for but not detected. Analyst: Chi Ma. End-member compositions determined by author DH using procedure of Locock (2008): Sample 3235: Pyr$_{49.00}$Alm$_{44.29}$Gro$_{5.10}$Sps$_{0.52}$And$_{0.48}$ Sample 3237: Alm$_{48.49}$Pyr$_{46.81}$Gro$_{3.57}$Sps$_{0.44}$

References


Green Prase Opal from the Kondo District, Tanzania

A historically important deposit of chrysoprase and praseopal in Tanzania is located at Haneti, situated north of Dodoma in central Tanzania (Shigley et al., 2009). During the 2015 Tucson gem shows, rough and polished material (e.g. Figure 7) from a new deposit in Tanzania was shown by Werner Radl (Mawingu Gems, Niederwörresbach, Germany). He indicated that mining started in early 2014 near Kwa Mtoro village in the Kondo District; this is also in the Dodoma region of Tanzania, but further north of Haneti. It is likely that several hundred kilograms of rough material have been produced. Radl obtained ~50 kg of rough, some of which he processed into spheres, cabochons and tumbled pieces.

Cara and Bear Williams (info@stonegrouplabs.com)  
*Stone Group Labs, Jefferson City, Missouri, USA*

Dr George R. Rossman  
*California Institute of Technology, Pasadena, California, USA*

Brendan M. Laurs  
*Dr Don Hoover, Springfield, Missouri, USA*

Radl donated two rough pieces (Figure 8) to Gem-A, and they were analysed by this author. Both were largely bluish green and translucent, with portions containing white opaque material (and also some dark brown matrix in one piece). They measured approximately $21.0 \times 20.7 \times 11.3$ mm and $24.3 \times 17.0 \times 18.0$ mm, and weighed 4.44 and 4.46 g, respectively.

A hydrostatic SG of 2.17 was measured on the larger sample. (The SG of the other piece could not be reliably measured, due to the presence of several cracks and voids.) Both samples appeared green through the Chelsea filter. Their reaction to long-wave UV radiation varied from partly inert to a weak chalky blue-
white fluorescence, whereas they showed a weak yellowish green fluorescence to short-wave UV. No phosphorescence was observed.

The SG value was clearly much lower than the ~2.6 expected for chrysoprase, and instead lies in the range of common opal. Both specimens increased in weight after hydrostatic SG weighing, and after one week they still retained a slightly higher weight, indicating some degree of hydrophane character. Infrared spectroscopy of both fragments (using a Thermo Scientific Nicolet iS50 FT-IR spectrometer) showed a pattern characteristic of opal, with a strong absorption band around 5200 cm\(^{-1}\) (Figure 9).

Raman spectroscopy (using a Thermo Scientific DXR Raman microscope with 780 nm laser excitation) produced spectra containing a broad band at ~325 cm\(^{-1}\) (the position varied slightly between the two samples), and peaks at 773 and 668 cm\(^{-1}\) (Figure 10). The broad band is due to the Raman shift of the O-Si-O bending mode, and its position is characteristic of opal-CT (not totally amorphous, but poorly crystalline cristobalite with some tridymite-like stacking; Fritsch et al., 2012). Moreover, Ilieva et al. (2007) showed that Raman spectra with the most intense (although poorly resolved) band centred near 330–360 cm\(^{-1}\) can be considered opal-T, with the proportion of spatial regions containing tridymite-type framework topology being higher than that of cristobalite-type

![Raman Spectra](image)

Figure 8: These rough pieces of prase opal (4.44 and 4.46 g) from the Kondoa District were examined for this report. Gift of Mawingu Gems; photo by Dirk van der Marel.

Figure 9: This representative Fourier-transform infrared (FTIR) spectrum of the rough material from the Kondoa District shows a strong absorption at ~5200 cm\(^{-1}\) that is characteristic of opal.

Figure 7: These polished spheres of prase opal (here, ~1.5–2.5 cm in diameter) are from a new deposit in the Kondoa District of Tanzania. Photo by Brendan M. Laurs.

![FTIR Spectrum](image)
framework typology. The Raman spectra shown in Figure 10 are very similar to the spectra of prase opal presented by Shigley et al. (2009).

EDXRF chemical analyses (with an EDAX Orbis Micro-XRF Analyzer) showed large variations in the Ni content of this prase opal. Analyses of three random spots (300 µm beam diameter) on both samples gave NiO contents of 3.64, 7.36 and 9.72 wt.% for the smaller opal, and 0.73, 3.08 and 5.09 wt.% for the larger piece. On average, the data reflect a relatively high NiO content of slightly below 5 wt.%. Additionally, Fe was not detected, and only traces of Ca were found (0.06–0.26 wt.% CaO).

The high Ni content of this strongly coloured prase opal appears to be consistent with the notion that chrysoprase with a lower degree of crystallinity tends to have greater amounts of Ni and a more intense colour (cf. Gawel et al., 1997), and also with the attribution of the colour to dispersed particles of Ni-containing minerals (cf. Shigley et al., 2009, and references therein).

It is highly likely that this prase opal was found in the same belt of metamorphosed ultramafic rocks that, from Haneti, are aligned in a north-westerly direction along regional shear zones.

J. C. (Hanco) Zwaan (hanco.zwaan@naturalis.nl) Netherlands Gemmological Laboratory National Museum of Natural History ‘Naturalis’ Leiden, The Netherlands

References


Flower-shaped Trapiche Ruby from Mong Hsu, Myanmar

Trapiche rubies have been known for years from marble-hosted deposits at Mong Hsu, Myanmar. They have been gemmologically characterized by Schmetzer et al. (1996), and their crystal growth mechanisms were studied by Sunagawa (2003). On three separate trips to Myanmar (Yangon in January 2011 and February 2013, and Mogok in December 2013), this author obtained five interesting flower-shaped trapiche rubies (e.g. Figure 11). They were cut and polished perpendicular to the c-axis, and ranged from ~5 to 7 mm in diameter and were 1.0–1.5 mm thick. At first glance, they showed a similar appearance and structure to ordinary trapiche rubies, with hexagonal cores surrounded by six sectors in a star shape that resembles the cogwheels used in sugar mills.

Microscopic examination revealed that they actually consisted of three separate growth layers (Figure 12), making them different from typical trapiche rubies. All five samples had small hexagonal cores that were overgrown by another hexagonal zone, which in turn was overgrown by radiating petals that originated from each prism face of the intermediate zone. The intermediate zone contained six thin arms extending outward from the corners of the core, producing six trapezoidal ruby sectors. The arms continued outward into the final growth layer to separate the six petals in the outer rim. Both the arms and the boundaries between each layer were delineated by thin white or yellow translucent areas. Carbonate mineral inclusions such as calcite and dolomite were documented in trapiche ruby arms by Schmetzer et al. (1996) and Sunagawa (2003).

When the samples were examined with transmitted light, the deep red cores and the six red
sectors in the middle layer appeared transparent, while the six petals of the outer rim appeared translucent pinkish red. In the middle and outer layers, the arms widened into branches toward the outer edges of those zones, forming snowflake-like patterns. The outer layer contained extensive elongate tube-like inclusions that were oriented in three directions, perpendicular to the three sets of hexagonal edges of the middle layer. Depending on the amount of weathering of the arms in the outer layer, the radiating patterns in this layer consisted of either six heart-shaped or six clothes-pin-shaped petals (again, see Figure 11).

Sunagawa’s (2003, 2005) diagram of trapiche crystal growth (Figure 13) shows how different kinds of growth mechanisms occurred on either smooth or rough interfaces, with the ‘driving force’ of crystallization (X-axis) plotted as a function of the growth rate (Y-axis). The dendritic growth of the arms and branches of a trapiche ruby are formed under an ‘adhesive-type’ multi-phase growth mechanism on a rough interface under high-driving-force conditions. The interstitial sectors are formed by a layer-by-layer growth mechanism on a smooth interface and a later infilling process within the interstices between the previously-formed dendritic arms and branches. Disturbances in the crystal growth by tiny fluid blebs or crystalline
During the February 2014 Tucson gem and mineral shows, gem dealer Dudley Blauwet obtained from an African supplier a parcel of rough sapphires that reportedly came from Kina in central Kenya, about an hour’s drive from Garba Tula. The parcel was particularly notable for its content of bicoloured sapphires, and Blauwet’s quick visual comparison with the gem corundum from Kenya’s Dusi deposit (near Garba Tula; see, e.g., Simonet et al., 2004) indicated that the present material was somewhat different. From 55 pieces of rough weighing 48.5 g, Blauwet had 57 stones faceted that weighed 83.54 carats and ranged from 0.40 to 2.40 ct. He loaned four samples to AGL for examination (Figure 14).

The three modified cushion cuts and one rectangular emerald cut ranged from 1.03 to 1.94 ct (6.50 × 4.41 × 3.30 mm to 7.85 × 6.36 × 4.23 mm, respectively). Viewed face-up with the naked eye, the stones appeared blue, green, yellow and bicoloured blue-yellow. However, when viewed with diffuse transmitted light in the microscope, they all showed exclusively blue and yellow colour zoning that was both straight and angular. Visible-range spectroscopy using an S.I. Photonics CCD (charge coupled device)-array

References

Figure 13: This ‘Sunagawa diagram’ (top) illustrates the crystal growth mechanisms of a corresponding trapiche specimen (bottom). The favoured growth mechanism is a function of the ‘driving force’ of crystallization versus the growth rate. The crystal in this example shows a sequence of growth similar to that of the trapiche rubies described in this study. Modified after Sunagawa (2003).
UV-Vis spectrophotometer showed that all four sapphires were coloured by a combination of Fe^{2+}–Fe^{3+}, Fe^{3+} and Fe^{2+}–Ti^{4+}, and revealed they were of a magmatic-related origin (Smith, 2010), consistent with their overall blue-green-yellow coloration. Mid-infrared spectroscopy of the blue sapphire using a Thermo Scientific Nicolet 6700 FT-IR spectrometer displayed a strong 3309 cm\(^{-1}\) series of peaks (strong 3309, 3232 and 3185 cm\(^{-1}\), and nominal 3367 cm\(^{-1}\)), while the yellow and green sapphires both showed a nominal 3309 cm\(^{-1}\) series (minor 3309 cm\(^{-1}\) and extremely small 3232 and 3185 cm\(^{-1}\)), while the bicoloured sapphire showed no OH-related features.

Semi-quantitative chemical analysis using a Thermo Scientific ARL Quant’X EDXRF spectrometer showed that all samples contained high amounts of Fe (0.91–1.68 wt.%), which is consistent with their magmatic-related origin. In addition, Ti ranged up to 0.01 wt.%. Neither V nor Cr was detected in any of the stones. Based on their high Fe content, it is not surprising that none of these four sapphires fluoresced to either long- or short-wave UV radiation.

Typical sapphire inclusions were observed in the four stones using a standard gemmological microscope. They consisted of bands of pinpoints (some coarse, some fine), strong straight and angular growth zoning, and a few frosty, whitish, fine-grained ‘fingerprints/healed fissures. Some of the more intriguing inclusion features were found in the yellow sapphire. The largest yellow colour zone in the stone contained an elongate planar cloud consisting of whitish, polka dot-like inclusions, as well as minute spots (Figure 15).

Wendi M. Mayerson (umayerson@aglgemlab.com)  
American Gemological Laboratories  
New York, New York, USA

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cabochons. Prior to cutting, they stabilized the material with resin at a pressure of 5,000 psi for nearly three weeks. The Kosnars kindly donated to Gem-A one slab (19.91 ct) and two flat cabochons (3.14 and 3.61 ct) along with a piece of unstabilized rough material (2.58 g), and these samples were examined by this author for this report (Figure 16).

All of the stones were opaque and showed pleasing light- and dark-blue colours, with the polished pieces having a slightly darker tone than the rough material. The rough consisted of sprays of radiating fibrous crystals. This same fibrous texture was exhibited by the two cabochons, combined with a locally more granular texture. The slab showed the same textures (Figure 17, left), combined with circular fibrous areas similar to patterns often seen in malachite (Figure 17, right).

Spot RI readings of the polished pieces were ~1.65, and hydrostatic SG values varied between 3.05 (for a cabochon) and 3.16 (for the slab). The stones were mostly inert to long- and short-wave UV radiation, except that the lighter blue parts showed a weak blue fluorescence to long-wave UV.

These properties did not match the known values of shattuckite, Cu₅(Si₂O₆)(OH)₂, which has RIs of 1.752–1.815 and SG values of 3.80–4.11 (Dedeyne and Quintens, 2007), so further testing was required. Raman analysis (with a Thermo Scientific DXR Raman microscope) identified areas of shattuckite, but also revealed the presence of another mineral showing a close match with reference spectra of bisbeeite (CuSiO₃•nH₂O) in the RRUFF database (Figure 18). The granular areas in the slab consistently gave Raman spectra for shattuckite, regardless of tone (light or dark), and an associated small green-stained area was identified as calcite (Figure 17, right). However, the areas of the slab showing fibrous structure were bisbeeite. The 3.61 ct cabochon also contained a fibrous area of bisbeeite, and an intermediate region with a fibrous/granular structure that showed mixed Raman peaks relating to bisbeeite and shattuckite. For the 3.14 ct sample, shattuckite...
was only identified in a small dark spot showing granular texture on one side of the cabochon, while the fibrous areas analysed were bisbeeite. Granular areas on the other side of the stone matched shattuckite, regardless of colour (dark or light blue). A flat fibrous area on the rough sample showed only bisbeeite. Thus it appeared that the fibrous portions of the material consisted of bisbeeite and the more granular parts correlated to shattuckite.

Shattuckite was discovered in Bisbee, Arizona, USA (Shattuck mine) as a pseudomorph after malachite (Schaller, 1915). Bisbeeite is another rare, but poorly defined, secondary copper mineral, which was confirmed by Laurent and Pierrot (1962) as a distinct species. However, Van Oosterwyck-Gastuche (1968) concluded that the validity of bisbeeite was doubtful, and the mineral was discredited by the International Mineralogical Association's Commission of New Minerals and Mineral Names in 1977, when it was considered as a synonym for chrysocolla, \((\text{Cu,Al})_2\text{Si}_8\text{O}_{22}(\text{OH})_4\cdot\text{nH}_2\text{O}\) (www.mindat.org/min-26553.html). Interestingly, the measured Raman spectra of bisbeeite in the samples we examined showed the best match with RRUFF reference spectra of bisbeeite from Shangulume, Katanga Province, DRC, which showed features significantly different from the spectra of chrysocolla (typically lacking a prominent peak at 211–210 cm\(^{-1}\), and showing a broad band in the 410 cm\(^{-1}\) range). Additionally, EDXRF chemical analyses (with an EDAX Orbis Micro-XRF Analyzer) revealed Cu and Si as the main elements in the samples, and did not detect any Al. Fleischer (1972) suggested that bisbeeite could be part chrysocolla and part plancheite, \((\text{Cu,Al})_2\text{Si}_8\text{O}_{22}(\text{OH})_4\cdot\text{H}_2\text{O}\), but Raman spectra do not support this possibility (cf. Frost and Xi, 2012).

From these preliminary data, as well as the radiating fibrous texture and deep blue colour seen in our samples, it appears that bisbeeite indeed differs from chrysocolla and needs to be better defined. Laurent and Pierrot (1962) gave RIs of 1.613–1.710 for bisbeeite, which explains the spot RI readings of ~1.65. Those values are significantly higher than the RI range for chrysocolla (1.46–1.57). Also, Laurent and Pierrot (1962) reported an SG value for bisbeeite of 3.45 ± 0.05, also higher than the SG of chrysocolla (1.93–2.45), and slightly higher than the SGs of 3.05–3.16 measured for the present samples. These low measured values are apparently due to the stabilized nature of the material.

As expected for the polished samples, which reportedly had been stabilized, Raman spectra showed features in the 3400–1200 cm\(^{-1}\) region that are typical of a polymer: main peaks in the 3100–2800 cm\(^{-1}\) region due to C-H stretching, a peak at 1725 cm\(^{-1}\) due to C=O stretching and a peak at 1457 cm\(^{-1}\) (Figure 19; cf. Johnson et al., 1999; Moe et al., 2007). The latter two peaks are similar to those at ~1730 and 1453 cm\(^{-1}\) that are characteristic of Norland Optical Adhesive 65, a colourless UV-hardened polymer that is used to stabilize turquoise (Moe et al., 2007). No such polymer-related features were recorded from the rough sample (reportedly untreated), which...
In the past few years, a relatively new alluvial deposit of tourmaline was found at Maraca, Mozambique. This area is located only ~20 km from the well-known Cu-bearing tourmaline deposits of Mavuco in the Nampula area (e.g. Laurs et al., 2008a). The Maraca area reportedly also has produced Cu-bearing tourmaline, although the stones are smaller and more included. Two water-worn pebbles from Maraca were loaned for examination by Michael Puerta and Farooq Hashmi (Intimate Gems, Glen Cove, New York, USA). Puerta obtained them during a visit to the nearby village of Iulùti (or Lulùti) in June 2014. The samples were medium purple and dark purple, and weighed 1.73 and 1.75 g, respectively (Figure 20). Their colours resembled those seen in some Cu-bearing tourmaline from Mavuco that is commonly heat-treated to a Paraíba-like blue appearance. The samples showed distinct pleochroism, in orangey yellow and purple, and in slightly greenish yellow and dark purple, respectively. The hydrostatic SG of both pebbles was 3.03. Viewed with a desk-model spectroscope, they showed a doublet at about 450 and 455 nm (with the first line being darker), a broad absorption band between 480 and 560 nm, and gradually decreasing absorption from ~530 to 560 nm; these features are common for purple tourmaline when viewed with a

\[ \text{Figure 19: The polished samples of shattuckite/bisbeeite showed features in the 3400–1200 cm}^{-1} \text{ region of the Raman spectrum that indicate the presence of a stabilizing polymer.} \]

\[ \text{Figure 20: These two transparent waterworn tourmaline pebbles (1.73 and 1.75 g) are from a new mine at Maraca, Mozambique, which is situated near the Mavuco Cu-bearing elbaite deposit. However, they were found to contain significant Fe and no Cu. Photo by Dirk van der Marel.} \]
spectroscope (e.g. GIA, 1995). The stones were inert to long- and short-wave UV radiation.

The Raman spectrum (obtained with a Thermo Scientific DXR Raman microscope) of the 1.73 g sample showed a good fit with spectra of liddicoatite in the RRUFF database, while the 1.75 g piece also showed a best match—although less convincing—with the reference spectra of liddicoatite (in addition, it roughly matched spectra for elbaite). Both samples had Raman spectra that were quite different from that of a slightly reddish purple Cu-bearing tourmaline from Mavuco (no. 510-10, characterized by Laurs et al., 2008a), which best matched elbaite in the RRUFF database (Figure 21).

Semi-quantitative EDXRF chemical analyses (Table III) were obtained from five random spots on each pebble using an EDAX Orbis Micro-XRF Analyzer. The instrument did not detect Cu in either sample, but showed significant amounts of Fe. This is unlike purple Cu-bearing elbaite from Mavuco, which consistently shows extremely low Fe content (again, cf. Laurs et al., 2008a).

The 1.73 g sample showed relative amounts of Ca and Na that would be expected for liddicoatite (although EDXRF spectroscopy is only marginally sensitive to Na). It also contained significant Pb, which is not typical for tourmaline from the Nampula region (cf. Krzemnicki, 2007; Laurs et al., 2008a,b), but has been documented in tourmaline from elsewhere (e.g. Madagascar: Lussier et al., 2006).

The 1.75 g pebble contained Na>Ca, which is not unusual for dark rubellite (cf. Deer et al., 1986). However, the calcium content was still much higher than in purple Cu-bearing elbaite from Mavuco, which typically has very low Ca.

As we analysed only two samples, this study can hardly be seen as representative for tourmaline from Maraca. The alluvial deposit could contain gem rough originating from various sources, and it would not be surprising for Cu-bearing tourmaline to be included among the production of stones from this new locality that is relatively close to Mavuco.

J. C. (Hanco) Zwaan

References
Tourmaline Slices from Myanmar

Large, colourful tourmaline slices displaying intricate patterns are well-known for liddicoatite from Madagascar (e.g. Dirlam et al., 2002). Recently, this author was surprised to see similar slices that reportedly came from Myanmar, in the collection of Bill Larson (Palagems.com, Fallbrook, California, USA). Larson obtained the two slices from Mark Smith (Thai Lanka Trading Ltd. Part., Bangkok, Thailand), who takes frequent buying trips to Myanmar. In February 2015, Smith encountered these colourful slices with a Burmese dealer who had six pieces that were all cut from the same piece of alluvial rough. The dealer reported that they came from Möng Long (or Maing Lon), which is located about 20 km south of Mogok. Smith purchased the three most attractive slices (Figure 22). In a subsequent trip in October 2015, the same dealer had some additional Möng Long slices, but they displayed an ordinary ‘watermelon’ concentric pattern with pale coloration. Smith reported that in the past, Möng Long has produced some cabochon- and facet-grade red and green tourmaline, but this is the first time he has seen slices from this locality. The patterns seen in the Möng Long tourmaline are typical of liddicoatite, although these samples have not been chemically analysed to determine the species present. Similar patterns were displayed in a tourmaline slice from Vietnam that proved to consist of Ca-rich elbaite and liddicoatite (Laurs et al., 2002).

Tourmaline slices also have been recently produced from an additional location in Myanmar: Khetchel (or Khetchey, Khet Chay) in the Molo area, Momel Township, located 75 km north-east of Mogok. The so-called mushroom

Figure 22: These three slices (5.7 × 4.6 cm each) were cut perpendicular to the c-axis from the same tourmaline crystal, which reportedly came from Möng Long, Myanmar. The pair on the left (101.76 and 112.42 ct) is in the collection of Bill Larson; photo by Orasa Weldon. The slice on the right (132.70 ct) is owned by Wing Chiu Li; photo by Mark Smith.
Figure 24: A single tourmaline crystal from Molo, Myanmar, was cut perpendicular to the c-axis into this series of slices (up to ~6.7 cm in diameter). Specimens and photo courtesy of Federico Bärlocher.

tourmalines from this area commonly have a black core and a bulbous triangular top consisting of pink-to-red fibrous elbaite (e.g. Lussier et al., 2008). When sliced perpendicular to the c-axis, they show various concentric patterns in pink-to-red, dark blue/green and black (Figures 23 and 24). They are frequently oiled due to their limited transparency. According to gem and mineral dealer Federico Bärlocher (Como, Italy), who specializes in Burmese stones, the size range of such slices is typically restricted by the relatively small size of the mushroom tourmaline crystals, as compared to the large liddicoatite specimens from Madagascar.

Brendan M. Laurs

References


Figure 23: These three slices (11.04, 23.95 and 37.96 ct, from left to right) were cut perpendicular to the c-axis from different crystals of mushroom tourmaline originating from the Molo area of Myanmar. Specimens and photo courtesy of Mark Smith.

Gem-quality Wurtzite from Tanzania

An interesting discovery of orange-brown gem-quality wurtzite took place in 2012 at the famous tanzanite deposits in the Merelani Hills of northern Tanzania (Hyrl, 2013). The wurtzite came from Block D of the mining area, and was associated with tanzanite or alabandite (a manganese sulphide, MnS). Wurtzite is the hexagonal polymorph of zinc sulphide (ZnS), and was named by the French chemist and mineralogist Charles Friedel (1832–1899) after his
tutor Charles Adolphe Wurtz (1817–1884). Well-known occurrences of relatively large crystals are Oruro and Animas in Bolivia, Huanzala in Peru and Talnakh in Russia (Bernard and Hyršl, 2015).

In nature, zinc sulfide generally occurs in the form of the cubic polymorph sphalerite ($\alpha$-ZnS), which crystallizes under a wide pressure-temperature range. Sphalerite deposits are the most important source of zinc. The crystallization of wurtzite ($\beta$-ZnS) is less common, and is typically linked to relatively high temperatures of about 1,020°C (Palache et al., 1944). Metastable formations may occur under lower-temperature conditions (e.g. in acidic solutions or favoured by the presence of cadmium; Okrusch and Matthes, 2014).

The partly translucent to transparent wurtzite crystals from Merelani are generally 2–3 cm in size (e.g. Figure 25), and faceted stones have been documented that weigh 0.30–1.74 ct (Hyršl, 2013) and 3.97 ct (Cooper and Renfro, 2014). More recently, a much larger wurtzite from Merelani was faceted: 76.42 ct (Figure 26).

The two smaller gems in Figure 26 (0.83 and 0.91 ct) were investigated for this report. Viewed with the polariscope, these distinctly fissured stones appeared streaky and exhibited tabby extinction. The high RI of wurtzite cannot be measured on a standard gemmological refractometer, but an approximate value of 2.36 was determined using a so-called digital refractometer (a lustre meter measuring reflectivity). An SG of 3.81 was measured with a hydrostatic balance. These values correspond to reference data for wurtzite (e.g. Phillips and Griffin, 1981).

Quantitative chemical analyses by electron microprobe (Jeol JXA 8200 at the Institute for Geosciences, Johannes Gutenberg-University Mainz, Germany) were obtained for these faceted wurtzite samples (Table IV). The significant Mn and low Cd contents of the two gems characterize...
them as the zinc-rich member (wurtzite) of the wurtzite-rambergite-greenockite series (ZnS-MnS-CdS).

Visible absorption spectra (e.g. Figure 27) of the gems were recorded with a PerkinElmer Lambda 12 spectrometer. The spectra were heavily distorted because of strong reflection effects. A broad band in the violet-to-orange spectral range (~400–600 nm) is thought to be caused by an electron transition between a Mn$^{2+}$ $d$-electron level and an unoccupied ZnS energy band (Prof. Dr A. N. Platonov, pers. comm., 2015).

Dr Ulrich Henn FGA (ulibenn@dgemg.com)
German Gemmological Association
Idar-Oberstein, Germany

Dr Jaroslav Hyršl (hyrsl@hotmail.com)
Prague, Czech Republic

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Zircon Showing Asterism

Zircon (ZrSiO$_4$) is an interesting mineral in gemmology, not only because it is found in attractive colours such as yellow, red, brown, green and even blue (due to heat treatment) combined with a high lustre, but also because it is important as a solid inclusion in numerous other gems. It may be useful for detecting heat treatment of corundum, and also for revealing information about the formation conditions/age and geographical origin of a gemstone.

Gem-quality zircon is typically transparent and cut into faceted gems. Rarely, zircon shows chatoyancy, and such gems have been documented from Sri Lanka (Fryer 1983, 1985; Hänni and Weibel, 1988). Hänni and Weibel described heated zircons containing two sets of tiny cleavage fissures, each responsible for a cat's-eye reflection. However, due to the geometric orientation of these tiny features, they did not produce a star effect.

During the early 2000s, one of the authors (MPS) obtained an attractive asteriated zircon in Ratnapura, Sri Lanka. After years of searching, he has been unable to find any publications mentioning star zircon. He recently loaned the gem to the Swiss Gemmological Institute SSEF for examination, and it was characterized by author MSK. The oval cabochon weighed 13.60 ct, and was light yellowish brown with reduced transparency due to the presence of multiple tiny inclusions. It showed no reaction to long-wave UV radiation, and a weak yellowish fluorescence to short-wave UV. The most notable characteristic of this zircon was the presence of moderate
asterism (Figure 28). Two branches of the star were rather weak and by visual observation oriented perpendicular to each other, with a third and more prominent bright band intersecting them with an angle of 45°. Close examination revealed an additional but very weak and short branch that was oriented perpendicular to the most intense band (horizontal in Figure 28). Depending on the observation conditions, this zircon thus revealed a star effect with six or maximum of eight rays. In addition to this, the centre of the star was further pronounced by a bright reflection from the overhead light source.

Microscopic observation of the asteriated zircon revealed three sets of oriented planar features (Figure 29, left), each perpendicular to the weaker branches of the star, combined with a set of very fine short tubes or fissures that were responsible for the distinctly more intense branch (vertical in Figure 28). The bright area at the centre of the star resulted from another set of micro-features (Figure 29, right) that was oriented perpendicular to the inclusions producing the star effect. Due to the highly included nature of

Figure 28: This 13.60 ct zircon cabochon shows moderate asterism and a bright reflection at the centre of the star. The vertical branch of the star is most prominent, followed by two weaker branches inclined 45° on each side of the vertical band. Additionally there is a very weak and short horizontal branch, thus resulting in a star with a total of eight rays when observed in optimum lighting conditions. Photo © V. Lanzafame, SSEF.

Figure 29: Microscopic observation showed that various micro-features are responsible for the star effect (left) and the central bright reflection (right) in the zircon. Photomicrographs © M. S. Krzemnicki, SSEF; magnified 75×.
the specimen, the crystallographic orientations of the observed micro-structures could not be determined.

Raman micro-spectroscopy of the inclusion features revealed only Raman peaks of zircon, so they are interpreted as micro-fissures along cleavage directions, or another type of micro-structure. Based on the similarity of these complex micro-features to those described by Hänni and Weibel (1988) for heated cat’s-eye zircon, it seems probable that the star effect in this specimen is also the result of a heating process. This is supported by the Raman spectrum of this zircon (Figure 30), which is characterised by very sharp and pronounced vibrational peaks, as would be expected in metamic and translucent zircon only after heat treatment (Zhang et al., 2000; Nasdala et al., 2002; Wang et al., 2006; Krzemnicki, 2010) or in well-crystallized (non-metamict) and commonly transparent zircon.

Dr Michael S. Krzemnicki (gemlab@ssef.ch)
Swiss Gemmological Institute SSEF
Basel, Switzerland

Martin P. Steinbach
Steinbach – Gems with a Star
Idar-Oberstein, Germany

References

ORGANIC MATERIALS

Amber Processing in Lithuania

On 1 September 2015, a group of participants from the International Gemmological Conference visited the Amber Queen processing facility in Klaipėda, Lithuania, as part of the post-conference field trip. The tour was led by Sigita Peveceviciute (Figure 31), who explained the various stages of amber processing and acted as an interpreter for our group’s questions. The factory employs 150 workers and processes 1.5 tonnes of Baltic amber per month.

The raw amber is initially sorted into transparent material (and rarely, amber containing interesting...
inclusions) versus that which needs to be clarified with treatment in an autoclave (Figure 31). We were told that, in general, approximately 20% of the raw amber is of jewellery quality, and the rest undergoes autoclave treatment. To remove bubbles and fractures, the amber is heated to 150–200°C at a pressure of 30 atmospheres in nitrogen gas.

The amber is then worked into pieces of various shapes followed by initial polishing using buffing wheels. Most of the pieces are drilled, either by hand (Figure 32, left) or by machine. Traditionally, drilling is done by men, while polishing is done by women. The beads are drilled from both sides to help prevent breakage and so they slide more smoothly during stringing.

Approximately 90% of raw Baltic amber is pale yellow, and it commonly undergoes a simple heat treatment procedure to darken its colour. The heating is done in air using conventional ovens at various temperatures and durations to create six colour categories ranging from yellow to orange, orangey brown and black. To obtain an attractive yellow colour, the amber is baked at 140°C for three hours, while ‘black’ amber (actually a black ‘skin’ on yellow amber) is produced by heating to 200°C for eight hours. Heating at lower temperatures for longer periods (e.g. 100°C for two weeks) is also done to give the amber an ‘aged’ appearance, to resemble that seen in vintage jewellery (e.g. Figure 32, right).

Figure 31: At the Amber Queen processing facility, autoclaves (left, with tour leader Sigita Pevceviute) are used to clarify the raw amber (right). Photos by B. M. Laurs.

Figure 32: Hand drilling of amber pieces from both sides requires experience and concentration (left). Either before or after drilling, much of the amber undergoes heat treatment to darken its colour or create an ‘aged’ appearance (right). Photos by B. M. Laurs.
Figure 34: These amber cabochons (approximately 1.5–2.5 cm long) have been carved on their bases to remove the black ‘skin’ created by heat treatment. Intricate patterns are seen through the polished domes of the cabochons. Photo by B. M. Laurs.

Final polishing is done using a two-step process. First the amber pieces are placed into vibrapolishers for 2–3 days together with various mixtures consisting of water, dish soap, ceramic pieces, fine quartz sand and glass balls. Then the amber pieces are put into rotating wooden drums with small pieces of beech wood and polishing powder (for 14 hours) or polishing liquid (for another 14 hours).

The beads are incorporated into a variety of jewellery pieces (necklaces, bracelets, earrings, etc.), and the various colours are often strung into attractive repeating patterns (e.g. Figure 33). Another product made by the factory consists of heat-treated amber cabochons from which the black ‘skin’ has been polished off the domes and the bases carved to create intricate patterns (Figure 34).

The various amber by-products from the factory (drill filings, powder, dust, etc.) are collected and sold for use in the electronics industry as well as in incense, facial creams and soap, so none of the amber that enters the facility for processing is wasted. No pressed amber products are made at the Amber Queen facility.

The jewellery is sold along with amber souvenirs and objets d’art in Amber Queen’s shops in Klaipėda and Vilnius (Lithuania) and in Riga, Latvia. Our group visited the main store in Klaipėda, which also hosts an amber museum that displays an impressive private collection of Baltic amber.

Brendan M. Laurs

Figure 33: Amber beads of various colours are strung into necklaces that display repeating patterns. Photo by B. M. Laurs.

Shungite for Jewellery Use

Recently a client submitted some pieces of a black gem material they called shungite. Initially we thought they were jet, but the gemmological properties were different. According to the literature, shungite is a mineraloid consisting of more than 98% carbon (Mastarlez et al., 2000). A mineraloid is a mineral-like substance that does not have a crystalline structure and possesses
chemical compositions that vary beyond the generally accepted ranges for specific minerals. Shungite was first described from a deposit near Shunga village, in Karelia, Russia, and it has been reported to contain fullerenes (molecules of carbon in the form of hollow spheres, tubes and other shapes; Reznikov and Polekhovskii, 2000).

The samples submitted by the client consisted of assorted broken fragments and some flat-backed pieces that were cut into various shapes for mounting in jewellery; we tested a 4.32 ct sample (Figure 35). It was opaque black with a vitreous lustre and a surface that showed conchoidal fracture patterns. It was inert to UV radiation and gave a black streak. The sample showed a spot RI value of 1.62 and a hydrostatic SG of 1.86. FTIR spectroscopy recorded an absorption band at ~1578 cm\(^{-1}\). According to information given in Reznikov and Polekhovskii (2000), shungite has an RI of 1.6, SG values between 1.83 and 1.96, and IR absorption between 1580 and 1575 cm\(^{-1}\).

The properties we determined for the 4.32 ct sample fell within the range for shungite and not jet (which has SG = 1.20–1.30).

The client explained that shungite is commonly used by crystal healers, and is also being mounted into some unusual designer jewellery (e.g. Figure 36).

Jayshree Panjikar (jayshreepanjikar@gmail.com)
Pangem Testing Laboratory & Pangemtech
Pune, India

References


Gem-set Cultured Pearls

The past several years have witnessed many creative innovations in modifying cultured pearls for use in jewellery, including carving their surfaces to create interesting patterns or expose an underlying bead made of various materials; embedding them with tags and other devices that can be used to include identifying information or custom-recorded audio, video or image files; and setting them with faceted gemstones (e.g. Hänni and Cartier, 2013; http://galateausa.com). Some new variations in setting gem materials into cultured pearls were recently developed, starting in March 2014, by Hisano Shepherd (little h, Los Angeles, California, USA).

Several cultured pearl varieties are used as starting materials, including both freshwater (soufflé and drop) and saltwater (Tahitian baroque, drop and keshi; golden and white South Sea baroque, drop and keshi; Sea of Cortez keshi; and Vietnamese blue akoya). These are carefully processed using three different methods. For the ‘Pearl Geode Collection’, they are sliced in half and each side is hollowed out, while for the ‘Finestrino Collection’ a concave opening is made into the interior of whole cultured pearls, and for the ‘Grotto Collection’ the cultured pearls are carved to create an opening that goes all the way through them (Figure 37). The interior surfaces of the cultured pearls are polished and then lined with a variety of different melee-sized gem materials (faceted stones or beads), including white and black diamonds, amethyst, ruby, emerald, sapphire and peridot, among others; cultured seed pearls also are used. The rubies and emeralds are commonly ‘reclaimed’ from old jewellery pieces, and the stone size and shape varies. The gemstones or seed pearls are affixed to the inner walls of the cultured pearls using resin.

The completed gem-set cultured pearls range from 9–10 mm up to 30+ mm, and are set into pendant, earring, ring and necklace designs. Shepherd has made over 300 of these items in her studio and office in Los Angeles. Her inspiration for creating them came from seeing quartz geodes at the Tucson gem shows, and she desired to recreate their geode-like appearance using cultured pearls.

Brendan M. Laurs

Reference

Figure 37: The earrings on the left are part of the ‘little h’ Pearl Geode Collection, and feature a pink soufflé cultured freshwater pearl measuring 13 × 20 mm that has been sliced in half and lined with light-to-dark pink sapphires (2.86 carats total weight) and set in 14-carat yellow gold. The Finestrino pendant in the centre is made from a pink soufflé cultured freshwater pearl measuring 30 × 33 mm that has been filled with ruby beads (40+ carats total weight) and set in a 14-carat rose gold necklace. The Grotto pendant on the right features a white soufflé cultured freshwater pearl measuring 20 × 31 mm containing ruby pieces (17.06 carats total weight) with a diamond-set bail in 14-carat white gold. Photos by Katja Bresch (left and right) and Angela Peterman (centre).
Sapphires displaying an attractive golden sheen reportedly were discovered in eastern Kenya in late 2009, and were recently brought to market in commercial quantities. The basic gemmological properties of the so-called Gold Sheen sapphires are consistent with typical corundum. Microscopic examination and Raman micro-spectroscopy showed that Fe-Ti oxides (hematite, ilmenite and magnetite) are the main solid inclusions, and they are oriented parallel to crystallographic directions in the basal pinacoid of corundum characterized by a six-fold rotational symmetry. Hematite and ilmenite are present in the form of exsolution intergrowths within platelets or needles. Magnetite typically appears as larger and thicker black platelets. The sheen effect in these sapphires originates from the simultaneous reflection of light from the oriented network of exsolved hematite-ilmenite inclusions.

Introduction
At the end of 2009, African gem brokers brought a new type of sapphire to the Bangkok gem market. While the rough material appeared dark and opaque overall, it displayed a peculiar weak golden shimmering effect on basal pinacoid surfaces. Author TKM, a gem cutter and dealer for over 25 years, identified a potential business opportunity in this sapphire, and entered into an exclusive selling agreement with the mine owner. The material reportedly was produced from pits measuring a few metres deep in eastern Kenya near the border with Somalia. From 2010 to 2014, the rough material was exported to Thailand. The deposit was subsequently exhausted, with only non-commercial-quality gems extracted during the past two years. About 25 tonnes of rough have been stockpiled in Bangkok, where experiments on cutting and polishing are being conducted to best emphasize the distinctive golden shimmer of this corundum. Its appearance led author TKM to name the stone ‘Gold Sheen’ sapphire; the gems also have been presented as ‘Zawadi’ sapphire by some suppliers (e.g. Laurs, 2015).

In this article, we present a detailed gemmological study of the Gold Sheen sapphires and their inclusions, and compare their properties to those of other sheen-displaying gems to further understand their distinctive optical effect.

Samples and Methods
For this study, author TKM supplied 105 samples of Gold Sheen sapphire with a total weight of 675 carats. The stones ranged from 1 to 30 ct.
Except for one rough sample, they were cut and polished as cabochons and faceted gemstones of various qualities with regard to the golden sheen effect (e.g. Figure 1). Most of the cabochons were double-sided and displayed a light yellow to golden six-rayed star under a point light source (e.g. Figure 2). The faceted gems were cut into various common and fancy shapes. Due to a lack of transparency in the material, the proportions of the crown and pavilion were optimized for weight rather than for brilliance. Some of the crowns displayed a modified brilliant style, but the majority were fashioned into checkerboard cuts. The cutting and polishing of the rough material was the only processing imposed on the stones. Therefore, the Gold Sheen sapphires and their visual effect are completely natural.

Basic gemmological characterization was performed on 46 samples at HRD Antwerp, and included visual observations, RI and hydrostatic SG measurements, polariscope and dichroscope reactions, hand-held spectroscope absorption spectra, and long- and short-wave UV fluorescence observations. In addition, the samples were studied with the D-Scope gemmological microscope from HRD Antwerp.

Energy-dispersive X-ray fluorescence (EDXRF) spectroscopy was achieved with a PANalytical Epsilon 5 instrument on 29 samples. For primary excitation, the Gd tube anode was operated with a current of 6–24 mA, a voltage of 25–100 kV and a power of 600 W, depending on the nine...
secondary targets used for the emission of the different characteristic X-ray lines. The samples were analysed for 10–300 sec, focusing on the analytical X-ray line of each target according to the elements of interest. We used the $K\alpha$ emission lines for most of the light trace elements and the $L\alpha$ emission lines for elements with $K\alpha$ lines greater than 20 keV.

Inclusions were identified in 20 samples using a Horiba LabRAM 800HR micro-Raman spectrometer at the Catholic University of Louvain (Louvain-la-Neuve, Belgium). Calibration was performed on a silicon substrate with a first-order Raman peak located at 520.7 cm$^{-1}$. A green laser (514 nm) was used to excite the samples, and its power was modulated to between 50% and 100%. The acquisition time for each spectrum ranged from 10 sec to 2 min, and each spectral acquisition was performed twice. Due to the very small size of the inclusions, we used magnifications of 500× and 1,000×. Raman spectra were normalized according to the most intense Raman peak, so as to plot several curves in the same graph. The background was not subtracted from the spectra.

The microstructure of the inclusions in one sample was investigated by a Zeiss Ultra55 field emission scanning electron microscope (SEM). We used a low accelerating voltage (2 keV) and the In-Lens secondary-electron detector with an optimized working distance (~2 mm) to obtain clear micrographs of the girdle profile of the sample where there was a high probability of surface-reaching needles and platelets. These parameters allowed us to resolve the cross-sections of the platelet inclusions to assess their thickness in SEM micrographs. The micrographs were horizontally aligned with the basal pinacoid and vertically aligned parallel to the c-axis of the corundum host.

All of the measurements were performed at ambient pressure and temperature, and none required any sample preparation.

Results

**Visual Observations: Colour and Transparency**

The body colour of the host sapphires was blue, green and/or yellow, with the latter being the most frequently encountered. The metallic sheen was characterized by a (golden) bronze colour that shimmered when the cabochons and faceted gems were illuminated. As demonstrated below, the shimmer was due to inclusions within the sapphires.

The c-axis of the corundum was oriented perpendicular to the crown/dome of the polished stones. Some samples displayed colour zoning in three orientations at 60°/120°, typical of the six-fold rotational symmetry in the basal plane of the rhombohedral system. Colour zoning in parallel lamellar patterns was created by layers containing various concentrations of inclusions that mechanically coloured those areas. Due to the reflection of light from the inclusions, those bands containing abundant particles appeared light, while the interstitial areas containing few inclusions showed the body colour of the sapphire, which generally appeared dark (especially for sapphires with blue body colour). Intermediate concentrations of inclusions exhibited a mixture of golden sheen and the body colour from the host sapphire.

Within areas showing the golden sheen, we typically observed dark surface-reaching cracks showing random paths. Their full extension was more visible when we observed the samples at an oblique angle to the surface of the stone.

In general, the diaphaneity of the sapphires varied according to the amount of sheen that they displayed. Samples showing less sheen were nearly transparent. Where the sheen was present over a larger area of a gemstone, the diaphaneity was translucent. In areas of darker bronze sheen, the stone could be completely opaque. This suggests that the inclusions responsible for the sheen also cause diminished transparency of the host sapphire.

**Physical Properties**

As the gemstones were heavily fractured, full of inclusions, typically translucent and not perfectly polished, routine gemmological testing was challenging. The overall results from the 46 samples were: RI—1.76–1.77 (spot reading), birefringence—0.01, SG—3.95–4.05, UV fluorescence—inert to long- and short-wave UV radiation, and spectroscope spectrum—absorption at 450 nm and in some samples a cutoff at ~500 nm. These are typical readings for corundum.
**Microscopic Characteristics**

Under the gemmological range of magnification (10×–80×), we clearly observed hexagonal growth patterns and colour zoning in the sapphires. Furthermore, areas showing the sheen correlated to networks of numerous tiny straight needles and flakes lying within the corundum basal plane (Figure 3). In reflected light, the inclusions were golden metallic, and thus reflections from the inclusion networks created the golden sheen. In transmitted light, the inclusions appeared more orangy brown, and under oblique illumination they exhibited various colours due to thin-film interference (see Figure DD-1 in the Data Depository). The latter observation indicates an inclusion thickness in the nanometre range.

As mentioned above, the inclusions were present in three different orientations intersecting at 60°/120°, typical of the six-fold rotational symmetry in the basal plane of the rhombohedral system. These orientations also were parallel to the corundum growth lines (Figure 4), which are aligned along the first-order hexagonal prism {101–0} (Hughes, 1997, p. 446). Also present in some samples were larger platelets that contained small dark areas (Figure 5).

Zones in the sapphires consisted of alternating bands of needles and platelets of different concentrations, at various positions along the c-axis (Figure 6). The bands containing inclusions of higher density and closer to the surface produced a golden bronze colour, while those of lower density and deeper inside the host produced a brownish bronze sheen, which resulted from a combination of reflections from the inclusions and the dark body colour of the host sapphire. This is well illustrated by comparing the appearance of a thin sample in reflected vs. transmitted light (again, see Figure 6).

Less abundant, but always present within the inclusion networks in the golden sheen areas, were black plates that were a similar size or larger than the platelets described above (Figure 7).

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*Figure 3: In areas of the sapphires showing sheen, networks of oriented inclusions consisting of needles and platelets lie within the basal pinacoid. Photomicrograph by T. N. Bui using brightfield illumination; magnified 60×, field of view 1.87 × 1.45 mm.*

*Figure 4: The surface of the basal pinacoid in this particular rough sapphire exhibits growth lines in three directions, parallel to \( (10\overline{1}0) \). The needle inclusions below the surface are parallel to these growth lines. Photomicrograph by T. N. Bui using brightfield illumination; magnified 100×, field of view 860 × 635 μm.*

*Figure 5: The platelets in this sapphire contain dark areas and appear to be composed of different minerals. Photomicrograph by T. N. Bui using brightfield illumination; magnified 50×, field of view 1.3 × 1.0 mm.*
Some of them were so large that they were visible to the naked eye, negatively affecting the appearance of the gemstone. The edges of these hexagonal-shaped inclusions were clearly parallel to the other inclusions and to the colour zoning.

The characteristics of the fractures within the sheen areas became more obvious when viewed with magnification. Their macroscopic ‘dark vein’ appearance correlated to the absence of inclusions around them. This indicates that these cracks were not created during the cutting of the stones. The absence of inclusions was evident only on one side of the fractures, characterized by a gradual increase in inclusion density away from the fractures. This asymmetry induced a colour gradient on one side leading up to the sharp boundary line of the fracture (Figure 8). This was easily observed with the naked eye in samples containing larger veins. Further microscopic investigations, combining brightfield and darkfield illuminations, showed a correlation between the asymmetry of the dark veins and the pattern of the associated fractures. The side of the dark vein presenting a concentration gradient of inclusions corresponded to the curvature direction.
of the fracture. The distance along which the gradient extended was proportional to the slope of the fracture curvature. The asymmetric dark veins thus constituted an indirect mapping of the cracks underneath, shadowed by the inclusions.

Some samples showed a series of parallel lines when viewed at certain angles along the girdle profile (in a direction perpendicular to the c-axis). The angle between the lines and the basal pinacoid was 58° and that between the lines and the c-axis was 32° (Figure 9). These parallel lines are attributed to polysynthetic twin planes corresponding to the rhombohedral {101–1} faces of corundum. We observed parallel long white needles coincident with these twin planes when we looked through the table of the gemstones in a direction close to the c-axis (see Figure DD-2).

Due to the limited transparency of the gems, other solid inclusions were difficult to locate and identify. However, some surface-reaching inclusions in the lower-quality samples are described further below. In addition, planar assemblages of negative crystals corresponding to healed fractures were seen in some samples (e.g. Figures DD-3 and DD-4).

**Chemical Composition**

Qualitative EDXRF spectroscopy revealed the presence of the following trace elements in all 29 samples analysed: Fe, Ti, V, Cr, Ga, Nb and Ta. A relatively large amount of Fe suggested that this element was probably the main ingredient of the inclusions, especially in the networks of needles and platelets.

There was no obvious correlation between the blue body colour of some of the sapphires and the presence of Ti, as peaks of a similar intensity were also present in samples showing yellow and green body colours. Therefore, Ti could mainly be attributed to the inclusions. Other trace elements that are usually encountered as impurities in corundum include Ga, Nb and Ta; their concentrations varied in our samples.

Some of the sapphires, particularly those of low quality, contained additional trace elements including Zr, S, Ba, Cu, K, Na and Si. These may be attributed to various inclusions other than the metallic-appearing needles and platelets.

**Inclusion Observations under High Magnification, and Raman Identification**

Raman micro-spectroscopy is a powerful tool for identifying microscopic inclusions that are located at or near the surface of a gemstone (Bersani and Lottici, 2010; Kiefert and Karampelas, 2011). Since some inclusions had lateral dimensions of only a few microns, we used an optical magnification of 1,000x in order to obtain a laser spot of 1 μm. All of the analysed inclusions could be successfully identified by comparing their Raman spectra to those in the RRUFF database.

The high density of the inclusions responsible for the golden sheen makes them suitable for investigation through Raman spectroscopy. In most cases, the networks of needles and platelets reached the surface of the gems, or were less than 5 μm from the surface. Individual needles/platelets had such narrow thicknesses (less than 100 nm) that their surface-reaching cross-sections were extremely small to analyse, so it worked better to look for those that were located just under the surface. The particles selected for analysis had no intervening inclusions between them and the surface, nor ones situated directly below them. Therefore, the Raman spectra consisted exclusively of the superimposition of signals from both the sapphire and the inclusion. Figure 10a shows the spectrum of a host sapphire ($\alpha$-Al$_2$O$_3$).
corundum), free of inclusions. In agreement with earlier studies (e.g. Xu et al., 1995), it includes peaks at 378, 416, 429, 448, 576 and 749 cm\(^{-1}\).

The built-in optical microscope of the Raman micro-spectrometer, with magnifications from 200\(\times\) to 1,000\(\times\), permitted us to identify some features that were barely distinguishable even when using the highest magnification of a typical gemmological microscope. Examples are provided by the needles and platelets illustrated in Figure 11. Several dark areas of various size and abundance were seen on many of the platelet inclusions. The duality of the colours within each inclusion suggested the presence of two different materials in the platelets. By contrast, in most cases the needles were of uniform colour, so they probably consisted of just one mineral. However, as the thickness of the needles increased, the probability was higher of observing colour inhomogeneities that may correspond to different minerals.

The platelets showed polygonal shapes with some of their edges parallel to the needles and other edges perpendicular to them. These edges were in turn parallel to the faces of the first- and second-order hexagonal prisms, \{10\(\overline{1}\)0\} and \{11\(\overline{2}\)0\},

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**Figure 10:** Raman spectra are shown for a host sapphire (a) and for various inclusions (b–f). The vertical dashed lines indicate the Raman peaks of corundum superimposed on those of the analysed inclusions. The two minerals present in the exsolved needles and platelets are hematite and ilmenite. Larger and thicker black plates were identified as magnetite. Diaspore and boehmite are the two polymorphs of Al\(_2\)O\(_3\)(OH) present in long white needles formed along the polysynthetic twin planes. (A peak that is present at 642 cm\(^{-1}\) in the spectra of both diaspore and boehmite is due to the A1g vibrational mode of the host corundum. These were the only spectra taken with the laser beam not perpendicular to the basal plane of the corundum.)

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<th>Raman Shift (cm(^{-1}))</th>
<th>a. Sapphire</th>
<th>b. Hematite</th>
<th>c. Ilmenite</th>
<th>d. Magnetite</th>
<th>e. Diaspore</th>
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of the rhombohedral corundum host. The angles between two edges of the same polygon thus have the following possible values: 30°/150°, 60°/120° and 90°. Depending on the sample, the lateral dimensions of the platelets ranged from just a few to hundreds of micrometres. In SEM images, we observed a series of short white lines parallel to the basal pinacoid, corresponding to the needle-like and platelet inclusions. High magnification (100,000×) revealed the thickness of these inclusions was around 100 nm (Figure 12).

Raman micro-spectroscopy identified the smaller needles and the light-coloured areas of the platelets as hematite (α-Fe₂O₃), with the largest Raman peak at 406 cm⁻¹ located near to that of sapphire, and other peaks recorded at 223, 240, 297, 491 and 605 cm⁻¹ (Figure 10b). This is in good agreement with previous work on hematite (e.g. de Faria et al., 1997). Raman spectra of the dark areas of the platelets, characterized by a strong band at 679 cm⁻¹, were assigned to ilmenite (FeTiO₃); the other vibration modes describing this mineral were 223, 254, 296, 330, 371, 451, 483 and 599 cm⁻¹ (Figure 10c). The obtained spectra are in good agreement with natural ilmenite for the main Raman peaks (e.g. Rull et al., 2004, 2007) and with pure synthesized ilmenite for the weaker Raman peaks (e.g. Sharma et al., 2009; Guan et al., 2013).

As mentioned previously, some black plates also were present in the golden sheen areas. The deep boundaries and terraces on the surfaces of these inclusions indicated that they are relatively thick (at the micron scale). Their
lateral dimensions were generally greater than the hematite-ilmenite platelets. Observations with the Raman microscope confirmed their polygonal shape, with edges showing the same orientations as the platelets (Figure 13). Raman microspectroscopy identified these black inclusions as magnetite (Fe₃O₄), with three characteristic peaks at 304, 535 and 665 cm⁻¹, the latter being the strongest (Figure 10d). The obtained Raman spectra compared well to previous investigations on magnetite (de Faria et al., 1997).

The long needles lying along the polysynthetic twin planes were seen at high magnification to consist of tiny particles rather than a monocrystalline mineral. The concentration of these particles was higher toward the central core of the needle (Figure 14). Raman spectra obtained from different locations of several needles showed that the particles consisted of two polymorphs of aluminium oxide hydroxide. Most common was diaspore [α-AlO(OH)], with peaks at 216, 287, 329, 447 (strongest), 497, 665, 794 and 1191 cm⁻¹ (Figure 10e). Occasionally, we found boehmite [γ-AlO(OH)], characterized by three Raman peaks at 362, 495 and 675 cm⁻¹, the first being the most intense (Figure 10f). All of these Raman features are in good agreement, for example, with a study on naturally occurring diaspore and synthesized boehmite (Ruan et al., 2001).

Several additional surface-reaching minerals were identified that did not contribute to the golden sheen: pyrite, barite, covellite, zircon, muscovite, albite and K-feldspar. Photomicrographs and/or Raman spectra of these inclusions are provided in the Data Depository (Figures DD-5 to DD-7).

**Discussion**

**Inclusions in the Gold Sheen Sapphires**

The physical properties measured for the sapphires were not affected by the presence of their abundant inclusions. The concentration or weight of the inclusions was negligible in regard to the sapphire host, and the SG, RI and birefringence remained consistent with corundum. Optical microscopy highlighted the presence of a network of metallic-appearing needles and platelets and some larger black plates. Raman spectroscopy identified those inclusions as the Fe-Ti oxides hematite, ilmenite and magnetite. The presence of these inclusions in areas showing the golden sheen is consistent with the overall relatively high concentration of Fe (and Ti) in these sapphires.

The alignment of the colour zoning and the networks of hematite-ilmenite needles along the second- and first-order hexagonal prisms, {1120} and {1010} respectively, is consistent with previous studies of similar inclusions in black sapphires from Australia (Moon and Phillips, 1984). In that article, it was estimated from energy-dispersive spectroscopy that the exsolved inclusions consisted ~50% each of hematite and ilmenite. This is in reasonable agreement with high-magnification observations of the inclusions in our samples, although we noted a slightly higher amount of hematite (e.g. Figure 11).
Figure 13: Black plates in the Gold Sheen sapphires were identified as magnetite. The edges of the inclusions are aligned along the first- and second-order hexagonal prisms. Photomicrographs by T. N. Bui using brightfield illumination; magnified 500× or field of view 175 × 130 μm (top left, top right and bottom left) and 1,000× or 80 × 60 μm (bottom right).

Figure 14: Needle-like inclusions consisting of diaspore and boehmite particles (appearing dark in brightfield illumination) lie along polysynthetic twin planes in the Gold Sheen sapphire. Photomicrograph by T. N. Bui; magnified 200×, field of view 360 × 300 μm.
As observed previously, in contrast to the needles, the edges of the platelets showing polygonal shapes were mostly parallel to both the first- and second-order hexagonal prisms of the host corundum. This difference highlights the preferential growth of the needles along the <10̅0̅1> direction, probably due to the structural mismatch between the Fe-Ti oxides and corundum. The in-plane orientation of the hematite-ilmenite needles and platelets, and the similar crystal structure of hematite and ilmenite to corundum, suggest that the basal pinacoid direction of the inclusions and the host are parallel.

The edges of the magnetite plates had the same orientation as the hematite-ilmenite platelets. As shown in Figure 13, the magnetite plates commonly had triangular and hexagonal shapes. Since magnetite belongs to the spinel group, which crystallizes in the isometric crystal system, these shapes indicate a tetrahedral crystal habit.

Magnetite is known to be the most magnetic naturally occurring mineral. We tested the magnetism of the sapphires with neodymium-iron-boron magnets, and those containing large plates of magnetite were attracted to the magnets when the samples were floated in water (cf. Gumpesberger, 2006). A few low-quality sapphires possessing eye-visible magnetite inclusions were attracted to the magnets even without flotation (see Figure DD-8).

The Fe-Ti oxides and the diaspore-boehmite needles all formed in the sapphire as a result of epigenetic solid exsolution (cf. Hughes, 1997, pp. 93–94). Hematite, ilmenite and magnetite all have different chemical compositions, but they grew according to the crystallographic directions in the basal pinacoid of the host corundum. Such epigenetic inclusions crystallize due to the presence of defects and impurities of Fe and Ti in the host crystal as it cools after its formation (Hughes, 1997, pp. 93–94), forming microscopic needles and plate(let)s. The network of hematite-ilmenite inclusions in these sapphires is responsible for the asterism as well as the golden sheen.

As demonstrated above and verified through optical microscopy, the colour zoning in the sapphires is a consequence of the presence of hematite-ilmenite inclusions grouped into bands parallel to the second-order hexagonal prism {11̅0̅2̅}. The resulting mechanical colour zoning is therefore linked to exsolution of these particles and also is epigenetic.

The dark-appearing veins following fractures in the Gold Sheen sapphires appear to have formed after the exsolution of Fe-Ti oxides. The exsolved inclusion particles evidently were not stable adjacent to (and on one side of) the fractures.

The presence of the long parallel white needles, identified as diaspore and boehmite, is correlated to the polysynthetic twin planes oriented in rhombohedral {1̅0̅1̅1} directions in the sapphire. In the literature, such inclusions are generally described as boehmite rather than diaspore (White, 1979; Hänni, 1987). Both diaspore and boehmite polymorphs of AlO(OH) were identified in our Raman spectra. They formed by the alteration of corundum at the intersections of two twin planes. Polysynthetic twin planes in corundum are created by mechanical stress after crystallization and are also known as slip twins (Hughes, 1997, p. 97). The angle of 58° between these twin planes and the basal pinacoid and 32° between the twin planes and the c-axis is consistent with the {1̅0̅1̅1} faces of the rhombohedral corundum.

**Fe-Ti Oxide Inclusions in Other Gemstones**

Plate-like inclusions of hematite and/or ilmenite also exist in other gem minerals. Their highly reflective surfaces produce optical effects such as aventurescence in oligoclase, often called sunstone (Gübelin and Koivula, 1986, pp. 165, 279; 2005, pp. 126, 413–415), and in cordierite (Gübelin and Koivula, 1986, pp. 163–164, 269; 2008, pp. 520–521). As in the Gold Sheen sapphires, the plate-like inclusions are parallel to the basal pinacoid. The cutting of the stones is such that the plates are oriented parallel to the girdle profile to highlight the optical effect. The abundance of the inclusions in the host also contributes to the body colour of the stones.

The aventurescence effect produces a kind of iridescence under oblique illumination, inducing various colours due to thin-film interference from the very thin plate-like inclusions. In oligoclase, beryl and cordierite, the inclusions are eye-visible, whereas in the Gold Sheen sapphires they are distinguishable
only with magnification. In the gems displaying adventurcenscence, the tiny reflective inclusions produce minute sparkles when the stone or the light source is moved. Gold Sheen sapphires display a golden shimmering effect originating from the specular reflections of light from the hematite-ilmenite inclusions. Instead of metallic single glitters, the microscopic network of oriented inclusions reflects light simultaneously, defining the golden sheen area. The smaller dimensions of the inclusions (below 100 μm) and their high concentration in the Gold Sheen sapphires account for the different appearances of the golden sheen and the adventurcenscence.

**Comparison with Black Star Sapphires**

Most cabochons of Gold Sheen sapphire display six-rayed asterism, similar to other star corundum. The presence of the asterism is dependent on the presence of oriented networks of hematite-ilmenite needles rather than platelets, and the sharpness of the star is determined by the aspect ratio of those needles. Since the hematite-ilmenite needles are perpendicular to the colour zoning, each ray of the star is, as a result, parallel to the colour zoning and to the second-order hexagonal prism \{11\overline{2}0\}. This optical characteristic is the same as that displayed by black star sapphires (Moon and Phillips, 1984; Hughes, 1997, p. 446). Those from Thailand, Australia and Laos are known to have inclusions caused by exsolution of hematite and ilmenite (Hughes, 1997, pp. 297, 380, 447).

In black 12-rayed star sapphires from Thailand, a less intense white six-rayed star is perpendicularly superimposed over a yellow/golden six-rayed star that originates from long, thin rutile needles aligned along the first-order hexagonal prism \{10\overline{1}0\} (Hughes, 1997, p. 447). In our samples of Gold Sheen sapphire, no rutile needles perpendicular to the hematite-ilmenite needles were found by optical microscopy, and so far we have not encountered any 12-rayed stars in these cabochons.

Due to the high concentration of hematite-ilmenite inclusions in black star sapphires, some of these gems show basal parting on their flat base, characterized by a step-like appearance. Fractures due to this basal parting may be filled by residue from the doping process during cutting (Hughes, 1997, pp. 125, 447). In Gold Sheen sapphires, no basal parting was seen in any of the cabochons. In a few faceted samples showing basal parting, the stones were completely opaque due to the high concentration of inclusions. As most Gold Sheen sapphires are translucent and not opaque, basal parting is not common.

**Geological Inferences**

Little information is available on the Gold Sheen sapphire deposit. According to the mine owner, it is located in eastern Kenya, near the border with Somalia. This area belongs to Kenya’s North Eastern Province and has a low relief with an elevation less than 500 m. The climate is semi-arid, with desert scrub vegetation being most common. The geology of north-east and eastern Kenya is characterized by Mesozoic (Karoo) and Quaternary sedimentary rocks. The former includes Jurassic limestone, shale and gypsum, as well as Cretaceous siltstone, mudstone, limestone and sandstone. The Quaternary sediments are composed of lacustrine and fluvial deposits and gypsum. This entire region of East Africa is located on the Somali Plate, adjacent to the East African Rift and the Nubian Plate. Linear trends in the sedimentary rocks are orientated in relation to the Kenyan Dome (Mathu and Davies, 1996).

Kenya’s previously known gem corundum deposits include the John Saul ruby mine located in Mangari (far south) and various other ruby and sapphire localities in the Mangari area, and the Turkana area in the north-western part of the country (Hughes, 1997, pp. 374–379; Shor and Weldon, 2009). To our knowledge, no corundum deposits have been reported in areas near Somalia.

The blue, green and yellow body colours of Gold Sheen sapphires are typical of magmatic-type corundum. Other magmatic deposits containing corundum with similar exsolved inclusions of Fe-Ti oxides are known from Australia (Anakie), Laos (Ban Huai Sai) and Thailand (Chanthaburi). The gemmological properties of black star sapphires from Australia and Thailand most closely resemble those of the Gold Sheen sapphire, including the high Fe content, lack of UV fluorescence, healed fractures and polysynthetic twinning. As there are no volcanic source rocks in the reported mining area for the Gold Sheen sapphires, their geological origin remains enigmatic.
Conclusion

This article investigates the recently discovered Gold Sheen sapphires from East Africa, focusing on their peculiar golden sheen effect (e.g. Figure 15). Optical microscopy verified that the sheen is due to the reflection of light from an oriented network of exsolved needles and platelets of Fe-Ti oxides (hematite and ilmenite). The oriented needles also cause asterism (i.e. a six-rayed star) to be seen in cabochons cut from this sapphire.

Black star sapphires may contain similar oriented assemblages of exsolved Fe-Ti oxides. The main difference is the absence of rutile needles from the Gold Sheen sapphires, which explains the lack of 12-rayed asterism. Despite the presence of similar hematite-ilmenite inclusions in both types of sapphire, the large difference in their appearances suggests the need for further investigations into their optical phenomena.

An already-exhausted mine is the only known source of the Gold Sheen sapphires. Cutting of the existing stock of rough material is expected to fulfil market demand for the near future.

References


The Authors

Thanh Nhan Bui
Boulevard Edmond Machtens 180
1080 Brussels, Belgium
Email: tnhan93@gmail.com

Katerina Dellousi and Dr Katrien De Corte
HRD Antwerp, Institute of Gemmology
Hoveniersstraat 22, 2018 Antwerp, Belgium

Tanzim Khan Malik
Genuine Gems & Jewellery Co. Ltd.
316/9 Silom Road, Bangkok 10500, Thailand

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Age Determination of Zircon Inclusions in Faceted Sapphires

Klemens Link

The age determination of zircon inclusions in faceted sapphires by LA-ICP-MS may provide a valuable tool to support geographical origin determination. In this initial study, U-Pb dating of a zircon inclusion in a pink sapphire from Madagascar yielded an age of 650 million years (Ma), suggesting a syngenetic origin (i.e. formed at the same time as the host sapphire) of the zircon. In a greenish blue sapphire from Madagascar, an included zircon yielded a U-Pb age of 1,750 Ma, pre-dating the host sapphire, and therefore indicating the zircon is an inherited inclusion (i.e. it originated from rocks that existed before the host sapphire crystallized). These results are supported by indications provided from conventional methods of geographical origin determination. This article also discusses the potential influence on U-Pb age dating of post-formation metamorphic events, laboratory heat treatment and the possibility of complex zoning in the zircon inclusions.

Introduction

Laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) has become an established tool in the past decade for use by prominent well-equipped gemmological laboratories (Breeding et al., 2010). Standard routines have been developed to measure trace-element concentrations in various gem materials to detect treatments and/or determine a stone’s geographical origin (e.g. Günther and Kane, 1999; Guillong and Günther, 2001; Abduriyim and Kitawaki, 2006). The geographical origin of high-end coloured stones is seen by the trade as a key value driver, and has developed into one of the main tasks for gem-testing laboratories. Initially LA-ICP-MS was mainly applied to research samples, but with increasing experience and confidence, as well as improved instrumentation, this technique is now routinely used for analysing client-submitted stones. The biggest challenge and the highest priority are to gain meaningful data without damaging or affecting the quality of the stone (i.e. to work quasi-non-destructively).

LA-ICP-MS is a well-established and frequently used method in the geosciences for measuring in situ uranium-lead (U-Pb) ages of zircon (e.g. Jackson et al., 2004). Microscopic crystals or grains of zircon can be dated regardless of their host matrix, provided that they reach the surface of the stone and thus can be sampled by the instrument’s laser beam.

Zircon inclusions in rough gem-quality corundum have been investigated by numerous researchers using LA-ICP-MS (e.g. Coenraads
et al., 1990; Sutherland et al., 2008; 2015), and recently the technique was used to perform U-Pb age dating of blue sapphires from Myanmar, Madagascar and Sri Lanka that were sawn and polished to expose zircon inclusions on their surface (Elmaleh et al., 2015). However, determining the age of zircon inclusions in high-quality faceted gemstones such as those commonly submitted to gem labs (e.g. Figure 1) has not been reported until now. Since July 2015, this procedure has been routinely applied to client stones at the Gübelin Gem Lab (GGL) when zircon inclusions are exposed on the surface and age data is particularly helpful for origin determination (e.g. for separating some blue sapphires from Myanmar and Madagascar). It can also provide indications of heat treatment.

Age data for zircon inclusions in sapphires can shed light on the genetic conditions under which the sapphire formed, as well as point to the original host rocks. The latter is particularly important for sedimentary deposits without any connection to their primary host rocks, such as the economically important Ilakaka mining region in south-western Madagascar (Rakotondrazafy et al., 2008).

**Materials and Methods**

The samples comprised two faceted fancy-colour sapphires (pink and greenish blue; see Figure 2), each weighing ~12 ct, that were submitted to the Gübelin Gem Lab in Lucerne by professional gem traders. Both samples contained zircon inclusions that reached the surface at the girdles, and routine origin determination procedures performed in our laboratory clearly indicated that both stones were from metamorphic-type deposits in Madagascar. The pink sapphire had clusters of small, colourless, rounded anhedral zircon that each measured a maximum 60 µm long and 30 µm wide (Figure 3a). Although heat treatment at relatively low temperatures could not be excluded, the stone clearly had not been exposed to high-temperature heating. The greenish blue sapphire, which was found to be untreated, contained randomly scattered zircon inclusions with subhedral elongated shapes (e.g. Figure 3b,c). The investigated zircon crystal in the greenish blue sapphire was ~90 µm long and 35 µm wide.

To avoid leaving eye-visible traces from LA-ICP-MS analysis, client stones are typically sampled...
with the laser only on their girdle (with some exceptions). The pit diameter must not exceed 50–70 µm, and the depth of the pit usually does not exceed its diameter. The resulting pits are not eye visible and have no significant effect on the weight of the stone.

For the U-Pb age dating of zircon inclusions in sapphires, to avoid sampling the corundum host, the LA-ICP-MS signal is carefully controlled for any sudden change in indicative elements such as Si or Zr. Although corundum usually does not contain significant U or Pb, and slightly ablating the host sapphire therefore should not disturb the results, we are sure to avoid any such possible contamination. For both samples described here, the spot diameter of the laser was limited to 30 µm by the size of the outcropping zircon inclusions (Figure 3), and this limited the depth of the pits to ~30 µm as well. The weight loss of the samples after analysis was calculated to be only approximately 0.000004 ct.

The analytical conditions used for this study are listed in Table I. The LA-ICP-MS system at the Gübelin Gem Lab consists of an ESI NWR193\textsuperscript{193}C ArF excimer-based UV laser ablation system with a large-format sample chamber and a flexible cup that collects the ablated material, which is coupled with a PerkinElmer ELAN DRC-e quadrupole ICP mass spectrometer (Figure 4). The laser has a wavelength of 193 nm, which allows precise ablation at the micrometre scale without cracking or splintering the sample. The ablated

<table>
<thead>
<tr>
<th>Laser</th>
<th>NWR193\textsuperscript{193}C from ESI</th>
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<tr>
<td>System</td>
<td>193 nm ArF excimer laser</td>
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<td>Sample cell</td>
<td>High-performance two-volume chamber system</td>
</tr>
<tr>
<td>Sample carrier gas</td>
<td>1,000 ml/min He</td>
</tr>
<tr>
<td>Laser pulse rate</td>
<td>14 Hz</td>
</tr>
<tr>
<td>Laser energy</td>
<td>6.3 J/cm\textsuperscript{2}</td>
</tr>
<tr>
<td>ICP-MS</td>
<td>PerkinElmer ELAN DRC-e quadrupole ICP-MS</td>
</tr>
<tr>
<td>Auxiliary gas</td>
<td>0.66 l/min Ar</td>
</tr>
<tr>
<td>Nebulizer gas</td>
<td>0.675 l/min Ar</td>
</tr>
<tr>
<td>Plasma gas</td>
<td>16.5 l/min Ar</td>
</tr>
<tr>
<td>RF power</td>
<td>1.350 W</td>
</tr>
</tbody>
</table>

Figure 3: (a) In this cluster of zircon inclusions within the pink sapphire, the surface-reaching zircons that were analysed for age determination are circled. (b) Internal features in the greenish blue sapphire consist of isolated zircon crystals (top-centre and top-right), among other inclusions. (c) This zircon inclusion in the greenish blue sapphire was used for in situ age determination; the circle marks the position and size of the applied laser pit. Photomicrographs (a) and (c) by Klaus Schollenbruch, GGL; (b) is courtesy of Bulgari, image width ~2 mm.

Figure 4: The instrumentation at the Gübelin Gem Lab used for this study consists of an ICP-MS (left side) and a laser ablation unit (right side). Photo by K. Link.
material is transported in a flow of He carrier gas to the Ar plasma of the mass spectrometer. Within the plasma, the 60–150 nm-sized particles are disintegrated at ~7,000°C into ions that are selectively detected by the mass spectrometer.

The optimal laser conditions were found by monitoring the U-Pb ratios and searching for the minimum deviation to reduce the errors in age calculations. The dwell times for individual mass scans were 10 milliseconds for all measured isotopes (28Si, 90Zr, 180Hf, 202Hg, 204Pb, 206Pb, 207Pb, 208Pb, 232Th, 235U and 238U). The background was analysed for 40 seconds, and the ablation signal from the zircon was measured until it became unstable after around 15 seconds (Figure 5). Only the area of the signal showing a flat plateau was used for integration. A Plesovice zircon (Sláma et al., 2008) was used for standardization; a GJ zircon (Jackson et al., 2004) and an in-house reference zircon were used for quality control.

For age determination (see Box A and Table II), 207Pb/235U ratios were calculated from the measured 206Pb/238U and 207Pb/206Pb ratios using a constant value for present-day 235U/238U. The ICP-MS was optimized on a daily basis for a maximum sensitivity to heavy elements with minimum (<0.5%) oxide generation (monitored using Th/ThO). Data reduction and the time-dependent laser-and mass spectrometer-induced inter-element mass fractionation (Pb/U) corrections were applied using in-house Microsoft Excel worksheets. Ages, errors (2σ) and concordia diagrams were produced using Isoplot3 macros for Excel (Ludwig, 2003).

Common lead was monitored via non-radiogenic 204Pb, and 202Hg was checked to estimate the interference of 204Hg on 204Pb. For both samples, 204Pb was below the detection limit, so we assumed that no common lead was present.

Results and Discussion

The results of U-Pb age dating of the zircon inclusions are presented in Table II and shown in Figure 6.

Pink Sapphire

The analysed zircon from the inclusion clusters in the pink sapphire yielded a concordant U-Pb age of 652 ± 41 Ma (Figure 6a). From the appearance of the zircon inclusions, they are interpreted as syngenetic with the host sapphire, and are considered to be in equilibrium with the corundum. Thus, the age we obtained should correspond to the formational age of this sapphire. The crystallization ages of the sapphires from Madagascar are not yet well known, but published work (e.g. Rakotondrazafy et al., 2008, and references therein) indicates ages around 560 Ma. Associated granulite- and amphibolite-facies rocks and linked felsic intrusives cluster between 560 and 650 Ma (Kröner et al., 1999). The basement rocks of Madagascar were affected by the Pan-African tectono-metamorphic event (730–550 Ma; Black and Liegeois, 1993), which extended across a broad region that included other sapphire-bearing areas such as East Africa.
and Sri Lanka, and led to the formation of the so-called Mozambique Belt. More research is needed on Madagascar and other Pan-African-related sapphire age populations before using them as hard criteria for origin determination.

**Greenish Blue Sapphire**

The zircon analysed in the greenish blue sapphire gave a concordant age of 1,742 ± 70 Ma (Figure 6b). The individual ages given in Table II for the various isotopic pairs ($^{207}$Pb/$^{235}$U, $^{206}$Pb/$^{238}$U)
and \(^{207}\text{Pb}/^{206}\text{Pb}\) show a slightly greater variance than those from the pink sapphire, but within their errors they provide good matches with the integrated concordia age, and correspond to an 82% probability of concordance. The reasons for the slightly varying individual ages may be related to post-formation diffusion processes, elemental zoning (see below), or slight differences in the accuracy or precision of measuring the various isotopes.

The ~1,740 Ma age does not coincide with the assumed Pan-African-associated formation of this Madagascar sapphire. Hence, this subhedral zircon is more complicated to interpret (see below).

### Influence of Post-Formation Metamorphism on Zircon

Once a zircon has crystallized, very high pressure-temperature conditions are required to destroy it (Watson, 1996). The closure temperature of zircon, which is above 900°C at most geologically relevant time scales (Cherniak and Watson, 2003), marks the condition at which diffusion becomes sufficient to exchange U and/or Pb, and therefore disturb the U-Pb system and thus the age determination. In most cases, temperatures during metamorphism are less than 1,000°C (i.e. combined with high pressures, as with upper granulite facies conditions). Since the Pb content of zircon is preserved through all but the most extreme conditions of metamorphism, its original formation age is usually not disturbed by such events (Watson, 1996). However, depending on the duration of a high-temperature metamorphic event, there may be a severe impact on the zircon (Blackburn et al., 2011). Uranium is rather compatible in the zircon structure, whereas Pb is not (Cherniak and Watson, 2003). Increasing temperatures drive recrystallization processes as well as diffusion rates (Nasdala et al., 2001). This leads to enhanced Pb diffusion toward the outer rim or completely out of the zircon. The loss of

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### Table II: Geochronological results for zircon inclusions in the two sapphires.

<table>
<thead>
<tr>
<th>Data</th>
<th>(^{207}\text{Pb}/^{206}\text{U} \pm 1\sigma)</th>
<th>(^{206}\text{Pb}/^{238}\text{U} \pm 1\sigma)</th>
<th>(^{207}\text{Pb}/^{206}\text{Pb} \pm 1\sigma)</th>
<th>roh*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pink sapphire</td>
<td>0.9003 0.045</td>
<td>0.1064 0.0056</td>
<td>0.0617 0.0019</td>
<td>0.94</td>
</tr>
<tr>
<td>Greenish blue sapphire</td>
<td>4.5779 0.212</td>
<td>0.3144 0.0202</td>
<td>0.1074 0.0051</td>
<td>0.72</td>
</tr>
<tr>
<td>Age (Ma)</td>
<td>(^{207}\text{Pb}/^{235}\text{U} \pm 2\sigma)</td>
<td>(^{206}\text{Pb}/^{238}\text{U} \pm 2\sigma)</td>
<td>(^{207}\text{Pb}/^{206}\text{Pb} \pm 2\sigma)</td>
<td>prob*</td>
</tr>
<tr>
<td>Pink sapphire</td>
<td>651 32</td>
<td>651 34</td>
<td>663 20</td>
<td>0.99</td>
</tr>
<tr>
<td>Greenish blue sapphire</td>
<td>1745 80</td>
<td>1762 112</td>
<td>1755 86</td>
<td>0.82</td>
</tr>
</tbody>
</table>

* Abbreviations: roh = error correlation between \(^{207}\text{Pb}/^{235}\text{U}\) and \(^{206}\text{Pb}/^{238}\text{U}\) ratios; prob = probability of concordance (taken from Isoplot).

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Figure 6: Concordia plots made with Isoplot software (Ludwig, 2003) are shown for the zircon inclusions in the pink sapphire (a) and the greenish blue sapphire (b).
(radiogenic) Pb changes the U/Pb ratio and resets the 'radiogenic clock'. This may be visualized in a concordia diagram (described in Box A), in which the so-called concordia line in the centre of the plot shows the U-Pb ratios for undisturbed, 'closed' systems where all the Pb originates from U decay. Disturbed U-Pb ratios result in combined ratios lying below the concordia on a line called the discordia which leads toward younger ages. In an ideal case, the discordia points to the age of the event that 'opened' the U-Pb system (Dickin, 2005). If the measured U-Pb data plot nicely on the concordia, it can be assumed that the U/Pb ratios were undisturbed by later events such as metamorphism.

Rocks affected by the Pan-African event were tectonically overprinted under amphibolite- to granulite-facies pressure/temperature conditions. Nevertheless, old inherited zircons that preserve the age of the rocks before the intense deformation are well known in the literature (e.g. Kröner et al., 1999). The 1,742 Ma age we obtained for the zircon inclusion in the greenish blue sapphire coincides with the age of zircons possibly derived from granulites found, for example, in southern Madagascar (Kröner et al., 1999). These granulites are interpreted to have formed at 1,740 Ma and to have been later tectonically overprinted during the Pan-African event. The somewhat rounded, resorbed-appearing morphology of the zircon inclusions in this sapphire supports an inherited (protogenetic) origin for these crystals (cf. Corfu et al., 2003). If this is correct, then these zircon inclusions must have been derived from the host rock and trapped in the corundum during its crystallization. Although proving such a scenario is beyond the scope of this article, it does fit well with the Madagascar origin of this sapphire. This is further supported by zircon inclusions in sapphires from Madagascar that have been previously described as ranging around 1,500 Ma (Elmaleh et al., 2015). In addition, the author is not aware of a similar published age for the other potential areas of origin such as Sri Lanka and East Africa.

Potential Effect of Heat Treatment
It is well known that sapphires are commonly heat treated to enhance their appearance. What is the effect of heat treatment on the calculated U-Pb age of their zircon inclusions?

Previous experiments indicate that sapphire heat treatment has an effect on the crystallinity of zircon inclusions—depending on temperature and time—although the extent of this effect is a matter for debate (Nasdala et al., 2001; Wang et al., 2006). Furthermore, it is not clear if or to what extent Pb loss in a diffusive process is measurable for these heated stones. Zircon heating experiments have been done to investigate the amount of Pb loss due to diffusion. Cherniak and Watson (2003) claimed that below 1,200°C, the time to reach 1% Pb loss in an effective 10 µm zone exceeds one year. More relevant is the temperature range between 1,200°C and 1,450°C. At these temperatures, measurable Pb loss can be assumed for heating periods of less than one day (Cherniak and Watson, 2003). Also, the diffusion rate may increase due to strong radiation damage in metamict zircon. Above 1,400°C, zircon (ZrSiO₄) becomes unstable and partially melts to form baddeleyite (ZrO₂) and silicate-rich phases (Wang et al., 2006; Váczi et al., 2009). More experiments in the range of 1,200–1,400°C are required to better quantify the diffusive effect on Pb in zircon.

Therefore, sapphire heat treatment may to some extent lead to Pb loss from zircon inclusions. As this does not consider the lifetime of the various U-Pb decay systems, the decay loss must result in an effect similar to natural Pb loss from high-temperature metamorphism. Thus the U-Pb ages of zircon inclusions in heated sapphires would be expected to plot beneath the concordia curve and follow linear trends towards younger ages. Conversely, this implies that concordant-plotting zircons most probably were not exposed to high-temperature heat treatment. U-Pb data that plot discordantly could be the result of exposure to either intense laboratory heat treatment or natural high-temperature metamorphism. Even apparently concordant-plotting zircons may to a minor extent be affected by Pb loss (their error ellipses plot on the concordia line, but the true ages within the ellipses can be slightly discordant). In such cases, the calculated ages represent minimum ages.

With a calculated probability of concordance of 99% (Table II), the zircon in the pink sapphire clearly yielded a concordant age. The age obtained from the zircon in the greenish blue sapphire was 82% concordant, so despite the
high level of confidence there is some possibility of slight discordance. As heat treatment of that sapphire could be excluded, this may be due to tectono-metamorphic events that the zircon was exposed to after its formation and before being trapped in the sapphire.

**Highly Zoned Zircons**

A potential complication for age dating could be caused by complexly zoned zircons, in which the varying zones represent different times of formation. If the zones with different ages are smaller than the spatial resolution of the laser spot, then mixed ages would result. In the concordia diagram, such results may plot similarly to zircons that have experienced Pb loss. In some cases, different growth zones might be indicated by sudden trace-element concentration changes in the mass spectrum during ablation. If available, cathodoluminescence (CL) imaging is the most powerful tool to identify these zones. The minimum spot size of the LA-ICP-MS instrument (and ion probes such as SIMS or SHRIMP) is around 10–15 μm in diameter, depending on the amount of U and Pb in the zircons, thus dictating the minimum homogeneous zone in a zircon that is required for a ‘good’ age determination. The zircon inclusions analysed for this article showed no evidence of multiphase mineral formation (i.e. there were no sudden variations in trace-element composition during the analyses).

**Conclusions**

LA-ICP-MS is effective for determining the age of zircon inclusions, even in valuable faceted stones, without damaging the host sapphire. The limiting conditions are the technical capabilities of the analytical devices on one hand and the characteristics of the zircon inclusions on the other (i.e. the sapphire must contain surface-reaching zircons, preferably on the girdle, that are large enough to analyse and lack fine-scale chemical zoning). The dating methods are applicable to any gemmological laboratory operating a LA-ICP-MS. Age data for zircon inclusions in sapphires provides useful information for origin determination, and can in some cases indicate the crystallization age of the host sapphire. Zircon ages that far exceed the inferred age of the surrounding sapphire can also provide valuable information. Depending on the error ranges, it may be more dependable to consider the data as minimum ages rather than the exact time of formation. This especially applies to those stones where heat treatment cannot be excluded. Although a discordant U-Pb age may be the consequence of a high-temperature (i.e. >1,200°C) heat treatment that was applied for a relatively long period, such discordance might also indicate that a high-grade metamorphic overprint caused loss of Pb and possibly U, or even point to a mixed age from sampling a complexly zoned zircon inclusion.

Although the routine age determination of zircon inclusions in sapphire is not yet frequently accomplished in gemmological laboratories, it is expected that this procedure will become more common in the future as LA-ICP-MS instrumentation becomes more available and better constraints are obtained on the ages of sapphires and their host rocks. It may even become an additional service requested by clients in addition to origin determination.

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The Author

Klemens Link is geochemical specialist at the Gübelin Gem Lab, Maihofstrasse 102, 6006 Lucerne, Switzerland.

Email: klemens.link@gubelingemlab.com

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Identification of a CVD Synthetic Diamond with a ‘Tree Ring’ Growth Pattern

Yan Lan, Rong Liang, Taijin Lu, Yong Zhu, Tianyang Zhang, Xuan Wang, Jian Zhang, Hong Ma and Zhonghua Song

The identification of CVD synthetic diamonds has become a challenge for the gem industry. Recently, a faceted 0.61 ct CVD synthetic diamond (VVS₂ clarity and L colour) was submitted to NGTC’s Shenzhen Laboratory without disclosure. A bluish green fluorescence pattern similar to the ‘tree ring’ growth features seen in natural diamonds was observed in the table of the sample with the DiamondView. X-ray topography and Laue diffraction revealed that the crystallographic orientation of the table facet was inclined approximately 20° to the {111} octahedral plane, rather than being oriented in the typical {100} cubic direction. The appearance of this growth pattern could cause confusion, and vigilance is needed to assess the observed pattern in combination with the luminescence colour in differentiating between CVD synthetic and natural diamond. The X-ray topograph and Si-related photoluminescence (PL) doublet at 737.6/737.9 nm clearly indicate a CVD synthetic origin for this sample. The presence of PL peaks at 415 nm (N3) and 503.2 nm (H3), as well as mid-IR absorption at 3107 cm⁻¹, indicate that the sample underwent post-growth high-temperature, high-pressure (HPHT) treatment.

Introduction

During the last few decades, a considerable number of gem-quality synthetic diamonds produced by chemical vapour deposition (CVD) have entered the market. Most of them have reportedly come from Apollo Diamond Inc., Gemesis Corp. and others (Wang et al., 2003, 2007b, 2012; Martineau et al., 2004; Wang and Moses, 2011). In 2003, the Gemological Institute of America (GIA) laboratory described a near-colourless gem-quality CVD synthetic diamond grown by Apollo Diamond (Wang et al., 2003). Subsequently, Wang et al. (2007b, 2010) reported on colourless, brown and orange-pink gem-quality CVD-grown synthetics from Apollo Diamond. Martineau et al. (2004) presented analytical results from the Diamond Trading Co. (DTC) Research Centre on CVD synthetic
diamond samples grown for research purposes by Element Six; these included as-grown and HPHT-treated nitrogen-doped samples, as well as boron-doped and high-purity CVD synthetic diamonds. Gemesis Corp. announced plans to market CVD-grown synthetics in November 2010, and these were described by GIA in 2011 (Wang and Moses, 2011). Subsequently, Wang et al. (2012) reported additional gemmological and spectroscopic properties of Gemesis CVD synthetic diamonds.

In recent years, greater identification challenges for CVD synthetic diamonds have resulted from refinements in their growth and processing, which have yielded products that are very similar to natural diamond in appearance, with variable properties according to the added impurities or post-growth treatment. In the past few years, undisclosed CVD synthetic diamonds have been submitted to the International Gemological Institute, National Gemstone Testing Centre (NGTC), Tokyo Central Gem Laboratory and others (e.g. Song et al., 2012; Kitawaki et al., 2013, 2015).

NGTC has carried out significant research on CVD synthetic diamonds, and has developed effective identification protocols using ultraviolet-visible–near infrared (UV-Vis-NIR) and infrared absorption spectroscopy, the DiamondView instrument, PL spectroscopy, etc. Of these, DiamondView fluorescence imaging is one of the most useful identification methods, since it reveals the striations associated with the layered growth of CVD synthetics (Martineau et al., 2004; Wang et al., 2010). However, this article documents a ‘tree ring’ growth pattern seen with the DiamondView in the table of a faceted CVD synthetic diamond that is similar to patterns seen in some natural diamonds. The gemmological characteristics of this sample are presented, and the reason for the unusual appearance of its growth pattern is analysed using X-ray topography and Laue diffraction to determine the crystallographic orientation of the synthetic diamond relative to the table facet.

Materials and Methods
A 0.61 ct round brilliant (Figure 1) was submitted to NGTC’s Shenzhen Laboratory for a grading report in February 2015. It was identified as a CVD synthetic diamond, and received a low colour grade (L) but showed good clarity (VVS2). The following investigations were carried out at NGTC, except for X-ray topography and Laue diffraction, which were carried out at De Beers Technologies in Maidenhead.

The sample’s fluorescence and phosphorescence to UV radiation were observed using 254 nm (short-wave) and 365 nm (long-wave) 4-watt UV lamps, and also with the DiamondView deep-UV (<230 nm) imaging system.

Infrared absorption spectra were recorded in the mid-infrared range (6000–400 cm⁻¹ and 2 cm⁻¹ resolution) at room temperature, with a Nicolet 6700 Fourier-transform infrared (FTIR) spectrometer equipped with a KBr beam splitter. UV-Vis-NIR absorption spectra in the range of 230–1000 nm were collected with an Ocean Optics GEM-3000 Jewel Identifying Instrument at liquid-nitrogen temperature. The sample was also tested using the DTC DiamondSure and DiamondPlus instruments.

Photoluminescence spectra were acquired with four different laser excitations (325, 473, 532 and 785 nm) using a Renishaw InVia Raman confocal micro-spectrometer with the sample cooled to liquid-nitrogen temperature.

X-ray topography (Mo Kα radiation, [533] reflection) using a Marconi GX20 rotating anode X-ray generator was done to visualize strain associated with dislocations that formed during the sample’s growth. The crystallographic orientation of the
The table facet was determined by Laue diffraction, using a Bruker SMART 1000 CCD single-crystal diffractometer. Laue diffraction patterns are useful for revealing the crystallographic orientation of a faceted sample. Named after Max von Laue, such images provide a photographic record of the diffraction pattern that is produced when an X-ray beam passes through a crystal (Warren, 1969). The patterns show a regular array of spots on a photographic emulsion resulting from X-rays scattered by certain groups of parallel atomic planes within the crystal. Those X-rays oriented at just the proper angle to a group of atomic planes will combine in-phase to produce intense, regularly spaced spots on the film or plate that indicate the sample’s crystallographic orientation relative to the X-ray beam.

Results

Luminescence
The sample was inert to long-wave UV radiation and showed moderate-to-strong green fluorescence to the short-wave UV lamp. No obvious phosphorescence was seen.

In the DiamondView, the sample displayed bluish green fluorescence with layered growth striations (Figure 2). Unlike previously reported CVD synthetic diamonds, when observed table-up the sample showed a ‘tree ring’ growth pattern, similar to that seen in some type I natural diamonds (Wang et al., 2007a; Sun et al., 2012; see Figure 2a). By contrast, when viewed from the pavilion the sample showed the characteristic parallel layers associated with the growth of CVD synthetic diamond (Figure 2b). As far as we are aware, the ‘tree ring’ pattern has not been previously reported in CVD synthetic diamond (cf. Martineau et al., 2004; Wang et al., 2007b).

Infrared and UV-Vis-NIR Absorption Spectroscopy
The absorption spectrum in the mid-infrared region (Figure 3) showed that the sample was type IIa, with very weak N-related absorption at 1344 cm⁻¹. Other features included H-related lines at 3107, 3029, 2919, 2880 and 2831 cm⁻¹, and weak bands at 1340, 1332, 1296 and 1128 cm⁻¹. Note that the weak line at 3107 cm⁻¹ and the missing 3123 cm⁻¹ line (a characteristic H-related feature in CVD synthetic diamond) provide strong evidence that the sample had been HPHT treated (Martineau et al., 2004).

The UV-Vis-NIR absorption spectrum revealed an N-related peak at 270 nm and decreasing absorbance from 300 to 700 nm (Figure 4). Neither the Si-V-related peak at 737 nm (typical of some CVD synthetic diamonds: Martineau et al., 2004; Wang et al., 2012) nor the N₃ absorption at 415 nm (common in natural diamond) were detected.
Verification Instruments
Testing with the DiamondSure resulted in ‘refer for further test: type II’, and the DiamondPLus indicated ‘Refer CVD’ from the PL measurement of the 737 nm Si-V⁻ centre.

Photoluminescence Spectroscopy
325 nm Excitation: A weak PL peak at 415.1 nm was excited by the 325 nm laser (Figure 5). This peak is attributed to the N3 defect (three nitrogen atoms in a [111] plane associated with a vacancy: Davies, 1974; Davies et al., 1978), which usually occurs in cape diamonds. Nitrogen in CVD synthetic diamond is commonly present in the form of single nitrogen, but may be aggregated during HPHT treatment to produce the N3 defect, particularly after prolonged annealing at 2,200°C (Martineau et al., 2004). In addition, a series of weak PL peaks in the 388–503 nm range were detected.

Figure 3: Infrared spectroscopy of the CVD synthetic diamond shows H-related lines at 3107 cm⁻¹ etc. (left) and very weak N-related 1344 cm⁻¹ absorption (right). The missing CVD-characteristic H-related absorption band at 3123 cm⁻¹ reveals that the sample has been HPHT treated.

Figure 4: The UV-Vis-NIR absorption spectrum of the CVD synthetic diamond shows a broad absorption band centred at ~270 nm attributed to isolated nitrogen.

Figure 5: The PL spectrum of the CVD synthetic diamond sample excited by the 325 nm laser at liquid-nitrogen temperature shows a weak emission at 415.1 nm from the N3 optical centre.
473 nm Excitation: The PL spectrum excited by the 473 nm (blue-green) laser is shown in Figure 6. The strongest zero-phonon-line (ZPL) emissions were at 575, 503.2 and 736.6/736.9 nm.

The 575 nm emission is from the NV<sup>0</sup> centre, which is commonly detected in CVD synthetic diamond due to the presence of single nitrogen and vacancies that are inevitably introduced during the growth process (Martineau et al., 2004).

The 503.2 nm ZPL is attributed to the H3 defect ([N-V-N]<sup>0</sup>), which can be produced by irradiation in diamond containing aggregated nitrogen, followed by annealing at approximately 800°C. Vacancies are generated during the irradiation and annealing, and are trapped at nitrogen A-aggregates (a nearest-neighbour pair of nitrogen atoms) to form H3 centres. In CVD synthetic diamond, this defect is produced when there is nitrogen and a source of vacancies in the pre-treated material. H3 defects also can be formed by high-temperature annealing without irradiation (Charles et al., 2004; Martineau et al., 2004; Meng et al., 2008). According to Meng et al. (2008), when the annealing temperature exceeds 1,700°C, H3 defects may be observed in CVD synthetic diamond. This defect is responsible for the green fluorescence excited by the short-wave UV lamp and the DiamondView (Wang et al., 2012).

The 736.6/736.9 nm doublet and its corresponding vibronic structure are attributed to the Si-V<sup>-</sup> centre. Silicon is often introduced into CVD synthetic diamond by the etching of Si-containing components forming the reactor (Robins et al., 1989; Barjon et al., 2005; Wang et al., 2012). The defect can exist stably after HPHT treatment (Martineau et al., 2004), and is usually regarded as one of the identification characteristics of CVD synthetic diamond (although not definitive, as a small number of natural diamonds also have this defect: Breeding and Wang, 2008).
The 473 nm laser also excited many unidentified sharp peaks, including those at 487, 488, 494, 495, 500, 501, 506 and 507 nm, as well as those at 975, 977, 983, 988 and 990 nm in the infrared region (not all peaks are shown in Figure 6).

532 nm Excitation: Photoluminescence peaks at 575 nm (NV⁰) and 736.6/736.9 nm (Si-V⁻) were detected in the sample when excited by the 532 nm laser (Figure 7). In addition, 637 nm emission attributed to the NV⁻ centre was recorded. Several unattributed emission peaks were detected in the 539–556 nm region, including those at 539.3, 540.1, 540.6, 541.6, 544.8, 547.7, 548.7, 552.5, 554.2 and 556.0 nm (not all peaks are shown in Figure 7).

785 nm Excitation: Weak PL peaks at 819.3, 824.5, 850.1 and 853.3 nm were detected in the sample when excited with the 785 nm laser (Figure 8). The defects responsible for these PL peaks have not been identified.

X-ray Topography

The X-ray section topograph of the sample is similar to those previously reported in CVD synthetic diamond (Martineau et al., 2004), showing a columnar texture with linear contrast streaks parallel to the growth direction (Figure 9). This appearance is quite different from that seen in topographs of natural diamonds (cf. Diehl and Herres, 2004). The contrast streaks are believed to be caused by the dislocations produced during the growth process. If the X-ray beam sampled a direction perpendicular to the growth direction, these dislocation bundles would appear as dark spots in the resultant topograph (Martineau et al., 2004). The X-ray topograph shows that the table of the faceted CVD synthetic diamond is oriented at a significant oblique angle to the crystal's growth.
direction, in contrast to that reported by Martineau et al. (2004) where the table was approximately perpendicular to the growth direction.

**Laue Diffraction**
A Laue diffraction image taken with the table parallel to the plane of the image (Figure 10) showed that the table facet of the CVD synthetic diamond was oriented approximately 20° to the {111} octahedral plane, in the {100} cubic direction.

**Discussion**
The angle between the octahedral and cubic planes in diamond is 54.7°. Laue diffraction allows the orientation of the CVD synthetic diamond’s table facet to be calculated (Figure 11), showing a deviation from the {100} cubic plane toward the {111} octahedral plane. In general, CVD synthetic diamonds are grown on plates oriented parallel to the {001} plane, producing growth in the <001> direction. The table facet is typically oriented approximately parallel to the seed plate plane (i.e. perpendicular to the growth direction of CVD synthetic diamond) to improve the cutting yield. The Laue diffraction pattern indicates that the ‘tree ring’ growth pattern observed on the table of the CVD synthetic diamond sample with the DiamondView is due to the orientation of the table facet.

**Figure 10:** Indexing of this X-ray Laue diffraction pattern of the CVD sample revealed that the table facet has an orientation that is inclined approximately 20° to the {111} octahedral plane toward the (100) cubic direction.

**Figure 11:** This schematic diagram of the cutting direction of the CVD sample shows that the crystallographic orientation of the table facet deviates from the {100} cubic plane and approaches the {111} octahedral plane. This differs from typical faceted CVD synthetic diamond, in which the table is oriented approximately parallel to the {001} plane.
table at just the right angle to the growth direction to produce very shallow angles between the growth planes and the table and crown facets at one position at the edge of the table. This results in the concentric ring-like appearance where the striations intersect the facets.

**Conclusion**

Refinements in CVD synthetic diamond growth technology, and the resulting increase in crystal size, have resulted in more flexibility regarding the cutting orientation used to facet such products. The ‘tree ring’ growth structure observed with the DiamondView in the table of a 0.61 ct CVD synthetic diamond is due to the crystallographic orientation of the table facet deviating from the {100} cubic direction toward the {111} octahedral plane to produce very shallow angles between the growth planes and the table and crown facets. This concentric pattern is different from the dislocation and ‘mosaic’ structures seen in DiamondView images of natural type Iia diamond (Martineau et al., 2004), but may resemble those patterns observed in natural type Ia stones; however, the luminescence of the latter gems shows a blue colour that is very different from that seen in CVD synthetics (Wang et al., 2007a; Sun et al., 2012). Also, compared to the regular striations in CVD synthetics, the growth patterns in natural diamond are more complicated and less orderly because of the complex geological environment of their formation. In addition, the CVD sample showed the Si-V–related doublet at 737.6/737.9 nm in PL spectra. This defect can be used to identify CVD synthetic diamond but is also seen very occasionally in natural diamond. The columnar texture of the X-ray topograph may be useful as an indicator of CVD synthesis (cf. Diehl and Herres, 2004; Martineau et al., 2004). The presence of the N3 (415 nm) and H3 (503.2 nm) defects, and also the 3107 cm⁻¹ absorption seen in the mid-IR spectrum, indicate that the CVD synthetic diamond has been HPHT treated. The 480–524 nm PL peaks excited by the 473 nm laser and the 535–560 nm PL peaks excited by the 532 nm laser have also been detected in other CVD synthetic diamonds that show green fluorescence and characteristics of HPHT treatment, and may be used as further indicators of CVD synthetic diamond.

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**The Authors**

Yan Lan, Rong Liang, Tianyang Zhang and Hong Ma  
National Gemstone Testing Center (NGTC)  
Gems & Jewelry Institute of Shenzhen  
13F NGTC Building, 4 # Beili South Road  
Luohu District, Shenzhen 518020, China  
Email: 858lan@163.com

Yong Zhu and Xuan Wang  
Chongqing Academy of Metrology and Quality Inspection, 1 # Yangliu North Road  
Yubei District, Chongqing 401123, China

Dr Taijin Lu, Jian Zhang and Zhonghua Song  
NGTC, Gems & Jewelry Institute of Beijing  
22F Tower C, Global Trade Center  
36 # North Third Ring East Road  
Dongcheng District, Beijing 100013, China

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Huntingtown, Maryland, USA

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Organic Gems, London

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Swiss Gemmological Institute SSEF, Basel, Switzerland

**Gagan Choudhary**  
Gem Testing Laboratory, Jaipur, India

**Dr Eloïse Gaillou**  
Musée de Minéralogie, Mines ParisTech, Paris, France

**Al Gilbertson**  
Gemological Institute of America, Carlsbad, California, USA

**Alan Hodgkinson**  
Ayrshire, Scotland

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Mary Johnson Consulting, San Diego, California, USA

**Dr Taijin Lu**  
National Gemstone Testing Center Laboratory, Beijing, China

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Pearl Paradise, Los Angeles, California, USA

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**Understanding Gems**
The annual conference of the Canadian Gemmological Association took place 17–18 October 2015 in Vancouver, British Columbia, Canada. The 118 people in attendance represented approximately 11 countries.

CGA president Donna Hawrelko introduced the conference, which was kicked off with a presentation by Gary Roskin (International Colored Gemstone Association, New York, New York, USA) on communicating colour. He asked the audience whether gem laboratory reports should be using scientific colour descriptions (i.e. hue, tone and saturation) or popular colour designations (e.g. 'Pigeon's Blood' red or 'Royal' blue) that gem traders can use as marketing tools. For the latter case, he recommended that labs should be consistent and have well-defined and published ranges for such colour terminology. Next, Dr Cigdem Lule (Gemworld International Inc., Glenview, Illinois, USA) warned against the abuse of commercial colour terms for marketing purposes when dealers “sell the report, not the stone”. She gave an example of the term 'Pigeon's Blood' appearing on an overly high percentage of ruby reports (90% of some 500+ surveyed), for stones that ranged from $450/ct to $50,000/ct. She, too, emphasized the need to establish clear gemmological nomenclature and be consistent in the way it is applied.

Dr James Shigley (Gemological Institute of America [GIA], Carlsbad, California, USA) provided an update on the identification of synthetic diamonds. He emphasized that only a small number are submitted to the GIA Laboratory (perhaps 10–15/month), and they continue to be readily distinguishable by well-equipped labs. Richard Drucker (Gemworld International Inc., Glenview) reviewed the pricing of synthetic and treated diamonds. Synthetic colourless diamonds are generally priced at 50% (up to 65% for larger sizes) of natural stones, except for melee which is ~US$100/ct less than natural diamonds. High-pressure, high-temperature (HPHT)-treated D–G colour diamonds typically are discounted by 40%–55% compared to equivalent untreated natural stones. Drucker also gave pricing data for fancy-colour synthetic and treated-colour natural diamonds in an informative handout. Alex Grizenko (Lucent Diamonds Inc., Los Angeles, California, USA) reviewed diamond colour enhancement, with an emphasis on multi-treatments involving HPHT annealing, irradiation, and further heat treatment at lower temperatures. Interestingly, he is asking the same price for both natural and synthetic Imperial Red diamonds (multi-treated type Ia).

Art Samuels (Vivid Diamonds & Jewelry and EstateBuyers.com, Florida, USA) passed along many diamond-buying tips gleaned throughout his career. For example, he explained how strongly blue-fluorescent stones (which are unnecessarily punished by the trade) and fancy shapes can be great bargains. He also recommended examining a gemstone closely both before and after obtaining a laboratory report to calibrate one’s observational skills, and to learn pricing by attending shows and asking questions.

Dr Lee Groat (University of British Columbia, Vancouver, Canada) surveyed Canadian gem localities. Diamond production is planned to begin during the second half of 2016 from the Gahcho Kué deposit in Northwest Territories and the Renard project in Québec, both of which are currently under construction. Canada also hosts significant deposits of nephrite and the world’s only commercial occurrence of Ammolite (iridescent fossilized ammonite). Other gems include amethyst from Thunder Bay, Ontario; tourmaline from O’Grady, Northwest Territories; sodalite from Bancroft, Ontario; opal from British Columbia; sapphire from Baffin Island and Revelstoke, British Columbia; emerald from Taylor 2 (Ontario), Anuri (Nunavut) and three additional localities in north-western Canada; aquamarine from the True Blue occurrence in Yukon Territory; green beryl from Mountain River, Northwest Territories; and spinel from Baffin Island. Simon O’Brien (De Beers Group of Companies, Toronto, Ontario, Canada) gave an update on De Beers’ diamond mining activities in Canada (i.e. Snap Lake, Gahcho Kué and Victor), and then described the evaluation of rough diamonds (e.g. Figure 1). The diamonds are (1) sieved into various
sizes; (2) evaluated into sawable and makeable groups followed by sorting according to their shape; (3) separated according to their clarity into gem, near-gem and industrial categories; and (4) assessed for their colour. Further sorting within the various categories leads to a total of 12,000 price points.

Andrew Fagan (True North Gems, Vancouver, Canada) described the geology and gemmology of the Fiskenaesset gem district in Greenland, where his company is preparing to open a ruby and pink sapphire mine at Aappaluttoq. Core drilling (to 220 m depth) and bulk sampling have been used to define the ore zone, and plans call for constructing two open pits up to 65 m deep with a predicted nine-year mine life. The mine economics are modelled on melee-sized material, although some larger stones will be produced. True North will sell the rough to suppliers (initially in 2016), and by 2017 they will be in full production with 20,000–30,000 tonnes/year of ore mined.

Robert Weldon (GIA, Carlsbad) recounted the history of the Chivor emerald mine in Colombia. Many famous emeralds have come from Chivor, and the height of commercial production occurred in the 1930s, when the mine was operated by Peter Rainier.

Dr Edward (Shang-i) Liu (The Hong Kong Institute of Gemmology) described several types of fei cui jade, consisting of various amounts of jadeite ± omphacite and kosmochlor. He demonstrated how different minerals can be present in various parts of the same cabochon, leading to challenges in proper identification and nomenclature. For the purposes of the gem trade, he advocated simplifying the terminology to indicate ‘natural fei cui’ on lab reports, with major mineral constituents specified upon the client’s request.

Shawn O’Sullivan (Eternity Natural Emeralds, Ridgewood, New Jersey, USA) described the impact of clarity treatment on emerald and tourmaline. He stated that there is generally a 5–10% improvement in appearance after treatment, and that it is difficult for gem laboratories to tell the amount of clarity enhancement because they do not see the stone’s appearance after it is cleaned and before its fractures/cavities are filled.

Alan Hodgkinson (Ayrshire, Scotland) highlighted various stones that he encountered at last year’s Tucson gem shows, and illustrated how they could be separated or identified using his techniques of ‘visual optics’. Ruby and diamond are the only gems that can be specifically identified using visual optics, and otherwise these techniques are good for eliminating possibilities, thus narrowing potential candidates.

Kelly Ross (owner of Ross Inc., Edmonton, Alberta, Canada, and formerly diamond program coordinator for the Royal Canadian Mounted Police) explained why jewellery is so common in ‘money laundering’, which he defined as the proceeds of a crime that must be sold to obtain cash and real property (i.e. fixed property such as land and buildings). Along with electronics and power tools, jewellery is commonly desired by burglars because (according to the acronym CRAVED) it is concealable, removable, available, valuable, enjoyable and disposable. Jewellers who are approached to buy possible stolen goods can help by reporting suspicious transactions, by keeping good records (of lab reports, etc.), and by getting the seller’s identification information.

The conference was preceded by a short-course on the geology of gem deposits and was followed by a jadeite identification and valuation workshop, both of which were filled to capacity.
First World Emerald Symposium

‘Be Part of the Change’ was the theme of the First World Emerald Symposium (WES), held at the Sheraton Convention Center in Bogotá, Colombia, 13–15 October 2015 (Figure 2). The advance registration was capped at 350 participants, and many more tickets were sold at the door (mostly to local Colombians), for a total attendance of 471. The WES was organized by the Colombian government and the Colombian emerald industry umbrella association Fedesmeraldas, an alliance of miners, manufacturers and wholesalers. The two most prominent corporate sponsors were Muzo International (Geneva, Switzerland) and Gemfields (London). Muzo International is the owner of the world-famous Muzo emerald mine, where they first began operations in 2009. Gemfields announced in September 2015 their acquisition of the historic Coscuez mine, some 10 km north of Muzo.

An important message from the WES is that, for the first time in history, Colombia is no longer the number-one producer of emerald in the world. Zambia now leads in annual emerald production by volume and by value. The precipitous drop in Colombia’s emerald production is due to the lack of investment by Colombians in their mines.

Zambia’s Minister of Mines, Dr Christopher B. Yaluma, spoke eloquently on his country’s success in the emerald market. Unlike Colombia, where emeralds have been mined continuously for 1,500 years, emeralds were discovered relatively recently (1929) in Zambia. Next, the Vice-Minister of Mines for Colombia, Dr Maria Isabel Ulloa, focused on the scourge of ‘illegal’ emerald mining. By her estimate, half of the small-scale emerald miners in Colombia lack proper title to the land. In the miners’ defence, government delays in issuing proper title under the updated mining law of 2012 have led to a three-year backlog in pending reviews and approvals. Minister Ulloa also stated that over 90% of the emerald licences are idle. Dr Carolina Rojas Hayes of the Colombian National Mining Agency reported that there were 1,496 exploration permits for some 7,500 prospectors, and another 359 licences for land parcels, with 178 parcels partially certified and another 49 under review. By her count, only two licences have been fully vetted, those of Gemfields and Muzo International.

Principals of coloured gemstone industry organizations discussed and then debated how guild organizations can promote business in a dynamic global market. ICA president Benjamin Hackman emphasized the need for full disclosure of treatments, saying: “Synthetic emeralds are better documented than natural emeralds that have been treated and enhanced.” Roland Naftule with CIBJO highlighted the economic power of the emerging generation of millennials, and contrasted their motivations for buying gemstones and jewellery with those of the ‘baby boomer’ generation, leading to the creation of new market channels rewarding ample information and social consciousness. Gerry Manning with AGTA stressed the importance for national organizations to represent collective interests to both recalcitrant government regulators and hostile media. He said, “Misinformation is pandemic, and clarity is critical to value.” Fedesmeraldas president Oscar Baquero hoped that the lasting impact of the WES would be closer coordination between Colombians and their international colleagues. Baquero reported officially that the 2014 emerald export for Colombia totalled US$145 million, derived from some 347 licences of which only 10% were active.

International gemstone laboratories were well represented during an afternoon session. In summary, the labs are confident they can distinguish Colombian emeralds from those of other sources, and can differentiate synthetics as well. Admittedly, the cost of testing melee parcels is prohibitive, rendering a risk of blended stock escaping detection. Although technology permits the identification of specific emerald fillers, there is presently no systematic reportage for treatments, nor any plans for such structure. Dr Thomas Hainschwang (GGTL Laboratories, Balzers, Liechtenstein) reviewed the standards and protocols for verifying emeralds in gem labs, especially infrared spectroscopy to differentiate fillers and fluorescence.

Figure 2: The theme of the First World Emerald Symposium was ‘Be Part of the Change’. Here, Philippe Scordia discusses emerald selection criteria used by luxury jewellery brands. Photo by W. Rohtert.
microscopy to map their distribution in a stone. Kenneth Scarratt (formerly of the GIA Laboratory in Bangkok, Thailand) spoke on the history of emerald enhancement, elucidating the multiple cycles of cleaning, treating and filling that any emerald might experience, as well as the breakdown over time of some fillers. Shane McClure (GIA Laboratory, Carlsbad) addressed the harmonization of reports, protocols and specific wording for emerald documentation. Ronald Ringsrud, speaking for Muzo International, focused on residues and other substances mistakenly classified as enhancements in emeralds—especially simple manufacturing residues. Ringsrud also delivered a passionate sermon on the importance of ‘romance and glamour’ as the driving factors in emerald sales, not scientific certificates. Dr Dietmar Schwarz (AIGS Lab, Bangkok) illustrated the many physical and chemical distinctions of Colombian emeralds as compared to those from other sources, notably their high Cr+V content and diagnostic three-phase inclusions, as well as characteristic growth features such as first-order prisms and pinacoids. Carlos Julio Cedeno (CDTEC Gemlab, Bogota) provided insight into some of the unique crystallographic features of Colombian emeralds derived from their growth within open spaces in a hydrothermal environment.

Muzo International president Charles Burgess delivered a keynote address focusing on the social responsibility of a modern gem mining company. Burgess said that “six years of positive social transformation has been key to Muzo’s commercial success” in Colombia. Corporate social responsibility is a foundation commitment, not an optional extravagance, he claimed. When they arrived at Muzo, they confronted a health-social-cultural crisis that was exacerbated by the modernization and mechanization of an historic mine site. There was a general lack of law and order, a legacy of rampant environmental damage, the constant risk of invasion by squatters and an absence of social services. To succeed, Muzo International assumed a proactive role normally assigned to government in addressing the challenges of unemployment, the need for schools and clinics, and support for the disabled and elderly. Muzo International financed outreach to the community and empowered women by financing local tailors to deliver clothing for miners, and by hiring women to engage in environmental restoration of the riparian environment along the Río Minero. Today, the mine employs over 600 workers and sustains a surrounding community of more than 2,500 people.

ICA director of communications Jean Claude Michelou spoke next on the traceability of coloured stones, with an update on ongoing initiatives and a way forward. He emphasized that documentation of provenance was critical to product branding and to building confidence with consumers. Captain Torres with the Colombian National Police then spoke on corporate and social traceability, and detailed the considerable capacity of the Colombian police and security forces in Boyacá, the state where the major emerald mines are located. Jaime Loder (Aegis Defense Services, London) and Adam Brown (Anuera Security, London) addressed private protection forces for the emerald industry in a high-risk environment, where safety originates in the village, and defence ultimately extends internationally to family, friends and business colleagues.

Another block of presentations concentrated mostly on the technical aspects of emeralds. Dr Gaston Giuliani (Centre de Recherches Pétrographiques et Géochimiques, Nancy, France) started the session with a review of the geology and gemmology of emerald deposits worldwide, highlighting laboratory determinative techniques for the differentiation of emeralds that are derived, ultimately, from differences in the style of mineralization. Marcelo Ribeiro, owner of the Belmont emerald mine in Minas Gerais, Brazil, gave a stunning presentation on their modern, mechanized, surface and underground, emerald mining operations. Belmont is a type example of how to correctly mine emerald deposits in South America, from the use of optic sorters to integration with a national marketing campaign. Clarissa Maciel (Brazilian Institute of Gems and Precious Metals, Brazilia) expounded on how her organization—a partnership between the government and private sector—promotes the gem business (including Belmont), nationally and internationally. Warren Boyd (R.T. Boyd Ltd., Oakville, Ontario, Canada) provided an interesting review and update on the geology and gemmology of the Malycheva emerald mine in the Ural Mountains of Russia. He noted that the ‘seizure’ of Malycheva from Canadian-owned Tsar Emerald Corp. coincided with Vladimir Putin’s shell companies consolidating control over the remnants of the beryllium industry of the former Soviet Union. Malycheva is Russia’s primary source of beryllium for their nuclear industry. Next, Gary Bowersox (GeoVision Inc., Honolulu, Hawaii, USA) covered the extensive history of emerald mining in Afghanistan, providing, as always, his own considerable personal experience in south-central Asia. He painted a hopeful picture of the Afghan emerald miners, emerging from decades of war, improving their lives and circumstances, despite difficulties that continue to this day. This author spoke next for SRK Consulting (a global mining engineering firm working with diamond, emerald, ruby and sapphire), describing
new mining and recovery tools and technologies useful in the Colombian emerald industry.

Vijay Kedia (Jewelers Association of Jaipur, India) recounted the Indian tradition with emerald of all origins and the market perception of Jaipur as one of the largest buyers and cutters. Left unresolved was the issue of blended melee parcels combined from multiple sources of supply. Philippe Scordia (Christian Dior Joaillerie, Paris, France) described the purchasing criteria, selection and certification of suppliers for luxury jewellery brands, and the increasing importance of provenance and social responsibility. Luxury designer Erica Courtney (Los Angeles, California, USA) illustrated how social media can be used to promote gems and jewellery, including emerald, to a new generation of media-saturated and techno-savvy buyers.

On the third and final day, Jaime Rotlewicz (C.I. Gemtec, Bogotá) began with a demonstration of acoustics and geo-gemmology, using various devices to amplify and record sonic signals, music and noise, from gemstone samples in his lab. David Lightle (The Wright Brothers, Dayton, Ohio, USA) re-emphasized the importance of global branding for service as well as product. Gabriel Angarita, a member of the WES organizing committee and president of the Colombian Association of Emerald Exporters, delivered a resounding review of Colombian emerald branding and lack of branding, ending with a plea for increased cooperation from all elements of the national industry. Andy Lucas (GIA, Carlsbad) gave a broadcast-quality still-and-video presentation on educating retailers and the global supply chain from mine to market, using specific examples from Asia and Africa.

Executive director of Gemfields Sean Gilbertson recounted the history of his company's activities in the coloured gemstone sector, focusing mainly on exploring and developing the Coscuez emerald district. Dr Sixtus C. Mulenga with Zambia's Extractive Industry Transparency Initiative considered the foundations for global gemstone growth to be honest and responsible practices. Darwin Fortaleche, CDTEC Gemlab’s chief gemmologist, presented research into a new emerald enhancement developed in Colombia, where the treatment of emeralds is routine and ever-evolving. Oded Ben Shmuel (Sarine Technologies Ltd., Kfar Saba, Israel) gave an update on his company’s tools applicable to the emerald trade, borrowing new technology from the electronics and aerospace industries. Dr Adolf Peretti (GRS Gemlab, Lucerne, Switzerland) discussed his colour terminology for gem reports, and emphasized its use as a marketing and communication tool. Hypone-Phyo Kan-Nyunt (Gübelin Gem Lab Ltd., Hong Kong) detailed the ultra-trace-element analysis of emeralds through a combination of techniques. Wei Ran (National Gemstone Testing Center [NGTC], Beijing, China) concluded the WES with a description of emerald investigations underway in the Research Department at NGTC.

A post-conference field trip brought participants to various emerald mines in Colombia. Although the symposium was organized rather quickly, it came together with resounding success.

William Rohtert Consulting LLC Phoenix, Arizona, USA

The annual Gem-A Conference took place in London on 21–22 November 2015, and was attended by 190 people from 20 countries.

The event was introduced by Gem-A’s interim CEO Nick Jones. Then, Jörg Gellner (Gellner, Bochum, Germany) provided a detailed description of pearl quality factors, which he referred to as the ‘5 S’s’: size, shape, shade, surface and shine. He gave the typical size ranges of various types of cultured pearls, and for each millimetre above the benchmark size he said the value should be adjusted by +35%. For shape, round is ideal and all other shapes correspond to reductions in value except for matched pairs of drop shapes, which are adjusted by +150%–200%. For shade (colour), different value factors are applied for white or black cultured pearl varieties (e.g. South Sea or Tahitian). Surface is evaluated according to ‘spot level’, with five categories differing in their value factors by 1.5x (e.g. 100% for no spots and 67% for the next category of lightly spotted). Shine (lustre) is also adjusted by 1.5x between categories, of which there are four (AAA, AA, A and B).

Jean Pierre Chalain (Swiss Gemmological Institute SSEF, Basel, Switzerland) recounted the history of developments surrounding the identification of HPHT-
treated diamonds. After the 1999 announcement by General Electric (GE) and Lazare Kaplan International about their ‘undetectable’ and ‘permanent’ diamond decolorization process, a close collaboration between SSEF and researchers from various centers including the University of Nantes and CIBJO laboratories helped develop, one year later, final identification criteria. Additional collaborations with De Beers and the Natural Historic Museum of Vienna later helped in consolidating the identification criteria of HPHT-treated type Ia diamonds.

Adolf Peretti (GRS GemResearch Swisslab Ltd., Lucerne, Switzerland) surveyed some commercially important ruby and sapphire sources, including Myanmar (Mogok and Mong Hsu), Madagascar (Didy and Ilakaka), Sri Lanka (Kataragama), Cameroon, Kashmir, Tanzania (Winza), Vietnam (Luc Yen), Tajikistan and Mozambique. The availability of abundant rough material from Mozambique has allowed the cutting of large ruby suites that were previously very difficult and time consuming to put together. Peretti showed video clips from his visits to some of the mines, and also screened a film that documented the cutting of a notable Mozambique ruby.

Dr Ilaria Adamo (Italian Gemmological Institute, Milan) reviewed the geology and gemmology—including origin determination—of demantoid sources. Serpentine-associated deposits are found in Russia (central Ural Mountains), Italy (Val Malenco), Pakistan (Kaghan Valley and Baluchistan) and Iran (Kerman Province), while skarn-hosted occurrences are in Namibia (Erongo) and Madagascar (Antetezambato). Adamo noted several differences according to the two source types, including their inclusions, reaction to heat treatment and chemical composition.

Dr Paul Rustemeyer (Gundelfingen, Germany) documented colour zoning and growth phenomena in tourmaline crystals. Colourful photographs of slices oriented both perpendicular and parallel to the c-axis showed a wide variety of features, including sequential and face-selective incorporation of chromophore ions, parallel crystal aggregates, re-growth or ‘healing’, corrosion intervals and delta structures corresponding to the appearance of a second colour phase crystallizing on the same face.

Dr Raquel Alonso-Perez (Harvard Mineralogical & Geological Museum, Cambridge, Massachusetts, USA) examined the historic Hamlin Collection of tourmalines from Mount Mica, Maine, USA. Raman spectra showed four peaks in the 3650–3450 cm⁻¹ region (corresponding to OH-stretching vibrations) that could be correlated to the colour of the tourmalines.

Andrew Cody (Cody Opal Australia Pty. Ltd., Melbourne, Victoria, Australia) reviewed the global sources of opal, including Australia (e.g. Figure 3), Brazil, Ethiopia, Honduras, Mexico, Indonesia, Slovakia and USA. He indicated that Australia’s opal production was formerly worth US$500 million/year, and although many deposits have played out, Australia still supplies 90% of the world’s opal by value.

Grant Hamid (Hamid Bros. Gem Merchants, Melbourne) reviewed important historical developments in the sources, supply, treatment and synthesis of gem corundum. He also showed how possessing good gemmological knowledge can be helpful for one’s business: he bought a 7.44 ct ‘synthetic sapphire’ cabochon for $300, and upon examining its inclusions he discovered it was actually a natural Kashmir sapphire.

Richard Drucker (Gemworld International Inc., Glenview) discussed various issues of current interest in the gem trade: coloured stone treatments; nomenclature issues surrounding colour terminology (on lab reports), geographical origin and trade names for gem varieties; and recent developments in synthetic diamond growth and production.

Martin Steinbach (Steinbach – Gems with a Star, Idar-Oberstein, Germany) covered asterism in gems, noting that 50 gem varieties are known to display asterism when cut as cabochons or spheres, and in 90% of the cases the star is due to rutile ‘silk’. He described several famous star rubies and sapphires, and also showed examples of rarities as well as asterism resulting from treatments.
Fabian Schmitz (German Gemmological Association, Idar-Oberstein) provided an overview of the coloration and identification of natural and synthetic quartz. The various colors shown by quartz are due to color centres (natural as well as laboratory-induced) and inclusions. In general, synthetic quartz may show swirl-like colour zoning, ‘breadcrumb’ inclusions or a seed plate, while natural quartz can display twin structures. Infrared spectroscopy is useful for separating them, but it is important to look at the entire spectrum rather than just one portion of it.

Shane McClure (GIA Laboratory, Carlsbad) described various oddities and scams that he has encountered in the GIA Laboratory over the years. Some standouts include ‘rainbow calsilica’ from Mexico consisting of dyed colour-banded calcite of an unknown (but clearly manufactured) origin; ‘night-glowing pearls’ that display strong green fluorescence and phosphorescence due to a coating containing rare-earth elements; various fake mineral specimens and gem crystals; and ‘Arabian sand diamonds’ consisting of quartz pebbles that were collected in Saudi Arabia by unsuspecting clients and then supplied to a gem cutter, with the resulting ‘gems’ actually being faceted cubic zirconia.

After the conference, three workshops covered coloured stone grading and pricing, visual optics and pearls, and private museum tours brought participants to the Natural History Museum (gem and mineral collection), the Tower of London (British Crown Jewels) and the Victoria and Albert Museum (Bejewelled Treasures: The Al Thani Collection).

Brendan M. Laurs

GSA 2015

A session on various aspects of research on gem materials was organized by GIA at the 2015 annual meeting of the Geological Society of America (GSA) in Baltimore, Maryland, on 1–4 November 2015. Abstracts of the oral presentations can be viewed at https://gsa.confex.com/gsa/2015AM/webprogram/Session37638.html, and poster session abstracts are available at https://gsa.confex.com/gsa/2015AM/webprogram/Session38771.html.

The talks were led off by Dr George Harlow (American Museum of Natural History, New York, New York), who cited three examples where the study of gem minerals has benefited from recent advances in the geological sciences. Occurrences of jadeite jade are related to particular formation conditions that are created by continental subduction. The trace-element study of ruby and sapphire using laser ablation–inductively coupled plasma–mass spectrometry has provided a new approach to understanding the geological environments (igneous and metamorphic) of gem corundum. Large gem-quality forsterite (peridot) crystals appear to grow from hydrous fluids along tension gashes in igneous dunite bodies.

In a presentation made in the absence of a speaker who could not attend the conference, Dr Wuyi Wang (GIA Laboratory, New York) described the occurrence of the silicon-vacancy defect in synthetic diamonds, which can be detected by photoluminescence spectroscopy, and which represents one of the most diagnostic features of synthetic diamonds grown by the chemical vapour deposition method.

Dr Karen Smit (GIA Laboratory, New York) and co-authors investigated sulphide inclusions in rare, bright-yellow type Ib diamonds from the Zimmi region of Sierra Leone. Re-Os isotopic compositions of the inclusions give a Pan-African diamond-growth age (~650 million years ago) that correlates with the assembly of the Gondwana supercontinent.

Dr Steven Shirey (Carnegie Institution of Washington, Washington DC, USA) and co-authors described the study of mineral inclusions in diamonds from the Juina area of Brazil, which are rather unique geologically because of their ‘superdeep’ origin (below the lithosphere from depths of 300–800 km). Such diamonds from the Collier 4 kimberlite are believed to have crystallized from carbonatitic melts derived from the recycling of oceanic lithosphere.

Using an 1851 plaster cast and a modern cubic zirconia replica of the original facet shape of the famous Koh-i-Noor diamond (now a 105.6 ct oval-cut stone in the Coronation Crown of the British Crown Jewels), Alan Hart of The Natural History Museum in London described how directional hardness anisotropy was a major constraint to the ancient polishing of the so-called Mogul-cut form of this diamond. Although a centrepiece display of the 1851 Great Exhibition in London, this diamond proved a visual disappointment to many exhibit visitors due to its lack of fire and brilliance, and it was subsequently recut to its present form.

Dr Keal Byrne (Smithsonian Institution, Washington DC) and co-authors investigated the luminescence behaviour of two classes of diamonds that exhibit a colour change when exposed to different
temperatures or light sources. Pink/brown diamonds display luminescence reactions that appear related to optical defects associated with their coloration. So-called chameleon diamonds display a characteristic luminescence peak centred near 560 nm with an intensity that is strongly temperature-sensitive.

The Hamlin Necklace, a unique 19th century jewellery piece containing tourmaline and beryl from Mount Mica in Maine, USA, was investigated by Dr Raquel Alonso-Perez (Harvard University, Cambridge, Massachusetts, USA). She used Raman spectroscopy and non-destructive chemical analytical methods to prove that the tourmalines in the necklace are elbaite.

Dr Aaron Palke (GIA Laboratory, Carlsbad) and co-authors documented glassy melt inclusions in alluvial sapphires from Montana. These sapphires are believed to have a metamorphic origin followed by transport to the surface in rhyolitic to dacitic volcanic eruptions. The melt inclusions are hypothesized to be the product of partial melting during high-grade metamorphism of the parent rock, which produced a silica-rich melt and an alumina-rich residue from which the sapphires crystallized.

John Koivula (GIA Laboratory, Carlsbad) and co-authors heated two kinds of synthetic rubies and sapphires in air at temperatures above 1,800°C, and were able to produce partially healed fractures (e.g. Figure 4) and web-like parting planes. These features display a similar appearance to those seen in heat-treated gem corundum that has been interpreted by gemmologists as having been formed during a flux-healing process. The authors conclude that if no contradictory visual evidence exists, synthetic gem corundum containing these visual features could erroneously be mistaken for heat-treated natural gems.

Dr Laurent Cartier (Swiss Gemmological Institute SSEF, Basel) and co-authors discussed the potentially valuable information that DNA testing can reveal about the formation conditions of organic gems such as pearl, coral and ivory that are the result of biomineralization processes. In the case of pearls (cultured or natural), the analytical method has been improved so that it is quasi-non-destructive. This method can provide information on the oyster species, and also geographic origin.

Xiayang Lin and Dr Peter Heaney (Pennsylvania State University, University Park, USA) reported on quartz crystals that display natural iridescence from cavities in the Deccan Trap basalts of India. The small iridescent z faces exhibit tiny periodic ridges visible with the atomic force microscope, and these ridges act as a diffraction grating for visible light. Non-iridescent r faces lack these periodic ridges. The authors interpret the formation of the surface topography of the z faces as the result of preferential dissolution.

Yury Klyukin (Virginia Institute of Technology, Blacksburg, USA) and co-authors investigated emeralds from the North American Emerald mine (at the former Rist mine site) near Hiddenite, North Carolina, USA. The gems occur in cavities associated with quartz, muscovite and carbonate minerals. The emeralds have fluid inclusions that contain two fluid phases (CO₂-rich and H₂O-rich). The presence of a CO₂-rich fluid suggests that the emeralds formed in a medium-grade metamorphic environment.

Dr William Simmons (Maine Mineral and Gem Museum, Bethel, USA) and co-authors described gem pollucite from the Mount Mica pegmatite near Oxford, Maine. The dyke is cavity-rich, averaging one pocket about every three metres. Gem-quality pollucite is rare in pegmatites, but one pocket found in 2014 contained a number of strongly-etched crystals measuring 2–3 cm in diameter.

The final oral presentation was made by Dr Michael Wise (Smithsonian Institution, Washington DC), who reported on emerald and hiddenite (Cr-bearing spodumene) deposits near Hiddenite, North Carolina. Both minerals occur in quartz-carbonate Alpine-type veins within Precambrian migmatic schists and gneisses. The gems appear to have been formed from hydrothermal fluids under low-temperature (<250°C) and low-pressure (~1 kbar) conditions. The host rocks are the most likely source of Cr, and local outcrops of granitic rocks provide evidence for the Be needed for emerald mineralization. However, recent discoveries of aquamarine in leucosomes within the migmatic indicate that the latter rocks may provide an alternative source of Be.

James E. Shigley (jshigley@gia.edu)
GIA, Carlsbad, California, USA
An innovator in gemstone reporting

- Identification of colored gemstones
- Country of origin determination
- Full quality and color grading analysis
The 2015 Gem-A Conference and 18th International Federation for European Education in Gemmology (FEEG) Symposium was held at Royal Institute of British Architects in Portland Place, London, on 21 and 22 November. A full report of the Conference and events was published in the January/February 2016 issue of Gems & Jewellery. Highlights of the presentations are given in the Conferences section, pages 716–718.

Seminars and workshops were presented on 23 November at the Gem-A headquarters. Visits were arranged on 24 November to the Victoria and Albert Museum to see 'Bejewelled Treasures: The Al Thani Collection', to the Natural History Museum for a guided tour of the Mineral Gallery, and to the Tower of London for a private viewing of the Crown Jewels.

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MEMBERSHIP

At a meeting of the Council held on 9 October 2015, Diploma graduates of the examinations held in June 2015 (included in lists on pages 723–733) were elected or transferred to Fellowship or Diamond Membership as appropriate.

At a meeting of the Council held on 4 November 2015 the following were elected to membership:

Fellowship and Diamond Membership (FGA DGA)
Feng Wei, Guangzhou, Guangdong, P.R. China
Pei Yu, Beijing, P.R. China

Fellowship (FGA)
Hsu Yen Hsin, Taipei City, Taiwan, R.O. China
Reuser, Laetitia, Amsterdam, The Netherlands

GIFTS TO THE ASSOCIATION

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

John Bradshaw, Coast-to-Coast Rare Stones International, Nashua, New Hampshire, USA, for 21 bags containing part-cut crystals of: apatite (Canada and Mexico), cassiterite (Namibia), celestine (Kansas, USA), cerrusite (Namibia), crocoite (Tasmania, Australia), diasporite (Turkey), oligoclase (Kenya), pollucite (Connecticut, USA), scheelite (Pakistan and Arizona, USA), smithsonite (Namibia), sphalerite (Spain), tourmaline (Maine, USA, and Afghanistan), tugtupite (Greenland), willemite/leucophoenicite (New Jersey, USA) and zincite on calcite (New Jersey); and also for 95 faceted mixed-shape tourmalines, mostly pink, green and blue.

From the estate of Ingeborg Bratman, a large collection of rough and fashioned gem materials.

Boris Brianceau, Nantes, France, for large faceted samples of fluorite and amethyst.

Andrew Cody, Cody Opal, Melbourne, Australia, for copies of the book *The Opal Story: A Guidebook* (with DVD) by Andrew and Damien Cody, to sell at the Gem-A Conference, which raised a total of £630.

Roy Duran, Finer Jewelry Inc., Chicago, Illinois, USA, for assorted orange and colour-change sapphires; small Colombian emerald crystals; a carved amethyst; a jadeite bead; cabochons of synthetic ruby, tourmaline and ‘white garnet’; and faceted aquamarine, garnet, peridot and sapphire.

Kwong Pui Ho (John Ho), Yangon, Myanmar, for assorted Ammolite, chrome tourmaline, hackmanite, thorite and ruby-in-quartz; rough amber, apatite, corundum, gypsum, jadeite, mica, moonstone, pollucite and tourmaline; crystals of spinel and zircon; cabochons of hematite, kyanite, opal and pargasite; and faceted quartz, spinel and tanzanite.

Alistair Laidlaw and Christine Marsden, Fort Augustus, Scotland, for a copy of *Dreams of Diamonds* authored by them.

Bill Larson, Palagems.com, Fallbrook, California, USA, for rough pieces of iridescent andradite from Mexico and a slab of jadeite from Russia.

Claire Mitchell FGA DGA, London, for a reconstituted malachite/azurite, two reconstituted turquoises, two sugilite simulants, and rough and cabochon-cut samples of omphacite jade from Val Pellice-Alpi Cozie, Piemonte-Nord, Italy.

Dominic Mok FGA DGA, AGII, Hong Kong, for a jadeite colour master set guide.

Saeko Nasao, Fukushima, Japan, for rough opal.

Adolf Peretti FGA, GemResearch Swisslab Ltd., Lucerne, Switzerland, for four issues of his book *Contributions to Gemology* (Nos. 4, 5, 7 and 11) to sell at the Gem-A Conference, which raised a total of £290.

Prof. Chiu Mei Ou Yang FGA, Hong Kong Institute of Gemmology, for a selection of jadeites of various colours and trade names.

Michiko Shimomura FGA, Tokyo, Japan, for a copy of *The Book of the Pearl: The History, Art, Science and Industry of the Queen of Gems* by George Frederick Kunz and Charles Hugh Stevenson.

Tay Thye Sun FGA, Far East Gemological Laboratory, Singapore, for several pieces of tumbled amber.
In the Gem-A examinations held in January, February and June 2015, 413 students qualified in the Gemmology Diploma examination, including 36 with Distinction and 51 with Merit, and in the Foundation Certificate in Gemmology examination 606 qualified. In the Gem Diamond examination 135 qualified, including 19 with Distinction and 22 with Merit.

In the Gemmology Diploma examinations the Christie’s Prize for Gemmology for the best candidate of the year was awarded to Mei Mei Sit of Central, Hong Kong. The Anderson Bank Prize for the best set of theory papers was awarded to Emilie Disner of Geneva, Switzerland. The Read Practical Prize for excellence in the practical examination was awarded to Ka Yi Man of Hong Kong.

In the Foundation Certificate in Gemmology examination, the Anderson Medal for the candidate who submitted the best set of answers which, in the opinion of the examiners, were of sufficiently high standard, was awarded to Christina Khoudian of Colchester, Essex.

In the Diamond Diploma examination, the Bruton Medal for the best set of theory answer papers of the year was awarded to Valentina Molon of Varese, Italy.

The Deeks Diamond Prize for excellence in the Diamond Practical examination, sponsored by Dominic Mok from AGIL, Hong Kong, was awarded to Louise Van Colen of Montreal, Quebec, Canada.

The Tully Medal was not awarded.

The names of the successful candidates are listed below.

Examinations in Gemmology

Gemmology Diploma

Qualified with Distinction
Aron-Brunetiere, Patricia, Raray, France
Arrive, Elodie Jacquinot, Annecy, France
Bai Qing, Beijing, P.R. China
Beaumont, Elizabeth, Montreal, Quebec, Canada
Chow Hiu Yan Bona, Central, Hong Kong
Griziot, David, Marseille, France
Guay, Richard, Saint-Justin, Quebec, Canada
Herbin, Thomas, Léssigny, France
Ito, Claire, Carlsbad, California, USA
Jacin, Irina, Noisy-le-Sec, France
Jonas, Helen C., Shellingford, Oxfordshire
Lai Hsin Han, Kaohsiung City, Taiwan, R.O. China
Lam Wai Chun, Tuen Mun, Hong Kong
Li Huan, Beijing, P.R. China
Liu, Dan, Yongxiu, Jiangxi, P.R. China
Nan Bo refugee, Beijing, P.R. China
Qi Zhaoxiu, Beijing, P.R. China
Qiao Lei, Beijing, P.R. China
Quan Xiaoyun, Beijing, P.R. China
Reich, Mary, Albuquerque, New Mexico, USA
Ren Weina, Beijing, P.R. China
Shen Jingyao, Beijing, P.R. China
Sit Mei Mei, Central, Hong Kong
Smith, Fiona, Hoddesdon, Hertfordshire
Soonthorntanikul, Wasura, Bangkok, Thailand
Tian Xiuang, Beijing, P.R. China
Wang Tian Xin, Tian Keng Leng, Hong Kong
Williamson, Anna Frances, Hamilton, New Zealand
Wu Oi Lam, Kwai Chung, Hong Kong
Ying Zongqi, Le Pontet, Vaucluse, France

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Oake, Shoko, Tokyo, Japan
Okubo, Emi, Sagamihara City, Kanagawa, Japan
Okuda, Ayako, Tokyo, Japan
Oomatsu, Akira, Tokyo, Japan
Paiwand, Abdul Rahim, Edmonton, Alberta, Canada
Parkin, Charlotte Hannah, Caterham, Surrey
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Zhu, Xiaofei, Shanghai, P.R. China
Zhu, Yuenan, Hangzhou, Zhejiang, P.R. China
Zou, Ran, Beijing, P.R. China

Foundation Certificate in Gemmology

Qualified
Abbassi, Matin, Highgate, London
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Aiken, Juliette, London
Allen, Pixie, Birmingham, West Midlands
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Araguiz Romero, Claudia Carola, Villars-sur-Glâne, Switzerland
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Chan Kam, Tsuen Wan, Hong Kong
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Dharmasiri, Anuruddha, Colombo, Sri Lanka
Dhunna, Divjot Singh, Punjab, India
Dieu De Bellefontaine, Mary, Billericay, Essex

Gem-A Notices

727
Katsakiori, Konstantina, Nea Smyrni, Greece
Ke Ding, Beijing, P.R. China
Kei Man Lai, Tsing Kwan O, Hong Kong
Kenouche, Naguib, Neudilly-sur-Seine, France
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Lu Yina, Hangzhou, Zhejiang, P.R. China
<table>
<thead>
<tr>
<th>Name</th>
<th>City/Location</th>
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<tbody>
<tr>
<td>Luete, Peggy</td>
<td>Neuilly-Plaisance, France</td>
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<td>Lui Wing-Tak</td>
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<td>Muskin, Sarah</td>
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730
Yeung Woon Ying, Maggie, Tsing Yi, Hong Kong
Yin Shihui, Ningbo City, Zhejiang, P.R. China
Yin Zhenzhong, Poissy, France
Yip Kar Men, Wan Chai, Hong Kong
Yoda, Yuko, Tokyo, Japan
Yu Ka Man, Kowloon, Hong Kong
Yu Shin Yang, Taipei City, Taiwan, R.O. China
Yu Tzu Fang, Zhudong, Hsinchu, Taiwan, R.O. China
Yu Yinglei, Beijing, P.R. China
Yuan Hang, Shanghai, P.R. China
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Yung Yat Kwok, Yuen Long, Hong Kong
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Zhang Jie, Beijing, P.R. China
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Zhang Lingxue, Guilin, Guangxi, P.R. China
Zhang Luqing, Shenyang City, Liaoning, P.R. China
Zhang Mei, Beijing, P.R. China
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Zhang Yan, Guangzhou, Guangdong, P.R. China
Zhang Yanling, Shanghai, P.R. China
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Zhang Yixuan, Beijing, P.R. China
Zhang Yu, London
Zhang Zhizhong, Beijing, P.R. China
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Zhao Xinyi, Beijing, P.R. China
Zhao Yanhong, Shanghai, P.R. China
Zhao Yuan, Shanghai, P.R. China
Zheng Chenyu, Nagoya City, Aichi, Japan
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Zhong Yuanyuan, Beijing, P.R. China
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Zhou Meng, Beijing, P.R. China
Zhou Quan, Beijing, P.R. China
Zhou Yurui, Tianjin, P.R. China
Zhou Zihan, Beijing, P.R. China
Zhou Ziyang, Guangzhou, P.R. China
Zhu Qianwen, Shanghai, P.R. China
Zhu Shichao, Guilin, Guangxi, P.R. China
Zhu Yuanhua, Shanghai, P.R. China
Zhu Yun You, Taoyuan City, Taiwan, R.O. China
Zhu Zilin, Beijing, P.R. China
Zhuang Shao Wei, Qingdao, Shandong Province, P.R. China
Zwick, Annette, London

Diamond Diploma Examination

Qualified with Distinction
Ashri, Atul, Reading, Berkshire
Beard, Thomas Whitbread, Eastbourne, East Sussex
Chan Hiu Ching, Shatin, Hong Kong
Cheer, Peter Richard, Somerton, Somerset
Lai Ka Man, Mayfair, London
Leung Ying, Evie, Tsing Yi, Hong Kong
Li Hiu Ying, Choi Wan, Hong Kong
Lineker-Mobberley, Maryanne, Bridgnorth, Shropshire
Molton, Valentina, Varese, Italy
Moorhead, Lisa, London
Newson, John Frederick, Calne, Wiltshire
Perry, Fran, Biggleswade, Bedfordshire
Ruddie, Elaine, London
Saleem, Melanie, Manchester, Greater Manchester
Sandum, Mark Antony, Bedale, North Yorkshire
Shaw, Stephanie Anne, London
Williams, Kathryn Ann Jenevora, Dover, Kent
Wyer, William, Wilmcote, Northampton
Yiu King Ting, Eric, Kowloon, Hong Kong

Qualified with Merit
Boyce, Georgina Elizabeth, London
Chu Pui Suen, Sham Shui, Hong Kong
Foxwell, Kim, Twickenham, Middlesex
Fritz, Eric, Tucson, Arizona, USA
Fung Hang Shun, Jessica, Tai Po, Hong Kong
Gonzalez, Olga, New York, USA
Harries, Rebecca, Long Ditton, Surrey
Jiang Haijing, Sai Ying Pun, Hong Kong
Le, Wai Hang, Lai Chi Kok, Hong Kong

Qualified
Lo Hau Yin, Kowloon, Hong Kong
Lo On Ki, Tsuen Wan, Hong Kong
Marshall, Georgia Black, Meopham, Kent
Nash-Wilson, Jake, Bristol
Rexworthy, Simon Ramsay, Market Drayton, Shropshire
Spencer, Sally Jane, Didcot, Oxfordshire
Steele, Sarah, York, Yorkshire
Tang Tiankai, Ningbo, Zhejiang, P.R. China
Velickaite, Akvile, London
Walker, Susan, Elwood, Victoria, Australia
Wu Weiran, Beijing, P.R. China
Yip Pui Sze, Tai Po, Hong Kong

Qualified with Merit
Boyce, Georgina Elizabeth, London
Chu Pui Suen, Sham Shui, Hong Kong
Foxwell, Kim, Twickenham, Middlesex
Fritz, Eric, Tucson, Arizona, USA
Fung Hang Shun, Jessica, Tai Po, Hong Kong
Gonzalez, Olga, New York, USA
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Le, Wai Hang, Lai Chi Kok, Hong Kong
Zhang Min Yu, Taoyuan City, Taiwan, R.O. China
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Zhu Yuanhua, Shanghai, P.R. China
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Zhu Zilin, Beijing, P.R. China
Zhuang Shao Wei, Qingdao, Shandong Province, P.R. China
Zwick, Annette, London

Qualified
Ball, Gareth, Letterkenny, County Donegal, R.O. Ireland
Bowkett, Alexandra, Stroud, Gloucestershire
Bullmore, Elizabeth Mary, Birmingham, West Midlands
Callan, George, London
Chan Im Fan, Central, Hong Kong
Chan Ka Ling, Tin Shui Wai, Hong Kong
Chan Lap Yee, Shenzhen, Hong Kong
Chan Nga Fong, Macau, P.R. China
Chan Tak Wai, Shatin, Hong Kong
Chau Kam Chi, Kowloon, Hong Kong
Cheang Chi Ioi, Macau, P.R. China
Chen Xiao Qin, Kwai Chung, Hong Kong
Cheng Hei Lam, Tai Po, Hong Kong
Cheng Shu, Shenyang City, Liaoning, P.R. China
Cheng Yi, Shanghai, P.R. China
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Zhang Yu, London
Zhang Zhizheng, Beijing, P.R. China
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Zhao Yuan, Shanghai, P.R. China
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Zhu Yuanhua, Shanghai, P.R. China
Zhu Yun You, Taoyuan City, Taiwan, R.O. China
Zhu Zilin, Beijing, P.R. China
Zhuang Shao Wei, Qingdao, Shandong Province, P.R. China
Zwick, Annette, London
Roger Leon Merk died on 3 November 2015.
Roger was one of a kind, an exceptional man, husband and friend. No tragedies stopped his zeal to live his life to the fullest. He lost his father at 6, his grandfather at 10, and his mother at 17. His Aunt Myrtle took him in and created a loving, caring home in San Diego, and helped him to become the educated man he was. Her husband Chuck got him interested in gems and minerals. He took gemmology to another level; he became an icon, educator, collector and mentor, with a particular passion for jade.

Tragedy struck when his heart failed at a young age. He was lucky enough to receive a heart transplant that gave him another 20 years.

Roger organized the annual Sinkankas Symposia (13 in all) in honour of John Sinkankas. These themed events were held at the Geological Institute of America campus in Carlsbad, California, USA, and were co-sponsored by the San Diego Mineral & Gem Society.

Roger is survived by a wealth of family and friends, his wife, this aunt, another aunt, his brothers, sister, and cousins.

Myrtle Peterschick

——

Douglas Brill FGA (D.1987), Halifax, West Yorkshire, died on 2 August 2015.
Ann P. Sabina Stenson FGA, Ottawa, Ontario, Canada, died recently.
Shine Bright

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# Learning Opportunities

## CONFERENCES AND SEMINARS

<table>
<thead>
<tr>
<th>Event Description</th>
<th>Date</th>
<th>Location</th>
<th>Website</th>
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<tr>
<td>Note: Includes a seminar programme.</td>
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<tr>
<td>AGA Cutting Edge Conference</td>
<td>3 February 2016</td>
<td>Tucson, Arizona, USA</td>
<td><a href="http://accreditedgemologists.org/currevent.php">http://accreditedgemologists.org/currevent.php</a></td>
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<td>Note: Includes a seminar programme.</td>
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<td>PDAC International Convention, Trade Show &amp; Investors Exchange</td>
<td>6–9 March 2016</td>
<td>Toronto, Ontario, Canada</td>
<td><a href="http://www.pdac.ca/convention">www.pdac.ca/convention</a></td>
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<tr>
<td>Session of interest: Diamonds in Southern Africa: Back to the Beginning</td>
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<tr>
<td>The Open Forum on Sustainability &amp; Responsible Sourcing in the Jewelry Industry</td>
<td>10–13 March 2016</td>
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New York, New York, USA
www.jewelryindustrysummit.com

Amberif—International Fair of Amber, Jewellery and Gemstones
16–19 March 2016
Gdansk, Poland
www.amberif.amberexpo.pl/title,SEMINAR,pid,1284.html

Note: Includes a seminar programme.

AGS Conclave
13–16 April 2016
Washington DC, USA
www.americangemsoceity.org/conclave2016

Swiss Gemmological Society Conference
17–19 April 2016
Magglingen, Switzerland
www.gemmologie.ch

Arusha Gem Fair
19–21 April 2016
Arusha, Tanzania
www.arushagemshow.com

Note: Includes a seminar programme.

Scottish Gemmological Association Conference 2016
29 April–2 May 2016
Peebles, Scotland
www.scottishgemmology.org/conference

2nd Mediterranean Gemmological and Jewellery Conference
7–9 May 2016
Valencia, Spain
www.gemconference.com

30th Annual Santa Fe Symposium
15–18 May 2016
Albuquerque, New Mexico, USA
www.santafesymposium.org

SNAGnext
19–21 May 2016
Asheville, North Carolina, USA
www.snagmetalsmith.org/events/snagnext

10th International Conference on New Diamond and Nano Carbons
22–26 May 2016
Xi’an, China
http://ndnc2016.xjtu.edu.cn

Compiled by Georgina Brown and Brendan Laurs
Learning Opportunities

Northwest Jewelry Conference
12–14 August 2016
Seattle, Washington, USA
www.northwestjewelryconference.com

46th ACE IT Annual Mid-Year Education Conference
13–16 August 2016
Newport Beach, California, USA
www.najaappraisers.com/html/conferences.html

2016 International Appraisers Conference
11–14 September 2016
Boca Raton, Florida, USA
www.appraisers.org/Education/conferences

IRV Loughborough Conference
17–19 September 2016
Loughborough, UK
www.jewelleryvaluers.org/Loughborough-Conference

EXHIBITS

Europe

Celts: Art and Identity
Until 31 January 2016
British Museum, London
www.britishmuseum.org/whats_on/exhibitions/celts.aspx

Urartian Jewellery Collection
Until 31 January 2016
Rezan Has Museum, Istanbul, Turkey

Brilliant! – Jewellery – Photograph – Sound
Until 31 January 2016
The National Museum of Finland, Helsinki, Finland
www.kansallismuseo.fi/en/nationalmuseum/exhibitions/temporary#brilliant_jewelry

Fitting and Befitting—Fibulae and Brooches
Until 21 February 2016
Schmuckmuseum, Pforzheim, Germany
www.schmuckmuseum.de/flash/SMP_en.html

Bejewelled Treasures: The Al Thani Collection
Until 28 March 2016
Victoria and Albert Museum, London
www.vam.ac.uk/content/exhibitions/exhibition-bejewelled-treasures-the-al-thani-collection

Take it Personally [Jewellery and Adornment]
Until 1 June 2016
Museum of Cultural History, Oslo, Norway
www.khm.uio.no/english/visit-us/historical-museum/temporary-exhibitions/2015/this-is-personal.html

Open Space—Mind Maps. Positions in Contemporary Jewellery
Nationalmuseum Design, Stockholm, Sweden
www.nationalmuseum.se/sv/English-startpage/Exhibitions/Upcoming-Exhibitions

A Motley Crew—New Pieces from the Collection
18 March 2016–12 June 2016

North America

The Glassell Collections of African, Indonesian and Pre-Columbian Gold
Until 30 January 2016
Museum of Fine Arts, Houston, Texas, USA
www.mfah.org/art/collections/Glassell-Gold-Collections

Turquoise, Water, Sky: The Stone and Its Meaning
Until 2 May 2016
Museum of Indian Arts & Culture, Santa Fe, New Mexico, USA
www.indianartsandculture.org/current?&eventID=1989

A Passion for Jade: The Heber Bishop Collection
Until 19 June 2016
The Metropolitan Museum of Art, New York, New York, USA
www.metmuseum.org/exhibitions/listings/2015/passion-for-jade

Variations on a Theme: 25 Years of Design from the AJDC
Until July 2016
Gemological Institute of America, Carlsbad, California, USA
www.gia.edu/gia-museum-variations-theme-25-years-design-AJDC


Heavenly Bodies—The Sun, Moon and Stars in Jewellery
8 July–30 October 2016
Schmuckmuseum, Pforzheim, Germany
www.schmuckmuseum.de/flash/SMP_en.html

Elements: From Actinium to Zirconium
Until 26 February 2017
Ulster Museum, Belfast, Northern Ireland
Thunderbirds: Jewelry of the Santo Domingo Pueblo
Until 5 September 2016
Abby Aldrich Rockefeller Folk Art Museum, Williamsburg, Virginia, USA
www.colonialwilliamsburg.com/do/art-museums/rockefeller-museum/thunderbirds-jewelry

Fabergé from the Matilda Geddings Gray Foundation Collection
Until 27 November 2016
The Metropolitan Museum of Art, New York, New York, USA
www.metmuseum.org/exhibitions/listings/2011/faberge

Glitterati. Portraits & Jewelry from Colonial Latin America
Until 27 November 2016
Denver Art Museum, Denver, Colorado, USA
www.denverartmuseum.org/exhibitions/glitterati

Arts of Islamic Lands: Selections from The al-Sabah Collection, Kuwait
Until 29 January 2017
Museum of Fine Arts, Houston, Texas, USA
www.mfah.org/exhibitions/arts-islamic-lands-selections-al-sabah-collection

Gold and the Gods: Jewels of Ancient Nubia
Until 14 May 2017
Museum of Fine Arts, Boston, Massachusetts, USA
www.mfa.org/exhibitions/gold-and-gods

City of Silver and Gold: From Tiffany to Cartier
Ongoing
Newark Museum, New Jersey, USA
www.newarkmuseum.org/SilverAndGold.html

Fabergé: From a Snowflake to an Iceberg
Ongoing
Houston Museum of Natural Science, Texas, USA
www.hmns.org/exhibits/special-exhibitions/faberge-a-brilliant-visions

Gemstone Carvings
Ongoing
Houston Museum of Natural Science, Texas, USA
www.hmns.org/exhibits/special-exhibitions/gemstone-carvings

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

Jewelry, from Pearls to Platinum to Plastic
Ongoing
Newark Museum, New Jersey, USA
www.newarkmuseum.org/jewelry

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

Australia

Opals
Until 14 February 2016
South Australian Museum, Adelaide, South Australia

A Fine Possession: Jewellery and Identity
Until 22 May 2016
Powerhouse Museum, Sydney, New South Wales, Australia
www.powerhousemuseum.com/exhibitions/jewellery

OTHER EDUCATIONAL OPPORTUNITIES

Gem-A Workshops and Courses
Gem-A, London

Lectures with The Society of Jewellery Historians
Burlington House, London, UK
www.societyofjewelleryhistorians.ac.uk/current_lectures
23 February 2016
Jo Whalley—A Journey to India: The Jewellers’ Art Revealed
26 April 2016
Henriette Lidchi—Navajo and Pueblo Jewellery of the American Southwest
28 June 2016
Neil Wilkin—Bronze Age Bodily Adornment: How was It Made and Worn
27 September 2016
Galina Korneva—The Grand Duchess Maria Pavlovna’s Contacts with Paris Jewellers and her Collection of Treasures
New Media

Tourmaline—Fascinating Crystals with Fantastic Inner Worlds


In the preface of this impressive book, the author states: “The observer might become meditatively immersed in the tourmaline paintings and may go on imaginative trips into the new landscapes.” Indeed the photographs in this book (many of which resemble beautiful paintings) certainly transport the reader to another world—the colourful patterns seen in slices of tourmaline.

The book is printed on high-quality paper, is beautifully designed and laid-out, and the reproduction quality of the photos is excellent. Many of the tourmaline crystals are shown before they were sliced and are accompanied by photographs of the resulting slices (or series of slices). Selected full-page enlargements of some of the more spectacular portions of the slices further reveal amazing colours and patterns that would mostly go unseen without magnification. A black background is used on every page not containing a full-page photo, allowing the images to truly ‘pop’. The limited amount of text (always appearing on left-hand pages) is well written and easy to understand for non-specialists. Different font colours are used for English (yellow) and German (white), making it easy for the reader to find their preferred language.

The author has arranged the sections of the book according to the main cause of the dominant patterns shown by the slices:

- ‘From Black Crystals to TurmalinArt’ presents a series of examples that reveal the inner beauty of black tourmaline crystals when thin sections of them are prepared perpendicular (and in some cases, parallel) to the c-axis. The author explains how he saws the crystals into slices and polishes one side before mounting them on glass slides for final grinding and polishing until the optimal colour appearance is displayed (typically only 0.1–0.01 mm in thickness).

- ‘The Structure of Tourmalines’ briefly reviews the crystal structure of the mineral to help put the geometric patterns seen in slices into context. Also included are photos of crystal specimens showing myriad variations in colour and morphology.

- ‘The Color Palette of the Tourmalines’ illustrates the tremendous variety of colours seen in faceted gemstones and in crystals. Simplified explanations of the causes of colour are provided.

- ‘The Growth of Tourmaline Crystals’ contains many attractive diagrams and photos of tourmaline specimens to illustrate their crystallization process in granitic pegmatites. (Tourmaline formation in metamorphic rocks is not covered.)

- ‘The Structures of Crystal Forms’ provides an excellent correlation between the various crystal faces and the patterns seen in slices cut perpendicular to the c-axis.

- ‘Rim Structures’ focuses on features seen within the concentrically zoned portions of slices, which correspond to prism faces.

- ‘Oriented Overgrowth’ displays the complex mosaic structures seen in slices when a crystal is overgrown by a series of needles and tubes parallel to the c-axis. Also shown are features attributed to skeletal overgrowths.

- ‘Delta Structures’ portrays a specific type of triangular zoning in tourmaline slices that corresponds to the localized growth of steeper pyramidal faces. The resulting features are particularly reminiscent of landscapes, especially when they are influenced by dislocations in the crystal.

- ‘Trigonal Dislocations’ provides examples of the complex patterns that result when defects in the lattice of a growing crystal propagate as dislocations.

- ‘Division into Parallel Aggregates’ shows interesting mosaic networks that result when a growing crystal gradually or abruptly changes into an aggregate structure that is oriented parallel to the c-axis.

- ‘The Healing of Broken Tourmalines’ records periods of regrowth in ‘bent’ and broken crystals, including the formation of parallel tubes that may create chatoyancy in cabochons.

- ‘Naturally Corroded Tourmaline Crystals’ depicts geometrical etch pits and hillocks
resulting from post-grown dissolution, beautifully revealed in photomicrographs

taken in reflected light.

- ‘Healing of Corroded Tourmalines’ shows the results of further crystal growth (often by
tourmaline of a different colour) after a period of dissolution.

- ‘Healed Corrosion of Cavities’ displays some particularly abstract patterns that are produced
when irregular areas of dissolution that penetrated deep within a crystal are filled-in
by subsequent tourmaline growth.

At the conclusion of the book, the author provides a brief bibliography of tourmaline monographs (with
a full listing of tourmaline literature supplied at http://
www.pfeil-verlag.de/ef1.html), as well as an index.

While it is easy to become pleasurably absorbed in
the richness of the photography, the scientific value of
this book should not be overlooked. Through the use
of helpful diagrams and photographic comparisons
of crystals before and after slicing, as well as neatly
arranged series of slices that were obtained from the
same crystal, the reader comes away with a much
better understanding of the complex crystal growth
history of tourmaline.

This reviewer noted only a few very minor errors
in the text: p. 42 indicates that the blue colour of
Paraiba tourmaline is due to 4% copper, while much
lower amounts of Cu are typical (i.e. ~0.5–2 wt.%
CuO); p. 44 gives the location of Sweet Home mine
rhodochrosite crystals as Utah, rather than Colorado;
p. 160 mentions earthquakes as the cause of broken
tourmalines that subsequently undergo regrowth in
pegmatite pockets, but such breakage is commonly
ascribed to pocket rupture due to fluid overpressure;
and throughout the book verdelite (green tourmaline)
is referred to as ‘verdilithe’. In addition, a table-of-
contents page would have been helpful for navigating
the book.

It is rare to encounter such an effective and
inspirational melding of art and science applying
to any mineral. This book is sure to please
tourmaline aficionados, and also will appeal to many
mineralogists, gemmologists, photographers and those
who appreciate the beauty of the natural world.

Brendan M. Laurs

Fei Cui Jade—A Stone & a Culture

By Chiu Mei Ou Yang and
Humphrey Yen, 2015.
Shanghai Translation
Publishing House,
Shanghai, China,
248 pages, illus.,
HK$480.00.

It is rare in the marketplace to see a comprehensive
book on jadeite that is written in English. Both authors
have over 30 years of expertise studying jadeite, and
they present their information from a Chinese and a
gemstone professional point of view.

The reader soon learns that in China what we call
jadeite is referred to as fei cui. This term is said to
come from the Chinese name for the kingfisher, as
its feathers are so beautiful. The authors repeat the
term fei cui jade hundreds of times in the book, and
this reviewer found this a bit redundant, although it is
understandable that the authors wish to promote
the terminology used by the Chinese. Many countries
have colloquial names for various gem materials. For
instance, colourless topaz is often called gouttes d’eau
in Brazil, alluding to the appearance of drops of water.

The book is well laid out, and includes the
following chapters:

1. The Concept and Definition of Jade
2. The Occurrence of Deposits of Fei Cui Jade
3. Color and Other Important Factors in the
   Valuation of Fei Cui Jade
4. The Varieties of Fei Cui Jade
5. Classification of Rough Fei Cui Jade
6. The Processing Techniques and Classification
   of Finished Fei Cui Jade Products
7. Jade-like Minerals and Simulants
8. Artificial Treatments of Fei Cui Jade and Their
   Identification
9. Valuation of Fei Cui Jade
10. The Trending in Marketing of Fei Cui Jade

Each chapter contains a variety of interesting facts
and explanations, and many of these will be unfamiliar
to most Westerners. For instance, Chapter 3 starts with (1)
why jadeite comes in so many colours, and then points
out the differences between (2) the primary colouring
elements Fe, Cr and Mn, and the secondary colours
caused by oxidation and decomposition, and ends with
(3) the ‘base’ or ‘fabric’ of fei cui jade. This reviewer has
not seen such a compilation discussed previously. The
authors further provide a classification of six ‘bases’, and
the most amusing is “4) Cooked lotus root: Translucent
color like the cooked lotus root used in Chinese cuisine
usually with a slight pink or purple color. A cooked lotus
root base is not considered very good.”

The book contains approximately 380 colour
photographs, illustrations and diagrams. The first
10 full-page colour photos are excellent, and in this reviewer’s opinion they alone are probably worth the price of the book. Also present are several tasteful advertisements (full-page size and in colour) that are not terribly distracting.

When gem collectors and dealers consider the market value of coloured stones, a comparison with jadeite yields an interesting perspective. The jade market changed in 2006 when the Burmese government brought the first Chinese dealers into the auctions, and jadeite sales went from millions to billions of dollars within a few short years. By comparison, a recent emerald auction held by Gemfields generated US$40 million and made international headlines. When this is compared to the ~US$2.04 billion generated by a recent Burmese jade auction, one realizes this is 50 times the size of that emerald headline. There have been many billion-dollar-plus auctions of Burmese jadeite (see www.palagems.com/gem_news_burma_stats.php), making it the most important coloured stone in terms of sales during the past decade.

William Larson

OTHER BOOK TITLES*

**Coloured Stones**

*Amazonite: Mineralogy, Crystal Chemistry and Typomorphism*

*Bursztyn i Forma—Amber and Form*

**Jade, 3rd edn.**


**Lapis Lazzuli—Magia del Blu**

**Turquoise, Water, Sky: Meaning and Beauty in Southwest Native Arts**

**Diamonds**

*All About Diamonds*

**Clarity, Cut, and Culture: The Many Meanings of Diamonds**

**Gem Localities**

České a Moravské Vltavíny. Czech and Moravian Moldavite


**General Reference**

Crystallization and Science of Crystals

Drawings of Mineral Masterpieces

Introducing Mineralogy

Latest in Crystal Growth

Minerals and Their Localities, 3rd edn.
By Jan H. Bernard and Jaroslav Hyršl, 2015. Granit,
Prague, Czech Republic, 920 pages, ISBN 978-8072960989. £120 hardcover.

**The Munich Show / Mineralitage München: Theme Book Precious Stones**  

**Rocks, Gems, and Minerals**  

**Understanding Minerals and Crystals**  

**Instruments and Techniques**

**Infrared Spectroscopy of Minerals and Related Compounds**  

**Modern Luminescence Spectroscopy of Minerals and Materials, 2nd edn.**  

**Jewellery and Objets d’Art**

**Bejewelled: Treasures of the Al Thani Collection**  

**Everything You Need to Know about the Crown Jewels**  

**The Guy Ladrière Collection of Gems and Rings**  

**If these Jewels could Talk**  

**Indian Folk Jewellery: Designs and Techniques**  

**Jewellery 1970–2015: Bollmann Collection**  

**Jewels of Miriam Haskell**  

**The Lost Treasure of Leicestershire**  

**Not Too Precious**  

**Le Piture delle Antichità di Ercolano nelle Gemme del XVIII e XIX Secolo. The Paintings of the Antichità di Ercolano in 18th and 19th Century Gem-Carving**  

**Precious Materials in Asian History: Essays on Turquoise, Amber, Ivory, Diamond and Gold**  

**A Rothschild Renaissance: Treasures from the Waddesdon Bequest**  

**Schmuckmuseum Pforzheim: Museum Guide**  

**Stoned: Jewelry, Obsession, and How Desire Shapes the World**  

**Take This Ring: Medieval and Renaissance Rings from the Griffin Collection**  

**Töchter der Steppe, Söhne des Windes: Gold und Silber der Turkmenen**  
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Email: info@marcusmccallum.com
Website: www.marcusmccallum.com
Coloured Stones


Diamonds


Gem Localities


Colombian trapiche emeralds: Recent advances in understanding their formation. I. Pignatelli, G. Giuliani, D. Ohnstenetter, G. Agroisi, S. Mathieu, C. Morlot and Y. Brancquet, *Gems & Gemology*, 743
**Literature of Interest**


**Instruments**


**Miscellaneous**


**News Press**


**Organic Gems**


**Pearls**


Pearls


**Synthetics and Simulants**


**Treatments**


**Compilations**


**Gem News International**. Large star emerald • Faceted red rutile • ‘Star and cross’ quartz from Brazil • ‘Olive’ green serpentine cabochon • Petrified wood from Thailand and Myanmar • Coated rock crystal imitation of ruby • Cubic zirconia as peridot imitation • Coral inclusions in plastic • Hydrogrossular imitating jadeite • Impregnated and dyed turquoise • Tino Hammid obituary. *Gems & Gemology*, 51(3), 2015, 334–345, www.gia.edu/gems-gemology.*

**Lab Notes**. Graining in pink diamond • Yellow HPHT-treated rough diamond • Color-zoned emerald • Orange faceted esphorite • Large faceted hibonite • Dyed and natural green jadeite • Coated kornurupine beads • Assembled cultured blister pearl • Large abalone pearls • Irradiated green-blue CVD synthetic diamonds • Polished topaz imitating diamond rough. *Gems & Gemology*, 51(3), 2015, 312–322, www.gia.edu/gems-gemology.*

**Conference Proceedings**


Notes on changes from prior subject indexes:
• Author names are no longer listed alphabetically by name within this index, but they continue to be shown in parentheses in this subject index.
• Book reviews and reviews of other media are now listed alphabetically by title under the single heading ‘Book and other media reviews’, instead of being individually listed throughout the Index.
• The Abstracts section of The Journal has been replaced by Literature of Interest.

A
Adularescence
in moonstone from Austria (Chaipaksa)190
Agate
genesis of, video of lectures (Grabowski)469
see also Chalcedony
Alexandrite
from Brazil (Schmetzer)32–40
Almandine
from USA (Williams)286–287
see also Garnet
Amber
from Myanmar (Tay Thye Sun)606–615
newsletter from the International Amber Association
(Laurs)557
processing in Lithuania (Laurs)673–675
from Slovakian archaeological sites
(Kadlečíková)510–517
Amethyst
from Brazil (Williams)288–289
simulated by doublets from Germany (Henn)479–482
see also Quartz
Andradite
demantoid from Pakistan (Adamo)428–433
from USA (Laurs)96
see also Garnet
Apatite
colourless cat’s-eye, from Brazil (Laurs)8
cat’s-eye, from Namibia (Johnston)191
green—
from Kenya (Zwaan)289–290
from Mozambique (Chaipaksa)654
Apps. see Computer software
Aquamarine
from Ethiopia (Laurs)8–9
simulated by doublets from Germany (Henn)479–482
Arizona, see United States of America
Arkansas, see United States of America
Assembled gem materials
doublet—
‘modern’, from Germany and India (Henn)479–482
ruby, synthetic, with natural-appearing sheen
(Choudhary)110–111
peridot fragments in polymer (Choudhary)401–402
triplet, beryl, simulating Colombian emerald in jewellery
(Laurs)109
see also Amber; Asterism; Emerald simulants; Opal simulants
Asterism
in diamond (Hainschwang)306–315
in sapphire, diffusion-induced (Tay Thye Sun)576–578
in zircon (Krzemnicki)671–673
see also ‘star’ under specific gem materials
Austria
moonstone from, with adularescence (Chaipaksa)190
Axinite
colour-change, from Tanzania (Laurs)191–192
Azurite
with malachite from Peru (Hyršl)564
B
Backscattered electron imaging
of demantoid from Pakistan (Adamo)428–433
of jadeite, kosmochlor and omphacite in jade from Myanmar
(Franz)210–229
of maw-sit-sit from Myanmar (Franz)210–229
see also Scanning electron microscopy
Birefringence and dispersion ratio in visual optics (Hodgkinson)281–283
see also Crystallography; Refractive index; Strain; specific gem materials
Bisbeeite
with shattuckite from Democratic Republic of Congo
(Zwaan)663–666
Bobdownsite
from Canada, faceted (Tait)97
Book and other media reviews
Amateur Gemstone Faceting, Vol. 1 and Vol. 2 by Herbst
(Gavrilenko)457
Chelsea and Synthetic Emerald Filters Made Easy by Matlins (Fellows)268–269
Crystal Mountains by Starkey (Hodgkinson)372
Dallas Mineral Collecting Symposium 2013 DVD by
BlueCap Productions (Mychaluk)178–179
Dichroscopes Made Easy by Matlins (Fellows)268–269
The Eduard Josef Gübelin Story: The Art and Science of Gems
by Gübelin Foundation (Hughes)372–373
Eleventh Annual Sinkankas Symposium—Ruby, Revised edn. ed. by Thoresen (Laurs)457–458
Fei Cui Jade—A Stone & a Culture by Chiu Mei Ou Yang
(Larson)739–740
The Fundamentals of Mining for Gemstones and Mineral Specimens by Clainin (Dryland)80
Gem Testing Techniques by Hodgkinson (Fellows)637–638
Gemstones of Western Australia by Fetherston (Coenraads)174–175
Gemstones in Victoria by Birch (Coenraads)373–375
A Geologist Speculates by Saul (Harding)80–82
Geology of Gem Deposits, 2nd edn. ed. by Gevat (Lauris)48
The Handbook of Gemmology, 3rd edn. by Dominy (Fellows)551–552, announcement (Lauris)382
Imperial Jade of Burma and Mutton-Fat Jade of India by Samuels (Larson)175
Ivyry by Campbell Pedersen (Rongy)638
Jewelry Appraisal Handbook, 8th edn. by American Society of Appraisers (Carmona)639
London’s Lost Jewels: The Cheapside Hoard by Forsyth (Hodgkinson)260
Loupes Made Easy by Matlins (Fellows)268–269
Photoatlas of Gem Spectra for Gemmology Students ed. by Armstrong (Mitchell)552
Refractometers Made Easy by Matlins (Fellows)268–269
Ruby & Sapphire—A Collector’s Guide by Hughes (Bohme)176–177
Sea of Pearls: Seven Thousand Years of the Industry that Shaped the Gulf by Carter (Fellows)177
Splendour and Science of Pearls ed. by Dirlam (Strack)270
SSEF Diamond-Type Spotter and Blue Diamond Tester Made Easy by Matlins (Fellows)268–269
Terra Garnet by Yavorsky (Dixon)178
Thirteenth Annual Sinkankas Symposium—Peridot and Tourmaline—Fascinating Crystals with Fantastic Inner Thirteenth Annual Sinkankas Symposium—Opal ed. by Terra Garnet by Yavorsky (Dixon)178
Tourmaline—Fascinating Crystals with Fantastic Inner Worlds by Rustemeyer (Lauris)738–739
Twelfth Annual Sinkankas Symposium—Peridot and Uncommon Green Gem Minerals ed. by Thoresen (Lauris)459
Ultraviolet Lamps Made Easy by Matlins (Fellows)268–269
Wonders within Gemstones II by de Goutière (Hyršl)271; reply (de Goutière)374
The World of Tourmaline—The Gerhard Wagner Collection by Mauthner (Dryland)553
see also Other Book Titles

Brazil
alexandrite from Hematita (Schmetzer)32–40
amethyst from São Paulo State (Williams)288–289
apatite from, colourless cat’s-eye (Lauris)8
chrysoberyl from, purple to reddish purple (Schmetzer)32–40
kunzite from Urumuc mine, large crystal (Lauris)386
lepidolite from Araquá (Lauris)102–103
quartz from Bahia State, with dumortierite inclusions (Lauris)391–392
rhodochrosite from Minas Gerais State (Zwaan)473–475
tourmaline from Cruzeiro mine, new production (Lauris)106–107

Bridges, Campbell
discoverer of tsavorite (Bridges)230–241

C
California, see United States of America
Campbell, Ian
obituary (Rothorn)630–631
Canada
bobdownsite, faceted, from Yukon (Tait)97
diopsite, colourless, from Québec (Kzemnicki)291–292
Cat’s-eye, see Chatoyancy; specific gem materials
Chalcedony
carnelian from Slovakian archaeological sites (Kadlecikova)510–517
dyed to imitate amazoneite (Williams)303–304
genesis of, video of lectures (Grabowski)469
jasper from Slovakian archaeological sites (Kadlecikova)510–517
see also Agate; Chrysocolla; Quartz
Chatoyancy
in apatite—
from Brazil (Lauris)8
from Namibia (Johnston)191
in axinite, cat’s-eye, from Tanzania (Lauris)191–192
and ‘coffee-and-cream’ effect (Killingback)524–530
see also ‘cat’s-eye’ under specific gem materials
Chemical composition (quantitative, includes electron microprobe) of garnet—
demantoid from Pakistan (Adamo)428–433
grossular, tsavorite from Kenya and Tanzania (Bridges)280–281
pyrope-almandine, purple, from East Africa (Williams)656–658
of jadeite, kosmochlor and omphacite in Myanmar jade (Franz)210–229
of maw-sit-sit from Myanmar (Frantz)210–229
of wurtzite from Tanzania (Henn)669–671
see also Backscattered electron imaging; Spectrometry [various]; Spectroscopy [various]; specific gem materials
China
scheelite from Inner Mongolia (Williams)202–203
Chondrodite
from Tanzania (Clark)655
Chrysoberyl
from Brazil, purple to reddish purple (Schmetzer)32–40
cat’s-eye, with ‘coffee-and-cream’ effect (Killingback)524–530
from Myanmar (Schmetzer)434–438
see also Alexandrite
Chrysocolla
from Peru (Clark)9–10
from Spain (Lauris)472
see also Chalcedony
CIBJO
Blue Books online (Lauris)3
Coral Book online (Lauris)649
Citrine, see Quartz
Clarity enhancement, see Filling, fracture or cavity; specific gem materials
Classification, see Nomenclature and classification
Coating
of emerald with amorphous carbon (Choudhary)242–246 of quartz to simulate star sapphire (Mayerson)485–486; letter on (Ster)604
Collections, see Museums and gem collections
Colour change
axinite from Tanzania (Lauris)191–192
Colour grading, see Diamond; Grading
Colour zoning
in diamond, synthetic CVD, type Ib (Kitawaki)594–604
in fluorite from Myanmar (Hlaing)563–564
in sapphire, with golden sheen, reportedly from Kenya (Bui)678–691
in tourmaline from Kenya, Cr- and V-bearing (Williams)476–477
see also Growth structure/zoning
Coloured stones, see specific gem materials
Composite materials, see Assembled gem materials
Computed tomography, see X-ray computed microradiography
Computer software
mobile apps—
for coloured gemstone education (Lauris)383
for hallmarks, from Birmingham Assay Office (Lauris)393
for photometric microscopy of inclusions (Prince)188–189
spectroscopy spectra database (Lauris) 185
Specklin 32 (Lauris) 448–449
see also Digital imaging

Conference reports and information
Accredited Gemologists Association, 2014, Tucson
(Lauris) 75–76; Las Vegas (Roskin) 160; 2015, Tucson
(Lauris) 444–445; Las Vegas (Lauris) 533–534
Canadian Gemological Association, 2015 (Lauris) 712–713
CIBJO Congress, 2013 (Lauris) 92
Federation for European Education in Gemmology
(FEEG) Symposium, 10th (Gavrilenko) 73–75
Gem and Jewelry Institute of Thailand, 4th (Lauris)
446–447
Gem-A, 2014 (Lauris) 162, 350–351, 356; 2015 (Lauris)
716–718
Gemological Society of America, 2015 (Shigley) 718–719
Gemmological Society of Japan, 2014 abstracts
(Lauris) 279
Gemstone Industry & Laboratory Conference, 2015
(Lauris) 445
Geological Society of South Africa Kimberly Diamond,
2nd (Janse) 351–352
Instituto Gemológico Español (Spanish Gemological
Institute) 2014 Congress (Gavrilenko) 73–75
International Colored Gemstone Association Congress,
2015 (Lauris) 558
International Gemmological Conference, 34th
(Lauris) 622–626
Mallorca GemQuest 2015 (Lauris) 534–535
Mediterranean Gemmological and Jewellery Conference,
1st (Chapman) 626–627
National Association of Jewelry Appraisers, 41st Tucson
(Lauris) 76–77; 2014 Mid-Year (Fritz) 352–353
Pueblo Gem & Mineral Show lectures, audio recordings
(Lauris) 280
Santa Fe Symposium proceedings (Lauris) 280
Scottish Gemmological Association, 2014 (Fel-
lows) 157–158; 2015 (Hodgkinson) 535–537
Sinkankas Symposium, 12th (Lauris) 156–157; erratum 207;
proceedings book (Lauris) 459; 13th (Lauro) 532–533
Society of Geology Applied to Mineral Deposits, 13th
(Gualdi) 627–628
Swiss Gemmological Society, 2014 (Krzemnicki) 158–160;
2015 (Hügi) 537–539
World Diamond Symposium, 2014 (Lauris) 560
World Emerald Symposium, First (Rohert) 714–716
World of Gems, IV (Lauris) 353–354
see also Notices

Congo, Democratic Republic of the [formerly Zaire]
shattuckite and biseenite from (Zwaan) 663–666
toarmuline mining in (Lauris) 475–476

Coral
simulant, Strombus gigas shell beads (Disner) 572–574

Corundum
diffusion treated—
with beryllium (Emori) 130–137
with chromium (Smith) 486–488
filled with coloured lead glass (Henn) 111–112
see also Ruby; Sapphire

Country of origin
of emerald by photoluminescence spectroscopy
(Thompson) 334–343; letter (Schmetzer) 441–443;
reply (Thompson) 443
of pearls, cultured page 241 (Err) 89
see also individual gem localities

Crystallography
of asterism in diamond (Hainschwang) 306–315
of chrysoberyl—
from Brazil (Schmetzer) 32–40
from Myanmar (Schmetzer) 434–438
of diamond, CVD synthetic, with ‘tree ring’ growth
pattern (Yan Lan) 702–710
of ruby, trapiche from Myanmar (Lio) 660–662
see also Growth structure/zoning; Twinning

Cuts and cutting
historical facet designs collection (Lauris) 279; (Err) 383
see also Diamond, cuts and cutting of; Lapidary arts

CVD [chemical vapour deposition]-grown synthetic
diamond, see Diamond, synthetic

D
Diamond
asterism in (Hainschwang) 306–315
colour grading, see grading, colour
doublet (Grabowski) 460–469
grading—
clarity, objective (Cowing) 316–332
see also Diamond, cuts and cutting of
in industry in 2015, report from Antwerp World Diamond
Centre (Lauris) 649
nomenclature and disclosure standards for consumers
from ISO (Lauris) 650
radiation stains, green, as proof of limited heating
(Hainschwang) 306–315
with synthetic-like DiamondView pattern (Delaunay)
107–108
see also Diamond, cuts and cutting of; Diamond,
inclusions in; Diamond simulants; Diamond, synthetic;
Diamond treatment; DiamondView imaging; Grading;
Instruments

Diamond, coloured, see Diamond, synthetic; Diamond
treatment

Diamond, cuts and cutting of
carving, horse-head (Panjikar) 571–572
history of, in Portuguese jewels during 16th–18th
centuries (de Carvalho) 116–128
portions, DiaMension Axiom instrument for measuring
(Brosh) 1185
see also other Diamond entries

Diamond, inclusions in
characteristics in clarity grading (Cowing) 316–332
clouds, star-shaped (Hainschwang) 306–315
synthetic—
yellow CVD-grown, type Ib (Kitawaki) 594–604
yellow-brown HPHT-grown, melee (Delaunay) 16–18

Diamond simulants
synthetic moissanite, black (Caplan) 399–401
see also Assembled gem materials; Moissanite, synthetic

Diamond, synthetic
CVD—
blue, on market (Lauris) 382
colourless to near-colourless —
identification of (Scarani) 2
with ‘tree ring’ growth pattern (Yan Lan) 702–710
melee—
colourless (Hainschwang) 518–522
yellow (Hainschwang) 300–302
pink, on market (Lauris) 383
yellow type Ib (Kitawaki) 594–604
HPHT—
colourless type IIa, identification of (Scarani) 2
octahedral crystals (Lauris) 559
melee in parcel with natural—
CVD in parcel with natural—
HPHT (Delaunay) 16–18

Diamond treatment
HPHT, identification of colourless type IIa (Scarani) 2
temporary masking of body colour (Lauris) 469

see also Growth structure/zoning; Twinning

volume index
**DiamondView imaging**
- of diamond—
  - CVD synthetic, with 'tree ring' growth pattern (Yan Lan)702–710
  - natural with synthetic-like pattern (DeLaunay)107–108
  - synthetic CVD, yellow type Ib (Kitawaki)594–604
  - synthetic yellow-brown melee (DeLaunay)16–18
- of sapphire, green lead-glass-filled (Leeawatanaaksan)420–427

**Diffraction**, see Spectroscopy; X-ray diffraction analysis

**Diffusion treatment**
- of corundum—
  - with beryllium (Emori)130–137
  - with chromium (Smith)486–488
- of sapphire to induce blue colour and asterism (Tay Thye Sun)576–578
- of spinel with cobalt (Laurs)468

**Digital imaging**
- Sarine system (Brosh)91–92
- see also Computer software

**Diopside**
- from Canada, colourless (Krzemnicki)291–292
- from Kenya, colourless (Krzemnicki)291–292

**Dispersion**
- and birefringence ratio in visual optics (Hodgkinson)281–283

**Doublets**, see Assembled gem materials

**Dravite**, see Tourmaline

**Dumortierite**
- from Brazil, as inclusions in quartz (Laurs)391–392

**Dyeing**
- of chalcedony to imitate amethyst (Williams)303–304
- of grossular to simulate ruby (Panjikar)204–205
- of labradorite (Henn)113
- of cultured pearls (Segura)203–204
- of quartzite—
  - to imitate amethyst (Williams)303–304
  - to imitate bicoloured tourmaline (Hyrl)402
- see also Specific gem materials

**F**

**Faceting**, see Cuts and cutting; Diamond, cuts and cutting of; Lapidary arts

**Feldspar**
- amazonite, imitation, dyed quartzite and chalcedony (Williams)303–304
- labradorite, dyed (Henn)113
- moonstone, rainbow, from Malawi (Williams)200–201; simulant (Henn)111
- see also Rocks

**Filling, fracture or cavity**
- of corundum with coloured lead glass (Henn)111–112
- of emerald, synthetic (Choudhary)483–484
- of ruby—
  - with barium glass (Hainschwang)574–576
  - with coloured lead glass (Henn)111–112
- of ruby, sapphire, spinel and tourmaline, tested in Thailand (Laurs)383
- of sapphire (Leeawatanaaksan)420–427; (Panjikar)488–489; (Laurs)558
- see also Inclusions

**Flame structure**
- in shell, Strombus gigas simulating coral (Disner)572–574

**Flash effect**
- in sapphire, lead-glass-filled (Leeawatanaaksan)420–427; (Panjikar)488–489
- see also Filling, fracture or cavity

**Fluorescence, ultraviolet [UV]**
- of diamond to high-power broadband source (Hainschwang)306–315
- of diamond, synthetic CVD—
  - colourless melee mixed with natural (Hainschwang)518–522
  - colourless near-colourless, identification of (Sscarani)2
- of diopside, colourless, from Canada and Kenya (Krzemnicki)291–292
- of ivory, hornbill (Jie Liang)42–49
- of opal—
  - hyalite, daylight fluorescent (Fritsch)294–296; (Fritsch)490–508
  - natural and synthetic black (Hodgkinson)470–471
- of pearl, 'tagging' with holographic image (Segura)478–479
- of resin imitating hornbill ivory (Jie Liang)42–49
- of ruby with barium glass filling (Hainschwang)574–576
- of volcanic rock marketed as Saguaro Stone (Krzemnicki)567–569
- see also DiamondView imaging; Luminescence; Specific gem materials
Fluorescence, X-ray, see Luminescence; Spectroscopy, energy-dispersive X-ray fluorescence [EDXRF]

Fluorite
green—
from Pakistan (Zwaan)192–194
from Vietnam (Chaiapaks)194–195
from Myanmar, colour-zoned (Haing)563–564
from Slovakian archaeological sites (Kadlečíková)510–517

Fourier-transform infrared spectrometer [FTIR], see Spectroscopy, infrared

Fracture filling, see Filling, fracture or cavity

G
Garnet
pyrope-almandine, purple, from East Africa (Williams)656–658
from Slovakian archaeological sites (Kadlečíková)510–517
see also Almandine; Andradite; Assembled gem materials; Grossular; Pyrope; Spessartine

Gem collections, see Museums and gem collections

Gem localities, see Country of origin; specific countries; specific gem materials

Gem-A
Bachelor of Science with Honours Degree in conjunction with Birmingham City University (Anon)540
diploma equivalency agreement with the Gemmological Association of Australia (Anon)539
The Journal of Gemmology—coverage in Thomson Reuters database (Lauris)647
photographic competition results, 2014 (Anon)358
see also Conference reports and information; Gem-A Notices

Gem-A Notices (section of The Journal)
Gem-A awards, conferences, events, meetings, reports and other announcements; donations, gifts, sponsorships and other support to Gem-A 78, 162, 202, 357, 360, 448, 540–541, 629, 721–722, 723–733
see also Conference reports; Errata; Obituaries; Photographs

Gem and Jewelry Institute of Thailand (GIT) conference, 2014 (Lauris)446–447
field studies in Sri Lanka (Wathanakul)256–261
laboratory updates (Lauris)3–4, 382

Gem Testing Laboratory (Jaipur, India) newsletter online (Lauris)3, 92, 381, 558

Gemmological Institute of America (GIA)
Gems & Gemology cumulative PDF file(Lauris)558
scanning of rare books (Lauris)650

Geochronology
U-Pb age determination of inclusions in sapphire (Link)692–700

Geographical origin, see Country of origin; specific countries; specific gem materials

Germany
buchite natural glass from Eifel Mountains (Henn)562–563

GGTL (Gemlab GemTechLab) Laboratories newsletter (Lauris)3, 382

Galileo Galilei
history of his gem testing in Europe (Mottana)24–31

GIA, see Gemmological Institute of America

Glass
with hologram, mounted with opal from Ethiopia (Mazzero)205–206
 imitation—
of emerald, lead (Williams)398–399
of malachite (Hyrs)302–303

Gold
demand, 2014 (Lauris)382; 2nd quarter 2015 (Lauris)560
hallmarks—
app from Birmingham Assay Office (Lauris)93
development in India, report from World Gold Council (Lauris)560
inclusions in quartz (Lauris)101–102

Grading
colour of synthetic moissanite (Johnson)384–385
see also Diamond, grading; Diamond, cuts and cutting of

Greenland
tugtupite, recent production (Rohtert)395–397

Grossular [grossularite]
hessonite—
dyed to simulate ruby (Panjikar)204–205
from Somalia (Clark)203
from Kenya—
bicoloured (Zwaan)195–197
tsaanite, discovery and mining of (Bridges)230–241

Growth structure/zoning
in chrysoberyl from Brazil (Schmetzer)32–40
in ruby, synthetic, doublet with natural-appearing sheen (Choudhary)110–111
see also Crystallography; DiamondView imaging

H
Halite
blue, from USA (Lauris)102–103

Hammid, Tino
obituary (Cowing)631–632

Heat treatment
of ruby from Mozambique, low-temperature (Lauris)469
see also Diffusion treatment; specific gem materials

High-pressure, high-temperature [HPHT] growth, see Diamond, synthetic

High-pressure, high-temperature [HPHT] treatment, see Diamond treatment

History
of cuts, historical facet designs collection (Lauris)279; (Err)383
of diamond cut design in Portuguese jewels during 16th–18th centuries (de Carvalho)116–128
of garnet, tsavorite (Bridges)230–241
of gem testing by Galileo (Mottana)24–31
of pearl, freshwater, from Russia (Stack)580–592
of Portuguese jewels during 16th–18th centuries (de Carvalho)116–128
see also Jewellery and objets d’art

Holography
image for ‘tagging’ of pearls (Segura)478–479

Hyalite, see Opal

I
Illumination techniques, see Instruments; Lighting
Imitations, see Glass; specific gem materials imitated or simulated

Impregnation, see Filling, fracture or cavity; specific gem materials

Inclusions
in amber from Myanmar (Tay Thye Sun)606–615
in amethyst, fluid, from Brazil (Williams)288–289
in andradite, demantoid, from Pakistan (Adamo)428–433

of tanzanite (Tay Thye Sun)109–110
of tourmaline from Mozambique (Lauris)484–485
natural—
buchite from Germany (Henn)562–563
genes of, video of lectures (Grabowski)469
see also Assembled gem materials; Filling, fracture or cavity

of tanzanite (Tay Thye Sun)606–615
in assembled gem materials, peridot fragments in poly-
mer matrix (Choudhary)401–402
in chondrodite from Tanzania (Clark)655
in chrysoberyl—
from Brazil (Schmetzer)32–40
nail-head spicles, from Myanmar
(Schmetzer)434–438
and ‘coffee-and-cream’ effect in cat’s-eye cabochons
(Killingback)524–530
in corundum—
diffusion-treated (Emori)130–137; (Smith)486–488
glass-filled, see Filling, fracture or cavity
see also ‘in sapphire’
in emerald coated with amorphous carbon (Choudhary)
242–246
in emerald, synthetic—
filled fractures (Choudhary)483–484
quartz, synthetic (Choudhary)483–484
in feldspar, orthoclase from Austria (Chaipaksa)190
in fluorite, green, from Vietnam (Chaipaksa)194–195
in garnet, see ‘in andradite’; ‘in grossular’; ‘in spessartine’
glass—
buchite (natural) from Germany (Henn)562–563
lead, simulating emerald (Williams)398–399
in grossular—
bicoloured, from Tanzania (Zwaan)195–197
hessonite, dyed to simulate ruby (Panjikar)204–205
in jeremejevite (Smith)138–142
in kyanite from Tanzania (Zwaan)198–200
in mosandrite from Russia (Henn)565–566
in opal, daylight-fluorescent hyalite from Mexico
(Fritsch)490–508
in phenakite, perettiite-(Y), new mineral (Laurs)559
in quartz—
carbonate mineral, well-formed (Laurs)392–393
dumortierite, from Brazil (Laurs)391–392
fibres, radiating (Krzemnicki)296–298
gold (Laurs)101–102
lizardite (Rossman)98–99
in rhodochrosite from Brazil (Zwaan)473–475
in sapphire—
filled with green lead glass (Leechavanansuk)420–427
with golden sheen, reportedly from Kenya (Bui)
678–691
from Kenya (Mayerson)662–663
spessartine from Tanzania (Clark)105–106

treated—
diffusion (Tay Thye Sun)576–578
glass filled (Panjikar)488–489
zircon, age determination of (Link)692–700
in shattuckite (Choudhary)566–567
in spinel from Myanmar, negative octahedra and ura-
ninite (Boehm)6–7
in taaffeite from Myanmar (Leechavanansuk)144–148
in tanzanite, fluid with H2S (Rankin)11–12
in tourmaline from Rwanda (Henn)344–349
see also Diamond, inclusions in; Diamond, synthetic; Filling,
fracture or cavity; Growth structure/zoning; Photomicrography;

specific host gem and inclusion materials

Index of refraction, see Refractive index
Infrared spectroscopy, see Spectroscopy, infrared

Instruments
Alpha Diamond Analyzer (Laurs)91
Automated Meelec Screening device (Grabowski)467
DiaMasion Axios (Brosch)185
Diamond Fluorescence Imaging Mid-UV Laser system
(Hainschwang)467

DiamondCheck (Laurs)91
Gemlogis Taupe Diamond Segregator (Panjikar)648
GemmoFtir spectrometer (Scarani)279
M-Screen (Laurs)648
Presidium Gem Indicator (Laurs)381
Presidium Synthetic Diamond Screener (Laurs)648
spectrometer, EDXRF, portable (Herzog)404–418
see also Backscattered electron imaging; Computer
software; DiamondView imaging; Digital imaging;
Fluorescence, ultraviolet; Lighting; Magnetism; Micro-
scopic techniques; Photography; Photomicrography;
Scanning electron microscopy; Spectrometry
[Various]; Spectroscope; Spectroscopy [Various];
X-radiography; X-ray computed microtomography;
X-ray diffraction analysis; X-ray topography

Interference
colours in opal, daylight-fluorescent hyalite (Fritsch)
490–508

Internal growth structure, see Crystallography; Growth
structure/zoning

International Amber Association (IAA)
newsletter (Laurs)557

International Consortium of Gem-Testing Laboratories
(ICGL)
newsletter (Laurs)4, 93, 279, 382, 469, 649–650

Iridescence
in rainbow moonstone from Malawi (Williams)200–201

Ivy
hornbill, natural and imitation (Jie Liang)42–49
regulations proposed in U.S. (Laurs)558
resin imitation of hornbill (Jie Liang)42–49

J
Jade
from Myanmar (Franz)210–229
nomenclature (Franz)210–229
see also Jadeite; Kosmochlor; Omphacite

Jade simulants
in Myanmar (Hlaing)197–198

Jadeite
from Myanmar (Franz)210–229
see also Jade; Kosmochlor; Maw-sit-sit; Omphacite

Japan
Be-diffused corundum in (Emori)130–137

Jasper
genesis of, video of lectures (Grabowski)469
see also Chalcedony

Jeremejevite
large faceted (Smith)138–142

Jewelers Vigilance Committee (JVC)
Essential Guides series online (Laurs)4

Jewellery and objets d’art
beads and intaglios from Slovakian archaeological sites
(Kadlečíková)510–517
consumer preferences, presentation on (Laurs)650
diamond cuts in 16th–18th century jewellery and sacred
objects in Portugal (de Carvalho)116–128
hallmarks app from Birmingham Assay Office (Laurs)93
manufacturing technology, Santa Fe Symposium proceed-
ings (Laurs)280
Mirsayet ring, with Ethiopian opal and hologram in glass
(Mazzero)205–206

Responsible Jewellery Council progress report, 2015 (Laurs)650
silver, buying trends survey (Laurs)280
see also History

The Journal of Gemmology, see Gem-A
K
Kenya
apatite from (Zwaan)289–290
diopside, colourless, from (Krzemnicki)291–292
grossular, bicoloured, from Kambanga (Zwaan)195–197
sapphire from Kina (Mayerson)662–663
tourmaline, Cr- and V-bearing colour-zoned from (Williams)476–477
tsavorite from Scorpion mine and history of mining (Bridges)230–241
Kerez effect in tourmaline, green (Fellows)652–653
Kosmochlor in jades from Myanmar, microscopic studies of (Franz)210–229
see also Jade; Maw-sit-sit
Kyanite
blue, from Tanzania (Zwaan)198–200; polycrystalline (Krzemnicki)293–294
yellowish green, from Madagascar (Laurs)102–103
Kunzite from Brazil, large crystal (Laurs)386

L
Labradorite, see Feldspar
LA-ICP-MS, see Spectrometry, laser ablation–inductively coupled plasma–mass
Lapidary arts
see Cuts and cutting; Diamond, cuts and cutting of
Lighting
fibre-optic and ‘coffee-and-cream’ effect (Killing-back)524–530
see also Instruments, Microscopic techniques
Literature of Interest (section of The Journal)
Lizardite from South Africa, orange (Rossman)98–99; (Laurs)102–103
Localities, see Country of origin; specific countries; specific gem materials
Loupe, see Digital imaging
Luminescence of opal, hyalite, laser-induced (Fritsch)294–296; (Fritsch)490–508
see also DiamondView imaging; Fluorescence, ultraviolet [UV]

M
Madagascar
kyanite from (Laurs)102–103
ruby from Andilamena (Laurs)559
Magnetism
magnetic susceptibility of tourmaline (Feral)2
see also Instruments
Maine, see United States of America
Malachite
with azurite from Peru (Hyršl)564
glass imitation of (Hyršl)302–303
Malawi
rainbow moonstone from (Williams)200–201
Mass spectrometry, see Spectrometry, laser ablation–inductively coupled plasma–mass [LA-ICP-MS]; Spectrometry, mass; Spectrometry, secondary ion mass [SIMS]
Maw-sit-sit from Myanmar (Franz)210–229
see also Jade; Kosmochlor
McInnes, Catriona Orr
obituary (McInnes)541–542
Merk, Roger
obituary (PeterSchieck)733
Metals, see Gold
Mexico
opal, daylight-fluorescent hyalite, from Zacatecas (Fritsch)294–296; (Fritsch)490–508
Mica
lepidolite from Brazil blue, from USA (Laurs)102–103
Microscopic techniques
differential interference contrast (Renfro)616–620
see also DiamondView imaging; Growth structure/zoning; Inclusions; Instruments; Photomicrography
Microtomography, X-ray computed, see X-ray computed microtomography
Miller indices, see X-ray diffraction
Mineralogical Record
online reports of interest to gemmologists, 2014 (Laurs)469
Mogok, see Myanmar
Moissanite, synthetic
black, large (Caplan)399–401
colour grading of (Johnson)384–385
Moonstone, see Feldspar
Morganite
simulated by doublets from Germany (Henn)479–482
Mosandrite from Russia (Henn)565–566
Mozambique
apatite from (Chaipaksa)654
ruby from, low-temperature heat treatment of (Laurs)469
tourmaline—
purple, from Maraca (Zwaan)666–668 simulated by glass (Laurs)484–485
Museums and gem collections
Gem Museum opens in Singapore (Loke)560
MIM Mineral Museum, Beirut (Laurs)4
Natural History Museum, painite specimen from 1914 identified (Hart)10–11
Myanmar [Burma]
amber from (Tay Thye Sun)606–615
chrysocolla, nail-head spicules in (Schmetzer)434–438
tourmalite, colour-zoned, from (Hlaing)563–564
Gems Emporium, report of 52nd (Hlaing)578
jadeite from (Fritsch)210–229
jade-like materials from (Hlaing)197–198
kosmochlor jade from (Fritsch)210–229
maw-sit-sit from (Fritsch)210–229
Mogok mines (U Tin Hlaing)18–19; (Pezzotta)55–60; (Fritsch)61–67; (Laurs)387–388, 390–390
omphacite jade from (Franz)210–229
production and mining in (U Tin Hlaing)304
ruby from—
Mogok, marble-hosted mine, visit to (Laurs)387–388
Mong Hsu, trapiche (Liu)660–662
sapphire from, green (Smith)104–105
taaffeite from (Leelawatanasuk)144–148
tourmaline from (Laurs)668–669
zircon from, orange (Mayerson)397
N
Namibia
apatite from, cat’s-eye (Johnston)191
Nelson, James Bowman
obituary (Green)450–451
The Netherlands
pearls from Zeeland (Zwaan)150–155
Newsletters, see issuing organizations
Nigeria
tourmaline from, red (Laurs)569
Nomenclature and classification
of diamond, ISO standard (Laurs)650
of garnet, tsavorite (Bridges)230–241
of jades (Franz)210–229

Nuclear magnetic resonance, see Spectroscopy, nuclear magnetic resonance [NMR]

O

Obituaries
Brill, Douglas 733
Campbell, Ian (Rothon)630–631
Cobden, Felix Sydney 262, 366
Hammid, Tino (Cowing)450–451
McInnes, Catriona Orr (McInnes)541–542
Merk, Roger (PeterSchick)733
Nelson, James Bowman (Green)450–451
Sierstorpff, Monika Grafin Von Francken 366
Stenson, Ann P. Sabina 733
Vuillet á Ciles, Pierre (Gravier)366

Objets d'art, see Jewellery

Oiling, see Filling, fracture or cavity

Oligoclase, see Feldspar

Olivine, see Peridot

Omphacite
jade from Myanmar (Franz)210–229
see also Jade

Opal
black, from Australia, compared to synthetic
(Hodgkinson)470–471
from Ethiopia, mounted with hologram (Mazzero) 205–206
hyalite, daylight fluorescent, from Mexico
(Fritsch)294–296; (Fritsch)490–508
pink, with play-of-colour from USA (Laurs)390–391
prase, green, from Tanzania (Zwaan)658–660
Sinkankas Symposium on (Laurs)532–533

Origin, see Country of origin

Orthoclase, see Feldspar

Other Book Titles (section of The Journal)
82–83, 179–180, 271–272, 374–376; 459–461, 554,
639–640, 740–741

P

Paintie
specimen from 1914 identified at Natural History Museum
(Hart)10–11

Pakistan
demanoid from Balochistan (Adamo)428–433
fluorite, green, from Stak Nala (Zwaan)192–194
scheelite from (Zwaan)298–299

Pearl
baroque, historic ‘Sleeping Lion’ (Zwaan)248–253
freshwater, from Russia (Strack)580–592
from The Netherlands (Zwaan)150–155
newsletter, Margaritologia (Laurs)280, 558–559
presentations at Inhorgenta Munich jewellery show
(Laurs)280
quahog, purple, from USA (Laurs)16
structure of, reprinted 69–72
‘tagging’ with holographic image (Segura)478–479
X-radiography of (Zwaan)248–253

Pearl, cultured
aging of, treated with silver nitrate (Segura)203–204
identification of origin, page 241 (Err)89
inlaid with gem materials (Laurs)677
newsletter, Margaritologia (Laurs)280, 558–559
presentations at Inhorgenta Munich jewellery show
(Laurs)280
‘tagging’ with holographic image (Segura)478–479
X-radiography of saltwater with thick nacre (Segura)13–14
see also Shell; X-radiography

Perettiite-(Y)
new mineral as inclusion in phenakite (Laurs)559

Peridot
in polymer matrix (Choudhary)401–402
simulated by doublets from Germany (Henn)479–482
at Sinkankas Symposium, 12th (Laurs)156–157; erratum 207

Peru
chrysocolla chalcedony from (Clark)9–10
malachite-azurite from (Hyrl)564

Phenakite
see also Perettiite-(Y)

Photography
Gem-A competition results, 2014 (Laurs)358
methods of—
accessory clips (Laurs)381
DiaCam360 for diamond photography (Grabowski) 468
DiaPix high-definition system (Laurs)557
see also Photomicrography

Photoluminescence spectroscopy, see Spectroscopy, photoluminescence

Photomicrography, methods of
’smartphone camera (Boehm)6–7
‘stacking’ software for depth of field (Prince)188–189
see also Inclusions

Plagioclase, see Feldspar

Play-of-colour, see Opal

Pleochroism
in chrysoberyl from Brazil (Schmetzer)32–40
see also Colour change

Portugal
jewellery and sacred objects from 16th–18th centuries
(de Carvalho)116–128

Prehnite
simulated by doublets from Germany (Henn)479–482

Pyrrhalite, see Garnet

Pyrope-almandine, see Garnet

Pyrope-spessartine, see Garnet

Pyroxene group, see Diopside; Jadeite; Kosmochlor;
Omphacite

Q

Quartz
from Brazil with dumortierite inclusions (Laurs)391–392
citrine, smoky, from California (Laurs)201–202
coated to simulate star sapphire (Mayerson)485–486;
letter on (Stern)604
simulated by doublets from Germany (Henn)479–482
sphere, with well-formed inclusion (Laurs)392–393
‘trapiche’, sold as (Krzemnicki)296–298
from USA, large faceted (Laurs)99–101
see also Amethyst

Quartz, cryptocrystalline, see Agate; Chalcedony

Quartzite
dyed—
to imitate amethystine (Williams)303–304
to imitate bicoloured tourmaline (Hyrl)402

R

Radio frequency identification tagging (RFID)
of cultured pearls page 241 (Err)89

Refractive index
Kerez effect in green tourmaline (Fellows)652–653
false reading due to facet planes (Hodgkinson)94–95
see also Crystallography; specific gem materials

Resin
imitation of hornbill ivory (Jie Liang)42–49
### Responsible Jewellery Council
- reports and presentations, 2014 (Laurs)93; Annual Progress Report (Laurs)650

### Rhodochrosite
- from Brazil (Zwaan)473–475

### Rocks
- volcanic glass with calcite, marketed as Saguaro Stone (Krzemnicki)567–569
  - see also Jade; Jadeite; Maw-sit-sit; Quartzite

### Rose quartz
- see Quartz

### Rubellite
- see Tourmaline

### Ruby
- matrix specimen investigated with X-ray computed tomography (Bouts)50–54
  - fracture filled—
    - with barium glass (Hainschwang)574–576
    - with coloured lead glass (Henn)111–112
  - from Myanmar, mining and cutting in Mogok (Pezzotta)538–539
  - trapiche from Myanmar (Liu)660–662
  - see also Assembled gem materials; Corundum

### Ruby simulants
- grossular, dyed (Panjikar)204–205
  - synthetic overgrowth on corundum (Laurs)560
  - see also Assembled gem materials

### Ruby, synthetic
- assembled, doublet with natural-appearing sheen (Choudhary)110–111
  - overgrowth on corundum (Laurs)560
  - see also Assembled gem materials; Ruby, synthetic

### Russia
- mosandrite from (Henn)565–566
  - pearls from, freshwater (Strack)580–592

### Rwanda
- tourmaline from (Henn)344–349

### S

#### Saguaro Stone
- see Rocks

#### Sapphire
- blue, from Tanzania (Clark)105–106
  - diffusion-treated—
    - with Be (Emori)130–137
      - to induce blue colour and asterism (Tay Thye Sun)576–578
  - filled with glass—
    - green (Leelawatanasuk)420–427
      - yellow (Panjikar)488–489; (Laurs)558
    - with golden sheen, from East Africa (Laurs)393–394;
      - (Bui)678–691
    - green, ‘pastel’, from Myanmar (Smith)104–105
      - from Kenya—
        - with golden sheen, reportedly from (Bui)678–691
        - from Kina (Mayerson)662–663
        - quartz simulant, coated to create star (Mayerson)485–486;
          - letter on (Stern)604
  - see also Assembled gem materials; Corundum; Filling, fracture or cavity

#### Sapphirine
- simulated by spinel (Hodgkinson)94–95

#### Scanning electron microscopy [SEM]
- (imaging only; for chemical composition determined using SEM, see Spectroscopy, energy-dispersive X-ray)
  - of opal, daylight-fluorescent hyalite from Mexico (Fritsch)490–508
  - of sapphire, with golden sheen, reportedly from Kenya (Bui)678–691

#### Scheelite
- from Inner Mongolia, China (Williams)202–203
  - from Pakistan (Zwaan)298–299

#### Shattuckite
- briolette (Choudhary)566–567
  - with bisbice from Democratic Republic of Congo (Zwaan)663–666

#### Shell
- beads of Strombus gigas simulating coral (Disner)572–574
  - quahog with pearl, from USA (Laurs)16

#### Shungite
- for jewellery use (Panjikar)675–676

#### Sillimanite
- see specific gem materials simulated

#### Slovakia
- archaeological jewels from (Kadlečíková)510–517

#### Software
- see Computer software

#### Somalia
- grossular (hessonite) from (Clark)293

#### South Africa
- lizardite from (Rossman)98–99; (Laurs)102–103

#### Soviet Union
- see USSR

#### Spain
- chryscolla chalcedony from (Laurs)472

#### Specific gravity
- Galileo and history of (Mottana)24–31

#### Spectrometry, laser ablation--inductively coupled plasma--mass [LA-ICP-MS] and --atomic emission [LA-ICP-AES]
- of demantoid from Pakistan (Adam)428–433
  - of jeremejevite (Smith)138–142
  - of pearl, cultured, determination of origin (Hanni)
    - 2013/33 page 241 (Err)189
  - of sapphire, diffusion-treated with beryllium (Emori)
    - 130–137
  - of taaffeite from Myanmar (Leelawatanasuk)144–148
  - of zircon, age determination of inclusions in sapphire
    - (Link)692–700

#### Spectroscopy
- database (Laurs)185
  - Spekwin 32 software for rendering spectra
    - (Laurs)648–649

#### Spectroscopy, energy-dispersive X-ray [SEM-EDX and EDXRF]
- of chrysoberyl from Brazil (Schmetzer)32–40
  - of diopside, colourless, from Canada and Kenya (Krzemnicki)291–292
  - of grossular, bicoloured, from Tanzania (Zwaan)195–197
  - instrument, portable, from Niton (Herzog)404–418
  - of jadeite, kosmochlor and omphacite jades from Myanmar (Franz)210–229
  - of moss-sit-sit from Myanmar (Franz)210–229
  - of ruby and barium glass filling (Hainschwang)574–576
  - of tourmaline—
    - from Mozambique, purple (Zwaan)666–668
    - from Rwanda (Henn)344–349
  - see also specific gem materials

#### Spectroscopy, fluorescence
- of amber from Myanmar (Tay Thye Sun)606–615
  - of amethyst from Brazil (Williams)288–289
  - of apatite from Kenya (Zwaan)289–290

#### Spectroscopy, infrared
- of opal, daylight-fluorescent hyalite (Fritsch)490–508
  - of ruby with barium glass filling (Hainschwang)574–576

#### Spectroscopy, infrared
- of opal, daylight-fluorescent hyalite (Fritsch)490–508
  - see also specific gem materials
of diamond with star-shaped cloud (Hainschwang) 306–315
of diamond, synthetic CVD—
   with ‘tree ring’ growth pattern (Yan Lan)702–710
   yellow—
      melee (Hainschwang)300–302
      type lb (Kitawaki)594–604
HPHT—
   colourless type IIa, identification of (Scarani)2
   yellow-brown melee (Delaunay)16–18
of diopside, colourless, from Canada and Kenya
   (Krzemnicki)291–292
of emerald for origin determination (Thompson)334–343;
   letter (Schmetzer)441–443; reply (Thompson)443
   specific gem materials

Spectroscopy, photoluminescence—
   of diamond—
      with star-shaped cloud (Hainschwang)306–315
      with synthetic-like DiamondView pattern (Delaunay)
          107–108
   of diamond, synthetic—
      CVD—
         colourless to near-colourless, identification of
             (Scarani)2
         colourless melee mixed with natural (Hainschwang)518–522
         with ‘tree ring’ growth pattern (Yan Lan)702–710
         yellow—
            melee (Hainschwang)300–302
            type lb (Kitawaki)594–604
HPHT—
   colourless type IIa, identification of (Scarani)2
   yellow-brown melee (Delaunay)16–18
of diopside, colourless, from Canada and Kenya
   (Krzemnicki)291–292
of emerald for origin determination (Thompson)334–343;
   letter (Schmetzer)441–443; reply (Thompson)443
   specific gem materials

Spectroscopy, Raman—
of amber, chalcedony, carnelian, fluorite, garnet
   and jasper from Slovakian archaeological sites
   (Kadlecikova)510–517
of bisbeeite from Democratic Republic of Congo
   (Zwaan)663–666
of chrysoberyl from Myanmar with nail-head spicules
   (Schmetzer)434–438
of emerald coated with amorphous carbon (Choudhary)242–246
   instruments—
      Diamond Fluorescence Imaging (DFI) Mid-UV Laser
         system (Hainschwang)467
      GL Gem Spectrometer NIR PL405 (Lairs)381

Spectroscopy, X-ray fluorescence, see Spectroscopy,
   energy-dispersive X-ray [SEM-EDX and EDSXRF]

Spessartine [spessartite]—
   from Democratic Republic of Congo (Clark)299–300
      as inclusion in sapphire from Tanzania (Clark)105–106
      simulated by doublets from Germany (Henn)479–482
   see also Garnet

Spinel—
   simulating taaffeite or sapphire (Hodgkinson)94–95
   treated with cobalt diffusion (Lairs)468

Spinel, synthetic—
   flux, from Taurus (Lairs)649

Sri Lanka—
   deposits, education and field studies of
      (Wathanakul)256–261
   Star, see Asterism; specific gem materials

Strain—
   in diamond, synthetic yellow CVD (Hainschwang)300–302

Surface coating, see Coating

Swiss Gemmological Institute SSEF—
   Facette magazine online (Lairs)4

Synthetic, see Diamond, synthetic; specific gem materials

T—

Taaffeite—
   from Myanmar (Leelawatanasuk)144–148
   simulated by spinel (Hodgkinson)94–95

Tanzania—
   axinite, cat’s-eye, from (Lairs)191–192
chondrodite from Tanga (Clark)655
garnet from, tsavorite, discovery of (Bridges)230–241
kyanite, blue, from (Zwaan)198–200; (Krzemnicki)293–294
opal, green prase, from Kondo District (Zwaan)658–660
sapphire with spessartine inclusion from Songea
(Clark)105–106
tremolite from (Zwaan)569–571
tanzanite from Merelani, with H2S fluid inclusions
(Rankin)11–12
wurtzite from Merelani Hills (Henn)669–671

Tanzanite
with fluid inclusions containing H2S (Rankin)11–12
simulant—
doublets from Germany (Henn)479–482
glass (Tay Thye Sun)109–110

Thermal enhancement, see Heat treatment
Thin films, see Coating; Treatment

Tinzenite
from Italy (Laur)102–103

Topaz
simulated by doublets from Germany (Henn)479–482

Tourmaline
from Brazil, Cruzeiro mine, new production
(Laur)106–107
from Democratic Republic of the Congo, (Laur)475–476
imitation bicoloured, of dyed quartzite (Heyri)402
from Kenya, Cr- and V-bearing colour-zoned (Williams)
476–477
Kerez effect in green (Fellows)652–655
magnetic susceptibility and colour of (Feral)2
from Mozambique, purple (Zwaan)666–668
from Rwanda (Henn)344–349
simulant—
doublets from Germany (Henn)479–482
glass (Laur)484–485
from USA—
California, Pala, Oceanview mine (Laur)201–202
Maine, Havey quarry (Laur)394–395
Usambara effect (dichromatism) in (Williams)476–477

Trapiche, see Quartz; Ruby

Treatment, see Coating; Diamond treatment; Diffusion
treatment; Dyeing; Filling, fracture or cavity; Heat
treatment; specific gem materials

Tremolite
from Tanzania (Zwaan)569–571

Triples, see Assembled gem materials

Tsavorite, see Grossular

Tucson gem and mineral shows
rare gem materials at (Laur)102–103

Tugtupite
from Greenland, recent production (Rohtert)395–397

Twinning
in chrysoberyl from Brazil (Schmetzer)32–40

Ultraviolet fluorescence, see Fluorescence, ultraviolet [UV]

Ultraviolet luminescence, see Fluorescence, ultraviolet
[UV]

Ultraviolet-visible–near-infrared spectroscopy, see
Spectroscopy, UV-Vis and UV-Vis-NIR

United States of America
almandine from Massachusetts (Williams)286–287
andradite from Arizona (Laur)96
halite from New Mexico (Laur)102–103
opal from Idaho, pink with play-of-colour (Laur)390–391
pearl, quahog from Rhode Island (Laur)16
quartz from—
Arkansas, McEarl mine, large faceted (Laur)99–101
California, Pala, Oceanview mine, smoky-citrine
(Laur)201–202
Saguro Stone from Arizona (Krzemnicki)567–569
tourmaline—
from California, Pala, Oceanview mine (Laur)201–202
from Maine, Havey quarry (Laur)394–395

Ureyite, see Kosmochlor

V

Vietnam
fluorite, green, from Cao Bang Province (Chaiapaksa)194–195

‘Visual optics’
and birefringence/dispersion ratio (Hodgkinson)281–283

Vuillet à Ciles, Pierre
obituary (Gravier)366

W

World Gold Council
2014 trends (Laur)382
2015 2nd quarter trends (Laur)560
report on hallmarking in India (Laur)560

World Diamond Mark Foundation
World Diamond Magazine in conjunction with Turkish
Jewelry Exporters Association (Almor)383

Wurtzite
from Tanzania (Henn)669–671

X

X-ray radiography [including Micro-radiography]
of corundum filled with coloured lead glass (Henn)111–
112
of pearl—
freshwater, from Russia (Strack)580–592
by micro-focus method (Strack)14–15
from The Netherlands (Zwaan)150–155
of pearl, cultured—
dyed with silver nitrate, aging of (Segura)203–204
beaded, resembling natural, using micro-focus
(Segura)13–14
of sapphire, green lead-glass-filled (Leelawatanasuk)
420–427

X-ray computed microtomography [Micro-CT] and
tomography
of pearl—
historic large nacreous (Zwaan)248–253
from The Netherlands (Zwaan)150–155
of ruby in marble host (Bouts)90–94

X-ray diffraction analysis
of diamond, CVD synthetic, with ‘tree ring’ growth pat-
tern (Yan Lan)702–710
see also specific gem materials

X-ray fluorescence [luminescence], see Luminescence
X-ray fluorescence spectroscopy, see Spectroscopy,
energy-dispersive X-ray fluorescence [EDXRF]

X-ray topography
of diamond, CVD synthetic, with ‘tree ring’ growth pat-
tern (Yan Lan)702–710
see also specific gem materials

Z

Zircon
age determination of inclusions in sapphire (Link)692–700
from Myanmar, orange (Mayerson)397
star (Krzemnicki)671–673

Zoisite, see Tanzanite

Zoning, see Colour zoning; Crystallography; Growth
structure/zoning; specific gem materials
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a little becomes a lot.

— Tanzanian proverb