# The Journal of Gemmology

Volume 35 / No. 8 / 2017

Gem-A
THE GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

The Gemmological Association of Great Britain

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SCHWEIZERISCHES GEMMOLOGISCHES INSTITUT
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The Journal of Gemmology
Volume 35 / No. 8 / 2017

## COLUMNS



p. 702
Jordan Wilkins photo

p. 713
A. Reys photo

V. L. Villani photo p. 758

## ARTICLES

### Feature Articles



**Cover Photo:**

Brazil is the source of a variety of coloured stones, as described in the article by A. Reys on pp. 708–726 of this issue. Shown here are several custom-cut Brazilian gems consisting of a 9.69 ct morganite, 12.73 ct Swiss Blue topaz, 7.99 ct amethyst, 3.29 ct tourmaline, 2.40 ct aquamarine, 1.12 ct Imperial topaz and 4.84 ct golden beryl. Courtesy of John Dyer Gems; composite photo by Ozzie Campos.

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The Journal of
# Gemmology



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# What’s New

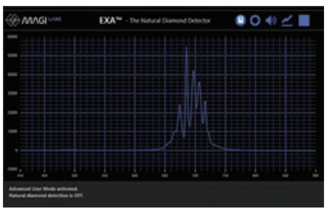
## INSTRUMENTATION

### D-Scope+ Microscope

Introduced in September 2017, the D-Scope+ microscope from HRD Antwerp is specially designed for use with diamonds. Improvements on HRD’s original D-Scope include its illumination, ease of use, and ergonomics. The user can choose from three colours of darkfield lighting: yellowish, white daylight, and strong white light. The controls to manipulate a stone have been redesigned to improve comfort, and the manipulation table can be moved up and down to achieve proper focus. For additional information, visit www.hrdantwerp.com/en/product/new-d-scope. *CMS*

### EXA Spectrometer

In November 2017, Magilabs released the EXA, a standalone spectrometer unit able to quickly identify natural diamonds and other gems by their fluorescence spectra. A coaxial fibre optic bundle collects spectra on both loose and mounted stones. EXA operates in two different modes: diamond testing and advanced. The first delivers a pass or refer message within a second of analysing a diamond (as small as 0.005 ct), referring possible CVD and HPHT synthetics and diamond simulants for further testing. The advanced mode is designed for gem identification, and displays a sample’s fluorescence spectrum on a 7-inch (18-cm) touchscreen. Examples for which EXA can provide identification include pink diamonds (natural, synthetic and treated), spinel, corundum, alexandrite, tanzanite, zircon, Imperial topaz and emerald (and its most common fillers). The unit measures 23 × 21 × 13 cm, weighs 3.3 kg and can be upgraded for additional applications. For more information, visit www.gemmoraman.com/Products/EXA.aspx.

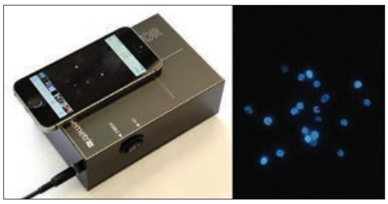
*Alberto Scarani and Mikko Åström*
*Magilabs, Helsinki, Finland and Rome, Italy*

### GIA iD100 Gem Testing Device

In April 2017, the Gemological Institute of America announced a new spectroscopy-based desktop instrument for the screening of natural diamonds from simulants and synthetic (HPHT and CVD) or treated diamonds. Stones 0.9 mm in diameter (approximately 0.005 ct) or greater, either loose or mounted, can be tested by pointing the probe at the sample. Within two seconds, the device displays either ‘Pass’ (i.e. natural diamond) or ‘Refer’ (for further testing). For additional information, visit www.gia.edu/id100. *CMS*

### Melee Inspector

New in August 2017 from Gemetrix Pty. Ltd. (Perth, Western Australia), the Melee Inspector is a short-wave (255 nm) UV unit designed to screen HPHT synthetic diamonds based on phosphorescence that can be captured with a smartphone camera. It is suited for use with rough and polished diamonds, loose (including parcels) or mounted, within a 45 × 45 mm viewing area. The unit also can operate on a 9V battery for portability. For additional information and a brief video demonstrating how to use the unit, visit www.gemetrix.com.au/melee.html. *CMS*



### Presidium Synthetic Diamond Screener II

Released in September 2017, the Synthetic Diamond Screener II from Presidium uses UV transparency to distinguish colourless type IIa from type Ia diamonds. Type IIa diamonds are more likely to be synthetic (CVD or HPHT) and require additional testing. The instrument delivers a result within two seconds and can be used on diamonds of 0.02–10 ct and D–J colour, either loose or mounted in an open-back setting. The unit measures 130 × 100 × 65 mm and operates on a variety of power sources, including battery, making it readily portable. To order, contact Gem-A Instruments (email instruments@gem-a.com); for more information see page 751 of this issue of *The Journal.* *CMS*

### SYNTHdetect Mounted Diamond Screening Device

In June 2017, De Beers' International Institute of Diamond Grading & Research unveiled its SYNTHdetect device for screening diamonds that are loose or mounted in jewellery. The instrument became available for delivery in September 2017 and uses a patented time-resolved photoluminescence technology to screen colourless to near-colourless samples with no lower size limit. With a very low referral rate, the unit reportedly reduces the need for additional off-site testing. For more information, visit www.iidgr.com. *CMS*

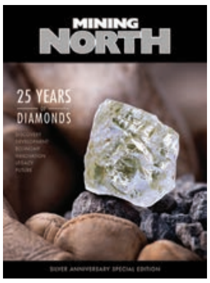

## NEWS AND PUBLICATIONS

### CIBJO Special Reports from 2017 Congress

Reports from eight commissions—Coral, Pearl, Gemmological, Ethics, Coloured Stone, Diamond, Precious Metals and Marketing & Education—prepared for the 5–7 November 2017 CIBJO Congress are available at www.cibjo.org/congress2017/special-reports. The reports were prepared before the conference to review issues for discussion by the various commissions. In addition, several news entries review the outcome of the conference sessions (click the News button). *CMS*

### Diamonds in Canada: 25th Anniversary

In November 2016, the 25th anniversary of the discovery of diamonds in Canada was marked by a special issue of *Mining North* magazine with the theme '25 Years of Diamonds'. The issue can be downloaded from www.miningnorth.com/25-years-of-diamonds, which also offers links to slide shows and oral presentations from a 'Diamond Gala' celebration of the 25th anniversary held in conjunction with the 2016 Yellowknife Geoscience Forum in Yellowknife, Northwest Territories. *BML*

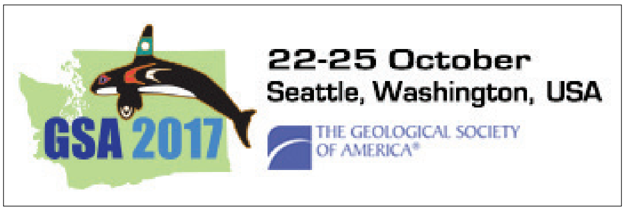



### GRS Colour Terms Defined

In December 2017, GemResearch Swisslab AG (GRS) released *GRS Color Terms Go Global*, a 63-page online booklet that illustrates and describes "the most popular GRS color descriptions that have been used by GRS and the global gemstone community over the past two decades". The colour terms are pigeon blood ruby, royal blue and cornflower sapphire, old mine/Muzo green emerald, sunrise and sunset padparadscha sapphire, honey-colour chrysoberyl and Paraíba-colour tourmaline. Each includes a definition, history, research, and related publications, as well as major geographical sources. The publication is bilingual in English and Chinese. To view or download the booklet, visit http://gemresearch.ch/grs-color-terms-go-global. *CMS*

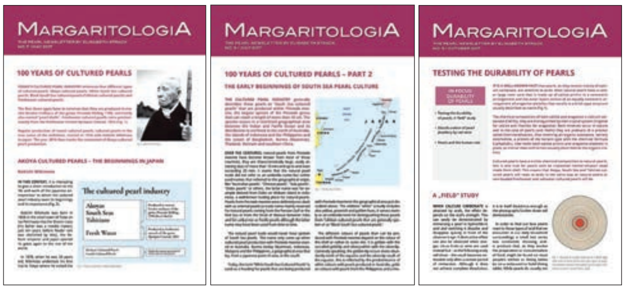
## GSA Gem Session Abstracts

Abstracts from the 22–25 October 2017 annual meeting of the Geological Society of America are available online. Of particular interest to gemmologists are the oral and poster presentations from the session 'Gemological Research in the 21st Century—Characterization, Exploration, and Geological Significance of Diamonds and other Gem Minerals', which can be viewed at https://gsa.confex.com/gsa/2017AM/meetingapp.cgi/Session/43031 and https://gsa.confex.com/gsa/2017AM/meetingapp.cgi/Session/44100, respectively. The abstracts cover a wide range of gemmological topics, including diamond, tourmaline, demantoid, spinel, emerald, corundum and instrumentation. *CMS*




## *Margaritologia* Pearl Newsletter Nos. 7/8/9

In May–November 2017, the Gemmologisches Institut Hamburg, Germany, released issues 7, 8 and 9 of *Margaritologia*. Issue No. 7 focuses on the history of pearl culturing in Japan and China in recognition of the 100-year anniversary of the 'regular production of round [Akoya] cultured pearls' by Kokichi Mikimoto. No. 8 continues the history with South Sea pearl culturing. Issue No. 9 features three articles: testing the durability of pearls when exposed to a variety of household products, discoloration of pearls by red wine, and how human skin affects pearls. To subscribe to the newsletter, visit www.margaritologia.de. *CMS*




## Santa Fe Symposium Proceedings

Papers from 22 presentations delivered at the 2017 Santa Fe Symposium (held in Albuquerque, New Mexico, USA, 21–24 May) are available for download, on topics such as metallurgy of precious metals, jeweller apprenticeships, manufacturing methods, digital innovations in the jewellery industry and more. Visit www.santafesymposium.org/papers to obtain PDF files of these papers, as well as those from earlier symposia dating back to 2000. *CMS*

## *Standard Methods for Testing Fei Cui for Hong Kong*

In February 2016, the Gemmological Association of Hong Kong (GAHK) issued its working group's recommendations for standardized gemmological methods to be used for testing *fei cui* (jadeite, omphacite and kosmochlor jades). The document includes gemmological descriptions of these three minerals—often intergrown—and reviews jade treatments. 'Standard' test methods are outlined for shape and cut description; measurement of dimensions and weight; identification of transparency and colour; polariscope examination; determination of RI and SG; examination using a UV lamp, Chelsea filter, spectroscope and microscope; and infrared spectroscopy (for detection of resin impregnation). Download the publication at www.gahk.org/attachment/feicui/HKSM%20FCT-2016%20(20170327).pdf. *CMS*


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

# Gem Notes

## COLOURED STONES

### Baryte from South Dakota, USA

Baryte (or barite) is an orthorhombic sulphate mineral that is sometimes found as well-formed crystals that are prized by collectors. One area in particular has yielded fine transparent baryte crystals that are colourless and yellow to yellowish brown (commonly referred to as 'golden'): Elk Creek in Meade County, South Dakota, USA (Campbell et al., 1987; see also https://collectorsedge.com/pages/elk-creek-barite-meade-county-south-dakota). Although these deposits have been known since at least 1891 and abundant mineral specimens have been mined there, it is rare to encounter gems faceted from this material. Therefore we were interested to examine three faceted South Dakota barytes (Figure 1) that were loaned by gem dealer Dudley Blauwet (Dudley Blauwet Gems, Louisville, Colorado, USA). The stones were cut from a 139 g parcel of rough that he obtained in January 2016, which contained pieces that were too broken to be sold as crystals. His cutting factory produced 25 stones weighing a total of 69.62 carats and ranging from ~1.2 to 8.30 ct; the yield was rather small due to fractures and cleavage issues.

The examined barytes weighed 2.27–7.90 ct and were very pale brownish yellow, medium brownish yellow and a cognac-like orangey brown. The RIs of all three stones were 1.634–1.647, yielding a birefringence of 0.013 (comparable with the 0.012 stated in the literature). The hydrostatic SG value of each sample was 4.49. The stones fluoresced a moderate-to-strong yellowish white to long-wave UV radiation (Figure 2) and a very faint yellowish white to short-wave UV. Microscopic observation revealed only minor cleavage effects and twinning planes. Analysis with a GemmoRaman-532SG confirmed the identification as baryte, and energy-dispersive X-ray fluorescence (EDXRF) spectroscopy with an Amptek X123-SDD instrument revealed the expected major amounts of Ba and S; there were no significant chromophores detected, even when comparing these differently coloured stones. This is consistent with the fact that radiation-damage centres commonly cause colour in baryte (Bartoshinsky et al., 1991).

Baryte occurs as transparent material and in various colours, but its status as a collector's stone is due to its low hardness (3 on the Mohs scale) and perfect cleavage, making it generally unsuitable for use in jewellery.

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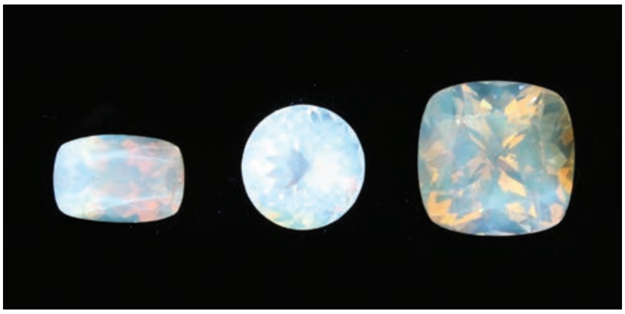
*Brendan M. Laurs FGA*

*Figure 1: These rare faceted barytes (2.27–7.90 ct) show the range of colour of material from South Dakota. Photo by Dean Brennan for Stone Group Labs.*

*Figure 2: All three of the barytes in Figure 1 fluoresce yellowish white to long-wave UV radiation. Photo by B. Williams.*



### References

Bartoshinsky V.Z., Shumsky A.A., Larikov A.L. and Dersky L.S., 1991. Paramagnetic and optically active centers in barites of the Ukraine. *Mineralogicheskii Zhurnal*, **13**, 73–78 (in Ukrainian).

Campbell T.J., Campbell D.R. and Roberts W.L., 1987. Famous mineral localities: Elk Creek, South Dakota. *Mineralogical Record*, **18**, 125–130.


## Gems from the Mong Long Area, Myanmar

For more than a century, the area near the town of Mong Long in Myanmar has been a source of gem-quality ruby, sapphire, tourmaline, spessartine and chrysoberyl, as well as other gem minerals. The mining area is situated in the Kyaukme District of northern Shan State, approximately 18 km south-east of Mogok (Figure 3). The region is mainly underlain by the Mong Long mica schist (La Touche, 1913), which lies adjacent to the Mogok Stone Tract of Iyer (1953) or the Mogok Belt of Searle and Haq (1964). According to recent field research done by one of the authors (Theint, 2017), the mining area encompasses the south-eastern part of the Mong Long mica schist and extends into the north-western part of the Mogok gneiss; the rocks are mainly composed of metasedimentary and igneous units such as mica schist, garnet-biotite gneiss and tourmaline-bearing muscovite-biotite granite. Mong Long hosts two main gem-mining areas: alluvial deposits in Namseka Valley and both primary and secondary deposits in Mong Pai Valley.

The Namseka deposit is located west of Mong Long near Nam Pai Stream, which is fed by Yeni Stream from the Mogok Valley, so it is possible that the alluvial gems mined there originally formed in the Mogok area. The gems are recovered as a by-product of alluvial gold mining. The rubies are light-to-medium purplish red (Figure 4a), and most of them are quite waterworn and irregularly shaped, although they are sometimes found as prismatic crystals terminated by rhombohedral faces and a pinacoid. The sapphires are medium violetish blue, light yellow, light pink and medium purple (again, see Figure 4a), and they mostly consist of waterworn subhedral crystals showing the hexagonal pyramid and a pinacoid. The rubies and sapphires typically measure 0.3–15 mm long. Other gems recovered from these deposits include spinel (Figure 4b), spessartine (Figure 4c), almandine, quartz, zircon, apatite, topaz, sillimanite, fluorite, chrysoberyl, chal-

*Figure 3: The Mong Long area is located south-east of Mogok, in central Myanmar.*

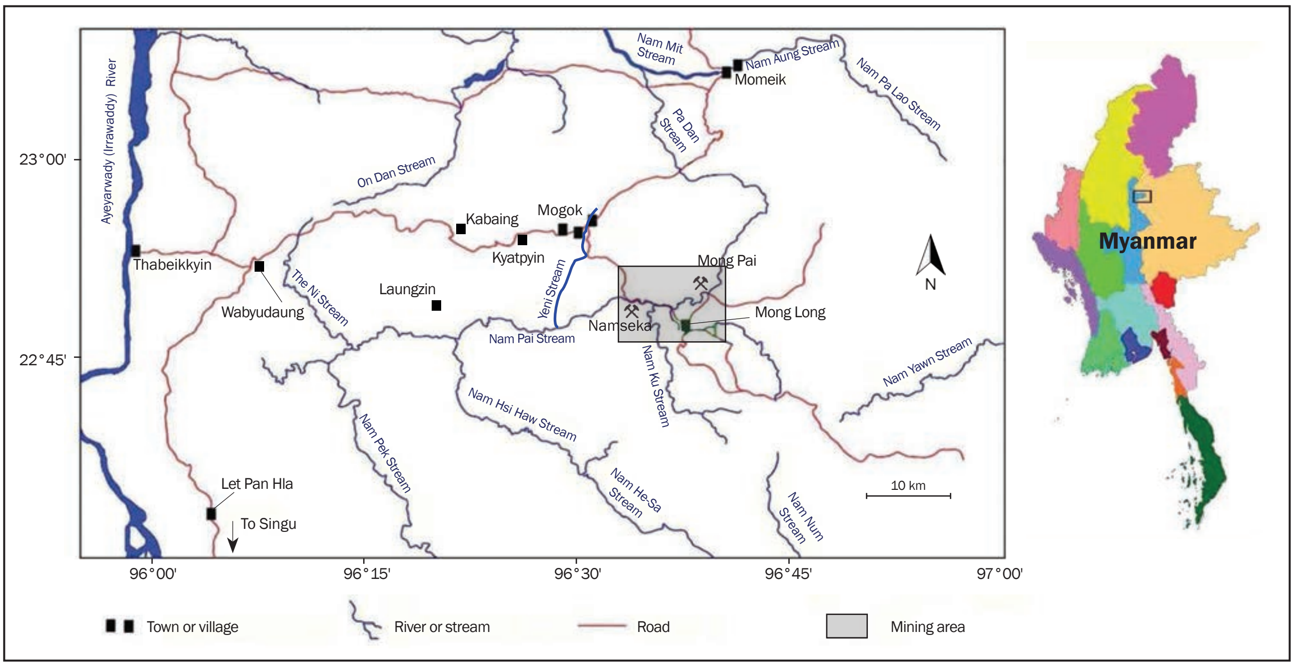



*Figure 4: Several gem varieties are mined in the Mong Long area, including: (a) ruby and sapphire from Namseka Valley (here, 0.97–1.38 ct faceted); (b) spinel from Namseka Valley (1.25–1.46 ct); (c) spessartine from Namseka Valley (1.62–2.19 ct); and (d) tourmaline from Mong Pai Valley (0.84–1.56 ct faceted). Photos courtesy of M. T. Theint.*

cedony (agate), danburite, scapolite, moonstone and kornerupine.

In Mong Pai Valley, which is located a few kilometres north-east of Mong Long, gems such as tourmaline (Figure 4d), aquamarine, spessartine, quartz, topaz, zircon and phenakite are mined. Tourmaline is recovered in various colours from both primary deposits (i.e. elbaite from the Legyi and Kyauktalon pegmatites) and secondary deposits (elbaite and dravite). Also, the Kyauktalon pegmatites are a source of beautiful 'sky' blue aquamarine crystals.

Six tourmaline samples from Mong Pai were sent to the Swiss Gemmological Institute SSEF, in Basel, Switzerland, for chemical analysis by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). The samples consisted of green, 'olive' green and pink crystals from the Legyi pegmatite, and some dark brown pieces from alluvial deposits. In addition to their constituent elements Si, Al and B, all of them contained the following: Li, Be, Na, Mg, K, Ca, Sc, Ti, V, Mn, Fe, Cu, Zn, Ga, Ge, Pb and Bi. Additional trace elements—such as Sr, Nb, Sn and Sb—were above the detection limits in some specimens. Relatively high Fe (up to 9,700 ppm) and Mn (up to 10,600 ppm) with significant Ti (725 ppm) were present in the green tourmaline, while the 'olive' green sample had less Fe (up to 2,550 ppm) and more Mn (up to 38,900 ppm) and Ti (880 ppm). Conversely, the pink stone contained very low Fe (up to only 16.4 ppm) and less Mn (1,980 ppm) than the green samples. Elevated Ti (up to 9,300 ppm) and low Mn (up to 29.5 ppm) were present in the dark brown samples. Enriched Mg (up to 101,500 ppm) also was measured in the dark brown samples, consistent with dravite. By contrast, the green, 'olive' green and pink tourmalines only contained traces of Mg and were characterized by higher amounts of Na (15,570–18,930 ppm) than Ca (930 to 3,080 ppm), consistent with elbaite. The possible presence of rossmanite was not considered since this is best assessed with electron microprobe data for calculating the amount of vacancies in the X site.

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Searle D.L. and Haq B.T., 1964. The Mogok Belt of Burma and its relationship to the Himalayan orogeny. *22nd International Geological Conference*, Delhi, India, 14–22 December, 132–161.

Theint M.T., 2017. Petrology, geochemistry and geochronology of igneous and metamorphic rocks in Mong-Long area. PhD thesis, Yangon University, Myanmar, 278 pp.

## Pyrite and Other Sulphides for Jewellery Use, from Peru

Pyrite has been used in jewellery for a long time, most commonly as small faceted stones sold as 'marcasite'. The source of much of this pyrite is the Huanzala mine in west-central Peru, which has probably yielded thousands of tonnes of specimens and rough material. Recently, a completely new type of pyrite for jewellery use emerged from another Peruvian deposit: the Quiruvilca mine in northern Peru. The as-mined specimens typically consist of flat druses of pyrite crystals with a pentagonal-dodecahedral form. The individual crystals are usually between 5 and 20 mm. For jewellery use, the druses are polished on the bottom and then cut as ovals or free-form pieces up to ~4 cm long (Figure 5). Together with pyrite, several additional sulphides from Quiruvilca have been prepared in the same way (Figure 6), although they are quite rare. These include black sphalerite, lead-grey tetrahedrite, silvery arsenopyrite and even very rare hutchinsonite as shiny black prisms on sphalerite.

Of course, pyrite is not an ideal jewellery stone because it is quite heavy. It also should not be washed with water because it is susceptible to corrosion; brushing or wiping off the surface or cleaning with alcohol is safer. Nevertheless, according to dealers in Lima, several thousands of pieces already have been sold to dealers in the USA and elsewhere. With proper care, the pieces can make an interesting addition to one-of-a-kind jewellery.

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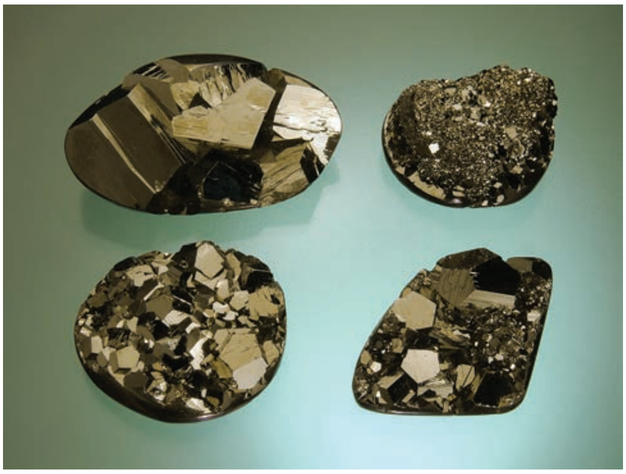

*Figure 5: These four pieces of pyrite from the Quiruvilca mine in Peru (up to 4.3 cm long) have been fashioned for use in jewellery. Photo by J. Hyršl.*

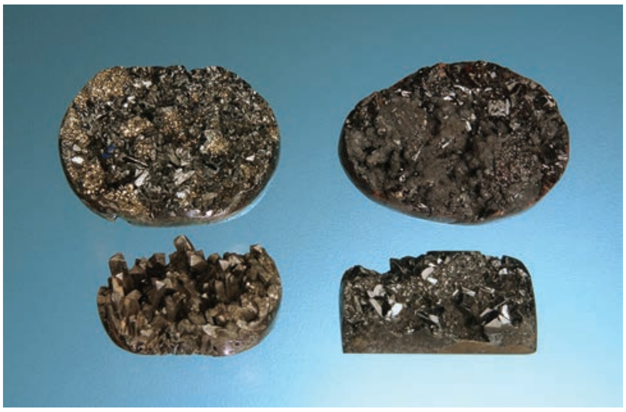

*Figure 6: Additional sulphides from the Quiruvilca mine besides pyrite have been similarly fashioned for mounting in jewellery. Shown here are pieces ranging up to 2.8 cm long that consist mostly of (clockwise from the upper left) sphalerite, hutchinsonite, tetrahedrite and arsenopyrite. Photo by J. Hyršl.*

## Purple Spinel from Badakhshan, Afghanistan

The Badakhshan area of Afghanistan adjacent to Tajikistan is famous for its production of large pink to red spinels (Hughes, 1994). Recently, a new find of attractive purple spinel occurred in Badakhshan. According to rough stone dealer Sir-Faraz Ahmad (Farooq) Hashmi (Intimate Gems, Glen Cove, New York, USA), the material was initially thought by some dealers to be amethyst. The first parcel that Hashmi learned about (through videos sent by his supplier) weighed ~1 kg and contained clean pieces weighing more than 50 g. Some of the spinel occurred in crystals with well-developed octahedral form, indicative of a primary deposit. Gem dealer Dudley Blauwet first learned about this new spinel in early November 2016, and in late March 2017 he obtained a 56 g parcel at the gem and mineral market in Peshawar, Pakistan. From this he had three larger gems faceted in Sri Lanka that were characterized for this report, and subsequently his cutting factory produced 46 smaller stones weighing up to 2.99 ct from 41.7 g of rough. Another rough parcel made its way to the market in Bangkok, Thailand, in early 2017 and reportedly yielded stones weighing up to 5–9 ct, with one exceptional gem of

Figure 7: These purple spinels (4.01–6.71 ct) are reportedly from Badakhshan, Afghanistan. Photo by D. Bakker.

15+ ct. Blauwet was told by his suppliers that the spinel came from the Parawara mine near the lapis deposits at Lajuar Madan in the Kokcha Valley. This is consistent with information on mindat.org (see www.mindat.org/loc-256247.html).

Blauwet loaned some rough and cut samples to this author for characterization. The faceted gems weighed 4.01, 5.01 and 6.71 ct (Figure 7), and the rough stone was 0.76 g. The samples all exhibited a strong purple colour with a hint of blue, and none showed any noticeable colour change between daylight and incandescent light. The RI and SG values of all four pieces were characteristic of those for natural spinel. All were inert to long- and short-wave UV radiation, and they did not change colour under the Chelsea filter. The broken piece of rough showed three distinct octahedral faces that were etched and slightly abraded. Microscopic examination revealed inclusions that resembled clusters and booklets of colourless mica (Figure 8); they were seen in one of the cut stones and in the rough sample. Similar mica inclusions also have been documented in pink spinel from Mahenge in the Morogoro region of Tanzania (Gübelin and Koivula, 2005, p. 682).

This new production of purple spinel from Badakhshan, Afghanistan, is a welcome addition to the gem trade, and hopefully more of this material will become available in the future. However, according to Hashmi the mine is located in a politically unstable area, and digging activities ceased in mid-2017. Blauwet also reported that, with few exceptions, since April 2017 only heavily included and/or small-sized rough material has been available in the market. It is unclear whether there will be additional production of high-quality spinel from this deposit.

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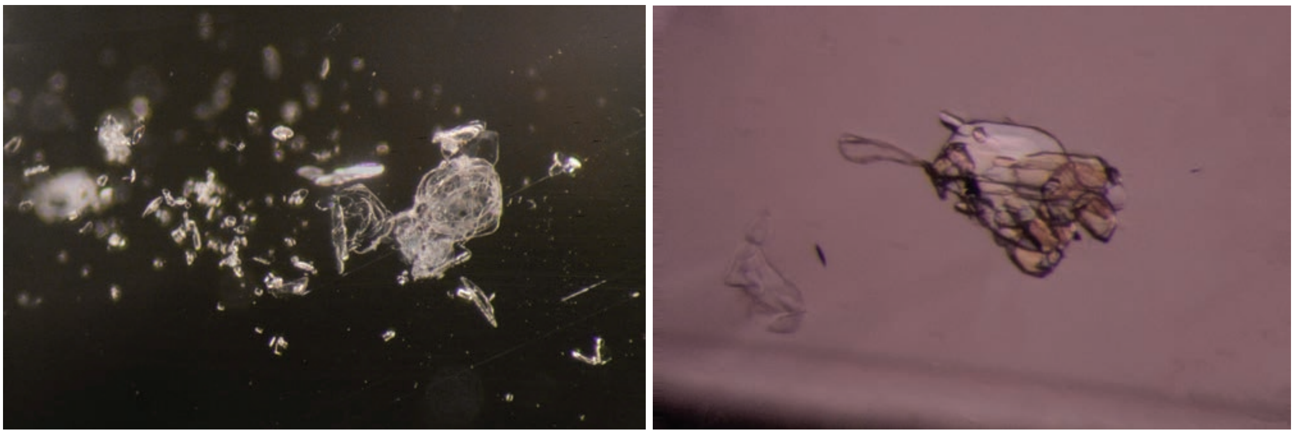
Figure 8: Inclusions with the appearance of mica are observed in the 5.01 ct purple spinel from Afghanistan, as shown here with darkfield lighting (left) and oblique fibre-optic illumination (right). Photomicrographs by E. Boehm; magnified 40×.



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## Windmill-cut Topaz from Namibia

Klein Spitzkoppe in west-central Namibia is a source of colourless or 'silver' topaz, as well as rare pale blue and pale yellow topaz (e.g. Cairncross et al., 1998). The crystals are typically mined by local Damara women and offered for sale to tourists and mineral collectors. During the 12–13 October 2017 Namibian Coloured Gemstone & Jewellery Showcase in Windhoek, Namibia, this author encountered an innovative faceting style that was developed specifically for colourless topaz from Klein Spitzkoppe. Called the *Windmill Cut*, it was displayed by Mike Thygesen (Desert Gems/Bead World, Swakopmund, Namibia). Although Thygesen initially developed this faceting style in the mid-1990s, this was the first time it has been actively promoted, with several hundred stones available in sizes ranging from 6 to 22 mm in diameter.

The Windmill cut is a variation of a single-cut round brilliant. The windmill-like appearance is created by alternating pavilion facets that have a matte finish, which provide a contrasting appearance with the adjacent highly polished pavilion facets (Figure 9). When viewed through the table, a pleasing spoke-like appearance is visible. By using a minimal number of crown and pavilion facets, the pattern is easy to see and is not broken up by multiple reflections. The effect is best seen in larger stones (i.e. those that are at least 6 mm in diameter). According to Thygesen, it is important to cut the topaz according to its critical angle because of the loss of some light return from the matte facets.

The goal of the Windmill cut is to benefit the local Damara women who mine the topaz by creating demand for the gem material. All of the Windmill-cut topaz is faceted from rough material that is purchased directly from these women, and the faceted stones are sold loose or mounted into creative windmill-themed jewellery designs.

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*Figure 9: Windmill-cut topaz displays a spoke-like pattern created by alternating pavilion facets that have a matte finish, as shown in these top and oblique views of a 24.80 ct stone. Photos by Adam Smaruj, Windhoek.*

## Tourmaline from Masisi, Democratic Republic of the Congo

For almost the past two decades, the Democratic Republic of Congo (DRC) has been a source of gem-quality tourmaline (Laurs et al., 2004, Henn, 2010; Laurs 2015). It typically has been recovered as a by-product of mining for industrial minerals—in alluvial, eluvial and primary (granitic pegmatite) deposits—although recently some of the miners have focused on gem tourmaline. Rough stone dealer Farooq Hashmi recently shared some information on tourmaline mining that has taken place in two areas of eastern DRC: Rwangara and Rubaya, which are both located in the Masisi region of North Kivu Province. Although Hashmi has not visited the mines, in late 2016 and in 2017 he went to the city of Giseni in Rwanda, which is on the border with DRC (adjacent to Goma) and is located ~50 km south-east of the Masisi area.

Hashmi reported that gem tourmaline has been mined in the Rwangara area since approximately 2004. Several tonnes of greenish blue tourmaline were reportedly recovered there, and most of it was sent to China and Hong Kong since the vast majority was bead/cabochon grade. In recent years, some near-colourless to pale brownish pink to brownish red material was produced from Rwangara. Efforts to irradiate the lighter-coloured material resulted in an unattractive brownish yellowish hue, and subsequently the mining activities at Rwangara have mostly ceased. Nevertheless, some greenish blue to pale green stones (mostly cabochon grade) were produced there in 2016.

The other mining area in the Masisi region, called Rubaya, has been worked for the past few years. Hashmi estimated that initially a few kilograms of cabochon- and facet-quality rough were sporadically recovered as a by-product of mining the pegmatites for industrial minerals. However, since mid-2017 some new mining ventures have specifically targeted gem tourmaline (e.g. Figure 10), resulting in the production of more and better-quality tourmaline from the Rubaya area. The initial output took place in June, and consisted of several kilograms of crystals that were commonly tricoloured (green, pale yellow and brownish pink) or bicoloured (light and dark green). From late June to August, additional tricoloured crystals were produced (Figure 11, left), as well as some bluish green tourmaline. Some tens of kilograms

*Figure 10: Gem tourmaline recently has been mined from narrow hand-dug tunnels such as this one in the Rubaya area of DRC. Photo by a local miner and courtesy of Farooq Hashmi.*

were produced, and many crystals possessed excellent transparency, with the largest clean pieces weighing ~100 g. In September, the colour of most of the tourmaline production shifted to a 'peachy' or brownish pink (Figure 11, right) and pale brownish green. Most recently, in October, the mines yielded similar but darker material. Of the several kilograms of this tourmaline that were mined in September–October, much of it was facet-grade with clean pieces weighing up to ~100+ g. Although the colours were not as desirable for cutting gemstones, some fine crystal specimens were produced.

Some of the Masisi tourmaline that Hashmi obtained in 2016 was faceted for this report, and


*Figure 11: These tourmalines were mined in the Rubaya area of DRC in 2017. Photos by Farooq Hashmi.*

rough and cut samples were investigated by authors AUF and WBS with standard-based scanning electron microscopy–energy-dispersive spectroscopy (SEM-EDS) chemical analysis using a JEOL JSM-6400 instrument equipped with the Iridium Ultra software package by IXRF Systems Inc. Initial EDS scanning of two samples from Rubaya (both blue-green; e.g. Figure 12, left) showed a likely Ca-bearing elbaite composition with Fe as the main chromophore. No Cu was detected in either sample. More-detailed analysis of several samples from Rwangara (Figure 12, right) showed that all of them were elbaite with some liddicoatite component. The content

*Figure 12: These DRC tourmalines were chemically analysed for this report. The 2.20 ct stone on the left is from the Rubaya area and was faceted by Jason Doubrava (Poway, California, USA). The faceted and cabochon-cut tourmalines on the right (0.46–7.33 ct) are from the Rwangara area and were cut by Todd Wacks (Tucson Todd's Gems, Tucson, Arizona, USA). Photos by Jason Doubrava (left) and Orasa Weldon (right).*

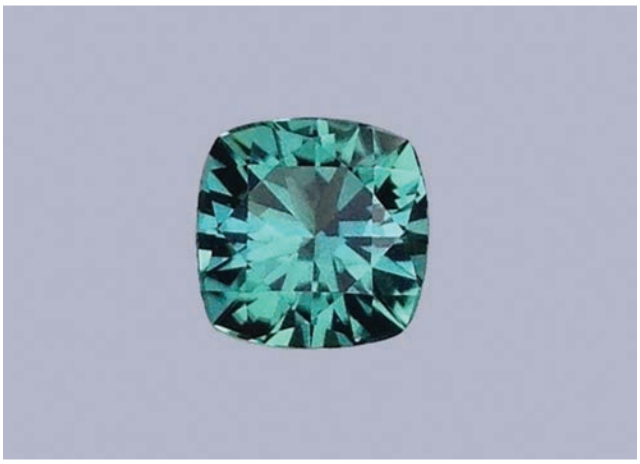


*Table I: Content of chromophore elements in tourmaline from Rwangara, DRC.*

| Oxide (wt.%) | Pink to red | Yellow-green | Light green | Blue |
|---|---|---|---|---|
| FeO | nd*–0.05 | 1.8–1.9 | 1.8–2.1 | 2.5–4.0 |
| MnO | 0.2–0.4 | 0.9–1.2 | 0.9–1.2 | 1.0–1.2 |
| $TiO_2$ | nd | 0.01–0.03 | nd–0.01 | 0.03–0.04 |

* Abbreviation: nd = not detected

of chromophore elements is summarized for the various colours in Table I; none of the samples contained any detectable Cu. A similar range of chromophore elements was obtained previously for several pieces of DRC tourmaline that were pink and yellowish green to blue (Laurs et al., 2004). However, those samples ranged from elbaite to liddicoatite and rarely rossmanite, in contrast to the elbaite composition of the present tourmalines.

The production of tourmaline from the Rubaya area of DRC is expected to continue, both as a by-product of mining for industrial minerals and from activities specifically aimed at recovering gem- and specimen-grade material.

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## Yellow Tourmaline from Mavuco, Mozambique

The Mavuco area of Mozambique is famous for producing Cu-bearing (Paraíba-type) tourmaline in a variety of colours (e.g. Laurs et al., 2008), which are sourced from alluvial deposits. In addition, aquamarine has been produced from granitic pegmatites in the area, such as in the northwest portion of Mozambique Gems' claim (Laurs, 2012). In late 2014, Mozambique Gems mined one of these pegmatites to a depth of approximately 60 m, and found three pockets containing tourmaline. The crystals mostly had cores that were dark brownish yellow or green with narrow pink rims. The overall dark tone was quite different from the lighter hues typically shown by the Cu-bearing tourmaline from this area. Heat treatment experiments were performed by 'Keké' Saint-Clair Fonseca Junior (BC Gemas do Brasil, Governador Valadares, Brazil), and heating to 500°C in air was successful in changing the brownish yellow tourmaline to light yellow (Figure 13).

Mozambique Gems donated the sawn fragments and preforms in Figure 13 to Gem-A, and these were sent to authors AF and WBS for standard-based SEM-EDS chemical analysis using a JEOL JSM-6400 instrument with the Iridium Ultra software package by IXRF Systems Inc. Although

*Figure 13: These tourmaline pre-forms were cut from material that was mined from a primary deposit at Mavuco, Mozambique. The brownish yellow colour shown by the stones on the left and centre changed to light yellow with heat treatment, as seen in the pieces on the right. No copper was detected in the samples, which have a total weight of 63.45 carats; the largest piece (which has been partially polished) weighs 21.12 ct and the smallest is 0.86 ct. Gift of Mozambique Gems; photo by B. M. Laurs.*

no Cu was detected by this technique (or by EDXRF spectroscopy), the analyses revealed relatively high Mn and Ti, significant Ca and very low Fe (i.e. 3.90–5.80 wt.% MnO, 0.30–0.46 wt.% $TiO_2$, 1.35–1.57 wt.% CaO and 0.03–0.08 wt.% FeO). Overall, the composition was similar to yellow tourmaline that these authors have analysed previously from Mozambique (Muva), Russia (Malkhan District), Madagascar (Tsilaisina) and Nepal. The Ca contents were higher than in yellow tourmaline from certain localities such as Zambia (Canary mine), Italy (Elba) and the USA (Himalaya mine in San Diego County, California). Nevertheless, the Mavuco material still plotted well inside the elbaite field, corresponding to a ratio of approximately 3:1 for elbaite:liddicoatite.

Although yellow Cu-bearing tourmaline is known—although uncommon—from Mozambique (see the 43.40 ct stone in 'Pala's Featured Stones' section of www.palagems.com/gem-news-2017-02#featured-stones), the lack of Cu in this production of brownish yellow material from Mavuco is consistent with previous reports that the mineralization in the pegmatites there is unrelated to the adjacent alluvial deposits that have been mined for Paraíba-type tourmaline. The original primary source of the Cu-bearing tourmaline remains unknown.

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## More Tremolite from Tanzania

A recent report in *The Journal* (Zwaan, 2015) described facet-grade tremolite from Mwajanga, Tanzania, which was encountered at the February 2015 gem shows in Tucson, Arizona, USA. Since gem-quality tremolite is uncommon, we were surprised to learn from gem dealer Dudley Blauwet about some additional tremolite from Tanzania that was somewhat different from the material described by Zwaan (2015). Blauwet first encountered it during the 2015 Tucson shows, when he was shown a parcel of rough material that his East African supplier thought was diopside. While some of the pieces appeared to be diopside, others had a flattened shape with cleavages that were characteristic of an amphibole mineral. Blauwet purchased 76.6 g of the amphibole-like material, and sent 26 pieces totalling 33.5 g to his cutting factory. Due to the brittle nature and well-developed cleavage, the cutting process yielded only 14 faceted stones ranging from 0.40 to 1.80 ct, with a total weight of 11.10 carats. During the 2016 Tucson shows, Blauwet's supplier showed him some more of this material, and stated that it came from the Merelani area (though presumably not from the tanzanite mines). Interestingly, a recent find of some dark green crystal clusters of tremolite was reported by Moore (2017) as coming from near the town of Mpwapwa in the Dodoma region of central Tanzania.

*Figure 14: This tremolite from Tanzania consists of a 1.80 ct faceted stone and four cleavage fragments weighing 0.81–1.01 g. Photo by Dean Brennan.*

Blauwet loaned one oval faceted stone and four rough samples to authors CW and BW for examination (Figure 14). The faceted stone weighed 1.80 ct, measured 7.82 × 7.03 × 5.38 mm and was a moderate, slightly greyish, yellowish green. The rough weighed 0.81–1.01 g and consisted of wedge-shaped cleavage fragments that were up to 15.86 mm long. The colour of the rough appeared slightly deeper green with more grey compared to the cut stone. The RIs of the faceted stone were 1.609–1.631, and the SG of the largest crystal was measured hydrostatically as 3.01. These values are consistent with the calcic amphiboles tremolite-actinolite, and the RIs correspond to a tremolite-rich composition (cf. Nesse, 1986). The faceted sample contained no visible inclusions when examined with the gemmological microscope; the rough pieces also had good clarity and contained only incipient cleavages. The GemmoRaman-532SG and the Enwave 789 nm Raman spectrometer both confirmed the identification as tremolite, based on comparisons with the RRUFF database. Chemical analysis with an Amptek X123-SDD EDXRF unit revealed the expected significant Ca and Fe contents, as well as traces of Cu, Ti and Cr. Although the presence of Fe suggests the actinolite end of this isomorphous series, Mg is only marginally detectable with this EDXRF unit, so the chemical composition obtained with this instrumentation was not entirely consistent with tremolite.

To confirm the identification as tremolite, electron microprobe analysis by authors FCH and MD yielded the following composition: $(Na_{0.38}K_{0.04})_{0.42}(Ca_{1.58}Na_{0.32}Fe^{2+}_{0.10})_2(Mg_{4.69}Al_{0.18}Fe^{2+}_{0.10}Ti_{0.03})_5(Si_{7.68}Al_{0.32})_8O_{22}(OH_{1.69}F_{0.28}Cl_{0.03})_2$. This composition corresponds to that of tremolite (Hawthorne et al., 2012).

The colour of this tremolite is similar to that documented by Zwaan (2015) from Mwajanga, although the latter had a somewhat lighter tone and was available as well-formed prismatic crystals, unlike the cleavage fragments shown by the present material.

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## Tsavorite Reportedly from Ethiopia

Tsavorite, the green grossular garnet originally found in the Tsavo area of Kenya, today comes mainly from various mines situated in the East Africa region, including Kenya, Tanzania and Madagascar; additional occurrences are known in Pakistan and eastern Antarctica (Feneyrol et al., 2014). However, a new mining area reportedly in Ethiopia recently has produced gem-grade tsavorite, and some of the authors acquired samples from various sources for analysis. The Bahrain Institute for Pearls & Gemstones (DANAT) received three rough samples (0.2–1.4 g; Figure 15, top) from Simon-Bruce Lockhart (Chanthaburi, Thailand), and Stone Group Laboratories received three faceted samples from Jason Doubrava (Poway, California, USA) and seven faceted samples from Meg Berry (Megagem, Fallbrook, California). The faceted samples weighed 0.25–3.56 ct, and were cut from several pieces of rough obtained by Steve Ulatowski (New Era Gems, Grass Valley, California, USA; see, e.g., Figure 15, bottom). The

*Figure 15: These crystal fragments and broken pieces of Ethiopian tsavorite weigh 0.2–1.4 g (top) and 1.4–4.5 g (bottom). Samples courtesy of Simon-Bruce Lockhart (top) and New Era Gems (bottom); photos by Hasan Abdulla © DANAT (top) and Jordan Wilkins (bottom).*

garnets ranged from yellow-green to deep green, sometimes resembling the colour of tsavorite from other sources (Figures 15 and 16).

The RI of the Ethiopian samples fell within a narrow range of 1.740–1.745, and their hydrostatic SG values were 3.62–3.65. All were inert to long- and short-wave UV radiation, and they did not change colour under the Chelsea filter. Semi-quantitative EDXRF analysis revealed Ca, Al and Si as major elements and confirmed the samples as grossular. Compared to tsavorite from other localities, these Ethiopian samples contained very low V (<200 ppm) and relatively high Fe (up to 2%). Preliminary ultraviolet-visible–near infrared (UV-Vis-NIR) spectroscopy showed that their green colour is mainly due $Cr^{3+}$, with absorption bands situated at ~430 and 600 nm. An absorption peak at ~370 nm also was observed and has been linked to $Fe^{3+}$ (Schmetzer and Bank, 1982). In addition, a continuum of unknown origin that gradually increased in absorption from the UV to the NIR region was responsible for a yellowish hue in some samples. The exact role of iron in the coloration of the samples is still under discussion. The Raman spectra of our samples were consistent with tsavorite from Kenya (Figure 17) and Tanzania in our reference collections.

Some yellowish green to green grossular (tsavorite) with relatively high iron (up to 8%) has been found in Mali (Johnson et al., 1995). However, those stones contained a relatively large andradite

*Figure 17: The Raman spectra of tsavorite from Ethiopia and Kenya are very similar.*

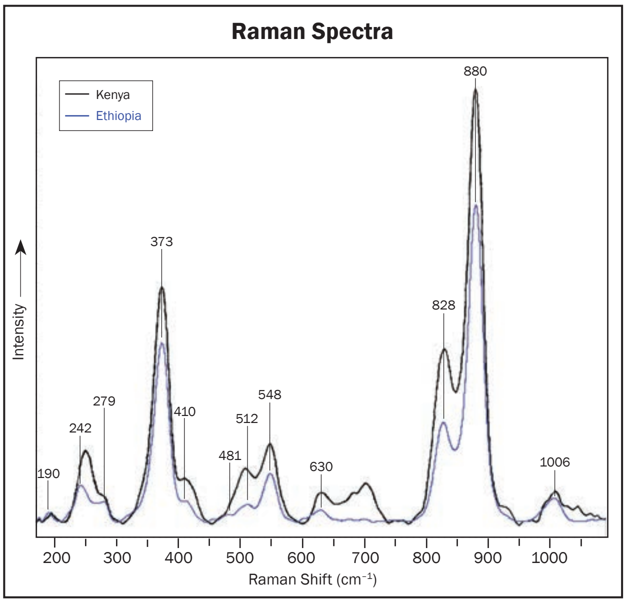


*Figure 16: The three faceted gemstones in the top photo are all Ethiopian tsavorite (1.66–3.55 ct). In the bottom image, the stone on the left is a 0.60 ct Ethiopian tsavorite, and is shown for comparison with a 1.10 ct tsavorite from Kenya. Photos by Orasa Weldon (top) and B. Williams (bottom); the Ethiopian samples were faceted by Meg Berry.*

component, as well as higher RI and SG values, compared to those from Ethiopia. The Ethiopian samples have similar characteristics (chemical composition, RI and SG) to green grossular from the Jeffrey mine (Quebec, Canada; Wight and Grice, 1982), although lower Ti.

It appears likely that the geological environment of Ethiopian tsavorite differs from that of the 'classic' tsavorite deposits in East Africa. More research is needed to better understand the geological origin and spectroscopic features of the Ethiopian tsavorite.

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# SYNTHETICS AND SIMULANTS

## Black Star Cubic Zirconia Sold as Natural Star Rutile

In August 2017, a Canadian collector bought from a U.S. dealer a 10.67 ct black cabochon showing asterism (Figure 18) for US$900. The gem was purchased as a natural star rutile from Sri Lanka, and submitted to CGL-GRS Swiss Canadian Gemlab for testing and a possible appraisal report.

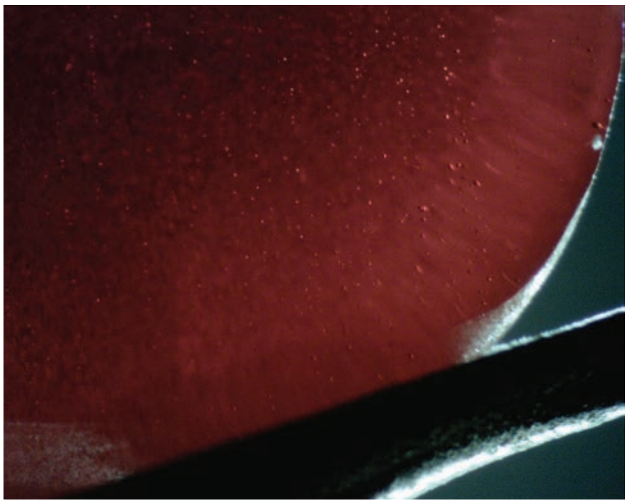
The star displayed eight rays, and the cabochon was black in daylight but appeared translucent brownish red when viewed with strong illumination (Figure 19). Routine testing revealed that its RI was over the limit of the refractometer (consistent with its highly metallic lustre), its hydrostatic SG was very high (5.97) and it was inert to long- and short-wave UV radiation. By comparison, natural star rutile has a lower SG (4.20–4.30) and has been documented only as very rare four-rayed stones (Steinbach, 2016, pp. 667–670). Microscopic examination showed numerous highly reflective rounded gas bubbles (Figure 19), indicating a manufactured material.

Figure 18: This 10.67 ct black star CZ was recently sold as natural star rutile. Photo by Matthias Alessandri.

Vis-NIR spectroscopy was recorded with an SAS 2000 instrument (range 400–1000 nm, resolution 1 nm). The spectrum (Figure 20) matched that of cubic zirconia in our database, with a series of rare-earth element (REE) absorptions in the 730–900 nm range (cf. Turner et al., 2015).

Most CZs on the market are transparent and near colourless to imitate diamond, but it is known that CZ is manufactured in a wide range of colours. It is interesting to note that this black star CZ was 5% heavier than typical CZ (SG ~5.7). Nevertheless, Günther (1988) reported that some CZ (e.g. Zirkonia, Fianit) may have SG values up to 5.9 due to doping with Y, making it heavier than CZ containing Ca (SG of 5.6–5.7). Both Y and Ca have been used to stabilize CZ, and a study of three black (non-phenomenal) Russian-grown specimens doped with Y gave SG values of 5.93–5.94 (Kammerling et al., 1991), approaching the 5.97 value obtained for the present specimen.

Figure 19: Numerous rounded gas bubbles are present in the star CZ, which appears brownish red under strong illumination. Photomicrograph by B. Deljanin; magnified 30×.



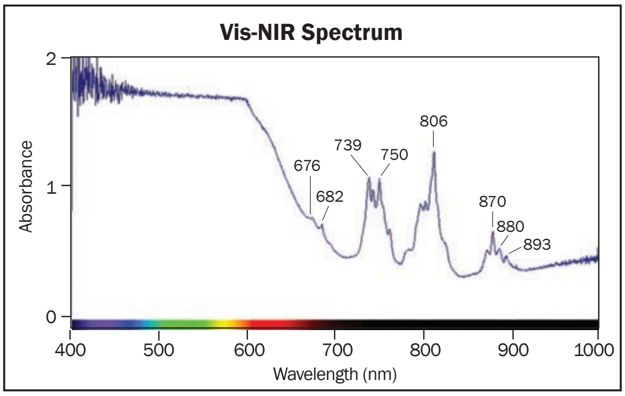



Figure 20: The Vis-NIR absorption spectrum of the black star CZ displays a series of REE-related peaks.

Figure 21: A similar, 8.77 ct reddish brown star CZ showing six-rayed asterism was recently encountered. A large fracture is present on the upper-left portion of the cabochon. The sample displayed no obvious internal features to account for the asterism when viewed with a gemmological microscope. Photo by Alberto Scarani.

To further document this new synthetic material, additional advanced testing was performed by Matthias Alessandri at the GRS laboratory in Hong Kong. Energy-dispersive X-ray fluorescence analysis with a Skyray Instrument EDXRF spectrometer (45 kV for 40 seconds) showed a large amount of Zr and Y. Raman spectroscopy with a GemmoRaman-532SG instrument showed the best match for CZ in the database.

The origin of the asterism in this black CZ was not established, since there were no obvious oriented elongate features seen with the gemmological microscope. It is known that the presence of an inadequate amount of stabilizer (for example, 5–6 wt.% instead of the usual 15–65 wt.% $Y_2O_3$) results in a material containing a multitude of tetragonal zirconia needles ($ZrO_2$) within a cubic zirconia matrix (Kammerling et al., 1991). A 'tweed-like' structure has been observed with very high magnification in material stabilized with 5 wt.% $Y_2O_3$ (Ingel, 1982), and reduced transparency also may be caused by light scattering from these tetragonal needles. We assume that such needles—too small to be resolved with a gemmological microscope—may be the cause of the asterism in the present cabochon.

To our knowledge, this is the first report of star CZ imitating a rare natural star stone (in this case rutile). The amount of such material on the market is unknown, but a similar specimen was recently encountered by Alberto Scarani (Magilabs, Rome, Italy). The 8.77 ct reddish brown cabochon displayed a six-rayed star (Figure 21) and was sold at the 2017 Facets Show in Sri Lanka; however, testing with a portable GemmoFTIR identified it as CZ (A. Scarani, pers. comm., October 2017). This particular cabochon contained a large fracture, but no other internal features or gas bubbles were visible with the gemmological microscope.

The presence of this star CZ on the market provides a good reminder that gemmological testing is prudent to confirm the identity of any stone offered as a very rare gem material.

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# MISCELLANEOUS

## Two Interesting Cameos in the Collection of the Natural History Museum, London

The collections of the Natural History Museum (NHM), London, include minerals, gemstones, worked objects and carvings. This author recently had the pleasure to study two chalcedony/agate cameos that were fascinating for their gemmological, mineralogical and historical interest. What made both so delightful was that they had been carved onto the exterior of geodes. Both were purchased from gem carver Wilhelm Schmidt by the Geological Museum of the British Geological Survey in the late 1800s; the specimens then became part of the NHM collection in 1985.

Wilhelm Schmidt (1845–1938) was born in Idar (now part of Idar-Oberstein, Germany). At the age of 15 he was sent to Paris as an apprentice to learn the craft of gem engraving, under the masterful eye of cameo cutter Arsène. He was trained in the neo-classical style, but stone cameos were going out of fashion when he graduated in the 1860s. Although Romanticism brought in new trends of Renaissance subjects for cameos, Schmidt's interest waned and he returned to Germany. Following the Franco-Prussia War in 1870 and subsequent events, Wilhelm moved to England with his brother Louis, where he changed his name to William. The brothers set up a business in Hatton Garden that ran from 1872 to 1915 (Seidmann, 1988). During this time William regularly sold cameos, intaglios and carvings to the Geological Museum. His work was of interest because he utilized more unusual materials such as labradorite, moonstone and opal.

*Figure 22: In the late 1800s, Wilhelm Schmidt carved this cameo of a Roman figure into chalcedony adjacent to amethyst crystals that originally formed part of a geode. This composite image shows four sides of the object, which measures 78 × 66 × 38 mm. Specimen BM.1985,MI5547; courtesy of NHM London, © The Trustees of the Natural History Museum, London.*

*Figure 23: This cameo (55 × 38 × 27 mm), also by Wilhelm Schmidt, depicts the head of Jupiter and is carved on the exterior of an agate geode, with the rear interior lined by quartz crystals. The raw material originated from Idar-Oberstein, Germany. Specimen BM.1985,MI6225; courtesy of NHM London, © The Trustees of the Natural History Museum, London.*

Of the two cameos documented here, the first specimen (Figure 22) is BM.1985,MI5547, described in the museum's handwritten register as "Cameo in Agate-Jasper on Amethyst". Depicting a Roman man with a wreath on his head, Schmidt carved the layer just beneath the amethyst druse, which consisted of pale orangey pink chalcedony containing fine crisscrossing dark veinlets and a few thin linear arrays of red iron-oxide spots. The layer of chalcedony continues into the background of the carving, giving a halo effect. The amethyst creates a simple dark backdrop, and it is a surprise to most viewers to find the centimetre-sized amethyst crystals on the back-side of the piece. The terminations of many of the crystals have been ground away, presumably to give the cameo a more even surface. The object measures 78 × 66 × 38 mm and was purchased from Schmidt on 23 December 1886 for £8. Although no location is given for the source of the raw material, it is likely to have been Rio Grande do Sul in Brazil, well known for its amethyst, agate and jasper, as well as its connections with Idar-Oberstein in the 1800s. [*Editor's note*: See the article by A. Reys on pp. 708–726 of this issue for more on this connection.]

The second cameo (Figure 23), BM.1985, MI6225, is described in the museum's register as "Head of Jupiter (after the antique) cut on the exterior of a hollow Agate from Oberstein". It is carved as the head of the Roman god Jupiter, with long flowing hair and beard. The agate is very pale purple to light beige and locally contains small, dark, translucent, angular areas. It also has very fine red veinlets and tiny spots with an iron-oxide appearance. On the rear, a fine layering of the agate can be seen around the edges of a hollow geode lined by a druse of sparkling quartz crystals up to 3 mm in size that range from colourless to an ever-so-slight hint of pale amethyst. The carving measures 55 × 38 × 27 mm, and was purchased by the Geological Museum on 25 March 1891 for £10.

Roman figures were a common theme for Schmidt, and the NHM collection includes other cameos that he carved with the head of Mars, several of Minerva and Julius Caesar, and a bust of Britannicus.

The beauty of these pieces—in the workmanship, in the gem materials used, and in the clever utilization of the geodes and adjacent chalcedony/agate—makes these two specimens a fascinating part of the NHM collection.

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# Coloured Stone Mining and Trade in Brazil: A Brief History and Current Status

*Aurélien Reys*

Coloured stones from Brazil have been sought after since the European discovery of the Americas more than 500 years ago. Numerous deposits have been explored, and gem cutting and trading activities also have emerged. As a result, Brazil is one of the world's most important gem suppliers. Although production continues, significant changes in the world market have greatly impacted Brazil's coloured stone industry, local miners and tradespeople. In addition to recounting the history of gem mining and trade in Brazil, this article provides a review of Brazil's proven and potential deposits of coloured stones.

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## Introduction

Brazil has been one of the world's major suppliers of coloured stones for decades. Deposits of emerald, aquamarine, tourmaline (e.g. Figure 1), topaz, chrysoberyl and quartz are widespread, and some of the mines have been explored extensively for centuries. Other gem materials, such as morganite, heliodor, amazonite, opal, kunzite, iolite, apatite, jasper and garnet, also have been found in abundance. According to both the Brazilian Ministry of Development, Industry and Foreign Trade (MDIC) and the United Nations, from 2011 until recently official exports of coloured stones from Brazil reached more than US$150 million annually (AliceWeb, 2016; UN ComTrade, 2016). This is twice as much as was documented during the previous decade, and is one of the highest reported export values for countries engaged in coloured stone mining (and the highest with regard to rough material). Based on the same sources, this figure also represents about 20 times more than all reported diamonds exported from Brazil. Moreover, the volume of gems illegally smuggled abroad likely represents a significant addition to the official exports and overall mining production. Because such data for Brazil and elsewhere often are unreliable, it is generally accepted that some countries, especially in Africa, have higher production than is reflected by official exports.

This article presents an updated overview of the Brazilian coloured stone industry based on results of field research undertaken by the author during several visits in 2011–2013, as well as access to various more recent Brazilian databases. In addition to chronicling the development of activities linked to gem exploration and mining, this article examines the effects of China's emergence as a consumer market on Brazil's gem industry. Furthermore, recent information on Brazilian gem occurrences is presented from data compiled by the Brazilian National Department of Mineral Production (DNPM) and other resources.

## Historical Review

Although gold and diamonds played an important economic role in Brazil's early history, emeralds were the resource that truly captivated the early pioneers (Reys, 2014b). Their discovery in Colombia during the 16th century convinced explorers that other emerald riches were hidden in the interior of Brazil's vast territory (Rocha Pombo, 1919).

### *Colonial Period (16th–18th Centuries)*

The history of Brazilian gemstones began with the early colonization period, when the *bandeirantes*—private slave-hunting expeditions with a secondary goal of locating potential mining areas—ventured into unknown territories (Weldon, 2012). The first of these raids was initiated in 1554, only a few decades after Brazil was claimed for Portugal by Pedro Álvares Cabral in 1500. Led by an explorer and a Jesuit priest, the raiders sailed up the Rio Mucuri to penetrate a heavily forested mountain range (Delaney, 1996; Castañeda et al., 2001). Then they continued overland to the modern-day town of Diamantina (Cornejo and Bartorelli, 2010). While the expedition opened new routes for other incursions in subsequent years, it failed to make any gem discoveries.

Indeed, no gem deposits were found until 1573, during an expedition led by Sebastião Fernandes Tourinho. Following the Rio Doce, Tourinho reached the legendary *Serra das Esmeraldas*, or 'mountain range of emeralds' (Saint-Adolphe, 1885). According to Cornejo and Bartorelli (2010), and based on information provided four centuries ago by the explorer Gabriel Soares de Sousa, the reported emeralds were discovered in the present-day Governador Valadares area, about 80 km north of the junction of the Doce and Suaçuí rivers (Soares de Sousa, 1938). However, since emeralds subsequently could not be verified in this region, the gems are now considered by most experts to have been green tourmaline (Saint-Hilaire, 1833b; Proctor, 1984; Cornejo and Bartorelli, 2010). Nevertheless, an emerald mine does exist in the area indicated by Gabriel Soares de Sousa and reportedly was later exploited for at least a decade until the 1990s.[1] This reopens the original hypothesis that emeralds could have been found in Brazil in the early years of colonization and not just in the 20th century. This also could explain why the *bandeirante* incursions continued in the region for over a century, even if most of them returned with only a few beryls or tourmalines of little value (Mauro, 1977).

*Figure 1: Multi-coloured tourmaline is emblematic of Brazil's gem production. These rough and cut examples are from the Cruzeiro mine in Minas Gerais State; the crystal is 6 cm tall and the gemstone measures 13 × 28 mm. Courtesy of Scott Rudolph; photo by Jeff Scovil.*

Although these early expeditions sought emeralds, in the late 17th century they found instead the legendary gold mines of Sabarabussu, located to the east of the present city of Belo Horizonte. The ensuing rush then expanded north, unearthing the first diamond deposits a few decades later near the town that would become Diamantina, located about 200 km from Sabara-

[1] This mine was partially owned by a gem dealer from Governador Valadares who confirmed a rumour brought to the author's attention by local gem brokers in the town square of Teófilo Otoni. One of these brokers had worked at the mine in question. The site was located in the municipality of Agua Boa, ~5 km from the Cruzeiro tourmaline mine in São José da Safira. (This is ~120 km north-east of the Itatiaia emerald deposit in the Conselheiro Pena area.)

Figure 2: The mining town of Ouro Preto was also the capital of Minas Gerais until the late 18th century. Photo by A. Reys.

bussu (Saint-Adolphe, 1885; Barbosa, 1991). The settlements that sprang up from these discoveries led to the consolidation of territories and the present-day state of Minas Gerais, an important step for Brazil (Rocha Pombo, 1919). The exploration for gold and diamonds overshadowed other gem mining activities until the 19th century, apart from the Imperial topaz deposits found nearby in the old Minas Gerais capital city of Ouro Preto (Figure 2; Machado, 2003). Yet the 18th century still can be considered the foundation of Brazilian gem mining culture. For example, it was during this time that the term *garimpeiro* emerged; this word comes from the French *grimper*, meaning 'to climb' (Pimenta, 2002). Originally referring to the lookouts for diamond smugglers who took refuge in the steep mountains, watching for the approach of Portuguese soldiers (Saint-Hilaire, 1833a), the term is still used to refer to independent miners.

### Post-Independence (19th to Mid-20th Centuries)

After Brazil's independence from Portugal in 1822, the new emperor Dom Pedro I opened the border to immigration with the goal of populating and consolidating this massive territory. Among the new arrivals were Germans, who concentrated in the present-day state of Rio Grande do Sul and initiated the first stage of development for the modern Brazilian coloured stone industry (Proctor, 1984; DNPM, 1998). Most of these immigrants working in the gem industry were from the town of Idar-Oberstein, an agate-mining community in Germany that remains an important commercial centre for gems. During this period, Idar-Oberstein was experiencing economic troubles, as the production from its agate mines dwindled. As a result, many residents left in search of other opportunities. Some travelled as far as southern Brazil, bringing their cutting and polishing techniques to the newly discovered agate and amethyst mines in Rio Grande do Sul (DNPM, 1998; Nadur, 2009). Thanks to their established trading networks, these immigrants played an important role in connecting local gem deposits with the world market. German immigrants also went to the north-eastern part of Minas Gerais, starting around the mid-19th century (Proctor, 1984; Castañeda et al., 2001; Figure 3). Within a few years, the region became Brazil's most important mining area, and the town of Teófilo Otoni was widely considered the main trading centre for gems in Brazil (Rocha Pombo, 1919).

The rise of the Brazilian gem industry also was fostered by an abundance of discoveries. Many occurred in north-eastern Minas Gerais (Gorceix, 1885). Among the most notable early finds was the 110.5 kg *Papamel* aquamarine, discovered in 1910 in the Marambaia Valley, as well as numerous emerald deposits. The first emerald site in modern times was discovered in 1912, 16 km

Figure 3: German immigrants from Idar-Oberstein initially went to Rio Grande do Sul State and later established gem-related businesses in Minas Gerais. Shown here in Minas Gerais from left to right are Viktor Bohrer-Borges, Hermann Kaucher, Herbert Wild, August Leyser, Stolley (a Brazilian dealer) and Karl Bank, circa 1907. They are holding small 'finger' bananas, a rather exotic fruit to them at the time. Courtesy of Paul Wild.

*Figure 4: The bright coloration shown by Paraíba tourmaline (here, 5.73 ct) as well as its rarity have contributed to its high value. Photo and stone courtesy of Paul Wild.*

from the town of Brumado in the deep south of Bahia State. Other emerald discoveries followed in the early 20th century at Sant'Anna dos Ferros (1919), later named Ferros, in Minas Gerais; at Itaberaí in the state of Goiás (1920); and at Anagé (1939) in Bahia (Delaney, 1996). Beryl, tourmaline, chrysoberyl and quartz also were found in abundance in those states. In the 1930s–40s, opal deposits were found near the town of Dom Pedro II in Piauí State, which at one point boasted the only explored opal deposits outside Australia (Delaney, 1996; Milanez and Puppim, 2009).

On the eve of World War II, gem-related activities in Brazil were mainly limited to mining. Although trade skills had been introduced by German immigrants a century before (Cornejo and Bartorelli, 2010), there is little evidence of a relevant coloured-stone cutting industry outside the south—at least this is what the available sources suggest (Barbosa, 1991; Nadur, 2009)—and until the 1940s diamond cutters outnumbered all other lapidaries. Most areas that are currently engaged in gem commerce were already established by this time, with the possible exception of Governador Valadares. This mid-size city was engaged in mining for industrial beryl and mica, which were used in metal alloy and insulation, respectively. Both commodities were much more profitable than gems during this period, and their global consumption peaked during World War II due to military applications (Castañeda et al., 2001).

### *The Contemporary Era*

The end of World War II, along with the advent of new synthetic materials, led to the widespread closure of industrial mineral mines in Minas Gerais. As a consequence, unemployment rose dramatically. Because tourmaline and other gems were usually found in the same pegmatite deposits as the industrial minerals, many of these mines turned exclusively to gem production (Proctor, 1984; Delaney, 1996; Castañeda et al., 2001). Accordingly, local lapidary and other trade activities grew dramatically. Within a decade, Governador Valadares became one of the most influential gem commerce centres, behind Teófilo Otoni.

The latter half of the 20th century also was marked by the emergence of a Brazilian jewellery industry and the creation of the country's two largest companies in this sector, H. Stern and Amsterdam Sauer (Nadur, 2009). Both founders, Hans Stern and Jules Roger Sauer, were Jewish immigrants fleeing Nazi persecution. In northern Minas Gerais they contributed to the rising demand for gems and even invested in some mining operations, such as the Cruzeiro tourmaline mine (Douglas Neves, pers. comm., 2013).

New deposits, often found near established mines, played an important role in the geography of gem cutting and trade. In 1954, a 34 kg aquamarine of 60% clarity, named *Martha Rocha* in tribute to the deep blue eyes of that year's Miss Brazil, was unearthed north of Teófilo Otoni. Over the next few decades, several new emerald deposits were discovered: at Itabira (1977) and Nova Era (1988) in Minas Gerais; at Santa Terezinha de Goiás (1981) in Goiás; and in the Serra de Carnaíba region (1983) of Bahia (Delaney, 1996). Alexandrite deposits also were located in the early 1980s in the municipalities of Malacacheta and Antônio Dias in Minas Gerais. Perhaps the most important discovery of the 20th century—for its singularity and its profitability—became known as Paraíba tourmaline. Uncovered for the first time in 1987 in the São José da Batalha district of Paraíba, this tourmaline's unique 'neon' blue-to-green coloration contributed to making it one of the most valuable coloured stones on the global market (Figure 4; Cornejo and Bartorelli, 2010).

Thanks to these discoveries, among other factors, Brazil emerged as one of the world's major gem exporters, creating jobs for local populations and enhancing the standing of Minas Gerais in the areas of gem production, cutting and trading. While some sources noted a slowdown in the 1970s (Proctor, 1984), others maintained that, to the contrary, numerous discoveries during this period provided a steady output into the late 1980s (Weldon, 1995; and several interviews with miners and traders). At the beginning of the 1990s, there were more than 2,700 lapidary shops in Teófilo Otoni alone, with hundreds of large, medium and small independent brokers frequenting the town centre (Robson de Andrade, pers. comm., 2013). The number of participants in Brazil's coloured stone industry then significantly decreased in the following years, especially cutters of lower-value stones such as quartz and garnet. This decline accelerated during the 2000s and seriously affected local employment in the gem industry (Reys, 2014a, 2015).

## Recent Factors Affecting Brazil's Gem Industry

What can explain the decline in production of a country as rich in gem deposits as Brazil, which has been actively engaged in the exploitation of these deposits for decades? According to official figures, Brazil remains one of the major producers of coloured stones (Reys, 2012). They even show that Brazilian exports might have increased recently, although its principal trade partners have changed during the last couple of decades (AliceWeb, 2016; UN ComTrade, 2016).

### *The Increase of Exports to Asia*

In the late 1990s, Brazilian gems were mainly exported to the United States, Europe and Japan. While the United States and Europe remain important trade partners, especially for cut gemstones, Japanese buyers practically disappeared in the 2000s. The biggest change, however, was the emergence of other Asian countries. Although Hong Kong and India have been important economic partners for Brazil, and gem exports to these countries have increased since the 1990s, they were joined by another major player: China. While China's international gem trade was negligible until the mid-1990s, the country has become one of the most important gem importers and, in 2011, the main partner in Brazil's gem commerce. In 2013, Brazil exported 60% by weight, or 25% by value, of its output to China (up to 50% by value if Hong Kong is included). Although exports to China have slightly decreased, they still represented 15% of Brazil's total output by value and 60% by weight in 2016 (AliceWeb, 2016; UN ComTrade, 2016). Indeed, the increase in exports of rough gem material to Asia has become very significant, and for a time most of it was being cut and polished in India and China. Although China has recently decreased its activities in the purchasing and cutting of coloured stones, India and Thailand furthered their positions, so Asian countries still remain at the heart of the gem industry.

Such developments have had a significant impact on the nature of local gem production in Brazil. Areas engaged with mining large quantities of quartz have benefited from the partnership with China. According to Brazilian tradespeople, the Chinese brokers began to arrive in the quartz-producing areas at the beginning of the 2000s. These brokers bought most of the cheaper gems and minerals available, especially rough mine-run quartz, contributing heavily to the rise in mining activities in areas such as Novo Horizonte in Bahia, and Curvelo and Corinto in Minas Gerais. Through the years, the Chinese dealers acquired a greater variety of stones, showing a preference for tourmaline, especially rubellite.

### *The Fall of Brazil's Lapidary Industry*

An unfortunate consequence of the increase in the trade with China has been the collapse of Brazil's domestic gemstone cutting and polishing industry for low-value materials (e.g. Figure 5), which has been unable to compete with cheaper labour in China and India. Some stones, especially quartz, were sent to China to be made into jewellery and then returned to Brazil to be sold (Figure 6). The negative effect on local economies is particularly apparent in northeastern Minas Gerais, which has traditionally specialized in handcrafted gems. In Teófilo Otoni, of the 2,700 lapidary businesses operating in 1993, only 360 remained in 2005 (GEA and IEL, 2005), and there have probably been further declines since then (Robson de Andrade, pers. comm., 2013). At least 90% of those operations had fewer than six employees and remained undeclared in the mid-2000s, indicating that the sector was still dominated by small businesses. Similar declines have been noted in Governador Valadares, as well as in larger cities such as Belo Horizonte and São Paulo.

However, gem cutting is a value-added activity and, according to Hécliton Santini Henriques, former president of the Instituto Brasileiro dos Gemas e Metais Preciosos, it should be possible to domestically process up to 80% of the gem material mined in Brazil (SEBRAE, 2006). Theoretically, this could produce more than US$50 million and also create thousands of additional lapidary jobs (SEBRAE, 2006). However, the situation has not evolved much since 2006, even if Brazil still remains significant for cutting higher-value gemstones. But since both the inexpensive and more valuable gems are included in the same statistical category, it is difficult to analyse the situation through the data usually provided (AliceWeb, 2016; UN ComTrade, 2016). In light of their differences in value, it might even be pertinent to ask whether a single 'coloured-stone' category is still relevant. For a better understanding of the geography of international trade, quartz and other lower-value stones could be grouped apart from more valuable gems such as aquamarine, tourmaline, kunzite and morganite.

*Figure 5: A lapidary facets a citrine in Governador Valadares. Photo by A. Reys.*

### Gem Business and Trading Centres

Despite their recent difficulties, Teófilo Otoni and Governador Valadares remain the major gem cutting and trading centres in Brazil (Reys, 2015), followed by the city of Belo Horizonte (the capital of Minas Gerais State). Soledade, a town in Rio Grande do Sul State, specializes in the trade of ornamental and rough agate, amethyst and other quartz varieties. The three mid-sized towns compete with, or even surpass in both cutting and trade, Brazil's three main metropolitan cities (São Paulo, Rio de Janeiro and Belo Horizonte), where jewellery businesses seem to dominate the gem-related activities. Low-cost jewellery industries are also located in São Paulo's outlying cities, such as Limeira and São José do Rio Preto (PORMIN, 2008; AliceWeb, 2016;

*Figure 6: These bead necklaces, seen in Teófilo Otoni, were manufactured in China from Brazilian rough material and then shipped back to Brazil for sale. The largest beads are approximately 8 mm in diameter. Photo by A. Reys.*

see also www.telelistas.net). However, the Brazilian gem industry remains limited in capacity on a global scale because of, notably, low Asian labour costs, high domestic taxes and bureaucracy.

Various urban centres engaged in some level of gem business host the country's main gem fairs, which are small venues compared with other international shows such as those in Tucson, Hong Kong, Bangkok, Basel and Munich. The *Feninjer Brazilian Gems and Jewellery Show* has taken place in São Paulo since the 1950s and remains a jewellery-focused event. Other exhibitions occur annually near the main mining areas. The largest of these is the *Feira Internacional de Pedras Preciosas* (FIPP) in Teófilo Otoni, which marked its 27th year in 2017. Other major gem fairs include the *Exposol* in Soledade and the *Feira de Pedras Preciosas e Semipreciosas* in Curvelo, both showcasing mainly quartz specimens, spheres and other ornamental quartz gems. The *Brazilian Gem Show*, which was marketed as the country's most important specialized fine-gems exhibition, has not taken place or has run only sporadically since the beginning of the 2010s, reportedly due to lack of interest and support from local agents and authorities.

*Figure 7: A gem broker in Teófilo Otoni waits for customers, who are becoming increasingly scarce. Photo by A. Reys.*

An important factor to note is the informal trading of gems. Several hundred individuals travel around the country and acquire rough material to sell later in the metropolitan areas, particularly in Teófilo Otoni (Figure 7) and Governador Valadares. In Teófilo Otoni, a gallery of about 25 shops associated with a local brokers' association was established at the beginning of the 1990s near the main town square and supported by local authorities in an effort to legalize gem trading practices. Other shops also can be found throughout the town, and they act as headquarters for regional companies engaged in mining in the surrounding areas.

While Teófilo Otoni remains the main centre for gem trading, other areas such as Peçanha and Afonso Pena streets in Governador Valadares and Praça Sete in Belo Horizonte also conduct trade activities. As noted above, additional centres exist, notably Soledade in Rio Grande do Sul. Smaller towns with trading centres include Ouro Preto, Curvelo, Itabira and Nova Era in Minas Gerais; Ametista do Sul and Lajeado in Rio Grande do Sul; Campo Formoso, Brejinho das Ametistas and Novo Horizonte in Bahia; Santa Terezinha de Goiás, Caldas Novas and Cristalina in Goiás; and Dom Pedro II in Piauí (PORMIN, 2008). The widespread adoption of modern technology such as the Internet and digital cameras has revolutionized traditional methods of trading over the past decade, making middlemen somewhat obsolete. In addition, a decline in business also might be due to the erosion of informal mining activities.

## Status of Mining Operations

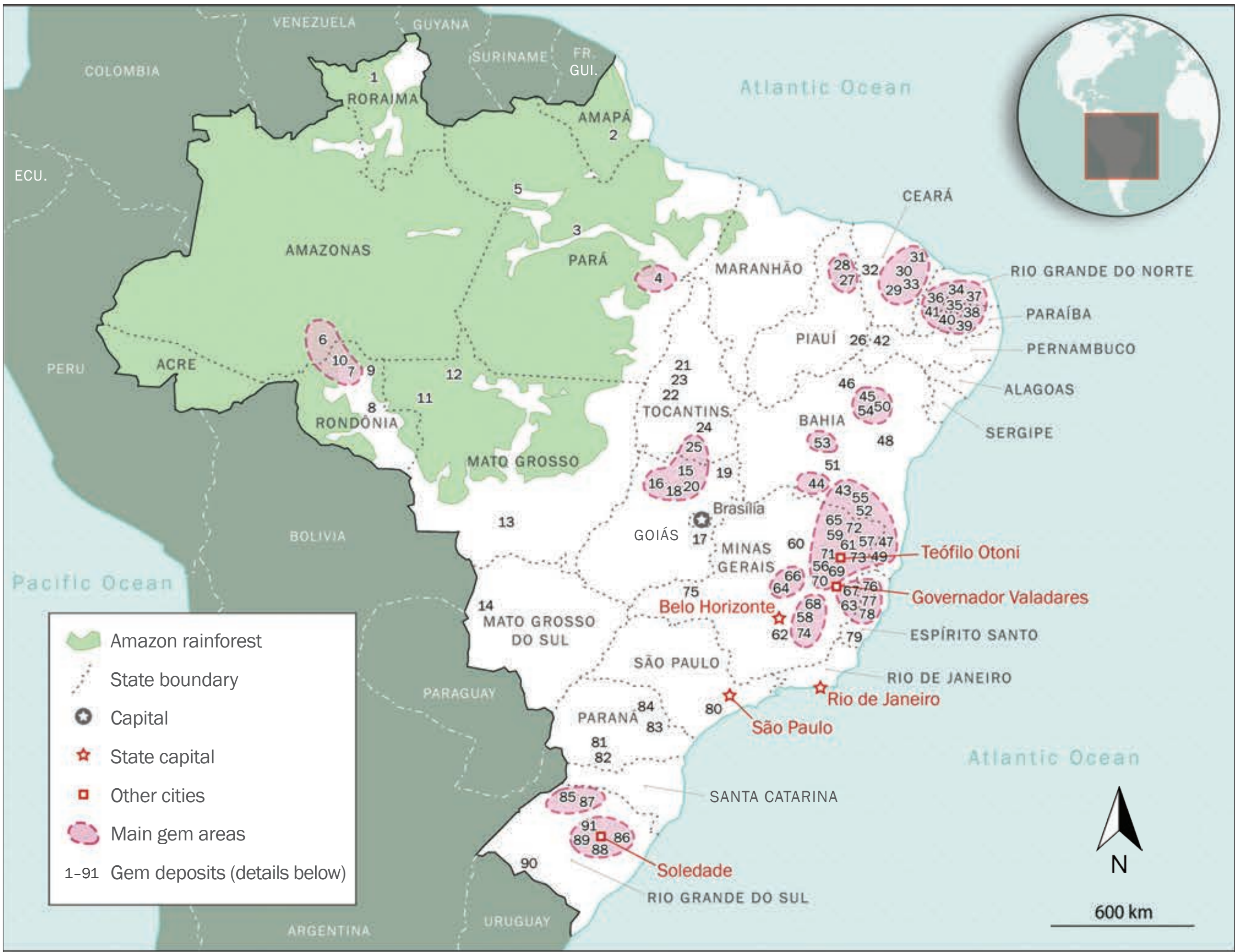
It can be challenging to judge the legality of a mining operation in Brazil, as even a legally registered one might use an undeclared labour force or might illegally export its production. Nevertheless, a mine remains technically legal as long as it is declared to the DNPM, so most smaller-scale operations (e.g. Figure 8) are therefore considered illegal, as they do not appear in official statistics. Although these small mines are important to the local gem industry, their number has fallen significantly during the last couple of decades, and local labour forces, gem merchants and associations assert that the number of *garimpeiros* has declined anywhere from 50% to 90% in Minas Gerais since the end of the 1980s (Reys, 2015).

*Figure 8:* Garimpeiros *dig for aquamarine in Catuji, located in the Marambaia Valley. This type of open-pit mine is called* cata *('pick off') by locals. Photo by A. Reys.*

Such declines are usually blamed on local authorities who support progressive measures to limit unauthorized mining. Yet several recent aspects have called this reasoning into question, besides the geographical and logistical difficulties in tracking down illegal mines. Mining regulations are expensive and difficult to enforce, and there are insufficient resources to accomplish such a mission. In Teófilo Otoni, for instance, there are only four agents assigned to an area of 8,100 $km^2$, and only one squad from DNPM is available for the entire north-eastern Minas Gerais region, where gem mining operations are scattered over a 100,000 $km^2$ area. Some places in the far west and north, near the Amazon rainforest, are extremely difficult to reach. Roads in such regions are rare or in poor condition, and furthermore, DNPM agents admit that they often avoid closing down illegal operations because the miners have no other employment opportunities in these poor rural areas. In addition, according to the present author's research, the impacts of the Brazilian Institute of Environment (IBAMA) and its fight against illegal small-scale gem mining are often overestimated. Contrary to popular belief, actions carried out by the Brazilian authorities so far have not been very effective. In northern Minas Gerais, for instance, there are still hundreds of illegal gem mines operating, sometimes quite close to the main roads.

Other factors are linked to diminishing Brazilian gem production, such as the evolution of the international market. Many African countries now produce a larger variety and quantity of gems than they did a couple of decades ago, and those stones usually are sold at somewhat lower prices than those from Brazil. However, the effects of this on the Brazilian market have been tempered by a rise in demand caused by the new middle class in emerging countries. Nevertheless, the author's research has linked the reduction in Brazilian gem mining activities with economic growth and improved living conditions. Indeed, in the past few years, several rural regions have experienced significant economic development, which has led to social improvements. With an increasingly stable political atmosphere followed by economic growth, the living standards of the most modest regions of Brazil have improved. Economic progress has provided new investment opportunities that carry less financial risk than gem prospecting. The growth of the economy also has had positive effects on employment: Workers are able to choose less-dangerous and less-exhausting jobs for comparable wages to mining. Most workers engaged in mining are more than 40 years old and want a different future for their children; and for their part, the younger generation seems to aspire to a more modern and comfortable lifestyle (Reys, 2104a, 2015).

The high cost of mining—because most of the current deposits require deeper tunneling since the easier-to-obtain gems have already been exploited—is another reason for the recent decline in mining and production.




**RORAIMA**
1. Amajari (Am)

**AMAPÁ**
2. Porto Grande (Tta)

**PARÁ**
3. Brasil Novo, Medicilândia (Am)
4. Marabá (Am, Qz)
5. Oriximiná, Óbidos (Col)

**AMAZONAS**
6. Lábrea (Am, Tp)

**RONDÔNIA**
7. Alto Paraíso, Ariquemes (Tp)
8. Ji-Paraná (Am, Qz)
9. Machadinho d'Oeste (Op, Qz)
10. Porto Velho (Am, Tp, Tu)

**MATO GROSSO**
11. Aripuanã (Am)
12. Colniza, Cotriguaçu (Tu)
13. Cuiabá, Várzea Grande (Qz)

**MATO GROSSO DO SUL**
14. Bodoquena, Corumbá (Am)

**GOIÁS**
15. Campinaçu, Campinorte, Minaçu (Be)
16. Campos Verdes, Santa Terezinha de Goiás (Em)
17. Cristalina (Qz)
18. Crixás, Uruaçu (Am)
19. Monte Alegre de Goiás (Qz)
20. Niquelândia (Qz)

**TOCANTINS**
21. Barrolândia (Be)
22. Cristalândia (Qz)
23. Monte Santo do Tocantins (Be, Em, Tu)
24. Peixe, Pindorama do Tocantins (Gr, Qz)
25. São Salvador do Tocantins, Palmeirópolis (Be, Tu)

**PIAUÍ**
26. Betânia do Piauí (Be)
27. Buriti dos Montes (Op)
28. Pedro II (Op)

**CEARÁ**
29. Acopiara, Piquet Carneiro (Am, Qz)
30. Banabuiú, Quixeramobim (Am, Be, Gr, Qz, Tta, Tu)
31. Beberibe (Am, Qz)
32. Crateús (Am, Qz)
33. Milhã, Solonópole (Be, Gr, Tu, Qz)

**RIO GRANDE DO NORTE**
34. Acari, Currais Novos, Jardim do Seridó, Santana do Matos (Be, Gr)
35. Carnaúba dos Dantas, Equador, Parelhas (Ap, Be, Eu, Gr, Qz, Tu)
36. Tenente Ananias (Be, Tu)
37. Lajes, São Tomé (Be, Em)

**PARAÍBA**
38. Assunção, Juazeirinho, Taperoá (Be, Qz, Tta, Tu)
39. Frei Martinho, Pedra Lavrada (Gr, Qz, Tta, Tu)
40. Salgadinho (Em, Tu)
41. Santa Cruz, São Francisco (Be, Qz, Tu)

**PERNAMBUCO**
42. Ouricuri, Santa Filomena (Alx)

**BAHIA**
43. Brumado, Anagé (Em)
44. Caetité (Am, Gr, Qz)
45. Campo Formoso (Alx, Em, Qz)
46. Casa Nova, Sento Sé (Am, Be, Gr, Qz)
47. Guaratinga (Alx, Be, Cb)
48. Ipirá (Ap, Be, Dio, Qz)
49. Itamaraju, Itanhém (Be, Cb)
50. Itiúba (Az)
51. Livramento de Nossa Senhora (Am, Qz)
52. Macarani, Maiquinique, Encruzilhada (Be, Qz, Tu)
53. Novo Horizonte, Oliveira dos Brejinhos (Qz)
54. Saúde, Pindobaçu (Cb, Em)
55. Vitória da Conquista, Itambé (Be, Eu, Gr, Qz, Tp)

**MINAS GERAIS**
56. Água Boa, Santa Maria do Suaçuí, São José da Safira (Be, Gr, Qz, Tu)
57. Almenara, Itaobim, Joaíma (Be, Qz, Tu)
58. Antônio Dias, Itabira, Nova Era (Alx, Be, Em, Qz, Tp)
59. Araçuaí, Itinga (Am, An, Be, Bz, Qz, Tp, Tu)
60. Bocaiúva, Montes Claros, Botumirim (Qz)
61. Caraí, Catuji, Padre Paraíso (Be, Cb, Qz, Tp, Tu)
62. Conselheiro Lafaiete (Gr)
63. Conselheiro Pena, Galiléia, Resplendor (Ap, Be, Em, Eu, Gr, Qz, Spd, Tu)
64. Corinto, Curvelo (Qz)
65. Coronel Murta, Salinas, Virgem da Lapa (Be, Qz, Tp, Tu)
66. Diamantina (Qz)
67. Divino das Laranjeiras (Am, Be, Bz, Qz, Tu)
68. Ferros, Santa Maria de Itabira (Alx, Az, Be, Eu, Em, Qz)
69. Franciscópolis, Itambacuri (Qz, Tu)
70. Governador Valadares, Tarumirim (Be, Gr, Qz, Tu)
71. Malacacheta (Alx, An, Be, Qz, Sa, Tu)
72. Medina, Pedra Azul (Be, Tp)
73. Novo Oriente de Minas, Teófilo Otoni (Be, Qz, Tp, Tu)
74. Ouro Preto (Eu, Tp)
75. Tupaciguara, Uberlândia (Am, Qz)

**ESPÍRITO SANTO**
76. Água Doce do Norte, Barra de São Francisco (Be, Qz, Tu)
77. Colatina, Itaguaçu, Pancas (Be, Cb)
78. Mimoso do Sul, Muqui (Be, Tp, Tu)
79. Santa Teresa (An, Be, Cb, Qz)

**SÃO PAULO**
80. Itariri (Qz)

**PARANÁ**
81. Chopinzinho (Am, Qz)
82. Clevelândia, Coronel Vivida (Am)
83. Cerro Azul, Jaguariaíva (Dio)
84. Congonhinhas, Ibaiti, Tibagi (Sa)

**RIO GRANDE DO SUL**
85. Ametista do Sul, Frederico Westphalen, Iraí (Ag, Am, Cac)
86. Caxias do Sul (Am, Qz)
87. Cristal do Sul, Rodeio Bonito (Ag, Am, Cac)
88. Progresso (Ag, Am, Qz)
89. Salto do Jacuí, Estrela Velha (Ag, Am, Op, Qz)
90. Santana do Livramento (Ag, Am, Qz)
91. Soledade (Ag, Am, Qz)

ABBREVIATIONS

| | |
|---|---|
| Ag: agate | Dio: diopside |
| Alx: alexandrite | Em: emerald |
| Am: amethyst | Eu: euclase |
| An: andalusite | Gr: garnet |
| Ap: apatite | Op: opal |
| Az: amazonite | Qz: quartz |
| Be: beryl | Sa: sapphire |
| Bz: brazilianite | Spd: spodumene |
| Cac: calcite | Tp: topaz |
| Cb: chrysoberyl | Tta: tantalite |
| Col: columbite | Tu: tourmaline |

Figure 10: Weighing 6.11 ct, this emerald is unusually large for clean material from Brazil. Courtesy of Paul Wild; photo by Jordan Wilkins.

Figure 11: This 22.93 ct aquamarine is from Santa Maria in Minas Gerais. Courtesy of Paul Wild; photo by Jordan Wilkins.

## Current Gem Deposits and Occurrences

Despite the above-mentioned forces, mining for various commodities remains the backbone of the Brazilian gem industry, and a wide variety of gems is still found throughout the country. According to DNPM, there were 2,294 gem occurrences in 401 different municipalities as of 2013, with 49.3% of them in Minas Gerais and 19% in Rio Grande do Sul (DNPM, 2013; Reys, 2015). The occurrences in the north-eastern part of the country have surely been underestimated, as it is a poorer and usually less regulated area. Emerald and other beryls, tourmaline, topaz and all types of quartz are the most widely mined coloured stone resources nationwide (see Figure 9 and Table I).

### *Emerald*

Since the 2000s, Brazil was usually ranked third among the world's leading emerald producers (e.g. Figure 10), behind Colombia and Zambia (Yager et al., 2008; UN ComTrade, 2016). Unlike Colombian emeralds, which have a hydrothermal origin, Brazilian emeralds occur in schist-type deposits, formed by the reaction of pegmatitic veins with ultramafic host rocks (Giuliani et al., 2013). Brazilian emerald production has occurred in three states—Goiás, Bahia, Minas Gerais—and mining operations are usually conducted by people originally from the state of Bahia. In recent years, output from Goiás has drastically slowed as the depths required have made commercial mining unprofitable. In Bahia, most of the production is in the vicinity of Campo Formoso in the Carnaíba region, while in Minas Gerais exploitation is run by the company Belmont in Itabira and by a cooperative in the neighbouring town of Nova Era. The Itabira emerald belt also includes Conta Galo, São Domingues da Prata, Piteiras and Rocha. Emeralds from Minas Gerais are deemed to have a higher purity and clarity than those found in Bahia, which are typically a deeper green.

An emerald deposit was discovered relatively recently in the Rio Doce Valley of Minas Gerais. Located at the Itatiaia mine in Conselheiro Pena, the area is being explored by Geometa, a company based in Governador Valadares. Geologist Jurgen Schnellrath from the Mineral Technology Center (CTM) in Rio de Janeiro believes that higher quality emeralds might be produced as mining continues (J. Schnellrath, pers. comm., 2013; see also Schnellrath et al., 2013). Additional locations in Tocantins and Rio Grande do Norte States also host emerald deposits (Johnson and Koivula, 1998; Zwaan et al., 2012). Other areas previously claimed by locals to produce emeralds, such as in Malacacheta or Novo Cruzeiro, in reality do not. Specimens extracted from these areas are usually Cr/V deficient and therefore too light coloured to be considered emerald.

### *Other Beryls*

Apart from emerald, beryl production is dominated by light to medium-dark blue aquamarine (e.g. Figure 11), of which Brazil may be one of the largest exporters. Historically, these gems came from deposits near Teófilo Otoni, within

Figure 9: The distribution of Brazil's current gem occurrences is shown in this map. Minas Gerais accounts for almost half of the deposits.

*Table I: Current coloured stone deposits of Brazil.*

*Sources*: DNPM (2013); locations not listed by DNPM (shown in italics) are documented by bibliographic references, and the ones underlined are sites visited by the author during fieldwork. Locations are listed by states (in capital letters) followed by municipalities. Not all of the deposits listed here are shown in Figure 9 due to lack of space.

| | |
|---|---|
| **Amazonite** | BAHIA: Itiúba, Macarani<br>MINAS GERAIS: *Araçuaí, Ferros, Jaguaraçu, Salinas, Santa Maria de Itabira* |
| **Andalusite** | ESPÍRITO SANTO: *Santa Teresa*<br>MINAS GERAIS: *Araçuaí, Itinga, Malacacheta, Minas Novas* |
| **Apatite** | BAHIA: *Capim Grosso, Ipirá, Senhor do Bonfim*<br>MINAS GERAIS: *Conselheiro Pena, São José da Safira*<br>RIO GRANDE DO NORTE: *Equador, Parelhas* |
| **Beryl (aquamarine, goshenite, heliodor, morganite)** | BAHIA: *Alcobaça,* Anagé, Cândido Sales, *Caravelas,* Casa Nova, Encruzilhada, Eunápolis, *Guaratinga*, Ipirá, *Itamaraju*, Itambé, *Itanhém, Itapetinga,* Macarani, *Maiquinique,* Maraú, Pilão Arcado, Piripá, Sento Sé, Vitória da Conquista<br>CEARÁ: Banabuiú, Independência, *Jaguaribe,* Milhã, Ocara, Russas, Solonópole<br>ESPÍRITO SANTO: Afonso Cláudio, Água Doce do Norte, Aracruz, *Baixo Guandu,* Barra de São Francisco, *Castelo,* Domingos Martins, *Fundão,* Ibitirama, *Itaguaçu, Mimoso do Sul, Muqui,* Pancas, *Santa Teresa*<br>GOIÁS: Campinaçu, Campinorte, Formoso, Minaçu<br>MINAS GERAIS: Água Boa, Águas Formosas, Aimorés, Almenara, Alpercata, Alvarenga, Antônio Dias, Araçaí, Araçuaí, Aricanduva, Ataléia, Barão de Cocais, Barão de Monte Alto, Bom Jesus do Amparo, Capelinha, Caraí, Carangola, Caratinga, Cataguases, Catuji, Chapada do Norte, Cipotânea, Conceição do Mato Dentro, Conselheiro Pena, Cordisburgo, Coronel Murta, Dionísio, Divino, Divino das Laranjeiras, Dom Silvério, Espera Feliz, Ferros, Franciscópolis, Frei Inocêncio, Galiléia, Goiabeira, Governador Valadares, Inhapim, Ipanema, Itabira, Itaipé, Itanhomi, Itaobim, Itinga, Jampruca, Jenipapo de Minas, *Jequitinhonha,* Joaíma, Jordânia, Malacacheta, Marilac, Marliéria, *Mata Verde,* Mathias Lobato, Medina, Mendes Pimentel, Minas Novas, Muriaé, Nanuque, Ninheira, Nova Era, Novo Cruzeiro, Novo Oriente de Minas, Padre Paraíso, Pavão, Peçanha, *Pedra Azul,* Piranga, Pocrane, Poté, Raul Soares, Resplendor, Rubelita, Sabinópolis, Salinas, Santa Bárbara do Leste, Santa Maria de Itabira, Santa Maria do Suaçuí, Santa Rita de Minas, Santana do Paraíso, Santo Antônio do Itambé, São Domingos do Prata, São Geraldo do Baixio, São Gonçalo do Rio Abaixo, São José da Safira, São José do Mantimento, São Sebastião do Maranhão, Serro, Simonésia, Sobrália, Tarumirim, Teófilo Otoni, Virgem da Lapa<br>PARAÍBA: Alagoa Grande, Alagoa Nova, Areia, Assunção, Barra de Santa Rosa, Bom Jesus, Cacimbas, Cajazeiras, Juazeirinho, Junco do Seridó, Pedra Lavrada, Picuí, Santa Cruz, Santa Luzia, São Francisco, São José de Espinharas, São José dos Cordeiros, *São Mamede,* Seridó, *Serra Branca,* Sossêgo, Sumé, Taperoá<br>PERNAMBUCO: Dormentes, Santa Cruz do Capibaribe, Santa Filomena<br>PIAUÍ: Betânia do Piauí<br>RIO DE JANEIRO: Laje do Muriaé<br>RIO GRANDE DO NORTE: *Acari,* Caiçara do Rio do Vento, Carnaúba dos Dantas, Cerro Corá, Currais Novos, *Equador,* Jardim de Angicos, Jardim do Seridó, Lagoa Nova, Lajes, Lajes Pintadas, Luís Gomes, Parelhas, Santana do Matos, *São João do Sabugi,* São Tomé, Tenente Ananias<br>TOCANTINS: Barrolândia, Jaú do Tocantins, Monte Santo do Tocantins, Palmeirópolis, Presidente Kennedy, São Salvador do Tocantins |
| **Beryl (emerald)** | BAHIA: Anagé, *Brumado,* Campo Formoso, Mirangaba, Pilão Arcado, Pindobaçu, Saúde, *Vitória da Conquista*<br>GOIÁS: Campos Verdes, *Pirenópolis,* Santa Terezinha de Goiás<br>MINAS GERAIS: *Água Boa,* Antônio Dias, Bela Vista de Minas, *Conselheiro Pena,* Ferros, Itabira, Nova Era, São Domingos do Prata<br>PARAÍBA: Juazeirinho, Salgadinho<br>RIO GRANDE DO NORTE: Caiçara do Rio do Vento, Lajes, São Tomé<br>TOCANTINS: Monte Santo do Tocantins, *Paraíso do Tocantins,* Presidente Kennedy |
| **Brazilianite** | MINAS GERAIS: *Divino das Laranjeiras, Itinga* |
| **Calcite** | RIO GRANDE DO NORTE: *Currais Novos*<br>RIO GRANDE DO SUL: Ametista do Sul, Cristal do Sul, Frederico Westphalen, Iraí, Planalto, Rodeio Bonito, Trindade do Sul |

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| **Chrysoberyl** | BAHIA: *Alcobaça, Caravelas, Encruzilhada, Guaratinga, Itamaraju, Mucuri, Pindobaçu, Prado, Teixeira de Freitas*<br>ESPÍRITO SANTO: *Colatina, Cachoeiro do Itapemirim, Itaguaçu, Pancas, Santa Teresa, Sooretama*<br>MINAS GERAIS: *Araçuaí, Caraí, Catuji, Itabira, Itambacuri, Jequitinhonha, Malacacheta, Minas Novas,* Padre Paraíso, *Pavão, Serro, Teófilo Otoni*<br>SÃO PAULO: *Itapecerica da Serra, Patrocínio Paulista* |
| **Chrysoberyl (alexandrite)** | BAHIA: *Campo Formoso, Guaratinga*<br>GOIÁS: *Minaçu*<br>MINAS GERAIS: Antônio Dias, Ladainha, Malacacheta, *Manhuaçu,* Nova Era, Santa Maria de Itabira, Setubinha<br>PERNAMBUCO: Ouricuri, Santa Filomena |
| **Columbite** | BAHIA: *Encruzilhada, Itambé*<br>PARÁ: Óbidos, Oriximiná<br>RONDÔNIA: Itapuã do Oeste |
| **Cordierite (iolite)** | BAHIA: *Nova Itarana, Teixeira de Freitas* |
| **Corundum (ruby)** | BAHIA: *Ponto Novo* |
| **Corundum (sapphire)** | BAHIA: *Itaetê*<br>MINAS GERAIS: Canápolis, *Caratinga,* Ituiutaba, Ladainha, *Malacacheta, Manhuaçu*<br>PARANÁ: Congonhinhas, Ibaiti, Tibagi |
| **Diopside** | BAHIA: Castro Alves, Ipirá, Rafael Jambeiro, Santa Teresinha<br>MINAS GERAIS: Capelinha<br>PARANÁ: Cerro Azul, Doutor Ulysses, Jaguariaíva, Sengés |
| **Euclase** | BAHIA: *Vitória da Conquista*<br>ESPÍRITO SANTO: *Cachoeiro de Itapemirim*<br>MINAS GERAIS: *Conseilheiro Pena, Ouro Preto, Santa Maria de Itabira, São Sebastião do Maranhão*<br>RIO GRANDE DO NORTE: *Carnaúba dos Dantas, Equador, Parelhas* |
| **Garnet (almandine, pyrope, spessar-tine)** | BAHIA: *Andaraí,* Caetité, *Curaçá,* Casa Nova, *Itambé, Mucugê, Vitória da Conquista*<br>CEARÁ: Banabuiú, *Orós, Quixeramobim, Solonópole*<br>ESPÍRITO SANTO: *Colatina, Guarapari, Santa Teresa*<br>GOIÁS: Ipameri<br>MINAS GERAIS: *Barbacena, Conceição do Mato Dentro,* Conselheiro Pena, *Galiléia, Governador Valadares, Itamarandiba, Resplendor, Santa Maria do Suaçui,* São José da Safira, Tarumirim, *Viçosa*<br>PARAÍBA: Frei Martinho, *Pedra Branca,* Pedra Lavrada, *Santa Luzia, Seridó*<br>RIO GRANDE DO NORTE: *Acari,* Carnaúba dos Dantas, *Currais Novos, Jardim do Seridó, Parelhas, São João do Sabugi, Várzea*<br>TOCANTINS: Peixe, Pindorama do Tocantins, São Salvador do Tocantins, São Valério da Natividade |
| **Kyanite** | MINAS GERAIS: *Coronel Murta,* Frei Lagonegro, Itamarandiba, São Sebastião do Maranhão |
| **Opal** | CEARÁ: Várzea Alegre<br>PARÁ: *São Geraldo do Araguaia*<br>PIAUÍ: Buriti dos Montes, Pedro II<br>RONDÔNIA: Machadinho d'Oeste<br>RIO GRANDE DO SUL: Estrela Velha, Fontoura Xavier, Lagoão, Salto do Jacuí |
| **Quartz (agate, chalcedony)** | MARANHÃO: São João dos Patos<br>PARÁ: São Félix do Xingu<br>RIO GRANDE DO SUL: Ametista do Sul, Boqueirão do Leão, Ciríaco, Cristal do Sul, Espumoso, Estrela Velha, Frederico Westphalen, Iraí, Júlio de Castilhos, Lagoão, Nova Prata, Planalto, Pinhal da Serra, Progresso, Rodeio Bonito, Salto do Jacuí, Santana do Livramento, Segredo, Soledade, Trindade do Sul |
| **Quartz (amethyst, citrine)** | AMAZONAS: Japurá, Lábrea, Novo Aripuanã, Presidente Figueiredo<br>BAHIA: Botuporã, Caetité, Casa Nova, Condeúba, Gentio do Ouro, Ibiassucê, *Itambé, Jacobina, Licínio de Almeida, Livramento de Nossa Senhora,* Presidente Jânio Quadros, Sento Sé |

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| **Quartz (amethyst, citrine)** (continued) | CEARÁ: Banabuiú, Beberibe, Crateús, Deputado Irapuan Pinheiro, Milhã, Novo Oriente, Piquet Carneiro, Quixeramobim<br>GOIÁS: Cavalcante, Crixás, Nova Iguaçu de Goiás, Uruaçu<br>MATO GROSSO DO SUL: Bodoquena, Corumbá<br>MATO GROSSO: Aripuanã<br>MINAS GERAIS: *Araçuaí,* Araporã, *Ataléia, Coronel Murta, Divino das Laranjeiras, Galiléia, Itinga, Montezuma, Ouro Verde de Minas,* Palma, Recreio, *São Geraldo do Baixio, São Miguel do Anta,* Senhora do Porto, Tupaciguara<br>PARÁ: Almeirim, Aveiro, Brasil Novo, Marabá, Medicilândia<br>PARAÍBA: *Santana da Mangueira, Juazeirinho*<br>PARANÁ: Chopinzinho, Clevelândia, Coronel Vivida, São João, São Jorge d'Oeste<br>PIAUÍ: Cocal<br>RIO GRANDE DO SUL: *Alpestre,* Ametista do Sul, Barros Cassal, Boqueirão do Leão, Caxias do Sul, Coqueiro Baixo, Cristal do Sul, Espumoso, Estrela Velha, Fontoura Xavier, Frederico Westphalen, *Gramado dos Loureiros,* Guaporé, Iraí, Júlio de Castilhos, Lagoão, Nova Boa Vista, Nova Bréscia, Nova Prata, Pinhal da Serra, Planalto, Pouso Novo, Progresso, Putinga, Relvado, Rodeio Bonito, Salto do Jacuí, Santana do Livramento, São José do Herval, São Martinho da Serra, Segredo, Soledade, Trindade do Sul<br>RONDÔNIA: Campo Novo de Rondônia, Costa Marques, Ji-Paraná, Nova Mamoré, Porto Velho<br>RORAIMA: Amajari<br>SÃO PAULO: Santo Antônio do Jardim<br>TOCANTINS: Chapada da Natividade, Gurupi |
| **Quartz (rose quartz, smoky quartz, rock crystal)** | BAHIA: Belo Campo, *Boninal,* Brotas de Macaúbas, *Brumado, Caetité, Campo Formoso,* Casa Nova, Condeúba, Contendas do Sincorá, *Encruzilhada,* Ibipitanga, *Ibitiara,* Ibotirama, Ipirá, Ipupiara, Itaju do Colônia, *Itambé,* Ituaçu, *Livramento de Nossa Senhora,* Macarani, *Maiquinique,* Novo Horizonte, Oliveira dos Brejinhos, Paramirim, Pau Brasil, Piripá, Rio do Pires, *Saude,* Sento Sé, Tanhaçu, *Vitória da Conquista*<br>CEARÁ: Acopiara, *Alto Santo,* Banabuiú, *Beberibe,* Cariús, *Crateús,* Deputado Irapuan Pinheiro, *Independência,* Itapiúna, Milhã, *Morada Nova, Nova Olinda, Novo Oriente,* Parambu, Piquet Carneiro, Quixeramobim, *Santa Quitéria, Solonópole,* Tamboril, Várzea Alegre<br>ESPÍRITO SANTO: Afonso Cláudio, Água Doce do Norte, Barra de São Francisco, João Neiva, Santa Leopoldina, Santa Teresa<br>GOIÁS: Campinaçu, Cristalina, Monte Alegre de Goiás, Niquelândia, Nova Roma, Teresina de Goiás, Trombas<br>MATO GROSSO: Cuiabá, Nova Monte Verde, Poconé, Várzea Grande<br>MINAS GERAIS: Açucena, Água Boa, Águas Formosas, Aimorés, Almenara, Alpercata, Alvarenga, Araçuaí, Araguari, Araporã, Aricanduva, Ataléia, Bandeira, Barão de Monte Alto, Belmiro Braga, Bocaiúva, Botumirim, Buenópolis, Capelinha, Caraí, Caratinga, Carbonita, Carmésia, Catuji, Chapada do Norte, Cláudio, Conceição do Mato Dentro, Congonhas do Norte, Conselheiro Pena, *Corinto,* Coroaci, Coronel Murta, Couto de Magalhães de Minas, Crisólita, Curvelo, Diamantina, Divino das Laranjeiras, Dom Joaquim, Entre Folhas, Espera Feliz, Ferros, Formiga, Francisco Dumont, Francisco Sá, Franciscópolis, Frei Inocêncio, Fronteira, Galiléia, Gouveia, Governador Valadares, Inhapim, Itaipé, Itamarandiba, Itambacuri, Itanhomi, Itaobim, Itinga, Jampruca, Jenipapo de Minas, Jequitaí, Joaíma, Jordânia, Ladainha, Limeira do Oeste, Malacacheta, Mata Verde, Mathias Lobato, Matias Barbosa, Mendes Pimentel, Minas Novas, Monte Alegre de Minas, *Montes Claros,* Muriaé, Nacip Raydan, Nanuque, Naque, Nova Era, Nova Módica, Nova Serrana, Novo Cruzeiro, Novo Oriente de Minas, Padre Paraíso, Patrocínio do Muriaé, Pavão, Peçanha, Periquito, Poté, Presidente Kubitschek, Raul Soares, Resplendor, Rubelita, Sabinópolis, Salinas, Santa Maria de Itabira, Santa Maria do Suaçuí, Santa Rita de Jacutinga,Santa Rita de Minas, Santana do Paraíso, São Domingos do Prata, São Félix de Minas, São Geraldo do Baixio, São João da Lagoa, *São João do Paraíso,* São José da Safira, São Sebastião do Maranhão, Senador Modestino Gonçalves, Senhora do Porto, Setubinha, Sobrália, Tarumirim, Teófilo Otoni, Tupaciguara, Uberlândia, Vargem Alegre, Virgem da Lapa, Virgolândia<br>PARÁ: Eldorado dos Carajás, Marabá, São João do Araguaia<br>PARAÍBA: Assunção, Barra de Santa Rosa, Bom Jesus, Cabaceiras, Cacimbas, Cajazeiras, Junco do Seridó, Monteiro, Pedra Lavrada, Santa Cruz, São Francisco, São João do Cariri, Sossêgo, Sumé, Taperoá<br>PARANÁ: Chopinzinho<br>RIO GRANDE DO NORTE: *Carnaúba dos Dantas, Equador*, Parelhas, São Miguel |

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| **Quartz (rose quartz, smoky quartz, rock crystal)** (continued) | RIO GRANDE DO SUL: Barros Cassal, Boqueirão do Leão, Caxias do Sul, Ciríaco, Espumoso, Estrela Velha, Fontoura Xavier, Jacuizinho, Júlio de Castilhos, Lagoão, Nova Prata, Pinhal da Serra, Progresso, Putinga, Salto do Jacuí, Santana do Livramento, Segredo, Soledade<br>RONDÔNIA: *Ji-Paraná*, Machadinho d'Oeste<br>SÃO PAULO: Icém, Itariri<br>TOCANTINS: Cristalândia, Dueré, Peixe, Pequizeiro, Pindorama do Tocantins, Santa Rita do Tocantins |
| **Rhodonite** | BAHIA: *Encruzilhada, Urandi*<br>MINAS GERAIS: *Conselheiro Lafaiete* |
| **Spodumene (hiddenite, kunzite)** | MINAS GERAIS: *Araçuaí*, Conselheiro Pena, *Galiléia*, *Novo Cruzeiro, Resplendor* |
| **Tantalite** | AMAPÁ: Mazagão, Pedra Branca do Amapari, Porto Grande, Serra do Navio<br>CEARÁ: Banabuiú<br>PARAÍBA: Frei Martinho, Juazeirinho, Nova Palmeira, Picuí, Seridó |
| **Titanite (sphene)** | MINAS GERAIS: Capelinha |
| **Topaz** | AMAZONAS: Lábrea, Manicoré<br>BAHIA: *Belmonte, Itambé, Vitória da Conquista*<br>ESPÍRITO SANTO: *Mimoso do Sul*<br>MINAS GERAIS: *Araçuaí, Caraí,* Catuji, Galiléia, Goiabeira, *Itabira,* Itaipé, *Itinga, Medina,* Nova Era, Novo Oriente de Minas, Ouro Branco, Ouro Preto, Padre Paraíso, Pavão, *Pedra Azul, Salinas,* São Domingos do Prata, Teófilo Otoni, *Virgem de Lapa*<br>RONDÔNIA: Alto Paraíso, Ariquemes, Itapuã do Oeste, Monte Negro, Porto Velho, Rio Crespo |
| **Tourmaline** | BAHIA: Brumado, Condeúba, *Encruzilhada,* Macarani, *Maiquinique,* Nordestina, Queimadas, *Vitória da Conquista*<br>CEARÁ: Apuiarés, Banabuiú, *Canindé, Itapiúna,* Jaguaretama, Milhã, Quixeramobim, Solonópole<br>ESPÍRITO SANTO: Água Doce do Norte, Barra de São Francisco, Ecoporanga, *Mimoso do Sul*<br>GOIÁS: Campinaçu, Montividiu do Norte<br>MATO GROSSO: Alta Floresta, Castanheira, Colniza, Cotriguaçu<br>MINAS GERAIS: Açucena, Água Boa, Águas Formosas, Aimorés, Almenara, Alpercata, Alvarenga, Araçuaí, Aricanduva, Ataléia, Bandeira, Barão de Monte Alto, Bela Vista de Minas, Capelinha, Caraí, Caratinga, Catuji, Chapada do Norte, Conselheiro Pena, Coroaci, Coronel Murta, Crisólita, Divino das Laranjeiras, Entre Folhas, Francisco Sá, Franciscópolis, Frei Inocêncio, Galiléia, Goiabeira, Governador Valadares, Inhapim, Itambacuri, Itanhomi, Itaobim, Itinga, Jampruca, Jenipapo de Minas, Joaíma, Jordânia, Ladainha, Malacacheta, *Mantena, Marilac,* Mata Verde, Mathias Lobato, Mendes Pimentel, Minas Novas, Muriaé, Nacip Raydan, Nanuque, Naque, Ninheira, Nova Era, Nova Módica, Novo Cruzeiro, Novo Oriente de Minas, Padre Paraíso, Patrocínio do Muriaé, Pavão, Peçanha, Periquito, Poté, Raul Soares, Resplendor, Rubelita, Sabinópolis, Salinas, Santa Maria do Suaçuí, Santa Rita de Minas, Santana do Paraíso, São Félix de Minas, São Geraldo do Baixio, São José da Safira, São Sebastião do Maranhão, Setubinha, Sobrália, Tarumirim, Teófilo Otoni, Vargem Alegre, Virgem da Lapa, Virgolândia<br>PARAÍBA: Assunção, Barra de Santa Rosa, Cacimbas, *Frei Martinho*, Juazeirinho, Junco do Seridó, *Pedra Lavrada*, Salgadinho, Santa Cruz, Santa Luzia, São Francisco, São José do Sabugi, São José dos Cordeiros, Sumé, Taperoá,<br>RIO GRANDE DO NORTE: Currais Novos, Equador, Parelhas, Santana do Seridó, São Tomé, *Tenente Ananias*<br>RONDÔNIA: Porto Velho<br>TOCANTINS: Chapada da Natividade, Jaú do Tocantins, Monte Santo do Tocantins, Palmeirópolis, São Salvador do Tocantins |

the Marambaia Valley in the Padre Paraíso, Caraí and Catuji areas. Aquamarine production subsequently extended north toward Medina and Pedra Azul, and further east into Bahia and Espírito Santo States, as well as close to the Minas Gerais border. Other sites can be found in various regions around the country, especially within Tenente Ananias in Rio Grande do Norte, but as indicated by data from DNPM and local travelling gem brokers around the country, there are many additional deposits to be explored throughout the north-eastern region.

Other Brazilian beryls include heliodor from Padre Paraíso, morganite from around Araçuaí

Figure 12: This suite of morganite (16.69–22.22 ct) was cut from Brazilian rough. The gems were fashioned into various custom cuts, including (from upper left to lower right) Concave, Super Trillion, Deep Concave and StarBrite. Courtesy of John Dyer; composite photo by Ozzie Campos.

and in São José da Safira (Figure 12), and greenish and brownish beryl, also found in quantity in the north-eastern part of Minas Gerais.

### Tourmaline

Brazil is one of the most important world producers of tourmaline, although in some recent years it has become more difficult to find on the market, as Chinese brokers have purchased it in large quantities. Prices escalated significantly in 2012–2014 in response to Chinese demand, which reduced the supply. However, since 2015 Chinese demand for all kinds of gems has dropped dramatically, which has considerably reduced the price of tourmaline to near-historic levels. Deep blue tourmaline can be found near Governador Valadares, while black tourmaline is very common in many areas. Green and multicoloured (e.g. Figure 13) specimens are available from Itambacuri and elsewhere. The Cruzeiro mine, located in São José da Safira, claims to be the major producer of pink-to-red tourmaline (Figure 14; Douglas Neves, pers. comm., 2013). Other important sources are found near Conselheiro Pena and in the region from Araçuaí to Coronel Murta (Barra de Salinas district) in the far north of Minas Gerais. There are also various tourmaline deposits still underexploited in the states of Rio Grande do Norte and Paraíba. Production of the famous 'neon'-coloured Paraíba tourmaline has dwindled in recent years.

Figure 13: This large colour-zoned tourmaline from Brazil weighs 144.75 ct. Courtesy of Paul Wild; photo by Jordan Wilkins.

*Figure 14: The Cruzeiro mine in Minas Gerais is known for producing fine pink-to-red tourmaline, such as this 9.00 ct rubellite. Courtesy of E. Schneider; photo by Jeff Scovil.*

*Figure 15: An attractive radiating pattern is displayed by this Brazilian rutilated quartz cabochon, which measures 26 × 30 mm and weighs 34.35 ct. Photo by Jeff Scovil.*

### Quartz Gems

China has created strong demand for quartz for the past decade, and Chinese buyers have established a presence near the main extraction areas in order to have first choice of the rough material. Stunning crystal clusters appreciated by collectors come from hydrothermal veins found in the Curvelo and Corinto areas of Minas Gerais. Rose quartz is found in pegmatites in the north-eastern part of Minas Gerais, most notably at Itinga and Joaíma, but also in central Bahia, where huge smoky quartz crystals also occur. Rutilated quartz also has been produced (Figure 15), mainly in the Novo Horizonte District of Bahia State, which formerly belonged to the Ibitiara municipality.

Quartz deposits also are worked in the far south of the country, primarily in Rio Grande do Sul. Huge amethyst geodes and most of the agates of the country have been mined in abundance in the interior of this state; these deposits have been worked for more than 150 years. Amethyst also is produced elsewhere throughout Brazil. The Brejinho das Ametistas District in the Caetité municipality of Bahia and the Marabá site near the historic gold mine of Serra Pelada in Pará State are both significant sources. Other sites exist where gem exploration otherwise is negligible, such as in Rondônia and Ceará States. Citrine is found in Rio Grande do Sul and around Araçuaí, but it is mainly brownish yellow (Figure 16); material from Bahia usually has a lighter yellowish colour. However, most of the citrine produced and exported from Brazil is actually heat-treated amethyst.

### Topaz

Brazil accounts for much of the world's topaz production. Most is colourless or tinged very light blue, and laboratory irradiation creates the bright blue colour appreciated by jewellers (Figure 17).

*Figure 16: Brazil is a significant source of citrine, as shown here from left to right by a 10.20 ct Super Trillion cut, a 34.42 ct StarBrite cut and 25.16 ct StarBrite cut. Courtesy of John Dyer; composite photo by Ozzie Campos.*

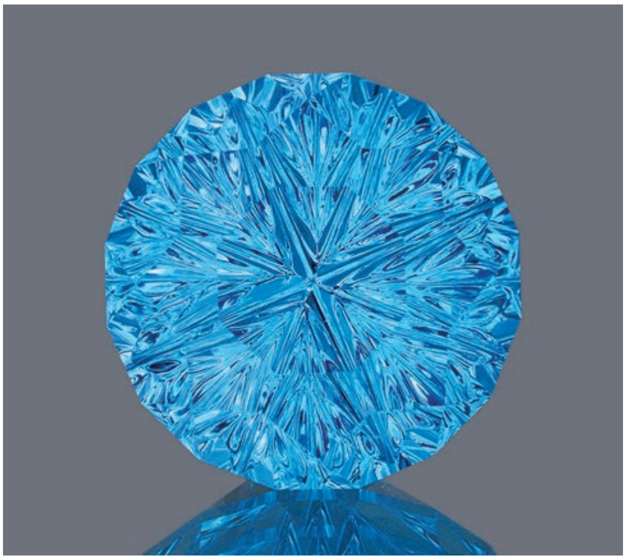

Figure 17: The colour of this Swiss Blue topaz (13.73 ct, StarBrite cut) was produced by laboratory irradiation, using colourless or pale blue starting material from Brazil. Courtesy of John Dyer; photo by Ozzie Campos.

Figure 18: Brazilian Imperial topaz is appreciated for its orange to orangey pink colour. This orange pear-shaped gemstone weighs 25.47 ct. Courtesy of Paul Wild.

Colourless topaz comes mainly from the northern region of Teófilo Otoni, but an increasing supply comes from further north-west, from both sides of the border between Amazonas and Rondônia States. The rare and famous orange to orangey pink Imperial topaz is still being produced from the Capão, Vermelhão and Antônio Pereira mines, as from other deposits near Ouro Preto in Minas Gerais, although production is greatly diminished and good-quality material (e.g. Figure 18) is particularly scarce on the local market.

### Chrysoberyl and Alexandrite

Chrysoberyl production seems to have seriously declined during the past decade and, as a consequence, good-quality material has become harder to find locally. Most production of chrysoberyl is still located in Minas Gerais and Bahia; the Padre Paraíso deposit in Minas Gerais was recently explored by a company based in Teófilo Otoni. Other sites are usually found near established emerald-extraction areas. Alexandrite production from Malacacheta has slowed during the last few years, as the greater depths required have made it a risky investment. Campo Formoso in Bahia and Hematita in the Antônio Dias municipality of Minas Gerais are still producing small quantities of alexandrite, with most of the output from the latter being exported to Asia.

### Other Gems

Many other gems and minerals are found throughout Brazil, and Minas Gerais hosts the greatest diversity of them. Kunzite is found in the Conselheiro Pena and Galiléia regions. Production of brazilianite continues in Divino das Laranjeiras and Itinga, although the material is becoming harder to find on the local market. Additional mining activity is taking place for sphene (titanite) in the municipality of Capelinha; andalusite at Itinga, near Araçuaí; and rhodonite at Conselheiro Lafaiete. Iolite, blue apatite and amazonite are all found in Bahia, while green diopside comes from Rio Grande do Sul.

## Conclusion

Coloured stones (e.g. Figure 19) have been mined for centuries in Brazil, and significant changes have recently affected the national industry, as the vast majority of gems extracted are directly exported abroad. New relationships with international partners, economic growth and improved living conditions in Brazilian rural areas have led to an evolution of the workforce, which is becoming less interested in and reliant upon mining via illicit operations.

Nevertheless, official data show that Brazilian gem exports remain robust (AliceWeb, 2016; UN ComTrade, 2016), although this might also be due to more mines becoming legalized and

*Figure 19: This gold necklace features a 2.11 ct tourmaline from Minas Gerais. Courtesy of Beau Soleil; photo by Jeff Scovil.*

the higher prices for gem material, rather than greater production. Progressively, gem mining in Brazil is seeing a shift toward bigger and more professional companies, and a national gem and jewellery industry strategy is being developed with the help of public and private institutions (Pobozzon Palma et al., 2014; Lourenção and Giraldi, 2015). Furthermore, the quantity of mining areas remains substantial and, probably, to a large extent underexplored. Yet the future of the Brazilian gem industry may not be determined by geological factors. Rather it may depend more on social issues, global market trends and an ability to establish efficient trade relationships.

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# Radiocarbon Age Dating of 1,000-Year-Old Pearls from the Cirebon Shipwreck (Java, Indonesia)

*Michael S. Krzemnicki, Laurent E. Cartier and Irka Hajdas*

The 10th-century Cirebon shipwreck was discovered in 2003 in Indonesian waters. The excavation yielded an incredible array of archaeological finds, which included pearls and jewellery. Radiocarbon dating of the pearls agrees with the age of the shipwreck, which previously was inferred using recovered coins and ceramics. As such, these are some of the oldest pearls ever to be discovered. Based on this example, the present article shows how radiocarbon age dating can be adapted to the testing of historic pearls. The authors have further developed their sampling method so that radiocarbon age dating can be considered quasi-non-destructive, which is particularly important for future studies on pearls (and other biogenic gem materials) of significance to archaeology and cultural heritage.

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## Introduction

The discovery of the Cirebon (or Nan-Han) shipwreck in the Java Sea in 2003 marks one of the most important archaeological finds in Southeast Asia in recent years (Hall, 2010; Liebner, 2014; Stargardt, 2014). Apart from ceramics, glassware and Chinese coins dating from the 10th century AD, the excavation of this ancient merchant vessel also produced a number of carved gastropod shells (presumably ritual objects, from *Turbinella pyrum*), jewellery (e.g. earrings with diamonds and sapphires), loose gemstones (e.g. sapphires, red garnet beads and rock crystal carvings) and a rather large number of small pearls (Tan, 2007; Liebner, 2010, 2014; Henricus, 2014). Of the more than 12,000 pearls that were recovered, most were less than a few millimetres in diameter (e.g. Figure 1).

Fishermen discovered the wreckage site accidentally in 2003, at depths greater than 50 m (Liebner, 2010) off the northern coast of Java, Indonesia, near the city of Cirebon (Figure 2). Excavation efforts were complicated due to legal uncertainties as to which companies/entities should be permitted to excavate the site, unfortunately leading to a period in which looting of the wreck occurred. Administrative, legal and diplomatic problems pertaining to the excavation, storage and ownership of recovered items continued in the following years (Tjoa-Bonatz, 2016).

The exact route of the ship is still disputed in academic circles (Liebner, 2014), but there is ample evidence of strong trading ties between China and western Asia, which are supported by shipping routes along the Strait of Malacca between the Malay Peninsula and the Indonesian

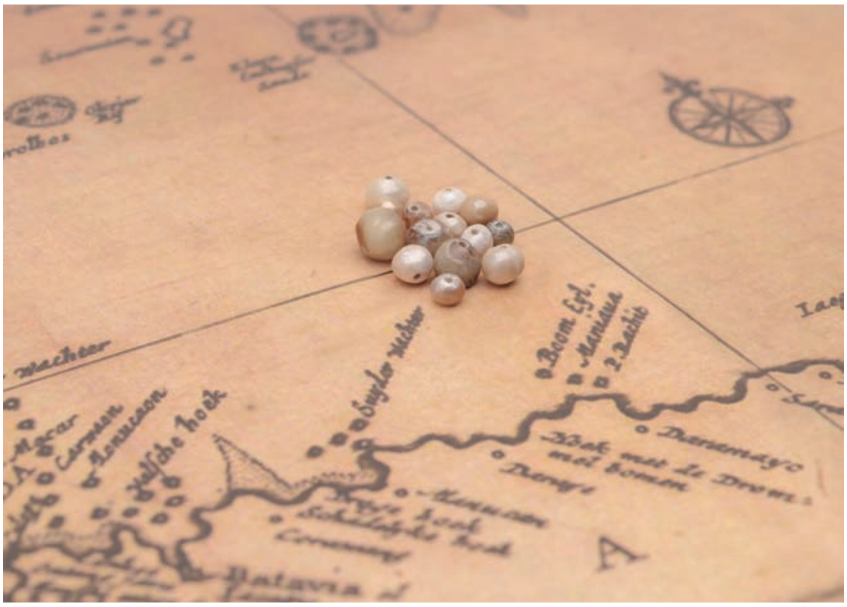
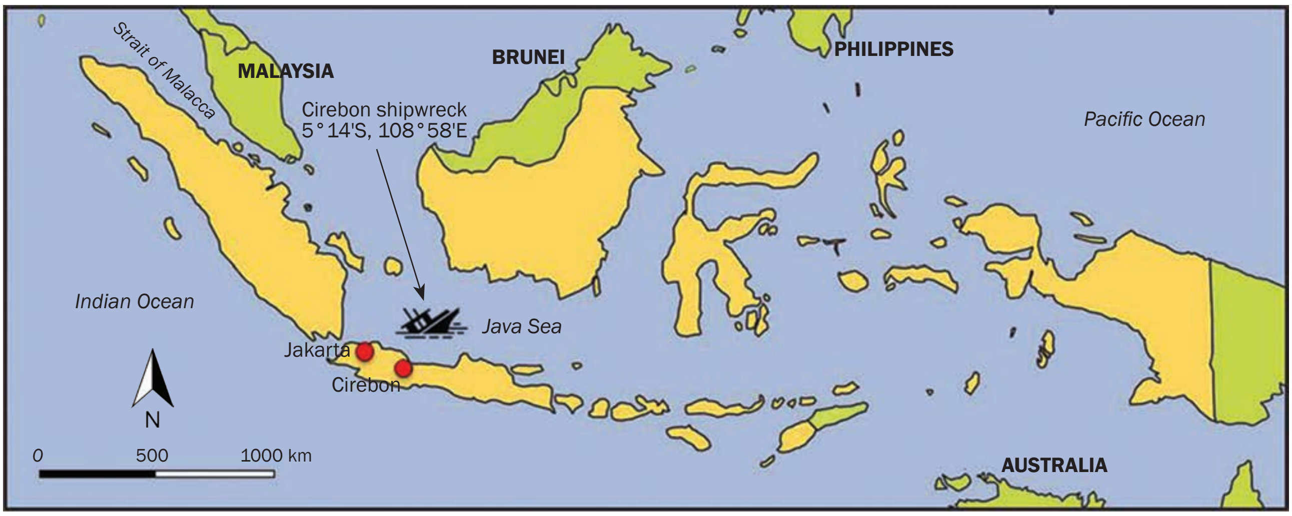


*Figure 1: A small selection of pearls (approximately 2–8 mm diameter) from the Cirebon shipwreck was investigated for this study. The pearls are shown on a historic map of the Java Sea, where the shipwreck was discovered. Photo by Luc Phan, SSEF.*

island of Sumatra in the 8th–10th century AD (Stargardt, 2014; Manguin, 2017; Shen, 2017). The recovery and study of artefacts from the Cirebon shipwreck offer a rare glimpse into trading practices of that period. It is thought that the trade in Yue ceramics (Chinese stoneware) peaked in the 10th century (Liebner, 2010), and they were a major export commodity during the Tang dynasty (Flecker, 2000). The form and decorations (including motifs) on Yue ceramics recovered from the wreck suggest a 10th-century period of manufacture and are complemented by potters' marks indicating 968 AD (Liebner, 2014). Furthermore, of nearly 5,000 individual coins recovered from the Cirebon shipwreck, eight were identified as "*Zhou Yuan tong bao*, a 955/6 issue by Shizong, emperor of the Later Zhou, mainly fashioned from confiscated 'Buddhist statuary of bronze [that] was mandated for recasting as coin' (Ouyang 2004: 115)" (Liebner, 2014, p. 197). Therefore, the coins and other recovered artefacts provided good evidence for a 10th-century age of the shipwreck. This time period corresponds to an era of upheaval in China called the 'Five Dynasties and Ten Kingdoms' during approximately 907–960 AD (Lorge, 2011); it was preceded by the Tang dynasty and succeeded by the Song dynasty (960–1127 AD). The pearls dated in this article yield further evidence documenting the 10th-century age of the shipwreck, and this provides an opportunity to better understand the rich history of this period in time.

*Figure 2: The 10th-century Cirebon shipwreck is situated in the Java Sea, north of the city of Cirebon on the island of Java. The yellow areas correspond to Indonesia.*



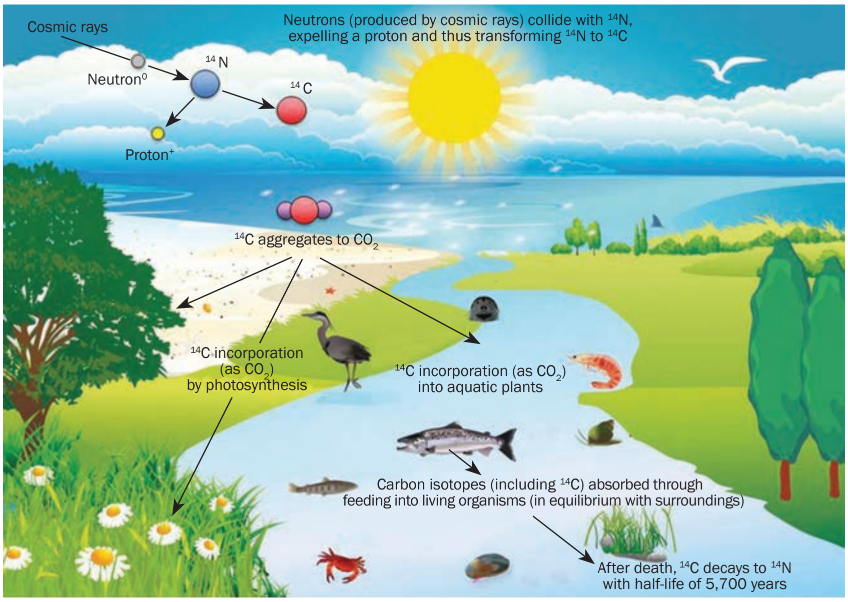



*Figure 3: As shown in this schematic diagram of the radiocarbon cycle, radiogenic $^{14}C$ is produced in the atmosphere by the collision of high-speed neutrons (produced by cosmic radiation) with nitrogen ($^{14}N$). The traces of $^{14}C$ are in-corporated into carbon dioxide, which is assimilated into plants by photosynthesis and into animals (e.g. shells of molluscs) via respiratory and metabolic pathways. After death, the lifelong exchange of carbon with the environment suddenly stops, resulting in slow radioactive decay of $^{14}C$, making it possible to determine the age of materials by radiocarbon dating. Illustration by M. S. Krzemnicki, using an artwork template from Inland Fisheries Ireland (www.somethingfishy.ie/resources/image_resources/image_estuary_food_web.jpg).*

So far, the world's oldest dated pearl was recovered in the Middle East, and the stratigraphic layer in which it was found was attributed by Charpentier et al. (2012) to be around 7,500 years old. Szabo et al. (2015) dated the material surrounding a pearl found in Australia to more than 2,000 years old. In both cases, the pearl itself was not dated, and in recent years there have been only a few studies on radiocarbon age dating of historic pearls. For example, Krzemnicki and Hajdas (2013) performed age dating on historic and modern pearls. Recently, Zhou et al. (2017) obtained radiocarbon ages in the 16th century for pearls that reportedly came from the Venezuelan island of Cubagua in the Caribbean Sea, which supported the pre- to early Columbian era assumed for these pearls. Advances in testing and future archaeological finds will contribute to this area of pearl research by providing further evidence for the fishing and trade of pearls since ancient times in diverse regions of the globe (Kunz and Stevenson, 1908; Donkin, 1998).

## Radiocarbon Age Dating

The underlying principle of the radiocarbon method is the constant production of radiogenic $^{14}C$ in the atmosphere by the interaction of secondary cosmic rays with nitrogen. The collision of high-speed neutrons produced by cosmic radiation with the nucleus of nitrogen results in the capture of a neutron and the expulsion of a proton, thus transforming the $^{14}N$ isotope into the radionuclide $^{14}C$. The radiocarbon, present only in trace amounts in the atmosphere (about 1 atom per 1,012 atoms of carbon) combines with atmospheric oxygen and forms radioactive carbon dioxide (Figure 3), which is then incorporated into plants by photosynthesis and subsequently into animals via respiratory and metabolic pathways (Bowman, 1990; McConnaughey et al., 1997; Hajdas, 2008). As a consequence, the radiogenic $^{14}C$ is incorporated into the endo- or exoskeletons (e.g. bones or shell structures) of animals (Hajdas, 2008; Douka et al., 2010).

After death, the lifelong exchange of carbon with the environment suddenly stops, resulting in a slow radioactive decay of $^{14}C$ in the dead plants and animals. By measuring the ratio of radiogenic and stable carbon isotopes ($^{14}C/^{12}C$), it is thus possible to determine their age. The so-called half-life of $^{14}C$ (that is, the time at which only half of the original $^{14}C$ still is present in a sample and, as such, represents the constant rate of decay over time) is about 5,700 ± 40 years (Godwin, 1962). As a consequence, the maximum age dating reliably possible with this method is up to approximately 50,000 years before present (BP).

The radiocarbon age dating method, first described by Nobel laureate Willard Libby in the 1940s (Libby, 1946; Arnold and Libby, 1949) has been applied since then as a standard tool in numerous scientific disciplines and has gained much interest of the public, especially in relation with archaeological studies of Egyptian pharaohs and the prehistoric mummy 'Ötzi' from Austria (Bonani et al., 1994). Although it is applicable to only a very short period in geological terms, the

*Figure 4: These 14 pearl samples (71742_A–N; approximately 2–8 mm diameter) from the Cirebon shipwreck were examined for this study. They are partially abraded around their drill holes and show some brown to grey colour alterations. Photo by Luc Phan, SSEF.*

method has proven quite useful for dating organic matter (trees, tissues, etc.) and carbonaceous materials such as charcoal and biomineralization products, including corals (Adkins et al., 2002), shells (Berger et al., 1966; Hänni, 2008; Douka et al., 2010; Hainschwang et al., 2010) and pearls (Krzemnicki et al., 2009; Krzemnicki and Hajdas, 2013; Zhou et al., 2017).

A pearl is a calcium carbonate ($CaCO_3$) concretion formed by biomineralization processes in a mollusc—very much the same processes as for shell (exoskeleton) formation. As such, pearls (and shells) contain carbon, mainly the stable isotope $^{12}C$ (as well as $^{13}C$) but also a small fraction of radiogenic $^{14}C$. The carbon used for the biomineralization of pearls and shells mainly originates from two very different carbon pools: (1) oceanic dissolved inorganic carbon; and (2) respiratory $CO_2$, mainly stemming from food metabolism (Tanaka et al., 1986; Gillikin et al., 2007; Douka et al., 2010). As such, the so-called marine reservoir age effect may distinctly affect the resulting $^{14}C$ ages of shells and pearls, especially in areas with upwelling of 'old' water. Hence, a correction is required to take into account the geographic location of the sample. For a more detailed discussion of this issue, see Rick et al. (2005), McConnaughey and Gillikin (2008), Douka et al. (2010), Krzemnicki and Hajdas (2013) and references therein.

## Samples and Methods

For this study, we investigated 14 pearls (nos. 71742_A–71742_N) from the Cirebon shipwreck (Figures 1 and 4) that weighed 0.14–0.85 ct and measured approximately 2–8 mm in diameter. They were round to button-shaped and baroque, and all showed a drill hole, indicating that they were originally at least partially strung on strands. This is further supported by the presence of abrasion marks around the drill holes, characteristic for pearls strung tightly in a row. The colour of the pearls ranged from white to light cream, some with brownish and greyish alterations (Figure 4) presumably due to oxidation of adjacent metallic material. Even after a prolonged period on the ocean floor, most of the pearls showed at least partially a soft nacreous lustre with some white dull weathered spots and patches.

All 14 pearls were analysed routinely by X-radiography (Faxitron unit) and X-ray luminescence (cf. Hänni et al., 2005), as well as by energy-dispersive X-ray fluorescence spectroscopy using a Thermo Quant'X instrument. We then selected four pearls (71742_A, B, I and J) for X-ray computed microtomography (micro-CT) analysis using a Scanco µCT-40 scanner. For radiocarbon age dating, we chose the three smallest pearls (71742_L, M and N). From each sample, ~8 mg of calcium carbonate was extracted either by abrading or chipping off nacre fragments from the pearls, which was facilitated by their slightly altered surface condition. However, based on this and more recent experiments, we now can perform quasi-non-destructive radiocarbon age dating with as little as ~2 mg (0.01 ct) of nacre taken from the drill hole, thus not affecting the outer surface of the pearl (Krzemnicki, 2017).

The calcium carbonate samples were washed in ultrapure water and leached to remove the surface layers (Hajdas et al., 2004). After the leaching of about 20% (by weight) of the original sample, approximately 6.4 mg of pearl material was placed in a gas bench tube and flushed with a flow of helium gas, then dissolved in concentrated phos-

*Table I: Results of $^{14}C$ analyses of three saltwater pearls from the Cirebon shipwreck in the Java Sea.*[a]

| Sample | $^{14}C$ age (BP, ±1σ) | $\delta^{13}C$ (‰)[b] | $F^{14}C$ (±1σ)[c] | Calendar age (calAD) | |
|---|---|---|---|---|---|
| | | | | 68.2% prob. | 95.4% prob. |
| 71742_L | 1,529 ± 25 | −0.7 ± 1.0 | 0.8267 ± 0.0026 | 878–1042 | 780–1130 |
| 71742_M | 1,493 ± 25 | −1.9 ± 1.0 | 0.8304 ± 0.0026 | 902–1072 | 816–1170 |
| 71742_N | 1,508 ± 25 | −3.2 ± 1.0 | 0.8288 ± 0.0026 | 894–1058 | 804–1156 |

[a] Abbreviations: BP = before present; prob. = probability.

[b] The isotopic signature $\delta^{13}C$ is a measure of the ratio of stable isotopes $^{13}C/^{12}C$, and is reported in parts per thousand (per mil, ‰).

[c] The fraction of modern radiocarbon ($F^{14}C$) is the conventional way of displaying the so-called 'bomb peak' in a radiocarbon vs. known age diagram for post-1955 events.

phoric acid (85%) and transferred to a graphitization system (Wacker et al., 2013). The graphite was then pressed into targets (cathodes), and the $^{14}C/^{12}C$ ratio was measured using the Mini Carbon Dating System (MICADAS; see Synal et al., 2007) at the Swiss Federal Institute of Technology, ETH Zürich, Switzerland. This optimized accelerator mass spectrometer (AMS) is characterized by a high yield and superior stability, thus enabling radiocarbon measurements at highest precision. Different from other mass spectrometer designs, the ions formed in the AMS ion source are negative, thereby filtering out $^{14}N$, which is an isobar of $^{14}C$. Then the ions are accelerated, reaching very high kinetic energies and resulting in a high resolving power for separating a rare isotope from an abundant neighbouring mass, such as $^{14}C$ from $^{12}C$. Moreover, a suppression of molecular isobars (e.g. $^{13}CH$ and $^{12}CH_2$) is achieved by passing the beam through a stripper gas. Finally, the $^{14}C$ atoms are detected by a gas ionization system (Synal et al., 2007).

After correction for blank values and fractionation ($\delta^{13}C$), the measured $^{14}C/^{12}C$ concentration was used to calculate conventional $^{14}C$ ages (Stuiver and Polach, 2016). For all samples, the calculated $^{14}C$ age BP was corrected by applying a marine reservoir correction (delta R = 89 ± 70) that was based on values for the Java Sea location (Reimer and Reimer, 2001, and references therein). These were estimated (weighted mean) based on 10 data points in the vicinity of the sampling site. The corrected $^{14}C$ ages were then calibrated using the Marine13 curve of Reimer et al. (2013).

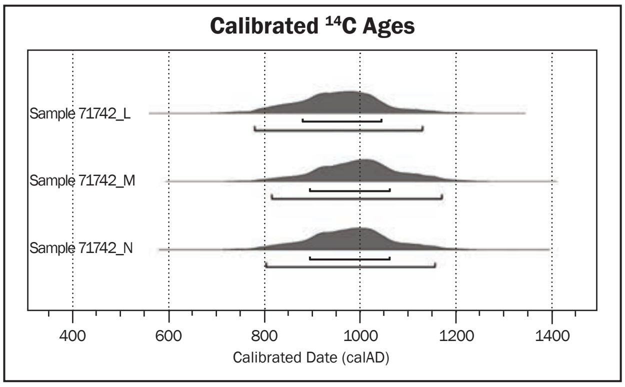
## Results and Discussion

Based on their X-radiographs, trace-element composition (cf. Gutmannsbauer and Hänni, 1994) and lack of luminescence to X-rays (cf. Hänni et al., 2005), the samples studied for this report were all saltwater natural pearls. The radiography and micro-CT scans (on pearls 71742_A, B, I and J) further revealed that their internal structure mainly consisted of fine ring structures typical of natural pearls.

Table I summarizes the results of radiocarbon age dating of the three pearls (71742_L, M and N). They all show very consistent $^{14}C$ ages and similar calibrated ages of 780–1170 AD (95.4% probability) or 878–1072 AD (68.2% probability) using the Marine13 curve (Reimer et al., 2013; Figures 5 and 6). The more precise mean value of 1,510 ± 15 BP results in a calendar age of 806–1151 AD (Figure 7). This relatively wide range in calendar age is due to uncertainty for the reservoir age correction.

The calculated age of the pearls, corresponding approximately to the end of the 10th century, correlates well with the age stipulated for the coins, pottery and other artefacts found in the shipwreck (Liebner, 2014). It places the sinking of the historic merchant vessel at the time of upheaval in China

*Figure 5: The three investigated pearls (71742_L, M and N) from the Cirebon shipwreck all show very similar calibrated ages corresponding to the late 10th century AD. The bracketed ranges represent 68.2% and 95.4% probabilities for the pearls' ages.*



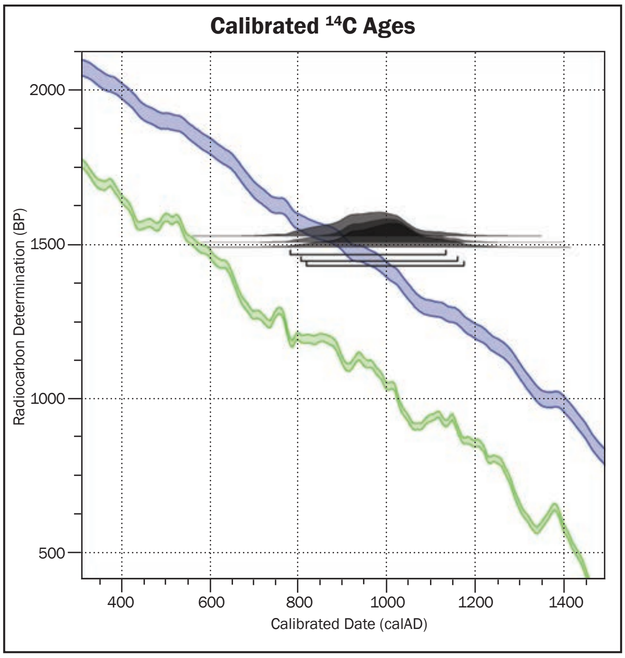



*Figure 6: The calibrated ages of the three investigated pearls from the Cirebon shipwreck were derived from the radiocarbon ages using OxCal 4.2 software (Ramsey and Lee, 2013). The purple band is the marine calibration curve (Marine13, Reimer et al., 2013), and the green band is the atmospheric curve (IntCal13, Reimer et al., 2013).*

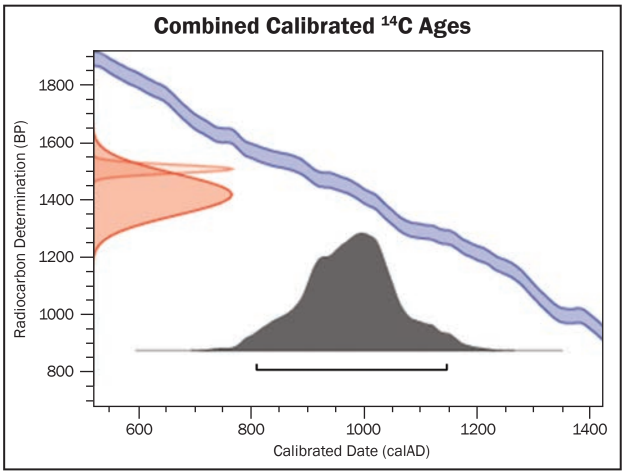


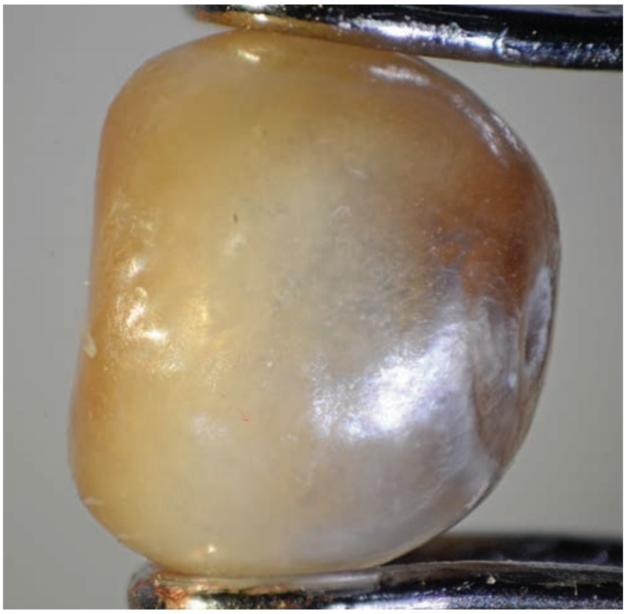

*Figure 7: The combined calibrated ages obtained from the three Cirebon pearls yield a range of 806–1151 AD at 95.4% probability. The red peaks represent the uncalibrated radiocarbon age (as measured and corrected for regional reservoir age) and the dark grey peak shows the distribution of calendar ages.*

called the 'Five Dynasties and Ten Kingdoms' (ca. 907–960 AD), which was also a time of extensive maritime trade in Southeast Asia.

These pearls likely originated from the Persian Gulf or the Gulf of Mannar (between India and Sri Lanka), both known since ancient times as sources of saltwater natural pearls (from *Pinctada radiata*; see Hornell, 1905; Carter, 2005). This assumption is mostly related to their size, bearing in mind that other molluscs also produced (larger) nacreous pearls during the same period (e.g. *P. margaritifera* in the Red Sea and *P. maxima* in Southeast Asia; Southgate and Lucas, 2008). The thousands of glass fragments and several unbroken blue and green glass objects found in the Cirebon shipwreck undoubtedly originated from the Islamic Middle East (present day Iran or Iraq and Syria; H. Bari, pers. comm., 2017). This indicates extensive trade in Southeast Asia along maritime routes (or a 'maritime silk route') at that time (Liebner, 2014; Manguin, 2017), of which the Cirebon merchant vessel was a part. This also supports a Persian Gulf origin for the pearls (H. Bari, pers. comm., 2017).

The partly abraded and brown-to-grey alterations around the drill holes of these pearls (Figure 8) suggest that they might have been in use for some time, strung on strands or set with metal linings in jewellery before they sank in the vessel with the rest of its cargo, including Sri Lankan sapphires (Henricus, 2014) and other gems (e.g. red garnet and quartz) of probable Sri Lankan, East African or Malagasy origin (H. Bari, pers. comm., 2017).

*Figure 8: Pearl 71742_A (0.85 ct) shows brownish colour alteration around its drill hole (visible on the right side), as would be expected from a setting with a metal lining that has oxidized. The abrasion features adjacent to the drill hole are consistent with wear marks commonly encountered on pearls that are tightly strung on wire or fibre strands. Photo by M. S. Krzemnicki, SSEF.*



## Conclusions

This study is the first to document radiocarbon age dating, along with gemmological testing, carried out directly on historic pearls dating back to the 10th century. Previous research on historic pearls, including the 2,000-year-old Brremangurey pearl from Western Australia (Szabo et al., 2015) or the 7,500-year-old Umm al-Quwain pearl from UAE (Charpentier et al., 2012), derived their ages by using associated materials found at the archaeological sites, rather than directly dating the pearls themselves.

By using the highly sensitive MICADAS system at the Ion Beam Physics Laboratory at ETH Zürich, it was possible to analyse very minute portions of the Cirebon pearls. The radiometric age dating of the three samples gave homogeneous results corresponding approximately to the end of the 10th century, closely matching the age stipulated for the shipwreck based on Chinese pottery and coins.

This study, and further age-dating experiments on pearls, also have resulted in a refined sampling process that allows us to work with tiny amounts of nacre powder (~2 mg) taken from the drill hole without any damage to the outer surface of a pearl. Thus, radiocarbon age dating can be considered a quasi-non-destructive test when following our sampling protocol. This has opened up new possibilities for research on historical biogenic objects and artefacts of significance to archaeology and cultural heritage.

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# Naming of the Koh-i-Noor and the Origin of Mughal-Cut Diamonds

*Anna Malecka*

For centuries, the Koh-i-Noor, or Mountain of Light, has been a diamond of exceptional renown in the East as well as in the West. Several legends circulate regarding this stone, and among these are tales of its origin and the way it received its name. This article attempts to verify the authenticity of these accounts and shows that the true origin of the diamond's name is connected to its appearance achieved through the faceting style known today as the Mughal cut. Although the provenance of this cut has thus far not been determined, this article proposes that it possibly originated in the 16th century in Goa, India, through the Gujaratis and under the influence of European diamond cutters. Various lines of evidence suggest that the Koh-i-Noor may have been worked in the 16th century by an Indian specialist in the Vijayanagara Empire.

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## Introduction

One of the world's most famous diamonds is the Koh-i-Noor, or *Mountain of Light* as it translates from Persian, the language of the Mughal court. The diamond originated in the treasury of the Great Mughals, and is currently mounted in the crown of the Queen Mother (wife of George VI and mother of Elizabeth II), which is kept in the Tower of London. It has the form of an oval brilliant and weighs 102.8125 English carats or 105.59 metric carats (Tennant, 1854b). The original Mughal-cut stone (cf. Figure 1) weighed 589.82 troy grains, corresponding to 186.0625 English carats, which is equivalent to about 191.09 metric carats (Tennant, 1854b; Story-Maskelyne, 1860) or 191.03 ct (Carriere and Sucher, 2008). It reached the United Kingdom in 1850 from India, where it was confiscated by the British from the last maharaja of the Sikh Empire, Dulip Singh (r. 1843–1849). For more background on this important stone, see Mīrzā ʻAṭā Muḥammad (1952–1953 (AH 1331), Bukhārī (1958 [AH 1337]), Howarth (1980), Gill (1982), Amini (1994), ʻAyn al-Salṭanah, (1995–2000), Shirazi and Muḥaddiṣ (2000) and Dalrymple and Anand (2016).

Several legends have circulated on the topic of the Koh-i-Noor, including a commonly cited story of how its name originated. According to contemporary gem writers, its name was assigned in Delhi, at the court of the Mughal emperor Muhammad Shah (r. 1719–1748); the person instrumental in giving the stone its name was the king of Iran, Nadir Shah (r. 1736–1747). The Shah of Persia invaded the Mughal capital in March 1739, after the battle at Karnal in which he overpowered the Indian armies. Although Nadir Shah did not deprive Muhammad Shah of the throne, he also did not refrain from confiscating his legendary treasures (Astarabadi and Rashad, 1994). The conqueror's interest was piqued by the huge diamond in the Mughal emperor's possession. The existence of this gem was told to the invader, it is said, by a woman from the Mughal's harem.

She was said to have revealed that her lord had a habit of carrying the stone in the folds of his turban. In order to take the gem while maintaining the appearance of respect for the conquered royal, Nadir Shah developed a ploy in which he proposed to the Indian emperor an exchange of headdresses, which symbolized friendship. The Mughal could do nothing else but hand over his turban, which contained the gem inside. Upon seeing its glow, Nadir Shah exclaimed "Koh-i-Noor", thus giving the diamond its name (Streeter, 1882; Amini, 1994; Balfour, 2009).

Although the authenticity of this legend has recently been questioned (Dalrymple and Anand, 2016), contemporary writers have not researched, to the present author's knowledge, the true origin of the name *Koh-i-Noor*.[1] In the present author's view, the name refers to the appearance of the diamond's faceting style, known today as the Mughal cut. Based on the analysis of gemmological material, researchers do not state unequivocally if this cut, widespread in Indian territory, was indigenous or created under Western influence. This article analyses primary literature sources from the 15th to the 17th centuries, as well as iconographic material, to investigate this matter and the validity of the stories about the naming of the Koh-i-Noor.


*Figure 1: This glass replica of the Koh-i-Noor diamond, as it appeared when it reached Great Britain in 1850, resides at the Corning Museum of Glass in Corning, New York, USA. It was made in 1851 by Falcon Glassworks of Apsley Pellatt & Co., London. More information is available at www.cmog.org/artwork/replica-koh-i-noor-diamond; courtesy of the Corning Museum of Glass.*

## Investigating the Tale of Koh-i-Noor's Name

The meeting of Nadir Shah and the defeated Mughal emperor did in fact take place, and the conqueror of Delhi did receive diamonds at that time (Malecka, in preparation). Analysis of sources from the epoch, however, indicates that the Koh-i-Noor could not have been one of them (Anonymous, 1866–1867 [AH 1283]). According to Nadir Shah's chronicler, a diamond called the Koh-i-Noor was indeed among jewels confiscated by his lord from the Mughal emperor, but it had been placed in the famous Peacock Throne of the Mughals—and not in the folds of the monarch's turban—as a decoration on the head of the eponymous bird adorning it. The historiographer of the king of Iran is a credible source, in the present author's view, because he saw the Peacock Throne in the Afghan city of Herat, to which it was transported from Delhi upon the order of the conqueror (Marvī et al., 1991; see also Tihrani and Sha'bāni, 1990 [AH 1369]). Since it follows that the name *Koh-i-Noor* already was used in the Mughal court in reference to this diamond, the name could not have been assigned by Nadir Shah.

How, then, did the story arise that Nadir Shah conferred the name on this diamond? None of the Persian sources from the time of Nadir Shah, to the present author's knowledge, cite this story. It appeared for the first time in the tale of the Koh-i-Noor written in 1850 by Theophilus Metcalfe, a functionary of the East India Company who, upon the order of the Governor-General of India, gathered stories circulating in Delhi on

[1] An author from the Indian subcontinent who was active at the end of the 19th century stated, without justifying his opinion, that the episode wherein the Koh-i-Noor was gained by exchange of turbans was untrue (Latif, 1956).

the topic of this stone (Singh and Singh, 1985; Kinsey, 2012; Dalrymple and Anand, 2016).[2] Metcalfe's report was not published. In printed form, one of the earliest English-language publications of this story was the catalogue of the Great Exhibition of 1851, at which the Mountain of Light was presented to the public (Ellis, 1851).

It also should be mentioned that, with regard to the Koh-i-Noor, the tale of the exchange of turbans did appear in Persian-language sources, but for a different owner of the stone: Ranjit Singh, the father of Dulip Singh. In 1813, this monarch forced the ex-king of Afghanistan, Shah Shuja Durrani, who at that time possessed the stone, to surrender it in order to close an agreement of friendship with him. To seal this pact, as Durrani himself affirmed in his memoirs, Ranjit Singh exchanged headdresses with him, and after this ceremony came the presentation of the stone (Shuja Shah, 1914/1915 [AH 1333]).

It is probable that this event had an impact on the development of the story about the acquisition of the Koh-i-Noor by Nadir Shah. It should be emphasized, however, that tales of the exchange of headdresses as a means to swindle gems had been circulating in India in earlier times. For example, a 19th-century researcher mentioned, on the basis of unpublished family annals of the rulers of the Chota Nagpur in India, that a similar event had taken place in 1772 (Dalton, 1872). According to this account, a British officer wished to acquire diamonds that the rajah of Chota Nagpur carried in his turban, and proposed to the ruler the exchange of headdresses as a gesture of eternal friendship, claiming this custom also was practised in Great Britain.

It should be underlined that the authors who saw the Koh-i-Noor in the court of Ranjit Singh do not refer to exchanging headdresses while mentioning its acquisition by Nadir Shah (Osborne, 1840; Hügel, 1848). It seems that this story gained popularity in the 1840s, both as a result of the wheedling tales that circulated in India during the Mughal epoch, as well as the actual turban exchange that accompanied the earlier transfer of the Koh-i-Noor in 1813.

## Connection Between the Koh-i-Noor's Name and Its Appearance

Researchers have been unable to explain how the Koh-i-Noor was originally included among the several hundred large diamonds in the Mughal treasury that were confiscated by Nadir Shah. In the present author's view, the stone was already in the possession of these rulers in the 1500s. It is known that a diamond weighing about 190 ct had been the property of Emperor Akbar (r. 1556–1605; AMIDRF, 1740; Malecka, in preparation). Even though Akbar's stone was the only diamond of such weight in the possession of the Mughals mentioned in 16th-century sources, we cannot simply assume it to be identical with the Koh-i-Noor on the basis of its approximate weight.[3] A mention of its shape allows a greater probability of identifying it as the Koh-i-Noor. Akbar's diamond was described by an author from the epoch (Malecka, in preparation) as having the form of a pyramid, which does correspond to the shape of the original Koh-i-Noor (Figures 1 and 2, left). Considering such factors as weight, shape and Mughal provenance, the identification of Akbar's stone as the Koh-i-Noor seems justified.

It is probable that Akbar had obtained the stone from the Vijayanagara Empire (1336–1646) in the southern part of the Indian subcontinent, which abounded in diamond mines.[4] Sources from the turn of the 16th/17th centuries mention a diamond of fabulous value purchased by the Great Mughal from the ruler of Vijayanagara.[5] In the present author's opinion, it is probable that the Koh-i-Noor remained in the Mughal treasury continuously from around 1600 to 1739, when it was looted by Nadir Shah. This is supported by the fact that Jahangir (r. 1605–1627), the son of

[2] Mention of the mythical history of the Koh-i-Noor did, however, appear in the British press in earlier years (Anonymous, 1849).

[3] Sixteenth-century sources also mention the so-called Babur's diamond. Some contemporary authors infer it to be identical with the Koh-i-Noor on the basis of its alleged weight of about 186 carats (Beveridge, 1899). In reality, Babur's diamond weighed significantly less than the Koh-i-Noor, and most probably it also was a rough stone (Malecka, in preparation).

[4] After the battle at Talikota in 1565 between the Vijayanagara Empire and a coalition of Muslim kingdoms of the Deccan, the mines gradually passed under the rule of Golconda, contributing to building the fame of the sultanate as the global diamond capital at the time. The mines were famous for producing exceptionally large stones, as attested by the following comparison: In the Mughal Empire, rough stones weighing as little as 2.5 ct automatically passed to ownership by the emperor, while in Vijayanagara the weight of diamonds subject to the monopoly of the king was set above 20–30 ct (Orta, 1891; Lopes, 1897; Foster, 1921; Vassallo e Silva, 1989). See also footnote 12.

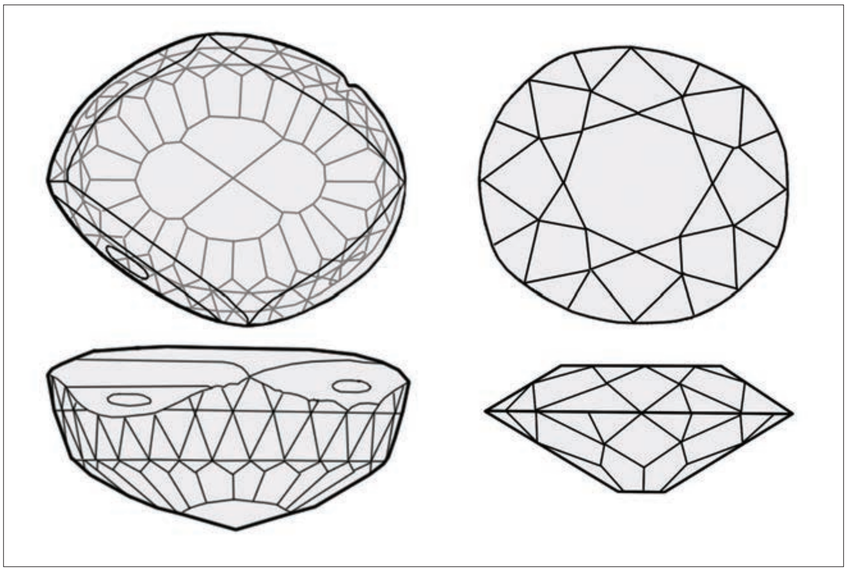

*Figure 2: These line drawings prepared by Al Gilbertson compare the appearance of the Koh-i-Noor before (left) and after re-cutting (right) in 1852. The cuts are shown from the top and side views.*

Akbar, was in possession of a diamond of similar weight (Malecka, in preparation).

The Koh-i-Noor was presumably wheel cut into a 169-facet stone measuring 40.85 × 32.57 × 16.18 mm (Carriere and Sucher, 2008).[6] It had a high-domed crown and flat base, with predominantly triangular and pentagonal facets (resembling rectangles with triangular pinnacles) covering its surface (Figure 2, left). It seems most probable that the Koh-i-Noor received its name because of the shape it was given during this 'rough fashioning', which was reminiscent of a mountain (Younghusband and Davenport, 1919).[7] It was common in the East to give names to gems that referred to their appearance, and particularly large stones were sometimes described as 'mountains'. Other important gems with names alluding to mountains include the Koh-i-Toor (or Sinai Mountain diamond), as well as al-Jabal (or Mountain), a huge red stone that was the property of the Abbasid caliphs (Ibn al-Zubayr et al., 1959; Ibn al-Athir, 1995; Malecka, in preparation). According to mistaken suppositions by some researchers, the full name of this last stone was Jabal al-Noor, or Mountain of Light, arising supposedly from translation of the Persian words *Koh-i-Noor* (Herzfeld, 1948). Islamic sources also mention other precious stones having the name of 'Mountain' (Farmān-Farmāyān, 1962; Malecka, in preparation).

The second part of the Koh-i-Noor's name has a connection to radiance. Names of large stones held by the Mughals often contained allusions to brilliance by including such words as *sun, moon* or *light* (Linschoten et al., 1885; Manucci and Irvine, 1907). Radiance was of key importance to the Islamic monarchy, because it was believed to embody the invisible perfection of God. Radiance attested to the connection between God and the ruler, who governed in His name on Earth (Bedik,

[5] A discussion of sources referring to this diamond is presented in Malecka (in preparation). Even though rulers in the East unwillingly parted with exceptional diamonds, a stone of 190 ct would certainly not have been deemed unique by Vijayanagara rulers, as their diamond treasury contained specimens weighing several hundreds of carats. In the 15th century, before the Mughal emperor Shah Jahan ordered construction of the Peacock Throne, similar fame was attributed in the East to the diamond throne of Vijayanagara, which was described as priceless (Sousa, 1666; Goes, 1749; Malecka, in preparation). It is probable that the reason the Koh-i-Noor (assuming it was identical to the diamond purchased from the Vijayanagara ruler) was sold to the Mughal was that it contained some blemishes (see below). It is known that Vijayanagara royals would sell large imperfect diamonds that they considered inauspicious (Malecka, 2018).

[6] Scott Sucher, an American cutter specializing in making replicas of historical stones on the basis of computer modelling, informed this author that analysis of a Koh-i-Noor model shows that it must have been wheel cut: "I can't imagine it being cut being hand-held. The laser scan data also supports this. There is facet rounding, as to be expected by the wheels of the time, but based on my best gem cutting experience (4+ decades), hand holding would have made the rounding far more pronounced."

[7] According to Metcalfe's unpublished report mentioned above, the stone was obtained thousands of years previously from the Koh-i-Noor mine, situated a four-day journey north-west from Masulipatnam, on the banks of the Godavari River (Dalrymple and Anand, 2016). However, this statement could not have been true. The Persian name would not have been used in reference to an ancient Indian mine; moreover, analysis of primary sources does not allow for the assumption that a mine had ever existed under this name.

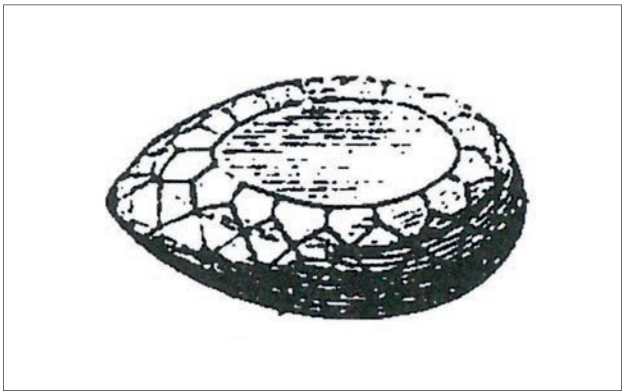

*Figure 3: This illustration of a 'Flat Mughal'-cut diamond appears in various editions of Tavernier's 1692* Les Six Voyages…, *Vol. 2.*

1676; Termezi et al., 1971; Soudavar, 2003). In early Islamic texts, the pearl was the quintessence of lustre, but after the 15th century—most certainly related to popularization in the East of European-cut stones—its place in Muslim literature was taken over by diamonds (Dankoff, 1991; Malecka, in preparation).

The Koh-i-Noor owed its radiance to its facet arrangement, known today as the Mughal cut. This term was introduced in the 1960s for stones of "rather lumpy form with a broad, often asymmetrical base, an upper termination consisting of a set of usually shallow facets or a table, and two or more zones of strip facets parallel to the base and oriented vertically" (Tillander, 1995, p. 64; see also Waite, 1968). The Mughal cut occurred in two versions. As a rule, it was rather flat, with the table usually surrounded by a number of smaller facets. The other version was topped with several facets and usually covered by a large number of small facets. The present author refers to the first of these as 'Flat Mughals' (Figure 3) and the second as 'High Mughals'; the Koh-i-Noor is assigned to the latter (Figure 2).

## Cutting History of the Koh-i-Noor

The original artisans who worked the Koh-i-Noor into the Mughal cut, as well as the place where the stone was cut and polished, are not known. In India, diamonds were worked by locals, as well as by European, Jewish and Armenian cutters, who were employed to fashion diamonds in the European way. During the 16th century, such European-cut stones reached prices several hundred percent higher on the Indian subcontinent than in the West, even compared to larger Mughal-cut diamonds (Malecka, in preparation). Given this, it seems likely that the expert who fashioned the Koh-i-Noor came from India.[8] According to a contemporary researcher whose analysis of a replica of the stone revealed that its facet corners met precisely at a point (Ogden, 2013), the Koh-i-Noor was polished with the greatest precision, so this specialist must have been a highly skilled professional. He also might have used a Western-type wheel in his work (Ogden, 2013).[9] As a rule, the most outstanding experts were employed for the royals. Assuming the Koh-i-Noor was the same as the diamond purchased by Akbar in Vijayanagara, it may have been fashioned in the 16th century in the large diamond centre of Vijayanagara by cutters and polishers working for the local ruler.

Mughal-cut diamonds were popular in India because this cut allowed for removal of small flaws, while retaining the greatest possible amount of material and simultaneously giving the diamond the desired brilliance (Haidar and Sardar, 2015). Due to high demand, on the Indian subcontinent such stones were the most expensive among the traditional cuts (Malecka, in preparation). However, this author has not found any evidence that diamonds of this cut were popular in the Near East where, as a rule, Western-cut stones were preferred (Malecka, in preparation; see also Bilirgen and Murat 2001). In the West, diamonds cut in this way were not considered worthy of attention until the second half of the 20th century. As a result, such diamonds were often either subjected to re-cutting upon their arrival in Europe or returned to India for sale (Burton, 1869; Hoey, 1880; Tillander, 1995).

[8] The widespread declaration that it was the Venetian Hortensio Borgio who worked the Mughal-cut diamond known as the Great Mughal is not true (Malecka, 2016).

[9] Even though precious stones were worked in India on wheels at the latest in the 13th–14th centuries, such equipment was not used that early for diamonds, for which polishing by hand was preferred (Malecka, in preparation). It is logical to assume that on the Indian subcontinent wheels were first applied to diamonds under Western influence, most certainly in the 16th century (see below). In contrast to Europe, where artisans used iron discs that did not need removal from the base, workers in 17th-century India used steel wheels that had to be taken off daily to be rubbed with emery. The result of these repeated relocations was the uneven run of the polishing tools, which made it impossible to produce diamonds with the high quality characteristic of Westerners' work (Tavernier, 1692). Such steel equipment was still in use by the Indians in the 19th century, although some used iron discs by that time (Newbold, 1843; Hoey, 1880).

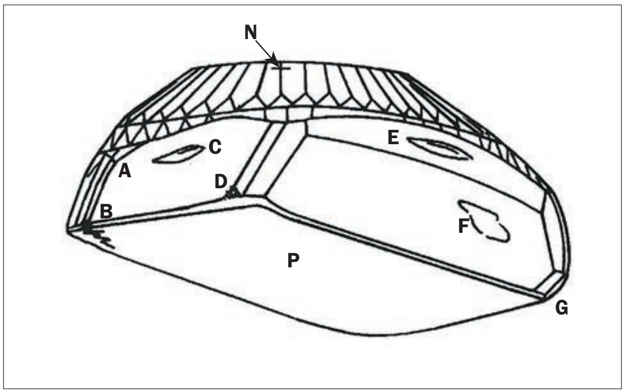


*Figure 4: According to Tennant (1854a, p. 136), "The flaws in the Koh-i-noor are…F…a large cleavage plane, produced by a fracture…(that) had not been polished…A…a flaw…most skilfully ground nearly out before any of the facets were cut. This flaw seems to proceed from a fracture B…C and E were little notches cut…for the purpose of holding the diamond in its original setting…N, a small flaw…almost required a glass to see it…D, a fracture from a blow or fall, showing at its base a cleavage plane." Image from Tennant (1854a).*

The Koh-i-Noor was received with just such disappointment in Great Britain (Hamlin, 1884). Although Hatleberg (2006) inferred that the Mughal-cut stone was actually a "very brilliant and highly dispersive" diamond, both the British royals and the public who viewed the Mountain of Light at the Great Exhibition of 1851 deemed it not radiant enough (Kinsey, 2009; Roberts, 2012), as they were accustomed to the appearance of brilliant-cut diamonds. In London, the Mughal way of working the diamond was described as so 'unskillfully executed that its appearance scarcely surpassed that of cut crystal'; other undesirable elements included its irregular egg form, 'grooves in the sides', and 'a small split near the top' (Figure 4; Anonymous, 1856, p. 221).[10]

To eliminate these flaws and make the diamond attractive to the Western public, the stone was refaceted into a brilliant cut. This enhanced its brilliance, as reflected in its name 'Noor', but paradoxically it also lost its 'mountainous' shape (and 43% of its weight), thus making the name 'Koh' inappropriate (Hatleberg, 2006).

## Indians' Views on Cutting Diamonds and Creation of the Mughal Cut

In literature on the subject, there is no conclusive answer to the question of whether the Mughal cut, as well as diamond cutting in general, were initiated in India independently or under Western influence (King, 1870; Tillander, 1995; Bari, 2001; Klein, 2005). Diamonds were worked on the subcontinent before the Europeans began to cut them towards the end of the 14th century (Tillander, 1995). However, this author could find no texts to support the assertion that these early Indian operations involved processes other than polishing, even though pre-Mughal sources report that hard stones were worked on the subcontinent with the use of various types of specialized tools (Malecka, in preparation). Since the value of diamonds depended on their weight, gem cutters of the Indian subcontinent were probably reluctant to radically diminish them (Malecka, in preparation).

The motivation for cutting diamonds in India was related to concerns about potentially breaking or damaging them. According to Hindu beliefs, gems that were broken, chipped, or had cavities and cracks, as well as those that were flawed or had a particularly coarse surface, were detrimental to the owner, and the amount paid for such stones was of course significantly lower than for good-quality specimens. Thus, the flaws were removed by polishing. Occasionally, this would make the edges of the diamonds less sharp or more even (Garbe, 1882; Varāhamihira and Ramakrishna Bhat, 1982; Shastri and Bhatt, 2008; Tiruttakkatevar and Ryan, 2012). However, at least until the 16th century, it seems that even diamonds without flaws but showing evidence of being worked (i.e. indications of their previous imperfections) brought a lower price in In-

[10] Scott Sucher, who analysed a plaster-cast model of the Koh-i-Noor, informed this author that the 'split near the top' could be one of several gashes 2–3 mm deep (three of which, in his view, were man-made) that were present on the stone (Figure 4). According to a British gem expert who examined the Koh-i-Noor in the middle of the 19th century, two of these cavities helped keep the stone in its setting (i.e. C and E in Figure 4; Tennant, 1854a; Malecka, 2018). Although they most certainly were used in this way, in the present author's view it is doubtful that in India an unblemished specimen would be purposefully defaced by engraving such cavities in it. (See below for the Indians' views on working diamonds.) According to traditional Indian criteria, such cavities would be counted among diamond flaws described as *gara* or holes on the surface, which could arise during the mining process or from removing inclusions that affected the price of a specimen to a greater degree than would the cavities (Tagore, 1879; Malecka, in preparation). Two of the Koh-i-Noor's cavities could have resulted from removing flaws, with both being worked in a similar orientation to provide the added benefit of being used to help keep the stone in its setting (Malecka, 2018; see also Brewster, 1863).

Figure 5: A faceting style reminiscent of the Mughal cut is displayed by the garnet in this 6th-century Byzantine ring. Photo © Les Enluminures.

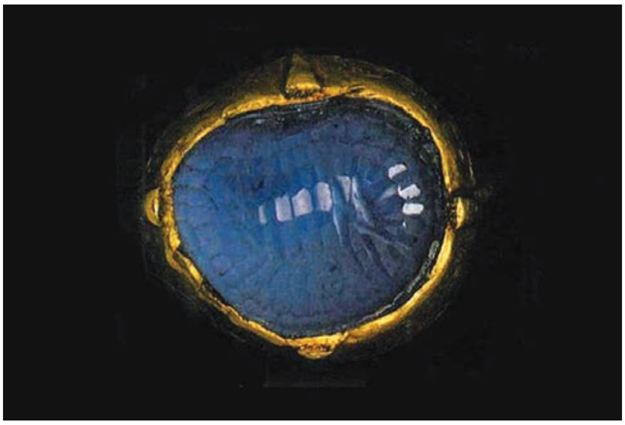

Figure 6: This Mamluk ring from the 13th–14th centuries is mounted with a sapphire cut in a style similar to the Mughal cut. Reproduced with permission from Content (1987); © Derek Content.

dia, and perhaps also in the Near East, than the unblemished, untouched-by-tradesmen rough termed 'virgins' (Linschoten et al., 1885; Shammā' and Tawfīq, 1999; Shcherbina, 2014).

Assuming the Koh-i-Noor was purchased in Vijayanagara by the Great Mughal, it is reasonable to conclude that diamonds were worked in the Mughal cut in India at the latest by the end of the 16th century. So if this cut had appeared on the Indian subcontinent at this time, what were the sources of its inspiration, and where was it most likely created?

In the Near East, cutting of minerals was deemed an Occidental art, at the latest in the 12th century. In a treatise on gems, and as part of a discussion of mounting diamonds in jewellery, an Iranian author of the time mentioned that cutting and polishing were practised in Europe, although exclusively on rubies and emeralds (Nīshābūrī, 2004). A gem expert active around the first quarter of the 16th century in Mughal India denounced the cutting of diamonds as an art of the "Franks" that "did not bring good results"; however, he also admitted that no one was more proficient in this trade than those "immoral infidels" (Rustamdari, 1852 [AH 1268]). A similar view also was held by an Arab gemmologist active at the turn of the 15th/16th centuries, as well as by a Persian-language author from the 15th century who nevertheless maintained that "within the last quarter of the century" it was the Europeans who had best mastered this art (Binesh, 1964; Shammā' and Tawfīq, 1999).

Such remarks suggest that, in the East in the 15th century, there were known 'Frankish' types of cuts. The table cut and the flat-bottomed Gothic rose cut were widespread in the West at that time, so it is logical to assume that remarks by the Eastern authors pertained to these cuts (Tillander, 1995). In the present author's view, it also is doubtful that diamonds cut by Westerners would be admired by Indian specialists if Mughal cuts were in use on the subcontinent before this time.

It should be noted that faceting styles reminiscent of the Mughal cut had been done on gems other than diamonds since ancient times. Examples of such stones include an early Byzantine garnet and several sapphires covered with numerous small facets, cavities or 'dimples' from about the 10th–14th centuries in India, Vietnam and Egypt (Content, 1987, 2016; Spier, 2012; see Figures 5 and 6). Similarly, as for the Mughal cuts, cavities covering most or all of their exposed surfaces were situated not merely to remove impurities, but also to show the gems to maximum advantage (Content, 2016). However, the present author has not found proof that this type of work—in the case of coloured stones, still appearing in India at least in the 17th century—constituted a direct inspiration for the creation of the Mughal cut for diamonds (Shcherbina, 2014).

In this author's view, the European cuts admired on the subcontinent were the direct inspiration for Mughal-cut diamonds. The earliest surviving examples this author has found of Mughal-cut diamonds in jewellery that can be dated come from the beginning of the 17th century, while in the West, diamonds reminiscent of the Flat Mughals were worked as early as the first quarter of the

16th century (Keene and Kaoukji, 2001).[11] One such stone decorates the hat ornament in a 1519 portrait of Anna Jagellonica (1503–1547), the wife of Holy Roman Emperor Ferdinand I Habsburg (Belozerskaya, 2005; see also Zimerman, 1887). Even though such diamonds theoretically could have had an impact on the origins of the Mughal cut, there is no evidence that they had reached the subcontinent by the early 1500s. Rather, it seems more likely that inspiration for Mughal-cut diamonds came from table- and rose-cut diamonds (see Tillander, 1995, and Galopim de Carvalho, 2014, for illustrations of these cuts). Such stones, including large exceptional ones, were available on the subcontinent at least by the first half of the 16th century; they were exported from Europe or fashioned locally by valued and usually well-paid Westerners (Castañeda, 1554; Vassallo e Silva, 1989; Malecka, in preparation). Among such experts were, for example, Francisco Pereira and Master Pedro, who were both present in the diamond-trading centre of Vijayanagara circa 1548 (Teles e Cunha, 2001).[12]

Most certainly at this time, Indian specialists already were engaged not only in polishing but also in cutting diamonds in Vijayanagara. A description of a mythical city patterned after the capital of the Vijayanagara Empire, written in about 1550 in the Canarese language, includes many gem traders active in its local bazaar, including diamond experts who had their own stalls, where they were engaged in polishing and cutting diamonds into various shapes and sizes (Dallapiccola, 2003). This text unfortunately does not contain information on whether the polishing and cutting were done by the same persons or, as was the case in the West, by different persons.

Evidence that Indians were engaged in diamond cutting under Western influence is found in a Portuguese treatise composed during about 1560–1580 or perhaps a bit earlier. The anonymous author of this work reported that "recently diamonds in India are worked as in our land" and added, in a tone of regret, that Indians "polish them in their own way" (Vassallo e Silva, 1989, p. 137). It is most probable that these remarks referred to early attempts at preparing the Mughal cut.[13] Information in the work of a Dutch author present on the subcontinent during 1583–1588 also must have pertained to Mughal-cut diamonds. He mentioned that diamonds prepared at that time in India were "pointed with three corners, h(e)arts, and such like sorts thereby to hide their fault( )s…made in that sort to hold (their) greatness and w(e)ight" (Linschoten et al., 1885, p. 153).

Even though the Mughal cut was effective for retaining the greatest possible amount of the weight, early efforts to prepare such stones apparently were not especially successful, from the point of view of Indian market requirements. The author of the Portuguese treatise stated that, as a result of the Indians' actions, a rough stone would sometimes lose about 30% and even (as was often the case for Western cuts) 50% of its weight (Vassallo e Silva, 1989).[14]

Westerners considered such stones to be badly worked, having "too much thickness underneath" and undoubtedly requiring re-cutting, as both Portuguese and Dutch writers stated that it was not economical for Europeans to buy them (Lin-

[11] In the 17th century, Mughal-cut diamonds were especially favoured among Indian Muslims (Ovington, 1690). However, their popularity on the subcontinent started to decline in the 19th century, and by about 1950 finding buyers for Mughal cuts became difficult (Christie's, 1997; Malecka, in preparation).

[12] Vijayanagara was at that time one of the most important global centres of diamond trade, where stones from elsewhere in India were brought for sale. Other gems also were traded in this centre (Schurhammer and Voretzsch, 1928). For information on European diamond specialists working in Vijayanagara, see Kömmerling-Fitzler (1968).

[13] It is rather doubtful, in the present author's view, that cuts prepared then by the Indians were Western-style roses or tables. As mentioned earlier, the market for these unusually costly and exotic stones was not large on the subcontinent at that time; it was most certainly limited to court circles. The wealthy Indians preferred to import such stones from Europe, send rough to be worked in the West or take advantage of the services of European cutters active in India (Malecka, in preparation).

[14] Perhaps the initial attempts by the Indians at working diamonds were not very successful due not only to a lack of capability and proper equipment, but also to the scarcity of specialists with a distinct knowledge of cutting or polishing on the subcontinent. Islamic texts mention two terms describing gem workers: *hakkak*—now usually rendered as a gem engraver, lapidary, or polisher—and *tarash*, or cutter. In the present author's view, both terms could have been used interchangeably in historical texts as general descriptions of gem workers. The specialists themselves possibly used *hakkak* specifically for a polisher and *tarash* for a cutter, although the meaning of either term may differ depending on the region (Çelebi, 1896; Kāshānī and Afshār, 1966/1967 [AH 1345]).

schoten et al., 1885, p. 153; Vassallo e Silva, 1989). The Portuguese writer maintained that it was more beneficial to buy 'developed and cleaned' diamonds from 'Moors' (most probably Muslims active in India), whose stones could be recut without losing much of their weight. Such diamonds probably were already polished in the mining areas according to the Indian custom of removing flaws (Vassallo e Silva, 1989, pp. 136–137; Malecka, in preparation).

What factors contributed to the rise of the Mughal cut? It is known that in India, hundreds of years before Europeans arrived there, diamonds with smooth polished edges were popular and considered auspicious (Hultzsch et al., 1916; Malecka, in preparation). As a result of these polishing activities, specimens with big tables probably existed already, although surviving examples of such stones are impossible to date earlier than Mughal times (Ivanov et al., 1984; Keene and Kaoukji, 2001; Tān, 2002). Although pre-Mughal Indian diamond experts were probably familiar with diamonds with tables, we have no evidence to support the placement of triangular facets in a regular pattern around the tables prior to Western influence. On some Mughal-cut diamonds, the first row of facets around the table was composed of trapezoids or rectangles, possibly inspired by Western table cuts. In the case of the High Mughals, the table was replaced by a small number of facets, which brings to mind early rose cuts (Tillander, 1995). Of course, the final form of the stone was determined by several factors: size and shape of the rough, type and positioning of flaws and directional hardness anisotropy, which in consideration of the primitive tools used at the time, was the greatest challenge for the cutters (Hart, 2015).

The Mughal cut was considered to be a local, Indian version of the rose cut. Prior to the 20th century, Mughal-cut diamonds (now described simply as 'Indian' or 'worked on in India') were described in Europe as 'roses' or 'Indian roses' (Ujfalvy-Bourdon, 1885; Nasiri, 1945 [AH 1364]; Copeland, 1960; Rybakov, 1975; see also Tarshis, 2000). It should be mentioned that the Mughal cut had 'flowery' connotations on the subcontinent. In conversations with this author, Indian gem merchants described High Mughals with the term *kanwal*, which in the Hindustani language means 'water lily'.[15] In reference to Flat Mughals, the present author's interlocutors used the term *parab* ('flat diamond' in Hindustani; see also Bala Krishnan and Ramamrutham, 2001). In the literature, the stones described today as Mughal cuts appear under the names *villandi* or *bullandi* (Persian 'buland' or 'high'), as well as *polki*, which is also used on the subcontinent to refer to rose cuts (Untracht, 1997; Shcherbina, 2014; Shor, 2016). It is possible that the same terms were used in somewhat different ways for the various methods of working in different areas of the Indian subcontinent at varying times.

Determining where in India the Mughal cut could have originated is not an easy task. It most likely happened in one of the centres in which European gem experts stayed: the above-mentioned Vijayanagara; Calicut, in which gem experts from the West already were present at the end of the 15th century; Cochin, the main seat of Portuguese India in 1503–1530; or Goa, which was conquered by the Portuguese in 1510. Through this last city, Western goldsmithing techniques reached the subcontinent, imported by Europeans as well as by Indians who travelled to Lisbon as early as the first quarter of the 16th century (Alves, 1935; Matos, 1989; see also Pissurlencar, 1936). Western diamond cuts appeared in Goa as imports, and also through the actions of the European workers operating in this city, among whom the Flemish and Portuguese distinguished themselves (Linschoten et al., 1885; see also Vassallo e Silva, 1995, 2004). Given this, it is logical to assume that around the middle of the 16th century diamonds were worked in Goa. In the present author's view, it is most likely that Goa is where the Mughal cut was created, as an example of Indo-Western syncretism typical of the artistic creativity in that city.

It is tempting to suggest that the Indian community of diamond workers were instrumental to

[15] It is interesting that the term 'water lily diamonds' might have been used in other parts of the Islamic world to describe rose cuts. It is known, for example, that stones fashioned in the shape of a water lily were ordered in the 1660s from the Dutch by a certain Sumatran royal (Chijs, 1893). In the Malay world at that time, the rose cut was considered exotic and was ordered from Western cutters, so it is highly probable that those 'water lily diamonds' were the same as roses. Diamonds described as *nilüferi* or water lily also were mentioned in an Ottoman text (Malecka, in preparation).

the rise of the Mughal cut, and in the present author's view the most probable candidates are the Gujaratis who were present in Portuguese Goa in the 16th century. It is known that the Gujaratis, who had already played an important role in the diamond trade for many centuries, had been moving between Goa and the diamondiferous Deccan area during the Mughal era (Orta, 1891; Malecka, in preparation). In view of the Gujaratis' presence in this centre in which Europeans were active, it is possible that the experts belonging to this community created the Mughal cut, modelling on the work of their Western colleagues but bearing in mind the aesthetic and material needs of the Indians. The above-mentioned pentagonal facets, which resemble rectangles with triangular pinnacles, and gave the stone a flower-like appearance, evoke a motif known from 16th-century Gujarati decorative art: a central medallion surrounded by rectangular, sharply finished 'petals' (Vassallo e Silva, 2001).

## Conclusion

Various versions of a story regarding Nadir Shah's acquisition of the Koh-i-Noor diamond and his naming of this stone gradually became established during the 19th century, in India as well as probably in Great Britain. The name *Koh-i-Noor*, in keeping with Eastern tradition, was directly related to the appearance of the stone (i.e. its radiance and shape), as displayed by its Mughal cutting style. Assuming the Koh-i-Noor to be Emperor Akbar's stone, it is logical to conclude that cutting and polishing of this diamond took place in the 16th century by an Indian specialist. It also is possible that the diamond was worked in the kingdom of Vijayanagara, where it might have originated.

In the present author's view, Mughal-cut diamonds appeared on the Indian subcontinent under the influence of European table and rose cuts. The Mughal cut was created most certainly before 1550, possibly in Goa through the Gujaratis. The largest market for diamonds worked in this way, at least prior to 1565, was probably Vijayanagara. This cutting style facilitated the removal of flaws that disfigured a diamond or made it susceptible to breakage, while simultaneously maintaining the greatest volume of material.

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# Characterization of Mexican Amber from the Yi Kwan Tsang Collection

*Vittoria L. Villani, Franca Caucia, Luigi Marinoni, Alberto Leone, Maura Brusoni, Riccardo Groppali, Federica Corana, Elena Ferrari and Cinzia Galli*

Twenty-seven amber samples from an important collection of 115 specimens from Chiapas, Mexico, were subjected to gemmological analysis, microscopy of the inclusions (including taxonomic classification), infrared spectro-scopy, X-ray powder diffraction (XRD) and mass spectrometry. Some of the data were compared to those obtained from amber samples from the Baltic Sea and the Dominican Republic. All the ambers had the same RI (1.54), but the Mexican samples showed slightly lower SG values (1.03) than the Dominican (1.05) and Baltic (1.06) ones. Mexican amber is notable for hosting a large variety of beautiful organic inclusions, in particular flower petals and leaflets of the extinct species *Hymenaea mexicana*, as well as a planthopper of the extinct species *Nogodina chiapaneca*, which dates back to the Middle Miocene and has been found only in amber from Chiapas. XRD analysis of samples from all three localities showed the expected amorphous pattern accompanied by traces of refikite and hartite, as well as calcite in the Mexican samples. Infrared spectroscopy was useful for identifying amber from each of the three localities. Mass spectrometry of the Mexican (and Dominican) amber showed that it lacked succinic acid and can therefore be classified as a resinite of Class IC (i.e. resinites with ozic acid and/or zanzibaric acid derived from the *Hymenaea* genus).

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## Introduction

Amber is like a screenshot of the past, when ecosystems were much different than presently known. A peculiarity of amber is that it may perfectly preserve an organism in its original life position. Amber is an amorphous and organic solid substance, characterized by a complex mixture of terpenoid compounds (aromatic hydrocarbons), alcohols, acids and water (Alekseeva and Samarina, 1966). It derives from fossilized resins produced by prehistoric trees, and is usually associated with coal or terrigenous deposits (Langenheim, 1966, 1969; Langenheim et al., 1967; Poinar, 1992; Rao et al., 2013). Such resins are produced by plants in response to certain circumstances, such as defence against insect pests or protection of wounds (Anderson and Crelling, 1995; Langenheim, 1995, 2003; Anderson, 1996).

The most important resin-producing plant families are classified among the gymnosperms (conifers) and the angiosperms (flowering plants). Conifers and their progenitors appeared earlier than angiosperms in the geological record (Hurd et al., 1962; Poinar, 1992; Anderson and Crelling, 1995; Poinar and Poinar, 1999).

Amber deposits are present worldwide; the oldest date back to the Carboniferous Period (~360–300 Ma [million years]; Grimaldi, 1996), but they still have not been investigated in detail. Important studied amber deposits (see Table I) date back to the Mesozoic Era—such as those from the Dolomites in Italy, Kachin and Magwe States in Myanmar, New Jersey in the USA and Manitoba in Canada—and also the Cenozoic Era—such as those from China, the Baltic Sea region, the Dominican Republic, Chiapas in Mexico and Sicily in Italy. The majority of Mexican amber comes from Late Oligocene/Early Miocene deposits in Chiapas State (e.g. Figure 1), although Late Cretaceous deposits are known in Baja California and Coahuila States (Riquelme et al., 2014).

Ambers are typically classified according to two criteria: their place of origin (Poinar, 1992) and their chemical composition (Anderson and Crelling, 1995). The latter classification considers


*Figure 1: This necklace from the Yi Kwan Tsang Collection contains amber beads from the San Cristóbal de las Casas area of Chiapas, Mexico, and was made by Francesca Montanelli (Lutezia Jewels, Stradella, Italy). Photo by Francesca Montanelli.*

*Table I: Age, origin and chemical classification of amber (based on succinic acid content) from selected deposits.*

| Deposit | Age | Paleobotanical origin | Chemical classification | Reference |
|---|---|---|---|---|
| Sicily, Italy | Miocene (22.5–6 Ma) | Angiosperm | Resinite | Beck and Hartnett (1993); van der Werf et al. (2016) |
| Chiapas, Mexico | Late Oligocene/Early Miocene (23–13 Ma) | Angiosperm | Resinite | Riquelme et al. (2014) |
| Dominican Republic | Middle Oligocene/Early Miocene (30–22.5 Ma) | Angiosperm | Resinite | Larsson (1978); Grimaldi (1995) |
| Baltic Sea, Europe | Eocene (40–35 Ma) | Coniferous | Succinite | Poinar (1992) |
| Fushun, Liaoning Province, China | Eocene | Coniferous | Succinite | Wang et al. (2014) |
| Cedar Lake, Manitoba, Canada | Late Cretaceous (Campanian, 78 Ma) | Coniferous | Resinite | Poulin and Helwig (2016) |
| New Jersey, USA | Late Cretaceous (Cenomanian, 94–90 Ma) | Coniferous | Resinite | Azar et al. (2015) |
| Hukawng Valley, Kachin State, Myanmar | Late Cretaceous (Cenomanian, 94–90 Ma) | Coniferous | Resinite | Cruickshank and Ko (2003) |
| Hti Lin, Magwe State, Myanmar | Late Cretaceous | Coniferous | Resinite | Sun et al. (2015) |
| Dolomites, Italy | Late Triassic | Coniferous | Resinite | Trevisani and Ragazzi (2013) |


*Figure 2: The state of Chiapas, Mexico, is the source of the amber specimens in the Yi Kwan Tsang Collection. Map adapted by A. Leone.*

the presence of succinic acid (which is a carboxylic acid): ambers are classified as *succinite* (i.e. containing succinic acid) or *resinite* (lacking succinic acid; Vávra, 2009). A more detailed chemical classification of fossil resins (Anderson et al., 1992; Anderson and Botto, 1993; Anderson, 1994) consists of five classes: Class I—succinites with succinic acid and communic acid (Class IA; Baltic amber and some Canadian amber produced from conifers), resinites with polymers of communic acid but without succinic acid (Class IB; amber from New Zealand) and resinites with polymers of ozic or zanzibaric acid (Class IC; East African, Mexican and Dominican ambers produced from *Hymenaea* species); Class II—fossil resins derived from Dipterocarpaceae; Class III—fossil resinites derived from Hamamelidaceae (a *Liquidambar* found in Germany); Class IV—amber-like materials of unknown botanical origin (from Moravia, Czech Republic); and Class V—fossil resins derived from angiosperms (from Ecuador and Austria).

The most important amber mines in Mexico are located in the area of Simojovel, but there are several deposits elsewhere in Chiapas State (Figure 2; Poinar, 1992). Chiapas is the southernmost state of Mexico and is relatively isolated from the rest of the country. Amber from this region was observed in jewellery of indigenous people by early European explorers, who at first believed the amber was derived from Baja California (Poinar, 1992).

The Yi Kwan Tsang Collection (named after the owner's wife) consists of 115 amber samples from Chiapas, many of which contain abundant plant and animal fossil inclusions. One sample even hosts an extremely rare frog inclusion. The ambers were acquired over a 10-year period (~2004–2013) in San Cristóbal de las Casas, which is the most important manufacturing centre for material mined in the area near Simojovel. Many of the amber pieces in the Yi Kwan Tsang Collection have been incorporated into jewellery (e.g. Figure 1), and the collection was displayed in 2015 at the Tucson Gem and Mineral Show and in 2016 at the Beijing International Jewelry Fair. This article characterizes Mexican amber from this collection using a variety of methods, including those not very common in gemmology, such as taxonomy studies and mass spectrometry using techniques optimized for organic molecules.

## Geological Setting

The geology of Chiapas is rather complex (Sapper, 1896; Moran-Zenteno, 1994; SGM, 2014). The southern part is underlain by Paleozoic plutonic rocks, while the central and northern regions consist of Mesozoic and Tertiary formations. Above these strata are Quaternary deposits that form extended plains (Böse, 1905).

The Simojovel area is characterized by three stratigraphic units that contain amber (Berggren and Van Couvering, 1974; SGM, 2014). From bottom to top, these are the La Quinta Formation (28–20 Ma), the Mazantic Shale (23–14 Ma) and the Balumtum Sandstone (16–12 Ma; see Licari,


*Figure 3: Chiapas amber is mined from hand-dug tunnels and pits, such as this one near Simojovel de Allende. Photo by the owner of the Yi Kwan Tsang Collection.*

1960; Castañeda-Posadas and Cevallos-Ferriz, 2007). The La Quinta Formation is comprised of three units: the Camino Carretero member (shales alternating with sandstones and limestones), the Florida Limestone member (sandstone strata with coal layers in the lower part and thick limestone layers eroded at the top) and the Finca Carmitto member (conglomerates at the bottom and sandstones at the top; Frost and Langenheim, 1974). According to Grimaldi (1996), most of the amber deposits are associated with lignites, friable shales and deltaic clays in the sandstones.

## Mining and Production

According to the owner of the Yi Kwan Tsang Collection, who visited the mining area during the 2002–2006 period, there are hundreds of amber mines in the tropical forest around Simojovel (e.g. Figure 3). Most of these workings consist of narrow tunnels about 1–2 m high that extend into the hills for 5–500 m, following the amber-bearing strata. The amber is mined manually using hammers and chisels. The miners sometimes work in precarious conditions, illuminating the tunnels with candlelight. The extracted material is carried out of the mines in wheelbarrows and buckets, and then dumped into large piles for sorting. The rough amber is taken to Simojovel or San Cristóbal de las Casas for cleaning, polishing and trading, and is then sold to intermediaries or directly to jewellers.

Amber extraction is not continuous through the year; during the rainy season (from late May to late October) mud often invades the tunnels, making mining almost impossible. Most of the miners are also farmers, and during the rainy season they cultivate their fields and coffee plantations.

The question of who owns the earth that the miners work is vexing. Some land is held in common and some is privately owned, and arguments over mining rights often set off fierce fighting. Some of the miners are independent, and others rent their mines from landowners.

## Materials and Methods

For this study, the authors had access to 27 pieces of amber from the Yi Kwan Tsang Collection that were selected by the owner for non-destructive examination, as well as three amber fragments (derived from the manufacturing of pieces in the Collection) for destructive analyses. All of the samples were polished and of gem quality; they ranged from 0.85 to 10.0 cm in maximum dimension. Nine samples (Figure 4; Table II) were studied using standard gemmological instruments. Refractive index measurements were performed with a Kruss ER6040 refractometer, which allowed RIs in the range of 1.30–1.80; all readings were taken from flat polished surfaces. Specific gravity was determined using a Presidium PCS-100 balance (0.002 g precision). Fluorescence was observed with an 8-watt UV lamp equipped with 254 nm (short-wave) and 365 nm (long-wave) bulbs. Inclusions were examined in all 27 samples using a stereoscopic microscope (30×–40× magnification).

Destructive techniques consisted of XRD analysis, Fourier-transform infrared (FTIR) spectroscopy and mass spectrometry. FTIR spectra were taken using three Mexican amber fragments (Figure 4, samples 1–3), as well as three Baltic and three Dominican ambers for comparison. (The

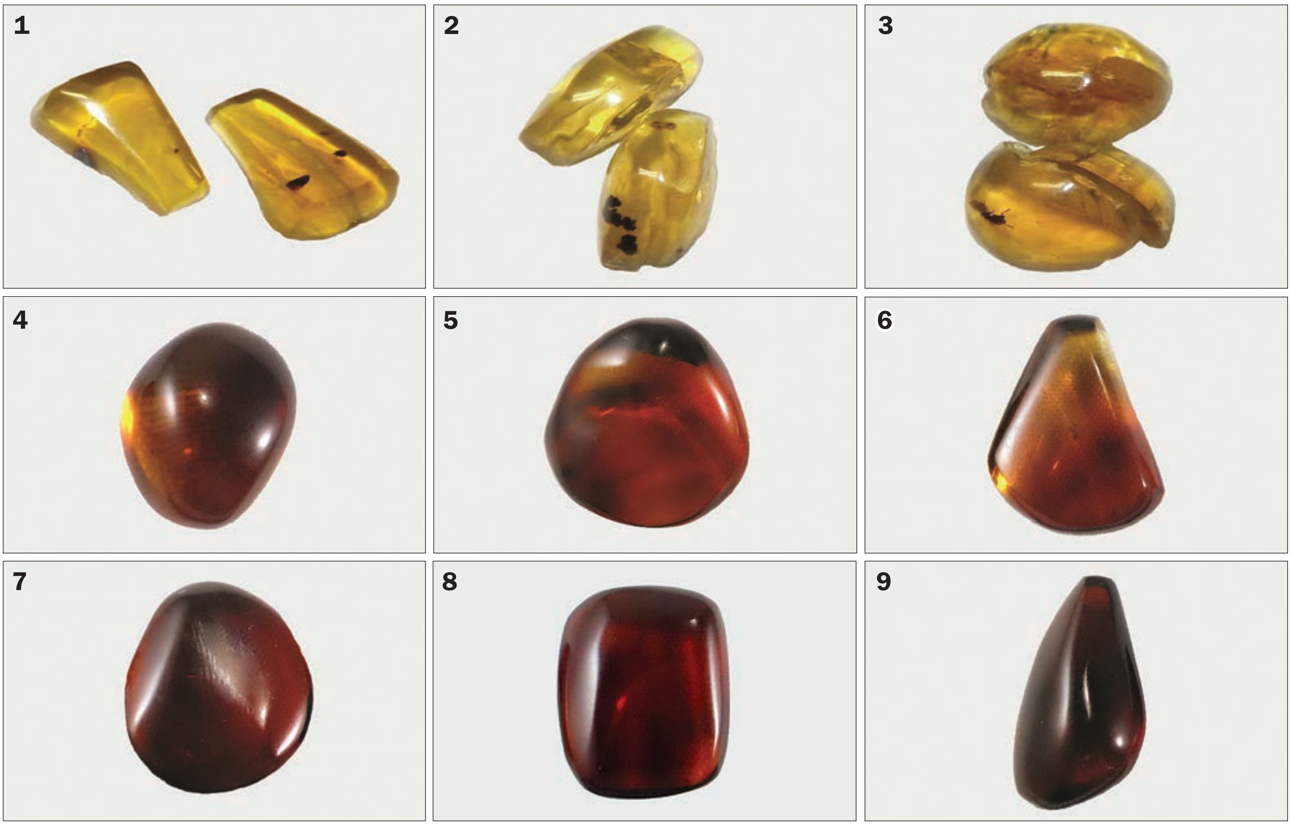


Figure 4: These nine pieces of Mexican (Chiapas) amber from the Yi Kwan Tsang Collection were used for gemmological analysis. Portions of samples 1–3 were used for destructive testing. See Table II for sample descriptions. Photos by V. L. Villani.

Baltic ambers ranged from golden yellow to red and measured 0.7–1.9 cm, while the Dominican ambers were orange to red and measured 0.4–1.7 cm.) XRD analysis and mass spectrometry were performed on one sample from each locality.

For XRD analysis and FTIR spectroscopy, the samples were powdered with a mortar and pestle. The XRD analyses were conducted with a Philips PW1800 powder diffractometer, using Cu*K*α radiation (λ = 1.5418 Å, 35 kV, 45 mA) and a scan speed of 1°/min, in the range 2–65° 2θ. Natural resin/amber is amorphous, so XRD analysis does not yield information on the amber itself but can identify mineral inclusions. The interpretation of the X-ray patterns was done with PANalytical X'Pert HighScore software.

Table II: Gemmological data for the Mexican amber samples in Figure 4.

| Sample | Size (mm) | Weight (ct) | SG | RI | Colour | UV fluorescence (long-wave)* |
|---|---|---|---|---|---|---|
| 1 | 17.7 × 8.5 | 5.32 | 1.03 | 1.540 | Dark golden yellow | Strong light blue |
| 2 | 18.4 × 11.5 | 7.46 | 1.03 | 1.540 | Dark golden yellow | Strong light blue |
| 3 | 14.0 × 13.7 | 5.84 | 1.03 | 1.540 | Dark golden yellow | Strong light blue |
| 4 | 15.7 × 9.7 | 5.60 | 1.04 | 1.540 | Orange-red | Weak chalky white |
| 5 | 21.2 × 9.4 | 9.86 | 1.03 | 1.540 | Orange-red | Weak chalky white |
| 6 | 27.2 × 14.0 | 10.69 | 1.03 | 1.540 | Orange | Weak blue |
| 7 | 27.2 × 13.0 | 6.74 | 1.03 | 1.538 | Dark orange | Weak chalky white |
| 8 | 27.0 × 15.0 | 9.47 | 1.03 | 1.540 | Orange-red | Weak chalky white |
| 9 | 21.3 × 19.0 | 7.63 | 1.03 | 1.540 | Dark orange | Weak chalky white |

* All samples were inert to short-wave UV radiation.

The FTIR spectra were collected in the mid-infrared range (4000–500 $cm^{-1}$) with a Thermo Nicolet Nexus 670 spectrometer equipped with a diffuse reflectance (DRIFT) unit coupled with a mercury-cadmium telluride (MCT) detector. About 20 mg of amber powder was mixed with 200 mg of KBr (1:10 ratio of sample:KBr) and compacted with a hydraulic press into a thin pellet for analysis. The spectral resolution was 4 $cm^{-1}$ (200 scans).

Mass spectrometry was performed to determine the presence of free succinic acid in the amber samples. This method leaves the polymeric structure of the resin unaltered, allowing the quantification of unbound, free succinic acid (which is used to distinguish succinites from resinites). The analyses were performed with a Thermo Scientific LCQ Fleet ion trap mass spectrometer, using 26.5 mg of Mexican amber, 24 mg of Baltic amber and 20.3 mg of Dominican amber. The samples were powdered in an agate mortar, and 1 ml of water+methanol (70:30 by volume) was added. The vials were sonicated for 20 minutes in an ultrasonic bath, which optimized the contact between the amber powder and the solution. The vials were then centrifuged for 20 minutes at 7,000 rpm, and the homogenized mixtures were filtered to prevent larger particles from entering the mass spectrometer. The resulting samples were diluted 1:10 with a mixture of water+methanol (50:50 by volume), and mass spectra of the solutions were taken to see if any impurities were present. For the acquisition of the amber mass spectra, each solution was injected into the mass spectrometer ionization source using specially designed inlets with controlled flow. The solutions were evaporated into a gas phase by heating, and then the gas molecules were ionized and the ions were mass analysed with the spectrometer. For a better signal, all measurements were performed in negative ion mode. The free succinic acid content of the amber samples was determined by adding known amounts of prepared standard solutions to the original solutions. The succinic acid standards were added to the amber solutions to obtain concentrations of added succinic acid of $0.25 \times 10^{-6}$, $5.0 \times 10^{-6}$ and $1.25 \times 10^{-6}$ M. The free succinic acid concentrations were calculated by the method of Tonidandel et al. (2008) using the function $I = fC$ (I = ion intensity, C = concentration).

## Results and Discussion

### *Gemmological Properties*

Gemmological data for the analysed Mexican ambers are reported in Table II. The 27 samples we examined for inclusions were transparent and typically ranged from golden yellow, orange and orange-red to dark orange; a few pieces were dark brown, and some displayed a little natural green coloration. However the colour range of all samples comprising the entire Yi Kwan Tsang Collection is more extensive: yellow to golden yellow, orange, dark orange and red.

Internal features consisted of inclusions (described below), as well as less common colour variations (e.g. dark stripes, see Figure 5) and small surface fractures (Figure 6). The fractures are probably related to stress associated with the

*Figure 5: These three amber samples from the Yi Kwan Tsang Collection range from golden yellow to orange. Dark stripes are shown by samples A and C. Sample A is ~4.5 × 3.8 cm, B is ~2.9 × 2.1 cm and C is ~4.0 × 3.4 cm. Photo by V. L. Villani.*

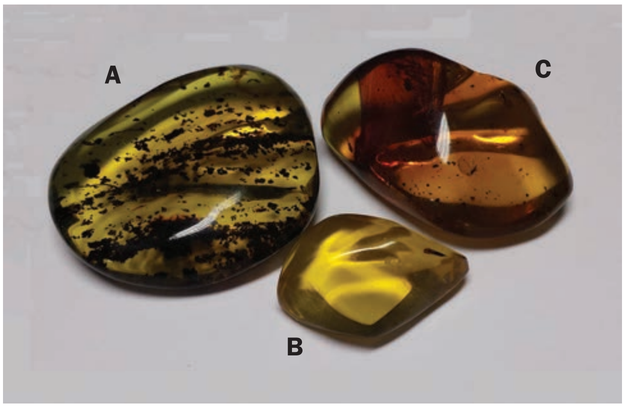



*Figure 6: Cracks are present in the surface of a Mexican amber sample. Photomicrograph by V. L. Villani; magnified 30×.*

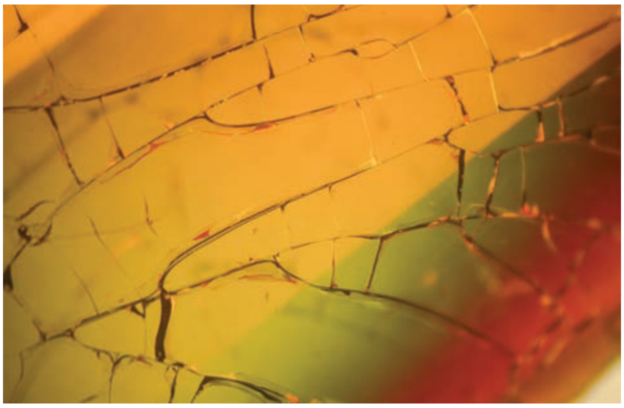


Figure 7: The Mexican amber samples showed a chalky white or light blue reaction to long-wave UV radiation. Photo by V. L. Villani.

polymerization of the resin. All of the pieces were inert to short-wave UV radiation but displayed weak to strong fluorescence to long-wave UV (chalky white or light blue; Figure 7). Such fluorescence behaviour also is seen in ambers from the Baltic Sea and the Dominican Republic (Villani, 2016). The RI values were constant (1.540 for all but one sample that showed 1.538), and they were similar to those of Baltic and Dominican amber (cf. Villani, 2016). Average SG values were found to be homogeneous and relatively low (1.03) compared to the literature in general (see, e.g., Abduriyim et al., 2009) and, specifically, as compared to Baltic (1.06) and Dominican (1.05) ambers (Villani, 2016). We hypothesize these differences are due to the different age and burial history of the ambers, which influence their chemical composition and structure.

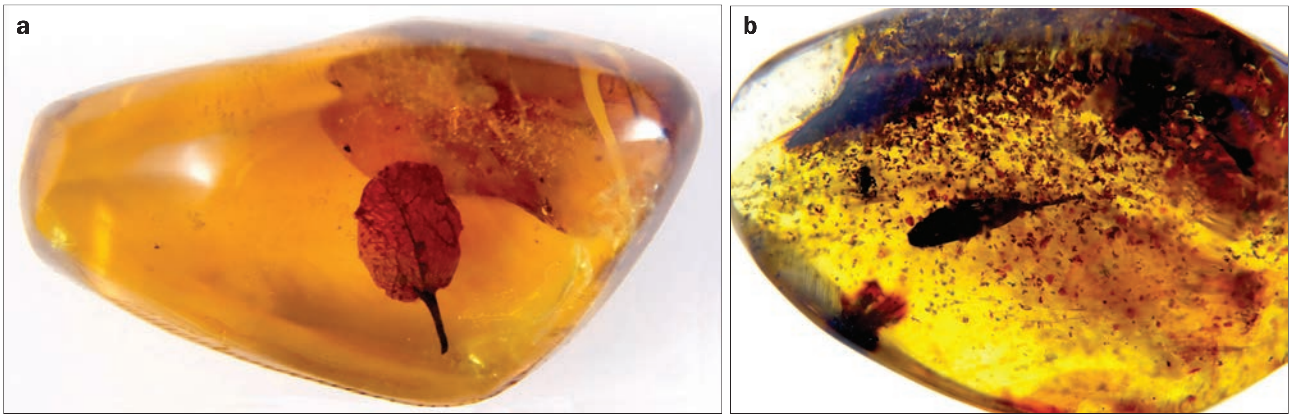
### *Botanical and Animal Inclusions*

To identify the animal and plant fossils in the amber, we relied on observation of their specific characteristics and comparison with the literature (McAlpine et al., 1981; Goulet and Huber, 1993; Brown et al., 2009; Calvillo-Canadell et al., 2010; Poinar and Heiss, 2011). The determination of the taxa was difficult because the species that lived in Chiapas during the Oligocene-Miocene were different from modern ones. Also, several of the insects were present as incomplete body parts and/or they were altered by the organic acids and/or glued together by the amber-forming resin. Figures 8–12 show the most significant botanical and animal inclusions in the examined samples, and Figure 13 illustrates soil fragments and bubbles.

From a paleontological point of view, the most important plant inclusions were represented by a petal (Figure 8a) and a leaflet (Figure 8b) of the genus *Hymenaea* (Poinar, 1991). The petal ranged from light brown to red and was completely glabrous (smooth), with a central vein and a path of secondary veins. According to Poinar and Brown (2002), such inclusions belong to the species *Hymenaea mexicana*, which is now extinct. It would be interesting to compare such inclusions with other species of *Hymenaea* found in amber from the Dominican Republic and East Africa, which are quite similar.

Animal inclusions were more common in the amber samples than those of botanical origin. They consisted of arthropods of the orders Diptera (Figure 9) and Hymenoptera (Figure 10), and

*Figure 8: (a) A flower petal inclusion of the species* Hymenaea mexicana *(Fabaceae family, Late Oligocene–Early Miocene; Poinar and Brown, 2002 and Calvillo-Canadell et al., 2010) is seen in this Mexican amber sample. The petal measures 1.1 cm long and 0.7 cm wide, and shows a narrow midrib base and basal laminar lobes with a central vein and branches of secondary veins. It appears completely glabrous (smooth). (b) The* H. mexicana *leaflet in this Mexican amber measures 3.3 cm long and 1.1 cm wide. The surface is glabrous and its veins are not visible in this view. Photomicrographs by V. L. Villani.*



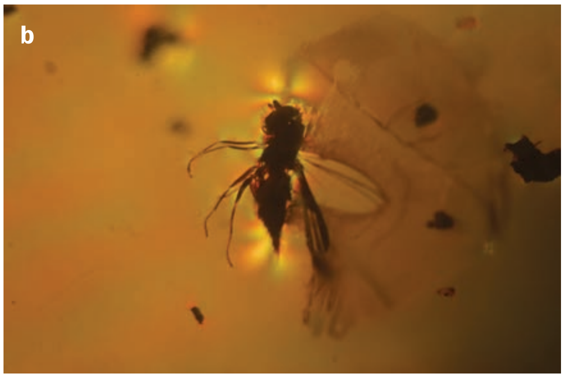




*Figure 9: (a) A female mosquito of the genus* Ochlerotatus *(order Diptera) is trapped near the top of this Mexican amber; it measures 0.7 × 1.0 cm. It displays two wings and a segmented abdomen, but the thorax and head are not visible. (b) This fly (order Diptera) in Mexican amber measures less than 0.3 cm long and shows a pair of functional and membranous wings. Photomicrographs by V. L. Villani, in plane-polarized light (a) and cross-polarized light (b).*

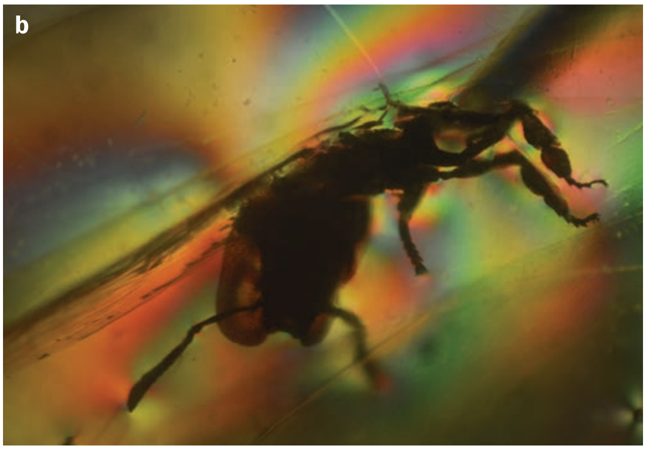




*Figure 10 (a) Shown adjacent to a fracture, this Hymenoptera inclusion (1.6 × 1.0 cm) in Mexican amber displays two pairs of wings and elongated legs. The antennae are geniculate (bent at a sharp angle). (b) This Hymenoptera insect inclusion in Mexican amber measures 1.84 × 1.15 cm. The hind wings are shorter than the forewings, and their membranes are not obscured by dense hair or scales. The morphology of the legs is decisive for the Hymenoptera identification. Photomicrographs by V. L. Villani, in plane-polarized light (a) and cross-polarized light (b).*

*Figure 11: A planthopper of the species* Nogodina chiapaneca *(order: Hemiptera, family:* Nogodinidae*; Solórzano Kraemer and Petrulevicius, 2007) is shown at the bottom of this sample. It measures 11 mm long, and displays a rounded head and a clearly visible thorax with one foreleg. The wings have several veins, but the scales are not preserved. This species is known only from Chiapas amber. Photomicrograph by V. L. Villani.*

*Figure 12: These winged termites and isolated wings (rare in Mexican amber) of the order Isoptera (reclassified as part of Blattodea) were likely trapped at the beginning of the wet season, when termites start to swarm and then shed their wings. The length of the wings is ~1.1 cm. Photo by V. L. Villani.*

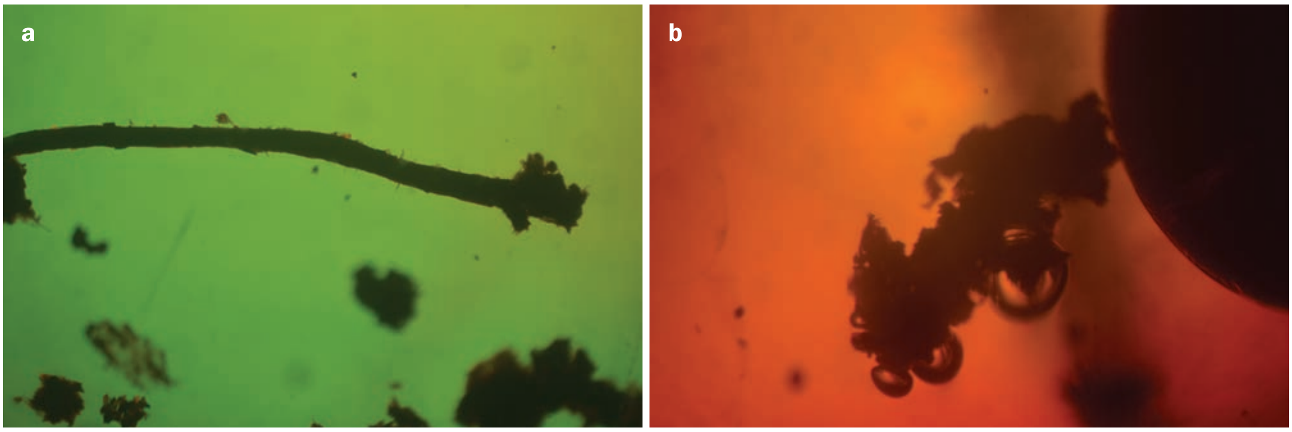


Figure 13: (a) Soil particles and a plant fragment (0.4 cm long) are observed in this Mexican amber sample. (b) Another Mexican amber sample contains a soil fragment and gas bubble inclusions (total dimensions 1.4 cm long and 2.7 cm wide). Photomicrographs by V. L. Villani, in cross-polarized light (a) and plane-polarized light (b).

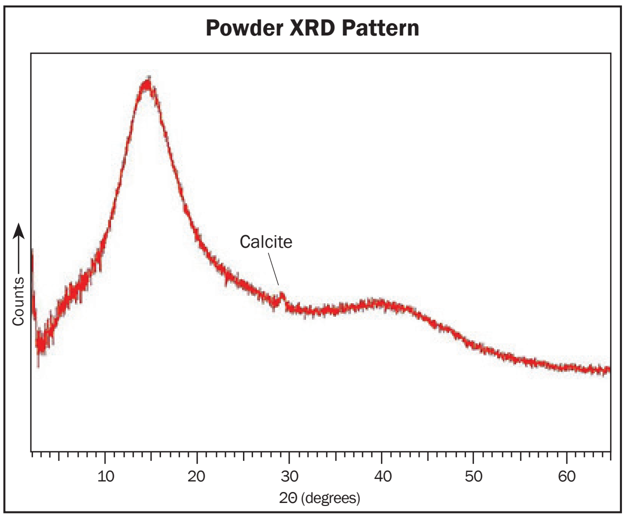
less commonly of the orders Hemiptera (Figure 11), Psocoptera and Isoptera (i.e. termites, which now are classified as part of the Blattodea order). The presence of termite wings in the amber samples is extremely rare (Figure 12; see also Snyder, 1960). At the beginning of the wet season, termites start to swarm and then shed their wings to establish a new colony. The planthopper species *Nogodina chiapaneca* (Figure 11; Solórzano Kraemer, 2007, 2010; Solórzano Kraemer and Petrulevičius, 2007) has been found only in amber samples from Chiapas. It is an extinct species dated to the Middle Miocene, and it lived in a tropical or subtropical climate. The presence of an arthropod of the genus *Ochlerotatus* (Figure 9a; female mosquito) indicates an aquatic environment. Overall, the fossil inclusions observed in Chiapas amber in this study and in the literature are consistent with a sub-tropical forest (Villani, 2016).

### X-ray Powder Diffraction Analysis

The XRD patterns showed the expected amorphous characteristics of amber (i.e. the broad peak at ~15° 2θ), but the software also identified very small amounts of some crystalline phases. In particular, we found the presence of refikite and hartite (both organic minerals), as well as calcite. Calcite was clearly identified only in the amber from Chiapas by a diagnostic peak at 3.03 Å (or 29.8° 2θ; see Figure 14). Refikite and hartite have a composition similar to that of resin but possess a crystalline structure. They have similar XRD patterns and were identified in the ambers from all three localities, according to very small peaks. They both have a main peak at about 5.5 Å (16.1° 2θ), while refikite has a second, more intense peak at 6.09 Å (14.5° 2θ), and hartite has additional peaks at 6.64 (13.3° 2θ) and 5.45 Å (16.25° 2θ).

Refikite ($C_{20}H_{32}O_2$) was originally found as incrustations and acicular crystals in the roots of fossilized spruce trees in a swamp in Kolbermoor (Germany) and in lignite strata near Teramo (Italy); its name derives from the Turkish journalist Refik Bey (Strunz and Contag, 1965; Mottana, 1990). This mineral also was found as thin and acicular crystals in the bark and wood of the remains of pine trees in a peat deposit in western Bohemia, Czech Republic (Pažout et al., 2015). Hartite ($C_{20}H_{34}$) is a diterpene hydrocarbon, originally described by Haidinger (1841). It is a vitre-

Figure 14: This XRD pattern from a Mexican (Chiapas) amber sample shows broad features that are typical of an amorphous material, along with a very small peak diagnostic of calcite.



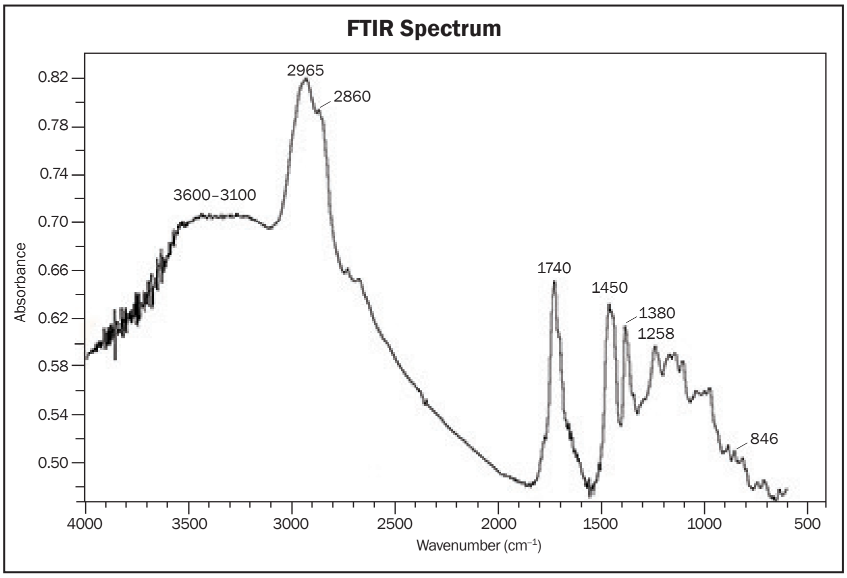



*Figure 15: FTIR spectroscopy of a Mexican (Chiapas) amber shows typical peaks at: 3600–3100 $cm^{-1}$ (broad absorption band due to the O-H stretching vibration); 2965 and 2860 $cm^{-1}$ (C-H stretching); 1740 $cm^{-1}$ (C=O stretching, esters and acid groups); 1450 and 1380 $cm^{-1}$ (C-H aliphatic hydrocarbons); 1260–1030 $cm^{-1}$ (C-O stretching aromatic esters and secondary alcohols); and 846 $cm^{-1}$ (C-C stretching of unsaturated olefins).*

ous white-grey mineral that is found in lignite seams and fractures in fossil coalfields and silicified tree trunks. Because refikite and hartite were scarce and yet ubiquitous in the ambers, these minerals could not be considered as markers of provenance. They are probably associated with the polymerization process of the resins.

### *FTIR Spectroscopy*

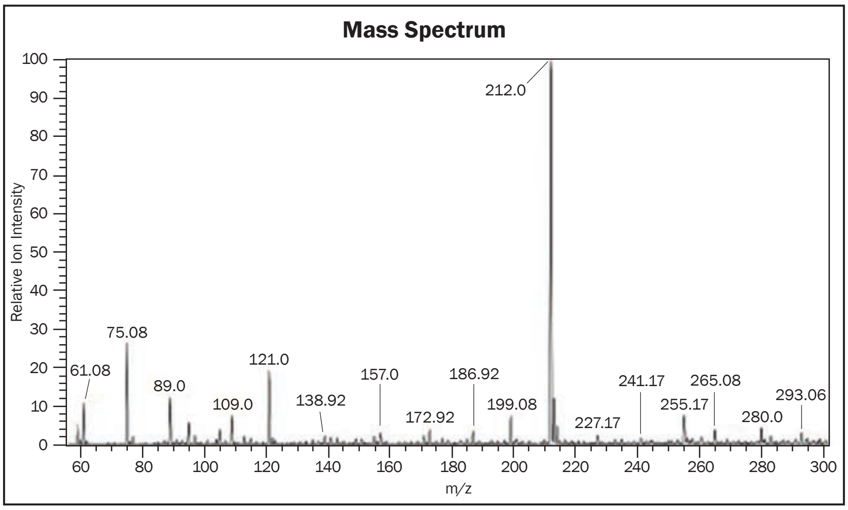
FTIR analysis provided important information about the chemical composition of the samples, which is related to the botanical typology and therefore to the provenance of the ambers. The obtained spectra may vary depending on the portion of the sample that is analysed, because amber has an amorphous structure that is affected by compositional heterogeneity. Three wavenumber ranges that are important for amber characterization are 3700–2000 $cm^{-1}$, 1820–1350 $cm^{-1}$ and 1250–1045 $cm^{-1}$; these regions are associated with hydroxyl and carbonyl groups and to C=C double bonds (Beck et al., 1964; Langenheim and Beck, 1965; Litescu et al., 2012, 2013). Samples from a particular deposit may show variations in the region related to methylene, methyl, etc. ($[CH_2]_n$, $CH_3$, CH, etc.) chains, namely 2962–2850 $cm^{-1}$, and to specific tensile bands of $CH_3$ at 1375 $cm^{-1}$ (Litescu et al., 2012, 2013). All of these features also could be observed in our amber samples, with small variations for each locality. The peak assignments in the following paragraphs are from Beck et al. (1964, 1965), Langenheim and Beck (1965), Cunningham et al. (1983), Litescu et al. (2012, 2013) and Rao et al. (2013).

The FTIR spectra of the Mexican amber (e.g. Figure 15) presented a broad absorption band in the 3600–3100 $cm^{-1}$ region due to the symmetric stretching vibration of O-H bonds associated with carboxylic acid. The peaks at 2965 and 2860 $cm^{-1}$ are linked to the stretching vibration of methyl and methylene groups, respectively, and reveal their cyclic ring structure. The intense peak at 1740 $cm^{-1}$ corresponds to the C=O stretching vibration of esters and acid groups. The two peaks at 1450 and 1380 $cm^{-1}$ are correlated to C-H aliphatic hydrocarbons. The absorption features at 1260–1030 $cm^{-1}$ are due to the C-O stretching of aromatic esters and secondary alcohols. This spectral region is quite different in Baltic amber, in which the area near 1260 $cm^{-1}$ is flat (known as the 'Baltic shoulder'; Beck et al., 1964; Villani, 2016). The weak peak at 846 $cm^{-1}$ is related to C-C stretching of unsaturated olefins.

The IR features of our Baltic samples were very similar to those of other Baltic amber reported in the literature. Absorption in the 3600–3100 $cm^{-1}$ region is due to the symmetric stretching vibration of O-H bonds associated with carboxylic acid. An absorption peak at 1650 $cm^{-1}$ was typical of Baltic amber. The 1260–1180 $cm^{-1}$ region was characterized by the broad horizontal 'Baltic shoulder' followed by a sharp absorption peak at 1159 $cm^{-1}$ (Beck et al., 1964, 1965; Abduriyim et al., 2009; Litescu et al., 2012, 2013) assigned to C-O stretching of –CO-O- (carboxylic single-bond groups, succinate).

The IR features of our Dominican amber samples were very similar to those described in the literature, which resemble those of Mexican amber

Figure 16: The mass spectrum of a Mexican (Chiapas) amber sample displays no peak of the m/z 117 ion related to the presence of succinic acid; we therefore classify the material as a resinite.




from Chiapas. However, a narrow peak at 3095 $cm^{-1}$ (C-H stretching) was not observable in the spectrum of our Mexican amber. Peaks at 2930–2860 $cm^{-1}$ are linked to C-H stretching of $CH_3$ methyl and methylene groups, and a doublet at 1730–1700 $cm^{-1}$ is linked to C=O stretching of carboxylic esters. A sharp peak also was present at 1800 $cm^{-1}$ in the Dominican amber, and a particular absorption morphology was recorded in the 1500–1000 $cm^{-1}$ region—with two isolated peaks at 1030 $cm^{-1}$ (C-O stretching) and 930 $cm^{-1}$ (C-H stretching) that are not present in the spectra of Mexican amber.

The Late Cretaceous ambers from Hti Lin in Myanmar show significant absorptions at 1225 and 1136 $cm^{-1}$ (Tay et al., 2015) that were not visible in the spectra of our samples from Mexico, the Baltic Sea or the Dominican Republic; in addition, the spectra of those Burmese ambers did not show the Baltic shoulder or the OH absorption band (i.e. 3700 $cm^{-1}$). FTIR spectra of Sicilian amber (simetite) show main absorption peaks in the 1300–1100 $cm^{-1}$ region (maximum absorption at 1245 $cm^{-1}$) and a secondary absorption at 1185 $cm^{-1}$ (Beck and Hartnett, 1993).

### *Mass Spectrometry*

Confirmation of succinic acid is obtained from the m/z 117 ion (the negative ion mass peak) corresponding to $(M\text{-}OH)^-$ of succinic acid (Tonidandel et al., 2008, 2009). The mass spectrum of the Mexican amber did not show the m/z 117 ion (Figure 16), so the level of succinic acid in this amber was lower than the limit of quantization (1 ppm by weight), classifying it as a resinite. The Dominican sample showed a spectrum very similar to that of the Mexican amber, indicating the absence of succinic acid, while the m/z 117 ion was clearly identifiable in the spectrum of the Baltic amber sample (indicating the presence of succinic acid).

## Conclusions

FTIR spectroscopy was confirmed as a useful technique to determine the provenance of the amber samples. Our data on Mexican and Dominican ambers and data from the literature on Burmese ones do not show the ‘Baltic shoulder’ in the wavenumber region 1260–1180 $cm^{-1}$. Also, only in the Mexican and Dominican spectra was there a peak at 2860 $cm^{-1}$ that reveals the cyclic structure of these ambers. Although the Mexican and Dominican spectra were quite similar, it was possible to differentiate between them: the Mexican amber spectra lacked the particular absorption morphology between 1500 and 1000 $cm^{-1}$ that is found in Dominican samples, as well as the absorption at 3095 $cm^{-1}$ and the two peaks at 1030 and 930 $cm^{-1}$.

XRD analysis revealed traces of the organic minerals refikite and hartite, and also calcite in the Mexican amber. The calcite probably originated from the amber-bearing strata. Mass spectrometry showed that free succinic acid was absent from the Mexican and Dominican samples, while it was present in the Baltic ones. The Mexican (and Dominican) amber therefore belongs to Class IC (resinites produced from *Hymenaea*) of the chemical classification of amber.

The taxonomical investigation of the inclusions revealed important information. The most common fossil animal inclusions in Mexican amber samples from the Yi Kwan Tsang Collection were arthropods of the orders Diptera and Hymenoptera, followed by the orders Hemiptera, Psocoptera and Isoptera (Blattodea). Most of the insects were eye-visible, while others were easier to identify at higher magnification (40×). Most of them are not indicative of a specific environment, while others (*Ochlerotatus*, female mosquito) are typical of aquatic or humid/warm environments. The identification of specific arthropods such as *Nogodina chiapaneca* confirms that the climate in Mexico during the Middle Miocene was tropical. Furthermore, the presence of isolated termite wings is indicative of a specific period at the beginning of the wet season.

In the investigated samples, botanic inclusions were rarer than animal ones, as commonly described in Mexican ambers (Calvillo-Canadell et al., 2010). The identification of a leaflet and a flower petal of the species *Hymenaea mexicana* clearly indicate a tropical environment. This paleoenvironment is consistent with the general abundance of biotic inclusions in amber from the Chiapas locality.

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# Conferences

## 2017 Dallas Mineral Collecting Symposium

This year's Dallas Mineral Collecting Symposium, held 25–27 August 2017, saw a transformation when the gem-related presentations at this primarily mineral-based conference approached 50% of the programme's content for the first time. The Symposium attracted more than 200 attendees, and a DVD containing the presentations was distributed to more than 5,000 others worldwide.

**Richard Hughes** (Lotus Gemology, Bangkok, Thailand) stressed 'humanistic gemmology' as the interaction of gems and people, as part of his whirlwind tour of the world's ruby sources.

**Federico Bärlocher** (Como, Italy, and Yangon, Myanmar) presented a video tour of some Burmese ruby mines. The video covered the 2,000-year history of ruby production in Mogok, where half-a-million people are involved with the gem industry. The video concluded with a 20 ct Mogok ruby that brought US$30 million at auction.

**Dr George Rossman** (California Institute of Technology, Pasadena, California, USA) discussed the science of colour in gems, including the absorption and reflection of light due to metal ions, as well as radiation effects. In addition, he showed how the colour of rose quartz is due to a fibrous mat of micro-inclusions. According to Dr Rossman, of the 5,300 known minerals, cause of colour has been studied in only 400.

**Dr Emanuele Marini** (Nimeral Min-Lab, Milan, Italy) provided his perspectives on the repair and restoration of mineral specimens in order to return the natural form to an otherwise damaged piece. Both the appearance and durability of a specimen can be altered. Although the gem world has dealt with treatments for a long time, now the restoration of mineral specimens is raising age-old questions. How should these treatments of minerals be disclosed? How can secondary buyers be made aware of such treatments?

**Christoph Keilmann** (The Munich Show, Munich, Germany) shared the history of The Munich Show, a family-owned gem, mineral and jewellery exhibition that has grown over the past 54 years. At its beginning in 1963, it had only 20 exhibitors. It now hosts 1,300 dealers and attracts more than 40,000 visitors.

**John Cornish** (John Cornish Minerals, Port Angeles, Washington, USA) took attendees on an in-depth journey into Australia's Adelaide mine, noted for its production of crocoite crystals. Cornish described the mining techniques, using chisels and handsaws, required to extract the fragile mineral specimens.

**Dr Peter Lyckberg** (European Commission, Brussels, Belgium) described the challenges of mining at elevations of over 14,000 feet (4,267 m) in the Shigar Valley of Pakistan, where more than 100,000 miners have been involved with exploiting granitic pegmatites for aquamarine, apatite and other minerals.

**Bruce Bridges** (Bridges Tsavorite, Nairobi, Kenya) presented a video celebrating the 50th anniversary of his father's discovery of tsavorite, and shared his views on the colour range, quality and value of this green garnet coloured by vanadium (primarily) and chromium. The East African tsavorite deposits formed approximately 550–600 million years ago.

**Dr Robert Hazen** (Geophysical Laboratory, Carnegie Institution, Washington DC, USA) discussed how mineralogists now look at mineral evolution alongside human development, as well as the predictability of new mineral deposits. Mineral network analysis follows much the same patterns as social networks and can be used to see how relationships in the mineral world behave similar to human social interactions.

*Eric Fritz FGA DGA*
*Gem-A, Tucson, Arizona*

## World of Gems Conference V

The 5th World of Gems Conference was held in Rosemont, Illinois, USA, on 23–24 September 2017. Approximately 150 people from a total of six countries were in attendance. The conference was opened by Richard Drucker (Gemworld International, Glenview, Illinois), who also was the moderator and one of the 11 speakers at the event (Figure 1).

**Dr Emmanuel Fritsch** (Institut des Matériaux Jean Rouxel, University of Nantes, France) reviewed the identification of natural vs. synthetic and HPHT-treated diamonds using short-wave UV phosphorescence, anomalous double refraction, luminescence imaging (e.g. using the DiamondView to see growth patterns) and photoluminescence spectroscopy. He predicted that synthetic diamonds will become more and more perfect in the future, but their growth patterns should still make them recognizable.

**Jon Phillips** (Corona Jewellery Co., Toronto, Ontario, Canada) provided an overview of the diamond industry, covering production, marketing and pricing. He mentioned that by the end of 2017 the Diamond Producers Association will have spent US$60

*Figure 1: The speakers at the 5th World of Gems Conference included (from left to right): Dr Emmanuel Fritsch, Nicholas Sturman, Alan Bronstein, Jon Phillips, Dr J. C. (Hanco) Zwaan, Richard Drucker, Al Gilbertson, Dr Çiğdem Lule, Stuart Robertson, Kerry Gregory and Roland Schlussel. Photo by B. M. Laurs.*

million on the generic marketing of diamonds. In addition, De Beers will spend $140 million on marketing in 2018 (the largest amount since 2008), which will be geared toward millennials and female self-purchasers.

**Nicholas Sturman** (Gemological Institute of America [GIA], Bangkok, Thailand) examined pearls, their molluscs and global sources (both saltwater and freshwater), and their treatments. Pearls may be both worked and polished, for mounting purposes or to enhance their shape and/or lustre. Other pearl treatments that continue to be seen are dyeing, irradiation, bleaching, filling and coating.

**Roland Schlussel** (Pillar & Stone International, Tiburon, California, USA) detailed the classification and quality factors of Burmese jadeite. The numerous varieties are defined by a combination of texture and transparency, colour and colour pattern, and mineral composition. Microscopic studies show that jadeite with the highest transparency contains small and uniformly shaped grains that show a preferred crystallographic orientation and have indistinct grain boundaries.

**Stuart Robertson** (Gemworld International) and **Dr Çiğdem Lule** (Kybele LLC, Buffalo Grove, Illinois, USA) reviewed gem treatments and then discussed the pricing of treated gems. In most cases, the price of an untreated stone serves as a benchmark, and its treated equivalent trades at a discount (e.g. diamond). Or, for gems that are nearly always treated (e.g. clarity-enhanced emeralds), the untreated stone will trade at a premium.

**Kerry Gregory** (Gemmology Rocks, UK) described how she quickly and efficiently separates the more valuable pieces among large quantities of gemstones recovered from scrapped jewellery. She first sorts them according to their colour category (red, green or blue) and then uses a polariscope, refractometer and sometimes a spectroscope (for red stones) to select those that are likely worth reselling.

**Dr J. C. (Hanco) Zwaan** (Netherlands Gemmological Laboratory, Naturalis, Leiden) started the second day of the conference with a detailed look at the geological origin of Sri Lankan sapphires. By studying known primary deposits, he inferred that sapphires in the economically important secondary deposits originally formed via a multistage process involving (ultra)high temperature metamorphism to 'prime' the host rocks by removing Si through partial melting, followed by tectonic activity along contacts between different rock types to create space for crystallization, and finally fluid/pegmatitic melt transfer to enable the formation of larger crystals though metasomatic processes.

**Dr Çiğdem Lule** examined the challenges of identifying black gems, including their lack of transparency, RI values that are commonly over-the-limit of a standard refractometer, and issues pertaining to nomenclature and disclosure. Properly identifying black diamonds can be particularly challenging because in addition to separating them from imitations, they should be assessed for treatments. Equipped with an understanding of the various black gem materials and their structures, microscopy can be helpful for concluding whether a black sample is diamond or not, which is often a sufficient determination for these low-value materials.

**Al Gilbertson** (GIA, Carlsbad, California) discussed the challenges of developing a fancy-cut grading system for diamond. Due to the abundance of measurement variables that may lead to an overwhelming number of parameters in comparison to round brilliants, it is necessary to simplify the process by limiting the fancy-cut grading system to the evaluation of carefully selected criteria.

**Alan Bronstein** (Aurora Gems, New York, New York, USA) shared his knowledge of the fancy-coloured diamond market. Although he estimated that 95% of fancy-coloured diamonds are cut as radiants to maximize their face-up colour, he indicated that there is no perfect all-around shape for these diamonds, and the goal of cutting should be to balance a stone's intrinsic colour and with its brilliance.

**Richard Drucker** covered gem pricing challenges. He noted that while useful, price lists do have their shortcomings: data are less reliable for higher-end stones and for gem varieties that are not heavily traded, since less information is available on them for comparison. Also, for jewellers and appraisers in particular, he mentioned that there is no uniform way to determine retail pricing since mark-ups vary in different markets.

The formal presentations were followed by an open discussion session in which conference attendees brought up a variety of subjects related to those covered by the speakers, as well as other topics.

A poster session was included for the first time at the World of Gems Conference. The seven posters covered topics that included the jet group; the effects of chromium in ruby, emerald and alexandrite; fluorescence in diamond; assessing and valuing coloured gemstones; and more.

A conference proceedings volume was distributed in print to all attendees and as a free PDF file to industry members. To obtain the PDF or purchase a print version, visit https://gemguide.com/events/world-of-gems-conference.

*Brendan M. Laurs FGA*

## Gem-A Conference

The annual Gem-A Conference took place 4–5 November 2017 at the etc.venues County Hall in London and was attended by approximately 220 people from 20 countries.

The event was introduced by Gem-A's CEO **Alan Hart**. Then **Adonis Pouroulis** (Petra Diamonds, Johannesburg, South Africa) provided an informative review of global diamond production, with a focus on Petra's five mines: Finsch, Cullinan, Koffiefontein and the Kimberley Ekapa Mining Joint Venture in South Africa, and Williamson in Tanzania. He stated that the new processing plant at the Cullinan mine is designed for the recovery of large diamonds and is the world's most technologically advanced facility of its kind.

**John Benjamin** (John C. Benjamin Ltd., Aylesbury, Buckinghamshire) provided an entertaining review of jewellery design during the Georgian period, a 135-year span that mostly covered the 18th century. Mourning jewellery was popular during this time and commonly contained a lock of hair of the deceased; the designs were initially rather revolting and shifted toward more attractive sentimental motifs by the 1800s. In the mid-18th century diamond jewellery became popular as a means of demonstrating one's social mobility, while designs featuring paste glass were sought by those who couldn't afford diamonds.

**Klemens Link** (Gübelin Gem Lab, Lucerne, Switzerland) gave a two-part presentation. First he discussed new technologies for the radiometric age dating of sapphires (using the U-Pb technique on zircon inclusions) and emeralds (using the Rb-Sr method to date the beryl itself). Then he described the 'Provenance Proof' system of marking rough or cut gems (mainly emeralds) using artificial DNA encased within tiny silicon beads (100 nm in diameter) that are introduced into microfractures within a stone. The technique allows information to be permanently implanted into a stone such as its country and/or mine of origin, when it was mined, cutter/manufacturer, etc.

**Evan Caplan** (Evan Caplan, Los Angeles, California, USA) reviewed the localities and quality factors for alexandrite. Brazil, Russia, Sri Lanka, India, Tanzania and Madagascar are the main sources, and stones should be evaluated according to the extent of their colour change, then their clarity and finally their cut. Caplan noted that gemmological laboratories may provide inconsistent colour descriptions, making it difficult to sell such stones.

**Reena Ahluwalia** (Reena Ahluwalia, Toronto, Ontario, Canada) explained how she tells stories through the jewellery she creates. Some examples included a jewel featuring diamonds from the Bunder mine in Madhya Pradesh (India), a canoe-shaped necklace showcasing Canadian diamonds, a diamond-set mace for the government of Ontario and a tiara featuring Royal Asscher-cut diamonds for Kate Middleton. Ahluwalia also described her large-format paintings of cut diamonds, which convey themes such as dreams, temptation, luminosity, perfection and eternity.

At the end of the first day of the conference, **Alan Hart** announced that **Andrew Cody** (Cody Opal, Melbourne, Victoria, Australia) had been awarded an Honorary Fellowship for his outstanding contributions to the industry.

**Patrick Dreher** (Dreher Carvings, Idar-Oberstein, Germany; Figure 2) started the second day of the conference by recounting his family's long history of carving gems, and then he outlined the steps involved in creating realistic renditions of animals in a variety of materials such as agate, quartz (rock crystal, citrine, smoky and 'strawberry'), tourmaline, beryl (aquamarine and heliodor) and obsidian. Dreher reported that carving a multi-coloured opaque stone such as agate is particularly challenging because it is not possible to see the contours of the colour layers inside the piece, and they must be precisely integrated into the particular form of the animal being carved.

**Dr John Rakovan** (Miami University, Oxford, Ohio, USA) reviewed factors that control the morphology and the flat faces exhibited by crystals, such as temperature, pressure, fluid and chemical composition, growth rate, and the presence and types of defects (e.g. dislocations). Conditions favouring morphological and internal perfection (such as exhibited by attractive mineral specimens and gem crystals) include unrestricted crystal growth, a slow growth rate and a homogenous stable environment.

*Figure 2: Patrick Dreher discusses his innovative gem carving techniques at the Gem-A Conference. Photo by B. M. Laurs.*

**Bernhard Berger** (Cartier Tradition, Geneva, Switzerland) described the Cartier Collection of historic pieces of jewellery, timepieces and *objets d'art* that are intended to educate and share Cartier's history with the public and their staff. He also recounted the history of the Cartier family saga and its employees and designers, and described several famous pieces and clients. He showed various examples that illustrated different styles (e.g. Garland, Art Deco and Tutti Frutti, as well as the Panther Collection), and also Mystery Clocks that are cleverly designed with hour and minute hands mounted onto rock crystal discs so they appear to float freely.

**Dr Ulrika D'Haenens-Johansson** (GIA, New York, New York) tracked the evolution of synthetic diamonds and their identification. Photoluminescence spectroscopy in combination with other techniques provides a reliable means of identifying these synthetics. Visual clues for identifying HPHT-grown synthetic diamonds include the presence of metallic rod-shaped inclusions, the lack of a discernible strain pattern visible with crossed polarizers and a cuboctahedral pattern that typically displays blue or green fluorescence with strong greenish blue phosphorescence when examined with the DiamondView. CVD-grown synthetics may contain small black inclusions/pinpoints (although are typically of high clarity), strain patterns visible with crossed polarizers, and orange, pink or red fluorescence (as-grown) or green to green-blue fluorescence with greenish blue phosphorescence (HPHT processed) along with striations, layers and/or violet-blue dislocation bundles when examined with the DiamondView.

**Vladyslav and Samanta Yavorskyy** (Yavorskyy, Hong Kong) showed photos (mostly from Vladyslav's various books) and videos depicting their travels in search of coloured stones in Central Asia, Sri Lanka, Myanmar, Tanzania and Madagascar. They promoted the importance of bringing back the glory and romance of natural untreated coloured stones.

At the end of the conference, Gem-A president **Maggie Campbell Pedersen** provided an insightful recap of the widely varying presentations that were delivered during the two days.

On 6 November, three workshops were held at Gem-A's headquarters: coloured stone grading and pricing (hosted by **Richard Drucker**, Gemworld International Inc., Glenview, Illinois, USA), jadeite testing and grading (hosted by **Dominic Mok**, Asian Gemmological Institute and Laboratory Ltd., Hong Kong) and separating black stones (hosted by **Sarah Steele**, Ebor Jetworks Ltd., Whitby, North Yorkshire). That evening marked Gem-A's graduation ceremony and presentation of awards at Central Hall Westminster in London.

On 7 November, two separate field trips took attendees for private viewings of the British Crown Jewels and of the Natural History Museum's gem and mineral collection.

*Brendan M. Laurs FGA*

## World Ruby Forum

The World Ruby Forum 2017 was attended by about 200 people and took place 4 November in Bangkok, Thailand, one day prior to and in conjunction with the annual World Jewellery Confederation (CIBJO) Congress. It was organized by the Gem and Jewelry Institute of Thailand (GIT) in collaboration with the Department of International Trade Promotion, Ministry of Commerce (DITP); the Asian Institute of Gemological Sciences (AIGS); and the Association Française de Gemmologie (AFG). The purpose of this forum was to promote, support, raise awareness and improve understanding of ruby, as well as to create global recognition of the value and beauty of ruby. The stone is considered a major strength of the Thai gem industry.

Following introductions by **Duangkamol Jiambutr** (director of GIT) and **Henry Ho** (chairman emeritus of AIGS; Figure 3), the forum was officially opened by **Apiradi Tantraporn** (Minister of Commerce).

The first speaker, **Didier Giard** (AFG, Lyon, France), stressed the importance of rubies and the psychological significance and symbolism of the colour red, creating an ultimate 'alchemy' between ruby and red. The different colour variations of ruby can be connected with people's personality and behaviour, as well as symbolize attractiveness, beauty, value, activity, fire and love, but also the sins of the flesh, death and hell, indicating a duality that is always present and reflected in how red is used in different cultures and religions. Giard also promoted the establishment of an annual international day for the sustainable management of gem mines, and advocated the protection of cities such as Mogok (Myanmar) by applying for UNESCO heritage status.

**Sean Gilbertson** (Gemfields, London) elaborated on the mining of rubies by Gemfields in the Montepuez area of Mozambique during the past six years, beginning with bulk sampling and the construction of an initial washing plant in 2012, and then the first auction of rubies in 2014, followed by the installation of a new washing plant in 2016 and the construction of a new sort house to be completed in December 2017. The largest portion of high-value rubies comes from the Mugloto secondary deposits (currently nine pits). The prices of the rough ruby vary widely from US\$0.02 to \$500,000 per gram (average of US\$29.55 per carat). Approximately 1,100 people are employed in processing 375,000 tonnes per month, equivalent to 514 tonnes per hour on a 24/7 basis, recovering 8.5 million carats per year. Apart from mining, Gemfields has built schools and introduced a mobile clinic that sees 4,500 patients each month. They also support efforts to prevent rhinoceros poaching.

**Nay Win Tun** (Ruby Dragon Group of Companies, Yangon, Myanmar) described Ruby Dragon's mines in Mogok and Mong Hsu. In Mogok, the group works four mines, including open pit (secondary) and underground (primary) deposits. One of the latter includes a 400 m shaft with a slope of 60°, and tunnels up to 3 m wide and high to allow the extraction of ore by trucks. Both primary and secondary deposits are mined in Mong Hsu, with one underground operation going 200 m deep with a shaft inclined at 35°. Only Myanmar citizens are allowed to extract rubies from the ground, but after the political change in 2011 there are fewer restrictions on stone trading. Continuous efforts are underway to create a more transparent, ethical and socially responsible business and attract more foreign investors.

**Dr Cedric Simonet** (Kenya Chamber of Mines, Nairobi, Kenya) gave an overview of African ruby deposits and their geological origin as they relate to the Pan-African Mozambique Belt (metamorphic rocks) and the Cenozoic rifts and associated volcanism (alkali basalts). In addition to the known deposits—such as the John Saul mine (Tanzania), the Baringo deposit (Kenya), the Longido mine (Tanzania) and the occurrences near Montepuez (Mozambique)—the Alale deposit in West Pokot, Kenya, is a new marble-hosted ruby occurrence that shows good quality and potential for the future. As in Longido and Lossogonoi, ruby is found in a 50-cm-thick zoisite-bearing amphibolite, which is hosted by a serpentinite body. However, the Alale rubies are much more transparent and of better quality than those in Longido. With regard to the Montepuez ruby deposits, an expansion of mining activities in this region may be accomplished via large-scale operations by mining companies or through well-organized artisanal mining within a formal structure. Active exploration also is needed; based on available geological data, there is great potential for the discovery of new deposits. Primary deposits are targets on their own, but these also should be considered as pathfinders for secondary deposits.


*Figure 3: Henry Ho, chairman emeritus of AIGS, welcomes participants to the 2017 World Ruby Forum in Bangkok.*

**Vincent Pardieu** (VP Consulting, Manama, Bahrain) presented an historical overview of ruby sources, including those in Mogok and Thailand (dominant during 1962–1992); Winza, Tanzania (since 2007); and Mozambique (since 2009). He also covered Longido, Tanzania; Chimwadzulu Hill, Malawi; discoveries in Madagascar, such as in Didy (2012); and Greenland. Many of the new discoveries are related to amphibole-bearing rocks, and the rubies from these might have similar (amphibole) inclusions. However, they can be separated by trace-element chemistry, using a binary V:Fe diagram, with Greenland rubies having more V than African stones.

**Gaetano Cavalieri** (CIBJO, Milan, Italy) explained that the needed corporate social responsibility (CSR) system for coloured stones has been delayed because production in the ruby industry is largely derived from artisanal and small-scale miners. Gemfields and Greenland Ruby A/S are the only two larger ruby mining companies in this sector. A viable CSR strategy needs to be defensive, socially active and inclusive, showing responsibility towards employees, customers, stakeholders (especially people who live close to a mine) and society at large. The need to take the initiative is urgent, and full transparency is required.

**Dr Visut Pisutha-Arnond** (GIT) stressed the importance of Thailand in the gem and jewellery industry. In Thailand the industry employs 700,000 workers, and the export of coloured stones generates US$1.07 billion. In total the export revenues of gems and jewellery are $6.97 billion. Thailand offers VAT exemption for importing rough material, will organize rough stone auctions, and has the ambition to make Chanthaburi the most important gemstone hub (‘gem metropolis’) by 2021. From a geological perspective, Thai rubies can be considered very rare, being related to pyroxenite xenoliths present in the Trat basalt, indicating a deep-mantle origin.

**Richard Hughes** (Lotus Gemology, Bangkok) elaborated on the psychology of colour and the history of red as ‘the first colour’. Red is the symbol of love, romance, luck; red is sexy; red is power; it stands out and runs deep in most cultures (e.g. red dragons, wedding dresses and envelopes in China; red ‘third eye’ and hand tattoos in India). Ruby is the ‘gem of the sun’, so it should be set in the centre of a piece of jewellery. Hughes stated that since many rubies formed during the Pan-African event 550–700 million years ago, holding a ruby is like holding eternity in the palm of your hand.

**Alessio Boschi** (Alessio Boschi, Bangkok) worked 27 years with masters in the jewellery design and branding field all over the world. He showed some of his very detailed and delicate work, which represents a ‘precious journey’—a story behind the inspiration of all his designs. He uses particular cuts and delicate gems such as tanzanite and opal. He employs platinum, titanium and palladium casting, as well as microsettings, which are considered to be a specialty of Asia. ‘Shading’ of colours is often employed in this type of work, and he showed examples of how he has used ruby and rubellite in this respect.

The Forum concluded with two panel sessions: (1) ruby trade and commerce, with panellists **Santpal Sinchawla** (Sant Enterprises, Bangkok), **Andrew Cody** (Cody Opal, Melbourne, Australia), **Paolo Valentini** (Italian Gem Association) and **Barbara Wheat** (AIGS, Bangkok), and (2) the laboratory perspective on ruby with regard to reporting and standards used, with panellists **Dr Pornsawat Wathanakul** (gemstone specialist retired from GIT), **Boontawee Sripasert** (GIT), **Dr Tajin Lu** (National Gemstone Testing Center, Beijing, China), **Hpone-Phyo Kan-Nyunt** (Gübelin Gem Lab, Hong Kong), **Kennedy Ho** (AIGS) and **this author**.

*Dr J. C. (Hanco) Zwaan FGA*
*Netherlands Gemmological Laboratory*
*Naturalis Biodiversity Center*
*Leiden, The Netherlands*

# Gem-A Notices

## GIFTS TO THE ASSOCIATION

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

**Ahmed Fadoul**, Khartoum, Sudan, for a small quantity of corundum from Western Sudan, an opal from Eastern Sudan and a quartz crystal.

**Eric M. Shelton**, Albuquerque, New Mexico, USA, for a dyed natural sapphire with a GIA report.

**Roger Trigg FGA**, Constantia, Cape Town, South Africa, for brilliant-cut samples of andalusite, chrysoberyl, hiddenite, scapolite and vesuvianite, and a cabochon of Gilson synthetic turquoise, plus two cases of minerals and gemstones.

## GEM-A CONFERENCE

The 2017 Gem-A Conference was held at etc.venues County Hall, London, on 4 and 5 November. A full report of the Conference and events was published in the Winter 2017 issue of *Gems&Jewellery*. Highlights of the presentations are given in the Conferences section of this issue of *The Journal*, pages 768–769.

Workshops were held on 6 November at the Gem-A headquarters. Richard Drucker (president, Gemworld International Inc., Glenview, Illinois, USA), presented a workshop on 'Coloured Stone Grading and Pricing', introducing new concepts in colour grading. Dominic Mok (founder and principal of AGIL, Hong Kong) presented a workshop titled 'Contemporary Jadeite Testing and Grading', providing theoretical and practical experience in jadeite testing. Sarah Steele (owner of Ebor Jetworks Ltd., Whitby, North Yorkshire) gave a workshop on 'Separating Black Stones', which covered a wide range of materials, both rough and in jewellery.

A visit was arranged on 7 November to the Mineral Gallery at the Natural History Museum for a guided tour by Mike Rumsey, senior curator in charge, followed by coffee hosted by Lyon & Turnbull at The Club at Ten Trinity Square where participants had the chance to view highlights from their November jewellery auction. A tour also was arranged to the Tower of London for a private viewing of the Crown Jewels.

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## GRADUATION CEREMONY

The Graduation was held on 6 November in the Lecture Hall at the magnificent Central Hall Westminster. The ceremony was attended by 122 graduates from Canada, China, French Guiana, Hong Kong, India, Japan, Madagascar, Taiwan and the USA, as well as various European countries.

The ceremony was opened by Alan Hart, CEO of Gem-A. The address was given by Richard Drucker (president, Gemworld International Inc., Glenview, Illinois, USA), who spoke about following one's passion and how fortunate we are to be in a business that attracts so many interesting people. Networking with these people can bring new opportunities and lifelong friendships. He also provided some inspiring quotes from advertisements he'd seen in airline jetways during his travels, and related them to the graduates' present situation of embarking on their exciting careers.

The ceremony was followed by a reception in the Library.


*Richard Drucker finishes his address to the graduates. Seated next to him are Maggie Campbell Pedersen (Gem-A President), Justine Carmody (Gem-A chair of the Board) and Alan Hart (Gem-A CEO).*

## GEM-A AWARDS

In the Gem-A examinations held in January and June 2017, 501 students qualified in the Gemmology Diploma examination, including 28 with Distinction and 63 with Merit, and 587 qualified in the Foundation Certificate in Gemmology examination. In the Diamond Diploma examination 118 qualified, including 27 with Distinction and 21 with Merit.

In the **Gemmology Diploma** examination, the **Christie's Prize for Gemmology** for the best candidate of the year was awarded to **Jiaqi Yu** of Beijing, China. The **Read Practical Prize** for excellence in the practical examination also was awarded to **Jiaqi Yu** as well as to **Mak Shuk Kwan** of Cheung Sha Wan, Hong Kong. The **Anderson Bank Prize** for the best set of theory papers was awarded to **Ungkhana Atikarnsakul** of Bangkok, Thailand.

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 **Zoe Elizabeth Lewis** of Sheffield, South Yorkshire, and to **Gaëlle Daru** of Antananarivo, Madagascar.

In the **Diamond Diploma** examination, the **Bruton Medal** for the best set of answers which, in the opinion of the examiners, were of sufficiently high standard, was awarded to **Marianne Pughe** of Hexham, Northumberland.

The **Deeks Diamond Prize** for the best set of theory answer papers of the year was awarded to **Anne Galmiche** of London.

The **Mok Diamond Practical Prize** for excellence in the Diamond Practical examination, sponsored by Dominic Mok of AGIL, Hong Kong, was awarded to **Lucy Bedeman** of London.

The **Tully Medal** was not awarded.

The names of the successful candidates are listed below.

## Examinations in Gemmology

### *Gemmology Diploma*

#### Qualified with Distinction

Atikarnsakul, Ungkhana, *Tungkru, Bangkok, Thailand*
Chen Shenrui, *Beijing, China*
Chen Yu, *Beijing, China*
Dong Kaihua, *Beijing, China*
Gong Linhui, *Changsha City, Hunan, China*
Guo Chulan, *Foshan, Guangdong, China*
Guo Hongshu, *Beijing, China*
Huang Haodong, *Beijing, China*
Jing Ruolin, *Beijing, China*
Li Jia Yuan, *Shanghai, China*
Li Wei, *Beijing, China*
Liao Siqin, *Beijing, China*
Liu Wenqing, *Beijing, China*
Lu Yuhan, *Kunshan City, Jiangsu, China*
Ma Chengyao, *Beijing, China*
Rogerson, Hannah, *Sevenoaks, Kent*
Rossi, Roberta, *Genoa, Italy*
Suzuki, Hiroki, *Tokorozawa-shi, Saitama, Japan*
Tanaka, Junko, *Tokyo, Japan*
Tsang, Rebecca, *San Marcos, California, USA*
Wang Xiaofang, *Beijing, China*
Wang Yu, *Beijing, China*
Wongrawang, Patcharee, *Bangrak, Bangkok, Thailand*
Wu Niuniu, *Beijing, China*
Xu Benyan, *Beijing, China*
Xu Hanyue, *Beijing, China*
Yu Jiaqi, *Beijing, China*
Zhao Chunyi, *Beijing, China*

#### Qualified with Merit

Bie Zhi Tao, *Shanghai, China*
Bigot, Violaine, *Versailles, France*
Chang Chia-Jui, *Taipei, Taiwan*
Chau Chui Ping, *Tin Shui Wai, Hong Kong*
Chau Pongki, *Beijing, China*
Chen Huimin, *Beijing, China*
Chen Yang, *Shanghai, China*
Chow Tinyi, *Prince Edward, Hong Kong*
Cui Jingjing, *Guangzhou, Guangdong, China*
Daru, Gaëlle, *Antananarivo, Madagascar*
Du Chen, *Shanghai, China*
Fukuchi, Yukiko, *Tokyo, Japan*
Grant, Henrietta, *London*
Huang Xiaotong, *Beijing, China*
Hung Chun Man, *Yau Ma Tei, Hong Kong*
Ju Dan, *Beijing, China*
Kang Jin, *Beijing, China*
Kawasaki, Kimie, *Tokyo, Japan*
Li Hiu Ying, *Chai Wan, Hong Kong*
Li Qiang, *Zhuhai City, Guangzhou, China*
Li Ruonan, *Shijiazhuang City, Hebei, China*
Li Xin, *Beijing, China*
Li Xinmei, *Beijing, China*
Li Yihang, *Beijing, China*
Liu Ruoyang, *Beijing, China*
Long Zhaoyang, *Beijing, China*
Lou Xiaomeng, *Beijing, China*
Lv Yingchen, *Beijing, China*
Maimenjiang Yilalai, *Beijing, China*
Masini, Chiara, *Florence, Tuscany, Italy*
Miao Ling, *Beijing, China*
Möller, Katharina, *Toronto, Ontario, Canada*
Peng Huizhong, *Beijing, China*
Sun Ziyin, *San Diego, California, USA*
Tian Yuan, *Wuhan City, Hubei, China*
Tjong Lee Ping, *Tsing Yi, Hong Kong*
Tong Hoi Yum, Louise, *Sham Shui Po, Hong Kong*
Tung Chun-Hsiao, *Douliu City, Yunlin County, Taiwan*
Von Baeyer, Anne, *London*
Wang Chenchen, *Beijing, China*
Wang Junlan, *Beijing, China*
Wang Xueding, *Beijing, China*
Wang Yuanyuan, *Beijing, China*
Wang Zihe, *Beijing, China*
Wei Zhongshu, *Shenyang City, Liaoning, China*
West, Beth, *Reading, Berkshire*
Xia Yuncong, *Wanchai, Hong Kong*
Xin Di, *Beijing, China*
Xu Chengcheng, *Beijing, China*
Xu Mudan, *Beijing, China*
Yan Hui Zhen, *Beijing, China*
Yang He, *Urumqi City, Xinjiang, China*
Yang Ruilan, *Beijing, China*
Yang Xihan, *Changde City, Hunan, China*
Yang Ming, *Beijing, China*
Yin Jiayi, *Beijing, China*
Yu Li, *Hamburg, Germany*
Zhang Biyao, *Beijing, China*
Zhang Shu, *Beijing, China*
Zhang Xiaomin, *Beijing, China*
Zhao Buqing, *Beijing, China*
Zheng Lili, *Beijing, China*
Zheng Yuyu, *Beijing, China*

#### Qualified

Agrawal, Rohan, *Bardonia, New York, USA*
Angus, Emily, *Petworth, West Sussex*
Baggott, Sophie Louise, *Plymouth, Devon*
Bai Liping, *Beijing, China*
Bai Yanning, *Beijing, China*
Bakshi, Anisha, *Birmingham, West Midlands*
Baume, Emilie, *Aigrefeuille-d'Aunis, France*
Benfield, Emma, *Winchester, Hampshire*
Bi Hanwen, *Shenzhen City, Guangdong, China*
Bockenmeyer, Ingrid, *Bangkok, Thailand*
Bupparenoo, Pimtida, *Bangkok, Thailand*
Cao Ying, *Bejing, China*
Chan Han-Wen, *Tainan, Taiwan*
Chan Yuen Ling Agnes, *Sheung Wan, Hong Kong*
Chang Tien-Chin, *Taipei City, Taiwan*
Chao Yi-Hsuan, *Taipei, Taiwan*
Chauvin, Alice, *Ventabren, France*
Che Zhengsheng, *Shaoxing, Zhejiang, China*

Chen Chi-Jer, *New Taipei City, Taiwan*
Chen Chi-Kuang, *New Taipei City, Taiwan*
Chen Hongyu, *Chongqing, China*
Chen Hsiao-Han, *New Taipei City, Taiwan*
Chen Hsuan-Wen, *Pingtung, Taiwan*
Chen Jianhua, *Chongqing, China*
Chen Jie, *Shanghai, China*
Chen Lian, *Guilin, Guangxi, China*
Chen Lu, *Danyang, Jiangsu, China*
Chen Suokai, *Shanghai, China*
Chen Wei Ci, *Shanghai, China*
Chen Wenwei, *Beijing, China*
Chen Xiaoxi, *Brockley, London*
Chen Xiaoyi, *Beijing, China*
Chen Yanqiu, *Beijing, China*
Chen Yuhan, *Guilin, Guangxi, China*
Cheng Wen Hsin, *Kaohsiung City, Taiwan*
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Cheung Shuk Ting, *Tsing Yi, Hong Kong*
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Yang Tsun-Wen, *Kaohsiung, Taiwan*
Yang Zhuo, *Beijing, China*
Yanping, Lan, *Colombo, Sri Lanka*
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Yin Wenqing, *Bangkok, Thailand*
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Zhang Hong, *Guangzhou, Guangdong, China*
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Zhang Shuo, *Tokyo, Japan*
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Zheng Zehui, *Kaifeng, Henan, China*
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Zhou Chen Yuan, *Hangzhou, Zhejiang, China*
Zhou Jie, *Hangzhou, Zhejiang, China*
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Zhuang Shao Bai, *Shanghai, China*
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## Diamond Diploma Examination

### Qualified with Distinction

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Garcia-Carballido, Carmen, *Tarves, Aberdeenshire, Scotland*
Guy, Angharad, *London*
Harding, Kealey, *Trinity, Jersey*
Haylett-Mustafa, Gaynor, *St Neots, Cambridgeshire*
Hug, Samuel Richard John, *Rochester, Kent*
Ibison, Hannah, *Garstang, Lancashire*
Katayama (Flores), Jurin, *St Andrews, Fife, Scotland*
Koroma, Barickeh Charles Kholifa, *Romford, London*
Li Renjing, *Beijing, China*
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Longhurst, Stephanie, *Blandford Forum, Dorset*
Patel, Hemma, *London*
Pregun, David, *Birmingham, West Midlands*
Pughe, Marianne, *Hexham, Northumberland*
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Wicker, Joanne, *Ashford, Kent*
Williams, Rick, *Henley on Thames, Oxfordshire*
Winnicott, Elizabeth, *Birmingham, West Midlands*
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### Qualified with Merit

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Chen, Victoria, *London*
Chow Pui Yi, *Lai Chi Kok, Hong Kong*
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Horner, Oliver, *Bounds Green, London*
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Kouya, Yuriko, *Tokyo, Japan*
Krontira, Sophia, *Lamia, Greece*
Lui Wing-Tak, *New Taipei City, Taiwan*
Pettersson, Rachel, *Norrtelje, Sweden*
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Wong Tik, *Kwai Chung, Hong Kong*
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Zirogiannis, Athanasios, *Athens, Greece*

### Qualified

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Brown, Gareth, *Bristol*
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Dang Jing, *Hunghom, Hong Kong*
Eguchi, Yumi, *Tokyo, Japan*
Farrell, Stefanie Patricia, *London*
Feng Shaw-Lynn, *Taipei City, Taiwan*
Ho Ka Ying, *Chai Wan, Hong Kong*
Hong Shilei, *Beijing, China*
Horrocks, Anthony, *Gillingham, Dorset*

Hsieh Meng-Chun, *Taipei, Taiwan*
Hung Erh-Nu, *New Taipei City, Taiwan*
Hunt, Lauren, *Birmingham, West Midlands*
Ibrahim Sharif, Sucaad, *Birmingham, West Midlands*
Kim, Heekyung, *New Malden, Surrey*
Ko Feng-Hua, *Taoyuan City, Taiwan*
Krawiec, Natalia, *Birmingham, West Midlands*
Lai Kwok Hung, Andy, *Tsing Yi, Hong Kong*
Lai Pin-Miao, *Taipei, Taiwan*
Lam Wing Yee, *Tin Shui Wai, Hong Kong*
Lau Yu Hang, *Kwun Tong, Hong Kong*
Law Lai Kuen, *Kowloon City, Hong Kong*
Lee Hsin Ping, *Taipei City, Taiwan*
Lee Tak Yan, *Tsing Yi, Hong Kong*
Lee Yu-Erh, *Taipei, Taiwan*
Leung Car Ni, *Quarry Bay, Hong Kong*
Leung Kin Ping, *Yau Tong, Hong Kong*
Leung Sze Wai, *Tsueng Kwan O, Hong Kong*
Leung Yuen Man, *Tseung Kwan O, Hong Kong*
Lister Kroening, Susan, *Leeds, West Yorkshire*
Liu Yi-Lin, *New Taipei City, Taiwan*
Lusher, Lila, *Whangarei, Northland, New Zealand*
Man Yat Chun, *Wong Tai Sin, Hong Kong*
Medi, Tanyol, *Eastbourne, East Sussex*
Mok Kan Pong, *Sheung Shui, Hong Kong*
Ng Chin Kiu, *Tin Shui Wai, Hong Kong*
Reid, Evie, *Tunbridge Wells, Kent*
Robinson, Sophie Helen, *West Hampstead, London*
Shih Yu Hong, *New Taipei City, Taiwan*
So Yuk Mei, *Tuen Mun, Hong Kong*
Statton, Andrew James, *Ivybridge, Devon*
Sze Yuen Tung, *Kwun Tong, Hong Kong*
Tam Wai Man, *Wanchai, Hong Kong*
Tang Chun Shan, *Tai Po, Hong Kong*
Templeton, Heather, *Stewarton, East Ayrshire, Scotland*
Thacker, Zara, *London*
Thomas, Lauren, *Birmingham, West Midlands*
Trolle, Natascha, *Copenhagen, Denmark*
Tsang Hing Cheung, *Sheung Wan, Hong Kong*
Westmoreland, Samantha, *Burntwood, Staffordshire*
Wong Shi Kam, *Tsuen Wan, Hong Kong*
Wong Cheuk Ying, *Kowloon Tong, Hong Kong*
Wright, Emma, *London*
Wu Chung-Kang, *New Taipei City, Taiwan*
Wu On Kei, *Wong Chuk Hang, Hong Kong*
Xia Liyu, *Beijing, China*
Xue, Zixuan, *Birmingham, West Midlands*
Yat, Richard, *Tung Chung, Hong Kong*
Yeh Ji-Miao, *New Taipei City, Taiwan*
Yoong Li Min, Rachel, *Birmingham, West Midlands*
Yu Wing Yan, *Tsing Yi, Hong Kong*
Yuen Angel, *Tsuen Wan, Hong Kong*

## OBITUARY

### Alfred Douglas Morgan
**1919–2017**

It is announced with great sadness that Alfred Douglas (Doug) Morgan FICME FGA (D. 1969), Birmingham, West Midlands, passed away on 20 November 2017. On 21 October 2017 he suffered a stroke which led to gradual deterioration of his health.

Born 1 March 1919, Doug lived to the age of 98. He pursued a varied career in the industries associated with cast iron and foundries, spearheading their technical development to general acclaim. Over the years and after his retirement, he became well-known in many spheres including mineralogy, microscopy, gemmology and faceting.

Doug received his early chemical and metallurgical training at Birmingham College of Technology. In 1936 he joined the British Cast Iron Research Association (BCIRA) as analytical chemist dealing with methods of microanalysis of non-metallic inclusions and, during World War II, he was involved with the development of nickel-molybdenum acicular cast irons and the physical testing of cast iron. In 1944 he became metallurgist at the Idoson Motor Cylinder Co., where he developed the production of acicular irons for the Avon aircraft jet engine and introduced the new shell moulding process for intricate automobile

*Doug at 95 years of age.*

cylinder castings. In 1953 he became chief metallurgist at the Radiation Group Central Research Laboratories, where he investigated problems arising in the vitreous enamelling of cast iron and steel and, as a Fellow of the Institute of British Foundrymen (now the Institute of Cast Metals Engineers), was awarded a diploma for his work on the role of manganese sulphide segregation in causing enamelling defects.

In 1956 he re-joined BCIRA as development engineer and, in 1959, was appointed head of the Moulding Materials and Methods Investigation Group. His work on the testing and control of processes using the newly introduced furfuryl-phenol formaldehyde resin binders resulted in the invention of the BCIRA hot distortion tester and the design of other high-temperature methods for testing core-making materials. Following this he was instrumental in developing the sand casting process.

His pioneering work on the study of waste foundry sand reclamation pertained to the industrial development of this highly important ecological and economical aspect of the industry, and indicated the direction that should be taken to avoid complex problems of nitrogen and hydrogen pick-up by the liquid metal. During this period he served as chairman of the Foundry Industry Joint Sand Committee, and also as a council member of the Institute of British Foundrymen and as Great Britain delegate to CIATF Commission 1.5 dealing with standardisation of test sieves for moulding sand. He continued to investigate slag and refractory problems and, in 1963, he published an article titled 'Identification of slag and dross inclusions' that became the main reference work dealing with the subject. The optical work involved with this research triggered his interest in crystallography and mineralogy, which later became his dominating interests.

Doug's lectures in moulding and core-making technology—usually ending in a specially composed verse—were well-known, and his publication of over 30 papers and technical articles resulted in him being awarded the prestigious Oliver Stubbs Gold Medal for services to the industry by the National Iron-Founding Employers Federation. Doug reported that, when presented with the medal, he was told "The best thing you can do with this, dear boy, is to pawn it!"

In 1969 Doug passed the Diploma of Gemmology and became a Fellow of the Gemmological Association of Great Britain. He lectured in this subject at Birmingham Institute of Art and Design School of Jewellery and Silversmithing (later to become the University of Central England and then Birmingham City University). In addition, he presented his 'Reflections on Gemstones' at numerous international conferences. He served as chairman of the Midlands Branch of the Gemmological Association during its 25th anniversary in 1977. Doug retired in 1984, and served on the council of the Association from 1983 to 1990. He became a skilled gem cutter and was a member of the UK Facet Cutters' Guild. His article 'Development of concave cutting of gemstones' was published in *The Journal* in 2002 (Vol. 28, No. 4, pp. 193–209).

Doug was curator of the reference collection of the British Micromount Mineral Society, and a member of the Postal Microscopical Society and the Russell Society. In 2000 he received the Eric Marson Award of the Queckett Microscopical Club for 'excellence in microscopical preparation'. In 2008 he was awarded the Founders' Cup of the British Micromount Society.

Doug continued to be an active committee member of the Midlands Branch of the Gemmological Association into his early nineties. In 2012 he exhaustively researched the formation of tiger's-eye in an article titled 'Tiger's-eye revisited', published in *Gems&Jewellery* (Vol. 21, No. 3, pp. 8–12). He had a special interest in producing superbly faceted fluorite, but less well known was that fact that he fashioned the neodymium-doped YAG filters for the Hubble telescope.

Doug was a lovely man of many facets whose life was remarkable. He was modest but aware of his valued contributions to many individuals and organizations, both official and informal, having been involved with diverse activities. His enthusiasm, great knowledge, wisdom and keen sense of humour inspired us all. He was always stimulating company, of enormous generosity giving readily of time and effort to those around him. His thought-provoking insights and quiet reflections, and the sensitive and understanding way he dealt with difficulties posed by others, made him a role model that few could emulate. His energy and drive were such that, in his nineties, he worked on and completed challenging projects that would have deterred many people half his age. His kind entertaining manner, keen mind and lively sense of humour will be sorely missed.

Doug's wife Edna, who died in 1996, was a great supporter of his activities, and her learning in languages and teaching had a strong influence on the quality of his work. We send our condolences and heartfelt good wishes to his daughters, son-in-law, grandchildren and great grandchildren. We have lost a man of great magnitude.

*Gwyn Green FGA DGA*

# Learning Opportunities

## CONFERENCES AND SEMINARS

**Symposium: 'Commerce with All the World'—Being a Goldsmith in the 16th and 17th Centuries**
19 January 2018
The Goldsmiths' Company, London, UK
www.thegoldsmiths.co.uk/company/today/events/2018/symposium-commerce-all-world-being-goldsmith-16th-

**49th ACE© IT Annual Winter Educational Conference**
28–29 January 2018
Tucson, Arizona, USA
www.najaappraisers.com/html/conferences.html

**Diamonds: Geology, Gemology and Exploration**
29 January–2 February 2018
Bressanone, Italy
www.internationaldiamondschool.org

**AGTA Gemfair**
30 January–4 February 2018
Tucson, Arizona, USA
www.agta.org/tradeshows/gft-seminars.html
*Note*: Includes a seminar programme

**2018 AGA Tucson Conference**
31 January 2018
Tucson, Arizona, USA
www.accreditedgemologists.org/currevent.php

**2018 Tucson Gem and Mineral Show: Crystals and Crystal Forms**
8–11 February 2018
Tucson, Arizona, USA
www.tgms.org/show
*Note*: Includes a seminar programme

**23rd Hasselt Diamond Workshop**
7–9 March 2018
Hasselt, Belgium
www.uhasselt.be/sbdd

**Jewelry Industry Summit**
9–10 March 2018
New York, New York, USA
www.jewelryindustrysummit.com

**Amberif—25th International Fair of Amber, Jewellery & Gemstones**
21–24 March 2018
Gdańsk, Poland
http://amberif.amberexpo.pl/title,Jezyk,lang,2.html
*Note*: Includes a seminar programme

**inArt2018—3rd International Conference on Innovation in Art Research and Technology**
26–29 March 2018
Parma, Italy
www.inart2018.unipr.it

**European Geosciences Union General Assembly 2018**
8–13 April 2018
Vienna, Austria
https://egu2018.eu
*Session of interest*: Gem Materials

**2nd International Conference on Diamond, Graphite & Carbon Materials**
16–17 April 2018
Las Vegas, Nevada, USA
http://diamond-carbon.conferenceseries.com/symposium.php

**45th Rochester Mineralogical Symposium**
19–22 April 2018
Rochester, New York, USA
www.rasny.org/minsymp

**American Gem Society Conclave**
23–26 April 2018
Nashville, Tennessee, USA
www.americangemsociety.org/page/conclave2018

**Scottish Gemmological Association Conference**
4–6 May 2018
Cumbernauld, Scotland
www.scottishgemmology.org/conference

**4th Mediterranean Gem and Jewellery Conference**
18–20 May 2018
Budva, Montenegro
www.gemconference.com
*Note*: Includes workshops on ruby and sapphire, emerald, diamond and diamond identification with advanced instruments

**The 32nd Annual Santa Fe Symposium**
20–23 May 2018
Albuquerque, New Mexico, USA
www.santafesymposium.org

Compiled by Sarah Salmon and Brendan Laurs

**The 12th International New Diamond and Nano Carbons Conference**
20–24 May 2018
Flagstaff, Arizona, USA
www.mrs.org/ndnc-2018

**Society of North American Goldsmiths' 47th Annual Conference**
23–26 May 2018
Portland, Oregon, USA
www.snagmetalsmith.org/conferences/made

**JCK Las Vegas**
1–4 June 2018
Las Vegas, Nevada, USA
http://lasvegas.jckonline.com/en/Events/Education
*Note*: Includes a seminar programme

**SAIMM: Diamonds – Source to Use 2018**
11–14 June 2018
Johannesburg, South Africa
http://tinyurl.com/y9k5spzu
*Note*: Includes a pre-conference workshop and post-conference technical visits

**Scandinavian Gem Symposium**
Kisa, Sweden
16–17 June 2018
https://sgs.gemology.se

**22nd Meeting of the International Mineralogical Association**
13–17 August 2018
Melbourne, Victoria, Australia
www.ima2018.com
*Sessions of interest*:
- Recent Advances in our Understanding of Gem Minerals
- Sciences Behind Gemstone Treatments
- Mantle Xenoliths, Kimberlites and Related Magmas: The Diamond Trilogy

**29th International Conference on Diamond and Carbon Materials**
2–6 September 2018
Dubrovnik, Croatia
http://tinyurl.com/yb5d9t4x

**6th European Conference on Crystal Growth**
16–20 September 2018
Varna, Bulgaria
http://eccg6.eu

**Mallorca GemQuest II**
22–23 September 2018
Sóller, Mallorca, Spain
www.mallorcagemquest.com

**2018 GIA Symposium: New Challenges. Creating Opportunities**
7–9 October 2018
Carlsbad, California, USA
http://discover.gia.edu/symposium

**CGA Gemmological Conference**
19–21 October 2018
Vancouver, British Columbia, Canada
Email: info@canadiangemmological.com

# EXHIBITIONS

## Europe

**Companions. Jewellery and Objects from Saskia Detering and Peter Frank**
Until 14 January 2018
GfG, Hanau, Germany
http://tinyurl.com/yayj2epx

**Dazzling Desire: Diamonds and Their Emotional Meaning**
Until 14 January 2018
Museum aan de Stroom, Antwerp, Belgium
www.mas.be/en/activity/dazzling-desire

**The European Triennial for Contemporary Jewellery 2017**
Until 4 February 2018
WCC-BF, Mons, Belgium
http://tinyurl.com/yc7l34ox

**The Russia Season: Royal Fabergé**
Until 11 February 2018
Sainsbury Centre for Visual Arts, Norwich, Norfolk
https://scva.ac.uk/art-and-artists/exhibitions/the-russia-season

**Hague Chic – Steltman: 100 Years of Jewellery and Silverware**
Until 18 February 2018
Gementeemuseum Den Haag, The Hague, The Netherlands
www.gemeentemuseum.nl/en/exhibitions/centenary-celebration-steltman-jewellers

**Pretty on Pink – Éminences Grises in Jewellery**
Until 25 February 2018
Schmuckmuseum, Pforzheim, Germany
www.schmuckmuseum.de/flash/SMP_en.html

**Contemporary Jewellery Exhibition "Heartbeats in Winter Mittens"**
Until 28 February 2018
Putti Art Gallery, Riga, Latvia

https://putti.lv/en/event/contemporary-jewellery-exhibition-heartbeats-winter-mittens

**Gold! Watches and Jewellery Collected by Sophia Lopez Suasso**
Until 2 April 2018
Cromhouthuis, Amsterdam, The Netherlands
www.cromhouthuis.nl/en/activities/gold-collected-sophia-lopez-suasso

**Modernist Jewellery**
Until 29 April 2018
National Museum of Scotland, Edinburgh
http://tinyurl.com/y9oq29p8

**Fibulae**
Until 3 June 2018
Rijksmuseum, Leiden, The Netherlands
www.rmo.nl/english/exhibitions/fibulae

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

## North America

**The Glamour and Romance of Oscar de la Renta**
Until 28 January 2018
The Museum of Fine Arts, Houston, Texas, USA
www.mfah.org/exhibitions/glamour-romance-oscar-de-la-renta

**Golden Kingdoms: Luxury and Legacy in the Ancient Americas**
Until 28 January 2018
Getty Center, Los Angeles, California, USA
www.getty.edu/visit/cal/events/ev_1726.html

**Wiener Werkstätte 1903–1932: The Luxury of Beauty**
Until 29 January 2018
Neue Galerie, New York, New York, USA
www.neuegalerie.org/content/wiener-werkst%C3%A4tte-1903-1932-luxury-beauty

**Extravagant Objects: Jewelry and Objects d'Art from the Masterson Collection**
Until 18 March 2018
The Museum of Fine Arts, Houston, Texas
www.mfah.org/exhibitions/extravagant-objects-jewelry-masterson-collection-rienzi

**Bestowing Beauty: Masterpieces from Persian Lands**
Until 11 February 2018
The Museum of Fine Arts, Houston, Texas, USA
www.mfah.org/exhibitions/bestowing-beauty-masterpieces-persian-lands

**Glorious Splendor: Treasures of Early Christian Art**
Until 18 February 2018
Toledo Museum of Art, Ohio, USA
http://tinyurl.com/y94bebz4

**Peacock in the Desert: The Royal Arts of Jodhpur, India**
4 March–19 August 2018
The Museum of Fine Arts, Houston, Texas, USA
www.mfah.org/exhibitions/peacock-in-desert-royal-arts-jodhpur-india

**Beads: A Universe of Meaning**
Until 15 April 2018
The Wheelwright Museum of the American Indian, Santa Fe, New Mexico, USA
https://wheelwright.org/exhibitions/beads

**Jewelry of Ideas: Gifts from the Susan Grant Lewin Collection**
Until 28 May 2018
Cooper Hewitt, Smithsonian Design Museum, New York, New York, USA
www.cooperhewitt.org/channel/jewelry-of-ideas

**American Jewelry from New Mexico**
2 June–14 October 2018
Albuquerque Museum, New Mexico, USA
www.albuquerquemuseum.org/exhibitions/upcoming-exhibitions?/exhibition/103

**Fabergé Rediscovered**
9 June 2018–13 January 2019
Hillwood Estate, Museum & Gardens, Washington DC, USA
www.hillwoodmuseum.org/exhibitions/faberg%C3%A9-rediscovered

**After Fabergé**
Until 24 June 2018
The Walters Art Museum, Baltimore, Maryland, USA
https://thewalters.org/events/event.aspx?e=4952

**Fabergé and the Russian Crafts Tradition: An Empire's Legacy**
Until 24 June 2018
The Walters Art Museum, Baltimore, Maryland, USA
https://thewalters.org/events/event.aspx?e=4769

**Past is Present: Revival Jewelry**
Until 19 August 2018
Museum of Fine Arts, Boston, Massachusetts, USA
www.mfa.org/news/past-is-present-revival-jewelry

**Centuries of Opulence: Jewels of India**
Until 10 October 2018
GIA Museum, Carlsbad, California, USA
www.gia.edu/gia-museum-exhibit-centuries-opulence-jewels-india

**Crowns of the Vajra Masters: Ritual Art of Nepal**
Until 16 December 2018
The Met Fifth Avenue, New York, New York, USA
www.metmuseum.org/exhibitions/listings/2017/crowns-of-vajra-masters

**Gemstone Carvings: The Masterworks of Harold Van Pelt**
Ongoing
Bowers Museum, Santa Ana, California, USA
www.bowers.org/index.php/exhibitions/upcoming-exhibitions/484-gemstone-carvings-masterworks-by-harold-van-pelt

## Australasia

**Cartier: The Exhibition**
30 March–22 July 2018
National Gallery of Australia, Canberra, New South Wales
https://nga.gov.au/cartier

# OTHER EDUCATIONAL OPPORTUNITIES

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

**The Oxus Treasure in Detail**
9 January 2018
The British Museum, London
http://tinyurl.com/y8bfbk33

**Talking Diamonds**
14 January 2018
Canadian Gemmological Association, Calgary, Alberta, Canada
www.canadiangemmological.com/index.php/education/gen-interest
*Note*: This five-hour course provides practical easy-to-understand essential information about diamonds.

**Gem Appreciation Workshop**
4 March 2017
Canadian Gemmological Association, Calgary, Alberta, Canada
www.canadiangemmological.com/index.php/education/gen-interest
*Note*: This five-hour course explores the nature of gemstones and their timeless allure.

**Gemstone Safari to Tanzania**
25 June–12 July 2018
Visit Morogoro, Umba, Arusha, Longido, Merelani and Lake Manyara in Tanzania
www.free-form.ch/tanzania/gemstonesafari.html
*Note*: Includes options for a lapidary class and/or a private visit to ruby mines near Morogoro and Mpwapwa (including Winza)

**Lectures with Gem-A's Midlands Branch**
Fellows Auctioneers, Birmingham, West Midlands
Email georgina@fellows.co.uk

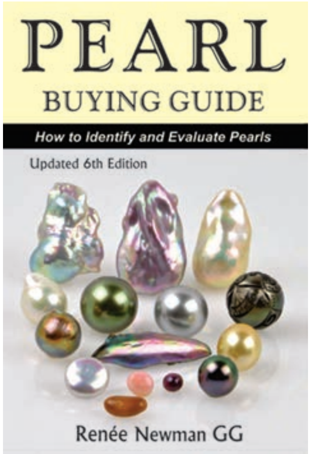
- 23 February 2018
  Gwyn Green—Diamond Treatments
- 23 March 2018
  Alan Hodgkinson—Zircon
- 27 April 2018
  James Gosling—The History of Stickpins

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

- 23 January 2018
  Helen Molesworth—A History of Gemstones
- 27 February 2018
  Cornelie Holzach—250 Years: The Jewellery Industry in Pforzheim, Rise and Transformation
- 27 March 2018
  St John Simpson and Aude Mongiatti—Gold of the Scythians: Art, Culture and Techniques
- 24 April 2018
  Dr Zara Power Florio—All that Glitters: Jewellers and Gems in Georgian Ireland
- 25 September 2018
  Christopher Thompson Royds—TBA
- 23 October 2018
  Anna Tabakhova—Clasps: 4,000 Years of Fasteners in Jewellery
- 27 November 2018
  Helen Ritchie—Designers and Jewellery: Jewellery and Metalwork from the Fitzwilliam Museum 1850–1950

# New Media

## Pearl Buying Guide: How to Identify and Evaluate Pearls, 6th edn.




By Renée Newman, 2017. International Jewelry Publications, Los Angeles, California, USA, www.reneenewman.com/pearl.htm, 153 pages, illus., ISBN 978-0929975528. US$19.95 softcover.

This well-written book contains a great amount of beneficial information for anyone—whether a novice or someone experienced in the gem and jewellery trade—who is interested in finding a variety of information on pearls. Over 300 fabulous colour photographs and diagrams are dispersed throughout the book. This edition is a little more informative than its predecessor, with some additional photos, diagrams and updated chapters, but overall the changes are somewhat limited compared to the 5th edition.

Chapter 1, titled 'Curious Facts About Pearls', has been updated with some informative colour diagrams. Chapter 2 covers 'Pearl Price Factors in a Nutshell'. Chapter 3—'Pearl Types'—dives into the many different pearl varieties and their localities. Chapter 4 covers 'Pearl Shapes' and Chapter 5 is on 'Judging Luster & Nacre Thickness'. Chapter 6, titled 'Judging Color', discusses the complex coloration of pearls, including main body colour, overtone, iridescence and orient, as well as the lighting used for viewing pearls. Chapter 7's 'Judging Surface Quality' covers additional factors to consider when selecting a pearl. Chapter 8 is about 'Size, Weight & Length'. Chapter 9, on 'Judging Make', explains how to assess how well pearls match or blend, how centred are the drill holes and how seamless is the transition of pearl sizes in a graduated strand. Chapter 10—'South Sea Pearls (White & Golden)—has been rewritten to discuss the topic in greater detail. Chapter 11, on 'Black Pearls', discusses their colour variations and localities. Chapter 12 covers 'Freshwater Pearls'.

Chapter 13—'Pearl Treatments'—points out what might have been done to a pearl after initial cleaning. Chapter 14, titled 'Imitation or Not', describes several tests that require no equipment other than a loupe. Chapter 15—'Natural or Cultured'—also covers several simple procedures that do not require expensive equipment, plus other more extensive testing procedures such as those involving the use of X-rays or UV fluorescence.

The remaining chapters are: Chapter 16, 'Antique Pearl Jewelry'; Chapter 17, 'Choosing the Clasp'; Chapter 18, 'Versatile Ways to Wear a Strand of Pearls'; Chapter 19, 'Creating Unique Pearl Jewelry with Colored Gems'; and Chapter 20, 'Caring for your Pearls'.

The *Pearl Buying Guide* is an interesting, easy-to-understand reference on pearls. I highly recommend it to consumers and professionals interested in buying or selling pearls, as it is a very useful, up-to-date tutorial to have in your library.

*Mia Dixon*
*Pala International*
*Fallbrook, California, USA*

## The Sisk Gemology Reference

By Jerry Sisk, 2016. America's Collectible Network Inc. dba Jewelry Television, Knoxville, Tennessee, USA, www.jtv.com/SGR, Vol. 1: Prominent Gems, 436 pages, illus., ISBN 978-0692713181; Vol. 2: Noteworthy Gems, 302 pages, illus., ISBN 978-0692794722; Vol. 3: Gallery of Gems, 302 pages, illus., ISBN 978-0692794739. US$199.99 hardcover with slipcase.

Gemmology is an ever-growing field with the discovery of new materials, treatments and synthetics occurring annually. Although excellent reference books on the subject exist, a fresh interpretation of a discipline in constant flux is often sought. Thus, an additional reference source for professional gemmologists to consult is always welcome.

The author, Jerry Sisk, was a Graduate Gemologist (GIA) and cofounder of Jewelry Television (JTV). He sadly and suddenly passed away in 2013, before this set of books was published. He was an accomplished gemmologist who was voted one of the five most influential people in the jewellery industry by

*JCK Magazine* in April 2012. A short biography of Sisk is provided at the start of each of the three volumes of *The Sisk Gemology Reference*, followed by a foreword by JTV president Timothy Matthews and tributes to Sisk from JTV cofounders F. Robert Hall and William Kouns. These provide a wonderful tribute to the author but do come across as somewhat repetitive.

The three volumes comprising the set are very well organized. The photography is stunning and beautifully illustrates rough, cut and mounted gems. The colour reproduction seems to be very accurate and the images are all crisp and detailed. An index is included at the back of each volume.

The first volume, Prominent Gems, is the 'meat' of the three-volume 'sandwich' so to speak. The first section—Gemstones and Their Properties—focuses on what a gemstone is, the classification and composition of gems and how to interpret each listing that follows. Crisp graphics and clear but simple explanations lead the reader through 'observational properties' such as colour, transparency, lustre and dispersion to more complex characteristics that require gemmological tools for measurement.

In the Optical Properties section, polariscope reactions and optic character depictions are clearly represented. Considering that the polariscope is so thoroughly discussed, I was surprised that the refractive index section does not mention different techniques used to obtain an RI reading, such as the spot method for curved surfaces. However, the birefringence section provides a nice illustration of the appearance of a doubly refractive material in the refractometer, explaining what the shadows on the numerical RI scale represent. Ultraviolet fluorescence and reaction to the Chelsea Colour Filter are presented correctly as additional diagnostic tools that can provide clues to identification but that should be used in conjunction with other tests. The section discussing absorption spectra and the spectroscope is brief, but the explanations are clear and easy to understand.

The section on Physical Properties covers fracture, cleavage, specific gravity, hardness, toughness, streak and the Mohs scale. Following the description of fracture is a helpful chart with thumbnail photos of different fracture surfaces. Cleavage is explained along with a colourful graphic that explains different types (e.g. basal, prismatic, etc.) as well as illustrations denoting the number of cleavage planes present in a given type. A definition of SG is provided and acknowledged as an additional diagnostic tool (i.e. a test that is indicative but not necessarily definitive). Hardness and toughness are defined, and a Mohs hardness scale is illustrated. Streak also is discussed and acknowledged as a destructive test that is rarely performed. I found it helpful to read the author's explanations of these physical and optical properties, which gave me different perspectives on these important characteristics.

The next part of Volume 1 provides descriptions of various gem types, listed alphabetically. Each one is accompanied by a box of properties for quick reference, which is very helpful if you don't want to hunt through paragraphs of text looking for basic numerical values such as RI or SG. Many of the entries have maps showing the principal deposits, and it is convenient to see all the localities in a single place. Some aspects I found to be interesting but more opinion than fact. For example, when picturing aquamarine from different sources, a greener example is labelled from Africa and a bluer one is labelled from Brazil. I am not aware that this distinction is generally accepted in the gemmological community, and of course heating can alter the colour of aquamarine. Some important treatments are not mentioned. For example, in the coral section there is no mention of dyeing or bleaching, which are commonly seen in the trade and should always be considered when identifying, pricing or purchasing coral. In other entries, the subject of treatment is more heavily emphasized. Several descriptions include an important historical stone or piece of jewellery; famous diamond replicas are included in the section on diamonds and the one on natural pearls includes a photograph and brief history of La Peregrina, a famous large pearl once owned by actress Elizabeth Taylor. There are small omissions: In the section on spinel, for example, Tajikistan is listed as a less-notable locality, although it is a historically important source of spinel that is still being mined today.

The first volume concludes with charts listing gem properties, including RI, hardness, SG, dispersion, cleavage, Chelsea filter reactions and organization by crystal system, group, species, variety and series. Following are gem spectra organized by colour. Also provided is a list of contributors followed by a fairly substantial bibliography and additional resources.

The second volume begins the same way as the first, and gemstone properties are reviewed again, sometimes placed in charts rather than (as in the first volume) discussed in paragraphs. I found the first portion of this second volume to be unnecessarily repetitive, but perhaps if only one volume is available it would be helpful. Following the first section, the book delves into brief but informational descriptions of lesser-known but noteworthy materials, from acanthite to zincite. Again, all the photographs are crisp and accurate regarding colour. Many of the specimens are depicted in their most prevalent crystal habit, helping with visual identification. Also convenient are the short but mostly accurate descriptions of each mineral. Following this encyclopaedic portion of Volume 2 is a fairly extensive section on gemmological terms, from 'abas' (an ancient Persian unit of weight) to 'zoning'. While informative for the amount of space given, these definitions sometimes lack key information or are otherwise incomplete. For example, under 'flame structure', no mention is made of conch or Melo pearls, which are both known for this appearance. The definition of a 'GG' mentions a designation earned after completion of GIA's Colored Stones programme, but Graduate Gemologists also must study Diamonds and Gem Identification. Interestingly, under the entry for 'Gemological Institute of America (GIA)', no mention is made of the diamond-grading scales that were developed by GIA and continue to be followed internationally. Under the 'phenomena' description, the term 'stars' is included after mention of aventurescence, rather than after asterism. The emphasis on terminology concerning blue topaz (i.e. Swiss Blue, London Blue) perplexed me until I realized that the author was writing primarily for the JTV audience, which were his customers. Thumbnail photographs or drawings that accompany many of the definitions help illustrate what is under discussion. Volume 2 concludes with a section citing contributors and a bibliography.

Volume 3 focuses on portraying stunning photographs of gems and mineral specimens. A section on famous diamond replicas already depicted in Volume 1 is unnecessarily repetitive. The photos are organized according to crystal structure, starting with organic and amorphous gems and then detailing gem and mineral specimens of each of the crystal systems. Although the photographs are of primary importance, a larger typeface would have been helpful to those who don't want to reach for their reading glasses!

Overall, I found this three-volume set an enjoyable if inconsistent read. If this set of volumes is to be used for reference, it should be backed up with at least one other source. The photographs were what I really found interesting. In gemmological science, I am a firm believer that the more you see, the more you learn, and the photographs in particular are really helpful and can teach a lot.

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