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ARTICLES

Feature Articles

Gemmological Brief

Cover Photo: Rough and cut gems (spinel, ruby and moonstone) photographed at the home of a mine owner in Mogok, Myanmar. Two field reports on Mogok appear in the Excursions section of this issue. Photo by Marco Lorenzoni.

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The Journal of Gemmology

Content Submission

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

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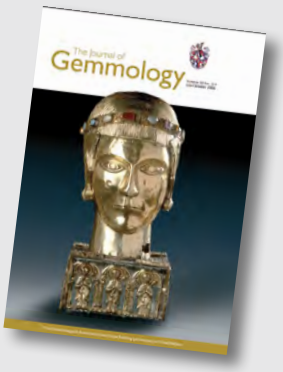
Understanding Gems™

Exciting Changes for *The Journal*



The Journal of Gemmology is the largest-circulated scholarly journal in gemmology. When first published in 1947, *The Journal* was a black-and-white booklet measuring 8¼ × 5½ inches with a grey cover. Occasional colour pages were introduced in the 1970s. A full-colour cover was added and *The Journal's* size increased to 9½ × 6¾ inches in 1986; it subsequently was expanded to A4 format in 2004. *The Journal* was published quarterly (except in 1987, when there were only three issues) until 2005. From 2005 to 2008 *The Journal* was published biannually, and during 2009–2012 it appeared annually in hardcopy, with PDF files of articles posted online as they were finalized. In 2013 two issues were published…and starting with the current issue *The Journal* will return to a quarterly format.

In this issue, you will notice a fresh look and the addition of some new sections, including regular columns titled Learning Opportunities, What's New, Gem Notes and From the Archives, as well as occasional sections called Practical Gemmology, Excursions and Conferences (which debuted last issue). Additional sections are planned for selected future issues: Appraiser's Corner, Instrumentation and Making History. Descriptions of all of these sections, and information on how you can contribute to some of them, are available on *The Journal's* web page at www.gem-a.com/publications/journal-of-gemmology.aspx.

In other regular sections, Gem-A Notices will continue to bring you the information communicated in the previously titled 'Proceedings of The Gemmological Association of Great Britain and Notices'. Book Reviews has been renamed New Media in anticipation of including DVDs as well as books, and this section also includes a supplemental list of additional titles that are not actually reviewed. The Abstracts section has been restructured into Literature of Interest, which features an extensive listing of articles useful to gemmologists, with links to the abstracts of those articles that are available online.

The foundation of *The Journal* will continue to be feature articles that have undergone rigorous peer review to ensure they are of high quality, are understandable to a wide audience and have practical value to gemmologists. Peer review of each article is done by at least three experts in the field, mostly drawn from an expanded list of 38 Associate Editors (see the masthead for their names). Three formats are envisioned: Feature Articles, Review Articles and Gemmological Briefs.

I am also pleased to announce that volume indexes are being created for issues dating back to 2004, and a cumulative index from 1947 to 2013 is in preparation. In addition, we are in the process of scanning all back issues of *The Journal* into PDFs, and in the future they will be made freely available to Gem-A members (in addition to the 2008–2013 issues currently online). Non-members will eventually be able to instantly purchase individual articles online.

I am grateful to Gem-A and the Swiss Gemmological Institute SSEF for their support of *The Journal's* transformation. Partial funding is also being supplied by a limited amount of select advertising. The previous issue marks the first time that outside advertisements have been included since 2006.

I hope that you enjoy the expanded content and high-quality research offered by *The Journal*, as well as the resumption of the quarterly publication schedule. I welcome your suggestions on how we can make future issues even more useful and educational.

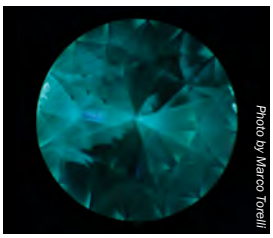
Brendan Laurs
Editor-in-Chief

What's New

INSTRUMENTS AND TECHNIQUES

Identifying HPHT-treated Natural Type IIa Colourless Diamonds and CVD Synthetic Diamonds

Since November 2012, a series of Application Notes have been posted on the M&A Gemological Instruments website at www.gemmoraman.com/articles.aspx. These cover various topics, including the use of a Raman spectrometer for separating heated from unheated spinel, identifying the colour origin of cultured freshwater pearls, red coral and conch pearls, and detecting resin-impregnated jadeite. Most recently (in September 2013 and January 2014), Application Notes were posted on two important diamond topics.



Detecting HPHT Treatment of Natural Type IIa Colorless Diamonds describes subtle differences in the gemmological properties and photoluminescence (PL) spectra between untreated natural type IIa diamonds and their HPHT-treated counterparts. The PL spectral acquisitions were carried out with a GemmoRaman spectrometer utilizing 532 nm laser excitation. Spectra were collected at both room temperature and with the samples cooled to liquid nitrogen temperature to obtain sharper PL peaks and reveal additional features not detectable at room temperature. Although the results obtained at room temperature were surprisingly good, cryogenic testing is recommended for confirmation of treatment detection in type IIa colourless diamonds.

Detecting Synthetic CVD-Diamond with Gemmo-Raman-532SG™ describes a testing procedure for identifying colourless to near-colourless CVD-grown synthetic diamonds. After initial screening for simulants and establishment of type II diamond type, a combination of UV fluorescence microscopy and PL spectroscopy is described for identifying CVD synthetics. The authors note that the SiV^- defect—which is typical of CVD origin—can often be detected at room temperature as a somewhat broadened PL peak at about 738 nm. However, careful interpretation of the spectrum is important, as many natural type IIa diamonds exhibit a weak-to-moderate GR1 peak located in close proximity, at 741 nm. Cryogenic cooling of the sample is recommended.

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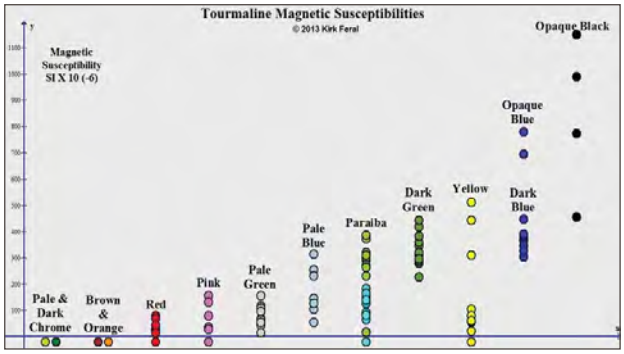
M&A Gemological Instruments
Rome, Italy and Järvenpää, Finland

Tourmaline Magnetism

In December 2013, a study of the relationship between magnetic susceptibility and coloration of gem tourmaline was posted at www.gemstonemagnetism.com/how_to_page_7.html. Quantitative magnetic measurements were taken with a Hoover balance of more than 150 samples, including a number of Paraíba-type tourmalines. A specific range of magnetic susceptibility was associated with each colour variety.



Of the transparent samples tested, red and pink gems had some of the lowest values, while dark green and blue gems had some of the highest; yellow samples showed the greatest variations in magnetic susceptibility. The study also showed that magnetic responses to a handheld neodymium magnet can be used to identify certain tourmaline varieties. For example, a drag response from any blue tourmaline was diagnostic of indicolite, while diamagnetic (repel) behaviour from any blue tourmaline was indicative of the Paraíba type. A diamagnetic response from any green tourmaline was consistent with 'chrome tourmaline' (coloured by chromium and/or vanadium).

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San Diego, California, USA

PUBLICATIONS

CIBJO Blue Books

Updated (2013) versions of *The Diamond Book, The Gemstone Book* and *The Pearl Book* are available for download at www.cibjo.org. These useful reference books cover terminology and classification as well as terms and definitions. In addition, comprehensive appendices supply the following information:

- *The Diamond Book*—contents of diamond grading reports, possible treatments, parts and facet arrangement of a round brilliant cut, and terms for colour and clarity grades.
- *The Gemstone Book*—a list of common and unusual coloured stones, their possible treatments (including stability and advice for their care) and whether they are available as synthetics.
- *The Pearl Book*—descriptions and definitions of pearl-producing molluscs, treatments (including advice for their care) and localities for natural and cultured pearls according to mollusc species.

Other CIBJO Blue Books available for download are 2012 editions of *The Precious Metals Book* and *The Gemmological Laboratory Book.*

GGTL Labs Newsletter

GGTL Laboratories has released its latest newsletter (No. 2, 2013), available at www.ggtl-lab.org/science/newsletter. It documents an F-colour natural type IaA diamond that had been misidentified by a laboratory as a synthetic diamond, the screening of melee-sized diamonds for CVD synthetics, properties of HPHT-grown synthetic diamonds that are irradiated and then annealed (or HPHT treated), a blue sapphire with subsurface synthetic corundum crystallites that formed due to treatment at very high temperatures, a bicoloured purple and blue 'Maxixe' beryl, an aquamarine that was fracture-filled with epoxy resin and an unpolished calcitic pearl with an 'olive' green overgrowth. Announced is the availability of GGTL photomicrographs for use in publications. Images can be freely downloaded from www.ggtl-lab.org/pictures, provided that the photos are credited to GGTL.

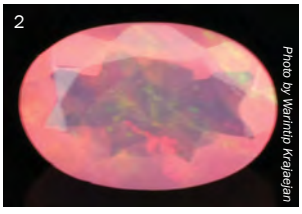
Gem Testing Laboratory (Jaipur, India) Newsletter

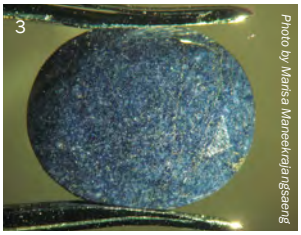
The latest Lab Information Circular (Vol. 68, November 2013), available at http://www.gtljaipur.info/Lab%20Information%20Circular.asp, describes sapphires enhanced with cobalt-coloured lead glass, CVD synthetic diamonds and rough diamond imitations (cubic zirconia and topaz).

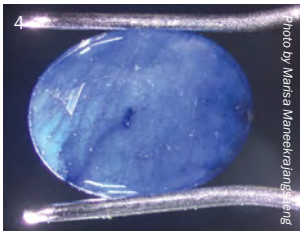
GIT Lab Updates

Since July 2013, the Gem and Jewelry Institute of Thailand has posted four lab updates at www.git.or.th/2013/index_en.html.

1. *GIT Exploring Ruby and Sapphire Deposits of the Mogok Stone Tract, Myanmar,* describes a June 2013 expedition to visit ruby, sapphire, peridot and spinel mines in this important gem-producing area.
2. *An Unusual Pink Opal* focuses on a 0.27 ct faceted opal with an orangey pink body colour that was found to be due to dye treatment.
3. *Reconstructed Sapphire: A New Type of Manmade Gem Corundum* identified two faceted dark blue stones (5.13 and 6.53 ct) as granular aggregates of corundum that were artificially assembled together with a new type of process.
4. *A Treated Stone Sold as 'Black Sapphire'* documents two representative faceted stones (1.44 and 1.91 ct) that were taken from a parcel of gems sold as 'black sapphire'. The report suggests low-quality colourless to pale-coloured sapphires with abundant open fissures were treated by the typical Ti-diffusion

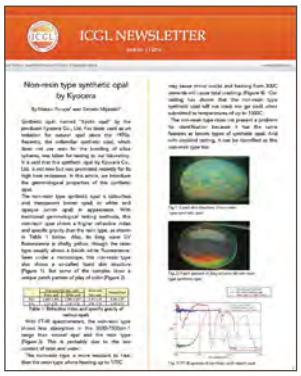






technique, and the exceptionally dark coloration resulted from Ti diffusion into fissures that were subsequently healed during high-temperature heat treatment.

ICGL Newsletter



The International Consortium of Gem-Testing Laboratories has released its latest newsletter (No. 1, 2014), available at http://icglabs.org. It describes a non-resin type synthetic opal by Kyocera, profiles petalite as a collector's gem and contains a review of the exhibition titled *The Cheapside Hoard: London's Lost Jewels*, on display at the Museum of London until 27 April 2014.

JVC Releases Two Essential Guides

In 2013, the Jewelers Vigilance Committee published two additions to its Essential Guides series (see www.jvclegal.org/index.php?categoryid=601). *The Essential Guide to Conflict Minerals and the Dodd Frank Act* explains legislation passed in 2010 that addresses 'conflict minerals' (tin, tantalum, tungsten and gold). *The Essential Guide to the U.S. Trade in Materials from Plant and Wildlife Products* covers organic gem materials that have been classified as protected by international, federal, and/or state laws.

SSEF Facette and Lab Alert

The Swiss Gemmological Institute SSEF has released the latest Facette Magazine (No. 21, 2014), which is available at www.ssef.ch/research-publications/facette. It describes several exceptional items sold at auction by Christie's and Sotheby's in 2013, an expedition to Mogok (Myanmar), a technique called 'automated spectral diamond inspection' for authenticating melee size-diamonds, DNA fingerprinting of pearls, blue cobalt-bearing spinel from Vietnam, a stability experiment on Ethiopian opal, colour-change garnets from Tanzania showing the Usambara effect, jadeite from Kazakhstan, an imitation amber carving, a brooch featuring a 110 ct non-nacreous natural pearl, rubies from Didy (Madagascar), spessartine from Nigeria and Mogok, 'Pipi' pearls from the Pacific Ocean, vanadium-bearing chrysoberyl, a topaz pendant that was evidently damaged in a barbeque, cultured pearls from French Polynesia containing new bead materials (organic nuclei and freshwater shell pieces) and a report on the International Gemmological Conference in Vietnam.

In September 2013, SSEF issued a lab alert on a new, unstable treatment of conch pearls that results in surface damage (see www.ssef.ch/research-publications/press-releases).

MISCELLANEOUS

MIM Mineral Museum Opens in Beirut

In October 2013, the MIM Mineral Museum opened at the Campus of Innovation and Sport, Saint-Joseph University, Beirut, Lebanon (www.facebook.com/mim.museum). The collection includes more than 1,400 minerals, and of particular interest to gemmologists are world-class gem crystals selected for their transparency, colour and morphology. There is also a large display of multi-coloured liddicoatite slices.


Photo by Mahmoud Doumani

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

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We proudly present the new Dr. Eduard Gübelin Research Scholarship, an annual grant supporting a scientific research project in the field of gemmology in the broadest sense. The annual value is CHF 30,000 (USD 33,000).

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Photomicrography Using a Smartphone Camera

Edward Boehm

While visiting mines, gem offices or trade shows, the travelling gemmologist is often challenged to come up with creative ways to identify gems and minerals using portable instruments. A few years ago, while in an office documenting some spinels that contained beautiful inclusions, I had access to a nice microscope but no SLR camera or attachment. So, I decided to try using the camera from my smartphone (iPhone) to see if I could capture the inclusions. It took a bit of practice and lots of patience, but I was able to make it work (Figure 1). Since then, I have improved the technique and also managed to take photomicrographs through a darkfield loupe (Figure 2).

When learning to take photomicrographs with a smartphone camera, it is best to start at a lower magnification and simply try to capture the entire gem in the field of view. The camera lens should be held approximately 1 cm away and directly over the centre of an ocular. Hold the camera phone as steady as possible using both hands, while using the other ocular for stability (Figure 3). If your microscope is equipped with eye shields, try resting the camera phone on a shield for stability. However, it may be easier to remove the shield if it is not positioned at the

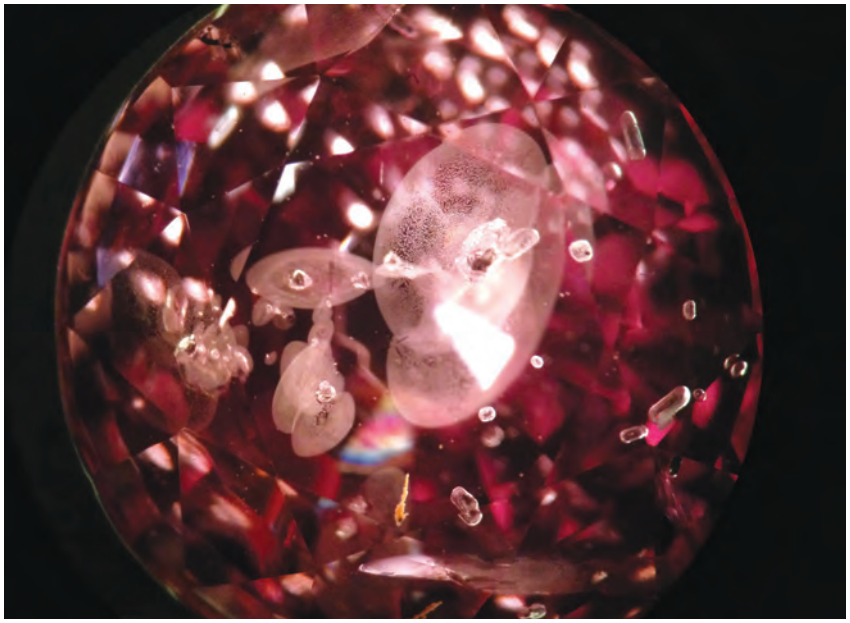

Figure 1: Viewed with a Zeiss microscope and photographed with an iPhone, these inclusions in a pink Burmese spinel consist of negative octahedral crystals with stellate clouds and rounded protogenetic apatites. A single black inclusion is also present (probably ilmenite or graphite). Photomicrograph by E. Boehm; magnified 20×.

Figure 2: These uraninite crystals with tension halos in a lavender Burmese spinel were captured with a 10× darkfield loupe and an iPhone camera. Photomicrograph by E. Boehm.

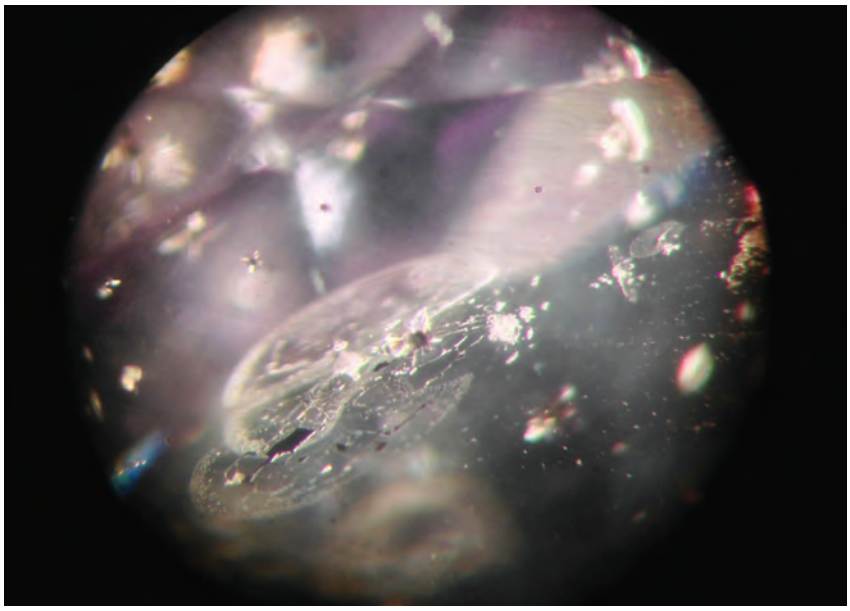

Figure 3: The author demonstrates the technique for taking photomicrographs using a smartphone camera. Here the lens of the camera is positioned over the right ocular, and the left hand is resting on the left ocular for stability. The camera lens is held approximately 1 cm above the ocular. Photo by Carley Boehm.

ideal distance from the ocular, or if it prevents the camera from being moved around until the correct image is displayed.

Tapping on the focus square and using the HDR mode should improve the picture quality. After a bit of practice, you will be able to zoom the microscope closer on the individual inclusions or surface characteristics that you wish to document. Although macro photography attachments are available for some camera phones, they should not be necessary for taking good photomicrographs using the technique described here.

While smartphone cameras cannot achieve the sharp focus or depth-of-field of digital SLR cameras, their ability to capture micro-features as well as the true colour of the host gem is exceptional. And, of course, their portability is superior. A smartphone camera should be considered one more indispensable tool in the travelling gemmologist's arsenal.

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Gem Notes

COLOURED STONES

Colourless Cat's-eye Apatite from Brazil

Intense blue apatite is known from Minas Gerais, Brazil, and cat's-eye stones in yellow and green have also been documented from this gem-rich country (O'Donoghue, 2006). In addition, a small amount of colourless cat's-eye apatite was recently produced, and shown to this author at the recent Tucson gem shows by David Epstein (Precious Resources Ltda., Teófilo Otoni, Brazil). He reported that the material was found in January 2013, and came from a parcel consisting mainly of greenish blue cat's-eye apatite. Some of the rough was colour zoned, and the colourless portions were polished into 40–50 pieces ranging from 1 to 4 ct (e.g. Figure 1), for a total of approximately 100 carats. The material is known to have been cut in Teófilo Otoni, but the origin of the unusual rough material within Brazil is unknown.

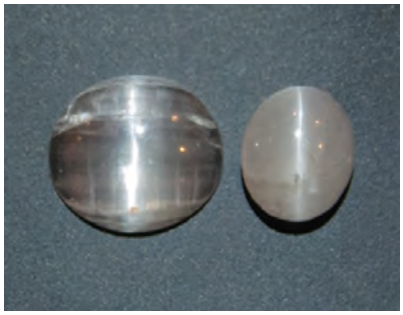

Figure 1: These cat's-eye apatites (2.45 and 3.80 ct) from Brazil are colourless, which is highly unusual for this material. Photo by B.M. Laurs.

Brendan M. Laurs

Reference

O'Donoghue M. (Ed.), 2006. *Gems,* 6th edn., Butterworth-Heinemann, Oxford, 382–384.

Prismatic Aquamarine Crystals from Ethiopia

Aquamarine has been mined from southern Ethiopia since at least 2010, but typically only a small proportion is of gem quality (Laurs et al., 2012). This is apparently because much of the production comes from crystals that were 'frozen' within pegmatite (rather than forming in open cavities) and therefore have low transparency. Most of the aquamarine has been recovered as broken pieces, some rather large.

Figure 2: These aquamarine crystals were reportedly produced in Ethiopia in mid-2012. They range from 3.5 to 7.5 cm long. Photo by B.M. Laurs.

During the September 2013 Hong Kong gem show, Farooq Hashmi showed this author some more recent production of Ethiopian aquamarine that was quite different from material seen in the past: the crystals were prismatic, well formed, and of fine gem quality (e.g. Figure 2). He first encountered this aquamarine during the September 2012 Hong Kong show, when he obtained approximately 2 kg of the better crystals from a parcel weighing 20–25 kg; about 30% of that parcel showed good transparency. He was told that the aquamarine was produced in mid-2012. Most of the crystals were partially covered with a hard coating that appeared to consist of iron-stained clay.

During a January 2013 buying trip to Ethiopia, Hashmi encountered more of these prismatic aquamarine crystals, with the same hard coating mentioned above. However, these were much smaller, ranging from 2 to 3 cm long and 2–4 mm in diameter. The parcel weighed a total of about 2/3

kg, and most of the crystals were <1 g. Although too small for cutting gemstones, they could make attractive pendants for jewellery.

Brendan M. Laurs

Reference

Laurs B.M., Simmons W.B. and Falster A.U., 2012. Gem News International: New gem discoveries in Ethiopia. *Gems & Gemology,* **48**(1), 66–67.

Blue Chrysocolla Chalcedony from Peru

In mid-2012, gem dealer Hussain Rezayee (Rare Gems & Minerals, Beverly Hills, California, USA) obtained some newly produced 'gem silica' from the Arequipa region of southern Peru. This area is known to produce fine-quality gem silica (chrysocolla chalcedony) that is typically greenish blue to blue-green (e.g. Hyrsl, 2001; Emerson and Darley, 2010). However, this newer material was bluer than previously reported. Rezayee obtained additional material on another trip to Peru in May 2013, bringing his total amount to 183 kg in various grades. He was told that the blue gem silica was found at the bottom of a mine shaft, and was completely worked out by the miners. Pieces weighing up to 58 kg were recovered, with gem-quality samples of 750+ g. None of the material is known to have undergone any treatment.

Rezayee initially cut 22 cabochons weighing 2.49–22.02 ct, and he loaned three samples for characterization (18.07–22.02 ct; Figure 3). Examination by one of us (BC) showed the following properties: colour—light greenish blue to blue; diaphaneity—opaque; lustre—waxy, dull; RI—1.55 (spot method); hydrostatic SG—2.58–2.61; Chelsea colour filter reaction—none; and fluorescence—inert to long-wave and zoned chalky bluish white to short-wave UV radiation. The zoned fluorescence was apparently due to the local presence of an unidentified impurity mixed with the silica. However, when the fluorescent areas were analysed with Raman spectroscopy, the signal was overwhelmed by the quartz matrix. Ultraviolet-visible–near infrared (UV-Vis-NIR) spectroscopy showed a broad absorption band from approximately 430 to 530 nm (Figure 4). Chemical analysis by energy-dispersive X-ray fluorescence (EDXRF) spectroscopy showed only Si and Cu as major elements. These properties (other than the short-wave UV fluorescence) are consistent with those reported for chrysocolla and quartz by O'Donoghue (2006).

Microscopic examination revealed a polycrystalline texture consisting of minute blue and white interlocking crystals. Magnification also showed faint colour banding of lighter and darker blue layers. Small yellow and dark-appearing discolorations were disseminated throughout the stones, and were probably due to epigenetic staining and inclusions.

Figure 3: These cabochons of blue chrysocolla chalcedony (18.07–22.02 ct) were cut from material recently produced in southern Peru. Photo by Bilal Mahmood.

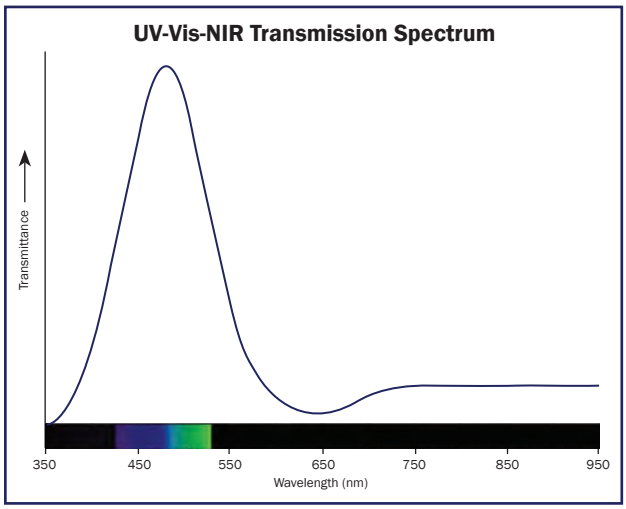

Figure 4: A broad transmission band extending mainly from approximately 430 to 530 nm was recorded in the UV-Vis-NIR spectrum of the chrysocolla chalcedony, which is consistent with copper as the chromophore for this material.

While calling this material *gem silica* is not technically incorrect, gemmologically it would be classified as chrysocolla within quartz, or simply chrysocolla chalcedony.

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Brendan M. Laurs

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Hyršl J., 2001. Gemstones of Peru. *Journal of Gemmology,* **27**(6), 328–334.

O'Donoghue M. (Ed.), 2006. *Gems,* 6th edn. Butterworth-Heinemann, Oxford, 306 and 339.

A Wonderfully 'Painful' Discovery

The Natural History Museum in London has been at the centre of several mineralogical and gemmological discoveries over the past two centuries. Many of these have interesting stories behind them, such as the recognition of a hitherto unknown specimen of the rare mineral painite in the Museum's main systematic mineral collection.

In 1952 A.C.D. Pain sent to London a small 1.7 g unidentified crystal found in the gem gravels of Mogok, Burma. It was not until 1956 that this crystal was described as a new species, painite (Claringbull et al., 1957), after analytical tests were performed at what was then the British Museum (Natural History). In 1959 a second painite crystal weighing 2.12 g entered the Museum's collection, and for 20 years these two crystals remained the world's only known specimens of the species. As such, these two slightly waterworn crystals were given the distinction of being the world's rarest gem mineral by the *Guinness Book of World Records* (McWhirter, 1983). In 1979 a third specimen was found and donated to the Gemological Institute of America by Ed Swoboda (Shigley, 1986). The fourth painite was not discovered until 2001 (http://minerals.caltech.edu/FILES/Visible/painite/Index.html), by which time the mineral had obtained an almost legendary status, with many collectors looking for this elusive gem species.

William Larson of Pala International (Fallbrook, California) was inspired to trace this enigmatic mineral when visiting Peter Embrey in the 1970s, then Curator of Mineralogy at the British Museum (Natural History). Through Larson's endeavours during numerous trips to Myanmar, and the efforts of local miners and geologists, painite was rediscovered and new specimens started to appear in 2002 (see www.palagems.com/painite.htm). When painite was later discovered in-situ near Mogok in 2005, many thousands of crystals and fragments were recovered (Rossman, 2005). Larson brought some of this new material to the Tucson Gem and Mineral show, and the Museum obtained samples to complement its original type holdings.

Figure 5: Originally acquired by the British Museum (Natural History) as a specimen of ruby and brown tourmaline in 1914, the 'tourmaline' actually turned out to be the as-yet undescribed gem mineral painite (top, 47×32×26 mm, BM 1914,1118). Also shown are the original type specimens of painite from gem gravels near Ohngang village in the Mogok area (bottom, BM 1954,192 and BM 1961,144). Photo by Harry Taylor, The Natural History Museum Picture Library.

It was through looking at this new material and noting the distinct differences from the original type specimens that a surprising discovery was

made by one of the authors (AH) in the Museum's main systematic mineral collection. Within the corundum collection was a specimen from Mogok labelled 'Corundum (ruby) pitted crystals on crystals of brown tourmaline with limonite'. The 'brown tourmaline' was an immediate visual match with material from the new painite discovery, and in December 2007 an electron microprobe analysis confirmed it was indeed painite. It is a fine specimen in terms of its form, size and association with ruby crystals that are up to 8 mm across (Figure 5). Astonishingly, the specimen had been acquired in 1914, from Francis Powell & Co., London. It was registered into the collection (BM 1914,1118) and remained misidentified for 93 years—and it also was present for 38 years before painite was formally discovered using the crystal donated to the Museum by Pain. It is ironic that this far superior specimen was sitting within the collection just meters away from the 1952 specimen that was on display for so many years as the 'best of species'. It is also interesting to note that the mineral would not have been named *painite* if the 'tourmaline' on the specimen acquired in 1914 had been recognized as a new species at that time.

For us it raises some important points. Although large mineral collections are known to play a role as long-term accessible repositories of important specimens, there is always the potential for new discoveries to be made within them. The distinctive look of the new painite specimens and our usual procedure of continually appraising the collection—especially acquisitions of new pieces and associated species—led us to visually identify this rather ordinary 'brown tourmaline' as a painite. Also, this example underlies the importance for collections staff having the opportunity to be 'out there', knowing what is on the market and critically comparing new materials against existing collections. We have scoured the collection for similar material, but have yet to find any more painite surprises. We urge other collections' custodians to take another look at their tourmaline drawers, as you never know what you might find.

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Mercaptans in Tanzanite from Merelani, Tanzania—A New Type of Stinkstone?

Stinkstein, or *stinkstone,* is a term used to describe the foetid odours when certain rocks and minerals are scratched or broken. The foul odours are usually described as being sulphurous, anthracitic or ozone-like. One of the earliest reports was from Agricola (1546) who recorded the smell of 'burning horn' when the Hildesheim marble from Saxony was 'struck with an iron or stone'. More graphic, present-day descriptions include the smell of decayed animals, which can be so distinctive from some feldspars to warrant the use of the varietal term *necronite*.

A common cause of these smells is release of malodorous volatiles trapped inside fluid inclusions. Notable gemmological examples include: (1) the bituminous smell from petroleum-bearing inclusions in 'Herkimer diamonds' (quartz crystals) from New York, USA; (2) fluorine compounds which account for the characteristic odour of *stinkspar* or *antozonite*, a dark purple fluorite from Bavaria, Germany; and (3) the recently reported 'rotten egg' odour of hydrogen sulphide in unheated zoisite from Merelani (Saul, 2013; Taylor et al., 2013).

Fluid inclusions in Merelani zoisite (including tanzanite; Figure 6) have unusual and distinctive carbon-hydrogen-sulphur (C-H-S) compositions compared to those commonly encountered in other gem minerals. Hydrogen sulphide (H_2S) is predominant in both the liquid and vapour phase. Besides minor nitrogen and methane, no other volatiles were previously identified from the

Figure 6: This multiphase C-H-S fluid inclusion in an unheated Merelani tanzanite comprises H_2S-rich liquid and vapour (distorted bubble), as well as solid graphite (opaque mass). Photomicrograph by D. Taylor.

Raman spectra of the vapour bubble. However, higher-resolution spectra have now revealed two smaller, previously undescribed bands at 2572 and 2585 cm^{-1} (Figure 7). The 2585 cm^{-1} peak can be ascribed to interference from Raman scattering of liquid H_2S surrounding the bubble, but the peak at 2572 cm^{-1} cannot. A search of published Raman spectral data revealed that this feature is well within the range of the S-H stretching mode (2560–2590 cm^{-1}) of thiol C-H-S compounds (Dollish et al., 1974), most notably methanethiol and ethanethiol (peaks at 2575 and 2571 cm^{-1}, respectively). Low molecular weight thiols such as methanethiol (CH_3SH, boiling point 6°C), and ethanethiol (C_2H_5SH, boiling point 35°C), also known as mercaptans, are renowned for their unpleasant smell even at concentrations down to 1 ppb in air. The odours are variously described as being like 'decaying animals', 'rotten cabbage' or 'smelly socks'. Methanethiol, a minor waste product of normal metabolic processes in humans, is particularly noteworthy as one of the main compounds responsible for the foul smells from bad breath and flatulence. Low molecular weight mercaptans are known to occur together with H_2S in some natural gas fields, and in associated minerals, in sedimentary rocks. But their presence in minerals formed at much higher temperatures and pressures such as those envisaged for the Merelani deposit is exceptional.

The proposed occurrence of mercaptans in fluid inclusions in unheated Merelani zoisite suggests that a small portion of 'putrid cabbage' can be added to the major presence of 'rotten egg' to account for the distinctive the odour from the opened inclusions. The contrast between the beauty of some unheated tanzanites and the foul smelling H_2S and mercaptans inside them is so striking that it begs the question as to whether it is appropriate to refer to inclusion-rich unheated Merelani zoisites as *stinkstones*. Maybe so, but an added benefit of heat treatment is that it not only enhances colour, but it also destroys most of the foul-smelling inclusions inside thus transforming the *stinkstone* into a desirable gem.

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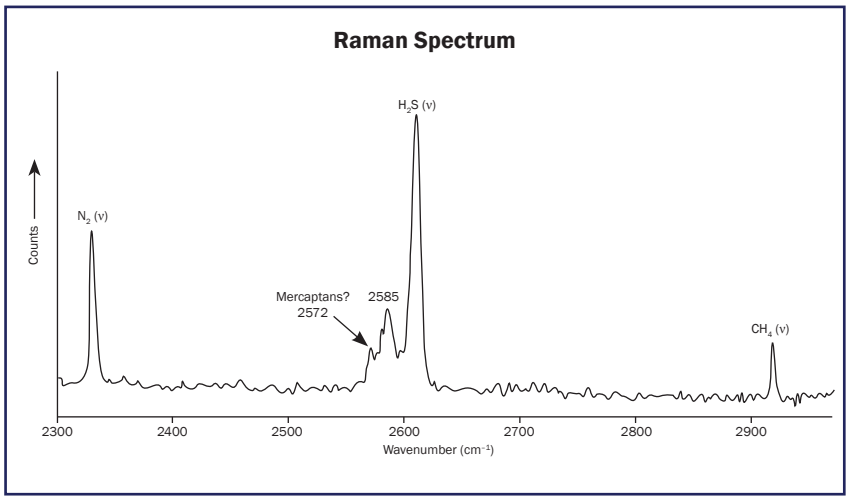

Figure 7: Raman spectroscopy of the H_2S-rich vapour phase in a C-H-S fluid inclusion in unheated Merelani tanzanite shows a suspected peak for mercaptans at 2572 cm^{-1}. Another peak at 2585 cm^{-1} may be ascribed to H_2S liquid and/or mercaptans.

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PEARLS

A Beaded Cultured Pearl Mistaken for a Natural Pearl

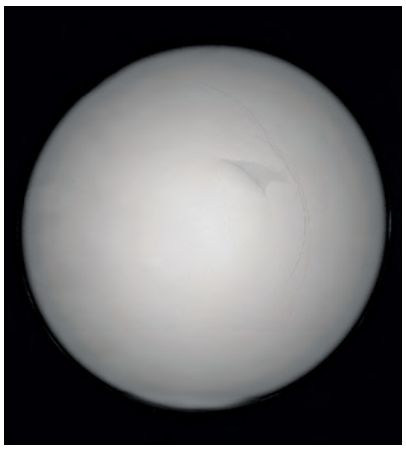
The Laboratoire Français de Gemmologie (LFG) received a 10.55 ct pearl for analysis that was accompanied by a recent laboratory report stating 'natural saltwater pearl'. Measuring 11.7 mm diameter, this round light grey pearl was undrilled and appeared to be from the *Pinctada maxima* species.

The saltwater origin was straightforward to confirm with EDXRF chemical analysis (there was more Sr than Mn), and as expected the pearl showed no visible X-ray luminescence.

Magnification revealed a few blemishes such as 'comet tails' and spots that are usually seen in cultured pearls. However, those characteristics also can be found occasionally in natural pearls, so they are not conclusive.

To further investigate the natural or cultured origin of the pearl, we analysed it with a Desktom X-ray microradiography-tomography instrument that was co-developed by LFG and RXSolutions (Chavanod, France). Our initial observation using a 'classical grey scale' (Figure 8) indicated a structure consistent with a natural pearl: a curved growth pattern a few millimetres below the surface, and a void or organic material located further down, in the shape of a shark's dorsal fin. There is no apparent nucleus or bead.

When observing radiographs at the LFG, the usual process is to vary the grey histogram in order to highlight different zones of a pearl, and thus to have a better perspective of the structures at different depths. As shown in Figure 9, this clearly revealed a round homogeneous structure as a central bead, on which the 'shark fin' structure seems to lie. The pearl is thus undeniably cultured. The diameter of the nucleus was measured at around 4.4 mm. This is a bit surprising, as one would not expect such a small bead in an 11.7 mm



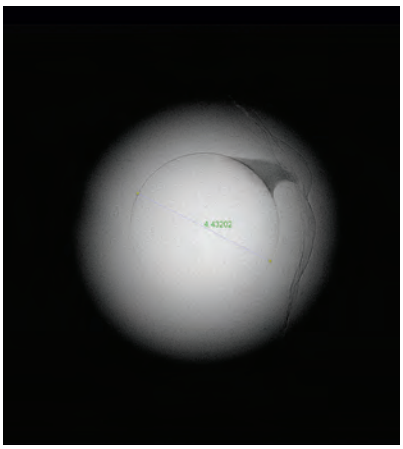


Figure 8 (left): Without the use of special techniques, micro-radiography of this 11.7 mm diameter 'natural saltwater pearl' showed only a curved growth pattern and a deeper feature interpreted as a void or organic material.

Figure 9 (right): With an appropriate selection of the grey value, micro-radiography revealed a 4.4 mm bead inside the 11.7 mm cultured pearl. (Note that the pearl outline is no longer visible in this view.) It is surprising to see a cultured pearl with more than 3.5 mm nacre thickness.

round cultured pearl. Usually the culturing process grows only a 1–2 mm thick layer of nacre around the nucleus.

In Figure 9 the void adjacent to the bead also became clearly perceptible. It corresponds with the location where the graft was inserted during the nucleation process. The line detected between the nucleus and the surface can be interpreted as a regrowth pattern, which is commonly seen in natural pearls or cultured pearls with a thick nacre layer.

This is a good example of the value of X-radiography technology designed specifically to work with pearls. Simpler instrumentation probably would not have detected this cultured pearl's unusual structure. Also, by highlighting different depths, the internal structures became obvious and further testing with X-ray computed tomography (very time consuming) was not necessary. This incident points out once again the difficulty in some cases of establishing whether a pearl is natural or cultured.

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Testing Natural Pearls with Micro-focus X-radiography—A Case Study

Pearls are routinely tested for natural or cultured origin using imaging techniques such as X-radiography (Schloßmacher, 1969; Strack, 2006). Such identifications require clear visualization of internal structures. This brief report explores how a recent advance in technology, the micro-focus technique, can enhance the capabilities of traditional X-radiography.

A pearl necklace was submitted to author ES for identification (Figure 10). Initial testing comprised taking a series of radiographs of various pearls in the necklace with a Kodak 2200 digital X-ray system (60–70 kV, 49 W). The radiographs showed various growth characteristics indicative of natural pearls, such as concentrically arranged lines, arcs and inner cores of organic substance. However, the centre pearl (7.8 mm diameter) revealed only a single irregular growth line that was suggestive of a natural pearl (Figure 11a) but not conclusive. Examination of the drill hole with a gemmological microscope revealed an inner core with a slightly more creamy colour than the pearl's body colour (Figure 12).

Consequently, the necklace was subjected to further testing with a Y.Cougar micro-focus X-ray system at YXLON company. The inspection was performed using 80–100 kV, depending on pearl size, and 3 W of power for the X-ray tube. A small focal spot of 1 μm, in conjunction with a digital flat-

Figure 10: This necklace contains 107 natural pearls of 3.2–7.8 mm in diameter, and has a total weight of 10.3 g. Courtesy of F. Hauser; photo by E. Strack.

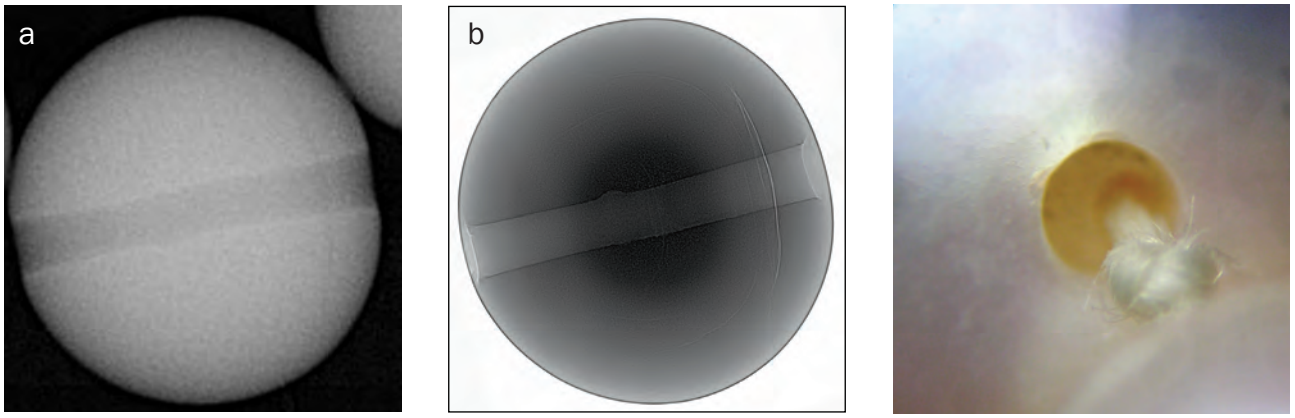

Figure 11: (a) This traditional X-radiograph of the centre pearl in the necklace (7.8 mm diameter) shows a single growth feature on the right side, which appears as a dark line in this 'positive' image. (b) The micro-focus radiograph of the same pearl shows several slightly curved growth lines, which appear as white lines in this 'negative' image.

Figure 12: The drill hole of the centre pearl, when examined with a microscope, revealed an inner core with a more creamy colour. Photomicrograph by E. Strack; magnified 20×.

panel detector, allowed for high magnification with a resolution of ~1 μm. Radiographs were taken of several individual pearls (including the centre one), as well as the entire necklace. The radiograph of the centre pearl (Figure 11b) shows several growth lines in a generally circular arrangement. This pattern positively identifies the pearl as natural. The differently coloured inner core seen through the drill hole with the gemmological microscope is therefore interpreted as being an internal layer of the natural pearl.

The high-resolution capability of the Y.Cougar instrument further allowed us to visualize a record of the growth processes in some of these natural pearls. The radiograph of pearl no. 51 (Figure 13a) shows an inner core with a prismatic-concentric structure, surrounded by rings in a circular arrangement within the nacre layers. A much different pattern is shown by pearl no. 68 (Figure 13b), which has an inner core composed of less-dense material (probably an organic substance), accompanied by additional arcs and rings.

In cases where higher resolution is desired than can be achieved with traditional X-radiography, the Y.Cougar instrument provides a viable option, in addition to X-ray computed tomography (e.g. Krzemnicki et al., 2010, and references therein).

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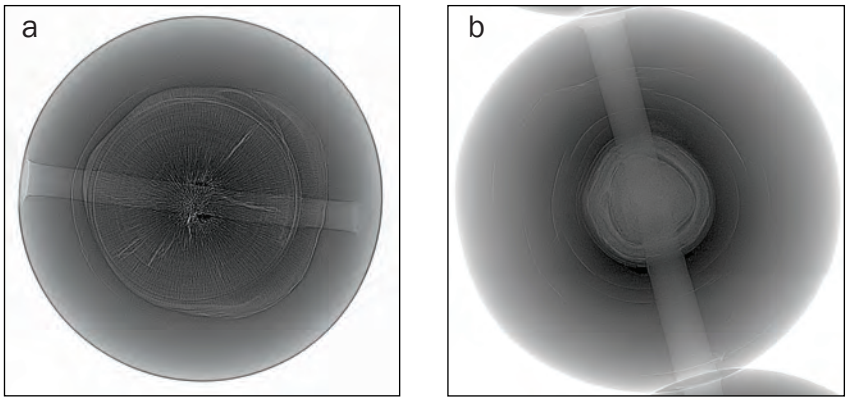
Figure 13: Micro-focus X-radiography may record details of the growth history of pearls. (a) Pearl no. 51 shows an inner core with a prismatic-concentric structure, surrounded by rings in a circular arrangement. (b) Pearl no. 68 shows an inner organic-rich core with an irregular round shape, surrounded by arcs and rings in a circular arrangement.



An Exceptional, Recently Discovered Quahog Pearl

Quahog pearls are produced by the clam *Mercenaria mercenaria* (or *Venus mercenaria*), which ranges along the Atlantic Coast of North America (Matlins, 2008). These pearls are so unusual that thousands of clams may be opened before one is found, and it is even rarer to find a quahog pearl that is round, of the desirable lilac-to-purple hue, and relatively large.

Figure 14: Seen at this year's Tucson gem shows, this 11.4 mm quahog pearl weighs 11.04 ct and was found in July 2012 in Rhode Island, USA. A depression near the edge of the shell on the right marks the place where the pearl formed in the host clam. Photo © Robert Weldon.

Therefore it was most interesting to see a recently discovered quahog pearl of exceptional quality, complete with its host shell (Figure 14), at this year's Tucson gem shows. The pearl was acquired by William Larson (Palagems.com, Fallbrook, California, USA), who reported that it was found in July 2012 at Misquamicut in Washington County, Rhode Island, USA. The location where the pearl formed in the clam was clearly evident by a depression near the edge of one of the shells. The 11.4 mm pearl was surprisingly large when compared to the size of the clam from which it came (57.5 mm long).

Brendan M. Laurs

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SYNTHETICS AND SIMULANTS

Two Synthetic Diamonds Identified in a Parcel of 7,000 Melee-size Yellow-Brown Diamonds

In late 2013, the Laboratoire Français de Gemmologie analysed a parcel of 7,000 melee-size (1 to 2.5 mm in diameter) yellow-brown diamonds. They were presented as natural 'cognac' diamonds, and reportedly had already been screened for synthetics.

The first step in our examination was to observe all the diamonds in long- and short-wave UV radiation (see Figure 15). Two of them emitted an intense green luminescence to short-wave UV, but remained inert to long-wave UV

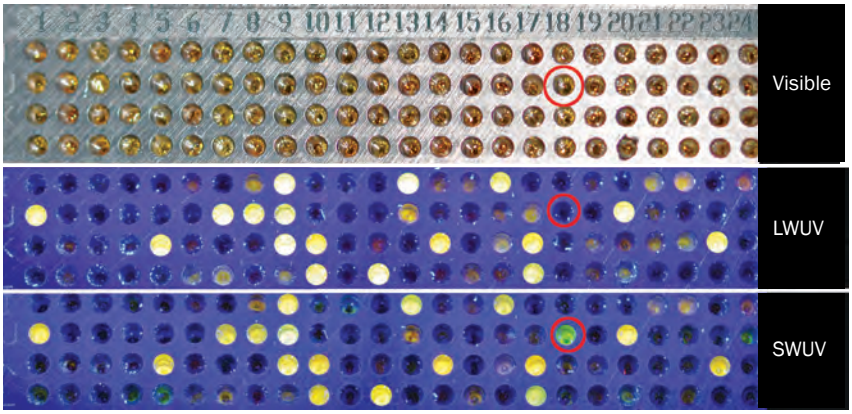
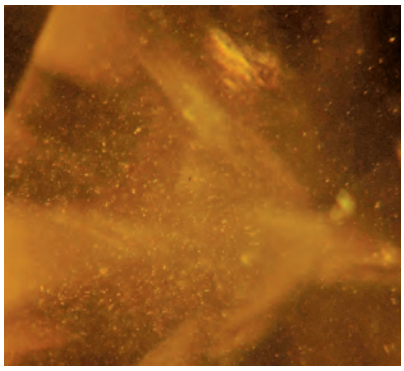


Figure 15: A portion of the melee-size diamond parcel is shown here in visible light (top) and while being exposed to long- and short-wave UV radiation (365 and 254 nm, respectively). The gem at position J18 has an intense green luminescence under short-wave UV and is inert to long-wave UV radiation. This observation raised suspicion that J18—as well as another gem in the parcel (not shown)—are synthetic diamonds. Photos by A. Delaunay.



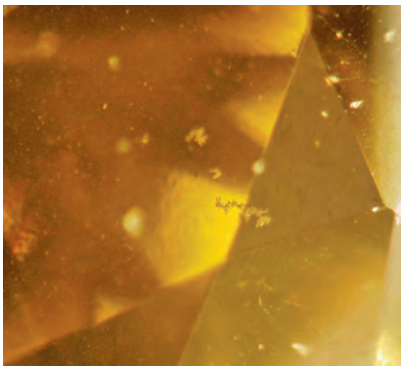


Figure 16: In the two suspect samples, clouds of pinpoints (left) or breadcrumb inclusions (right) provide further indication of synthetic origin. Photomicrographs by A. Delaunay; magnified 320×.

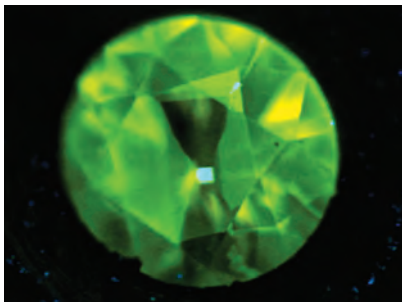


Figure 17: The DiamondView image of sample J18 (1.7 mm in diameter) is typical of synthetic diamond, with cubic and octahedral growth sectors. Photo by A. Delaunay.

radiation (e.g. the gem at J18 in Figure 15). Such behaviour may be indicative of high-pressure, high-temperature (HPHT)–grown synthetic diamond (see, e.g., Shigley et al., 1986).

The parcel was then subjected to infrared spectroscopy using a special automated batch analysis system (HTS-XT, meaning High Throughput Screening eXTension) developed in partnership with Bruker Optics (Marne-la-Vallée, France), and later patented. The spectra of the two gems tagged earlier as potentially synthetic showed them to be purely type Ib, with only isolated nitrogen impurities and no trace of hydrogen. This is typical of synthetic diamonds grown by the HPHT process, furthering our suspicions. The other stones in the parcel were all type Ia with aggregated nitrogen and often with hydrogen impurities.

Under magnification (Figure 16), one of the suspect gems revealed a cloud of pinpoints, the other breadcrumb-like inclusions. Such features, due to remnants of the metal solvent used in the growth process, are often observed in HPHT-grown yellow synthetic diamonds (see, e.g., Kitawaki et al., 2008).

To further study the two potentially synthetic diamonds, we examined their growth structures with the DiamondView, a high-energy ultra-short-wave (almost 220 nm) UV luminescence imaging device. It is well known that HPHT-grown synthetic diamonds display cubic growth sectors, in addition to the typical octahedral growth sectors seen in natural stones. Both of the gems clearly showed a central square pattern surrounded by the two types of growth sectors (Figure 17), identifying them without ambiguity as HPHT-grown synthetics.

Photoluminescence spectroscopy (e.g. Figure 18) of the two synthetic diamonds at liquid-nitrogen temperature with 514 nm laser excitation

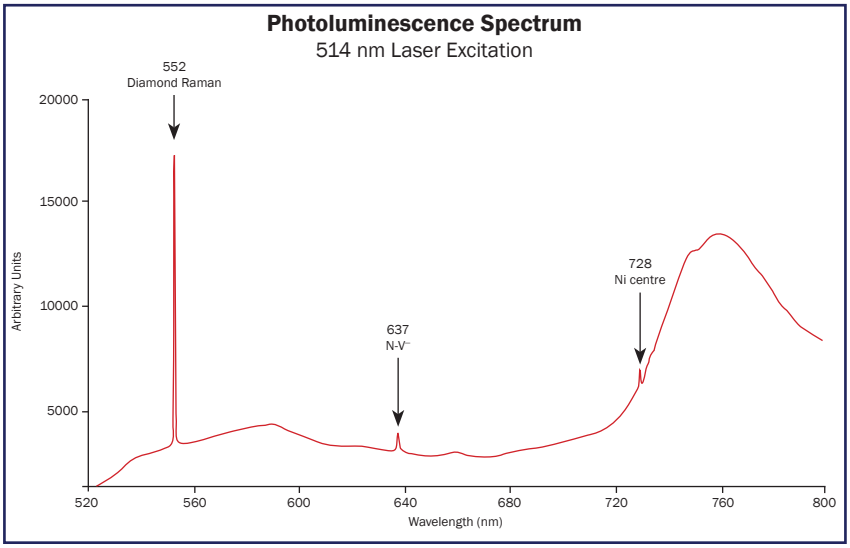


Figure 18: Photoluminescence spectroscopy of the two synthetic diamonds (here, sample J18) showed an emission at 728 nm that is due to nickel impurities. Also present is a peak at 637 nm attributed to N-V⁻ centres.

showed the 728 nm emission that is attributed to nickel impurities in diamond. Although Ni-related defects may be found in some unusual natural diamonds (see e.g. Hainschwang et al., 2013), nickel is also the most common solvent used in HPHT diamond growth. Its presence, in combination with the other characteristics described above, is proof positive that these diamonds are indeed synthetics.

These are the first synthetic diamonds ever identified in our laboratory, from more than 100,000 stones submitted. This discovery thus provides an initial indication that even with careful screening, yellow-brown synthetic diamonds are being mixed with natural diamonds on the French market.

Aurélien Delaunay and Emmanuel Fritsch

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MISCELLANEOUS

A Visit to Mogok, Myanmar

During the last week of January 2014, this author visited the Mogok area to obtain information on rare stones for a research project. The largest mine toured during this trip was operated by Lian Shan Co. and located at Ingaung village (near Kyatpyin, west of Mogok; Figures 19 and 20). Recent production has consisted of ruby, sapphire, spinel, quartz, zircon, apatite, tourmaline and topaz (e.g. Figure 21). During a visit to a small private mine east of Bamon village (located south of Mogok), the owner showed this author some nice samples of ruby in marble matrix, as well as a diverse collection of rare stones. Various mines in the area continue to occasionally produce good-quality rubies in marble (e.g. Figure 22).

A new road was taken for the trip home, which went from Mogok to Pyin Oo Lwin via Mong Long. Fine-quality orange spessartine has been produced from secondary deposits in the Mong

Figure 19: Residual deposits of gem-bearing gravels are mined from weathered karst at the Lian Shan mine near Ingaung. Photo by U Tin Hlaing.

Figure 20: The washing plant at the Lian Shan mine is fully mechanized. Photo by U Tin Hlaing.

Figure 21: Some of the recent production from the Lian Shan mine consists of spinel, quartz, blue apatite and green tourmaline. Photo by U Tin Hlaing.

Figure 22: This ruby specimen (~10 cm across) is from the Bawpadan area north of Mogok. Photo by U Tin Hlaing.

Long area (Nam Pai stream valley), along with rubellite, chrysoberyl, rose quartz, rock crystal, black tourmaline and gold. Spessartine is becoming popular in the Burmese gem market, even at half-carat sizes, and prices are increasing.

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Learning Opportunities

CONFERENCES

Annual Conference of the Scottish Gemmological Association
2–5 May 2014
Peebles, Scotland
www.scotgem.co.uk/SGAConference2014

Swiss Gemmological Society Conference
4–6 May 2014
Flüeli Ranft, Switzerland
www.gemmologie.ch/de/Aktuell.php

28th Santa Fe Symposium [of Jewellery Manufacturing Technology]
18–21 May 2014
Albuquerque, New Mexico
www.santafesymposium.org

2014 CIBJO Congress
19–21 May 2014
Moscow, Russia
http://congress2014.cibjo.org

New Diamond and Nano Carbons Conference
25–29 May 2014
Chicago, Illinois, USA
www.mrs.org/ndnc-2014

Mindat.org 2014 Conference and Field Trip: Madagascar
28 May–13 June 2014
Antananarivo, Madagascar
www.mindatconference.org

Accredited Gemologists Association Conference: Synthetic Diamonds—Prevalence, Pricing and an Inside Look at the Industry
29 May 2014
Las Vegas, Nevada, USA
http://accreditedgemologists.org

Historical Metallurgy Society Conference and Annual General Meeting 2014: Metals Used in Personal Adornment
31 May–1 June 2014
Birmingham Museum and Art Gallery, Birmingham, West Midlands
http://hist-met.org/meetings/personal-adornment.html

5th Italian Scientific Gemology Conference (CIGES 2014: V Convegno Italiano di Gemmologia Scientifica)
15–17 June 2014
Rome, Italy
http://musmin.geo.uniroma1.it/Ciges

11th International GeoRaman Conference
15–19 June 2014
St. Louis, Missouri, USA
http://georaman2014.wustl.edu

Machinery, Equipment, Technology & Supplies for Jewellery & Watch Industry (METS 2014)
25–28 June 2014
Hong Kong
www.mets.hk/en

Jewelry Television 'Gem Lovers' Conference
18–20 July 2014
Knoxville, Tennessee, USA
www.jtv.com

68th Gemmological Association of Australia Annual Federal Conference
Adelaide, Australia
26–29 July 2014
www.gem.org.au/68th_gaa_annual_federal_conference

Jewelry Camp
31 July–1 August 2014
New York, New York, USA
www.jewelrycamp.org

South American Symposium on Diamond Geology
3–7 August 2014
Patos de Minas, Minas Gerais, Brazil
www.simposiododiamante.com.br/apresentacao.htm

25th Colloquium of African Geology (CAG25)
11–14 August 2014
Dar es Salaam, Tanzania
www.cag25.or.tz
Note: Field trips will include visits to the Merelani tanzanite mines and the Williamson diamond mine.

Northwest Jewelry Conference 2014
15–17 August 2014
Bellevue, Washington, USA
www.northwestjewelryconference.com

Dallas Mineral Collecting Symposium
22–23 August 2014
Dallas, Texas, USA
www.dallassymposium.org/2014-symposium

21st General Meeting of the International Mineralogical Association (IMA2014)
1–5 September 2014
Johannesburg, South Africa
www.ima2014.co.za
Sessions:
- The Geology of Gems and their Geographic Origin
- Cratons and Diamonds
- Pegmatites and Pegmatite Mineralogy
- Africa: A Mecca of Kimberlite, Alkaline Rock and Carbonatite Geology
- Certification of Geological Materials / Analytical Fingerprint of Minerals
- Computed Tomography—Pushing Frontiers in Imaging of the Third and Fourth Dimensions
- Modern Luminescence Methods and their Application to Mineralogy
- Mineral Inclusions—Their Genesis and Fate

Field Trips:
- Cullinan Diamond Mine and Tswaing Tour
- Gem Potential Madagascar Pegmatites
- Rosh Pinah and Oranjemund Alluvial Diamonds
- Namibian Pegmatites and Industrial Minerals

International Conference on Diamond and Carbon Materials
7–11 September 2014
Madrid, Spain
www.diamond-conference.elsevier.com

Kimberley Diamond Symposium
11–13 September 2014
Kimberley, South Africa
http://ima2014.co.za/documents/kimberley-diamonds-first-announcement.pdf

Manufacturing Jewelers' and Silversmiths' Association Jeweler's Bench Conference & Trade Fair
13–14 September 2014
Warwick, Rhode Island, USA
www.mjsa.org/events_and_programs/jewelers_bench_conference_and_trade_fair

Institute of Registered Valuers Loughborough Conference
13–15 September 2014
Loughborough
www.jewelleryvaluers.org/Loughborough-Conference

77th Annual International Appraisers Conference
14–17 September 2014
Savannah, Georgia, USA
www.appraisers.org/Education/conferences/ASA-Conference

Association for the Study of Jewelry & Related Arts 9th Annual Conference and Study Day: Jewelry & Related Arts of Asia
20–21 September 2014
New York, New York, USA
www.jewelryconference.com

World of Gems IV
20–21 September 2014
Rosemont, Illinois, USA
http://gemguide.com/events/world-of-gems-conference

National Association of Jewelry Appraisers 42nd ACE-It Mid-Year Conference
22–23 September 2014
Rosemont, Illinois, USA
www.najaappraisers.com/html/conferences.html

30th International Conference on Ore Potential of Alkaline, Kimberlite and Carbonatite Magmatism
29 September–2 October 2014
Antalya, Turkey
http://alkaline2014.com

Portland Jewelry Symposium
6 October 2014
Portland, Oregon, USA
www.portlandjewelrysymposium.com

Geological Society of America Annual Meeting
19–22 October 2014
Vancouver, British Columbia, Canada
http://community.geosociety.org/gsa2014
Note: Topical Sessions titled 'Gemological Research in the 21st Century: Exploration, Geology, and Characterization of Diamonds and Other Gem Minerals' and 'Pegmatites I Have Known and Loved'

Gem-A Conference 2014
1–2 November 2014
London
www.gem-a.com/news--events/gem-a-conference-2014.aspx

GIT 2014: The 4th International Gem and Jewelry Conference
8–9 December 2014
Bangkok, Thailand
www.git.or.th/2013/index_en.html

EXHIBITS

Asia

India: Jewels that Enchanted the World
Until 27 July 2014
Moscow Kremlin Museums, Russia
www.kreml.ru/en

Urartian Jewellery Collection
Until 31 July 2015
Rezan Has Museum, Istanbul, Turkey
www.rhm.org.tr/en/events

Europe

Fabergé. The Tsar's Jeweller
Until 18 May 2014
Kunsthistorisches Museum, Vienna, Austria
www.khm.at/de/besuchen/ausstellungen/faberge

Chroma Jewellery Collective
Until 7 June 2014
Museum of the Jewellery Quarter, Birmingham, West Midlands
www.bmag.org.uk/events?id=3120

Hellhounds and Doves of Love—5,000 Years of Animal Myths in Jewellery
Until 22 June 2014
Schmuckmuseum, Pforzheim, Germany
www.schmuckmuseum.de

Silversmithing: A Celebration of Excellence
Until 30 June 2014
The Goldsmiths' Centre, London
www.goldsmiths-centre.org/whats-on/exhibitions/silversmithing-a-celebration-of-excellence

51st Sainte-Marie-aux-Mines Mineral and Gem Show
27–30 June 2014
Sainte-Marie-aux-Mines, France
www.sainte-marie-mineral.com/centre/an_centre_vis_min_exp.php
Note: Jewellery and gem exhibits will be on display during the show.

The Treasure of San Gennaro
Until 20 July 2014
Musée Maillol, Paris, France
www.museemaillol.com/expositions/tresor-de-naples/english-informations

From the Coolest Corner: Nordic Jewellery
Until 11 May 2015
The Estonian Museum of Applied Art and Design, Tallinn, Estonia
www.coolestcorner.no

North America

Turquoise, Water, Sky: The Stone and Its Meaning
Until 2 May 2014
The Museum of Indian Arts & Culture, Santa Fe, New Mexico, USA
www.indianartsandculture.org/upcoming-exhibitions&eventID=1989

From the Village to Vogue: The Modernist Jewelry of Art Smith
Until 18 May 2014
Cincinnati Art Museum, Ohio, USA
www.cincinnatiartmuseum.org/explore/exhibitions/current-exhibitions

Fabergé: A Brilliant Vision
Until 31 May 2014
Houston Museum of Natural Science, Houston, Texas, USA
www.hmns.org/faberge

Jewels, Gems, and Treasures: Ancient to Modern
Until 1 June 2014
Museum of Fine Arts, Boston, Massachusetts, USA
www.mfa.org/exhibitions/jewels-gems-and-treasures

Bangles to Benches: Contemporary Jewelry and Design
Until 8 June 2014
The High Museum of Art, Atlanta, Georgia, USA
www.high.org/Art/Exhibitions/Bangles-to-Benches.aspx

Colors of the Universe: Chinese Hardstone Carvings
Until 6 July 2014
The Metropolitan Museum of Art, New York, New York, USA
www.metmuseum.org/exhibitions/listings/2013/chinese-carving

Arts of Islamic Lands: Selections from The al-Sabah Collection, Kuwait
Until 31 August 2014
Museum of Fine Arts, Houston, Texas, USA
www.mfah.org/exhibitions/al-sabah-collection

Multiple Exposures: Jewelry and Photography
13 May–14 September 2014
Museum of Arts & Design, New York, New York, USA
http://madmuseum.org/exhibition/multiple-exposures

Arthur Koby Jewelry: The Creative Eye
Until 5 October 2015
Kent State University Museum, Kent, Ohio, USA
www.kent.edu/museum/exhibits/exhibitdetail.cfm?customel_datapageid_2203427=3506741

Bulgari: 130 Years of Masterpieces
2 May–5 October 2014
Houston Museum of Natural Science, Houston, Texas, USA
www.hmns.org/index.php?option=com_content&view=article&id=687&Itemid=722

Fabergé: Jeweller to the Tzars
14 June–5 October 2014
Montreal Museum of Fine Arts, Canada
www.mbam.qc.ca/en/expositions/a-venir/faberge

***Gems & Gemology*: 80 Years of Excellence, Featuring the Artistry of Harold & Erica Van Pelt**
19 May–December 2014
Carlsbad, California, USA
www.gia.edu/gia-museum-gems-gemology-anniversary

Cartier: Marjorie Merriweather Post's Dazzling Gems
7 June–31 December 2014
Hillwood Estate, Museum & Gardens, Washington DC, USA
www.hillwoodmuseum.org/whats/exhibitions/cartier-marjorie-merriweather-posts-dazzling-gems

Gemstone Carvings: Crystals Transformed Through Vision & Skill
On display (closing date to be determined)
Houston Museum of Natural Science, Houston, Texas, USA
www.hmns.org/index.php?option=com_content&view=article&id=481&Itemid=502

Australia

Afghanistan: Hidden Treasures from the National Museum, Kabul
26 July–16 November 2014
Western Australian Museum, Perth, Australia
http://museum.wa.gov.au/whats-on/afghanistan-hidden-treasures

OTHER EDUCATIONAL OPPORTUNITIES

American Society of Appraisers Introduction to Gems & Jewelry Appraising – Intended Use, Insurance Coverage
30 April–3 May 2014
Carlsbad, California, USA
www.appraisers.org/Education/ViewCourse?CourseID=448

2nd China Mineral & Gem Show 2014
15–20 May 2014
Changsha, China
www.chinaexhibition.com/Official_Site/11-4519-CMGS_2014_-_The_2nd_China_(Changsha)_Mineral_and_Gem_Show_2014.html
Note: Forums and 'science learning experiences' will take place.

JCK Las Vegas
30 May–2 June 2014
Las Vegas, Nevada, USA
http://lasvegas.jckonline.com/Education--Events/Events-Schedule
Note: Educational events take place 29 May–1 June.

Hong Kong Jewellery & Gem Fair
19–22 June 2014
Hong Kong
http://exhibitions.jewellerynetasia.com/6jg/fairinfo/specialevents/tabid/5294/language/en-us/default.aspx
Note: Educational presentations take place 21–22 June.

Gem-A Field Trip to Idar-Oberstein, Germany
21–28 June 2014
www.gem-a.com/news--events/events/gem-a-field-trip-to-idar-oberstein.aspx

51st Sainte-Marie-aux-Mines Mineral and Gem Show
27–30 June 2014
Sainte-Marie-aux-Mines, France
www.sainte-marie-mineral.com/centre/an_centre_vis_min_con.php
Note: A variety of workshops, seminars, film screenings and a photo contest will take place.

Gem Stone Safari Tanzania
5-22 January 2015
www.free-form.ch/tanzania/gemstonesafari.html

Galileo as Gemmologist: The First Attempt in Europe at Scientifically Testing Gemstones

A. Mottana

Galileo Galilei is credited with being one of the greatest contributors to the 'scientific revolution', particularly because of his discoveries in astronomy. He also introduced into European gemmology his 'language of mathematics' (i.e. experimental science) with the invention of the *bilancetta* (little [hydrostatic] balance). He conceived it to recheck Archimedes' determination of the gold content of a royal crown, and also used this balance to measure the mass of 23 gem samples in air and in water. However, much of his data was inconsistent with the inferred identity of his samples, since many were simulants. The results of his investigations did not circulate, and only after three centuries was Galileo's handwritten *tavola* (table) of gem data discovered.

The Journal of Gemmology, 34(1), 2014, pp. 24–31.

Introduction

In 1586 Galileo Galilei (1564–1642; Figure 1), a 22-year-old drop-out from the University of Pisa, returned to Florence and wrote a short essay describing a hydrostatic method (Figure 2) for testing precious metal alloys. He developed the technique to improve upon the methodology articulated by Vitruvius (1567, IX.10–12), who described the ancient Greek scientist Archimedes' efforts to verify the composition of the gold in the crown of King Hiero (the Greek Sicilian king of Syracuse from 270 to 215 BC). Archimedes devised a method based on buoyancy, and determined that the crown was not pure gold but rather a silver-gold alloy. Galileo did not believe in the fairly simple solution reported by Vitruvius and looked for a more sophisticated one, also based on buoyancy, but with rigorous hydrostatic constraints. He wrote his essay in Italian, in a first attempt at breaking the use of Latin as the universal language of science and scholarly pursuits. Indeed, the name *bilancetta* (little [hydrostatic] balance) plays down, perhaps intentionally, the instrument he conceived and built; his balance was far from being little, with a yoke over 1 m long. Galileo tested his new instrument on three metals (gold, silver and copper) and, seeing that it worked well, pursued additional measurements on gem materials (see below).

Galileo's results exceeded his own expectations, going beyond Archimedes' ingenuity. Even so, he set aside his manuscript (and the balance) and forgot it. Only several years later, after he had attained wide notoriety in Europe because of his discoveries in astronomy, did he allow one of his pupils (Benedetto Castelli) to copy the essay. After

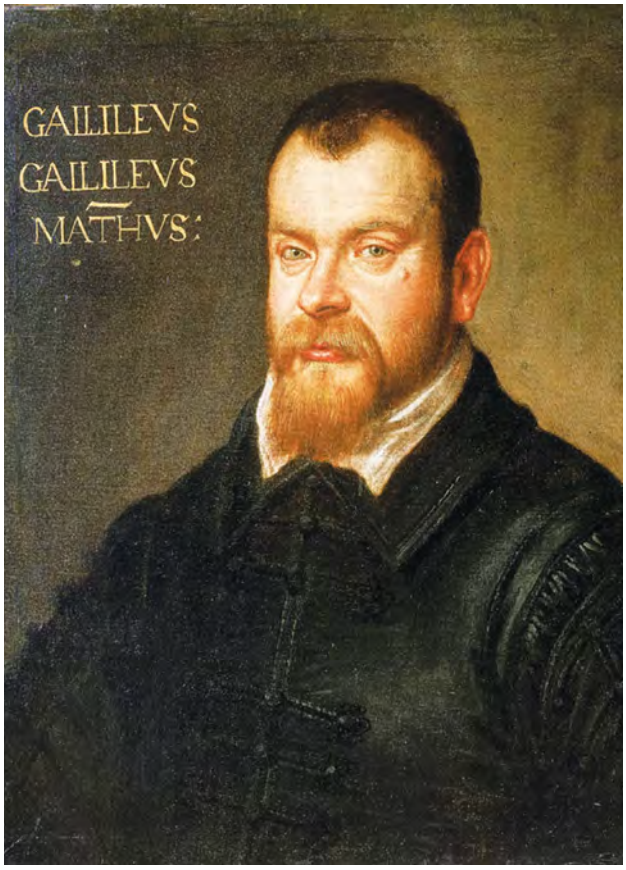


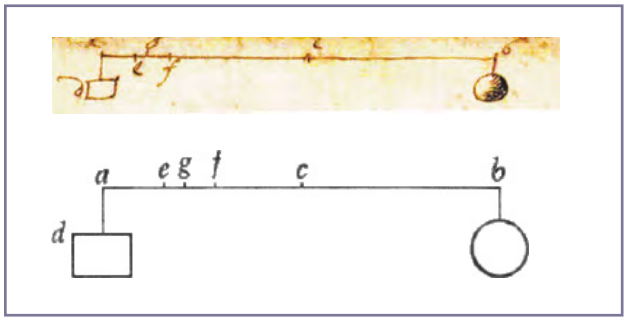
Figure 1: This portrait of Galileo as a professor of mathematics at Padua University was painted in 1605 by Domenico Tintoretto (Domenico Robusti; Venice, 1560–1635).

Galileo died, one of his followers from Palermo (Gian Battista Hodierna) dared to print it, being careful to forge a vague title to avoid stirring the suspicions of the Inquisition (Hodierna, 1644). *La Bilancetta* appeared under this title in all early editions of Galileo's *Opera* (Collected Works)—Bologna (1656), Florence (1717) and Padua (1744)—and in numerous others until the publication of the state-sponsored Edizione Nazionale (National Edition) compilation by Favaro (1890). It was not translated into a foreign language until Fermi and Bernardini (1961) published a selection of Galileo's works in English.

Archimedes' approach to verifying the composition of the gold in King Hiero's crown had stirred interest among many people, leaving them unsatisfied with the technique described by Vitruvius. The hydrostatic weighing solution suggested by Galileo generated a few imitations and improvements, as well as clever alternatives (e.g. the pycnometer made by Wilhelm Homberg in 1699 and the aerometer devised by William Nicholson in 1785). Nevertheless, that was all. Information from the Arab world—where effective instruments to hydrostatically measure gem materials had been used since the 10th century AD (e.g. by al-Rāzi, al-Bīrūnī and al-Khāzinī, just to mention a few)—had not arrived in Europe, or such knowledge was too vague to give rise to substantial practical results.

The reason for the scientific community's lack of consideration or recognition of *La Bilancetta* probably lies in an editorial blunder. When Castelli copied the essay, he omitted the three sheets containing the results originally described by his master: those that are now known as the *tavola* (table). So, when Hodierna asked Castelli for a copy of the essay, he received only the description of the instrument, but no examples of its application. The incomplete work was published by Hodierna, as well as by all subsequent compilers of Galileo's works, for almost three centuries. The *tavola* was finally discovered in 1879 by Antonio Favaro, a mathematician and science historian who was collecting everything written by Galileo and his pupils in an effort to compile an official complete edition of his work. Favaro found a few of Galileo's handwritten papers inserted in the surviving scripts preserved at the Florence National Library (Par. II. T. XVI. Car. 60–62), relating to *La Bilancetta* (Par. II. T. XVI. Car. 55). Favaro immediately published them under the title *Tavola delle proporzioni delle gravità in specie de' metalli e delle gioje pesate in aria ed in aqqua* (Table of the proportions of gravities

Figure 2: (Top) Galileo's original schematic diagram of his hydrostatic balance as it appears in his draft manuscript (Mss. Galil. Vol. 45, Car. 55v, Raccolta Palatina, Biblioteca Nazionale di Firenze) and (bottom) redrawn in the Edizione Nazionale of his collected works (Favaro, 1890, p. 217). Key: a–b = balance yoke; b = weight; c = suspension point; d = counterweight in air; e = counterpoise in water for pure gold; f = counterpoise in water for pure silver; g = counterpoise in water for a metal alloy or gem material.



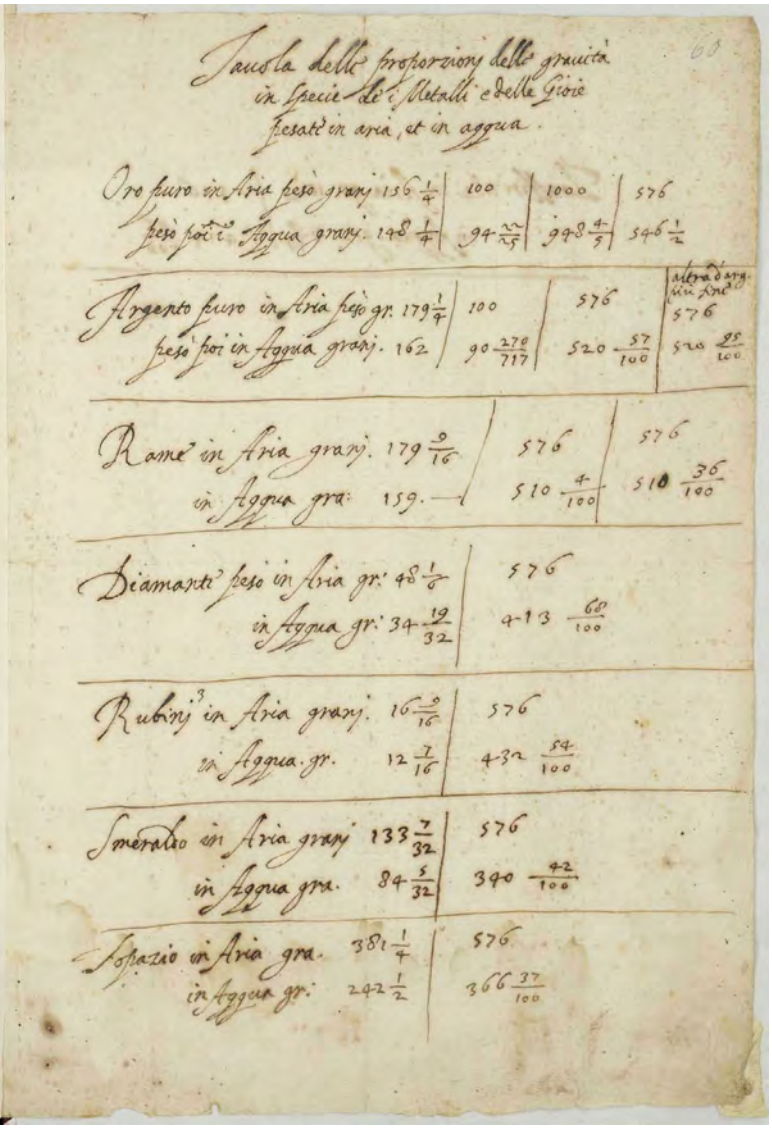


Tavola delle proporzioni delle gravità in specie de' Metalli e delle Gioie pesate in aria, et in acqua.

Oro puro in Aria peso grani 156 1/4 | 100 | 1000 | 576
peso poi in Acqua grani 148 1/4 | 94 22/25 | 948 4/5 | 546 1/2

Argento puro in Aria peso gr. 179 1/4 | 100 | 576 | ultra d'arg. fino 576
peso poi in Acqua grani 162 | 90 270/717 | 520 57/100 | 520 95/100

Rame in Aria grani 179 0/16 | 576 | 576
in Acqua gra 159. | 510 4/100 | 510 36/100

Diamanti peso in Aria gr. 48 1/8 | 576
in Acqua gr. 34 19/32 | 413 60/100

Rubini in Aria grani 16 0/16 | 576
in Acqua gr. 12 7/16 | 432 54/100

Smeraldo in Aria grani 133 7/32 | 576
in Acqua gra. 84 5/32 | 390 42/100

Topazio in Aria gra. 381 1/4 | 576
in Acqua gr. 242 1/2 | 366 37/100

Figure 3: The first hand-written page of the 'Table of the proportions of gravities especially of metals and gems weighed in air and water' by Galileo (Mss. Galil. Vol. 45, Car.60r, Raccolta Palatina, Biblioteca Nazionale di Firenze). The weighing unit was the Florentine grain (1 grain = 0.5894 gram). It was followed by additional sheets containing the results obtained during two sessions of measurements.

especially of metals and gems weighed in air and water; Favaro, 1879). Indeed, this was a slightly modernized version of the title given by Galileo himself (Figure 3). Favaro later republished the table, with trifling modifications in the numbers, in Book 1 of Edizione Nazionale (Favaro, 1890, pp. 211–212) which contains all the works by the young Galileo: the *Juvenilia* (Youth Works; cf. Castagnetti and Camerota, 2001).

Surprisingly, the publication of Galileo's experimental data did not spur scientists to a thorough analysis of the results. The one exception was the German doctoral student Heinrich Bauerreiß: in his dissertation he calculated SG values from the experimental data recorded in the table, for metals and gem materials alike. He pointed out how good the data were for the metals, but did not comment on the gems (Bauerreiß, 1914, pp. 62–64).

The Materials Studied by Galileo

Why Galileo measured the buoyancy behaviour of metals is obvious: he wanted to find a better method than the one devised by Archimedes and described by Vitruvius. For pure metals, Galileo's measurements yield SGs of 19.53 for gold (versus a calculated ideal density value D = 19.302 g/cm^3), 10.46 for silver (D = 10.497 g/cm^3) and 8.83 for copper (D = 8.930 g/cm^3). His data were quite close to the ideal calculated values, although somewhat higher for the heaviest metal and lower for the lighter ones. Such results were obtained without many of the experimental constraints required by modern methods, thus showing that the young Galileo was possibly still rather crude as an experimental scientist, but his results were trustworthy. Indeed, the scatter is less than ~1%. In addition, Galileo tested metals used for minting coins: the gold-silver alloy of an *óngaro* (Hungarian ducat) and the silver-lead alloy of a *testone* (one fourth of a Florence gold ducat, locally called a *fiorino* or florin). His data showed that their SG values were lower than those of refined metals, but within the expectation of what was then considered an honest mintage composition (~2%): their calculated finenesses were 968‰ and 987‰, respectively.

Galileo tested an even greater number of gem materials (Table I). He apparently made the measurements in two sessions, as the table consists of two parts written on separate sheets. In the first session, the paper sheet (Par. II. T. XVI. Car. 60r–60v; e.g. Figure 3) lists: *diamante* (diamond), *rubini* (ruby), *smeraldo* (emerald), *topazio* (topaz) and *zaffiri* (sapphire). In the second one, the two paper sheets (Par. II. T. XVI. Car. 61r–62v) list again the data for the same gems and, in addition: *crisolito* (chrysolite, referring to peridot), *turchina* (turquoise), *perla* (pearl), *granata* (garnet), *calcidonio* (chalcedony), *amatista* (amethyst), *aqqua marina*

Table I: The gem materials studied by Galileo, with their inferred identification via calculated SG values.[a]

Name given by Galileo	Expected SG range[b]	Weight in air (grains)[c]	Weight in water (grains)[c]	Calculated SG[d]	Inferred identification	Range of known SGs[e]
Session 1						
Diamante	3.50–3.53	48.17	34.59	3.55	Colourless topaz	3.49–3.57
Rubini 3	4.00	16.56	12.44	4.02	Ruby	4.00
Smeraldo	2.67–2.78	133.22	84.16	2.72	Emerald	2.67–2.78
Topazio	3.49–3.57	381.25	242.50	2.75	Heliodor	2.68–2.74[f]
Zaffiri 2	4.00	10.50	7.56	3.57	Blue spinel	3.54–3.63
Session 2						
Diamante	3.50–3.53	48.17	34.59	3.55	Colourless topaz	3.49–3.57
Smeraldo	2.67–2.78	133.22	84.16	2.72	Emerald	2.67–2.78
Topazio	3.49–3.57	210.34	131.19	2.66	Citrine	2.65
Crisolito	3.28–3.38	310.19	217.88	3.36	Peridot	3.28–3.38
Crisolito	3.28–3.38	68.56	40.94	2.48	Green glass	Variable
Topazio	3.49–3.57	381.25	242.50	2.75	Heliodor	2.64
Zaffiro	4.00	5.75	4.25	3.83	Gahnospinel(?)	3.54–4.00
Rubini 3	4.00	16.56	12.44	4.02	Ruby	4.00
Rubino	4.00	49.10	35.31	3.56	Red spinel	3.54–3.63
Zaffiri 2	4.00	10.50	7.56	3.57	Blue spinel	3.54–3.63
Turchina	2.31–2.84	36.75	23.31	2.73	Turquoise	2.31–2.84
Turchina	2.31–2.84	22.81	14.56	2.77	Turquoise	2.31–2.84
Perla	2.60–2.85	91.88	56.38	2.59	Pinctada sp. pearl or nacre	2.60–2.85
Perla	2.60–2.85	29.13	19.00	2.88	Strombus sp. (conch) pearl	2.18–2.87
Granata	3.78–4.10	89.77	64.88	3.61	Grossular (hessonite)	3.57–3.65
Granata	3.78–4.10	224.50	168.13	3.98	Pyrope-almandine	3.80–3.95
Zaffiro	4.00	103.38	63.25	2.58	Blue glass (or iolite?)	Variable (or 2.58–2.66)
Calcidonio	2.58–2.64	61.56	37.94	2.61	Chalcedony	2.58–2.64
Smeraldo	2.67–2.78	192.25	129.63	3.07	Tourmaline (uvite)	2.82–3.32
Crisolito	3.28–3.38	102.63	72.19	3.37	Peridot	3.28–3.38
Amatista	2.65	102.81	56.81	2.24	Purple glass	Variable
Aqqua marina tenera	2.68–2.74	65.31	41.31	2.72	Aquamarine	2.68–2.74
Cristallo	2.65	229.75	143.25	2.66	Quartz (rock crystal)	2.65

[a] *The screened rows refer to simulants.*
[b] *Expected values if the gem names given by Galileo were correct (Dominy, 2013).*
[c] *Fractions have been converted to decimals; in units of Florentine grains (1 grain = 0.5894 gram).*
[d] *Calculated here from the weights in air and water measured by Galileo.*
[e] *Empirical measurements on relevant gem-quality minerals (Dominy, 2013).*
[f] *Values reported are for aquamarine, as there are no typical SG values for heliodor given in the literature.*


LIBRI TRE
DI M. LODOVICO
DOLCE;
NE I QVALI SI TRATTA
delle diuerse sorti delle Gemme,
che produce la Natura,
DELLA QVALITA',
grandezza, bellezza, & virtù loro.
CON PRIVILEGIO.
BIBLIOTH CORSINIA VETVS
IN VENETIA APPRESSO
GIO. BATTISTA, MARCHIO
SESSA, ET FRATELLI.
BIBLIOTHECA

Figure 4: The title page of Lodovico Dolce's 1565 translation of Camillo Leonardi's 1502 book, nowhere showing the name of the true author. This is a typical case of Renaissance-style plagiarism, yet with the very effective outcome of spreading knowledge on gem materials with their proper Italian names.

tenera ('soft' aquamarine) and *cristallo* (quartz). Unfortunately no description of the samples was provided, so their transparency and rough/cut state are unknown. Only indirectly can we infer that all samples were single gems except for *rubini 3* (three rubies measured as a single sample) and *zaffiri 2* (two 'sapphires', actually spinel, again measured together). All the names used by Galileo were the current Italian gem names, which were those given by Lodovico Dolce (1565; Figure 4) when translating Camillo Leonardi's (1502) *Speculum Lapidum* (Mirror of Stones). Dolce's definitions include a description of the colour for some gems (e.g. topazio is a yellow stone), but the colours of several of Galileo's samples cannot be inferred.

The *'diamante'* measured by Galileo was not a diamond at all. He should have guessed this from the start, as the gem weighed slightly more than 48 grains (i.e. 28.3 grams or 141.5 ct), and therefore would have been extremely costly. According to de Boot (1609, pp. 128–132), a *perpolitus, & absque omni vitio* (flawless diamond) of 12 ct—which was considered to be an enormous crystal for diamond at that time—would then sell for 11,600 florins, which was the price of a very large house. A stone like that certainly did not belong either to Galileo or his family. Galileo's own perspicacity should have advised him that the man (a friendly gem dealer, possibly) who had loaned the gem to him either wanted to test his instrument or make a fool of him, considering Galileo too young for such a business. In any case, Galileo measured the stone twice and his data yield a consistent SG of 3.55. This is very close to the SG of OH-free topaz (3.56), which can have a rather similar appearance to diamond. Simulants for diamond were common in Galileo's time, and were well known to gem merchants. The main ones cited at the time were very light coloured sapphire, amethyst, chrysolite and, indeed, topaz (de Boot, 1609, pp. 117–118). All these gems, except topaz, have SG values much different from Galileo's measurements.

The reliability of Galileo's balance is strongly supported by the SG value of the next gem he tested, ruby. His data for *rubini 3* yielded an SG of 4.02, against a theoretical D = 3.989 g/cm^3, which is within the 1% error of determination. A second round of measurements on *rubini 3* gave the same value. By contrast, Galileo's data for another sample called *rubino* gave an SG value of 3.56, which does not fit with corundum, but is consistent with spinel. Most likely, this gem was a *balascio* (balas) or red spinel. *Balas ruby*, as it was sometimes called, was a very popular stone. An additional sample measured by Galileo, consisting of two blue stones named *zaffiri 2* (sapphire), yielded an SG of 3.57, also likely spinel.

It is possible that all the gem samples mentioned so far were from Sri Lanka (then known as Ceylon) or Myanmar (then Pegu), where gem-quality spinel, topaz and, to a wider extent, corundum are well known. Sri Lanka and southern India were the major sources of gems arriving in Europe through the Portuguese maritime trade, which at Galileo's time had ousted the traditional long-distance caravan route through Asia (Vassallo e Silva, 1993). A Sri Lankan origin is also supported by the fact that one of the three 'emeralds' Galileo measured

had an SG of 3.07, corresponding to uvite, which is occasionally found together with spinel in the Uva Valley gravel beds (Dunn et al., 1977).

Galileo used the names *zaffiro* and *smeraldo* for blue and green stones, respectively, irrespective of their measured values. However, two green stones did yield measurements giving SG = 2.72, which is within the range of emerald (Dominy, 2013). Another sample with the SG of beryl was referred to as aquamarine, but its description as *'tenera'* (soft) is inexplicable. As for the three samples labelled sapphires, none of them was corundum: one was a blue spinel (SG = 3.57); another was possibly a gahnospinel (SG = 3.83), which is a gem that only recently was encountered in the European market; and the third one (SG = 2.58) may have been either cobalt-blue glass or cordierite (i.e. iolite). All these gem varieties are known from some Sri Lankan basement rocks and related gravel beds (Oltean et al., 2011; Gorghinian et al., 2013). They additionally support Sri Lanka as the possible origin of some gems available in Europe during the Renaissance, although we cannot rule out the possibility of their coming from elsewhere in southern Asia.

The case of Galileo's yellow *topazio* is rather peculiar. None of the three *topazio* stones weighed by Galileo met the SG requirements of topaz: two appear to have been beryl (SG = 2.75), in the yellow variety that came to be known as heliodor in the early 20th century, and the other one apparently was citrine, the yellow variety of quartz (SG = 2.66). At that time, citrine was the most widespread yellow gem available, as it was found sparsely in the Bohemia-Saxony silver-bearing ore district. Notably, true topaz was also well known there, and was commonly mistaken for citrine if yellow or for diamond if colourless (i.e. *Adamas Bohemicus:* Bohemian diamond; de Boot, 1609, p. 219).

Quartz (*cristallo,* i.e. the colourless variety known as rock crystal) was measured by Galileo with amazing precision (SG = 2.66 versus D = 2.655 g/cm^3). The *calcidonio*, with SG = 2.61, fits well into the highly variable properties of chalcedony, which is always less dense than macrocrystalline quartz because of its porous texture. By contrast, Galileo's *amatista* was by far too light (SG = 2.24) to be amethyst; it may have been purple glass. It appears that one of his *crisolito* (chrysolite) samples was also glass, with a relatively low SG of 2.48. Glass imitations are known from Roman times and were not uncommon during the late Middle Ages, where the production of glass of various colours and forms had advanced considerably although only by empirical methods (O'Donoghue, 1997). Notably, not all *crisolito* samples measured by Galileo were imitations. Indeed, two of them had SG = 3.37, which is consistent with olivine that is intermediate in the forsterite-fayalite series (i.e. peridot).

At the time of Galileo one would already easily distinguish between massive dark blue lapis lazuli and light blue *turchina* (turquoise), which displays variable specific gravity due to its porous texture (for Galileo's samples, SG = 2.73 and 2.77). One would also be able to distinguish garnets from other red stones (Gilg, 2008), although there was not yet knowledge that garnets constitute a large group. Indeed, Galileo used *granata* (garnet) to refer to a stone that, on the basis of its SG value (3.61) might have been the orange hessonite variety of grossular, and also to another sample that could have been pyrope-almandine (SG = 3.98). In the same way, he was unable to distinguish between pearls from what were later known to be from a *Pinctada sp.* mollusc (SG = 2.59) and a *Strombus sp.* gastropod (i.e. conch; SG = 2.88).

Conclusion

Within the framework of late Renaissance gemmology, Galileo was unique as a scientifically inclined researcher, which also made him a pioneer for all Western Europe. At his time, almost all treatises on minerals and gems consisted of the mere description of a number of stones from the viewpoint of a traditional set of external characteristics such as colour, shape, transparency and hardness. Most often, this objective information would be provided with remarks on their mysterious properties, mostly of a mystical nature, which had been passed down from the Middle Ages (Mottana, 2006). Galileo introduced a scientific measurement that, eventually, would prove to add significantly to the characterization of minerals and gems (e.g. Figure 5).

In actuality, the young Galileo had no idea about specific gravity as a property of materials, nor had he developed systematic thought about it: he only conceived an instrument appropriate

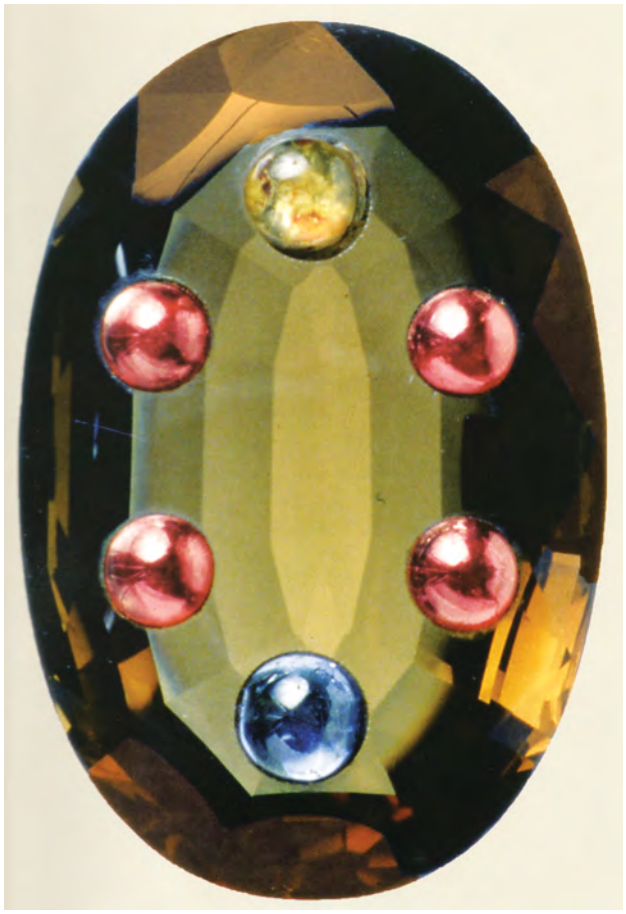


Figure 5: The Medici coat of arms, a Florentine artwork made in 1590–93 that originally decorated the front of the disassembled cabinet of grand duke Ferdinand I (1587–1609). It provides a good example of the need for scientific gemmology to be applied to historical jewels. The faceted 6 × 4 × 2 cm stone was originally believed to consist of a 'topaz of Spain' (citrine), and was set with six half-spheres of rock-crystal (four had backs painted in red, one in blue and one was left unpainted). The half-spheres simulate rubies, a sapphire and a diamond (Heikamp, 1963). The faceted stone was recently re-identified as a smoky quartz (Fantoni and Poggi, 2012, p. 54, Fig. 1). This artwork is preserved as Inv. 13201 in the historical collection of the Museo di Storia Naturale, Sezione di Mineralogia e Litologia, Università di Firenze. Photo by Saulo Bambi.

to determine if Archimedes could accurately test the composition of objects made by two alloyed precious metals, and extended its use to gem materials. He did not even describe the gem materials he measured, but apparently only took for granted the names provided by the merchant(s) who loaned or sold the samples to him, with only the precaution of checking their spelling against Dolce (1565), which was the gemmological reference book in Italian of his time (again, see Figure 4).

Galileo's hydrostatic balance was a valuable scientific innovation for Europe, where the Arabic studies on hydrostatics applied to gem materials had not filtered in yet. However, the new instrument did not continue to be used for testing gems, since neither Galileo himself nor any of his pupils and followers did so with a consistent methodology. There were indeed hydrostatic essays made and reported by innovative scientists such as Simon Stevin (1586) in The Netherlands, Gian Battista Della Porta (1589) and Marino Ghetaldi (1603) in Italy, and Francis Bacon (quoted in Davies, 1748, p. 421) in Britain in the early 17th century, but they mostly used metals for their experiments. Consequently, Robert Boyle is credited for the most significant 17th-century gemmological treatise, which includes considerations of specific gravity (Boyle, 1672).

One reason for the neglect of Galileo's attempt at testing gem materials by the hydrostatic method may be that the possible users (i.e. gem merchants) would have considered it slow and confusing. Indeed, gemmology continues to wrestle with this problem: being a branch of applied mineralogy, it must always balance the requirements of science with those of the business of gems.

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Purple to Reddish Purple Chrysoberyl from Brazil

Karl Schmetzer, Jaroslav Hyršl, Heinz-Jürgen Bernhardt and Thomas Hainschwang

Mineralogical and gemmological data of two intensely coloured chrysoberyls from Brazil are presented. Both samples are twinned, and they appear violet-purple or purple in daylight, and reddish purple or red-purple in incandescent light. They have good transparency, but appear very dark in reflected light due to their enriched chromium contents. In one sample, an average of 1.54 wt.% Cr_2O_3 was measured, together with 0.60 wt.% Fe_2O_3. The high Cr content is responsible for a reduced transmission in the blue-green range of the visible spectrum, which causes a shift in the daylight coloration from blue-green for typical Cr-bearing chrysoberyl (alexandrite) to violet-purple or purple for such samples with distinctly higher Cr values.

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Introduction

Alexandrite deposits were discovered near the town of Malacacheta in Minas Gerais, Brazil, in 1975. These secondary (alluvial) deposits are located about 20–30 km north of Malacacheta and west of Teófilo Otoni, along the Córrego do Fogo, Ribeiro Setubinha and Ribeiro Soturno rivers. Prior to the discovery of the Hematita deposit in 1987, Malacacheta was the major alexandrite-producing area in Brazil (Bank, 1986; Proctor, 1988; Cassedanne and Roditi, 1993; Basílio et al., 2000, 2001). It is situated within the so-called Eastern Brazilian pegmatite province in Minas Gerais State (Pedrosa-Soares et al., 2009).

Based on the mineral assemblages present in the secondary deposits and as inclusions in the alexandrites, a metasomatic-metamorphic formation is assumed, specifically an interaction of granite-related or pegmatitic Be-rich fluids with ultramafic rocks (Basílio et al., 2000, 2001; Pedrosa-Soares et al., 2009). This is the classic formation mechanism of alexandrite in various deposits worldwide, such as in the Ural Mountains of Russia, at Lake Manyara in Tanzania, and at the Novello Claims in Zimbabwe.

Purple to reddish purple chrysoberyl (also designated as 'red' chrysoberyl) from the Malacacheta area was briefly described by Proctor (1988) and has also been mentioned more recently as a rare gem mineral from that area (e.g. D. Schwarz, pers. comm., 2011, 2012). However, to the knowledge of the present authors, gemmological and mineralogical data for this type of reddish purple chrysoberyl are not available. Thus, the purpose of this article is to describe two chrysoberyl samples with this rare coloration (Figure 1) and to evaluate the cause of their colour.

Background

The pleochroism and colour-change behaviour of typical chromium-bearing chrysoberyl (alexandrite) recently have been studied in natural samples from various sources and in synthetic material produced by various techniques (e.g. Schmetzer and Bosshart, 2010; Schmetzer and Malsy, 2011; Schmetzer et al., 2012, 2013). The coloration and colour change of individual samples is a complex function of different parameters, mainly trace-element contents (especially Cr, but also Fe and V), crystallographic orientation and sample thickness. Different coloration is observable in polarized light (designated colours of X, Y and Z) and in non-polarized light (designated colours parallel to the a-, b- and c-axes).

Faceted alexandrites from various localities that weigh about 0.5 to 1.0 ct and are accepted in the gem trade as having a 'good' colour in daylight and incandescent light (i.e. samples that appear transparent and are not overly dark) generally contain 0.4–0.7 wt.% Cr_2O_3. Smaller faceted samples showing good colour may have up to 1.0 wt.% Cr_2O_3 (see, e.g., Bank et al., 1988; Malsy, 2010; Schmetzer and Malsy, 2011). Alexandrites with higher Cr are known, but are mostly valued as collectors' stones due to their interesting morphology and twinning, rather than for jewellery purposes. Samples from the Novello Claims in Zimbabwe, for example, reveal extremely high chromium values of up to 3.2 wt.% Cr_2O_3 (Bank et al., 1988; Okrusch et al., 2008; Schmetzer et al., 2011). In reflected daylight, this material, which in general is also heavily fractured, appears extremely dark green or nearly black. Relatively dark alexandrite is also known from the Carnaíba and Campo Formoso mining areas in Bahia State, Brazil (Couto, 2000). These crystals may contain 1–3 wt.% Cr_2O_3 (K. Schmetzer, unpublished research), but they are, in general, also heavily fractured and translucent at best.

Samples and Methods

Both of the samples described in this article (Figure 1) originated from Brazil. A twinned crystal weighing 1.91 ct that shows intense purple and colourless portions was purchased in 2006 from a local dealer in the Malacacheta area by one of the present authors (JH). The second sample, a faceted gemstone of 0.49 ct, is from a private collection and is known only as originating from 'Brazil'. According to this gem's properties, it might have also come from the Malacacheta area, but other contact metamorphic sources such as Carnaíba cannot be ruled out completely.

Figure 1: These two purple to reddish purple chrysoberyls were studied for this report, and are shown here in daylight (top) and incandescent light (bottom). The faceted stone weighs 0.49 ct and the crystal is 1.91 ct. Photos by K. Schmetzer.

The growth structures, inclusions, and coloration of both samples were studied in immersion with a horizontal gemmological microscope. Inclusions in the faceted stone were identified by micro-Raman spectroscopy. Energy-dispersive X-ray fluorescence (EDXRF) spectroscopy utilized a Spectrace 5000 Tracor X-ray spectrometer. Electron microprobe analyses were performed across the table of the faceted stone—and also on a faceted 0.11 ct alexandrite from Hematita, for comparison—with a Cameca Camebax SX 50 instrument. The Hematita sample (from the collection of author KS) appears intense blue-green in daylight and purple in incandescent light; it was selected for analysis because its thickness of 1.8 mm is somewhat comparable with that of the 0.49 ct faceted chrysoberyl of the present study (2.4 mm). Ultraviolet-visible (UV-Vis) spectra were recorded for both of the reddish purple Cr-rich samples, and for our faceted Hematita alexandrite, using a CCD-type Czerny-Turner spectrometer in combination with an integrating sphere.

Figure 2: Fibre-optic illumination of the chrysoberyl samples reveals the intense colour and transparency of both the faceted stone (0.49 ct) and the crystal (1.91 ct). Photos by K. Schmetzer.

Appearance, Mineralogical and Gemmological Properties

In reflected light, both the crystal and the cut stone appear very dark violet-purple or purple in daylight, and reddish purple or red-purple in incandescent light (Figure 1). Fibre-optic illumination shows them to be intensely coloured and transparent (Figure 2). The colour and colour variation between daylight and incandescent light resemble some dark purple or purplish red garnets of the pyrope-almandine series, or some purplish rubies.

The crystal specimen consists of a tabular contact twin with (031) or (0$\bar{3}$1) as the twin plane, as commonly observed in chrysoberyl and alexandrite. A dark, somewhat rounded core is partially surrounded by a colourless overgrowth (Figure 3). The rounding of the core indicates that a period of chemical resorption or transport and, most probably, a mechanical abrasion of the edges of the crystal took place between two different growth phases. The colourless part of this twinned crystal shows a dominant **a** pinacoid

Figure 3: The chrysoberyl crystal is colour zoned, with a dark reddish purple core and an almost colourless overgrowth; the edges of the core are somewhat rounded. Immersion, incandescent light, view parallel to the a-axis (top, crystal measures 8.8×7.7 mm) and perpendicular to the a-axis (bottom, crystal measures 8.8×3.3 mm). Photomicrographs by K. Schmetzer.

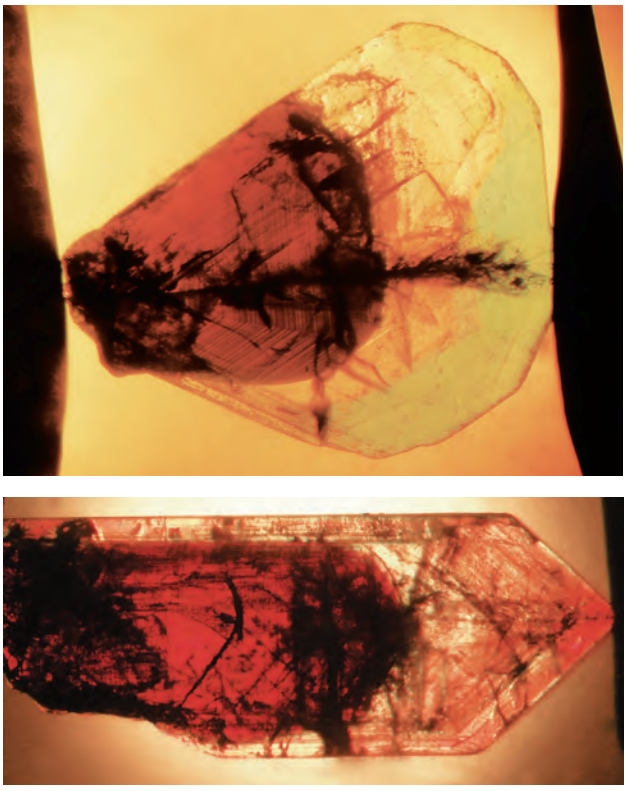


*Figure 4: This idealized crystal drawing (clinographic projection) of the twinned chrysoberyl crystal from Malaca-cheta shows a tabular habit with a dominant **a** {100} pinacoid (the other forms are listed in Table I). Drawing by K. Schmetzer.*

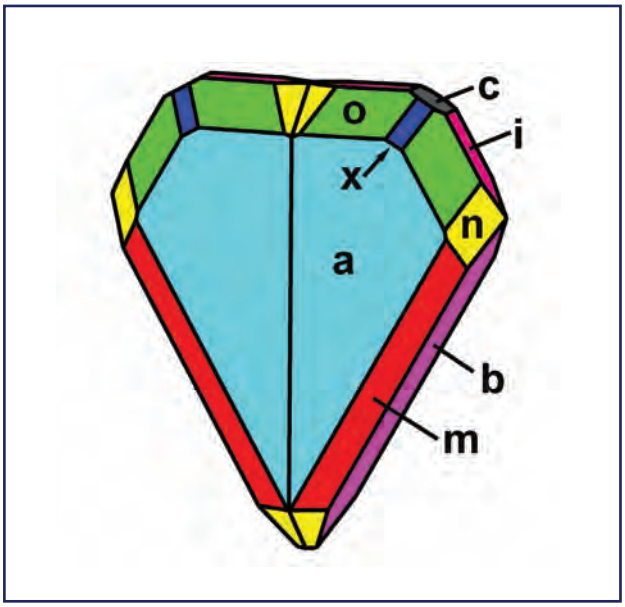


Table I: Mineralogical and gemmological properties of two Cr-rich chrysoberyls from Brazil.

Morphology*, microscopic, chemical and spectroscopic properties			
Sample	Crystal specimen, twinned 1.91 ct, 8.8×7.7×3.3 mm		Faceted gemstone, twinned 0.49 ct, 4.8×4.6×2.4 mm
	Overgrowth	Core	
Variety	Colourless chrysoberyl	Reddish purple chrysoberyl	Reddish purple chrysoberyl
Habit	Tabular after **a** {100}	Tabular after **a** {100}	Unknown
Forms	**a** {100}, **b** {010}, **c** {001} **x** {101}, **i** {011}, **m** {110} **o** {111}, **n** {121}	**a** {100} **i** {011} **o** {111}	**a** {100}, **b** {010} **i** {011}, **m** {110} **o** {111}
Mineral inclusions	None	None	Birefringent platelets (phlogopite)
UV-Vis spectrum	Fe	Cr	Cr
EDXRF spectrum	Fe	Cr, Fe	Cr, Fe
Colour and pleochroism to the unaided eye in different directions			
Daylight	Yellowish orange, blue-green, violet-purple		
Incandescent light	Purple, blue-violet, red-purple		
Colour and pleochroism for polarized light*			
	X ‖ a	Y ‖ b	Z ‖ c
Daylight	Violet-purple	Yellowish orange	Blue-green
Incandescent light	Red-purple	Reddish orange	Blue-green

** Based on a morphological cell with a = 4.42, b = 9.39 and c = 5.47 Å.*

with smaller **b** and **c** pinacoids; **x**, **i** and **m** prism faces; and **o** and **n** dipyramids (Figure 4, Table I). This morphology, especially with **c** pinacoids and **x** prism faces, represents a habit that is typical for pegmatitic chrysoberyl from many localities, such as Sri Lanka (see, e.g., Schmetzer, 2011). The internal growth pattern observed in the coloured portion consists of **i** prism faces in a direction of view parallel to the a-axis (Figure 5), and of growth faces parallel to the **a** pinacoid and parallel to the **o** dipyramid in other directions of view.

The faceted stone is also twinned, with an orientation of the twin boundary slightly oblique to the table facet, thus subdividing the table plane into two different parts (Figure 6). Growth planes showing distinct zoning associated with layers having a lighter and darker coloration (Figures 6 [left] and 7) are seen parallel to the pinacoids **a** and **b**, parallel to the prism faces **i** and **m**, and parallel to the dipyramid **o**. This chrysoberyl also contains birefringent platelets (Figure 8), identified as phlogopite by micro-Raman spectroscopy.

Similar platelets have been previously described as inclusions in Malacacheta alexandrite (Basílio et al., 2000, 2001), but they are not commonly seen in samples from Hematita (Bank et al., 1988; Pohl, 1989). The growth structures seen in Hematita alexandrite (Schmetzer, 2011; Schmetzer and Hainschwang, 2012) are also different from those described in the two reddish purple chrysoberyls. Specifically, stones from Hematita frequently show a distinct, jagged boundary between different growth zones, while growth planes within the individual zones are weak. Occasionally, this growth feature is combined with colour zoning consisting of an intensely coloured core and a lighter but not colourless rim (for further details, see the references cited above).

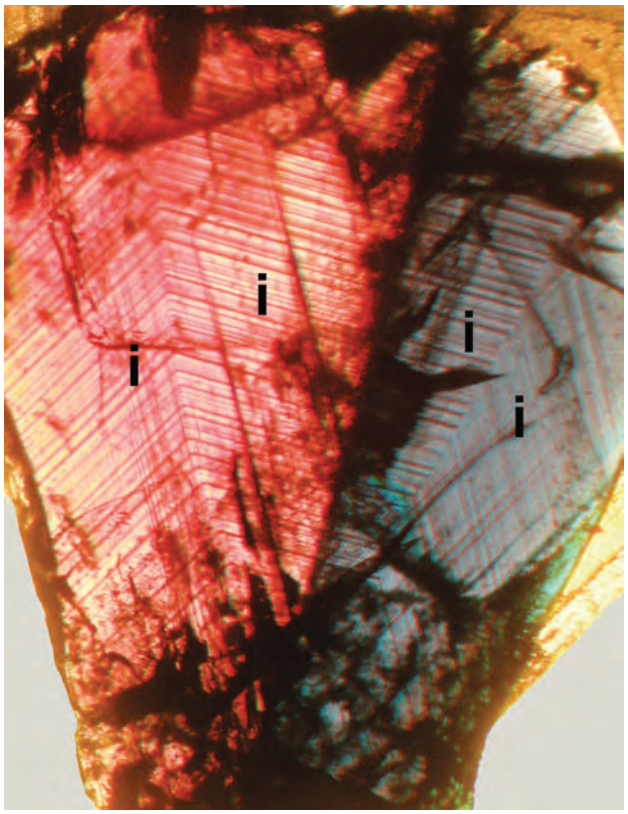
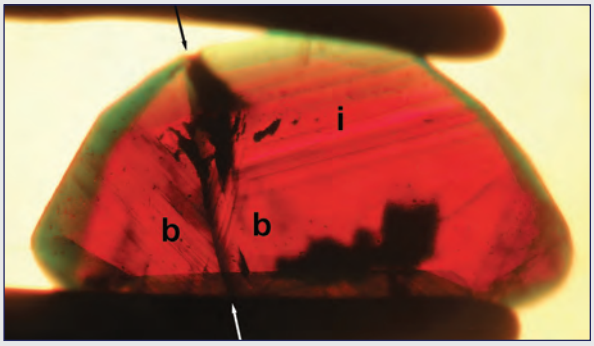


*Figure 5: This view parallel to the a-axis of the twinned chrysoberyl crystal shows growth planes parallel to different **i** (011) prism faces. Note also the pleochroism displayed by the two portions of the twin. Immersion, polarized light, field of view 5.3×4.0 mm. Photomicrograph by K. Schmetzer.*

Colour and Pleochroism

Due to the twinned nature of both samples, it is not possible without immersion microscopy to view them parallel to each of the three axes (a, b and c) in an orientation where light passes through only a single individual of the twin. In the crystal specimen in particular, it is only possible to look parallel to the a-axes of both individuals (which are parallel to each other). This view is perpendicular to the larger **a** (100) pinacoid (see again Figures 3 [top] and 4). In views perpendicular to this direction (Figure 3, bottom), the light path travels through both individuals.

In the faceted sample, the two parts of the twin show different coloration face-up in transmitted polarized light. The twin plane is slightly oblique to the table facet, and a view parallel to the a-axes of both individuals is nearly parallel to the girdle of the faceted stone (Figure 6, left). The table facet is subdivided by the twin plane into two different parts (Figure 6, right) and is oriented oblique to all three axes. For observations parallel to the b- and c-axes (i.e. oblique to the table facet), the light also travels through both individuals of the twin. In contrast, in the immersion microscope, and especially using polarized light, it is possible



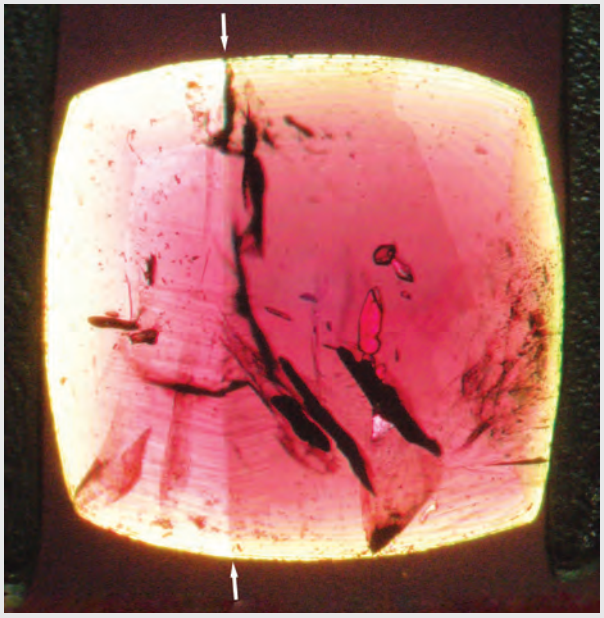


*Figure 6: Twinning, growth patterns and inclusions are seen in these photos of the faceted chrysoberyl. Left: Viewed parallel to the a-axis, which is also parallel in both parts of the twin, growth planes parallel to two different **b** {010} pinacoids and parallel to one **i** (011) prism are observed (immersion, field of view 5.3×4.0 mm). Right: Viewed perpendicular to the table facet, the twin boundary subdivides the sample into two parts of different size; the birefringent platelets are phlogopite (immersion, crossed polarizers, field of view 5.6×5.6 mm). The twin plane in both photomicrographs is marked by arrows. Photomicrographs by K. Schmetzer.*

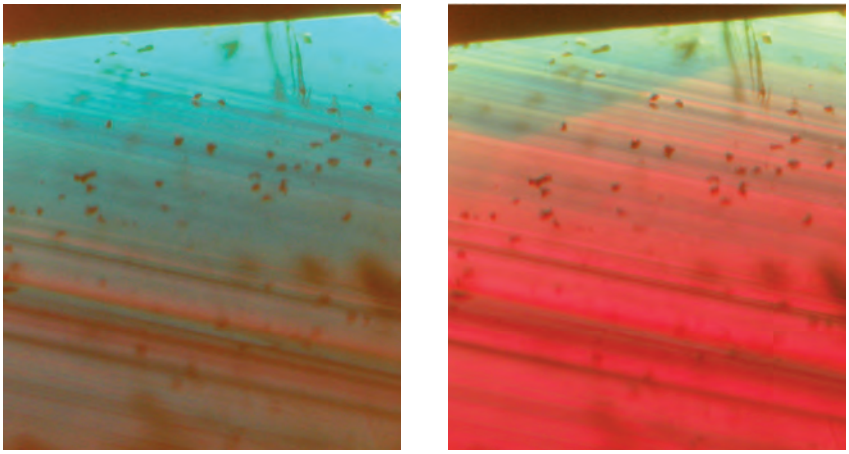


Figure 7: Growth zoning and pleochroism associated with colour zoning are seen in these images of the faceted chrysoberyl. Immersion, polarized light, field of view each 0.9×1.1 mm. Photomicrographs by K. Schmetzer.

to orient the different parts of the twin parallel to the light path in the microscope and to correctly observe the colours of X, Y and Z.

Consequently, for non-polarized light we can give just an approximate description of the pleochroism in daylight and incandescent light, since only a slight deviation from the ideal direction causes a large divergence in the colour that is visible to the observer. Observations with both polarized and non-polarized lighting are summarized in Table I.

Compared to the colour change seen in alexandrite, the most significant difference in the coloration of these Cr-rich samples is for Y in polarized light. Y is normally the lightest of the three colours, but shows the largest hue angle difference between daylight and incandescent light. For typical Cr-bearing chrysoberyl (alexandrite), Y is yellow-green or yellowish green in daylight and yellow-orange to orange in incandescent light. In contrast, for the two Cr-rich samples examined, Y is yellowish orange in daylight and reddish orange in incandescent light. The colour of X and Z, on the other hand, is less significantly changed: X is violet-purple to purple in daylight and reddish purple to purplish red in incandescent light for typical alexandrite. For our samples, the redness of X only slightly increased from daylight to incandescent light. The third colour, Z, of our samples is blue-green in both daylight and incandescent light.

Chemical and Spectroscopic Properties

Qualitative EDXRF spectroscopy of both samples generally showed strong Cr peaks and additional distinct Fe signals. The colourless part of the rough twin, however, revealed only weak Fe lines.

In Table II, quantitative electron microprobe analyses of the faceted stone are compared with data for alexandrite from the Malacacheta and Hematita areas. The analyses of the 0.49 ct faceted reddish purple chrysoberyl show a strong variation in Cr concentration across the table facet. This wide range (1.36–2.23 wt.% Cr_2O_3), which is consistent with the observed colour zoning (see again Figure 7), is quite unusual, and the average value (1.54 wt.% Cr_2O_3) is also much higher than the range of chromium contents reported in the literature for alexandrite from Malacacheta. The Fe content of this stone, on the other hand, is comparable to the values given in the literature for alexandrite from this deposit.

Figure 8: Birefringent platelets of phlogopite form inclusions in the faceted chrysoberyl from Brazil. Immersion, crossed polarizers, field of view 2.2×2.2 mm. Photomicrograph by K. Schmetzer.

*Table II: Chemical properties of a reddish purple chrysoberyl from Brazil and typical alexandrites from Malacacheta and Hematita, Minas Gerais, Brazil.**

Variety	Reddish purple chrysoberyl		Alexandrite	
Locality	Brazil		Malacacheta	
Reference	This paper		Bank et al. (1988)	Pinheiro et al. (2000); Basílio et al. (2001)
Oxide (wt.%)	Range (10 analyses)	Average	Range (7 samples)	Range (2 samples)
TiO_2	0.04–0.26	0.10	na	0.29–0.33
V_2O_3	nd–0.03	0.02	0.02–0.05	na
Cr_2O_3	1.36–2.23	1.54	0.26–0.74	0.59–0.65
MnO	nd–0.02	0.01	na	na
Fe_2O_3	0.50–0.78	0.60	0.40–0.60	0.57–0.59

Variety	Alexandrite				
Locality	Hematita				
Reference	This paper		Bank et al. (1988)	Pohl (1989)	Malsy (2010)
Oxide (wt.%)	Range (10 analyses)	Average	Range (12 samples)	Range (18 samples)	Range (46 analyses)
TiO_2	0.08–0.12	0.10	na	nd–0.34	na
V_2O_3	0.01–0.03	0.02	0.01–0.03	nd–0.11	0.01–0.02
Cr_2O_3	0.58–0.66	0.63	0.30–0.50	0.03–0.64	0.05–0.55
MnO	nd–0.01	0.01	na	na	na
Fe_2O_3	1.11–1.16	1.13	0.87–1.59	0.63–1.61	0.71–1.39

** Abbreviations: na = not analysed, nd = not detected. All analyses are by electron microprobe except for those of Malsy (2010), which are by laser ablation–inductively coupled plasma–mass spectrometry.*

The Cr content of our intense blue-green/purple alexandrite from Hematita is at the upper range measured for material from this important Brazilian deposit. This is understandable since the other studied samples were described as having varying colour intensities, some of which were substantially lighter than our stone. In addition, our stone was a relatively small sample of only 0.11 ct. In general, the Fe contents measured for the different samples from Hematita are higher than those observed for alexandrite from the Malacacheta area.

The absorption spectra of the faceted reddish purple chrysoberyl and the analysed alexandrite from Hematita (Figure 9) both show the known Cr^{3+} absorption bands of chrysoberyl, with some additional weak Fe^{3+} bands in the spectrum of the Hematita alexandrite. The spectrum of the dark part of the colour-zoned crystal specimen was similar to the spectrum of the faceted reddish purple chrysoberyl depicted in Figure 9, while the colourless portion showed only some weak Fe^{3+} absorption lines. This is consistent with the chemical data of both samples (Tables I and II).

The main difference in the spectra of the reddish purple chrysoberyl and the alexandrite from Hematita is an elevated intensity of the Cr^{3+} absorption. This difference is caused by the enriched Cr contents of the reddish purple material, which is more than twice the value measured for the Hematita alexandrite. The elevated intensity of the Cr^{3+} absorption bands results in a distinctly lower transmission for the absorption minimum at about 490 nm in the blue-green range.

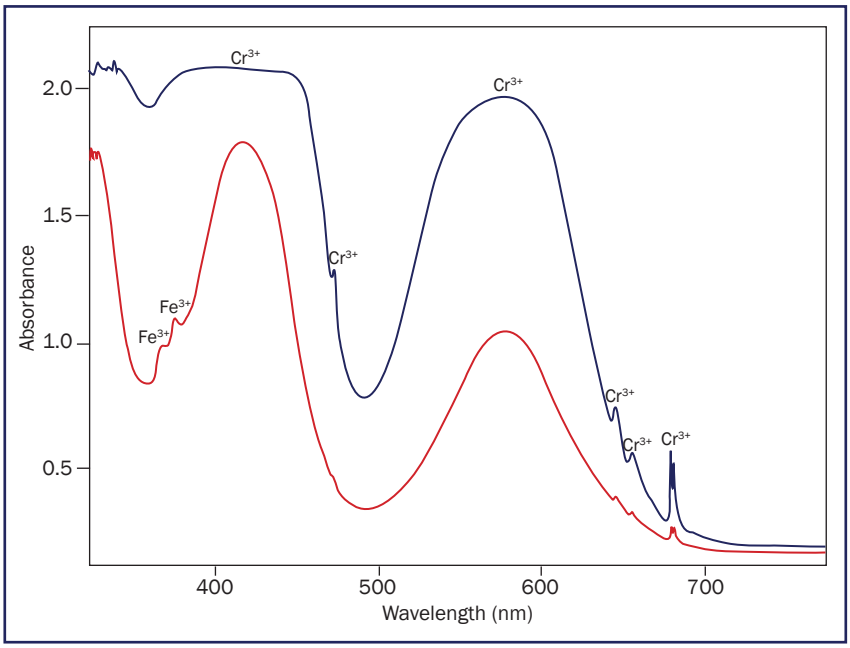


Figure 9: UV-Vis absorption spectra are shown for a faceted alexandrite from Hematita, Brazil, with an average of 0.63 wt.% Cr_2O_3 (red line, sample thickness 1.8 mm) and a faceted reddish purple chrysoberyl from Brazil with an average of 1.54 wt.% Cr_2O_3 (blue line, sample thickness 2.4 mm). In the sample with higher Cr, the transmission in the blue-green range at about 490 nm is distinctly reduced.

Discussion

The external morphology and internal growth patterns of the faceted gemstone and the dark reddish purple portion of the crystal specimen are consistent with the properties of alexandrites from Malacacheta (K. Schmetzer, unpublished research). The inclusions seen in the faceted stone are also similar to those documented in alexandrite from this locality, as are the Fe contents (Basílio et al., 2000, 2001). The famous Hematita deposit can most probably be excluded as a possible origin for both Cr-rich samples due to their inclusion pattern, growth structures and trace-element contents.

Colourless chrysoberyls are very rare; they are known mainly from Mogok, Myanmar, and from Sri Lanka. A colourless overgrowth on a dark, high-chromium core was not previously known to the present authors. The growth structure of the colourless portion is typical for chrysoberyl of pegmatitic origin.

The intense coloration of these chrysoberyls in daylight and incandescent light is a result of their enriched Cr contents. Even higher Cr contents are known for samples from the Novello Claims (Zimbabwe) and from Carnaíba and Campo Formoso (Brazil). Recently, the Cr analogue for chrysoberyl [$BeAl_2O_4$] was discovered in the famous Mariinsky mine (also called the Malysheva deposit) in the Ural Mountains, and named mariinskite [$Be(Cr,Al)_2O_4$]. With a chromium content of 58 wt.% Cr_2O_3 (Pautov et al., 2013), this material shows that replacement of even far greater percentages of Al by Cr is possible in the crystal structure of chrysoberyl.

For typical chrysoberyl, in both daylight and incandescent light it is known that with increasing thickness of a sample (which produces a correspondingly longer path of light travelling through the stone), the redness likewise increases in all three directions of view (i.e. parallel to the a-, b- and c-axes; Schmetzer et al., 2013). In the present samples, a similar effect is observed, which here is caused by enriched Cr. In the visible range, the transmission in the blue-green area of the spectrum is distinctly reduced, as compared to the absorption spectra of typical alexandrite that shows a good colour change.

Conclusion

The high Cr contents of the studied chrysoberyls cause a distinct change in transmission in the blue-green spectral range. In typical alexandrite showing a good colour change, the transmission in this area is balanced with the transmission in the red, causing the colour change between daylight and incandescent light. For reddish purple chrysoberyl with enriched Cr, this balance is not present, and the consequence is an increase in the redness of the colour in both daylight and incandescent light. In daylight, this increase in redness causes a dramatic change in the overall coloration of a sample, but in incandescent light this effect is less noticeable to the observer.

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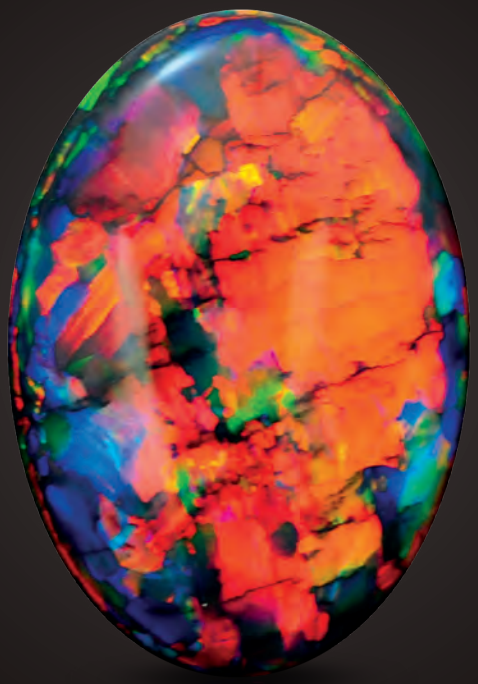
The Fire Within

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

– Roman Elder Pliny, 1st Century AD



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JOG

Identification Characteristics of Natural and Imitation Hornbill Ivory

Jie Liang, Haibo Li, Taijin Lu, Jun Zhang, Meidong Shen and Jun Zhou

Natural hornbill ivory (from the bird *Rhinoplax vigil*) is a rare gem material, and in recent years imitations and composites have appeared on the Chinese gem market. In this study, the gemmological properties of these products were systematically investigated using microscopic observation, FTIR spectroscopy and UV fluorescence. The key identification features for natural hornbill ivory are a layered structure with minute pigmented dots, which were not present in polymer resin imitations. Air bubbles were detected in both the imitations and in composites made from hornbill ivory and resin. FTIR spectroscopy is useful for confirming the presence of resin.

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Introduction

Hornbill ivory is an attractive organic gem material derived from the colourful casque of the bird *Rhinoplax vigil*, also called the helmeted hornbill. The bird is native to Southeast Asia, particularly the Malay Peninsula, and also Sumatra and Borneo in Indonesia (Brown and Moule, 1982). The male hornbill grows a large beak and a solid casque that is composed of keratin, which is typically pale orangey yellow with a thin outer red layer. The casque, which is a large protuberance covering a portion of the head and bill (Kane, 1981), has been carved and polished into ornamental objects and jewellery pieces. Although referred to as hornbill 'ivory', the material has no relation to mammal tusks or teeth, and the name is only an expression of the material's resemblance to ivory (Espinoza and Mann, 1991).

Rhinoplax vigil is a near-threatened species (International Union for Conservation of Nature, 2012) that is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). It is illegal to trade in specimens of species listed in CITES Appendix I, except under exceptional circumstances (see www.cites.org/eng/app/index.php).

Hornbill ivory is named *Hedinghong* in Mandarin Chinese which means the red part of the red-crowned crane. This beautiful name refers to the bright red colour present on some samples (e.g. Figure 1). The earliest full description of the bird *Rhinoplax vigil* in ancient Chinese history dates back to the Ming Dynasty (1368–1644; Zheng, 1947). However, the use of hornbill ivory in decorative arts probably dates back much earlier than this record (Brown and Moule, 1982).

The material was carved into various art objects and incorporated into belts for men, personal seals and jewellery items (e.g. Hurwit, 1997). Its historic popularity in China was due to its rarity, beautiful colorations, and its ability to take a fine polish. The material shows a subdued waxy lustre, which is similar to elephant ivory (Zhang, 2006) and rhinoceros horn.

Today hornbill ivory is an unusual and precious organic gem material that is generally unknown in the modern gem industry. Nevertheless, with the growth of the jewellery market in China over the last few years, new gem materials continue to appear and some old-fashioned products such as hornbill ivory are being seen again.

Given the protected status of *Rhinoplax vigil*, the authors oppose any trade in contemporary hornbill ivory; the purpose of this article is to aid in the identification of hornbill ivory from a gemmological point of view. For this purpose, hornbill ivory is compared to its polymer resin imitations, and also to recently encountered composite specimens made with natural yellow hornbill ivory and red resin.

Figure 1: Hornbill ivory is a rare gem material that has been fashioned into a variety of decorative objects and jewellery, such as this beaded bracelet (average 17 mm in diameter; sample no. 8 in Table I). Three of the beads turned out to be composites made of genuine hornbill ivory and red resin. Photo by Jie Liang.

Samples and Methods

For this study, the authors obtained eight samples (some of which consisted of multiple pieces) from various Chinese collectors. These included hand-carved art pieces, beaded bracelets, loose beads, hornbill raw material and a sawn fragment (see Table I and Figure 2). The authors also visited international exhibitions and marketplaces to make visual observations of several samples that consisted mostly of beaded bracelets and carved pieces of varying weight and form.

Standard gemmological testing was carried out at the National Gemstone Testing Center Laboratory in Beijing. All samples (including each bead in samples 2, 7 and 8) were observed with microscopy and a long- and short-wave UV lamp. Microscopy employed various light sources, using a GIA tripartite microscope with an electronic camera, and a Keyence VHX-600 microscope equipped for three-dimensional observation. The Keyence microscope can be used to observe surface and internal features down to the micron scale, and can take photographs. All polished samples were tested with the refractometer using the distant vision technique. Mid-infrared spectral analysis was performed on all samples (including each bead of each bracelet) with a Nicolet 6700 FTIR spectrometer in the range of 4000–400 cm^{-1}, with a resolution of 4.0 cm^{-1} and 16–64 scans (with the minimum number of scans needed to get high-quality spectra). Several points on each sample were analysed, especially in different colour regions.

Results

During the course of our investigation, it became clear that while some samples were genuine hornbill ivory, others consisted of polymer resin imitations or composites of natural hornbill ivory with polymer resin (Table I). The resin identification was confirmed by IR spectroscopy.

Colour, Lustre and Structure

The genuine hornbill ivory varied from pale to bright yellow and orangey yellow with a red patch on one side of the carvings or beads. These

Table I: Gemmological characteristics of hornbill ivory, plastic imitations, and composites.[a]

Sample no.	Type	Size/weight	Colour	Lustre and transparency	RI[b]		UV fluorescence		Identification
					Y	R	Long-wave	Short-wave	
1	Carving	50×30×30 mm	Patchy yellow and vivid patchy red	Waxy Translucent to opaque	1.52	1.53	Y: moderate bluish white R: inert	Y&R: inert to very weak	Natural, except red dot on forehead was artificial
2	Bracelet (14 beads)	20 mm in diameter	Patchy yellow; each bead had a round red spot	Waxy Translucent to opaque	1.54	1.53/1.48	Y: inert to weak whitish blue R: weak–moderate bluish white	Y&R: inert to very weak	All yellow portions were natural; all red spots except one were composite
3	Bead	12 mm in diameter	Yellow with red spot, both patchy	Highly waxy Translucent	1.52	1.53	Y: inert R: weak–moderate bluish white	Y: inert R: inert to very weak	Natural
4	Carving	115×35×10 mm/ 23.53 g total	Orangey yellow and patchy red with some dark brown streaks	Waxy Translucent to opaque	-	1.54	Y: inert R: moderate bluish white	Y: inert R: weak	Natural
5	Sawn fragment	35×8 mm; 1.28 g	Orangey yellow, with vivid red ends	Dull waxy Translucent to opaque	-	-	Y: whitish R: moderate bluish white	Y: inert R: weak bluish white	Natural
6	Raw material	~200×125 mm; 190.47 g total	Yellow and patchy red	Waxy Opaque	-	-	Y: inert R: moderate bluish white	Y: inert R: weak	Natural
7	Bracelet (14 beads)	16 mm in diameter avg.	Orangey yellow (patchy) and vivid red (mostly even)	Waxy Translucent to opaque	1.54/1.49	1.52/1.48	Y: inert to very weak bluish R: inert to weak bluish white	Y: inert to very weak R: inert	Only one bead was natural; others were imitations
8	Bracelet (14 beads)	17 mm in diameter avg.	Patchy yellow and dark brownish red	Waxy Translucent to opaque	1.51-1.52	1.53/ 1.48-1.49	Y: inert to strong whitish R: inert to moderate bluish	Y: inert R: weak bluish	11 were natural and three were composites

[a] *Abbreviations: Y = yellow and R = red part of sample.*

[b] *Lower values (1.48–1.49) correspond to polymer resin imitations.*

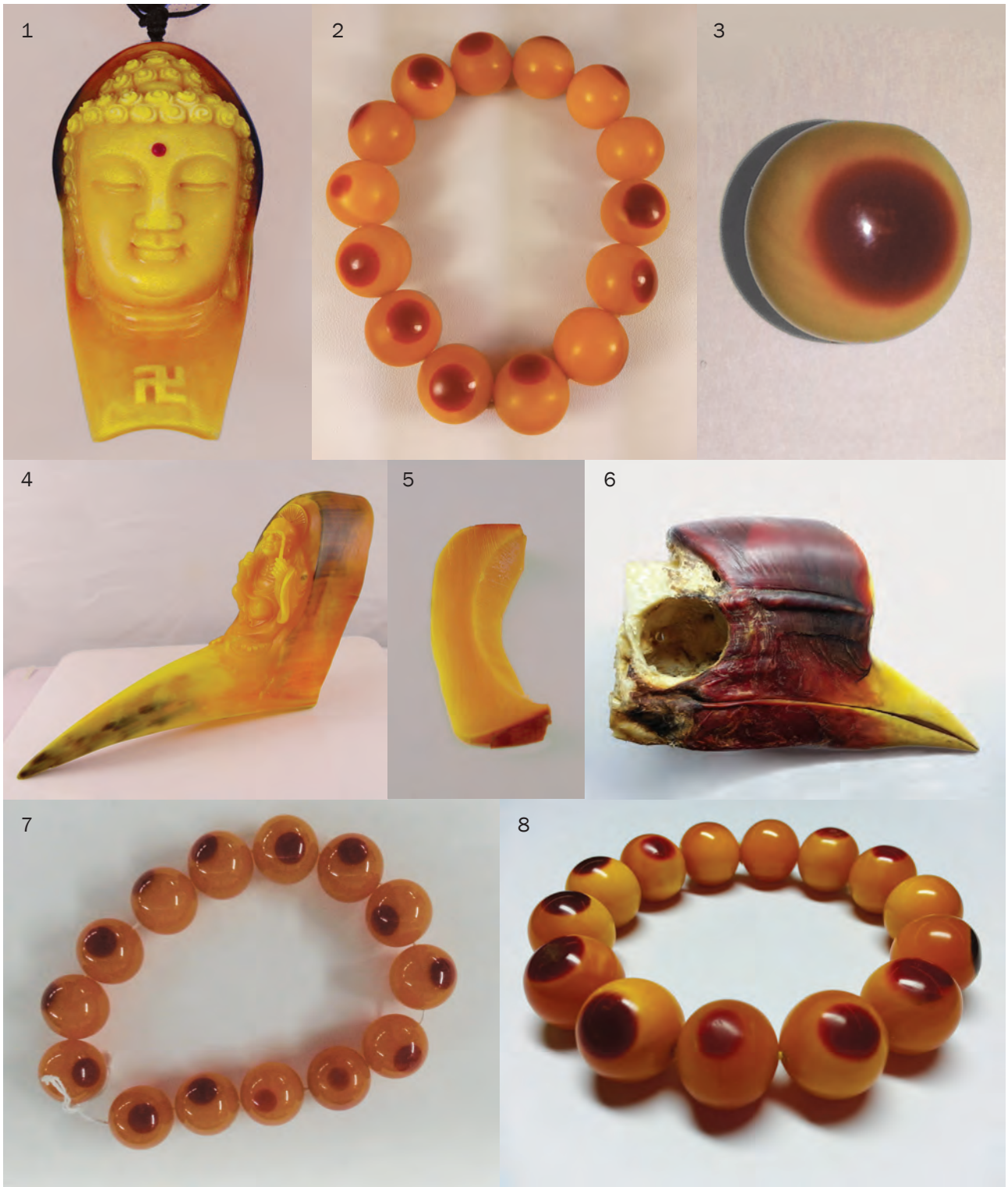


Figure 2: Eight samples were examined for this study: (1) a hand-carved pendant with a Buddha motif that is mostly orangey yellow with a red portion framing the upper part of the head, and a red dot added to the forehead (50×30 mm); (2) a beaded bracelet showing bright red patches (each bead is ~20 mm in diameter); (3) a single loose bead (12 mm in diameter); (4) a hand-carved art piece made from a beak and associated casque which has been polished so the red layer is very thin, producing a paler red colour (115×35 mm); (5) a sawn fragment with red patches at both ends (35×8 mm); (6) the beak, casque and part of the skull of a hornbill (~200×125 mm); (7) a beaded bracelet with most pieces showing even yellow and red coloration (average 16 mm in diameter); (8) a beaded bracelet displaying colour patches that are mostly brownish and dark red (average 17 mm in diameter). See Table 1 for the identification of each sample as natural, imitation or composite. Photos by Jie Liang.

patches commonly ranged from light pinkish red, dull red and brownish red to vivid red, and in some samples they were very dark brownish red (nearly brown-black). The best colours after polishing were bright orangey yellow with vivid red. The coloration of the resin imitations was quite similar (typically orangey yellow and vivid red), but more even.

The genuine hornbill ivory samples displayed a waxy lustre, and were translucent to nearly opaque. By comparison, most of the resin imitations had a highly waxy to vitreous lustre and were mostly translucent.

Important differences were seen in the structural features of the hornbill ivory and the resin imitations. The yellow portion of the hornbill ivory was layered (Figure 3), resembling the growth structure of shells. The layers were of variable thickness and were marked by differences in transparency and saturation of the yellow colour. The layers were not always perfectly parallel; some were wavy and others displayed intersections at various angles. The red portions of the hornbill ivory also displayed layered growth (e.g. Figure 4), which was more easily observed in the unpolished raw material and/or larger carved pieces with red areas preserved. In the beads, the layered structure was not always observed in the red portion. However, the boundary between the red and yellow areas may show dark brown striations (e.g. Figure 5, left). In addition, there were commonly small cracks oriented almost perpendicular to these dark brown striations. By contrast, the resin imitation did not show any layered structures, brown striations or small cracks.

Microscopic Characteristics

Observed with the microscope using low magnification, the colour boundary in the hornbill ivory appeared vague. At higher magnification, the more translucent samples showed pigmented spots along the boundary between the two colours (Figure 5). These tiny dots were yellow in the yellow region and red or brownish red in the red part (or dark brown in the brown coloured patches).

The imitation hornbill ivory showed a sharp colour boundary in the full-resin beads, and only a somewhat sharp boundary in the hornbill-resin

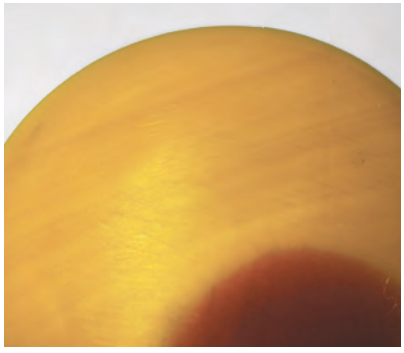
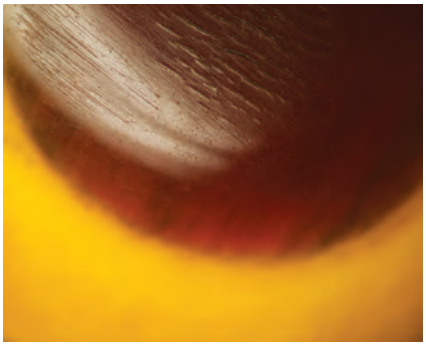


Figure 3 (top left): A layered structure is apparent in this bead of hornbill ivory (sample no. 3; 12 mm in diameter). Photomicrograph by Jie Liang; magnified 10×.

Figure 4 (bottom left): The layered structure of hornbill ivory is obvious in unpolished sample no. 6 (125 mm tall). The red colour forms a thin layer over the yellow core. Photo by Jie Liang.

Figure 5 (below): On the left, a hornbill ivory bead from sample no. 8 shows tiny yellow-pigmented dots, which are easiest to observe along the colour boundary; note also the underlying brown striations in this area. On the right is a composite bead from sample no. 2, which displays a sharp curved boundary between the hornbill ivory (top) and the resin (bottom). Air bubbles in the resin create a sponge-like structure, while tiny red- and yellow-pigmented dots are visible in the hornbill ivory. Photomicrographs by Jie Liang; magnified 12.5× (left) and 20× (right).



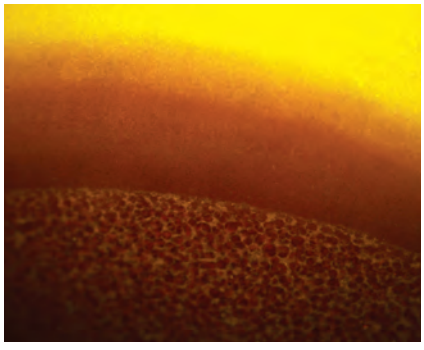


Figure 6: This imitation hornbill ivory bead from a bracelet (sample no. 7; 16 mm in diameter), shows a sharp and regular colour boundary. It appears that the red portion was set into the yellow area and then the sample was fashioned into a bead. Photo by Jie Liang.

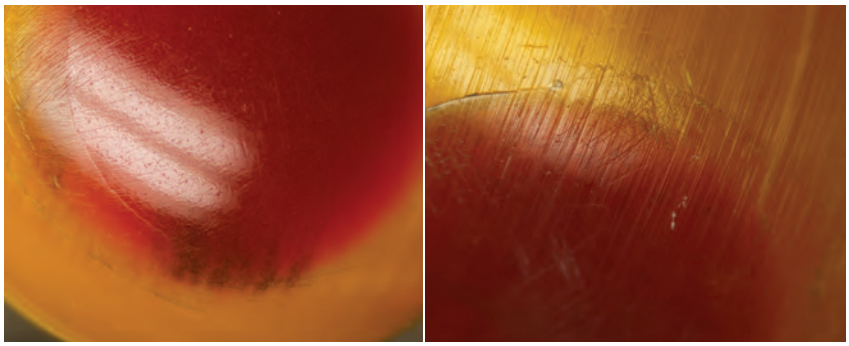


Figure 7: These beads from sample no. 8 (16 mm in diameter) proved to be composites of hornbill ivory (orangey yellow) and resin (red). Both show the boundary with the resin as a distinct line in reflected light. In the left photo, a small amount of red hornbill ivory was retained, with resin added on top of it; note the higher lustre in the resin. The sample on the right shows distinct polishing lines on both the hornbill and resin portions, and the boundary is clear. Photomicrographs by Jie Liang.

composites (Figures 6 and 7). In both of those products, a distinct line could be seen with reflected light on the beads' surface, which corresponded to the boundary between the two coloured areas. Careful observation of the resin with transmitted lighting showed a grainy sponge-like structure due to the presence of numerous minute air bubbles, as well as larger and more distinct bubbles (Figure 8). These features provide proof of artificial origin.

Other Gemmological Properties

RI readings taken from the hornbill ivory were significantly higher (1.51–1.54) than those measured from the resin (1.48–1.49; Table I). In addition, most hornbill ivory samples showed some areas of whitish blue to bluish white UV fluorescence (stronger to long-wave [Figure 9] than short-wave UV), while the resin was inert.

Infrared Spectroscopy

Both the yellow and red parts of the hornbill ivory samples showed the same absorption bands, at 3300–2860 cm^{-1} and 1750–1200 cm^{-1}, with the strongest absorption at ~1650 cm^{-1} (Figure 10, top). The imitations showed a series of absorption bands that were different from the natural material, with the strongest at 1730 cm^{-1} (Figure 10, bottom). Spectra from the imitations were consistent with polymer resin (Wang et al., 1990).

Identification Features

Identification criteria are summarized in Table II. All of the imitations examined in this study had a red colour patch. Material showing such coloration should be carefully screened. In natural hornbill ivory, the red area (if present) is restricted to a thin outer layer surrounding the orangey yellow core. The amount and distribution of any red patches in carved or otherwise polished samples should be consistent with this distribution in the raw material. In addition, red patches that are deeply coloured or show an even vivid red colour should arouse suspicion.

Figure 8: The red (resin) portion of these composite beads from bracelet sample no. 2 displays a grainy sponge-like structure due to the presence of numerous minute air bubbles. Larger bubbles are also visible in the image on the right. Photomicrographs by Taijin Lu (left, magnified 10×) and Jie Liang (right, magnified 12.5×).

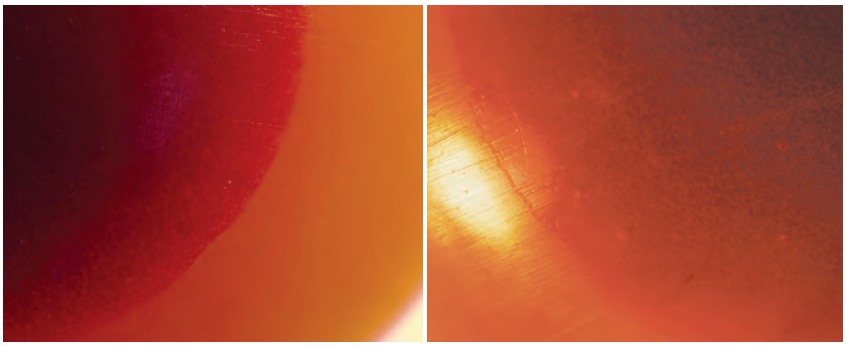


Figure 9: Sample no. 4 is shown here in incandescent light (left; photo by Jie Liang) and under long-wave UV radiation (right; photo by Haibo Li). The main orangey yellow portion is inert, while the thin red edge of the sample displays moderate bluish fluorescence.

A layered structure is a key diagnostic feature of hornbill ivory. Microscopic observation shows a diffuse boundary between the orangey yellow and red colours in hornbill ivory, whereas this boundary appears sharper in imitations and composites. The resin used for those materials also displays a grainy sponge-like appearance, as well as distinct air bubbles.

FTIR spectroscopy can be used to confirm the presence of resin, either forming entire samples or in composites together with genuine hornbill ivory.

Conclusions

Like elephant ivory and rhinoceros horn, trade in hornbill ivory is presently illegal due to the protected status of these species. In recent years resin imitations of hornbill ivory have entered the market, but they are straightforward to identify. All the imitations tested for this study consisted of polymer resin.

The most effective methods to identify hornbill ivory are microscopic observation and

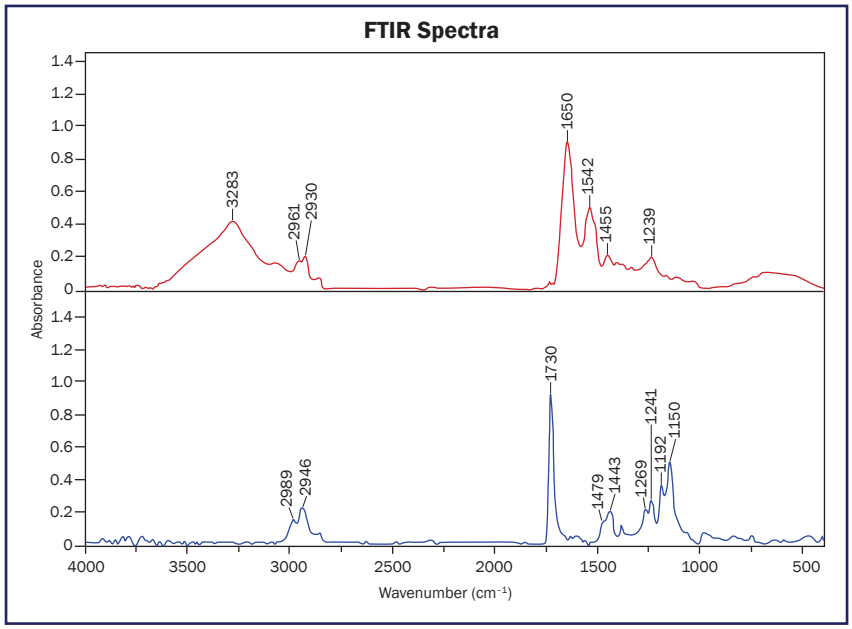


Figure 10: The FTIR spectrum of hornbill ivory (top, from sample no. 6) is distinctive from the spectrum of a resin imitation (bottom).

Table II: Gemmological properties of natural hornbill ivory, its resin imitation and composite material.

	Natural	Resin	Composite
Colour	Patchy, in orangey yellow and red	Even yellow and red colour	Yellow: often patchy Red: even
Diaphaneity	Translucent to opaque	Translucent	Translucent to opaque
Structure	Layered	Grainy, sponge-like	Yellow: layered Red: grainy, sponge-like
Microscopic features	Tiny pigmented dots that are more obvious at the colour boundary	Air bubbles	Yellow: tiny coloured dots Red: air bubbles
RI	1.51–1.54	1.48–1.49	Yellow: 1.51–1.54 Red: 1.48–1.49
UV fluorescence	Inert or weak-to-moderate, bluish white and whitish blue	Inert	Yellow: Inert or weak-to-moderate, bluish white and whitish blue Red: Inert
IR features	Main band at 1650 cm^{-1}; smaller bands at 3300–2860 cm^{-1} and 1750–1200 cm^{-1}	Main band at 1730 cm^{-1}	Combination of natural and resin features

FTIR spectroscopy. Other tests, such as RI and UV fluorescence observations, provide additional distinguishing criteria but not conclusive identification.

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Detection of Ruby Crystals in Marble Host Rock by X-ray Computed Tomography

Antonia Bouts

X-ray computed tomography (CT) is a technique that is most commonly used in the medical field to visualize the internal organs and structures of the human body. To investigate whether a medical CT instrument can be used to detect gems inside their host rock, a piece of ruby-bearing marble was imaged with CT. The scanning indicated the presence of a ruby inside the specimen, and this was confirmed by slicing the sample in half, which revealed a ruby crystal at the predicted location within the marble.

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Introduction

Most imaging techniques in gemmology have been developed to analyse the properties of a gemstone (or pearl) itself and to examine its inclusions. However, little research has been done on detecting the presence of gems inside their host rock. Some gems mined from primary deposits—such as marble-hosted ruby (e.g. Figure 1), schist-type emerald and others—may not be directly visible without crushing or sawing the rock in which they formed, which could lead to breakage or damage of valuable gem material.

This study investigates whether X-ray computed tomography (CT) can be used to reveal the presence of a gem within its host rock, using instrumentation developed for medical applications. CT is a non-destructive technique that visualizes the internal structure of objects, and is dependent on variations in the density and atomic composition of the material. Besides a wide range of applications in medical science, the use of CT has also been explored in geology, such as imaging the interior of fossils or meteorites, examining

Figure 1: Marble-hosted rubies, such as this fine crystal from Jegdalek, Afghanistan, need to be exposed from their host rock before they can be evaluated for gem rough or used as mineral specimens. The piece shown here measures 3 cm across and is courtesy of Jim and Gail Spann; photo by Thomas Spann.

the texture of igneous and metamorphic rocks, studying the porosity of rocks and soils, and analysing ore samples (e.g. Baruchel et al., 2000; Ketcham and Carlson, 2001; Cnudde et al., 2006; Cnudde and Boone, 2013; Mees et al., 2013). In gemmology, micro-CT has proved useful for discriminating between natural and cultured pearls when ordinary X-radiography proved insufficient (Wehrmeister et al., 2008; Karampelas et al., 2010; Krzemnicki et al., 2010).

The present author, who is a medical doctor, became interested in whether the CT instrumentation used in human clinical practice (e.g. Figure 2) could be applied to detecting rubies in marble host rock during the course of her gemmology diploma studies. The article reports on the process and results of imaging this sample.

Figure 2: The Philips Brilliance CT 64-slice scanner was used for this study. Courtesy of Philips.

Background

In human medicine the CT imaging technique is used to give detailed information on the internal organs and other structures of the body (e.g. Prokop et al., 2003; Bellin et al., 2004; Patel et al., 2009). The CT scanning method was developed by Godfrey Hounsfield, for which he received the Nobel Prize in Physiology and Medicine in 1979. The first clinical CT scans of human patients were performed in 1972. The instrumentation consists of an X-ray irradiation source (the X-ray tube) and a detection system that measures the attenuation of the X-ray beams that traverse an object from various angles. The attenuation values from all different angles are stored in a matrix, from which a computer reconstructs images of the interior of the object using the so-called filtered back projection algorithm (Prokop et al., 2003). The attenuation value for each point of the matrix is called the CT value or Hounsfield unit (HU), which indicates the attenuation of X-rays in the object with reference to water. The HU is calculated using the following formula: $HU = ((\mu_{material} - \mu_{water})/\mu_{water}) \times 1000$ (Prokop et al., 2003). The μ value of various materials is defined as the attenuation coefficient at a certain kV (kilovolt, referring to voltage of the X-ray tube). Water has an HU = 0, air = –1000 and bone ≥ 1000. In a CT scan that is used for human medical applications, the HU may range from –1000 (least attenuating) to +3071 (most attenuating; Prokop et al., 2003).

CT scanners can be grouped into four categories, based on their spatial resolution and the size of the objects that are imaged: conventional, high-resolution, ultra-high-resolution and micro-tomography scanners (Ketcham and Carlson, 2001; Cnudde et al., 2006). Most medical systems fall into the category of conventional CT. The other types of scanners generate much more detailed images (Landis and Keane, 2010; Cnudde and Boone, 2013). A further important difference between a medical CT and micro-tomography is the rotational movement. In medical CT the patient remains stationary while the X-ray source and detector rotate (Figure 3). In most micro-tomography systems it is the object that rotates. The limitation of micro-tomography is the penetrating ability of the X-rays relative to the

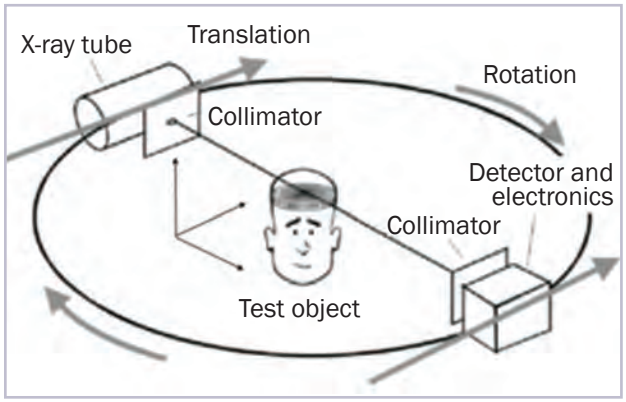

Figure 3: This schematic diagram shows the working principle of a medical CT scanner. Adapted from Kalender (2000).

Figure 4: The ruby-bearing marble specimen used in this study measured approximately 75×50×40 mm. Photo by A. Bouts.

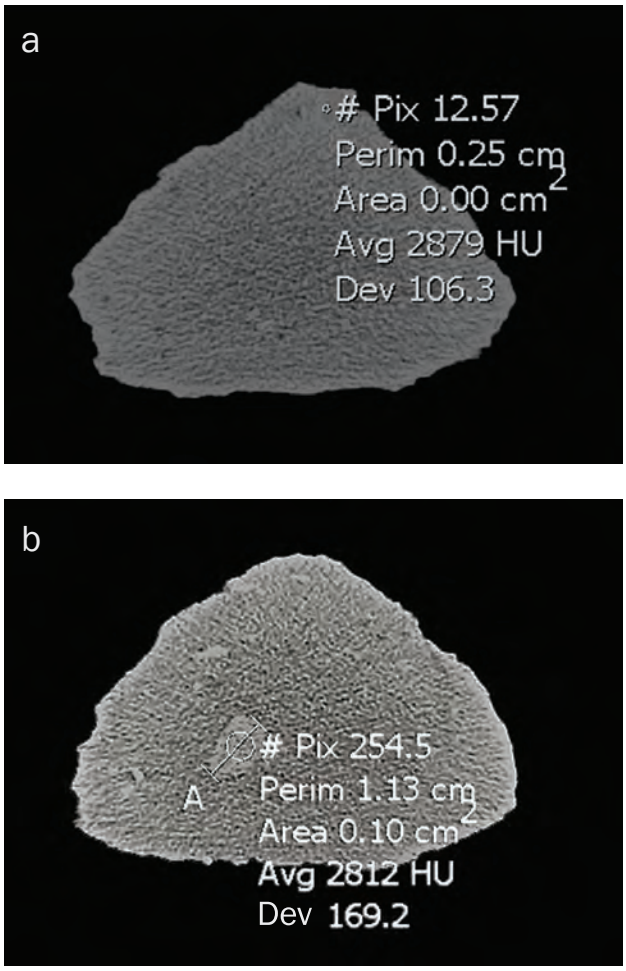

Figure 5: (a) This CT scan shows a slice through the marble specimen, underneath the exposed ruby crystal at the top of the piece showing a mean HU value of +2879. (b) A slice through the centre of the sample revealed a crystal with a mean HU value of +2812, which proved to be a ruby.

density of the sample. For example, dense metals require either very high-energy X-rays, or very small specimens.

Visualization of CT images can be generated by the computer in two- or three-dimensional views (Landis and Keane, 2010).

Methods

This study utilized a piece of white granular marble measuring approximately 75×50×40 mm that showed some small ruby fragments on the surface (Figure 4). We wondered if the marble contained more ruby crystals inside.

The sample was initially investigated with a 10× loupe, a microscope and a spectroscope. To get information about the internal structure, we then used a Philips Brilliance CT 64-slice scanner (typical for medical investigations). The marble fragment was placed in the CT scanner, together with a faceted synthetic ruby and a natural ruby crystal to compare and calibrate the imaging results. In addition, pieces of feldspar, quartz, fluorite, topaz, beryl and amber were tested with the CT scanner, to use as separation values for various other gem materials.

Three scan series were performed with different settings as follows: (1) 120 kV voltage and 199 mAs (milliampere seconds), (2) 80 kV and 400 mAs, (3) 140 kV and 197 mAs. The voltage determines the beam quality or the ability of the beam to penetrate the object. The mAs value controls the beam intensity or the number of X-ray photons in the beam. The thicker the object, the more absorption of X-rays occurs, requiring higher mAs values. CT slices of the sample were generated at 1 mm intervals.

Results

The surface of the specimen showed a pink-red opaque crystal of 7×3 mm with a dull vitreous lustre. In addition, three other pink-red crystals of smaller size and one brown-black crystal were present on the surface of the stone. The pink-red crystals were semi-translucent and had no discernible crystal habit. Parallel striations were present on the faces of the largest crystal, and the absorption spectrum in general was typical for ruby.

CT scanning showed that the mean HU of the loose faceted synthetic ruby was +2976, exactly the same as for the loose natural ruby crystal. The mean HU of the ruby crystal on the surface of the investigated marble was +2879 (Figure 5a), while the mean HU of the host rock was +2516. The scans revealed an object inside the marble with a similar HU (mean +2812) as the ruby crystal on the surface and the loose natural and synthetic ruby samples (Figure 5b). The dimensions of this object were 8.0×6.0×6.6 mm. These findings indicated the presence of a ruby crystal within the marble.

The results for the mean HU of feldspar, quartz, fluorite, topaz, beryl and amber are shown in Table I. All these samples have different HU values. However, the HU value of the fluorite is in the same range as the rubies tested. Since these measurements were made from only one specimen each, the results should be considered provisional, and it will be necessary to measure more samples to confirm these values.

Table I: Results of HU measurements of various minerals.

Mineral	Mean HU
Feldspar	+1880
Quartz	+1915
Fluorite	+2976
Topaz	+2640
Beryl	+2033
Amber	+22

To confirm the CT results, the marble specimen was then cut open, revealing a ruby crystal in the expected position inside the host rock (Figure 6). The ruby crystal was also the size predicted by the CT scanning.

Discussion and Conclusion

This study indicates that computed tomography can be used to identify the presence of a ruby within its marble host rock. Whether CT can be used to detect other gem materials inside their host rocks needs to be analysed: this depends on the difference in HU between the gem material and the surrounding material.

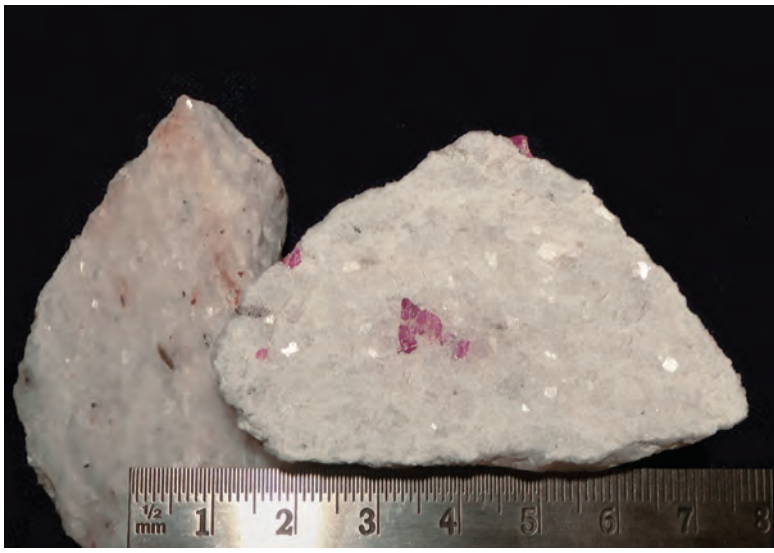

Figure 6: The presence of ruby in the marble sample was confirmed by cutting the stone into two pieces. Photo by A. Bouts.

In this study the tested sample had a diameter of less than 80 mm. The upper size limit of rock material that can be accurately scanned by CT remains to be determined.

In practice, CT scanning may prove helpful in identifying the presence of gem minerals within high-value specimens being investigated for rough material or being prepared for museums or collectors. However, the technique does not give any information about the actual quality of the gems detected inside their host rock.

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A Journey to the Legendary Mogok Mines in Myanmar

December 2013

Federico Pezzotta

This author was invited by gem dealer Federico Barlocher (Lugano, Switzerland), who has over 30 years of gem-trading experience in East Asia, and especially in Myanmar, on a trip to Mogok. This area was re-opened to foreigners in July 2013 (after being closed for approximately 10 years), although access to Mogok still requires special visa permission from the Burmese government. Accompanying us were videographer Bryan Swoboda (BlueCap Productions, Honolulu, Hawaii, USA), former mineral collector and dealer Dave Wilber (Tucson, Arizona, USA), and mineral specimen miner and speleologist Marco Lorenzoni (Lucca, Italy). The trip took place from 28 November to 10 December, and Barlocher's goal was to produce a unique film documentary for television containing unseen footage of mining for rubies and other gems in Mogok.

For reference during the trip, the author brought the book *Gems and Mines of Mogok* (Themelis, 2008), which was of fundamental importance for understanding the relations between the local geomorphology and the geology and distribution of the gem mines. The book was also helpful for learning about the history of Mogok mining and the nature and quality of the gem material from each mine. Also, Atichat and Hughes (2013) provide a useful introduction to the geologic processes responsible for the exceptional mineralogical and gemmological variety of Mogok.

We travelled in a four-wheel-drive minibus from Mandalay, via the historic route through Thabeikkyin, and then to Mogok. The trip took about seven hours on a good paved road. On the way we passed through Latpanhla village, which is known for tourmaline-bearing pegmatites. However, mining activities were stopped at least three years ago by the government. Most of the tourmaline was recovered in 2006–2008. The area produced several tens of kilograms of vivid pink gem tourmaline of faceting and carving quality, and also crystals in pegmatite matrix, that were sold in markets in Mandalay and Yangon.

At sunrise, mist shrouds the Mogok valley. Photo by F. Pezzotta.

The author (centre) and Federico Barlocher (far right) discuss the geology of the Bawpadan mine. Photo by M. Lorenzoni.

The author enters the Sakangyi topaz mine, without shoes as requested by the Buddhists who operate some mines. Photo by M. Lorenzoni.

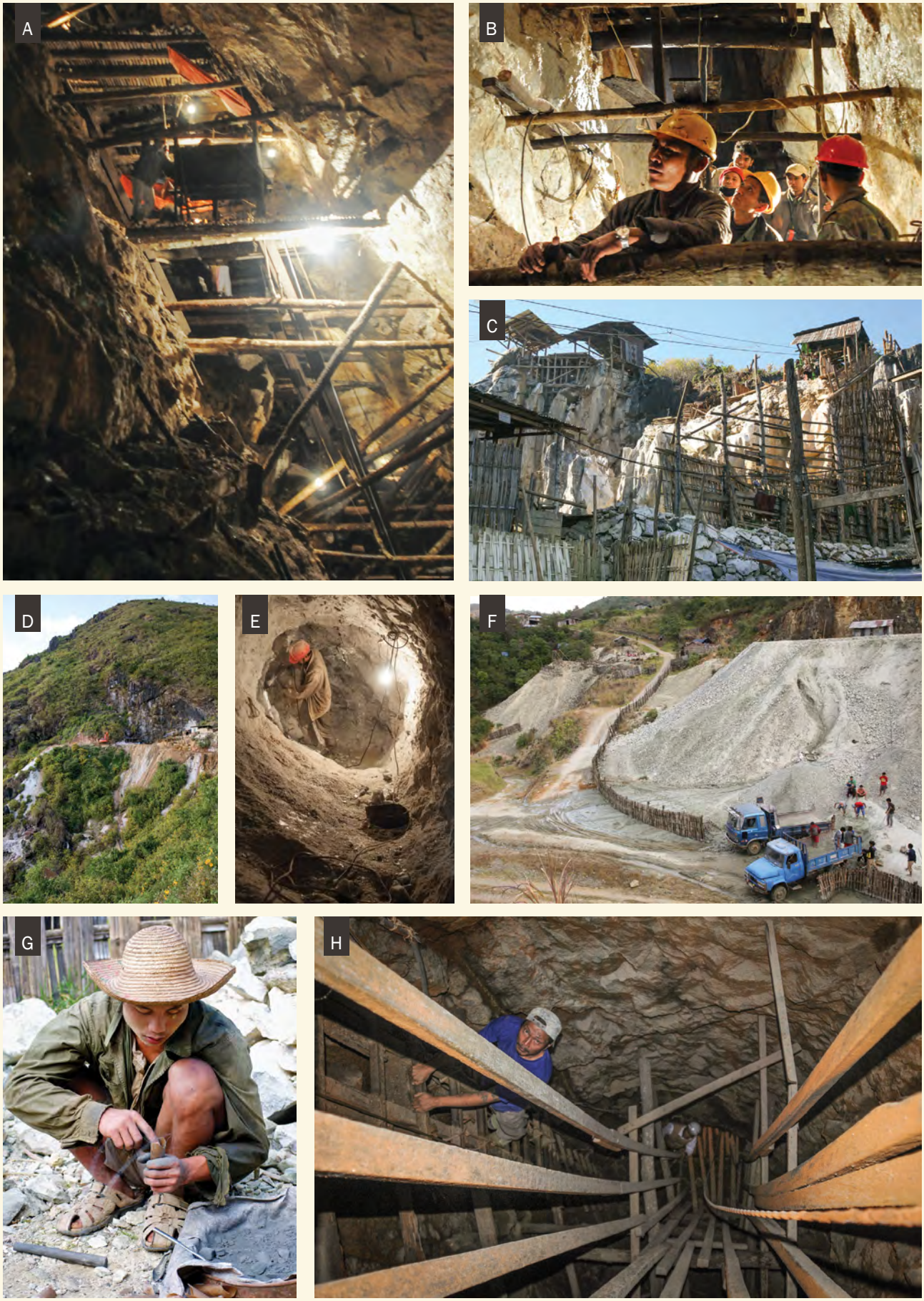
While exploring Mogok, we resided at the Golden Butterfly, a good hotel (considering the remote location) that is perched on a hillside several kilometres from the town and has a spectacular view of the valley. The most important localities visited by the group are described below.

Sakangyi: This area become famous for the late-2006 discovery of a spectacular giant pegmatite cavity lined with quartz, feldspar and mica crystals, with associated colourless to pale blue and pale yellow topaz (Praszkier and Sacchi, 2012). With permission obtained by Barlocher from the mine owner, we visited the short tunnel where the cavity had been found. During our visit, several small mines were actively exploring both primary and alluvial deposits in the area. They produce mostly topaz, but also some aquamarine and multi-coloured tourmaline. Minor amounts of ruby and sapphire were recently found in a narrow coarse-grained calcitic marble lens discovered at the bottom of a small valley.

The pegmatitic veins seen by our group were mostly steeply dipping, up to a few metres wide, and hosted by deeply weathered gneiss. They cut across the foliation and metamorphic structures in the gneiss, and were characterized by (1) a border zone composed of a fine-grained biotite-bearing aplite or medium-grained pegmatite; (2) an intermediate zone consisting of coarse-grained pegmatite composed of quartz, feldspars and biotite; and (3) a core zone containing coarse- to very coarse–grained miarolitic pegmatite with smoky quartz, graphic intergrowths of perthite and quartz, 'clevelandite' feldspar, and large muscovite blades, with accessory topaz and beryl. The large cavity mentioned above was associated with a coarsening of the vein minerals, and was located where the orientation of the pegmatite changed from a steep to gentle dip.

Bawpadan: This famous mining area follows a layer of ruby-bearing marble for more than 1 km. The ruby-mineralized unit, called the 'Marble Arc' by Themelis (2008), extends more than 15 km east of Mogok town. As for many ruby mines in Mogok, the surface is divided into mining claims measuring 200×200 ft (61×61 m). The claims are assigned at auction, and a single company can obtain multiple claims. The mine we visited had been greatly improved in the past few years, with tunnels providing access for large dump trucks. Here the ruby-bearing layer had a thickness of ~1–4 m, and it was still productive where it was currently being mined at a depth of more than 200 m below the surface.

Kodoke-tat: Located at the western termination of the Marble Arc, this mining area follows about 1.5 km of the



(A) A complex network of timbers, scaffolding and cables is seen here at Kodoke-tat, at about 200 m depth. (B) Local miners pause at the 380 m level of Kodoke-tat. (C) Winches are perched on top of marble outcrops at Kodoke-tat. (D) This old mining operation at Dattaw is being reopened. (E) A miner looks for rubies in a tunnel at Dattaw. (F) Large piles of tailings mark the location of peridot mines at Pyaunggaung. (G) A miner makes explosive charges at Pyaunggaung. (H) A wooden chute is used to remove mined material from the shaft at a peridot mine in Pyaunggaung. Photos by M. Lorenzoni (A, B, E, G and H) and F. Pezotta (C, D and F).

ruby-bearing layer. The deposit has been mined in an enormous trench excavated along the near-vertical ruby-mineralized band. The trench is interrupted by wooden barriers representing the limits of the mining claims assigned to different companies. Down-dip below the trench are subvertical interconnected galleries that have been excavated to a depth exceeding 400 m. The workings are supported by a few rock pillars and by thousands of timbers. Wooden ladders with small landings are attached to the marble walls to allow access to the bottom of the mine. We saw complex systems of ropes and winches that were used to bring the excavated marble to the surface, where it was routed to crushing and washing machines. The rubies were hand-picked from the washed and crushed marble. The marble tailings were then dumped into a publically accessible area where local people (mostly women and children) tried their luck in finding small fragments of ruby.

A single mine at Kodoke-tat can have around 200–300 miners, with two groups of workers allowing 24 hours of activity. The total number of miners at Kodoke-tat, in both the trench and underground workings, was around 6,000 at the time of our visit. At least as many people were working at the surface, making this one of the largest mining operations in the world for a primary coloured gemstone deposit.

Dattaw: This mining area is located north-west of Mogok. Dattaw hill is composed of exceptionally coarse-grained calcite marble that contains several ruby-bearing bands. Tunnels have been driven along these bands, and also follow residual

(A) A peridot miner rests next to buckets containing powdered rock and rolls of explosives. (B) This pendant containing a large faceted peridot gemstone was seen in Mogok. (C) Miners excavate gem-bearing soil at Pyant-Gyi, a source of high-quality red spinel. (D) Women search for gems at Pyant-Gyi. (E) Residual deposits are mined from weathered karst in this open pit at Htin-Shu-Myaing. Photos by M. Lorenzoni (A–D) and F. Pezzotta (E).

(A) Miners operate a small washing plant at Htin-Shu-Myaing. (B) At the end of the day, gems are hand-picked from the jig at Bernardmyo. (C) This view from a helicopter shows a portion of the Mogok valley. (D) The Kodoke-tat mine is visible on the left skyline in this aerial photo. (E) A merchant examines rough rubies in the Mogok market. (F) These spinel crystals were presented at the home of a local dealer. (G) A woman examines a rough blue gem in the busy Mogok gem market. Photos by F. Pezzotta (A), F. Barlocher (B and D) and M. Lorenzoni (C, E and F).

A Mogok dealer wearing a ring containing a locally mined sapphire and ruby presents a large ruby crystal. Photo by M. Lorenzoni.

deposits concentrated at the bottom of naturally occurring caves and karst formations. Most of the mines were recently assigned to new companies from Hpakan (the jadeite area located in northern Myanmar). During our visit, two major mining operations were under development. One was located halfway up the hill, with plans to restore and partially mechanize the old large underground workings. The other was situated at the bottom of the hill, where a vast area was apparently being prepared for open-pit mining by numerous dump trucks and excavators. In addition, small underground mines have begun in the last two years at various elevations on the hill.

Pyaunggaung: Deposits in this area are famous for producing magnificent peridot crystals from dunite host rock. We visited the Panlin-Pyaunggaung F7/8 mine, the largest in the area. The dunite was rather fine-grained and compact, but it locally contained coarse-grained pods and veinlets that sometimes host gem-quality peridot. We observed at least two such pods, with a diameter up to ~30 cm, that were filled with talc and what appeared to be enstatite, amphibole and phlogopite, together with rounded crystals of gem-quality peridot up to 2 cm in diameter. During the past year, this mine produced several kilograms of high-quality peridot gem rough, including some crystals approaching 100 g.

We also visited several alluvial mines and residual karst deposits in the Mogok area, such as Hta-Yan-Sho and Pyant-Gyi (located west of town), and Htin-Shu-Myaing, Bernardmyo and Panlin-Injauk (located north of Mogok). All these mines typically produce a variety of gems. Some rather large-scale mechanized operations have been developed in these areas.

While we were in Mogok, an eminent Burmese politician arrived by helicopter and Barlocher was able to arrange a flight for our group over the town and the nearby mines, allowing a spectacular panoramic view of the area.

Despite the huge amount of mining activity in the area, we were surprised to find that rough and cut stones offered in the local markets were rather scarce and of low quality (with the possible exception of peridot). Prices of the few good cut stones were typically high. One possible reason for the lack of gems being offered is that most of the mine owners are storing their production as an investment for the future.

We departed Mogok on a new paved road to Pyin Oo Lwin (formerly Maymyo) and then Mandalay; this route took nearly six hours. The road passed close to Mong Long, which is famous for producing coloured tourmaline from secondary deposits. Unfortunately, this area was inaccessible due to a resurgence in the activity of rebels belonging to the Shan ethnic group.

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Mines and Markets of Mogok, Myanmar

December 2013

*Emmanuel Fritsch**

This author visited the Mogok area with Henry Ho (Jewelry Trade Center and Asian Institute of Gemological Sciences, Bangkok, Thailand) and two of his associates, Ho Yu Low and Win Aung. We flew from Bangkok to Mandalay, where we met with 'Jordan' Aung Naing, a Mogok miner who was our guide. We then drove to the Mogok area, an approximately six-hour trip, with about four of those spent on very windy roads. From 10–15 December we visited mines and the two local markets: the morning 'crystal' market and the afternoon gem market.

We were told that about 100 'billionaires' live in the Mogok valley. This may explain why you can find excellent bottles of Bordeaux wine for sale (e.g. Pauillac vintage 2002 for about US$45), but there is no heating available in the hotel rooms! With an estimated 1,200–1,500 gem mines, and innumerable shrines, the Mogok area exhibits something seen nowhere else in the world: wherever you turn, you see either a mine or a stupa (Buddhist shrine).

Ball Lone Gyi: Located approximately 10 km west of Mogok, this ruby deposit is marked by a large white scar on a hillside above Ball Lone Gyi village. A portion of the village actually had to be moved so that mining could take place. Piles of crushed marble from the mine were evident throughout the village, where the material had been processed for gems. It was not difficult to find well-recrystallized greyish blue calcite specimens with a bright red ruby spot. The primary deposit was being worked by mechanized equipment, but the most visible activity was a crowd of locals looking through the crushed rock. They used metal blades (as seen almost everywhere in the Mogok area) to sort through the centimetre-size pieces of marble in search of ruby and other gems.

We purchased on-site a large number of small ruby crystals of excellent colour. The euhedral crystals were mostly bipyramids up to 1 cm in their longest dimension, with an almost prismatic appearance. A smaller number of blue sapphires were offered. Although they were larger sized (up to ~3 cm), they were generally translucent at best. Polished surfaces of these crystals showed typical pseudohexagonal growth patterns highlighted by whitish silk. Also available was zircon, although small and of greyish colour. Unidentified green and black crystals were shown to us as well.

Many karst outcrops in the Mogok area are topped with a golden stupa. This one (~1 m tall) is located near Pyaunggaung.

* All photos by the author.

BALL LONE GYI AREA

(A) Locals sort through bags of crushed and washed marble, looking for gems. (B) Women in traditional straw hats peddle rough gems. The white tailings pile in the background marks the location of the mine. (C) Ruby and sapphire are offered for sale on a traditional round brass tray.

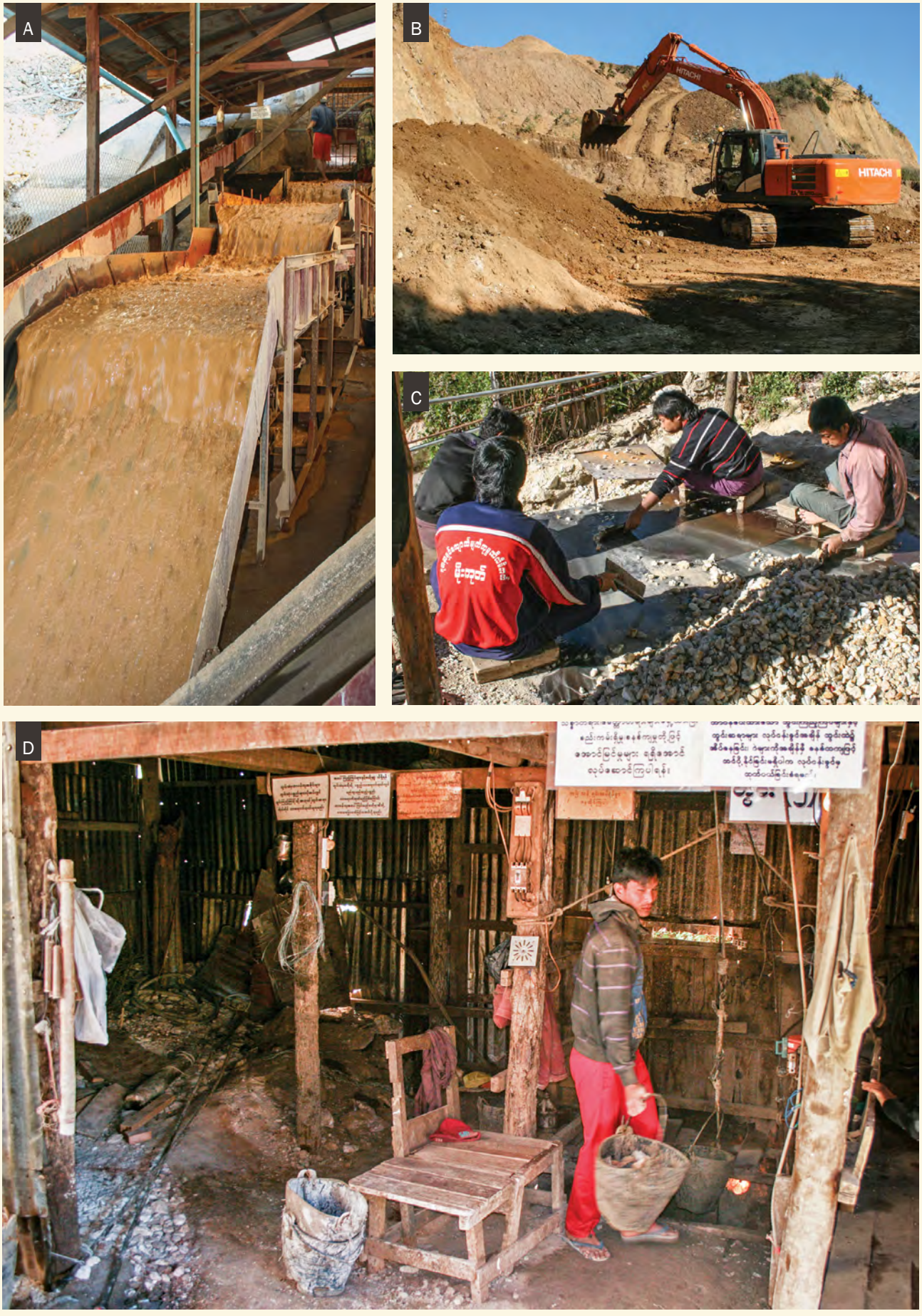
Yadana Shin: Located on top of a hill, this highly mechanized operation was active both underground (in a small shaft) and on the surface (in an open pit). As we often saw in the Mogok region, the excavators were large, numerous, of top brand and appeared quite new. This gives an indication of the financial backing behind such ventures. The treatment plant was most impressive. The mined material was first routed through a large screen (mesh size ~10 cm) and then passed into a concrete holding area where four people used water jets to wash everything into a large triple jig. The concentrate was poured onto a conveyer belt and hand-picked for ruby, red spinel, moonstone and other gems. The oversize and rejected material was passed through a crusher, washed, and then delivered to four workers who sorted through it with metal blades. The tailings were then deposited down the hill in a spectacular stream of muddy debris, where they were processed further by small groups of local people.

Shunt Pann (Shon-Ban-Lay) Mine: At this large open-pit mine owned by 'James' Bhone Myint Aung, the miners extract gem gravel, or *byon*, from the bottom of ancient underground river and cave deposits in the weathered karst. The marble landscape exhibits typical karst relief, with subsurface depressions that have captured and accumulated accessory minerals—including gems—concentrated by erosion.

The byon was excavated, stockpiled and then processed with hydraulic washing. The resulting slurry was pumped into a large jig. The concentrate was then sorted further by hand. The mud leaving the jig was panned outside the limits of the mine by many locals, who commonly find small red spinel octahedra.

The mine mainly produces rubies ranging from light red to purple- red, some several centimetres in size. We also observed large non-gem spinel octahedra, tabular black tourmaline, brown zircon, light blue apatite, and quartz and feldspar. Some of the transparent quartz crystals had translucent central cores filled with tiny whitish fibres.

Dragon Ruby Mine: We were told that we were among the first foreigners to visit this famous mine, where a 128 ct piece of ruby was discovered in August 2013. The mine extends



YADANA SHIN MINE

(A) The mined material is washed in a large triple jig. (B) A relatively new excavator works a portion of the open pit. (C) Workers sort through material that has been recrushed and washed. (D) Material is hoisted from a small mine shaft. Explosive charges hang from the pole on the far left.

SHUNT PANN (SHON-BAN-LAY) MINE

(A) Stockpiled byon undergoes hydraulic washing. The inset shows Win Aung (left) and mine owner 'James' Bhone Myint Aung. (B) In this large open pit, gem gravels are mined from residual deposits within weathered karst. (C) These recently mined rubies measure up to ~3 cm in longest dimension. (D) The Shunt Pann mine forms the major brown scar at the centre of this view of Mogok. Compare this image to the lead photo of Federico Pezzotta's article on p. 55 of this issue.

(A) At the Dragon Ruby mine, buckets made from recycled tyres are stacked on boulders of marble awaiting processing. (B) After the mined material is crushed and washed at the Dragon Ruby mine, it is passed into these two sorting lines. Note the 'Safety First' sign, absent from most mines of the area. (C) Local people look for peridot and other gems in mine tailings near Pyaunggaung. (D) This man collected a handful of peridot crystals from the mine tailings.

over 100 m underground via three sequential vertical shafts. The ruby-bearing marble layer dips at about 45° and is up to 2 m thick. The marble is brought to the surface for crushing and hand sorting, and that morning we saw only half a dozen rubies, a few millimetres in size, come from the ore.

Compared to other mines we visited in the Mogok area, this one seemed to be operated with the most sophistication. They employ a mine geologist (U Tint Aung), and the mine's office contains a display of all the rocks found there, properly labelled. This display itself showed the diversity of Mogok's geology:

- a multiplicity of white marble varieties (not as coarsely recrystallized as the 'blue' marble that hosts the ruby mineralization) that locally contain spinel, graphite, phlogopite and sometimes dark brown titanite (up to 3 cm) or dark green diopside
- marble with lapis-lazuli, which deserves special mention, as magnificent pieces of lapis have been unearthed in this area (and are quite unexpected next to ruby)
- garnet-biotite gneiss
- skarn (i.e. formed by the reaction between granite and marble)
- black phlogopitite (more familiar at an emerald deposit than next to a ruby mine)

Also found in the mine area are huge colourless scapolite

crystals, with one over 10 cm across that was on display. Some broken scapolite pieces showed an attractive, fairly dark pink colour, but were not gemmy.

Peridot Deposits: In the Pyaunggaung area, next to the main peridot mine (Panlin-Pyaunggaung F7/8) are several small ones consisting of a single shaft or small incline. There was little activity at these small mines, with no significant finds in over a year. We visited locals working the tailings of the small mines, and they were finding well-formed crystals of peridot up to 1 cm in size within small talc-lined 'pockets'. We were also shown a large piece of brown transparent rough material, up to 20 cm long, that was probably an amphibole. In the tailings we observed pieces of what they called agate, but they were actually veins of common opal.

Local Markets: Almost every afternoon around 3:00, the Mogok gem market opens. Upon arriving, we were impressed by the perfect, almost crystalline organization of the numerous motorbikes. Inside, under large umbrellas, customers sit at tables and wait for dealers to offer gems. We were presented mostly ruby, sapphire and spinel, but also some peridot and zircon. We also saw a fine yellow star sapphire, which is not a common sight anywhere. Attractive large crystals, mostly corundum, were also offered for sale. However the prices seemed well above market value. Food was often offered on the various tables, a pleasant testimony to the Burmese hospitality toward foreigners and potential customers. This author's favourites were Mogok fried chicken, clementine oranges and papayas.

MOGOK GEM MARKETS

(A) At the afternoon gem market, trading occurs under umbrellas at tables where food such as clementine oranges are offered to potential buyers. (B) These large red spinels were available at the gem market. (C) Also seen was this unusual yellow star sapphire displaying sharp asterism. (D) A variety of rough material was offered at the Mogok morning crystal market, from river pebbles to lower-quality sapphire and ruby, feldspar, quartz and even black tektites.

Another attraction was the so-called 'crystal market', which takes place early in the morning. On both sides of the street, gem-selling women (recognizable by their straw hats or woolly bonnets) offered small treasures on brass plates or simply laid out on white bed sheets. They had everything from river pebbles to modest faceted gems. Ruby and sapphire of lower quality were quite common, as was red spinel. Some of the parcels looked like little more than gravel. Feldspar rough was cheap, as were local black tektites, some reaching well over 20 cm. Fine hackmanite and deep violetish blue lapis could be found as well. There was a variety of unusual rocks and ornamental stones (e.g. cabochons consisting of graphic intergrowths of feldspar and quartz mined from local pegmatite). For the more bizarre samples, the sellers were not always certain of their identity, leading to animated discussions (provided one speaks Burmese). We saw little evidence of any imitations or synthetics.

Other Attractions: Just above town, in a beautiful, luxuriant setting, is the former home of famed gemmologist A.C.D. Pain. This wooden structure has been abandoned for years but was in the process of being restored, with the goal of turning this historical building into a gem museum.

One of the most spectacular monuments in the Mogok area is the Kyauk Pyat That temple, perched on a weathered black karst outcrop. From the top of the temple (accessible only to men) there is a wonderful view above the village of two old mines in which painite was found. It is said that the sacred ground just around the temple hides some of the best blue sapphires of the Mogok gem tract. This explains why, despite the religious constraints on mining in this area, local people sometimes dig at night in search of treasure. A few hundred metres down the road, just outside the limit of the sacred ground, we saw three locals removing byon from the weathered karst and washing it with water.

Although the Mogok area has been mined for centuries, numerous holes are opened every week in search of rich gem gravel still hidden in the thousands of cubic kilometres of unexplored weathered karst.

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Crowning a karst outcrop, the Kyauk Pyat That temple offers a view of nearby painite occurrences, and reportedly hosts a blue sapphire deposit on its sacred ground.

The Journal of Gemmology has published many ground-breaking and thought-provoking articles over the years. We thought it would be interesting to reprint some of the best which show us what gemmology was like yesteryear and how in some cases it has barely changed. This article demonstrates the historical importance of visualizing pearl structures to help determine their natural vs. cultured origin. A comparison between the X-radiographs in this article and those shown, for example, in the Gem Notes section of this issue (pp. 13–15) clearly illustrates the advancements in technology for imaging pearls, and the need for a highly trained gemmologist to interpret such images.

SOME UNUSUAL STRUCTURES in PEARLS and CULTURED PEARLS*

By ROBERT WEBSTER FGA

MODERN techniques employing the revealing eye of the X-ray beam have opened up a new era in pearl testing, and during the past decade many peculiar structures in pearls have been observed by X-ray photography, some of which may well be of interest to readers of the *Journal of Gemmology*.

It may be an advantage to preface these notes with a short explanation of the principles of direct X-radiography. Quite soon after Röntgen made his classic discovery of X-rays it was observed that the degree of transparency of a substance to the rays was, broadly speaking, in inverse ratio to the atomic density of the substance. Therefore, a body having a structure made up of different substances may show different intensities of shadow to rays and thus so affects a photographic film, or a fluorescent screen, as to make the structures visible.

From the foregoing it will quite easily be understood that the structures of the animal frame will be readily revealed by the density of shadow given by the bones, containing the atoms of calcium (atomic weight 40) and phosphorus (atomic weight 30), as against that of the flesh which is made up of the light atoms, carbon, nitrogen, oxygen and hydrogen (with atomic weights of 12, 14, 16, and 1 respectively). This is illustrated by the radiograph of part of a human hand. Fig. 1.

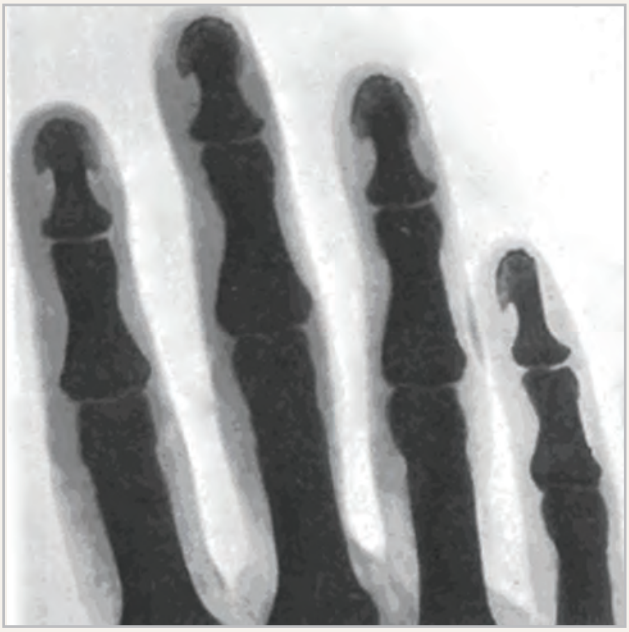


Fig. 1. X-ray picture of a human hand showing the greater opacity of the bones to the rays than is the case with the flesh.

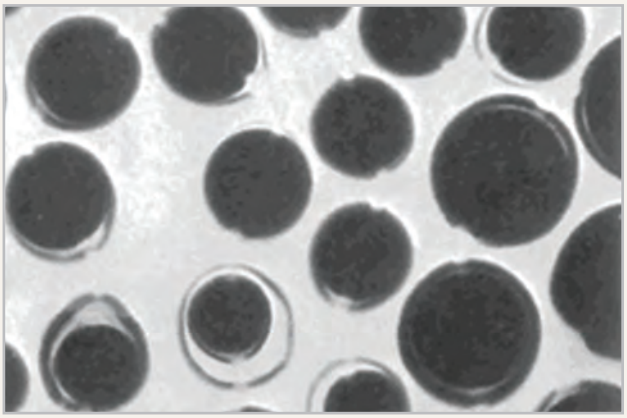
The radiography of pearls is based upon the same principle of differential X-ray transparency, but owing to the very fine structures usually involved, special techniques are necessary. Gemmologists know that a genuine pearl consists of a mineral part, calcium carbonate ($CaCO_3$), usually in the form of pseudo-hexagonal twinned crystallites of aragonite arranged in concentric layers with their vertical axes radial to the centre, cemented with an

* Reprinted from *The Journal of Gemmology, Vol. 4, No. 8, October 1954, 325–334.*

Fig. 2. Radiograph of a number of genuine pearls; some of which show the "tree ring" effect.

organic substance called conchiolin. Therefore the analogy of bone and flesh again becomes evident. The conchiolin, however, need not be sufficiently concentrated to show up boldly like the picture of flesh and bone. It is much more likely to show up as fine line structures where the organic matter has been relatively more thickly deposited between the layers of the crystallites. The X-ray picture may then show black lines as arcs or even complete circles, the latter producing a "tree ring" effect. Most oriental pearls will show very little or nothing at all, although a conchiolin-rich centre is sometimes seen and indicates a natural pearl. Some of the structures seen in natural pearl are illustrated in Figure 2, which is a radiograph of some pearls showing much structure, an effect which is not often seen.

Fig. 3. Radiograph of cultured pearls showing the bead nucleus outlined by the conchiolin layer (white in this positive print but would show dark in the negative). One pearl appears to have had a cultured pearl used as the nucleus.



The finer structures seen in the X-ray photographs of genuine pearls rarely bear reproduction for illustrations. In every case of identification it is the film that is studied and even then must be examined closely in order to discern these fine structures which indicate the natural origin of the pearl. It must be mentioned at this stage that all the illustrations are positive prints, and are also (except Figure 1) enlargements of the original film. Thus the white parts in the illustration will be black in the original negative—the blackening showing where the beam has been more easily able to penetrate. That is where the conchiolin patches lie.

In the case of cultured pearls with their relatively large mother-of-pearl nucleus, the bead centre often shows a slightly greater opacity to X-rays than the outer nacreous layer, and, shows no structure, except, when the position of the straight layers is parallel to the X-ray beam, when some differential absorption of the beam produces a weak but distinct banded appearance to the opacity of the bead nucleus.

What is usual in cultured pearls is to find that the bead is surrounded by a relatively thick layer of conchiolin. It is as though the oyster objected to the job of coating a large insertion and secreted conchiolin first and then completed the surface with pearly nacre. Figure 3 shows this effect well, but many cultured pearls show only a fine line encircling the bead—or sometimes the nature of the pearl may be seen only by the slight difference in the transradiability of the nucleus and the outer nacre. Often, especially with baroque pearls, the conchiolin deposit is considerable and irregularly arranged, an effect seen in some of the pearls shown in Figure 10. This is true also in the case of cultured drop-shaped pearls, which usually owe their shape to a patch of conchiolin producing the "pip" at one end (Figure 4).

It is not, however, the intention here to discuss the techniques of pearl X-radiography, but merely to illustrate some of the more unusual structures met with in the course of routine testing.

In general the bead nucleus inserted into the Japanese pearl oyster *(Pinctada martensi)* is a spherical bead, but this need not be so, and some cultured pearls may show nuclei of different shapes. These

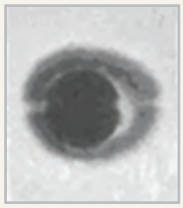


Fig. 4. Radiograph of a drop-shaped cultured pearl showing an excess of conchiolin at one end thus producing the pear shape, the bead nucleus being spherical.

Fig. 5. Button-shaped cultured pearls with oval-shaped nuclei. Radiograph by Robert Crowningshield of New York.

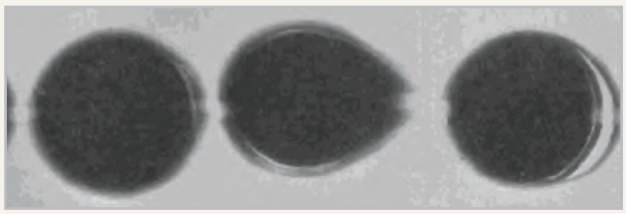


Fig. 6. A drop-shaped cultured pearl with a pear-shaped bead nucleus. The pearls on each side are normal cultured pearls with spherical beads.

are rare, for it is understood that the oyster does not take kindly to a nucleus of any shape other than spherical. It is said that nuclei of other shapes produce a greater mortality in the animals making the controlled production of pearls of other shapes than round to be less commercially practical, so that they are rarely used. That drop and button-shaped cultured pearls often occur adventitiously is well known, but these have round mother-of-pearl beads as cores and the resultant shape is due to vagaries of deposition of the conchiolin and nacre produced by the animal.

The writer has not happened upon an oval bead nucleus (used to produce button-shaped pearls) but is indebted to Mr Robert Crowningshield of the Gem Trade Laboratory at New York for the illustration of a pair of such pearls (Figure 5). Mr Crowningshield reports having met several pearls with such oval nuclei. Recently a case where the nucleus was pear-shaped was observed (Figure 6). Proof that this pearl was indeed a cultured pearl was made by the lauegram method. Laboratory records show that once before such a drop-shaped nucleus had been encountered, but in this case the direct picture did not show the outline at all well.

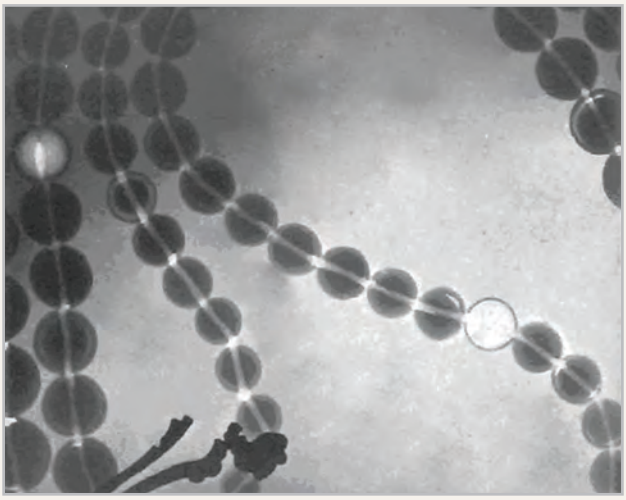


Fig. 7. The two cultured pearls with light coloured centres were found to have nuclei made of steatite (soapstone).

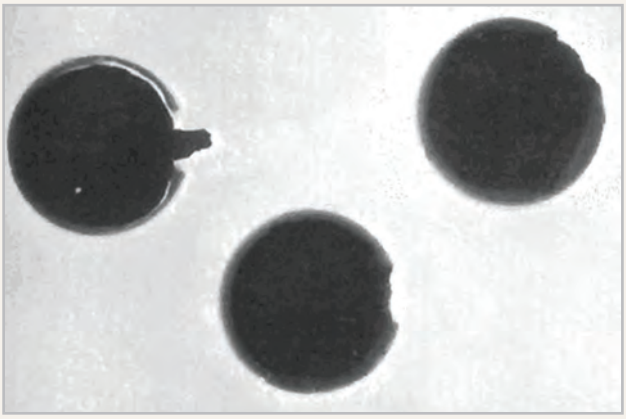


Fig. 8. Three cultured pearls which had their centres filled with cement.

Several other cases of unusual nuclei in cultured pearls have been shown by direct X-radiography. Particularly interesting are the two pearls shown with white centres (black on the film) in the illustration of part of a cultured pearl necklet in Figure 7. As permission was given for these pearls to be removed and examined the nature of the nucleus could be determined. They were found to be banded steatite (soapstone). This effect has been seen since, a necklet subsequently tested showing a similar transparent-centred lone pearl. No opportunity was given to test this bead, which may even be one with a plastic core, it not being unreasonable to suppose that such a type of core could have been tried out experimentally.

Figure 8 shows three cultured pearls—at least they had nacreous skins—in which the inside was filled with some form of cement. Figure 9 shows three different views of a cultured pearl with

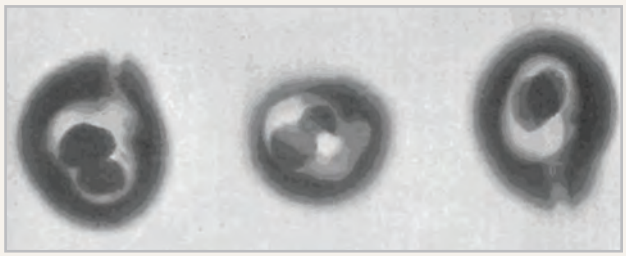


Fig. 9. A cultured pearl with "twin" nuclei. The pearl has been radiographed in three different directions.

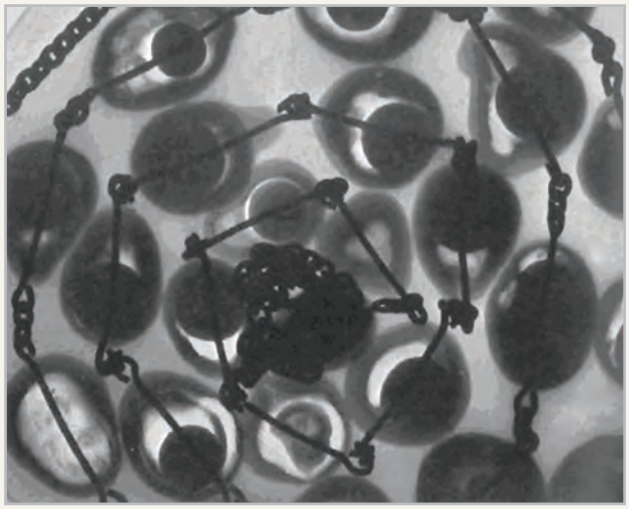


Fig. 10. Radiograph of a very baroque necklet showing some pearls without nuclei. These pearls are probably from the fresh water pearl clam (Hyriopsis schlegeli) *of Japan. The nucleated pearls may probably be also from the same animal.*

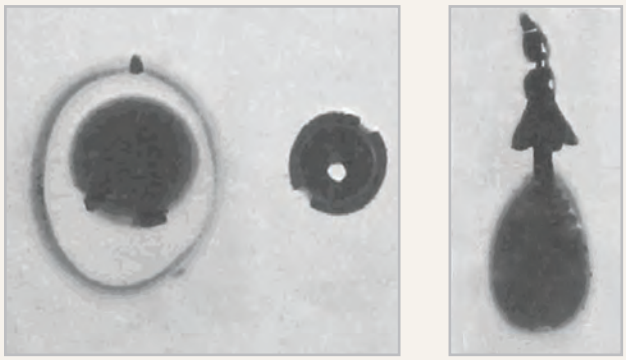


Fig. 11 [left]. Cultured pearls in which the bead nucleus had become loose and had rotated.
Fig. 12 [right]. A genuine drop pearl with secondary drilling filled up with several seed pearls.

Fig. 13. One of this pair of pearls was seen to be clearly genuine from the negative. The other seemed to be just as clearly cultured. Both pearls were found to be natural by the lauegram method.

irregular "twin" nuclei. The mate of this pearl was a perfectly good baroque cultured pearl with spherical nucleus.

The necklet illustrated in Figure 10 shows various types of baroque pearls including some without a nucleus. These latter are thought to be some experimental non-nucleated pearls cultured from the freshwater pearl clam *(Hyriopsis schlegeli)* which lives at the south-eastern edge of the Biwa-Ko in Shiga Prefecture, Japan. The other pearls showing bead nuclei may also be from the same animal, for it is known that experiments with nucleated pearls were also carried out using the *Hyriopsis schlegeli*.

It is often noticed that the bead nucleus of a cultured pearl becomes loose and is able to rotate within the nacreous shell. Figure 11 shows two examples of this effect, in one of which metal pins are evident.

Figure 12 shows a genuine drop-shaped pearl which has been "Chinese drilled", or drilled to relieve stress in a cracked pearl. In this case the secondary drilling has been filled up with four or five seed pearls.

Finally, reference must be made to the danger of direct X-radiography as a testing tool. The method requires experience in mastering the techniques necessary to produce a good negative but considerably more in the interpretation of the negative itself. Figure 13 illustrates this point well, for on inspection of the negative it seemed clear that one of the pearls was genuine but that the other was cultured. The arcs and rings in the one pearl (much more clearly seen in the negative than in the positive reproduction) left no doubt as to its genuineness. The other pearl, however, showed only the one ring and there seemed little doubt that it was cultured. Lauegrams of the pearls, however, showed *both* to be natural pearls.

Conferences

IGE 2014 International Gemmological Congress and 16th FEEG Symposium

On 17–19 January, in Madrid, Spain, the IGE 2014 Congress was organized by the Spanish Gemmological Institute (Instituto Gemológico Español or IGE), and held together with the annual Symposium and Diploma Ceremony of the Federation for European Education in Gemmology (FEEG). More than 200 attendees from 16 countries took part in the event. Sixteen oral and four poster presentations were given, and nine workshops and demonstrations were held, covering a wide range of topics related to modern gemmology. All materials from the event, including extended abstracts of the presentations, can be downloaded at www.ige.org/congress2014.

Diamonds were covered in various presentations. **Juan Cózar** (IGE Gem Testing Lab, Madrid) and co-authors explained the use of a combination of advanced techniques—Raman and photoluminescence (PL) spectroscopy and the DiamondView—for the detection of colourless HPHT- and CVD-grown synthetic diamonds and HPHT-treated colourless diamonds. A comparison of PL spectra recorded at room temperature and at −180ºC confirmed the necessity of cryogenic testing when performing PL spectroscopy. In another presentation, **Cózar** (with **Anthony Cáceres**) provided colour grading data for hundreds of diamonds examined in his lab using a Sarin Colibri colorimeter, and compared these results to traditional visual grading with diamond master stones. The Colibri instrument showed variations of up to four colour grades from visual grading, especially in diamonds with non-typical colours. **Geoffrey Dominy** (Gemmologist FGA with Distinction, Canada) focused on the importance of the cut grade in diamond valuation, including the role of the cutter, the importance of yield, and how shape, clarity, colour, cut, optical phenomena and market considerations affect the overall value of a faceted diamond. (In a separate presentation, he also presented his new book titled *The Handbook of Gemmology,* which was reviewed on pages 252–253 of *The Journal of Gemmology,* Vol. 33, No. 7–8, 2013). **Dr Pilar Diago Diago** (Zaragoza University, Spain) provided an overview of the problem of 'conflict diamonds' in international trade, with a general explanation of the Kimberley Process and related international and European laws. **Igor Klepikov** (St. Petersburg State University, Russia) and co-authors presented a detailed spectroscopic study of diamonds from alluvial deposits of the north-eastern Siberian platform. Optical absorption, infrared, PL and electronic paramagnetic resonance spectroscopy were used to characterize nitrogen aggregates and crystal structure defects in 120 diamonds. The micromorphology of diamond crystals from the north-eastern Siberian platform was reported by **Nadezhda Erysheva** (St. Petersburg State University, Russia), who found a direct relationship between microrelief features and crystal habit. **G.F. Anastasenko** (St. Petersburg State University, Russia) and co-authors studied the morphological characteristics of alluvial diamonds from the north-eastern Siberian Platform by scanning electron microscopy. The crystals were dominated by octahedral, dodecahedral and combined forms, with flat- and curve-sided shapes. **Anastasenko** and co-authors also described a diamond collection in the mineralogical museum of St. Petersburg State University consisting of more than 1,000 rough samples. The collection started in 1875 with the acquisition of diamonds first from Brazilian deposits and then from South Africa. After the discovery of diamonds in Yakutia (Siberia) in 1954, the museum obtained a large number from both primary and secondary deposits.

Among coloured stone presentations, **Miguel Ángel Pellicer García** and **Dr Cinta Osácar Soriano** (Zaragoza University, Spain) discussed the challenges of the geographic origin determination of coloured stones (Figure 1), with some examples from published studies on emerald, ruby, sapphire and garnet. The authors emphasized the importance of using comparison samples of known origin in such studies, and

Figure 1: The IGE 2014 Congress and 16th FEEG Symposium were held at the Spanish Gemmological Institute in Madrid. This photo was taken on the first day of the Congress during a presentation by Miguel Ángel Pellicer García and Dr Cinta Osácar Soriano. Courtesy of IGE.

also the necessity of establishing the range of property variations within each deposit. **Dr Klaus Schollenbruch** (DGemG, Idar Oberstein, Germany) summarized glass filling treatments for ruby and sapphire, including the processes used, diagnostic features and stability issues for the treated stones. **José Antonio Espí** (Madrid School of Mines, Spain) explained the geological setting, formation process and mining of larimar (blue pectolite) deposits in the Dominican Republic. He showed spectacular photos of larimar substituting for ancient fruit and tree trunks. He found greater amounts of vanadium and copper in larimar samples with a deeper blue coloration. **Espí** also described the origin and geology of amber deposits in the Dominican Republic. The amber is hosted by two major geographic domains: the Cordillera Septentrional (or Northern Range, where primary deposition sites occurred in clay-rich host rocks) and Cordillera Oriental (or Eastern Range, where remobilization and concentration of amber occurred in alluvial paleochannels with an abundance of organic material). Texture and sometimes colour are related to the specific conditions of amber formation. **Oscar R. Montoro** (Madrid Complutense University, Spain) and co-authors provided evidence of chemical processes that occurred during the formation of fossil resins, by examining the reactivity of pure communic acids and comparing their FTIR and Raman spectra to those of fossil resins. The results may help differentiate amber from other natural and synthetic resins.

Three presentations covered evolving technology. **Helena Calvo del Castillo** (University of Liège and Belgian Gemmological Association, Belgium) presented a review of a wide range of advanced spectroscopic techniques used in gemmology, their principles, advantages and limitations, as well as examples of their use to resolve contemporary problems. **Mikko Åström** and **Alberto Scarani** (M&A Gemological Instruments, Finland and Italy) described their GemmoRamanPL-532SG instrument, a scientific grade Raman-PL spectrometer for gemmological laboratories. They also explained some applications of this instrument beyond standard gem identification, such as identifying jade and spinel treatments, characterizing emerald, determining the colour origin of cultured freshwater pearls and coral, discriminating Imperial topaz according to chromium content and quickly separating type I from type II diamonds. **Menahem Sevdermish** and **Guy Borenstein** (GemeWizard, Ramat Gan, Israel) presented the latest developments of GemeWizard, a digital colour communication and analysis system for coloured gemstones and fancy-colour diamonds. The system allows users to describe, grade, price and communicate the colour of gems. A digital colour-based online gem marketplace, GemeShare, is used to perform colour analysis on a vast scale, and a search engine

enables the user to search for a stone of a specific colour.

In other presentations, **Gonzalo Moreno Díaz-Calderón** (IGE, Madrid) explained the Virtual Gemmological Laboratory, an online educational tool from IGE designed for distance learning of gemmology. Students are taught how to use basic gemmological equipment and even virtually analyse gems using a polariscope, refractometer, spectroscope, hydrostatic balance and microscope. **Dr Pilar Diago Diago** (Zaragoza University, Spain) and **Dr Cinta Osácar Soriano** provided an example of cooperative and interdisciplinary education through seminars on the legal aspects of gemmology that are attended by students of both gemmology and law, as well as professionals from the jewellery sector. **Viktor Tuzlukov** (College of Gem Cutting, Moscow, Russia) provided his vision of lapidary work as an artistic creation process. He showed how his designs can evoke symbols in the pattern of their facets.

The following **workshops and demonstrations** were held during the Congress:

- Raman and photoluminescence spectroscopy in the gemmological laboratory, by Mikko Angstrom and Alberto Scarani, M&A Gemological Instruments, GemmoRaman.com
- GemRam Raman gem identification system, by Ignacio Sánchez-Ferrer Robles, Microbeam S.A.
- Digital grading and pricing of coloured stones and fancy-colour diamonds with the GemeWizard system, by Menahem Sevdermish and Guy Borenstein, Gemewizard.com
- Detection of synthetic diamonds using the DiamondView, by Juan Cózar and Anthony Cáceres, IGE Gem Testing Laboratory
- OGI Scanox Planner HD, a device for the digital analysis of diamond cut quality, by Juan Cózar and Anthony Cáceres, IGE Gem Testing Laboratory
- Inclusion photomicrography using MacroRail products and software, by Óscar Fernández Arcís, MacroRail.com
- Automated 3D/360º photography applied to gems and jewellery, by Óscar Fernández Arcís, MacroRail.com
- Advanced methods for the design and manufacture of new gem cuts: GemCad, GemRay and DiamCalc, by Egor Gavrilenko, IGE
- Analysis of jewellery and precious metals with X-ray fluorescence, by Joan Pujol, Fischer Instruments S.A.

The FEEG Diploma Ceremony and the IV Antonio Negueruela Jewelry Design Awards Ceremony took place during the last evening of the Congress.

Egor Gavrilenko (info@ige.org)
Spanish Gemmological Institute
Madrid, Spain

AGA Tucson Conference

The 2014 Accredited Gemologists Association Conference in Tucson, Arizona, USA, took place 5 February, with the theme 'Gems: Fabulous, Fake, and Nefarious!' **Donna Hawrelko** chaired the conference and was also warmly recognized for her leadership of AGA at this conclusion of her term as president.

Olivier Segura (Laboratoire Français de Gemmologie, Paris, France) summarized the identification criteria for natural, treated and cultured pearls. Treatments may be revealed by observation of dye concentrations or by chemical analysis and Raman spectroscopy. General indications of a cultured origin may be provided by observations of the drill hole (if present) and surface characteristics. For confirmation of natural or cultured origin, it is necessary to view the internal structures with X-radiography or X-ray computed tomography, and some challenging case studies were described (for one example, see pages 14–15 of the Gem Notes section).

Thomas Hainschwang (GGTL Gemlab–Gemtechlab Laboratory, Principality of Liechtenstein) delivered a presentation for **Franck Notari** on the cause of colour and potential radiation hazards of green diamonds. He indicated that

the only samples that can be reliably ascertained as natural colour are those mined during the early part of the 20th century (mostly from Brazil) that have been kept in museums since that time. Extremely high residual radioactivity may be shown by diamonds irradiated by direct contact with radium salts, particularly those with residues that are trapped in open cracks and cavities. By contrast, diamonds that have been treated by modern irradiation methods (e.g. with electrons) pose no radiation risk to the end user.

Hainschwang then reviewed luminescence phenomena in diamond and their importance in gem testing. The colour and distribution of luminescence can be a useful indicator for the origin of a diamond's colour, but extensive experience is needed. Similar luminescence colours may be caused by a variety of defects, so photoluminescence spectra are needed to assess and measure defects at extremely low concentrations when determining the origin of colour or whether a diamond is natural or synthetic.

Manfred Eickhorst (Eickhorst & Co., Hamburg, Germany) explored applications of LED lighting in gemmology, including refractometer stands with built-in strong yellow LEDs, polariscopes with LEDs that provide diffuse lighting, and microscopes with intense illumination of a yellowish colour that mimics traditional incandescent lamps.

Craig Lynch (Somewhere In The Rainbow Collection) described the challenges of building a world-class gemstone and modern jewellery collection. In addition to the problem of finding available pieces due to their rarity, establishing a fair price for them can be difficult since there are so few top-end pieces for comparison.

Dr Lore Kiefert (Gübelin Gem Lab, Lucerne, Switzerland) documented the mining and gemmology of sapphires from Mogok, Myanmar. During a 2013 visit to the mines, she witnessed extensive sapphire mining activity, and she noted that some of the stones recently produced (which are of metamorphic origin) may be confused with sapphires of basaltic origin.

Shane McClure (Gemological Institute of America, Carlsbad, California, USA) examined the potential for the co-diffusion of multiple elements into sapphire. Relatively thick layers (up to 1 mm) of diffused blue colour due to Ti and Fe have been seen recently in both natural and synthetic sapphires, and the presence of surface-related concentrations of additional elements such as Mg, Ga, V and/or Be suggests that they may enhance the diffusion process.

Brendan M. Laurs

NAJA Conference in Tucson

The 41st Annual Winter ACE-It Education Conference organized by the National Association of Jewelry Appraisers took place in Tucson, Arizona, USA, on 2–3 February 2014. (Also, a preconference seminar on 1 February was given by **Dr Cigdem Lule**, titled 'Emerald Treatments and Pricing Workshop'.) NAJA executive director **Gail Brett Levine** introduced the conference and helped everything run smoothly. This author attended the talks described below, and additional presentations were also given by **Steve Begner** ('Southwestern Indian Silverwork and Jewelry—In The Eye of The Appraiser'), **Martin Fuller** ('The Many Faces of Value'), **Sindi Schloss** ('Exotic Organics in Jewelry'), **Patrick Coughlin** ('Discovering, Marketing and Branding a Gemstone') and **Arthur Skuratowicz** ('How Much is that Bauble in the Window?').

Edward Boehm (RareSource, Chattanooga, Tennessee, USA) presented useful techniques for assessing gem rough while on the go. He described using a loupe (and especially the darkfield loupe) to help identify rough material and determine its quality for cutting, and how a dichroscope is useful for separating spinel from sapphire and tourmaline from pezzottaite. To become proficient at using a loupe to observe inclusions, he suggested looking at several example stones with a microscope and then training your eye to see the same features with the loupe. He also emphasized the importance

Figure 2: This carved Mogul emerald is photographed to show its transparency, colour and the intricate carved patterns on its surface. Known as the Schettler Emerald, it weighs 87.64 ct and was probably used in the head ornament of a prince. Courtesy of the American Museum of Natural History, New York, USA; photo by Tino Hammid.

of learning the properties of gems, and how a collection of journals and the *Photoatlas* books are gemmological tools in themselves.

Tino Hammid (Tino Hammid Photography Inc., Los Angeles, California, USA) discussed gem photography while showing examples of spectacular images (e.g. Figure 2) to illustrate several points: (1) lighting defines an object, and the use of selective and subtle reflections helps to convey its shape; (2) shadows provide a sense of place, and reflections of the object below the stone add reality to the image; and (3) colour accuracy is critical, and using a ColorChecker card and a monitor calibrator are highly recommended.

Gary Bowersox (GeoVision Inc., Honolulu, Hawaii, USA) described his multiple trips over 42 years to Afghanistan for exploring mines, purchasing gem rough, and helping the local people through education and donations. He mentioned that access to the Panjshir Valley emerald deposits is much easier since a new road from Kabul to Khenj was constructed in 2013. However, reaching the original lapis lazuli mines at Sar-e-Sang in Badakhshan Province is much more difficult, as shown in a fascinating film clip that he screened for the audience.

Brendan M. Laurs

Gem-A Notices

GIFTS AND DONATIONS TO THE ASSOCIATION

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

Apache Gems, San Carlos, Arizona, USA (Warren Boyd and Charles Vargas), for two andradites and a chalcedony from San Carlos, Arizona.

Don H. Ariyaratna FGA DGA, London, for a copy of the 7th edition his book *Gems of Sri Lanka*.

Marcus McCallum FGA, London, for three rough Usambara-effect tourmalines.

William R. (Bobby) Mann GG, Temple Hills, Maryland, USA, for a copy of his book *Ivory Identification: A Photographic Companion*.

Guillermo Ortiz, Bogota, Colombia, for two 'trapiche' quartz tablets.

Mauro Pantò, The Beauty in the Rocks, Citta della Pieve, Italy, for an orange lizardite and a lizardite-included quartz.

Nalini Pattni, Anaheim, California, USA, for a rough garnet reportedly from Benin.

German Salazar, Bogota, Colombia, for a tablet of 'trapiche' quartz from Penas Blancas, Colombia.

Jason Williams FGA DGA, G.F. Williams & Co., London, for a large selection of coloured faceted cubic zirconias.

Monetary donations were gratefully received from:

Manon-Océane Bruyère FGA, Nouméa, New Caledonia

Caroline Maclachlan FGA DGA, Edinburgh

Maggie Yuk Ling Pun FGA, Richmond, British Columbia, Canada

Paul Siegel FGA, New York, USA

Tak Yi Yung FGA, Shau Kei Wan, Hong Kong

MEMBERSHIP

At a meeting of the Council of the Association held on 5 March 2014, the following were elected to membership:

Fellowship and Diamond Membership (FGA DGA)

Ferder, Edward, Lyndhurst, Hampshire
Leung, Jeannie, Kowloon, Hong Kong
Yu Ho Fai, Miranda, Sai Kung, Hong Kong

Fellowship (FGA)

Bailey, Kathryn, Aberdeen
Bosshard Schreckenberg, Astrid, Zurich, Switzerland
Bouts, Antonia, Amsterdam, The Netherlands
Buckley, Amanda, Auckland, New Zealand
Chandrasiri, Hemali, Colombo, Sri Lanka
Chong, Ronald R.K.K., Amsterdam, The Netherlands
Corbin, Marie-Hélène, Montreal, Quebec, Canada
Day, Helen, Walsall, West Midlands
Delor, Claude Pierre, Orléans, France
Fritsch, Emmanuel, Nantes, France
Fritz, Eric, Banner Elk, North Carolina, USA
Gautier, Isabelle, Bry-sur-Marne, France
Hammarqvist, Susanne E., Stockholm, Sweden
Homkrajae, Artitaya, Bangkok, Thailand
Howard, Naomi, Calgary, Alberta, Canada
Ijima, Kaori, Saitama-ken, Japan
Knochenhauer, Cecilia, Stockholm, Sweden
Lau Man Wa, Eukice, Mong Kok West, Hong Kong
McKenzie, Troy, Greenslopes, Queensland, Australia

Mendes, Isabella, Dagnall, Hertfordshire
Muyal, Jonathan Daniel, Bangkok, Thailand
Noble, Frances, Wendover, Buckinghamshire
Ostergaard, Marlon, Caloundra, Queensland, Australia
Qiu Yun, Conan, Zetland, New South Wales, Australia
Ranatunga, Gallage, Meetiyagoda, Sri Lanka
Saeseaw, Sudarat, Bangkok, Thailand
Siritheerakul, Piradee, Bangkok, Thailand
Steele, Sarah Caldwell, York, North Yorkshire
Suthiyuth, Ratima, Bangkok, Thailand
Walker, Megan G., Edinburgh
Watrelos, Céline, Joinville-e-Pont, France
Wijesekera, Maduni Champika, Kandy, Sri Lanka

Diamond Membership (DGA)

Brown, Debra, Great Sutton, Cheshire
Crowther, Lucy, London
Hancock, Elizabeth Ann, Leatherhead, Surrey
Horst, Kirsti, Trier, Germany
Ilich, Helen, Haymarket, New South Wales, Australia
Karlsson, Patrik, Lidingö, Sweden
Legros, Maria, London
Li Wenjie, Guangzhou, Guangdong, P.R. China
Rapaport, Martin, Las Vegas, Nevada, USA
Reimi, Olesja, Tallinn, Estonia
Tsang Wing Hang, Wong Tai Sin, Hong Kong

Associate Membership

Adejugbe, Murphy Opeyemi, Lagos, Nigeria
Berger, Claudia, Vienna, Austria
Brossmer, Teri, Glendora, California, USA
Dempsey, Michael, Golden, Colorado, USA
Groat, Lee A., Vancouver, British Columbia, Canada
Guanghai Shi, Beijing, P.R. China
Harlow, George, New York, USA
Hatzigeorgiou, Michael, Brighton-Le-Sands, New South Wales, Australia
Henn, Ulrich, Rheinland-Pfalz, Germany
Jain, Raj, London
Jones, Samuel, Newark, Nottinghamshire
Karampelas, Stefanos, Lucerne, Switzerland
Khanbhai, Saifudin, Arusha, Tanzania
Kimsey, Kristi, London
Larson, William, Fallbrook, California, USA
Laurs, Brendan, Encinitas, California, USA
McClure, Shane, Carlsbad, California, USA
Menon, Sreekumar, Cambridge
Middleton, Nick, Billingsley, Shropshire
Nielsen, Stig, Toftlund, Denmark
Oppenheim, Ruth, London
O'Sullivan, Shawn, New York, USA
O'Sullivan, Terry, Glenside, Pennsylvania, USA
Ozen, Fazil, Istanbul, Turkey
Pezzotta, Federico, Milan, Italy
Post, Jeffrey, Washington DC, USA
Revell, John, London
Rossman, George, Pasadena, California, USA
Roy, Ajit, North Little Rock, Arizona, USA
Saito, Mari, Tokyo, Japan
Santo, Valentina, London
Scherer, John, New York, USA
Spencer, Sally Jane, Didcot, Oxfordshire
Tay Thye Sun, Singapore
Turner, James, London
Turner, Stephen, Atlanta, Georgia, USA
Venturi, Anna, London
Welbourn, Chris, Waltham St Lawrence, Berkshire
Willems, Bert, Bayern, Germany

Transfers

Fellowship to Fellowship and Diamond Membership (FGA DGA)

Barrows, Michael James, Kidderminster, Worcestershire
Hardy, Sarah, Bryngwran, Isle of Anglesey
Hughes, Beata, Sutton Coldfield, West Midlands
Hunt, Glynis, Andover, Hampshire
Lally, Jo, Southampton, Hampshire
Riley, James H., Knutsford, Cheshire
Simon, Gowry Raji, Wolverhampton, West Midlands
Weyers, Stefanus, Bloemfontein, Free State, South Africa
Woodrow, Gillian, Wokingham, Berkshire

Diamond Membership to Fellowship and Diamond Membership (FGA DGA)

Ludlam, Louise, Birmingham, West Midlands

Associate Membership to Fellowship (FGA)

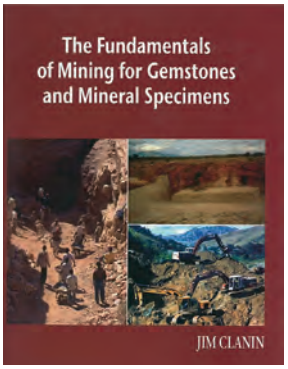
Bauer, Ronnie, Glen Iris, Victoria, Australia
Blake, Andrea Renae, Chevy Chase, Maryland, USA
Dishington, Megumi, Shizuoka-ken, Japan
Laurs, Brendan, Encinitas, California, USA
Rongy, Amandine, London
Street, Neil, Wilton, Connecticut, USA
Tay Thye Sun, Singapore

Associate Membership to Diamond Membership (DGA)

Bragg, Caitlin Louise, Bristol

New Media

The Fundamentals of Mining for Gemstones and Mineral Specimens



Jim Clanin, 2012. New England Historical Publications, Boston, Massachusetts, USA, 402 pages, illus., hardcover, www.jcmining.com, ISBN 978-0-615-50108-6. US$49.95.

This book covers fundamental knowledge for small-scale mining, covering aspects of geology, mineralogy, mining practices and marketing, as well as the all-important but readily forgotten aspects of local regulations, first aid and safety.

Following an introduction to gem mining, the author covers several topics from basic geology to how to map and understand the potential scope of a gem deposit. He describes the various types of mining tools available and the best way of investing in them, from hand tools to large equipment such as excavators. Also discussed is the proper way to use explosives so as not to damage and devalue gem material or specimens, as well as best practices for safely handling and storing explosives. Then the main types of mining are described, detailing the most cost-effective methods of extraction of gem material. The author proceeds to explain a number of different processes for cleaning and preparing mineral specimens for sale.

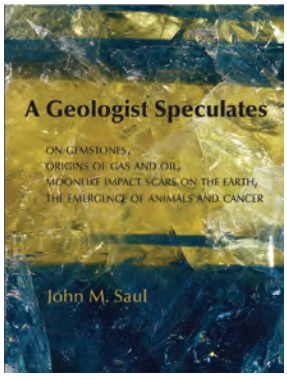
The next couple of chapters cover site management and logistics, and there is also a comprehensive first aid section detailing the potential injuries associated with mining and their appropriate treatment. This is followed by a section describing the author's experience with local customs and etiquette in the areas where he has worked. Such considerations are especially important when working in remote localities.

A very interesting part of the book is a section describing eight case studies showing how mining techniques are customized for different localities and mineral types. Some examples include open-pit mining for emeralds in Madagascar, alluvial deposits in Tanzania that produce a range of gems, ruby deposits in Kenya and underground mining for fluorite in northern England. Each case study reinforces the fundamentals discussed in the previous sections with real-life scenarios and whether the mining ventures were successful.

The book has colourful photography and several detailed annotated diagrams. Its only disappointments are the need for editing and the fragmented nature of the layout on some pages. Nevertheless, the author has managed to share his 35 years of hands-on mining experience in a clearly passionate way, and the book should therefore be inspiring and educational for any gem or mineral miner.

Davina Dryland BSc (Hons) FGA

A Geologist Speculates



John M. Saul, 2014. Les 3 Colonnes, Paris, France, 149 pages, illus. in colour and black-and-white, paperback, ISBN 978-2-37081-004-5. €28.

This book's subtitle, 'On Gemstones, Origins of Gas and Oil, Moonlike Impact Scars on the Earth, the Emergence of Animals and Cancer' is, at first sight, a very disconnected series of topics. But a revealing comment on page 119 indicates the fundamental motivation of the author in light of a discussion with Professor Théodore Monod deep in Egypt's Western Desert. They explored the twin tasks of scientists in describing nature in all its

detail and of synthesizing these descriptions in the search for reasons and understanding. Monod was a prolific devotee of the former task while Saul made the case for periodic review and synthesis, and this book is the timely result of one such assessment.

Of immediate and absorbing interest for gemmologists is the first section in which the topics addressed include not only gem rarity but also other ways in which gems are peculiar and the important but infrequently tackled question of why they are so transparent. There is considerable analysis and discussion of metamorphism, pressure and temperature and the role of each in the genesis of gems, with copious notes, explanations and references augmenting the 30 pages of text and illustrations in this section. The marked concentration of beautiful gem minerals in only a few geographical locations is attributed to a pattern of continental drift and collision which brings into play much recent thinking on global tectonics and mineral age determination.

In my career as a geologist having mapped a number of new areas, I have often seen how easy it is to miss certain features of the rocks that one only appreciates with another look after seeing surrounding areas. I think Saul may be keenly aware of this aspect of scientific understanding as revealed in his comment (p. 94) '…once we had the idea in mind…'. The relative significance and connectedness of different features of gems is important to understand, and sections 2 and 3 of the book on deep carbon and impact scars go a long way to augment and clarify the ideas developed in the first gem section.

Section 2 summarizes evidence for the abiogenic origin of most deep carbon in the form of gas and oil; diamond is also briefly discussed in this context. Section 3 is the longest in the book. It deals in detail with ascribing to asteroid impacts a wide range of features on the earth's surface that are visible from space, and includes linking some of the plainly visible arcuate patterns with specific gem deposits in a most convincing way. Linkages are also made with hydrocarbons (Section 2) not only because they appear in these generally arcuate areas but also because they are sometimes found within inclusions in gems such as tanzanite.

While looking all the time for patterns, Saul repeatedly emphasizes the uniqueness of particular features of Earth history, which of course is very relevant to gem occurrences. On p. 87 he quotes Lyell's '…the present is key to the past…' (1833) and comments on the discussions this generated about uniformitarianism and catastrophism—with the ultimate general acceptance of the former. At first sight, Saul's emphasis on the uniqueness of features may not seem to fit comfortably within the uniformitarian framework, but Lyell's principle continues to have merit so long as 'key' is not misinterpreted to mean 'the same as'.

In Section 4 Saul first outlines six major gem deposits that lie along the circumference of a circular topographic feature about 300 km in diameter in Kenya/Tanzania, all within rocks that emit noticeable foul-smelling odours when cracked apart. The rest of the section then deals with the development of single- and multi-celled life, the ways they survive in dealing with oxygen and calcium toxicities, links with the Pan-African mountain-building events just before the explosion of life in Cambrian times, and the 'sudden' global availability of phosphorus. These developments and conditions enabled the first biominerals to form which in turn enabled shells (exoskeletons) and bones (endoskeletons) to form, with a few being preserved for posterity as fossils. This has particular relevance for gemmologists studying the origin of ivories and pearls. Regarding the latter, Saul also speculates about which factors might control secretion of calcite or aragonite.

The last section of the book is very short and highlights the relatively new situation where the principles and laws of physics, chemistry and biology, which controlled the development of Earth materials, have been joined by mental and historical parameters that have a great influence on human evolution. The elements of consciousness and desire are major factors in what we do and how we do it, and the discussion includes a number of pointers to a contemporaneous book by the author titled *The Tale Told in All Lands*. We are all, ultimately, stardust, and in that book astronomy is demonstrated to have had as great an influence on the mental activities of humans (from the earliest times) as it has in the formation and history of the earth.

A few minor aspects detract somewhat from the book: there is no index, and the black-and-white photographs are poorly reproduced (in contrast

to the beautifully clear black-and-white aerial photograph on the back cover). In terms of ideas, one also has to consider the limitations imposed by the relatively few gem species the author is considering. But the author quite clearly states in the title that the book is about speculations, and if one provisionally accepts this, the book goes on to assemble such a large, well-referenced collection of information that the ideas gain considerable credibility and provide a platform to stimulate the next wave of thinking about the origins of gems.

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Erratum

Page 241 of the article by H.A. Hänni and L.E. Cartier titled 'Tracing cultured pearls from farm to consumer: A review of potential methods and solutions' (Vol. 33, No. 7–8, 2013) indicated that both laser engraving and embossing a hologram onto the surface of the cultured pearl are slightly destructive techniques. The article should have referred to only the laser inscription method as being destructive.

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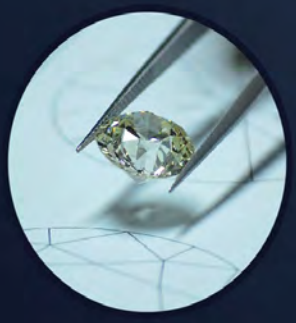

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