Facette

MAGAZINE

INTERNATIONAL ISSUE NO.26, MAY 2020

COLOUR VARIETIES / AGE DATING / GEMTRACK
DNA / EMERALD ORIGINS / DIAMONDS
SSEF AT AUCTION / SSEF IN TUCSON

SSEF
SCHWEIZERISCHES GEMMOLOGISCHES INSTITUT
SWISS GEMMOLOGICAL INSTITUTE
INSTITUT SUISSE DE GEMMOLOGIE

Dear Reader

When we started to collect the topics for this latest issue of the SSEF Facette in December last year, we were full of hope that the year 2020 holds promising opportunities for all of us, trade members and laboratories alike. Unfortunately, as I am writing this editorial at the end of April, the picture is very different and challenging due to the global spread of the COVID-19 pandemic, which has brought so much sorrow and pain to vulnerable people and communities in our close neighbourhoods wherever we look.

Still, it is my strong belief and hope, that the vibrant gem trade will recover from this crisis to bring new perspectives and prospects in the near future. My hope is based on the fact that this trade is not driven by large corporations, but strongly relies on the strength, ingenuity and collaboration of a densely interwoven fabric of stakeholders, many of them small scale family-owned businesses with a tradition spanning generations.

With this 26th issue of our annual magazine Facette, we want to give modest relief in such difficult times, and present all our readers with latest information on coloured stones, diamonds and pearls.

When editing and finalising the Facette, it is a moment for me and my colleagues at SSEF to look back on what we as a team have achieved in the past few months. It's also an opportunity to unveil our latest research findings and to present you our commitment and fascination for our profession, which is testing your gems and jewels with foremost scientific methods and utmost accuracy and rigor. Very often, new insights and findings start from an item submitted to us by a client for routine testing. Whether it is a deviation in observed or measured data or just a result of professional curiosity, such a case may finally become the cornerstone of an extensive research project, involving partners from other research institutions or laboratories.

Ultimately, such new findings add – at least for us gemmologists – a further facet and colourful reflection to the apparent visual beauty of the investigated gems, and we hope that reading through this magazine will give you the same pleasure.

Let me wish you, your families, and your co-workers and teams all my best wishes for a better time to come. And I hope to see you soon again, be it at SSEF, at a trade show, or at a gemmological conference, so that we all can look back and say, that we have safeguarded our families, communities and our common passion of being fascinated by nature's sparkling treasures.

Dr. Michael S. Krzemnicki
Director SSEF

Download this SSEF Facette

COVER PHOTO ▷

Ruby miner in the Mogok Stone Tract.

Photo: M.S. Krzemnicki, SSEF

TABLE OF CONTENTS

IMPRINT
Annual publication by **Swiss Gemmological Institute SSEF** Aeschengraben 26, CH-4051 Basel SWITZERLAND
tel. **+41 61 262 06 40**, fax. **+41 61 262 06 41**, e-mail: **admin@ssef.ch**, website: **www.ssef.ch**

ISSN : 2296-214X

COLOUR VARIETIES OF GEMS – WHERE TO SET THE BOUNDARY?

In theory it is simple: a gemstone is a mineral formed in nature by geological processes and, as such, it has a mineralogical name that is scientifically defined and accepted by the International Mineralogical Association (IMA) and its Commission of New Minerals, Nomenclature and Classification (CNMNC). In some cases, this mineral name is known and valued by the trade and consumers (e.g. diamond) and does not need further classification. However, for most coloured gemstones, things are much more complex, as most of them are known to consumers and the trade only by their variety names.

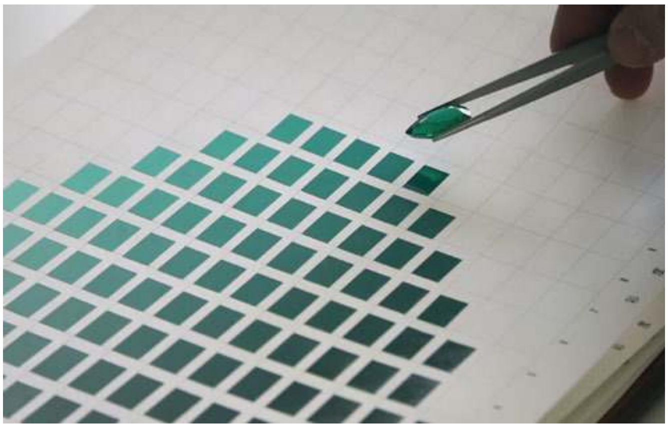
△ **Figure 1: Red ruby or pink sapphire: that's the question. Photo: A. Castillon, SSEF.**

Generally, variety names are related to variations in chemical composition and colour of a mineral. Some variety names are well-known in literature since the advent of modern mineralogy in the 18th century (e.g. ruby, sapphire, emerald), whereas others have been introduced in the last few decades with the aim of making a new gem material more appealing in the market (e.g. tanzanite for vanadium-bearing variety of zoisite, tsavorite for vanadium-bearing variety of grossular garnet). In some cases, such variety names are also linked to external appearance, such as for example single crystalline quartz (e.g. rock crystal) and polycrystalline chalcedony. Although the classification of variety names often seems straightforward (e.g. emerald for the chromium-bearing green variety of beryl and aquamarine for the iron-bearing light blue variety of beryl), we need to remember that they are generally rather vaguely defined, especially when it comes down to separating different varieties of the same mineral from each other (Hughes 1994).

In this article, we would like to provide insight into the issue of classifying coloured gems into their respective varieties and present a number of case studies to illustrate the topic from a laboratory perspective. This is based on an earlier presentation given on the topic and that also provides further examples (see Krzemnicki, 2019 under www.ssef.ch/presentations).

Creation of Standards

The main prerequisite for any gemmological laboratory is to follow an internally defined standard procedure to be able to evaluate and classify colour varieties of gems in a consistent manner over many years. In the absence of globally agreed standards, it may thus be necessary for a lab to create internal standards using for example selected master stones, colour measurements (based on spectroscopy), or colour tables (e.g.



△ **Figure 2: Colour observation using the Munsell Color Chart. Photo: A. Castillon, SSEF.**

Munsell colour chart or ColorCodex™; Smith, 2020). Such an internal standard may later become internationally harmonized and accepted by laboratory and trade organizations (e.g. LMHC, CIBJO, ICA).
Colour observation of coloured gemstones is a complex issue, based on three main factors:

- the light source (emission characteristics),
- the observer (protocol, tools and training),
- and the observed item (e.g. ruby or pink sapphire).

To grade colour consistently, it is mandatory to use standardized light with a high colour rendering performance (Krzemnicki, 2019). In addition, it is advisable to slightly tilt the gemstone in all directions by 10°-20° when observing its colour from atop (at about 25 cm distance to light and observer) to better judge the full colour sparkle or less desirable colour zoning effects of a stone.

△ **Figure 3:** Colour range of chromium-bearing corundum from red ruby to pink and purple sapphire. Please note that the colour of the photo in print may not be the same as that of the stones themselves. (The same applies to the other figures). Photo: M.S. Krzemnicki, SSEF.

Three Case Studies

The following case studies are separated into cases where the classification of varieties is based on (1) colour and (2) colour and spectroscopy/chemistry. All these examples are based on the authors' laboratory experiences and procedures encountered on a daily basis while testing gemstones.

Ruby Versus Pink Sapphire

Corundum coloured by traces of chromium can yield a wide range of red saturation, ranging from dark red to vivid red and light red (e.g. pink) (Figure 3). They are classified traditionally by the trade into the two varieties, ruby and pink sapphires. The boundary between these two varieties has never been internationally well defined, although it is of major importance for the trade, as there is commonly an important price difference between these two varieties.

Although it may seem obvious that a threshold value of chromium concentration to classify these stones either as ruby or pink sapphire could be defined, this hypothetical option is not applicable in reality. The reason is that such chemical analyses (usually measured on the table facet) may be strongly influenced by chemical zoning and the effects

△ **Figure 4:** Set of master stones (synthetic rubies to pink sapphires) put together in the 1980s by ICA. Photo: V. Lanzafame, SSEF.

of the cutting style and proportions, thus leading to inconsistencies when using this simplistic approach. Not to speak of critical differences in chromium concentration measurements due to different analytical setups used in different laboratories.

A much more realistic approach is to separate rubies from pink sapphires based only on colour by visual comparison with colour charts or master stones. At the Swiss Gemmological Institute SSEF, we have used, for many decades, a set of synthetic corundum master stones, originally put together by ICA in the 1980s (see Figure 4). Such a master set allows the most straightforward colour evaluation, as these master stones show matching reflection patterns and pleochroic colour effects that are also present in rubies or pink sapphires being tested in the lab. Another option is to use colour charts made with corrugated metalic foils (e.g. Color Codex™, see Smith, 2020), which to some extent mimic the reflection effects due to the facets of a cut stone.

Cobalt-Blue Spinel Versus Blue Spinel

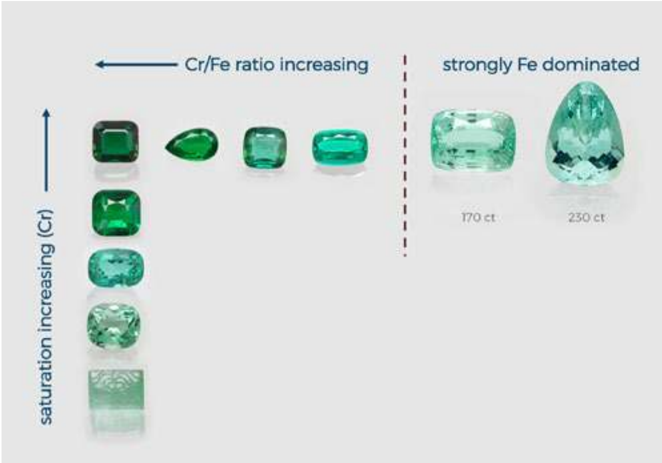
Spinel of blue colour is a highly attractive and appreciated gemstone in the trade. The blue colour may be due to traces of cobalt or iron or a combination of both elements and as a result they come in a range of colours from vivid cobalt blue to greenish grayish blue and purplish blue (Figure 5). The 'magic' term in this respect is cobalt, and so the key question from the trade is often whether a blue spinel is a cobalt spinel or just a more common blue spinel. This can only be solved by combining the colour observation with a very detailed analysis of its absorption spectrum. The absorption spectrum can show us how specific colouring elements (e.g. cobalt) contribute (absorption and transmission bands) to the colour of a stone, which ultimately results in the colour of the stone that we see.

△ **Figure 5:** Range of colours of blue spinel, but which of these are cobalt spinel? Photo: SSEF.

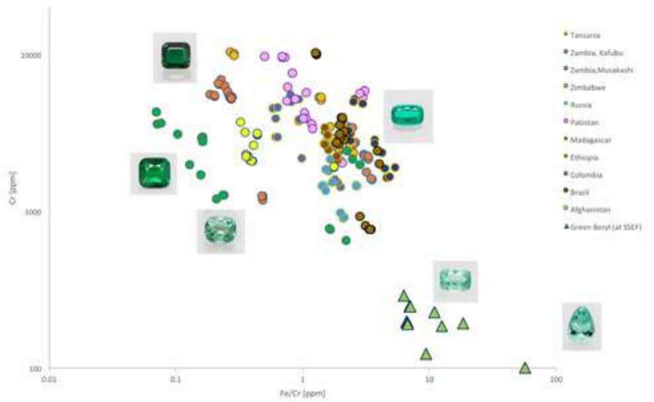
Similar to the ruby/pink sapphire classification, a cobalt concentration threshold value is not applicable. The reason is that some spinels get their blue colouration from iron absorption features and may, in addition to iron, also have cobalt, in some cases even at higher concentrations than some vivid cobalt-blue spinels. The key defining characteristic is which colouring element is dominating in the absorption spectrum (Shigley & Stockton 1984; Chauviré et al. 2015; D'Ippolito et al. 2015).
Interestingly, those blue spinels that are coloured by a combination of both cobalt and iron may show a subtle and attractive colour change from purplish blue in incandescent light to blue in daylight (Senoble 2010; Hanser 2013).

Emerald Versus Green Beryl

Commonly, an emerald is described as a chromium-bearing variety of beryl, although other transition metals such as vanadium and iron may considerably contribute to their apparent green colour. Emeralds have been treasured since historic times for their saturated green colour and rarity, although emeralds of lighter saturations may occur. Emeralds are often found as rather small and included rough crystals; this is related to their complex geological formation in the context of metamorphic processes and late stage rock deformations (Giuliani et al. 2019).
In recent years, we have repeatedly seen light green to bluish green gems in the lab, mostly of exceptional size (100 carats and above) and purity (Lind et al. 1986; Hänni 1992). Many of these stones formed in pegmatites (e.g. in Nigeria and Madagascar) in a very different geological setting compared to all classic emerald deposits (e.g. Colombia, Afghanistan, Zambia, Russia, Pakistan, to name a few) (Figure 6).
In addition, the absorption spectra of many of these gems is strongly dominated by an iron-related absorption band centered in the near infrared (actually responsible for the light blue colour in aquamarine), with only very tiny chromium-related absorption bands in the visible part of the spectrum, thus slightly shifting their colour to a light green or greenish blue colour (Cevallos et al. 2012). This is very much in contrast to the absorption spectra of emeralds from the above-mentioned classic sources that are dominated by chromium (and vanadium) absorption bands with none to only a moderate iron band in the near infrared.
This spectroscopic difference is also well reproduced when comparing the chemical composition (chromium to iron ratio) of these two different beryl varieties (see Figure 7). The plot clearly shows two different distribution clouds, with emeralds from all the above-mentioned classic emerald sources being clearly enriched or dominated by chromium. In contrast to this, many of the light green to bluish green beryls are characterized by low chromium concentrations, but relatively high to very high concentrations of iron (about 10x-100x more iron than chromium).



△ **Figure 6:** Colour range of emeralds and green beryl containing chromium traces. Photo: M.S. Krzemnicki, SSEF.



△ **Figure 7:** Plot visualizing the chemical separation of emeralds from the described light green to bluish green beryls. Figure: M.S. Krzemnicki, SSEF.

Conclusions

This article sought to provide an overview of a lab's perspective on defining colour terms using specific examples. As labs and the industry strive to achieve greater harmonization in the definition and use of variety and colour terms, it is important to be aware of the scientific challenges and limitations in doing so. As past discussions at CIBJO, GILC/ICA and LMHC have shown, there is a need to accept the complexity in defining set boundaries and the fact that ultimately a colour or variety opinion of a lab is based on observational and analytical data that ultimately forms an expert opinion.

SSEF has for many years been at the forefront of these discussions within different industry forums (e.g. CIBJO, LMHC) with the aim of harmonizing the criteria and standards used by labs and the trade, and also by publishing and sharing research on these important topics. The recent CIBJO congress special reports of both the Gemmological Commission and the Gemstone Commission show that these themes are important on the industry's agenda. We strongly welcome the trend for further harmonization and argue that it is a multi-pronged approach. This includes harmonizing definitions and harmonizing testing procedures where possible, in order to provide the trade and end-consumers greater clarity and transparency in the use of names and terms. * **Dr. M.S. Krzemnicki**

REFERENCE (FURTHER REFERENCES THEREIN)

Krzemnicki M.S., Cartier L.E., Lefèvre P., Zhou W., 2020. Colour varieties of gems: where to set the boundary? InColor, 2020 Winter, 45, 92-95.

△ **Different colour varieties of beryl. Photo: M.S. Krzemnicki, SSEF.**

AGE DATING AS A TESTING PROCEDURE FOR GEMSTONES AND BIOGENIC GEMS

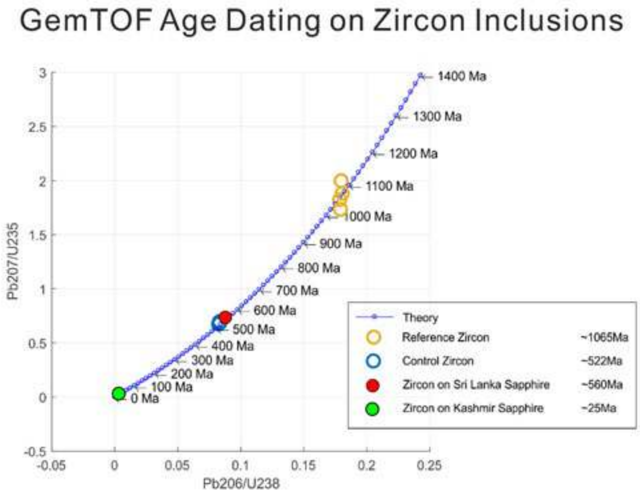
Radiometric age dating is a well-established method in geochronology (Earth sciences) and archaeology. There are numerous studies highlighting the use of radioactive decay of U-Pb, K-Ar (amongst many others) for geological age dating and radiocarbon ^{14}C for biogenic material (bones, shells) of antique to pre-historic age. In gemmology, the application of age dating as an analytical method is still rather limited, although pioneering work was already published many years ago (Coenraads et al., 1990; Sutherland et al., 2002).
With the recent progress of analytical capabilities (e.g. GemTOF: LA-ICP-TOF-MS, see Wang et al., 2016) we have been able in the past few months to carry out radiometric age dating on a large number of gemmological samples, partly from our research collection, but in great number also as part of our testing procedure on gemstones and biogenic materials (pearls and corals) from our clients (Figure 1).

△ **Figure 1: Age dating on a tiny zircon inclusion at the surface of this Kashmir sapphire (22 ct), yielded an age of approximately 24 million years, fitting well into the geological context of the Kashmir (Himalayan) mountain range. Photo: M.S. Krzemnicki, SSEF.**

In the context of a gemmological laboratory, radiometric age dating of gem materials or their inclusions is often a very useful addition to data gained by more traditional gem testing procedures. It may bolster conclusions deduced from other tests and may even deliver crucial information without which a conclusion would not be possible.

Supporting Evidence for Origin and Historic Provenance

For gemstones, radiometric age dating is specifically useful in cases where the origin of a gemstone is in question, but could be resolved by knowing its age of formation. Such age dating may reveal that a gemstone is very old, i.e. related to Neoproterozoic to early Palozoic geological events 1000 - 500 million years ago, such as is the case for many gems from Madagascar, East Africa, or Sri Lanka. Or it may conclusively show that it is of much younger age, i.e. related to Cenozoic geologic events 65 - 1 million years ago, such as is the case for sapphires from Kashmir or gemstones from Mogok (Myanmar) (Figure 2). Evidently, age dating – if applicable – can be crucial for lab gemmologists, for example to determine whether a velvety blue sapphire originates from Kashmir or Madagascar. The only drawback for age dating on gemstones is that, in most cases, it is possible to be carried out only if a tiny surface-reaching inclusion is present which can be dated by appropriate methods (see also Link, 2016; Sorokina et al., 2017).



△ **Figure 2: Age dating results on zircons found as inclusions in Kashmir sapphire and Sri Lankan sapphire, together with reference zircons. Figure: H.A.O. Wang, SSEF.**

When applying (radiocarbon) age dating to biogenic gem materials such as pearls, we may gain information a) to confirm a historic age ('provenance') of a historic pearl (Krzemnicki et al., 2017), and b) it may support the identification of a natural pearl based on its formation age dating prior to pearl cultivation (Krzemnicki & Hajdas, 2013).

Challenges of Age Dating

Radiometric age dating is a promising but complex analytical method with limitations and challenges, well-known and described in literature (Reiners et al., 2018 and references therein). For radiocarbon ^{14}C dating, these include contamination effects from the jewellery mounting, during sampling, or over-assessed ages (i.e. too old) when the skeleton of the biogenic material (e.g. shell, pearl, coral) uses/recycles bicarbonate from older sources (so-called hard water effect, Shotton, 1972). In geochronological dating (e.g. U-Pb of zircon), leaching/contamination effects and complex growth zoning (e.g. old detrital zircon grain is overgrown by a much younger rim) may affect the results considerably, for example resulting in 'mixed' ages (Schoene, 2014; Reiners et al., 2018). The ability of TOF-MS to analyse not only a small number of isotopes necessary for age dating, but to provide nearly the full mass spectrum simultaneously is in this respect very helpful (Wang et al., 2019), as it is possible to detect complex growth zoning and epitaxial overgrowth patterns (e.g. zirconolite grown on zircon, Phyo et al., 2020), thus supporting the interpretation of radiometric age dating results.

Age Dating on Client Gemstones

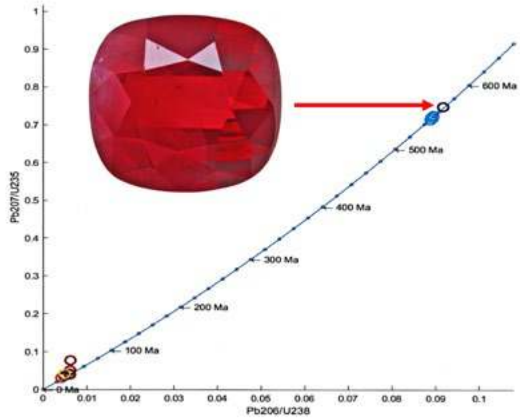
In the past few months we have applied radiometric age dating (Th-Pb and U-Pb) on a large number of corundum and spinel samples, many of them submitted by our clients for testing and origin determination, but also samples studied for a PhD project in collaboration with Basel University (Phyo et al., 2020). For this, we used surface-reaching inclusions present as time-capsules in these gemstones. So far, we were able to apply radiometric age dating not only on zircon inclusions, but additionally on inclusions of zirconolite, xenotime, monazite, baddeleyite, rutile, apatite, and titanite. This range of inclusions considerably increases the ability to apply dating as an additional method in gemmological testing in the laboratory. In addition to this, certain sapphires may contain considerable trace amounts of high-field-strength-elements (HFSE) such as Sn, Nb, Ta, W, Pb, Th, U, presumably accumulated as fine dispersed sub-microscopic (syngenetic) inclusions within these sapphires (Shen et al., 2009). As a consequence of this, it is in such cases possible to carry out radiometric age dating in-situ and simultaneously with the chemical analysis of the sapphire independently of the presence of any surface-reaching inclusion (e.g. zircon) (Wang et al., 2019).

Presentation of Real Cases

To have a detailed look on real cases, we refer our readers to a presentation, which was given at the 36th International Gemmological Conference IGC last summer (see https://www.ssef.ch/wp-content/uploads/2019/10/IGC-Nantes_MSK.pdf)

Another interesting example is the historic 'Ana Maria Pearl'. Our analyses confirmed that this pearl (presumably from *Pinctada mazatlanica*) formed in the early 16th to late 17th century. Our age dating thus provided supporting evidence for its documented historic provenance. Age dating has also been useful for a pearl with internal structures reminiscent of beadless cultured pearls, which could be identified as a saltwater natural pearl based on radiocarbon analyses, dating this pearl to the late 17th to mid 19th century, thus well before commercial pearl cultivation was developed. Furthermore, research on cultured pearls from *Pinctada maxima* from Australia (kindly loaned by Paspaley) harvested in the past three decades has also been successful (Figure 3).

We also want to mention cases in which origin determination was only possible by combining a classical approach (microscopy, chemical composition and spectroscopy) with radiometric age dating. These cases include a 5.1 ct ruby originating from a marble deposit and showing



◁ **Figure 4: East-African ruby with a small zircon inclusion dated to approximately 565 million years. Figure: H.A.O. Wang and M.S. Krzemnicki, SSEF**

Burma-like inclusion. Based on the geologically 'old' U-Pb age of a tiny surface-reaching zircon (565 million years), we were able to exclude Burma (and other Himalayan-related deposits) and could finalise the origin of the ruby as East Africa (Figure 4), as the calculated age is well in agreement with the age of ruby formation in marbles along the Mozambique Mobile Belt in East Africa.

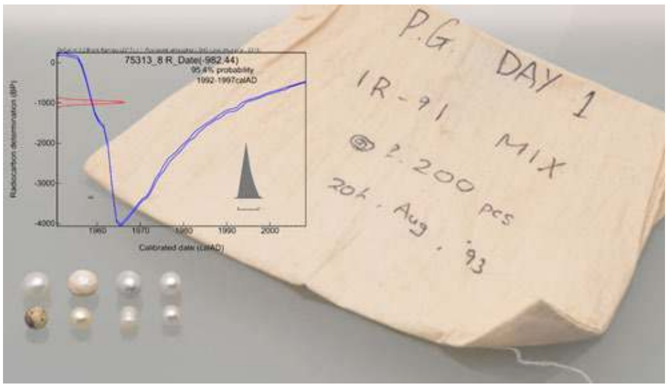
Age Dating on SSEF Reports

Based on our research, age dating is a very promising tool and will become increasingly important in gem testing in future. As could be demonstrated, it provides additional and unique information which may substantially help to establish the origin of a gemstone or the historic provenance and identity (cultured or natural) for biogenic materials.

We strongly believe that radiometric age dating not only is helpful to gemmologists as a supporting analytical testing method, but also relevant for the trade, especially if it refers to an iconic gemstone or pearl, such as the displayed 22 ct Kashmir sapphire (Figure 1), the 12 ct pigeon-blood ruby from Mogok, set in a Harry Winston necklace (see Facette 2019), or the historic Ana Maria pearl. Apart from being fascinating options for 'storytelling', it truly adds relevant information to a specific gemstone or pearl and thus provides consumers a deeper understanding of its age and provenance.

Age dating of pearls is a routine procedure and offered since early 2017 as a service to our clients for an additional testing fee. As radiometric age dating on (coloured) gemstones is only possible occasionally - mostly only possible in presence of surface-reaching inclusions, we offer dating on gemstones with no extra costs apart from the normal testing fee.

Since 2020, SSEF not only issues an additional special letter in case age dating was successful, but also adds a special comment on the SSEF report, with the aim to make such fascinating scientific results more visible. * **Dr. M.S. Krzemnicki**



△ **Figure 3: Cultured pearls harvested in 1993 by Paspaley in Australia. Their age was well confirmed by our radiocarbon dating. Figure: M.S. Krzemnicki, SSEF.**

REFERENCE (FURTHER REFERENCES THEREIN)

Krzemnicki M.S., Wang H.A.O., Phyo M.M., 2019. Age dating applied as a testing procedure to gemstones and biogenic gem materials. Abstract Proceedings of 36th International Gemmological Conference, 48-50.

GEMTRACK™: DOCUMENTING THE LINK BETWEEN ROUGH AND CUT GEMSTONES

In early 2019, SSEF launched GemTrack™ as a new service to the trade. This was done to address not only the growing demand for traceability and transparency—including tracking (from mine to market) and tracing (from market to mine)—of gemstones in the jewellery industry, but also to expand gemmological documentation of how a rough stone becomes a cut stone and eventually finds its way into a beautiful piece of jewellery.

A GemTrack™ document links a cut stone to a specific rough stone using gemmological techniques. GemTrack™ is based on a combination of crystallographic, structural, chemical and microscopic analyses that allow for detailed and potentially unique characterisation and fingerprinting of a rough stone. These same features are later investigated in the cut stone, following the cutting and polishing process. Currently, SSEF offers GemTrack™ services only if a specific rough stone is made into one cut stone. A GemTrack™ document can only be issued if sufficient crystallographic and microscopic characteristics are present in a stone. GemTrack™ provides expert scientific opinion linking a rough stone to a cut stone, thereby gemmologically documenting part of a stone's journey from mine to market. It does not make any specific claims of mine of origin. When credible documentation is provided (e.g. transparent sales receipts from a rough auction), a GemTrack™ document may state that based on provided documentation a gemstone was sourced from a specific company or auction. GemTrack™ does not make any claims about how and when a gemstone was mined, as this cannot be ascertained using gemmological methods. GemTrack™ is a SSEF document, which presents data of a specific stone in its rough and cut state, and is only issued in addition to a SSEF Report for the cut stone. A GemTrack™ document may also be issued if a gem is later mounted in jewellery, in order to document the stone from rough to jewellery.

In the past year we have issued numerous GemTrack™ documents and for gemmologists who often only get to see study a gemstone in its cut state, it's a privilege to be able to study rough stones in greater detail. One of the most exceptional stones we've recently analysed was an exceptional tsavorite garnet (analysed rough in 2018 at nearly 284 ct) owned by Bridges Tsavorite (Tucson, USA) that was cut into a square cushion-cut shape in 2019 weighing 116.76 ct after cutting by Victor Tuzlukov. The stone was fittingly named 'The Lion of Merelani' in honour of Campbell Bridges who first discovered this new gemstone variety in the early 1960s in Tanzania and Kenya and who was known as The Lion, Mzee Simba (The Old Lion), and The Lion of Tsavo by the locals in Kenya.
Needless to say that it's an honour to be able to study such exceptional stones in rough and cut states and contribute to the scientific characterisation that can provide further documentation and education to end consumers.
For more questions about GemTrack™ please don't hesitate to contact us.
*** Dr. L.E. Cartier**

SCHWEIZERISCHES GEMMOLOGISCHES INSTITUT
SWISS GEMMOLOGICAL INSTITUTE
INSTITUT SUISSE DE GEMMOLOGIE

SSEF GEMTRACK™ DOCUMENT

ROUGH TSAVORITE

Testing by SSEF

Date of Testing:	17 January 2018
Weight:	283.758 ct
Measurements (approx.):	40.20 x 38.20 x 25.80 mm

CUT TSAVORITE

Testing by SSEF (Report No. 107576)

Date of Testing:	30 May 2019
Weight:	116.764 ct
Measurements:	26.95 x 26.78 x 19.30 mm

TRACKING RECORD

1 The rough tsavorite (283.758 ct) was submitted to SSEF and meticulously analysed and characterised on the 17th of January 2018.

2 The cut tsavorite (116.764 ct) was resubmitted to SSEF and extensively analysed on the 3rd of June 2019.

3 Gemmological analysis by SSEF indicates an East African origin for this tsavorite.

Based on the consistency of the analysed properties and internal features of the described rough and cut tsavorite, it is the opinion of the SSEF that the tsavorite of 116.764 ct described in SSEF Gemstone Report No. 107576 was cut from the 283.758 ct rough tsavorite, tested by SSEF before cutting.

Disclaimer: SSEF makes no warranty for the provided documentation and issues this GemTrack™ document based on provided information and within the limits of gemmological characterization of gemstones. Measurements and photos are approximate.

Mandatory document verification: www.myssef.ch

△ The Lion of Merelani, a 116 ct cushion-shaped tsavorite garnet of exceptional quality cut from a nearly 284 ct piece of rough.

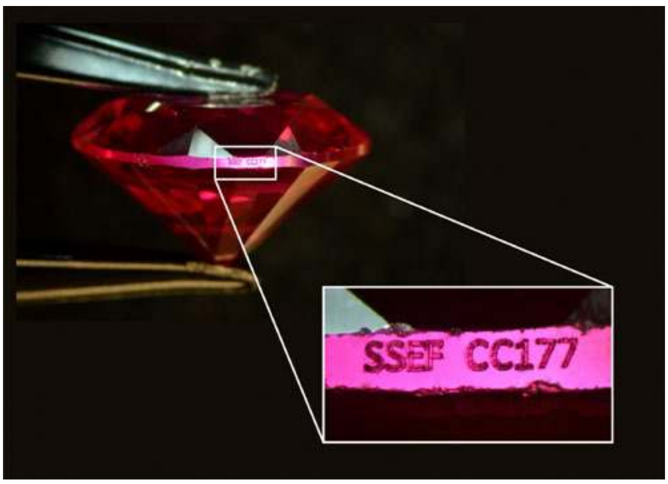
SUB-SURFACE LASER INSCRIPTION AND MARKING OF GEMSTONES

Inscription of diamonds and gemstones has been offered for several years, whereby a logo or a report number is inscribed on the girdle of a stone after cutting and polishing. This is done by some natural diamond sellers or grading laboratories and synthetic diamond manufacturers to document the provenance of such products (Eaton-Magaña and Shigley, 2016). It may also be done for coloured gemstones (Figure 1) and even pearls (Hänni and Cartier, 2013). The drawback associated with physically marking gems on their surface is the possibility that they may be re-cut and such markings thus lost. More problematic is the concern that surface marks may be fraudulently used or modified.

This article seeks to present existing options and share results of a study recently carried out by SSEF with Opsydia Ltd., a spinout company from the University of Oxford that is specialized in sub-surface laser inscription of materials such as diamonds. In the context of this study, different coloured gemstones were marked with various forms of inscription at different depths below the surface. One advantage of such complex sub-surface laser marking technology is that it cannot be removed unless considerable material is cut and polished away. Additionally, there are significant challenges in sub-surface laser marking, decreasing the potential for fraudulent replication.

Surface Laser Inscription on Girdle or Table

Basic surface laser inscription (e.g. of a report number, logo or message, see Figure 1) of diamonds and gemstones on the girdle is quite common, and offered by a number of gemmological laboratories as a service upon a client's request. Laser inscribing instruments are available on the market from companies such as Sarine (DiaScribe) and OGI (GemScribe). These laser inscription technologies remove material from the surface of the stone through an ablation process. After the material is removed, a trace of redeposited particles from the ablation process may be left in the trenches of the mark, which may increase its visibility. However, the surface nature of the inscription means that it may be completely erased by slight polishing.

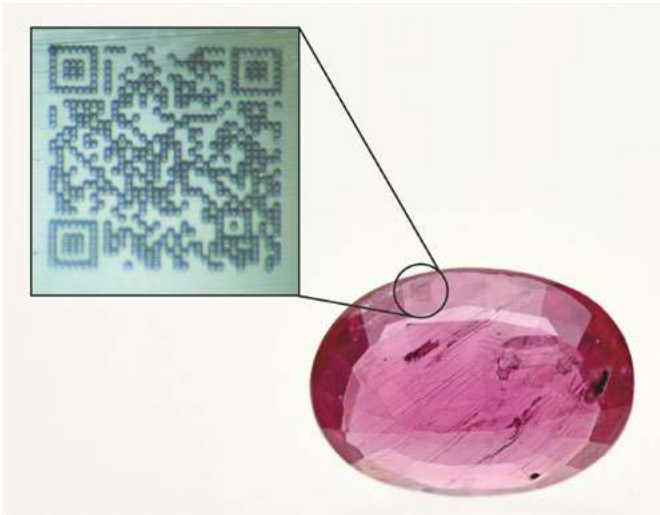


△ **Figure 1:** Laser inscription on the girdle of a cut ruby weighing 5.475 ct (e.g. with a gem lab report number). Photo: L. Phan, SSEF.

QR Codes and Data Matrices for Additional Information

Many high-end gemstones today are tested using LA-ICP-MS technology (Wang et al., 2016). As part of this process, minute amounts of material are ablated from the girdle of a stone to provide detailed trace-element chemistry data, leading to additional information for treatment detection and geographic origin determination. Rather than ablate minute laser pits, GemTOF technology developed at SSEF enables us to carry out the test while at the same time creating a QR (quick response) code of the ablated area (Figure 2).

The inscription of such a QR code can link to further information about a stone that is accessible to consumers. The advantage of such testing is that it requires no extra material to be ablated (i.e. the amounts ablated are insignificant such that a stone does not appreciably change in weight).



△ **Figure 2:** A tiny QR code can be inscribed on a gemstone during chemical analysis with GemTOF instrumentation (Wang and Krzemnicki, 2016). The QR code shown here measures 500 × 500 μm and has been inscribed on the girdle of a ruby weighing 1.311 ct. The material ablated during the inscription of the code is used to measure trace-element concentrations that are evaluated for determining country of origin. The code can be read (after magnification) using a QR reader on a smartphone, and gives the user access to various types of information on the stone. Composite photo: H. A. O. Wang and L. Phan, SSEF.

Sub-Surface Laser Inscription Experiments

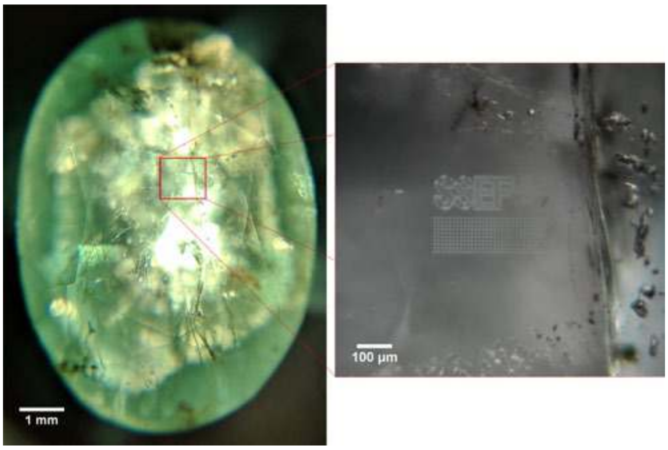
In the collaborative study by SSEF and Opsydia Ltd., sub-surface laser marking was investigated for coloured gemstones. This technology has been developed for both natural and laboratory grown diamonds and is already being applied by De Beers for Lightbox laboratory grown diamonds. Using this technology, the laser marks are customizable in shape, size and location; the laser process parameters can be tuned to create marks visible through a 10x loupe, or to be much smaller and only visible through a high magnification microscope, such that the clarity grade of a diamond, for example, is unaffected.

The laser pulses used are less than a trillionth of a second (sub-picosecond) in duration, allowing accurate sub-surface marking of features with dimensions below a micrometer. All fabrication takes place within the laser focus, with no modification to the diamond surface or surrounding regions. The feature visibility can be altered using different sets of laser parameters for fabrication and features may be arbitrarily placed in three dimensions.

For coloured gemstones, different modification regimes were investigated for this study. The marks were checked offline using a laboratory microscope. Testing demonstrated that markings could be created with various visibilities. The high-precision sub-surface laser process has been successfully demonstrated to reliably create 1µm sized features up to 250µm below the surface of all coloured gemstones tested. In the case of the ruby and emerald samples (Figures 3 and 4), larger geometric features comprised of lines have been demonstrated, with two modification regimes identified for writing marks in this study: a weak change, which is only visible as a small refractive index modification, and a stronger effect causing lattice disruption.

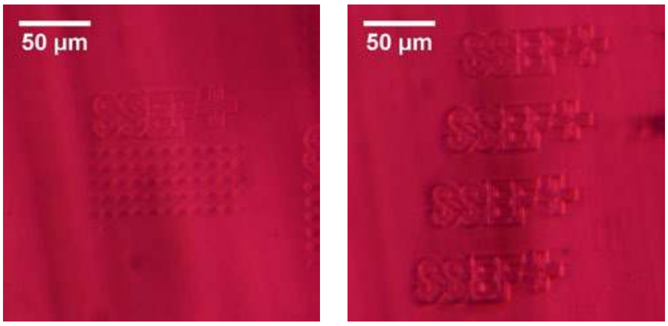
Both the index change and lattice disruption modification regimes offer promising development opportunities, leading to ultra-precise marks that do not affect the integrity of a gemstone:

- Index change—robustly creates controllable, faint marks that have no effect on the surrounding crystal structure. Future work would focus on developing a customer specific mark compatible with illumination and detection methods.
- Lattice disruption—robustly creates more visible marks, with some effect on the surrounding crystal structure (see Figure 4 for examples). Future work could focus on creating customized laser control schemes to constrain the modification to the desired mark geometry.



△ **Figure 3:** Left: Photograph of the emerald sample taken after fabrication testing using a 20x macro lens (this is similar to looking through a standard eye loupe). The sample has inclusions, is filled in and cracked over large areas. The only mark written in the emerald sample can be seen in the square annotation, but is difficult to see and is not legible at this magnification. Right: Higher magnification transmission microscope image of the square annotated region from the left image, focused on the fabricated feature at a depth of 250µm below the table surface. (Photos: Opsydia)

The advantage of sub-surface laser inscription is that the marker sits below the surface, which prevents the easy removal of the marker. As seen in our preliminary tests, the laser inscription may purely involve changing the refractive index of the material, without any lattice breakdown or removal of material. Therefore no trace of redeposited particles can be



△ **Figure 4:** Transmission microscope images of a set of test marks written inside the ruby sample table, all written at approximately 250µm below the surface. Left: 100µm-width SSEF logo and 10x5 array of 5µm-diameter dots written as an index change mark. Right: 100µm-width SSEF logo written with four different parameter sets, increasing the intensity of each subsequent mark downwards. (Photos: Opsydia)

observed at the boundaries of the features, generating a barely visible mark.

The lattice disruption regime is accessed using a higher range of pulse energy from the fabrication laser, causing not only change in refractive index, but also lattice breakdown at a microscopic scale (without compromising the stability of the gem). As shown in the right-hand image of Figure 4, these stronger modification marks are more visually perceptible compared to those produced by the index-change method. When compared to surface laser inscription, such a sub-surface inscription technique offers potential for more secure marking in coloured gemstones while still being invisible through a loupe.

Conclusions

While the methods outlined in this article are not currently being offered as a standard service for coloured gemstones, such protocols are becoming increasingly feasible due to the rapid developments in technology.

One major issue to be addressed with coloured gemstones is the large variability in the purity of stones, and thus standardizing the location of laser marking so that it become easily visible. Heavily included or fractured stones make sub-surface laser markings more difficult for a user to localize and recognize.

We also note that there are a whole range of issues pertaining to the accountability and veracity of the information documented by such technology, but that goes beyond the scope of this article and will be addressed elsewhere. Meanwhile, we look forward to continuing our research in this technology development and providing secure marking solutions that are widely applicable for the gemstone trade.

*** Dr. L.E. Cartier**

REFERENCE

Cartier L.E., Krzemnicki M.S., Rimmer A., Fish L., Myles D., Wang H.A.O., Chalain J.-P., 2019. Laser Inscription and Marking of Gemstones: An Overview of Options. Incolor, Summer 2019, 43, 66-69.

DNA FINGERPRINTING OF PEARLS AND PRECIOUS CORALS: NEW SERVICE

△ **Figure 1:** A natural pearl necklace with pearls likely from *Pinctada radiata* of the Arabian/Persian Gulf. DNA fingerprinting can provide further documentation of the provenance for such exceptional pearls. Photo by L. Phan, SSEF

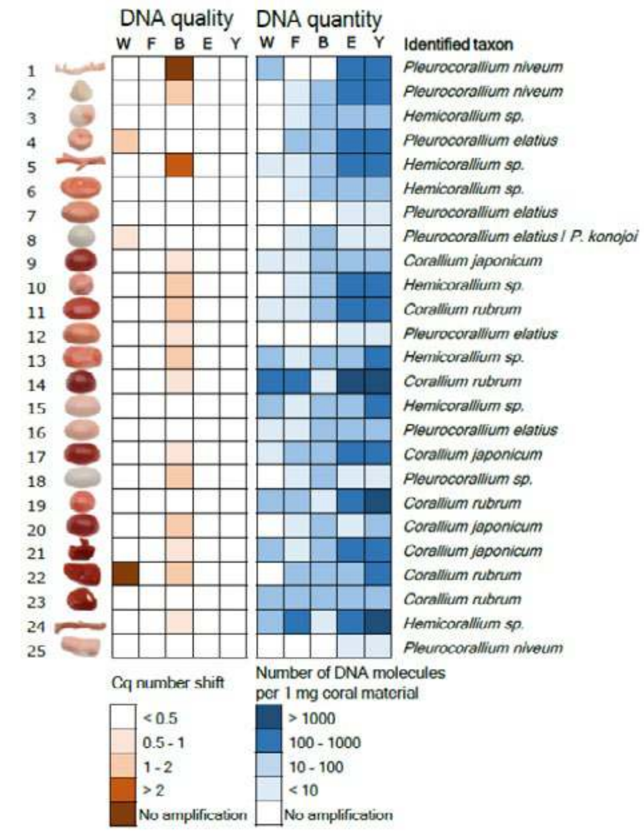
Organic gems such as pearls and precious corals (Figure 1) usually contain minute amounts of organic matter bound by a mineral matrix. Both the organic matter and the matrix may contain small amounts of DNA that can be extracted and analyzed using novel extraction and fingerprinting techniques. This method was developed by SSEF with partners at ETH Zürich and published in 2013 using different types of pearls and oyster species (Meyer et al., 2013). The method has been further refined since 2013 so that the pearl does not need to be destroyed (i.e. quasi non-destructive) and the amount of required material has been considerably reduced. DNA fingerprinting can thus offer conclusive identification of the oyster species to which a pearl or precious coral corresponds.

DNA fingerprinting can increase transparency (through origin and species determination) and prevent fraud by identifying protected species for other organic gems, and help in documenting the provenance of natural pearls, cultured pearls and precious corals.

In recent months, we have expanded our DNA fingerprinting reference database and capabilities from an initial three species (*Pinctada margaritifera, Pinctada maxima and Pinctada radiata*) to a total of seven oyster species commonly found in the natural and cultured pearl trade. We are proud to be able to provide DNA fingerprinting as a new service to clients in collaboration with the Institute of Forensic Medicine (IRM) of the University of Zürich.

DNA in Corals

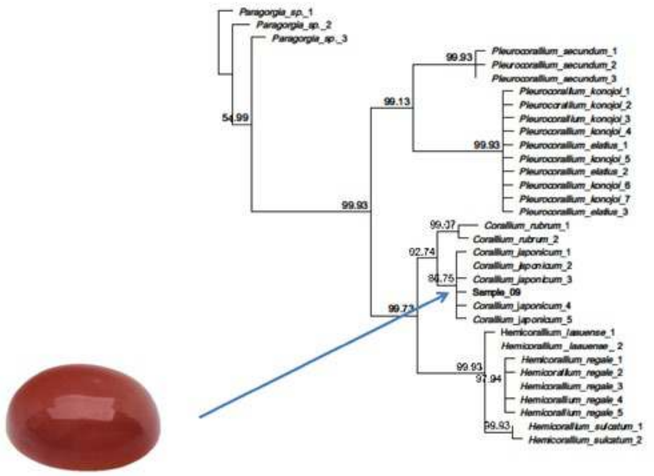
In the past year we have carried out detailed DNA extraction and fingerprinting efforts on the eight main precious coral species used in jewellery (a selection of these is presented in Figure 2). This involved a comprehensive study examining the best possible DNA extraction methods for precious corals and possibilities for sequencing and taxonomic attribution. The study has just been published in the peer-reviewed journal Scientific Reports (Nature Group).



△ **Figure 2.** Results of the DNA extract purity and quantity measurement experiment and taxonomic identification of 25 worked precious coral samples. Five methods were used to extract DNA from equal amounts of material from each sample. PCR inhibition measurement and absolute template quantification was performed with quantitative real-time PCR. Two short mitochondrial DNA fragments were sequenced and each specimen was taxonomically assigned. cQ corresponds to the quantification cycle. Source: Lendvay et al. (2020).

We aimed to explore whether precious coral skeleton fragments cut, carved and polished for jewellery could be taxonomically identified through genetic analysis. We compared five different DNA extraction methods to find the method producing the highest purity and quantity of DNA (figure 2), then applying the most successful technique to extract DNA using a minimally destructive sampling method and amplify and sequence the recovered DNA to taxonomically identify the coral samples (figure 3). The study shows that genetic analysis of gem-quality precious corals is an efficient method to assess their species identity and that it can be applied to precious corals found in the trade. The extensive methodological research has also allowed us to reduce the amount of sample material required, as we were able to recover DNA from as little as 2.3 mg of material.

Furthermore, this study has uncovered a new species of precious coral previously unreported in the trade even though it was identified amongst studied coral samples which we sourced from the trade. A number of studied samples turned out to be *Pleurocorallium niveum* (found in the Pacific), which can be considered a new species for the jewellery world. Having access to powerful DNA analysis technology – which itself is rapidly developing too- will allow us to uncover many other mysteries of pearls and precious corals in future.



△ **Figure 3:** Majority-rule Bayesian phylogenetic tree constructed from combined mitochondrial LR and MSH region DNA sequence data of worked precious corals and reference samples. Posterior probability value is displayed after each tree node.Following DNA fingerprinting, the sample shown on this photo fits corallium japonicum reference data. Figure: B. Lendvay, IRM/SSEF.

New Service: DNA Fingerprinting of Precious Corals and Pearls

DNA fingerprinting as a tool in gemmology illustrates the importance of collaborating with researchers from other fields in order to develop new gemstone testing techniques for the 21st century. It provides an opportunity for conclusive species identification and potentially even geographic organic determination for certain types of pearls, precious corals and ivory specimens.

We will shortly be launching DNA fingerprinting analysis as a regular service for clients for pearls (natural and cultured) and precious corals. You can read more about the method used to carry out DNA fingerprinting of precious corals in the article that is referenced below (Lendvay et al., 2020). This is the first ever scientific peer-reviewed article on DNA fingerprinting of precious corals used in jewellery, and we are pleased to share our approach and methodology with a wider audience. Stay tuned for SSEF publications and announcements on this research theme in the coming months. * **Dr. L.E. Cartier**

FURTHER READING

Lendvay B., Cartier L.E., Gysi M., Meyer J.B., Krzemnicki M.S., Kratzer A., Morf N.V., 2020. DNA fingerprinting: an effective tool for taxonomic identification of precious corals in jewelry. Scientific Reports, https://www.nature.com/articles/s41598-020-64582-4

GENETIC IDENTIFICATION OF IVORY SPECIES: RESEARCH AND TESTING

△ **Figure 1:** A sample of ivory, about 5 centimetres in length, which was conclusively identified as being from extinct mammoth ivory (Mammuthus sp.), following DNA fingerprinting analysis. Photo: SSEF

In 2019, SSEF became the first gem laboratory worldwide to introduce DNA fingerprinting of ivory as a standard client service. This work is done in collaboration with the Institute of Forensic Medicine at the University of Zurich, one of Switzerland's leading forensic institutes. DNA fingerprinting of ivory involves a scientific method that can provide valuable information about the species of ivory being used in jewellery and ornamental objects, in order to determine whether it is CITES-listed elephant ivory or non-listed mammoth ivory. DNA fingerprinting, together with a morphological analysis of an ivory sample, helps ascertain whether an item of ivory originated from a historic or modern source. This is particularly helpful in identifying cases of fraud where, for example, CITES-regulated elephant ivory is misrepresented and sold as mammoth ivory. To conclusively identify the species of ivory using commonly available gemmological lab techniques can be challenging, especially if Schreger lines are not evidently visible.

Elephant ivory from African (Loxodonta spp.) and Asian (Elephas spp.) elephant tusks is comprised of collagen and carbonate-rich hydroxyapatite (dahllite, $Ca_{10}[PO_4]_6[CO_3] \cdot H_2O$). Ivory can be found in a large number of animal species, of which elephant ivory is the most studied due to its value, recognition and cultural importance. In recent years, mammoth ivory has appeared more widely on the market, as elephant ivory trade restrictions have taken force (e.g. under the Convention on International Trade in Endangered Species of Wild Fauna and Flora, or CITES; www.cites.org/eng/niaps). CITES regulates the trade in biogenic gem materials that are produced by species included in its Appendices I, II or III.

The need to conclusively identify the source and species of samples of ivory in the trade has become more urgent following discussions in August 2019 by the Convention on International Trade in Endangered Species (CITES) on the possible inclusion of mammoth ivory in the CITES appendices. Mammoth ivory is used in carvings and jewellery, and is mainly sourced from the remains of mammoths preserved in the permafrost of current-day Siberia. The mammoths, which were common to the region, became extinct about 10,000 years ago.

△ **Figure 2:** Ivory sample preparation by Nadja Morf for subsequent DNA fingerprinting analysis at the Institute of Forensic Medicine of the University of Zürich. Photo: IRM.

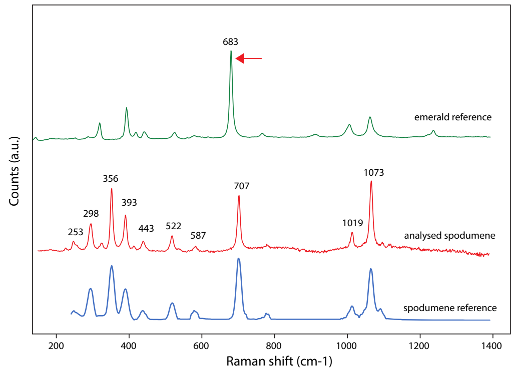
With ivory, origin determination based on DNA analysis has already been proven possible (Wasser et al., 2004). However, the available methodology requires large amounts of sample material and is thus not appropriate for jewellery or other items that cannot be destructively tested. The method used by SSEF requires much less material (ca. 100 mg) for testing of such samples.

The ability to trace ivory back to its species-related and geographic origins can provide greater transparency and help curb trade in illegal materials (and thus restrict poaching and smuggling). It will also help in the documentation of historic samples.

Please contact us for more information on this service. *** Dr. L.E. Cartier**

GREEN SPODUMENE SOLD AS EMERALD IMITATION

△ **Figure 1:** Spodumene crystals (longest item about 50 cm long and 5.9 kg heavy) submitted to SSEF as new 'emeralds' from Pakistan shown here together with a faceted emerald from Pakistan (magnified size). Photo: L. Phan, SSEF.



△ **Figure 2: Comparison of Raman spectrum of the analysed green spodumene with spodumene reference and emerald reference. Both silicates (beryl and Li-pyroxene) show similar pattern of Raman peaks, but still with distinct and characteristic differences in the peak position.**

By the end of 2019, we received three transparent crystal fragments of vivid green to greenish blue colour totaling a weight of 13 kg. These crystals reportedly came from a new find of 'beryl' in Pakistan and came along with reports declaring them to be emeralds of high value. If true, such a mesmerizing find could be a bonanza for the early birds, and therefore no time was lost after delivery from Peshawar to send us these stones for ID testing. Although SSEF does not issue any reports for rough items, we were still interested to check and analyze these announced wonders of nature.

Still, testing such large items is quite challenging, as no normal refractometer or hydrostatic balance would be able to handle such a giant. When carried on our heavy duty trolley, a first visual check already raised doubts and eyebrows alike. The crystals – as beautiful and gemmy as they looked – showed conspicuous orthogonal cleavage planes and rather orthorhombic crystal shape; as such definitively not matching to the properties of any beryl.

Given the dimensions and the etched surface of these crystals, our first choice for a definitive identification was quickly found by using Raman spectroscopy. This easy and straightforward analytical method registers the characteristic spectral 'fingerprint' of any substance (e.g. mineral or gemstone) which is caused by the inelastic scattering of light (e.g. laser beam) by the molecular structure of the analyzed substance. The result was crystal clear and confirmed our first assumptions (Figure 2). In fact, we had in our hands a nice selection of spodumene (lithium-bearing member of the pyroxene group), a mineral found in quite large specimens and quantities in Li-enriched pegmatites, namely along the Himalayan mountain range, and in many other localities worldwide.
The observed vivid green to greenish blue colour has to our knowledge only been reported from irradiated spodumene and is considered unstable when exposed to sunlight (Nassau 1994, Tay 2008, Bosshart et al. 2011, Liu et al. 2017). Based on the literature, we strongly presume that the analyzed spodumene crystals were intentionally irradiated (treated) to generate the vivid green colour with the aim to imitate emerald as far as possible.

Unfortunately, such sudden gemmy finds often end in trouble and disappointment as in this case. Still, good to know that Pakistan is a real source of fine quality emeralds (e.g. Swat valley in Northern Pakistan) – but usually of distinctly smaller size. ***Dr. M.S. Krzemnicki**

REFERENCE

Bosshart, G., Tay, Y.K., Hainschwang, T., Krzemnicki, M., Dressler, R., 2011. Colorimetric investigation of unstable and stable spodumene colours. IGC 2011 Abstracts Proceedings, Interlaken, Switzerland, 26-30.

Liu S.E., Bosshart G., Ming-sheng P., 2017. Reinvestigation of the causes of colour in natural and irradiated green spodumene. Journal of the Gemmological Association of Hong Kong, Vol. 38, 79-80.

Nassau K., 1994. Gemstone Enhancement. Butterworth-Heinemann, Oxford, England.

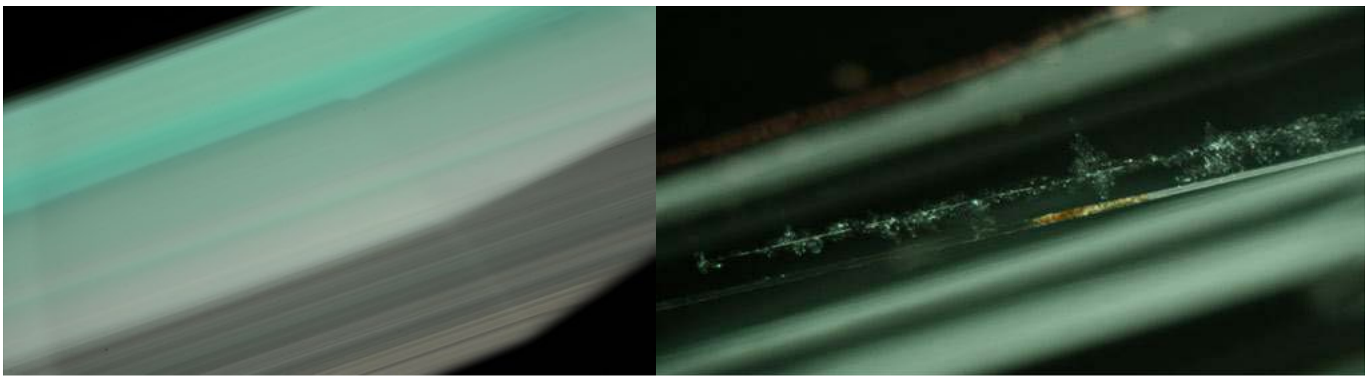
Tay, T.S., 2008. Unusual colour of green spodumene from Pakistan. Australian Gemmologist 24, 230.

EMERALDS FROM RIVERINA, AUSTRALIA

△ **Figure 1:** Emeralds (4.98 – 5.80 ct) from the Riverina deposit in Western Australia, some which possess exceptional gem quality. Photo: L. Phan, SSEF.

In early 2019, an Australian client submitted a small series of gem-quality light green emeralds ranging from 2.01 – 5.80 ct in weight, which reportedly originated from the same rough crystal from the Riverina deposit in Western Australia (Figure 1). Known since the late 1970s (Whitfield, 1975), this deposit has been worked sporadically in the past decades, mostly producing only small amounts of facet grade material.

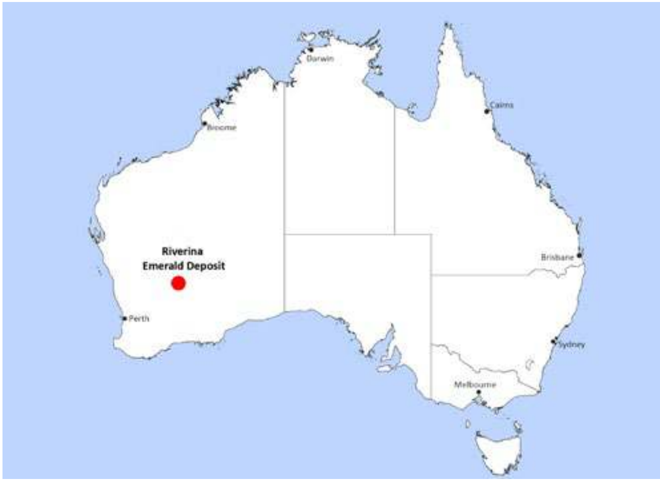
Found in the dusty outskirts about 6 km north of the Riverina station, this emerald deposit is related to Archean greenschists (chromium-rich metabasalts), cross-cut by Be-rich pegmatite dykes (Stocklmayr et al., 2017), a geological setting well-known from large economic sources such as for example Kafubu in Zambia (Zwaan et al., 2005).

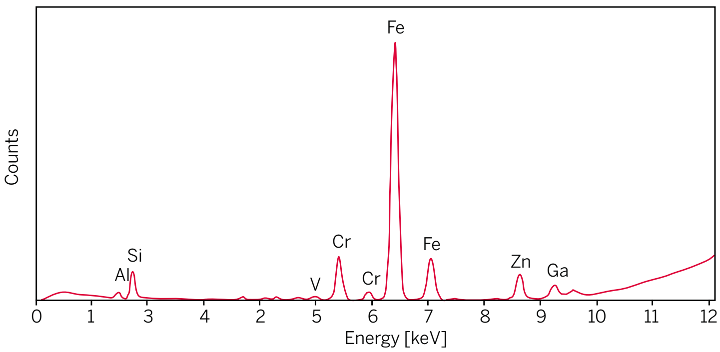


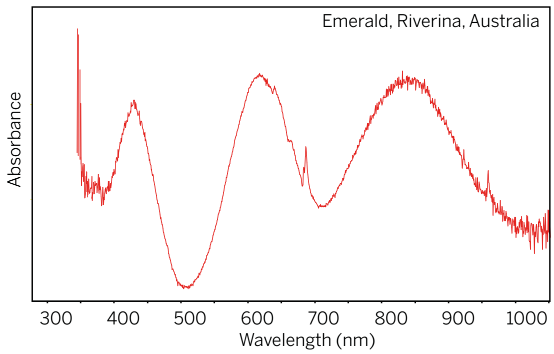
△ **Figure 2a (left):** Distinct zoning parallel to prism faces. **Figure 2b (right):** Hollow channel with brownish Fe-hydroxide and subtle rhombic whitish patches. Photos: M.S. Krzemnicki, SSEF.

The investigated samples – all of rather light green colour - showed very consistent analytical properties and microscopic inclusions. These included very distinct prismatic zonation features (Figure 2a), and hollow tubes parallel to the c-axis with subtle rhombic clusters (probably of tiny fluids) forming whitish patches (Figure 2b). These characteristics have all already been well described by Stocklmayr et al. (2017). The studied Riverina emeralds are rich in iron (Figure 3), with a Cr:Fe ratio of approximately 1:4, resulting in a distinct Fe-related absorption band in the near infrared (± 850 nm, see Figure 4).

Although only rarely found in the trade today, these emeralds from Australia of bright and vivid green colour are a very attractive addition to the treasures this continent down under offers to the gem world.
*** Dr. M.S. Krzemmicki**







△ **Figure 3 and 4:** **ED-XRF and UV-Vis-NIR spectra of a Riverina emerald from Western Australia.**

VISIT TO MUZO

Muzo in Colombia is a mythical place in the world of gemstones. It has produced some of the finest emeralds the world has seen in the last few centuries. We had the privilege of visiting the area in October 2019 and getting a first-hand impression of mining activity in and around Muzo. We were also able to visit a number of emerald cutting and trading facilities in Bogotá that allowed us to better understand the state of the emerald trade in Colombia.

Emeralds were prized by the local Muzo population long before the Spanish arrived in South America. The Muzo area came under control of Spanish conquistadores in 1567. The 'discovery' of the Colombian emerald mines in the 16th century eventually led to considerable international trade in these highly prized emeralds, many of them finding their ways to Mughal India for example.

Although Colombia boasts other emerald mining areas (including Coscuez, La Pita, Chivor), the Muzo area remains iconic and well known amongst emerald collectors. Access to the area was challenging for a long time due to instability and local conflicts. As peace slowly returned to the Muzo area and Colombia at the turn of 20th century, this presented new opportunities for the emerald sector. In 2009, The Muzo Companies (TMC) Colombia began operations and brought improved geological exploration and modernisation to the mine. In 2013, The Muzo Companies acquired licenses and concessions necessary to operate the mines in a new way and brought about a transformation of how emeralds are mined and processed.

It was also a great opportunity to study the geological context of Muzo in more detail and collect samples first-hand for the SSEF reference collection. We greatly appreciate the hospitality of The Muzo Companies, including EDLA in Bogotá and the EMS team at the mine in Muzo. Thanks also to Guillermo Galvis and Rodrigo Giraldo for their kind support in Bogotá in visiting the emerald district. * **Dr. L.E. Cartier**

△ **Helicopter ride from Bogotá to the Muzo mines offers the most efficient mode of transport and incredible vistas. Photo: A. Castillon, SSEF.**

△ **Remote lush valley visible on the flight over the Andean Cordillera on the way to Muzo in Boyaca district. Photo: A. Castillon, SSEF.**

△ **A black shale-rich river bed in the Muzo region. Photo: L.E. Cartier, SSEF.**

△ **An EMC (part of The Muzo Companies) employee walking to work. The contrast of the black (emerald-rich) shale gravels and green vegetation is impressive. Photo: L.E. Cartier, SSEF.**

△ The Muzo mine (now owned and operated by EMS, The Muzo Companies), one of the most modern gemstone mines in the world. Photo: A. Castillon, SSEF.

△ Underground in the Puerto Arturo shaft of the Muzo mine, searching and sorting for emeralds. Photo: L.E. Cartier, SSEF.

△ Emerald crystals in the host rock, consisting of black organic-rich shales and calcite veins (white). Photo: A. Castillon, SSEF.

△ Cutting of emeralds at EDLA in Bogotá. Photo: A. Castillon, SSEF.

△ Rough and cut emeralds. Photo: A. Castillon, SSEF.

△ Visit of the Muzo mines with EMS geologist Nicholas Nardini. Photo: A. Castillon, SSEF.

△ Dr. Laurent E. Cartier, Arthur Castillon and Judith Braun of SSEF on the Plaza Bolivar in Bogotá. Photo: Andrea.

UPDATE ON UNHEATED MOZAMBIQUE RUBIES

△ **Figure 1:** Iconic rubies from Mozambique all tested by SSEF and described below, all of exceptional size and quality. Photo assemblage: M.S. Krzemnicki, SSEF.

In the past decade, rubies from Montepuez in the Cabo Delgado province of northeast Mozambique have been the most significant source of gem-quality rubies in the market.

These include iconic stones such as the Rhino ruby (22.04 ct), the Scarlet Drop (15.95 ct), the the Heart of Mozambique (8.08 ct), and the Eyes of the Dragon (matching pair of 11.3 ct and 10.7 ct), to name only a few (Figure 1). The best of this material is characterized by a very homogeneous and beautifully saturated red colour and an exceptional purity, very difficult to be matched by rubies from other sources.

The presence of iron and traces of titanium in these rubies results in some cases in subtle slightly bluish zones, thus slightly shifting the colour of these rubies to purplish red, at least in part of their volume (Figure 2). This explains, in our opinion, why quite a substantial number of fine rubies from Mozambique have been treated by a so-called low-temperature heating (at about 1000 °C) in recent years, aiming to remove this slight bluish hue.

Originally a challenge for labs, the detection of such low-temperature rubies has become more straightforward in recent months, based also on research conducted at SSEF and detailed in SSEF press release published 12th September 2018 (see also Facette 2019, page 9).

As a positive side effect of research into this issue and the gearing-up of SSEF and other labs to safely detect such low-temperature heated rubies, we have seen in the past few months a growing number of Mozambique rubies with very subtle blue hues in our laboratory. This indicates that such stones are currently rather kept unheated, even with what was considered a few years ago a slight blemish in colour. This is done to maintain and safeguard the unheated status of the ruby and to acknowledge this slight colour shift in the stone as part of its individuality and beauty (Figure 2). * **Dr. M.S. Krzemnicki**

△ **Figure 2:** Matching pair of unheated Mozambique rubies (7.69 ct and 7.16 ct) with excellent purity, both showing subtle bluish zones. Although evident in this photo (due to the white background), this effect is less pronounced when looking at these stones in reality with their apparent colour dominated by internal reflections. Photo: J. Xangsongkham, SSEF.

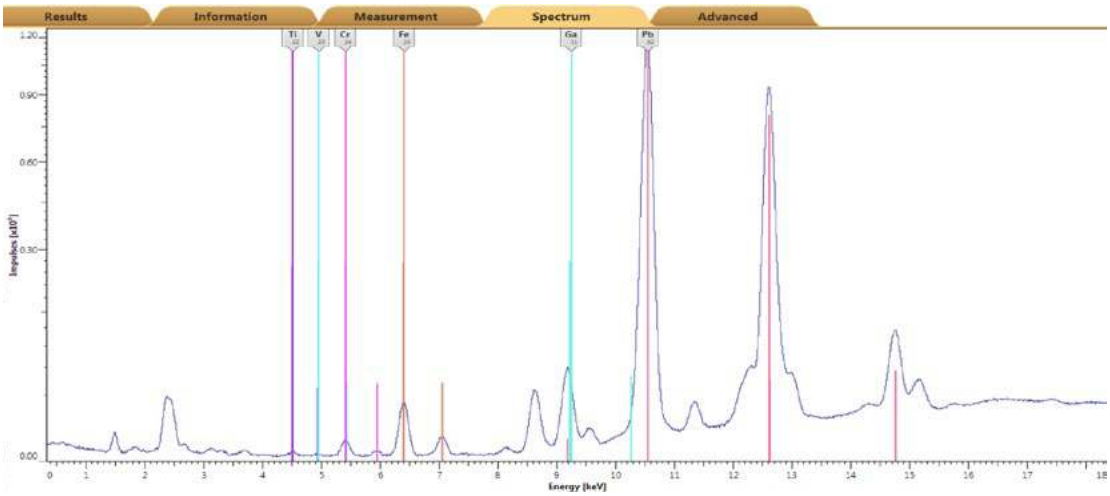
LEAD GLASS FILLED PINK SAPPHIRE WITH TRAPICHE-LIKE PATTERN

In summer 2019, we received an interesting pink sapphire cabochon for testing, displaying a fixed six-rayed star. Although somehow reminiscent to a Trapiche pattern, a microscopic study easily revealed that this was not the case.

Based on previous studies, the intriguing Trapiche pattern originally described from Colombian emeralds (Mc Kague 1964, Nassau & Jackson 1970), but also from Zambian tourmaline and from corundum, is the result of specific growth dynamics – i.e. textural sector zoning and skeletal crystal growth during which the edges of certain crystal planes grow much faster than the faces itself (e.g. Schmetzer et al., 1996; Sunagawa, 2005, Pignatelli et al. 2015). In our specimen, however, the observed phenomenon is the consequence of six triangular 'silk' zones (zones of tiny and densely arranged rutile inclusions) when looking along the main crystallographic axis of this pink sapphire and not the result of specific growth dynamics.

In addition, however, the close microscopic observation further revealed yellowish glassy residues in fissures and cavities, which were easily detected as lead (Pb) glass using energy-dispersive X-ray fluorescence. Based on these findings, it became clear that this intriguing sample with a fixed star pattern was treated corundum which had been moderately heated to introduce Pb-glass into its fissures and cavities. And so it was described as such on the SSEF Test Report that was issued.

△ **Figure 1:** Trapiche-like pattern of pink sapphire (8.55 ct) treated with lead (Pb) glass. Photo: V. Lanzafame SSEF.



△ **Figure 2:** ED-XRF spectrum of the above-described pink sapphire. Spectrum: SSEF.

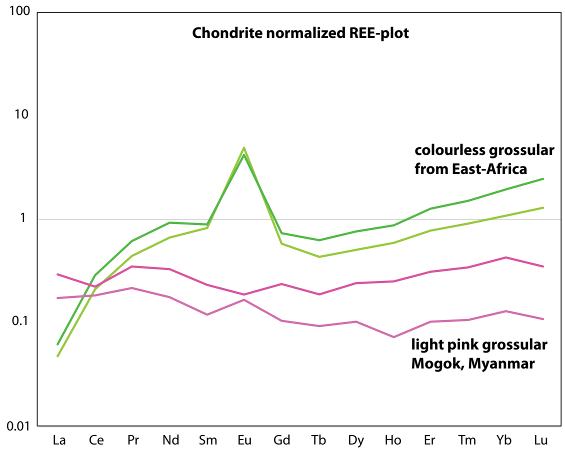
PINK GROSSULAR GARNET FROM MOGOK

△ **Figure 1:** Light pink grossular (3.43 ct and 1.74 ct) from Pein Pyit in eastern Mogok, Myanmar. Photo: V. Lanzafame, SSEF.

During the Hong Kong Jewellery Show in March 2019 we received two samples for research of newly discovered grossular garnet reportedly from Pein Pyit in eastern Mogok, Myanmar (Mark H. Smith, Thailanka Trading Ltd., Bangkok). These garnets are characterized by a subtle pink colour in daylight, and they mostly show distinct orangey-red fluorescent zones under longwave ultraviolet and an even stronger yellowish white reaction under shortwave ultraviolet (Figure 2).

△ **Figure 2:** UV fluorescence of the described grossular garnets when exposed to longwave UV (left) and shortwave UV (right). Photo: L. Phan, SSEF.

Standard gemmological testing and Raman spectroscopy quickly identified these two stones as grossular garnets. The UV-Vis absorption spectrum shows a weak and broad absorption band between 450-600 nm, related to traces of Mn replacing Al in the crystal structure of grossular (Artecki & Burgess, 2000). To further understand this material, we analyzed its chemical composition, using GemTOF (see www.gemtof.ch). Apart from main elements Ca, Al, Si for grossular garnet, these two samples proved to contain distinct traces of Be, B, Ga, Zr, Nb, Sn, Hf, W, Ta, U. Interestingly, their rare earth element concentration is very low but shows no depletion in LREE and no positive Eu anomaly compared to near-colourless grossular garnets from East Africa which we analyzed and described recently (Hänsel, 2019) (Figure 3). *** Dr. M.S. Krzemnicki**



△ **Figure 3:** Chondrite-normalized rare earth element plot showing distinctly different REE pattern for light pink grossular from Mogok compared to near-colourless grossular from East-Africa.

FURTHER READING

Hänsel S., 2019. Grossular from Tanzania with uncommon inclusions. Journal of Gemmology, 36(6), 500-501.

DEEP PURPLE VESUVIANITE FROM PAKISTAN

Pakistan has a number of gemstone deposits that are related to the collision of the Indian continent with the Eurasian plate, a consequence of global plate tectonic movements.
The gem-producing areas lie in a thrust zone known as Karakorum Suture Zone. There, sediments from the Tethys Sea were welded on the Eurasian plate when the Indian continent collided into Eurasia some 65 Mio years ago. Triassic carbonate sediments and oceanic crust were imbricated in a tectonic movement. Better known examples of gemstone formations from Pakistan are emerald, topaz, peridot and many more. Sannan Skarn, a green ornamental stone, is a more recent discovery (see Hänni in SSEF Facette No. 24).
Recently, we got new material from Rainbow Minerals Ltd. (Peshawar) that turned out to be vesuvianite. Vesuviane is a complex calcium silicate that is known as facetable single crystals, but also as polycrystalline vesuvianite. Common colours are green to brown, and the colour giving element commonly is iron. Thorough chemical analyses by LA-ICP-TOF-MS revealed that the new material from Pakistan is coloured by traces of manganese and iron that lends the stone a deep purple colour (Fig. 1). Identification was straightforward and done by Raman spectroscopy. A summary chemical analysis by ED-XRF shows the chemical elements in a qualitative way, but does not provide a mineral formula. For the precise quantitative composition values of the samples, mass spectrometry was used. By scanning electron microscopy (SEM) tiny inclusions were found and identified as apatite. The described deep purple polycrystalline vesuvianite from Pakistan is translucent and can serve for cabochons and carvings. A more detailed description of this material will be published soon in gemmological journals in German, Chinese and English.

*** Prof. Dr. H.A. Hänni, SSEF Senior Research Associate**

△ **Figure 1:** A sample of rough deep purple Vesuvianite (4 cm) from northern Pakistan and cabochon of 10.73 ct. Photo: H.A. Hänni

NEW STATISTICAL METHODS FOR ANALYSIS OF GEMSTONES

In the past decades, multi-element information has become more and more important in gem testing, not only for material identification, filtering out synthetic and treated materials, but especially for determining geological origin of gemstones. Such information is not accessible by conventional gemmological testing instruments, hence making LA-ICP-MS a unique tool in gem testing labs. At the IGC conference in Namibia in 2017, we reported a study comparing advantages and disadvantages of LA-ICP-Quadrupole-MS and LA-ICP-Time-Of-Flight-MS (LA-ICP-TOF-MS, such as GemTOF at SSEF, see in Krzemnicki et al. 2017). As described then, not only is the TOF-MS instrument capable of simultaneously acquiring almost all elements in the periodic table, it also excels in mass resolving power, which allows correction of mass interferences and improvement in quantification accuracy. In gemstone analysis, below ten parts per billion (ppb) limits of detection can be routinely achieved for heavy masses, and several hundreds of ppb for light isotopes.

LA-ICP-TOF-MS: Paradigm Shift of Multi-Element Analysis for Gemstones

During more than two years of measurements with GemTOF, the authors often encounter scenarios that a priori knowledge about multi-element content of the sample cannot be presumed, for example rarely occurring elements in gemstones, or solid or fluid inclusions in geological samples. Moreover, the isotope of interest for a specific element may also be changed in the post-data processing in case we encounter unforeseen mass interferences, which may be realized only after the measurement is done or the stone has left the premises. In this short note, we would like to revisit the advantages of TOF-MS, especially the novel acquisition scheme of FIRST measure, THEN determine which isotopes are of interest. We consider this paradigm-shift to be very useful for trace element analysis on gemstones.

Based on real case studies on sapphire and emerald specimens, we here present how a simultaneous multi-element approach assists origin determination. Instead of pre-defining a list of isotopes in advance, routine analysis of blue sapphires using LA-ICP-TOF-MS detects rarely occurring trace elements such as beryllium (Be), zirconium (Zr), niobium (Nb), lanthanum (La), cerium (Ce), hafnium (Hf), thorium (Th). These elements have been observed more frequently in sapphires from Madagascar than Kashmir ones (Figure 1). Interestingly, radioactive thorium isotope (^{232}Th), as a rarely occurring isotope, decays to one of the lead isotopes (^{208}Pb) at a constant rate. By measuring intensities of parent and daughter isotopes, the formation age of the stone can be estimated without using 'time capsule' inclusions, such as zircon. This can sometimes be helpful, as the zircon inclusions are rarely found to be reaching to the surface of gemstones, hence challenging for age dating by LA-ICP-MS. In an example of a blue sapphire (Figure 2), conventional gemmological testing suggests Madagascar as its origin rather than Myanmar. During routine elemental analysis, rarely occurring ^{232}Th isotope was detected in this sapphire. Thanks to the full mass spectrum acquisition by GemTOF, all of the Pb isotopes (^{204}Pb, ^{206}Pb, ^{207}Pb, ^{208}Pb) were collected simultaneously without re-ablation, and indicated no common Pb contamination. The estimated age (~500Ma) is in agreement with that of Madagascar samples expected in other study (Elmaleh et al. 2015), which adds more evidence to the origin determination. More about our research in age dating of gemstones is given on pages 10-11 of this Facette.

		Be	Zr	Nb	La	Ce	Hf	Th
Median Conc. [ppm]	Kashmir	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
	Madagascar	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Occ. Freq. [%]	Kashmir	3.7	***1.7***	***4.3***	4.3	6.6	***2.9***	***6.0***
	Madagascar	17	***42***	***46***	14	18	***35***	***31***

△ **Figure 1.** Frequency of rarely occurring elements observed in blue sapphires from Kashmir and Madagascar. Median concentrations are below LODs.

◁ **Figure 2.** Sapphire of more than 100 ct sapphire from Madagascar. Age dating: ~500 Ma. Photo: SSEF.

Multi-Dimension Data Visualization: PCA and t-SNE

Conventionally, trace element results of gemstones are shown in bivariate plots, tri-plots, and three dimensional scatter plots to compare their elemental similarities with reference samples from database. As an example for emeralds, Figures 3a and 3b display a bivariate plot (Li-Cs) and a three dimensional scatter plot (Li-Fe-Cs) using SSEF emerald database. LA-ICP-TOF-MS intrinsically produces multi-element results (high dimensional dataset), therefore one would need to compare multiple bivariate-plots for a comprehensive data analysis, because direct visualization of the high dimensional dataset is challenging. Alternatively, statistical dimension reduction can be applied on the original dataset. Our high dimensional space of twenty element concentrations of more than 700 emerald analyses is projected onto a two dimensional space.

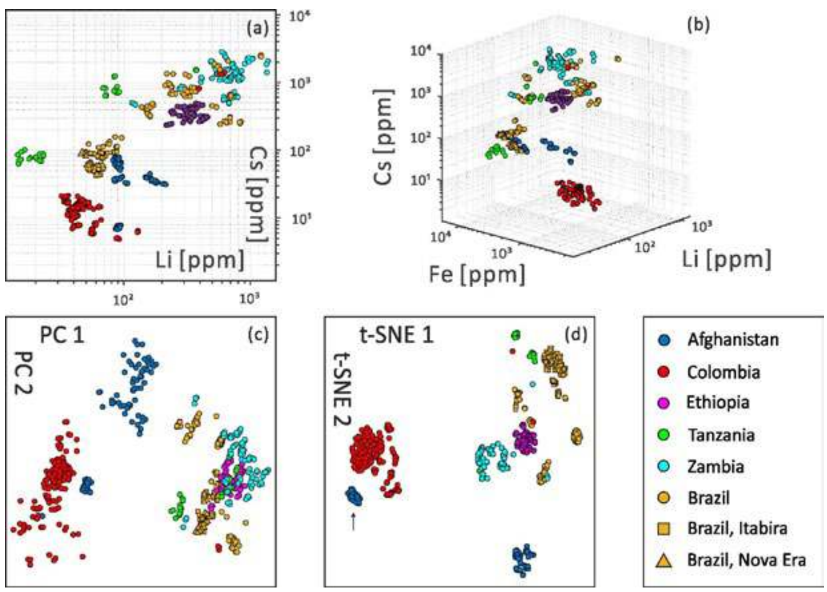
Using this example, linear principle component analysis (PCA) and non-linear machine learning algorithms (t-SNE, Van Der Maaten, 2008) were applied on our datasets (Figures 3c and 3d). Both analyses are unsupervised, meaning colours (indicating various origins) of the scatter dots are labeled only after the reduction process. In this way, groups of data points are solely dependent on the elemental similarities among the analyzed gemstones and without prior information about their origins. Based on our research, we can see that, compared to PCA, we achieve a better separation of different origins when using t-SNE algorithm (Figures 3c and 3d). In this example, the emeralds from different geographical origins can be separated from each other. Emeralds from a new find in Afghanistan (black arrow in Figure 3d), which are gemmologically similar to Colombian material (Krzemnicki, 2017), can also be distinguished from more classic emeralds from Panjshir valley in Afghanistan and Colombia. It seems that non-linear dimension reduction algorithm t-SNE is more suitable for multi-element data visualization comparing to other types of linear algorithms.

Conclusions

Although the present study reveals the potential of elemental analysis combined with statistical analysis to separate gemstones from different origins and geological settings, it is important to mention that this method is not always conclusive. Especially for corundum, multi-element analysis is rather providing complementary information, to assist microscopic observations and further analyzed properties before concluding on an origin opinion. However, as shown in this study, such statistical methods can be a valuable tool, when studying elemental similarities of gemstones from various origins. Ongoing studies focus on combining elemental data with data from other analytical methods, such as (UV-Vis, FTIR, Raman) spectroscopy and microscopy, with the aim to advance our understanding of the geological conditions during formation of gemstones and finally deepen our knowledge about origin determination of gemstones as a service to the trade. * **Dr. H.A.O. Wang**

REFERENCE

Wang H.A.O., Krzemnicki M.S., Büche S., Schmid R., Braun J., 2019. Multi-element Analysis of Gemstones and its Applications in Geographical Origin Determination. Abstract Proceedings of 36th International Gemmological Conference, 176-178.



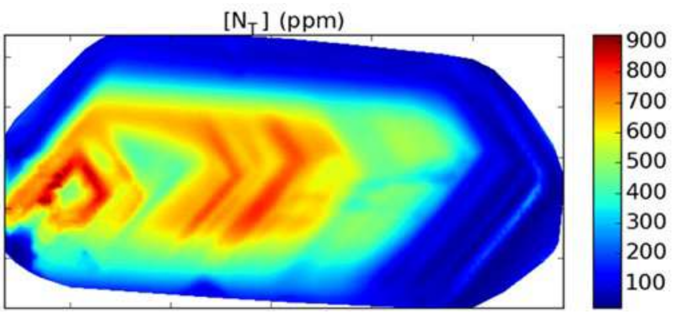
▷ **Figure 3.** Multi-element data visualization using a) bivariate plot of Li and Cs concentrations (log scale); b) 3D scatter plot of Li-Fe-Cs concentrations (log scale); high dimensional elemental data visualization using c) linear Principle Component Analysis (PCA); and d) non-linear machine learning algorithm (t-SNE). Both PCA and t-SNE analyses result from 20 element concentrations and are unsupervised, meaning origin information (colour of scatter dots) are only draw after dimension reduction.

DIAMONDS AS A WINDOW INTO THE EARTH

Diamond is valuable as a gemstone but it is also a mantle geologist's best friend because it provides a rare opportunity to study processes that occur deep in the Earth. Most diamonds form in the so-called lithospheric mantle within a fairly narrow depth-range between 140 and 200 km. However, diamonds from deeper sources, some in excess of 600 km, have been reported as well and continue to fascinate geologists.

Diamond is a valuable source of information for geologists because they can contain mineral inclusions, small pieces of other minerals present in the mantle entrapped within the diamond during growth. Protected by the diamond almost like a time-capsule, these are the only pristine samples of mantle material that geologists can study. But inclusions are not the only aspect about diamonds that make them valuable for research. Diamonds can contain a number of impurities such as nitrogen and hydrogen that can be present in different configurations in the crystal lattice. Some of these defects, most notably those related to nitrogen are known to transform according to the conditions the diamond has experienced. As a result, geologists can reconstruct the history of a diamond, and thus study conditions and processes that occur at depths that are otherwise inaccessible. The same circumstance allows gemmologists to accurately identify synthetic and heat-treated diamonds because they have been subjected to conditions that are different to naturally grown untreated stones. Thus, understanding the formation of diamond in the mantle, their storage and journey to the surface and the traces these processes leave is important in gemmology as well.

Nitrogen is the most common impurity in natural diamond. At mantle conditions (diamonds form at pressures on the order of 5-7 GPa and temperatures of 1100-1250 °C), nitrogen is mobile and can move through the crystal lattice to form different types of defects. This process referred to as nitrogen aggregation takes several hundred million or even billions of years to complete. When the diamond is brought to the surface by kimberlite magma, the process is stopped in its tracks. Using infrared spectroscopy, its progress can be measured and the temperature of mantle residence can be calculated.



△ **Figure 1:** Distribution of nitrogen in an elongated diamond from the Mir mine (Siberia) resembling growth rings in a tree. Analysis shows that this diamond has experienced temperatures between 1175 and 1125 °C. Length of the crystal ca. 6 mm.

During nitrogen aggregation in natural diamonds, another type of defect forms: platelets. This type of defect consists of additional carbon atoms forming an extra plane within the crystal lattice. At high temperatures, platelets can break down. Many of the diamonds from the Argyle mine (Western Australia) show evidence of platelet breakdown, sometimes the platelets have disappeared completely.

Platelet defects, similarly to nitrogen, can be measured by infrared spectroscopy and play an important role in authentication of natural diamonds. In an effort to simplify and speed up data processing, a new software tool was developed by the author for automatic processing of IR spectra of diamond, mainly for research purposes. The python software, called QUIDDIT (Quantification of Infrared-active Defects in Diamond and Inferred Temperatures) is available free of charge on GitHub (https://github.com/LauraSp/QUIDDIT3). * **Dr. L. Speich**

QUIDDIT
Quantification of Infrared-active Defects in Diamond and Inferred Temperatures

FURTHER READING

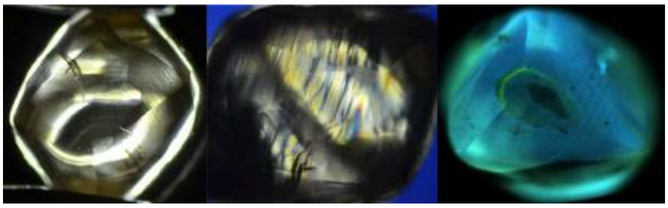
Shirey, S.B., Shigley J.E., 2013. Recent advances in Understanding the Geology of Diamonds. Gems & Gemmology, 49, 4, 188-222.

QUIDDIT project, https://www.researchgate.net/project/QUIDDIT-a-software-tool-for-automated-processing-of-diamond-IR-spectra

Speich, L., Kohn, S.C., Bulanova, G.P. et al., 2018. The behaviour of platelets in natural diamonds and the development of a new mantle thermometer. Contrib Mineral Petrol 173, 39, doi:10.1007/s00410-018-1463-4

RESEARCH NOTE: NATURAL DIAMONDS FROM KALIMANTAN

In September 2019, Tay Thye Sun (Far East Gemological Laboratory) loaned six natural diamonds from the Kalimantan alluvial placer (Borneo) to SSEF. The stones had been described before in literature (Sun et al., 2005) but were re-examined in our lab using standard gemmological methods including Fourier Transform Infrared spectroscopy, Raman spectroscopy and UV-Vis-NIR spectroscopy. Previous results were confirmed showing that the colourless to yellow and brown diamonds contain variable amounts of nitrogen (type Ia) and display blue to green UV-fluorescence. We were able to obtain additional information performing low temperature photoluminescence spectroscopy using green (514 nm) and blue (405 nm) laser sources for excitation on these diamonds for the first time. The stones show photoluminescence peaks typical for natural diamonds, including for example N3 (a common defect containing nitrogen). In addition, the presence of a perovskite inclusion was confirmed in one diamond. This mineral is known to occur at great depths in the Earth's mantle, attesting to the deep origin of this stone. The collected data will serve as reference information for natural diamond. *** Dr. L. Speich**



△ **Figure 1:** Brown rough diamond from Kalimantan (Borneo). Left to right: 1) Microphoto showing graining typical for brown diamonds. 2) Microphoto taken using polarising filters. The diamond shows birefringence due to strain. 3) DiamondView image showing typical blue and green fluorescence and graining under UV excitation. Photos: SSEF.

SYNTHETIC/NATURAL DIAMOND DOUBLET

One of the earliest gemmological descriptions on the deposition of CVD diamond films onto the surface of natural diamonds dates from 1993 (Fritsch & Phelps, DRM, 1993). Much later, in 2017 two gemmological papers were reporting - not anymore on 'CVD film deposition' - but on 'CVD layer overgrowth' (Moe et al., 2017, Serov et al., 2017). Such overgrowths on the surface of natural diamonds may have a thickness of several dozen microns.

The difference between 'film deposition' and 'layer overgrowth' is the thickness of the deposition. From a nomenclature perspective, a stone obtained after a 'film deposition' could rather be assimilated to a coated diamond, which is considered a treated diamond. On the contrary, a stone obtained after a 'layer overgrowth' could easily be assimilated to a 'synthetic/natural doublet'. Due to the extreme rarity of this product - to the best of our knowledge it is currently produced only as research samples-, the nomenclature of this peculiar artificial product is not specifically defined.

Such 'synthetic/natural doublets' have sometimes been named 'hybrid diamonds'. This appellation should be abandoned because it fails to address the most important artefact of the product, namely its synthetic portion. Moreover, by not addressing its synthetic part, this last term rather evokes a natural diamond which is misleading information.

CVD growth technology is constantly progressing. The thickness of CVD layers can today be thicker than one millimetre and from an identification perspective the detection of such a doublet requires the systematic use of advanced technological investigations. Unfortunately, simple traditional gemmological inspection will fail to correctly identify such a product. When observed with a microscope, the limit between the CVD layer and the natural diamond is not always visible (Tang et al., 2018).

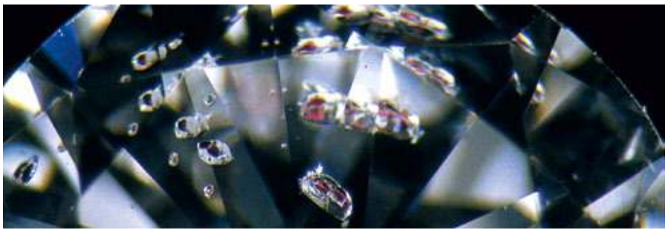
At the last CIBJO congress, the Diamond Commission instructed all diamond grading laboratories, regardless of their size, to take all the necessary measures so that these artificial products can be correctly identified prior to grading. Such measures should include luminescence imaging: either cathodoluminescence or Diamond View™ imaging.

It is noteworthy that most of the luminescence reactions of the synthetic and natural portions are quite different (e.g. strong orange versus strong blue) and thus give a straightforward characterization of the product. SSEF recently launched its own 'synthetic/natural diamond doublet' research programme to further study such samples.

In conclusion, it is important to underline that so far only a very few 'synthetic/natural diamond doublets' have been reported. Nevertheless, it is important for all laboratories to be proactively aware of a possible sudden arrival of such artificial products, so that they can at present take all the necessary measures to be able to detect 'synthetic/natural diamond in future. *** J.-P. Chalain**

RESEARCH ON SOLID INCLUSIONS IN DIAMONDS

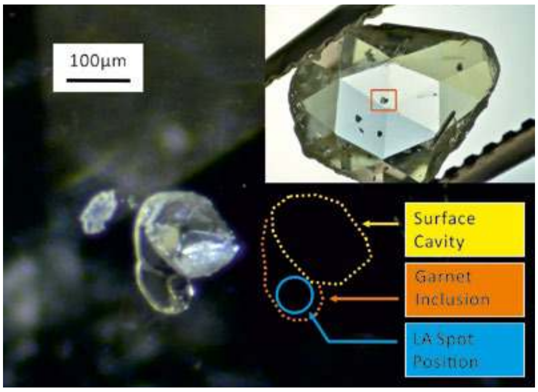
During routine gem testing in gem laboratories, the characterization and identification of solid-state inclusions in diamonds is neither widely applied nor is it considered as important as in coloured gemstones, e.g. sapphire and emerald. This is because a diamond is commonly graded and valued based on a 4Cs scheme. On the contrary, diamond inclusions are popular in geological research, since they carry key information of the composition and conditions in the Earth's mantle. By investigating diamond inclusions, scientists are able to better understand the Earth's evolutionary history (Smith et al, 2016) and the carbon cycle in the lower mantle (Walter et al, 2011).



△ **Figure 1:** Garnet inclusions observed in a cut diamond, showing multiple reflections of the inclusions through the facets of a brilliant cut. Photo: H.A. Hänni, SSEF.

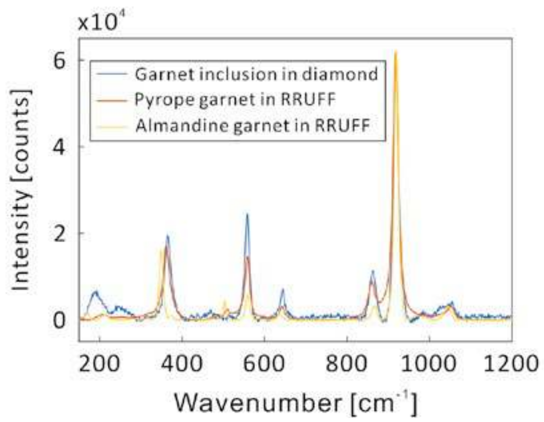
Inclusions, in general, are tiny foreign minerals or materials that either formed earlier than or at the same time as the formation of the host gem (Figure 1). In diamond, various inclusions can be found, such as garnet, magnetite, olivine, rutile, etc., which represent hints of the geological environment in which they formed. However, many inclusions are small in size, for example the garnet inclusion in Figure 2 is about 100µm in diameter (human hair diameter ≈ 75µm). Researchers obtain elemental as well as spectroscopic information from such tiny inclusions using routine analytical tools, especially Raman spectroscopy for inclusion identification. When they cannot be identified by Raman, or if their trace element composition is of interest and they are buried underneath (but close to) the surface, advanced techniques such as laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) will be needed. Even though challenges remain as conventional ICP-MS needs a pre-defined list of elements before analysis. Obtaining such a list usually involves much 'guess-timation', because obviously we cannot know the result before analysis.

In the advent of a new generation of instrumentation, LA-ICP-Time-Of-Flight-MS (GemTOF) installed at the SSEF since 2016 is able to capture almost the entire periodic table of elements without prior knowledge about the composition of samples (inclusions or gemstones). With the GemTOF setup, we are able to FIRST measure, THEN determine which elements are of interest in post-data processing procedures. This can be crucial for catching rarerly occurring elements in inclusions and analysing unknown inclusions. Although GemTOF introduces a tiny and shallow spot on the sample surface (same as any other laser ablation MS instruments), it does not affect the weight and is almost invisible to the naked eye. Due to its distinct advantage in simultaneously measuring almost all elements from major and minor to (ultra-) trace concentrations, GemTOF provides key information towards gemmological research of inclusions and gemstones, as well as country of origin determination, hence strengthening the confidence of gemstone testing.



△ **Figure 2:** Analyzed garnet inclusion in a diamond research sample. The inset photo shows the whole diamond. The boundaries of the surface cavity and garnet inclusion are sketched in yellow and orange dashed lines respectively. The laser ablation spot is marked as a blue circle at the position where the inclusion is buried about 50µm underneath the diamond's surface. Photo: J.-P. Chalain, SSEF.

In a recent project, we focused on a garnet inclusion observed in a diamond research sample (Figure 2). Raman spectroscopy identified the inclusion as pyrope garnet (Figure 3). Afterwards, we explored the possibility of analysing this garnet inclusion using GemTOF, even though the inclusion is buried about 50µm below the diamond's surface. This is so called in-situ analysis, meaning that we can analyse the inclusion as it is untouched in the diamond. This avoids the loss of elements in the inclusion or addition of foreign elements from external sources that may happen if we were to polish down to the level of the inclusion using conventional methods. In order to perform the in-situ analysis, we continuously ablate the sample from the surface (blue circle in Figure 2), while monitoring the increase of certain elements (silicon Si and aluminium Al), which indicate that the laser ablation has reached the inclusion. In post-data processing, we then extract only the signal recorded during the ablation into the garnet inclusion, and quantify multi-element concentrations using an external calibration standard (NIST610).



△ **Figure 3:** Raman spectrum of the analysed garnet inclusion in diamond. This spectrum seems to be in good agreement with that of pyrope garnet from the RRUFF database, supporting the hypothesis that this inclusion is a pyrope garnet. However, detailed species information can be difficult to obtain from the Raman spectrum.

Since GemTOF acquires nearly all elements at the same time, we were able to determine which elements are present in the inclusion, after the measurement. As shown in Table 1, magnesium (Mg) is a major constituent in the inclusion, pointing to a pyrope-rich garnet. In addition, minor amounts of calcium (Ca), iron (Fe), chromium (Cr) and manganese (Mn) were detected. The evidence reveals that this garnet inclusion is not a pure pyrope garnet, but a mixture of different species of garnet (as calculated in Table 1). The inclusion is made of pyrope garnet (primarily so, and this fits with the Raman spectrum indications), almandine garnet, uvarovite garnet, knorringite garnet and spessartine garnet.

Oxide Composition in Weight Percent of the Garnet Inclusion in Diamond			
SiO_2	40.2 wt%	Al_2O_3	20.8 wt%
MgO	21.0 wt%	CaO	4.1 wt%
$Fe^{TOTAL}{}_2O_3$	6.0 wt%	Cr_2O_3	7.2wt%
MnO	0.2 wt%	**Total**	**99.5 wt%**

Calculated Chemical Formula of the Garnet Inclusion		**Mole Fraction**
Pyrope	$Mg_3Al_2(SiO_4)_3$	66.6 %
Almandine	$Fe_3Al_2(SiO_4)_3$	11.8 %
Uvarovite	$Ca_3Cr_2(SiO_4)_3$	10.8 %
Knorringite	$Mg_3Cr_2(SiO_4)_3$	10.3 %
Spessartine	$Mn_3Al_2(SiO_4)_3$	0.5 %

△ **Table 1:** Chemical composition of the garnet inclusion in the studied diamond sample.

Trace elements of garnet inclusions often provide hints about the geological environment in which the diamond may have formed. Based on the composition of CaO and Cr_2O_3, we assume that this garnet inclusion in diamond may be of harzburgitic paragenesis (Stachel and Harris, 2008). Furthermore, 40 additional elements at (ultra-)trace levels have been detected in this garnet inclusion. We were able to measure a wide range of elements from sodium (Na) to thorium (Th), including a complete suite of rare earth elements (REE).

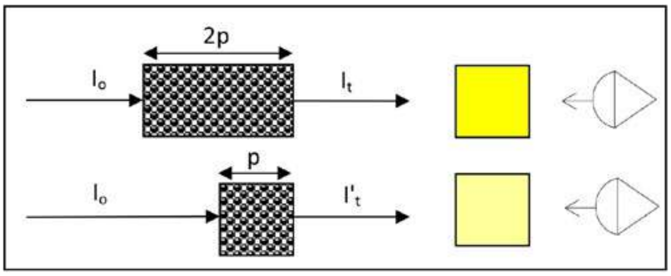
From the 7 (major and minor) + 40 (trace) = 47 elements in this garnet quantified by GemTOF, we would like to highlight a potential 'elemental fingerprint' for garnet inclusions in diamond. This 'fingerprint', characterized by 47 parameters is unique for each garnet inclusion. When a multivariate statistical analysis is applied on this high dimensional dataset, we expect to see that garnet inclusions can be grouped based on the similarities of their 'fingerprints'. Similar statistical analyses have successfully provided insights into coloured gemstones' countries of origin, such as emeralds and Paraíba tourmalines (Wang et al, 2019). Nevertheless, one issue remains, which is the difficulty to analyse such inclusions when they are not close to surface of diamond. Ongoing and future research on the correlation between elemental composition and optical spectroscopic properties of an inclusion (e.g. micro Raman and micro FTIR) may provide further insights. *** Dr. H.A.O. Wang**

HPHT SYNTHETIC DIAMOND: COLOUR VS SIZE VS SWUV TRANSMISSION

Non-treated nitrogen-rich HPHT synthetic diamonds are of type Ib, they contain solely single substitutional nitrogen atoms responsible for their typical yellow colour, sometimes referred by the trade to as a 'canary' colour (Collins, 1982).

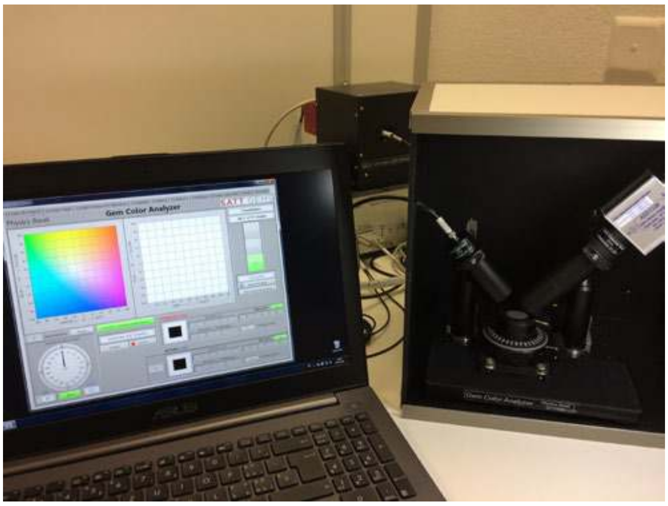
The yellow saturation of type Ib diamonds is directly proportional to their nitrogen concentration and of course to the path length of light (Kiflawi, et al., 1994). Thus, the colours of type Ib diamonds of equal nitrogen concentration are only depending on the path length of light inside the stone (Figure 1)

This study presents the comparison of the colours and of the Short-Wave Ultra-Violet (SWUV) transmissions of four as-grown HPHT synthetic diamonds of type Ib of equal and very low nitrogen concentrations (approximately 1 ppm). This enables a better understanding on the effectiveness of Diamond Verification Instruments (DVI) such as the ASDI instrument (Chalain, 2014) which screens melee-size colourless diamonds for separating natural diamonds from possible synthetic diamonds based on their relative SWUV transmission.



△ **Figure 1:** When a light source (I_o) passes through two samples of the same transparent material, the colour of the thicker sample appears more saturated than that of the thinner sample (from the 'Lambert law'). The yellow squares represent the different saturations seen when observing the samples in the direction of the light source (I_o).

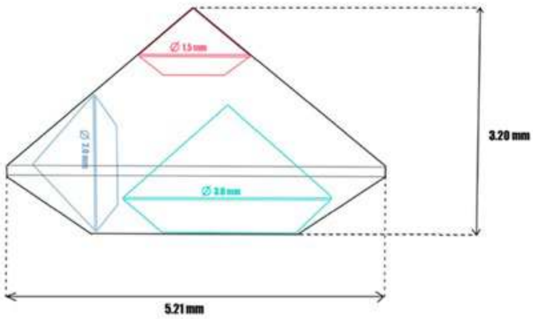
Before recut, the large diamond was weighting 0.532 ct and had a diameter of 5.21 mm. Its colorimetric measurements (Table 1) were recorded on an in-house colorimeter (Figure 2).



△ **Figure 2:** The in-house built 'SSEF Gem Colour Analyzer' was used to measure the CIE Lab colour coordinates of the studied stones. They are placed table down in a dark chamber. A very thin beam of calibrated light is focused on their pavilion. The detector measures the colour coordinates of the stone during a 360° rotation.

Reference	Ø (mm)	CIE (L*a*b*)	Colour Grade	Transmission (1) @ 270 nm	Absorption coefficient @ 270 nm
97768	5.2	(103.4152, -2.1697, 6.2871)	S-Z	NA	4.9 cm-1
97768A	3.0	(101.4331, -0.1404, 1.5446)	G	7.5 V	2.5 cm-1
97768B	2.0	(98.6827, -3.0896, 7.8891)	S-Z	0.2 V	14.3 cm-1
97768C	1.5	(76.0195, 0.3616, 3.1669)	M-R	0.7 V	NA

△ **Table 1;** (1) Voltage measured by the ASDI device; NA: Not Applicable due to the size out of specifications



△ **Figure 3:** Recut specification of the 0.532 ct synthetic diamond into three melee-size stones.

After the colour measurement of the large stone, the infrared and UV-Vis absorption spectra were recorded and finally it was recut into three melee-size round brilliant stones as shown in Figure 3.

The pre-shaping of the three melee-size stones was performed at Synova SA (www.synova.ch) on a 5 axes high precision water guided Laser MicroJet LCS 305 machine (Figure 4). This unique technology enables parallel kerfs of only 50 to 65 µm.

These 3 stones were then polished in three full-cuts (32/24) on a traditional scaife. Their final diameters are: 3.0 mm, 2.0 mm and 1.5 mm. Later, the CIE lab colour-coordinates of the three stones were measured (Table 1). And their SWUV absorptions were recorded on an in-house built spectrometer.
The comparison of the SWUV absorptions, SWUV transmissions and colour coordinates of the four stones enables establishing the correlation between colour and SWUV transmission.
It illustrates why and how it is efficient to screen colourless (D to J) synthetic diamonds based on the measurement of their SWUV transmission, even though some of them would have a very low nitrogen concentration. *** J.-P. Chalain**

REFERENCE

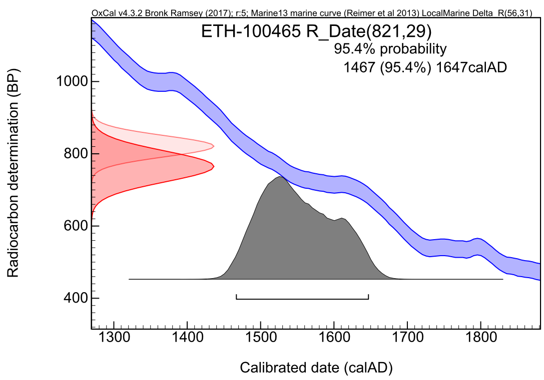
Chalain J.-P., Phan L., Krzemnicki M.S., Pausch J., Steinacher M., 2019. Study of a recut HPHT synthetic diamond: colour vs size vs SWUV transmission. Abstract Proceedings of 36th International Gemmological Conference, 35-37.

△ **Figure 4:** The SYNOVA LCS 305 sawing device (left image) is a 5 axes water-guided laser-MicroJet machine which enables very precise (+/- 0.1°) cutting profile. The precise positioning of the stone (right image) is observed via the help of a digital camera. Please note the white substance lying at the culet side of the stone enables the laser to easily penetrate into the stone. Photo: Synova.

AGE DATING OF CORAL

◁ **Figure 1:** Sciacca coral item from which beads were selected for age dating. Also in this picture are two pieces of raw *corallium rubrum*. Photo: M. Bichsel, SSEF.

Since 2017, the Swiss Gemmological Institute SSEF offers radiocarbon dating of pearls as a service. To further expand our knowledge about this method and its applicability to other biogenic gem materials, we were happy to receive a number of small coral beads for age dating (kindly donated by E. Liverino). These beads were reportedly carved from so-called 'Sciacca' coral, *corallium rubrum* of historic age, sedimented in coral deposits off the coast of Sciacca, a small town in southwestern Sicily, Italy. In this area, frequent volcanic and tectonic activity in the past 10'000 years (Holocene) has resulted in a submerged volcanic relief (known as the Graham bank) but also the sedimentation of fossil corals in three giant deposits. After their discovery, these deposits of fossil red corals were quickly and extensively depleted during the last part of the 19th century (Lodolo et al. 2017, DiGeronimo et al. 1993, Rajola 2012) and this material then has been widely used for jewellery until today.

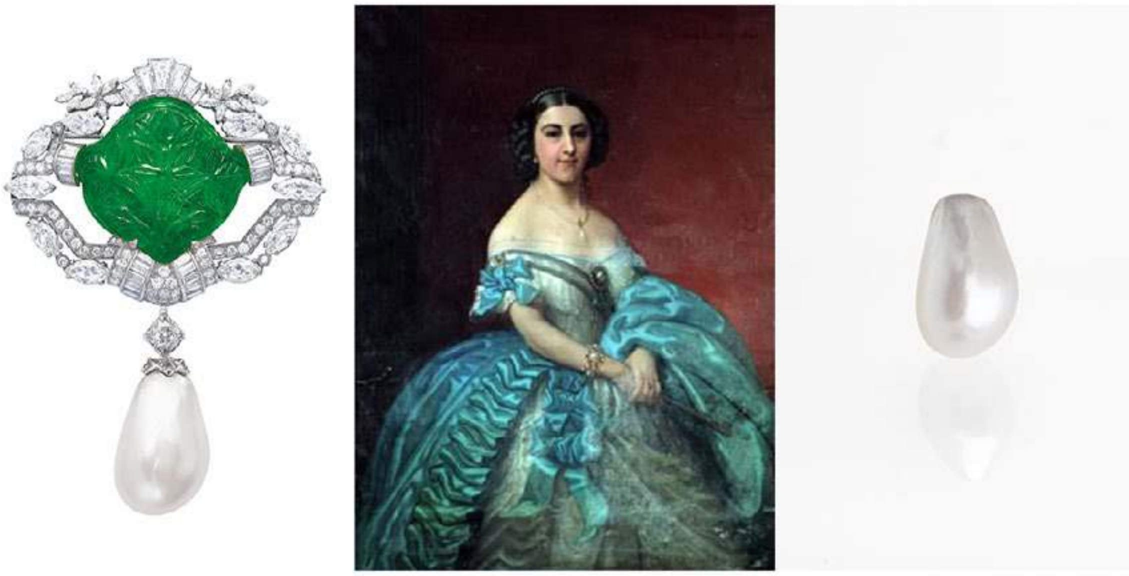


△ **Figure 2:** The radiocarbon dating of the analyzed Sciacca coral reveals its historic age (between 1467 – 1647 AD; 95.4 % probability).

For the ^{14}C radiocarbon dating on our Sciacca corals, we extracted a sample of calcium carbonate powder from a selected bead, to then be analysed by accelerated mass spectrometry (Micadas system) at the Laboratory of Ion Beam Physics of the ETH Zurich.
Our data confirmed that the analysed coral sample is not recent but of historic age. The radiocarbon method dates it back to the late 15th to early 17th century (Figure 2), which is well in line for fossil Sciacca corals being sedimented due to repeated volcanic events in historic ages. Based on our data we can definitively exclude a recent age (post-bomb peak in the late 1960s) of this coral sample.

With this promising result, we are now carrying out a broader radiocarbon dating study on gem-quality corals of historic age to gain further insights into their provenance and age. Due to the fact that we apply an in-house developed sampling method which uses less than 4 mg sample powder, radiocarbon dating can be applied quasi non-destructively even on items of historic relevance and value. *** Dr. M.S. Krzemnicki**

AGE DATING OF THE ANA MARIA PEARL



△ **Lot 264 from Christie's Magnificent Jewels Sale in Geneva on May 7, 2019: The Ana Maria Pearl set as watch-brooch. In the centre is a portrait of Ana Maria de Sevilla, wearing the pearl, painted by Jean Baptiste Eugene Reverdy in 1861. Copyright: Fundacion Casa Ducal de Medinaceli.**

We successfully age-dated the historic 'Ana Maria Pearl' using carbon-14 (^{14}C) in early 2019. This is the first time such a procedure has been conducted on a historic natural pearl offered at auction, to provide valuable and new information on the age of a gem. The Ana Maria pearl was due to be offered at Christie's Geneva as lot 264 in the Magnificent Jewels auction on May 15th, although the lot was withdrawn from the sale shortly before the auction date.

The data from this first-ever radiocarbon analysis revealed that the historic formation age for this natural pearl was between the 16th and mid-17th century AD. This fits perfectly with the documented historic provenance of the 'Ana Maria Pearl', once owned by Ana María de Sevilla y Villanueva, XIV Marquise of Camarasa (1828-1861), which is presumed to have been discovered during the Spanish conquest of the Americas in the 16th century.

The pearl is a slightly baroque drop shaped natural saltwater pearl of 30.24 carats, set as a detachable drop of a beautiful brooch, which contains an invisible watch by Audemars Piguet, a design from the 1960s. It is an honour for us to be able to provide additional scientific evidence to the historic provenance of this important natural pearl. We are in the process of further developing radiocarbon analysis and other scientific techniques to verify the historic provenance of antique jewellery and iconic natural pearls. The ^{14}C research and services offered by SSEF are done in partnership with the Ion Beam Physics Laboratory at ETH Zürich, one of the world's leading universities. *** Dr. L.E. Cartier**

THE QUEEN MARY PEARL

△ **The Queen Mary Pearl in a setting by Cartier. Photo: L. Phan, SSEF.**

As a foremost authority in the testing of natural pearls, the SSEF has had the chance in the past few decades to see and analyse the most unique and outstanding natural pearls in the market, many of them of historic provenance, such as the Peregrina pearl (see Facette No. 19, 2012), the Marie-Antoinette pearl pendant (see Facette No. 25, 2019), and the Ana Maria pearl (see article page 37) to name only a few. As a true highlight of this illustrious collection, we recently had the pleasure to analyse the Queen Mary Pearl, a drop-shaped natural pearl of 41.5 ct (166 grains) of finest quality and lustre.

Based on the provided documentation, this pearl is of historic provenance and is known as the 'Queen Mary Pearl', once owned by Queen Mary (1867-1953). She had accumulated a collection of priceless jewels during her life and they were passed on to her only daughter Princess Royal Mary, Countess of Harewood (1897-1965) after her death. The Queen Mary Pearl of was finally given as a gift to Patricia Lascelles (1926-2018) upon her marriage in 1967 with George Lascelles, 7th Earl of Harewood (1923-2011) and the grandson of the king of the United Kingdom, George V and Queen Mary. Until very recently, this historic pearl was kept as part of the family treasure of the Count and Countess of Harewood.

As this example perfectly shows, gemmological testing of historic items is not only pure material science, but also inspires us as we learn more about the historic provenance and importance of the items we test.
*** Dr. M. S. Krzemnicki**

PINNIDAE PEARLS WITH NACREOUS SURFACE

△ **Figure 1:** A Pinnidae pearl tested recently at SSEF. Photo: V. Lanzafame, SSEF.

By coincidence, two clients independently submitted to us in 2019 within the space of a few days each a beautiful and interesting Pinnidae pearl for testing. These saltwater natural pearls of remarkable size (maximum diameter 22.80 mm) were baroque in shape and showed a greyish brown colour with attractive rosé and green overtones (Figure 1).

Radiography quickly revealed that both of these pearls were hollow, also known in the trade as 'soufflure' thus reducing their weight considerably compared to their dimensions.
A close study with the microscope unveiled their intriguing surface texture. Although they resembled a nacreous texture in visual terms (pearly lustre and orient), a close inspection revealed that the surface of both pearls is not covered by tiles of stacked aragonite platelets. Instead, it is layered by thin transparent and crazed nacreous-like calcium carbonate (Figure. 2a), covering the main and characteristic texture of Pinnidae pearls consisting of prismatic calcite forming jigsaw puzzle-like patterns (Figure. 2b).

△ **Figure 2:** Nacre-like crazed surface of the two analysed Pinnidae pearls (2a, left) and jigsaw puzzle pattern of prismatic calcite (2b, right) characteristic of Pinnidae pearls. Photos: M.S. Krzemnicki, SSEF.

The described Pinnidae pearls were reportedly found in Baja California (Mexico), where the Pinnidae family - bivalve marine mollusks also known as pen shells- have a wide biogeographic distribution. As part of the Pinnidae population in the Baja California, four species were identified: *Pinna rugosa*, *Atrina tuberculosa*, *Atrina oldroydii* and *Atrina maura*, the latter with a relative abundance of approximately 95% (Escamilla-Montes et al. 2017).

Atrina maura, in Mexico also known as 'Hacha China', represents one of the most valuable fishery resources on the coast of the Mexican Pacific and is thus extensively fished, as it has an edible adductor muscle that is highly valued in the national and international market.
As a by-product of fishing of the shell, it is thus also possible to occasionally find a pearl in the mollusk. Due to overfishing, the natural shell banks have significantly diminished in recent years, which will hopefully lead to nature conservation regulations in the near future.
*** Dr. M.S. Krzemnicki**

REFERENCE

Escamilla-Montes R. et al., 2017. Ecology, Fishery and Aquaculture in Gulf of California, Mexico: Pen Shell Atrina maura (Sowerby, 1835), Organismal and Molecular Malacology, Sajal Ray, IntechOpen, DOI: 10.5772/68135.

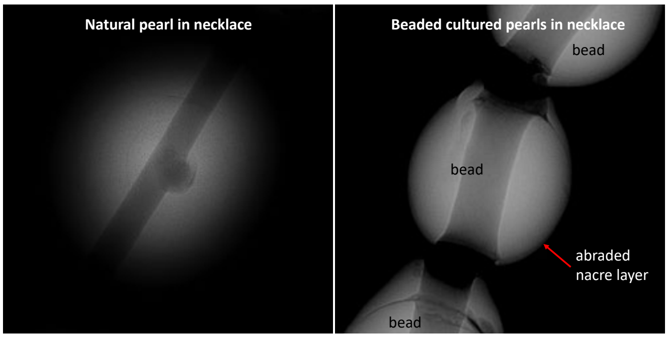
ONE NATURAL PEARL IN A CULTURED PEARL NECKLACE

△ **Figure 1:** Cultured pearl necklace containing one natural pearl. Photo: V. Lanzafame, SSEF.

Testing pearl necklaces can be rather painstaking work, as at least two gemmologists at SSEF meticulously and individually check a necklace pearl by pearl, with the aim of finding one (or more) cultured pearl(s) possibly hidden somewhere in the strand. Countless natural pearl necklaces tested at SSEF in the past decades contained one to few cultured pearls, presumably added unknowingly during a later addition or during the repair of a broken strand by a jeweller who may have used a lot of untested pearls available in the workshop.

To our surprise, we recently encountered the opposite situation with a pearl necklace submitted for testing. X-ray luminescence and microscopy readily unveiled that the necklace consisted predominantly of beaded cultured pearls of Ayoka type. Only by checking pearl-by-pearl on the radiographies, it became obvious that one of the pearls in fact is a saltwater natural pearl, showing a distinct and characteristic onion-like internal growth structure with a dark organic-rich centre (Figure 2a). Based on the extent of wearing visible on these pearls, notably with some pearls showing a nearly abraded nacreous layer on top of their round freshwater beads (Figure 2b), we presume that this necklace is made of cultured pearls from an early Akoya pearl production and was worn quite many years by its owner. The presence of the natural pearl is possibly best explained as above during a repair/addition at later stages.

Not so surprisingly, our client was much less intrigued by our findings than our gemmologists, who had never seen such a case before.
*** Dr. M.S. Krzemnicki**



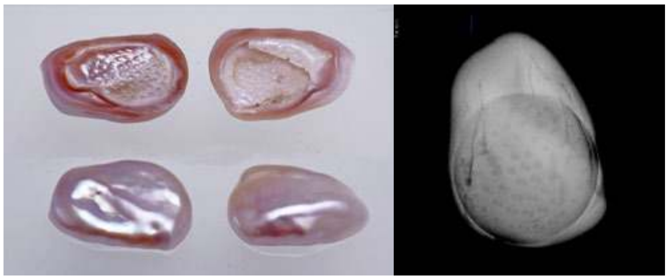
△ **Figure 2:** Radiographies of the natural pearl and some beaded cultured pearls with abraded nacre layer from the described pearl necklace. Figure: J. Braun & M.S. Krzemnicki.

SURPRISING NEWS IN CULTURED PEARLS

Let's start with grey to dark grey baroque shaped saltwater cultured pearls from *Pinctada margaritifera* (also known as Tahiti cultured pearls). Obviously, baroque shapes have been quite in fashion in recent years. However, to grow non-beaded cultured pearls of large baroque shape would take too much time. Therefore, baroque-shaped beads are often used (Figure 1). Normally, they are cut from freshwater mussels, with the thicker parts deriving from the hinge area of the shell. The mantle tissue transplant that forms the pearl sac is taken from juvenile mantle tissue of the donor oyster (*Pinctada margaritifera*). As the mantle tissue is producing dark nacre when young, but forms brighter nacre with age, it is important that the formation of the cultured pearl does not take too long if a dark colour with attractive orient is desired. The nacre precipitations after one year are grey or even white as the capacity of the tissue to produce the dark colour pigment is gradually reducing.
We first encountered baroque-shaped beads in saltwater cultured pearls in 2011. The beads used at that time consisted of Chinese freshwater pearls. Similar material using first an organic bead and subsequently a baroque shell bead for the 2nd-generation cultured pearl was studied two years later (Cartier & Krzemnicki 2013). In both cases, these baroque-shaped cultured pearls were then misnamed as Keshis in the trade. But Keshis are non-beaded cultured pearls formed as a result of a mantle injury or by bead rejection during pearl cultivation in any oyster (Hänni, 2006). The rejection can happen after the first bead is introduced together with a tissue graft. The mantle tissue transplant then remains in the oyster and forms a pearl sac that will subsequently become filled by nacre without a pre-defined spherical shape. The product is usually a roundish beadless cultured pearl (1st generation Keshi). When a beaded cultured pearl is harvested, and its quality is good, a second bead can be put into the already formed pearl sac. Sometimes, this second bead is rejected by the oyster. In that case, the pearl sac collapses as it is not filled anymore with the bead. But as the pearl sac still continues to produce nacre, it will now produce a baroque-shaped beadless cultured pearl as the pre-defined spherical shape of the bead is missing. Summarizing, the use of the term Keshi is not appropriate for cultured pearls containing baroque shaped beads as shown in Figure 1.

△ **Figure 1:** Baroque cultured pearls from P. Margaritifera containing baroque bead nuclei. Sizes around 15 mm.

At the Hong Kong September Show (Asia World Expo) in 2019, we found interesting new contributions to cultured pearl material found in the market. Large (>25 mm) freshwater cultured pearls of baroque shape were found to contain disc-shaped plastic beads with a peculiar pimply structure which is even visible in x-ray radiographies (Figure 2). A Raman analysis of this transparent bead material revealed that it consists of polystyrene, one of the most widely used plastics. So far, the plastic beads used for pearl cultivation were spherical. The disc-like shape seems to facilitate the production of baroque cultured pearls that are trendy nowadays. These new freshwater cultured pearls convince with a large size and beautiful pastel colours typical for the Hyriopsis species.



△ **Figure 2:** Pastel coloured freshwater cultured pearls with a discoid plastic bead. Length is 25 mm. Photos: H.A. Hänni & G. Brombach, SSEF.

As an update to the so-called Mini Ming cultured pearls of pastel colours reported two years ago (see Facette 2018, page 25), we found new production of white Mini Ming cultured pearls (Figure 3). These beaded freshwater cultured pearls from China now form a competitive alternative to the more traditional Akoya cultured pearls (beaded saltwater cultured pearls, originally from Japan). These new cultured pearls are grown in the mantle of Chinese freshwater mussels and result in 7.5 to 9 mm cultured pearls with a 3.5 mm bead. The thickness of the nacreous layer grown on the bead is 2 to 2.7 mm, thus much thicker than commonly found with Akoya cultured pearls. To form such a thick nacre layer requires a longer cultivation period, which as a side effect unfortunately can lead to slightly off-round shapes.
Mini Ming cultured pearls can be separated from Akoya cultured pearls by X-ray radiographies. The Mini Ming cultured pearls (mantle grown) are characterised by a drill hole in the bead, similar to the larger Ming pearls (gonad grown). For both cultured pearl products, the bead is drilled so that the mantle tissue piece that ensures the formation of the pearl sac can be plugged into this drill hole. Because both, Mini Ming and Ming cultured pearls are freshwater formations, their nacre contains distinct amounts of manganese (Mn). Due to this, it is quite straightforward to separate them from beaded saltwater cultured pearls (South Sea and Akoya) which contain much less manganese. In a gemmological laboratory, analysis of the Mn concentration is usually performed using X-ray fluorescence. Jewellers may use the Merck manganese test kit, a do-it-yourself method to bring Mn in evidence.

*** Prof. Dr. H.A. Hänni, SSEF Senior Research Associate**

◁ **Figure 3:** White beaded freshwater cultured pearls, Mini Ming from China, with Ø 7.5 – 9 mm. Photo: H.A. Hänni

ROMAN SAPPHIRE INTAGLIO

△ **Figure 1:** Roman sapphire intaglio engraved with the mythical creature hippocamp. Photo: V. Lanzafame, SSEF.

In 2019, the Swiss Gemmological Institute SSEF in collaboration with the Istituto Gemmologico Nazionale IGN Rome (Italy) were able to analyse in detail a unique Roman sapphire intaglio (Figure 1), excavated in 1986 in the House of Gemmarius (Sodo, 1988) in the UNESCO World Heritage site of Pompeii (Italy). The described Roman intaglio can be considered a unique cultural heritage, not only because it is made of sapphire, a gem known to Romans but only rarely used in their jewellery (Spier, 2012), but also because it combines beauty and quality (the craftsmanship of an ancient gem engraver) with excellent conservation and a fully documented archaeological provenance. This is very much in contrast to other ancient sapphire intaglios and carvings described in literature, most of which are from historic gem collections and have a much more debatable and obscure original geographic and historic provenance. Furthermore, our study is one of the rare cases where a documented archaeological jewel could be analysed in a laboratory with advanced analytical methods.

Ancient Pompeii

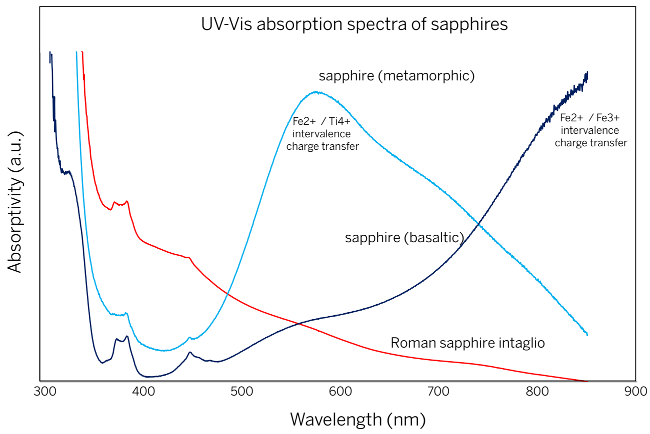
Ancient Pompeii was an urban settlement, located on the southern slopes of Mount Vesuvius in southern Italy. Thanks to its climate and its location, Pompeii became an important commercial centre even before becoming part of the Roman Empire in the 1st century BC. In November 79 AD, an explosive eruption of the volcano Mount Vesuvius buried Pompeii under about six metres of pumice and ashes. During the eruption about 1,500 inhabitants died (the city's population was estimated to be between 6,000 and 20,000 people), among them the famous naturalist Pliny the Elder, author of the encyclopaedic Naturalis Historia, still today a fundamental reference work for the ancient use and provenance of gems. Pompeii was not rebuilt again, and by 120 AD vegetation began to cover the territory it once occupied until it definitively disappeared until the first archaeological excavations in the 18th century rediscovered it.

△ **Painting by Joseph Wright of Derby (1734-1797) of the eruption of Vesuv in 79AD. Source: Huntington Library, San Marino, California.**

During the excavation of Pompeii, a large number of jewellery and gem objects were discovered. In the House of Gemmarius, considered the private house and (work)shop of a gem cutter and jeweller in the southeastern part of ancient Pompeii, two wooden boxes were discovered in 1986, containing amongst others the described Roman sapphire intaglio.

Results of the Study

The investigated sapphire intaglio is a flat oval cabochon of 11.62 ct, engraved with the mythical hippocamp, a winged 'sea-horse' with the upper body of a horse and the lower body and tail of a fish. Since ancient times, this mythological creature is one of the most common emblems of the marine world and especially often engraved in 'sea-coloured' gem materials, notably aquamarine (pers. comm. Thoresen, 2019).



△ **Figure 3: Polarized absorption spectrum of the Roman sapphire intaglio (red trace) compared to typical metamorphic and magmatic (basaltic) sapphires which owe their blue colour mainly to intervalence charge transfer absorption bands.**

Interestingly, the bluish grey appearance of the Roman sapphire intaglio is due to Rayleigh scattering by sub-microscopic inclusions and is not related to any intervalence charge transfer process (e.g. Fe^{2+}-Ti^{4+} and Fe^{2+}-Fe^{3+}) as can be seen in the UV-Vis absorption spectrum (Figure 3). In transmission mode, the sapphire intaglio is in fact greyish brown (Figure 4) related to the visible turbidity caused by the presence of tiny and dispersed sub-microscopic inclusions. Similar scattering effects are well known in metamorphic sapphires (e.g. from Kashmir, Sri Lanka and Madagascar) and basaltic sapphires, but only rarely seen as being the only cause of colour (e.g. basaltic sapphires from Nigeria; Pardieu et al., 2014).

△ **Figure 3: A comparison of the Roman intaglio in reflected light (left) and transmitted light (right) reveals the different colour appearances of the sapphire (bluish grey and greyish brown, respectively). Photos by M. S. Krzemnicki, SSEF.**

Based on our analytical data and microscopic observations, we can conclude that the studied Roman intaglio was crafted from an unheated sapphire originating from an alkali basalt-related deposit. An origin from the gem-gravels of Sri Lanka - known since antiquity as a source of (metamorphic) sapphires and many other gemstones- can be definitively excluded, although the gem's light bluish grey colour and appearance might be considered reminiscent of some Sri Lankan sapphires. Due to its close similarity in trace-element composition to basaltic sapphires from various deposits, a clear geographic attribution for the origin of this Roman sapphire intaglio cannot be accomplished based on the currently available data.

Origin of the Ancient Sapphire

In addition to the existing literature, which commonly refers to the origin of ancient sapphires as Southeast Asia and the Far East, we propose in light of historically documented extensive trade relations between ancient Rome and Ethiopia (the kingdom of Aksum) that an Ethiopian origin of the studied Roman sapphire intaglio as similarly plausible, although we have no direct evidence (by gemmological data, archaeological excavations, or historical accounts) for our hypothesis. Another option for such basalt-related sapphires might be the sites in the Massif Central in France. Although first mentioned only in the 13th century (Forestier, 1993), they might have been known as early as the 1st century AD.

△ **Figure 5: This map illustrates ancient trade routes from Aksum towards the Roman Empire and elsewhere. Modified from Addis Herald, www.addisherald.com/aksumite-empire/#gmedia10093. Courtesy of Journal of Gemmology, 2019.**

This study clearly shows that more detailed research on basalt-related ancient (Roman) sapphires is necessary. Especially with the recent progress in gemstone testing using chemical fingerprinting (e.g. GemTOF; Wang et al. 2016), statistical methodology (e.g. non-linear algorithms; see Wang et al., 2019) and stable isotopes (oxygen; see Giuliani et al. 2000, 2009, 2014) it might be possible to verify in future if the recently discovered sapphire-rich deposit near Aksum was known in ancient times as a source for gem-quality basaltic sapphires of milky bluish and dark blue colours. * **Dr. M.S. Krzemnicki**

FURTHER READING

Krzemnicki, M.S., Butini, F., De Carolis, E., 2019, Gemmological Analysis of a Roman Sapphire Intaglio and Its Possible Origin, Journal of Gemmology, 36(8), 710–724, http://doi.org/10.15506/JoG.2019.36.8.710

TALISMAN OF CHARLEMAGNE

The talisman of Charlemagne, a gem-bearing reliquary of historic provenance and importance closely associated to the history of Europe (Figure 1), was recently investigated by historians and gemmologists including from SSEF in a collaborative research project led by Prof. G. Panczer from the Claude Bernard University of Lyon. This interdisciplinary approach allowed to combine insights from historical science with findings based on the analyses of the gems present on the talisman, and thus resulting in a better understanding of its creation, modifications, and uses through history.

The legend of this jewel follows figures such as Charlemagne, Napoleon I, Empress Josephine, Hortense de Beauharnais, Napoleon III, and Empress Eugénie. At various times it has been said to contain fragments of the hair of the Virgin Mary and a remnant of the True Cross, and is therefore a reliquary, a container in which sacred relics are kept.
Although attributed to the Emperor Charlemagne (748-814 AD) –hence its name, this origin remains doubtful and unproven. In fact, the first depictions of the reliquary did not appear until the seventeenth century. However, its design and workmanship suggests a medieval Carolingian age at least as early as the late ninth century.

The present study was the first scientific gemmological analysis of this item of cultural heritage (Figure 2), carried out on-site at the Palace of Tau Museum in Reims (France) with portable instrumentation. Still, we were able to identify a large blue cobalt-bearing glass cabochon on the front, a large blue-gray sapphire on the back, and an assortment of further coloured stones and pearls. Based on our data and comparison with similar objects of the Carolingian period, we assume that the blue-gray sapphire is of Ceylonese (Sri Lankan) origin. The estimated weight of this center sapphire is approximately 190 ct, making it one of the largest known sapphires as of the early seventeenth century.

*** Dr. M.S. Krzemnicki**

△ **Figure 1.** Portrait of Hortense Eugénie Cécile de Beauharnais (1783-1837) Queen of Holland and mother of Napoleon III, wearing the talisman with the front side facing out. Painting by Felix Cottreau. Courtesy of Napoleon Museum Thurgau.

△ **Figure 2:** The talisman of Charlemagne from the front (with blue glass cabochon), from the back (with large blue-grey sapphire), and from the side. Photos by G. Panzcer.

FURTHER READING

Panczer G., Riondet G., Forest L., Krzemnicki M.S., Carole D., Faure F., 2019. The Talisman of Charlemagne: New Historical and Gemological Discoveries. Gems & Gemology, 55(1), 30-46.

EXHIBITION GOLD AND GLORY IN BASEL

△ **Figure 1:** **The golden altar frontal from the cathedral treasury. Photo: Basel Historical Museum.**

In honour of the millennium of Basel Cathedral, which was consecrated in 1019 AD in the presence of the last Ottonian Emperor Henry II and his wife Kunigunde, the Basel Historical Museum in collaboration with the Kunstmuseum Basel organized an impressive special exhibition from October 2019 to January 2020. In Gold & Glory – Gifts for Eternity, they presented the public a selection of the most spectacular treasures from the Basel Cathedral, many of these precious artefacts on loan from private and public collections in Europe and the United States.
1000 years ago, Henry II and his successors endowed the bishop of Basel with countless rights and properties, making him the most powerful ruler in the region. This in turn transformed what had been essentially a rural settlement on a bend in the River Rhine into a major urban centre. The structure, development and flourishing of Basel as today's economic hub in the trinational region on the Upper Rhine in Europe can thus be traced back to these events.

△ **Figure 2:** **The reliquary cross (left) and the Dorothy monstrance (right), both part of the Basel Cathedral treasure and dating from 15th century AD were gemmologically investigated by SSEF. Photos: Historic Museum Basel, Switzerland.**

The emperor's lavish gifts – the 'Gifts of Henry' – formed the founding stone for the Cathedral Treasury, which over the centuries became one of the most important church treasures in Switzerland and beyond, containing a rich selection of magnificent medieval goldwork encrusted with gems, bronzes, and textiles, outstanding examples of book painting and ivory carving from the cultural centres of the Ottonian empire.
Interestingly, the Swiss Gemmological Institute SSEF collaborated already in 1998, at that time under the lead of Prof. Henry A. Hänni, with the Basel Historic Museum in an early Raman research project on two of these Cathedral treasures, the reliquary cross and the Dorothy monstrance, both dating from 15th century AD (Figure 2). A detailed description and identification of the gems of these two items was published in 1998 in Gems & Gemology and can be found in the SSEF online library (https://www.ssef.ch/wp-content/uploads/2016/06/1998_Haenni_Raman-Muensterschatz.pdf). Interestingly, these authors found that although the metalwork of these items appears to be of high craftsmanship, many of the 'coloured stones' in both investigated pieces are actually colourless materials backed with a coloured pigment, coloured glass, and quartz doublets with a (presumably dyed) cement layer. Nevertheless, there were also some attractive natural gems found by Raman microspectrometry, including peridot, sapphire, garnet, spinel, and turquoise, as well as quartz varieties. *** Dr. M. S. Krzemnicki, SSEF**

For interested readers, a detailed archive of the exhibition and treasury is accessible online on https://www.muensterschatz.ch/en/
Including a virtual tour through that exhibition on https://www.hmb.ch/en/news/exhibitions/gold-glory/

An antique imperial spinel, pearl and emerald necklace. Sold at Maharajas & Mughal Magnificence sale of Christie's in New York in June 2019 for US$ 3,015,000. Photo: Christie's.

A ruby and diamond bracelet with 93 rubies totalling 47.40 ct all from Burma with no indications of heating. Sold at Phillips Hong Kong in May 2019 for US$ 140,026.

Ring with a no-heat pigeon blood red ruby (5.22 ct) from Burma. Sold at Phillips Hong Kong for US$783,789. Photo: Phillips.

5.85 ct unheated Burma ruby set in a ring. Sold at Tiancheng Autumn 2019 auction for US$ 244,723. Photo: Tiancheng.

5.14 ct unheated ruby of Burmese origin set in a ring by Bulgari. Sold at Sotheby's Geneva for US$ 1,687,743 in May 2019. Photo: Sotheby's.

Ruby and diamond bracelet, Van Cleef & Arpels with approx. 55 ct of rubies (Burma, no heat, none to minor oil). Sold at Christie's Geneva May 2019 for US$ 1,575,000. Photo: Christie's.

'The Dupont ruby' an exquisite pigeon blood ruby (11.205 ct), emerald, diamond and natural pearl brooch. Sold at Christie's New York in December 2019 for US$ 8,957,750. Photo: Christie's.

Ruby and diamond bib necklace by Van Cleef & Arpels. Approx. 90 ct of rubies, Burma, no heat, a few with minor oil. Fetched US$ 2,415,000 at Christie's May 2019 auction. Photo: Christie's.

Mid-19th century ruby (Burma, no heat, none to minor oil) and diamond necklace formerly the property of the late Cornelia, Countess of Craven. Sold at Christie's Geneva in November 2019 for US$ 615,000. Photo: Christie's.

3.61 ct ruby set in a ring. Ruby of Burmese origin, with no indications of heating, pigeon blood colour, ring sold at Sotheby's Geneva November 2019 for US$112,500. Photo: Sotheby's.

Exceptional ruby and diamond ring by Harry Winston with an unheated Burmese cushion-shaped ruby of 22.86 ct. Sold at Christie's Geneva in May 2019 for US$ 7,198,500. Photo: Christie's.

Fine sapphire and diamond necklace, circa 1890, set with a cushion-shaped sapphire weighing 14.97 carats of Kashmir origin. Sold for US$ 1,340,000 at Sotheby's Geneva in December 2019. Photo: Sotheby's.

Unheated Kashmir cushion-shaped sapphire (13.88 ct) of royal blue colour, in a ring. Sold for US$ 2,471,475 at Sotheby's Hong Kong in April 2019. Photo: Sotheby's.

Burmese unheated royal blue sapphire of 42.97 ct set in a pendant sold for US$ 2,535,000 at Christie's Geneva November 2019 auction. Photo: Christie's.

Ring with a 17.62 ct sapphire from Burma, no heat of royal blue colour. Sold at Phillips Jewels & Jadeite Hong Kong auction in November 2019 sold for US$ 523,000. Photo: Phillips.

39.19 ct Ceylon sapphire with no indications of heating, of royal blue colour and set in a Cartier brooch. Sold for US$ 1,995,000 at Christie's Geneva in November 2019. Photo: Christie's.

16.72 ct unheated Kashmir sapphire of royal blue colour set in a ring. Sold at Christie's New York December 2019 auction for US$ 1,695,000. Photo: Christie's.

Cabochon sapphire of 30.14 ct in a ring. Kashmir, no indications of heating, sold at Christie's New York in December 2019 for US$ 3,015,000. Photo: Christie's.

10.15 ct sapphire in ring, Kashmir origin with no indications of heating and a royal blue colour. Sold for US$ 687,000 at Sotheby's Geneva November 2019 sale. Photo: Sotheby's.

Pair of unheated Kashmir sapphires (3.01 ct and 2.98 ct) set in earrings and sold at Koller Auktionen in Zürich for US$ 165,000 in 2019. Photo: Koller Auktionen.

Sapphire and diamond bracelet by Cartier, with a Burmese cabochon sapphire (no heat, royal blue colour) weighing 47.07 ct. Sold for US$ 6,072,900 at Sotheby's November Geneva auction. Photo: Sotheby's.

12.65 ct unheated sapphire from Kashmir set in a ring. Realised US$ 879,000 at Christie's Geneva November 2019 auction. Photo: Christie's.

Emerald, diamond and pearl earrings with pear-shaped emeralds of 23.34 and 23.18 ct both with no indications of clarity modification and from Colombia. Sold for US$ 4,452,000 at Christie's Hong Kong in May 2019. Photo: Christie's.

The Imperial Emerald of Grand Duchess Vladimir of Russia. An emerald and diamond pendent necklace with a pear-shaped emerald from Colombia (minor oil) of 75.61 ct. Sold at Christie's Geneva 2019 spring auction for US$ 4,335,000. Photo: Christie's.

An untreated jadeite-jade (9.78 ct) cabochon in a ring. Sold at Poly auction in April 2019 for US$ 393,333.

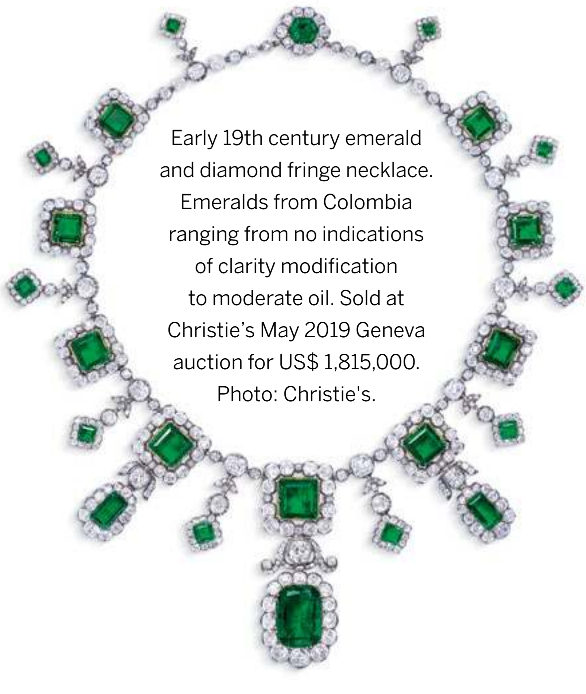
5.33 ct emerald from Colombia with no indications of clarity modification, set in a ring. Sold by Phillips at auction in Hong Kong for US$ 159,000. Photo: Phillips.

12.59 ct emerald. Colombian origin, no indications of clarity modification. Realised US$ 750,000 at Christie's Hong Kong auction. Photo: Christie's.

Emerald and diamond necklace, circa 1935, from the collection of Hélène Beaumont. All emerald no indications of clarity modification to minor oil and with Colombian origin. Sold at Sotheby's Geneva in May 2019 for US$ 3,620,000.

Emerald and diamond pendant/brooch combination by Cartier with cabochon emeralds of Colombian origin, with a minor to a moderate amount of oil in fissures. Lot sold at Sotheby's November 2019 auction in Geneva for US$ 1,052,000. Photo: Sotheby's.

Square-shaped emerald of 3.58 ct (Colombia, no indications of clarity modification) set in a ring with a diamond. Sold for US$ 325,000 at Christie's Geneva May 2019 auction.



Early 19th century emerald and diamond fringe necklace. Emeralds from Colombia ranging from no indications of clarity modification to moderate oil. Sold at Christie's May 2019 Geneva auction for US$ 1,815,000. Photo: Christie's.

12.97 ct Colombian emerald with no indications of clarity modification, set in a ring. Sold at Christie's Hong Kong May 2019 auction for US$ 1,060,000. Photo: Christie's.

Alexandrite (approx. 6.1 ct) in a ring from Brazil, no indications of treatment, with a distinct colour-change. Sold at Christie's Hong Kong in May 2019 for US$ 140,000.

Cushion-shaped pink sapphire of 12.20 ct from Madagascar (no heat) set in a ring. Sold at Christie's Hong Kong in May 2019 for US$ 92,000. Photo: Christie's.

Natural pearl, conch pearl and diamond bracelet sold for US$ 52,000 by Christie's Paris in December 2019. Photo: Christie's.

Ring with 61.95 ct aquamarine, no indications of heating and considered 'Santa Maria type'. Sold at Phillips auction in Hong Kong for US$ 61,000. Photo: Phillips.

Pair of heated Paraiba tourmalines from Brazil of 5.52 and 5.31 ct set in earrings. Sold at Christie's Hong Kong for US$ 750,000.

Conch pearl, gem set and diamond brooch, 'Blue Magpie' by Anna Hu. Sold for US$ 254,920 at Sotheby's Hong Kong auction. Photo: Sotheby's.

Pear-shaped unheated yellow sapphire from Burma set in a pendant by Meister. Sold for US$ 56,520 at Christie's Geneva. Photo: Christie's.

36.68 ct unheated spinel from Burma set in a necklace. Sold at Bonhams Hong Kong sale for US$ 472,000.

Heated Paraiba tourmaline (5.07 ct) from Brazil set in a ring. Sold at Christie's Hong Kong May 2019 auction for US$ 287,000. Photo: Christie's.

A sautoir with one hundred and ten natural pearls, of approximately 14.75 to 7.45 mm diameter. Sold at Christie's Geneva in May 2019 for US$ 5,723,000. Photo: Christie's.

Natural pearl sautoir with one hundred and seventy-one natural pearls, of approximately 12.55 to 4.45 mm diameter. Price realised US$ 1,095,000 at Christie's Geneva May 2019 sale.

Coloured natural pearl, natural pearl and diamond earrings by Boucheron. Sold for US$ 150,000 at Christie's November 2019 Geneva sale. Photo: Christie's.

Sixty-three and fifty-nine graduated natural pearls of approximately 11.65 to 5.95 mm diameter. Sold at Christie's Geneva November magnificent jewels sale for US$ 711,000. Photo: Christie's.

Natural pearl drops (80 and 76 grains) set in a pair of earrings. Auctioned for US$ 872,000 at Christie's Hong Kong November sale.Photo: Christie's.

Pair of natural pearl and diamond earclips, by Sterlé. Sold at Bonhams London sale in December 2019 for US$ 348,000. Photo: Bonhams

Five graduated strands of three hundred and seventy-seven natural pearls of 9.45 to 3.90 mm, twenty-four natural pearls on neckchain, drop-shaped natural pearl on clasp. Sold at Christie's New York Maharajas & Mughal Magnificence jewelry auction for US$ 1,695,000. Photo: Christie's.

Natural pearl, coloured diamond and diamond jewellery suite by Cartier. Sold for US$ 1,393,000 at Christie's Hong Kong in November 2019. Photo: Christie's.

Natural pearl and diamond ring, mounted by Cartier. Sold at Christie's New York December 2019 auction for US$ 193,750. Photo: Christie's.

A graduated strand of thirty-seven round to oval natural pearls of 14.00 to 7.05 mm. Sold at Christie's New York Maharajas & Mughal Magnificence jewelry auction for US$ 1,095,000.

13 pink sapphires from Burma of total 60.78 ct (declared)
set in a necklace with diamonds. Photo: SSEF.

SSEF COURSES
in 2020

2019 was a rich year for our courses at SSEF. Our very practical courses have a strong international reputation and we see more and more gemmologists, jewellers and gemstone and pearl professionals from very different countries attending our courses. It's interesting to have participants from so many different gemmological and international backgrounds. In 2020, we will again be offering a wide range of courses. The SSEF Basic Gemmology Course (08 – 19 June, 21 September – 02 October and 09 - 20 November 2020) and the SSEF Basic Diamond Course (12 - 16 October 2020) offer good introductions, and participants can graduate with a certificate after taking theoretical and practical examinations. For more in-depth courses we offer Advanced Training Courses on coloured gemstones, pearls and small diamonds. Finally, the Scientific Gemmology Course (SGC) is an ideal course for those interested in learning about the advanced instruments used in laboratory gemmology today and should be available again in 2021.

ADVANCED PEARL COURSE

This two-day pearl course (07-08 December 2020) is ideally suited for participants who want to know more about how pearls are formed, possible treatments, and how natural and cultured pearls can be identified and separated. SSEF's important collection of shells and pearls offers a good opportunity for practicing and expanding your skills and knowledge of pearls. The course also offers an introduction into the use of UV-visible spectrometry, EDXRF, X-ray radiography and luminescence for pearl testing in a scientific laboratory.

ADVANCED COLOURED GEMSTONES COURSE

The advanced coloured gemstone training course is an intense gemmological programme that offers a detailed hands-on approach to identifying treatment and origin of ruby, sapphire and emerald. Please note that this course is always in high-demand and already fully booked for the July 2020 session. The last remaining spots are available for the course 19 – 23 October 2020 and 30 November – 04 December 2020. In this course we demonstrate the possibilities and limitations of treatment detection and origin determination of corundum and emerald. Participants will have the opportunity of analysing and testing numerous samples from our collection.

SMALL DIAMOND COURSE

The SSEF small diamond course (next in early 2021, please contact us for more details), which focuses on diamonds of a diameter between 0.7 and 3.8 mm, mainly used in the watch industry, enables participants to themselves perform the quality control of such small diamonds. These courses are aimed at people working in the jewellery and watch industry, and can be tailored to your company's specific needs. Previous gemmological experience is welcome but not a requirement.

SCIENTIFIC GEMMOLOGY COURSE

In 2020, the one-week Scientific Gemmologicy course will not be taking place. We are currently revamping this course that has been very successful in recent years by focusing on the scientific aspects of gemmology. This includes learning about techniques and applications of instruments like X-Ray fluorescence spectrometry, UV-Visible-NIR spectroscopy, GemTOF, Raman and FTIR spectrometry in the field of gemmology, as performed at the Swiss Gemmological Institute SSEF.

SSEF COMPANY COURSES

The SSEF Swiss Gemmological Institute can personalise a course based on your or your company's specific requirements. This course format is especially suited for companies that need specific gemmological training for their employees. In 2019, a number of companies have benefited from such courses that were tailored to specific topics including small diamond quality control, diamond treatments or learning to identify coloured gemstones from different origins. If you or your company are interested, please contact us to discuss how a gemmological course can be tailored to your needs.

△ ATC Small Diamond Course participants in October 2019 in Basel. Photo: SSEF

CONGRATULATIONS:

The Swiss Gemmological Institute SSEF wants to express its congratulations to the following persons for graduating from the following courses in 2019:

Basic Gemmology Course

- Agathe Weishaupt
- Martha Rabe
- Cornelia Merk
- Brigitte Scattarreggia-Kellenberger
- Limor Talasazan
- Shirin Talasazan
- Ariel Talasazan
- Akitsugu Sato
- Philipp Tesarik
- Reneé König
- Angel Zahner
- Thomas Weller
- Ivana-Maria El Tabbah
- Laura Speich

Basic Diamond Course

- Ivana-Maria El Tabbah
- Ajith Karunamuni de Silva
- Elena Staub
- Michael Rytz
- Laura Speich

Advanced Pearl Course

- Charlotte Hanson
- Brigitte Scattarreggia-Kellenberger
- Ivana-Maria El Tabbah
- Marie-Cécile Cisamolo
- Giovanna Gabbin
- Diana Pogojeva
- Elena Staub
- Astrid Bosshard
- Laura Speich
- Susanne Büche

Advanced Gemstone Course

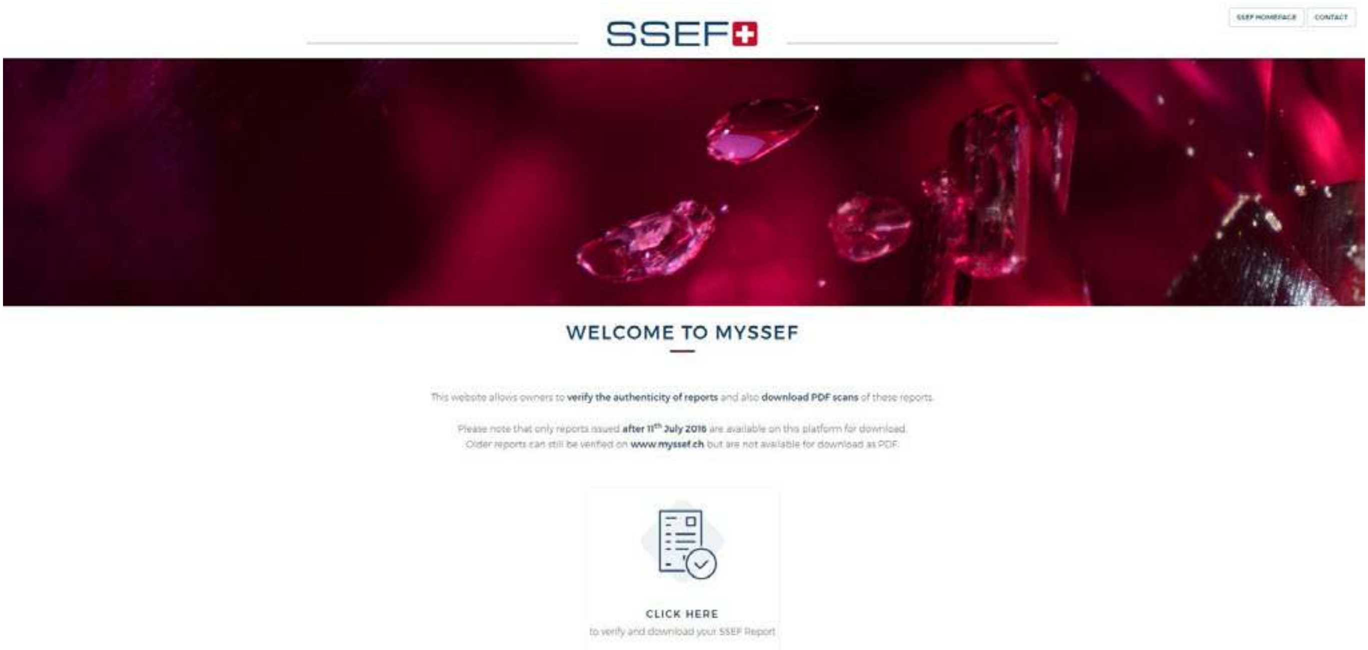
- Alexander van Esser
- Théodore Rozet
- Dacian Halas
- Kyaw Thu
- Aviral Dangayach
- Linda Schwieger
- Kelly Kaneko
- Lucia Boffetta
- Elisa Colosimo
- Anaïs du Colombier
- Jennifer Tang
- Iryna Omelchenko
- Maria Belmont
- Kelly Dang
- Marta Mainardi
- Nelson Biehler
- Antoine Barrault
- Anthony Van Esser
- Ivana-Maria El Tabbah
- Marek Klimek
- Luca Ghirondi
- Laura Speich
- Hannah Amsler
- Thomas Gohl
- Rossana Ferrarese
- Marco Capeder

Advanced Small Diamond Course

- Elena Vaccari
- Ivana-Maria El Tabbah
- Hélène Duquet
- Daphné Geoffroy
- René Lamotte
- Charles Fernandes de Oliveira
- Maham Ali
- Alix van der Wat
- Laura Speich

△ ATC Coloured Gemstone Course participants in April 2019 in Basel. Photo: SSEF

FAKE SSEF REPORT RECENTLY UNCOVERED



SSEF came across a serious case of fraud in late 2019, in which an existing SSEF report for an emerald was electronically altered and faked. This confirms the need for mandatory report verification on the MySSEF platform (www.myssef.ch) by clients, as a further measure of security for the trade.

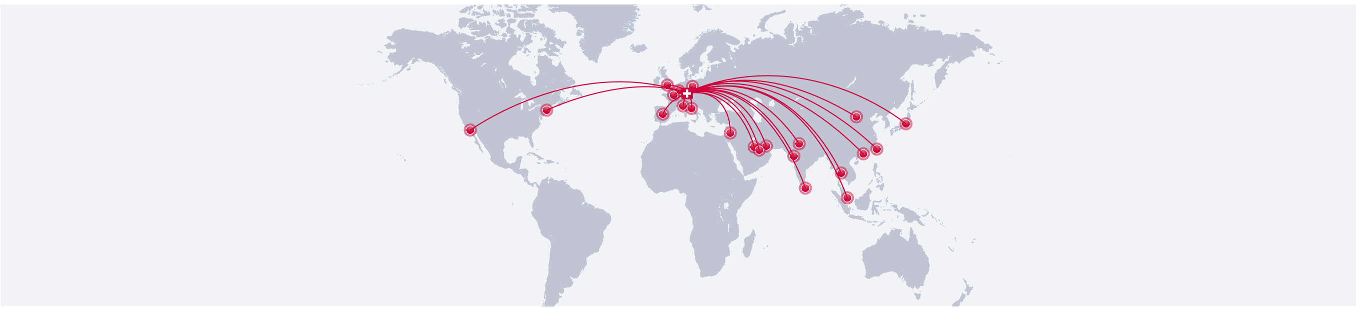
In this given case, an individual submitted a stone together with a photo of a digitally faked SSEF report that was using an existing SSEF report number. The weight of the stone had been digitally modified to match the weight of the submitted stone. Other important characteristics, such as the dimensions of the stone, had also been altered. No physical copy of the original report for this stone could be provided by the individual in question. Importantly, other security features available on SSEF reports clearly indicated that this was in fact a digitally manipulated copy of an old report.

SSEF introduced unique Prooftag labels on all its signed and laminated reports as an additional security measure in June 2009, ultimately serving to further protect the trade from fraudulent practices. These tags have unique identifying bubble constellations that are random and cannot be reproduced. Furthermore, each of these tags has its own identifying number. The report number together with the identifying number of the tag can be used to verify the authenticity (by comparing the unique bubble constellation of the physical report with the bubble set referenced online) of an SSEF report on the website www.myssef.ch. We would like to remind clients to request the physical SSEF report from sellers as this provides greater assurance. Finally, SSEF reports issued since 2016 are available on the MySSEF platform for download as PDFs.

We take the integrity of our reports extremely seriously and continue to invest in making our reports as secure as possible, in order to protect the trade. We will pursue such fraudulent cases with all legal means available to us. **Furthermore, we would like to remind all our clients that online verification of SSEF reports on www.myssef.ch is mandatory in order to confirm the authenticity of a report.**

For any questions on report security or the MySSEF platform please contact us (admin@ssef.ch).

SSEF-FERRARI SHUTTLE SERVICE



DAILY SHUTTLE BETWEEN GENEVA - SSEF

call Ferrari **Geneva** office **+41 22 798 82 60**

Costs: 100.- Swiss Francs per round trip.
For values > 500'000 Swiss Francs, an additional liability fee of 0.035% is charged for the amount exceeding this limit, based on the declared value.
Example 1: declared 100'000 SFr > shipping costs: 100 SFr
Example 2: declared 1'000'000 SFr > shipping costs: 255 SFr

WEEKLY SHUTTLE BETWEEN LONDON, PARIS, MONACO - SSEF

call Ferrari **London** office **+44 1753 28 78 00**
call Ferrari **Paris** office **+33 1 49 96 60 60**
call Ferrari **Monaco** office **+377 97 70 34 92**

Costs: 160.- Swiss Francs per round trip and an additional liability fee of 0.035%
Example 1: declared 100'000 SFr > shipping costs: 195 SFr
Example 2: declared 1'000'000 SFr > shipping costs: 510 SFr

ON REQUEST SHUTTLE BETWEEN DUBAI (UAE), SINGAPORE, BANGKOK, MUMBAI, JAIPUR - SSEF

call Ferrari **Dubai** office **+971 4295 1089**
call Ferrari **Singapore** office **+65 6547 5560**
call Ferrari **Bangkok** office **+6622674755 to 8**
call Ferrari **Mumbai** office **(Tel: +91 22 3392 34 59; +91 22 3392 19 63)**
call Ferrari **Jaipur** office **+91 9782526618**

Costs: 240.- Swiss Francs per round trip and an additional liability fee of 0.035%
Example 1: declared 100'000 SFr > shipping costs: 275 SFr
Example 2: declared 1'000'000 SFr > shipping costs: 590 SFr

ON REQUEST SHUTTLE BETWEEN SPAIN, TAIPEI - SSEF

call Ferrari **Spain** office **+34 915 572 648**
call Ferrari **Taipei** office: **+886 2 25078511**

Costs: on request

WEEKLY SHUTTLE BETWEEN NEW YORK, HONG KONG, LA - SSEF

call Ferrari **New York / LA** office **+1 212 764 06 76**
call Ferrari **Hong Kong** office **+852 2 264 20 01**

Costs: 160.- Swiss Francs per round trip and an additional liability fee of 0.035%
Example 1: declared 100'000 SFr > shipping costs: 195 SFr
Example 2: declared 1'000'000 SFr > shipping costs: 510 SFr

ON REQUEST SHUTTLE BETWEEN ITALY, ANTWERP - SSEF

call Ferrari **Italy** office **+39 0131 208520**
call Ferrari **Antwerp** office **+32 3 4752723**

Costs: 160.- Swiss Francs per round trip and an additional liability fee of 0.035%
Example 1: declared 100'000 SFr > shipping costs: 195 SFr
Example 2: declared 1'000'000 SFr > shipping costs: 510 SFr

ON REQUEST SHUTTLE BETWEEN TEL AVIV, COLOMBO (SRI LANKA) - SSEF

call Ferrari contractor office in **Tel Aviv**
(D2D Val express Israel) **+972 3 575 4901**
call Ferrari contractor in **Colombo**
(Dart global logistics Ltd.) **+94 11 460 09 600**

Costs: 240.- Swiss Francs per round trip and an additional liability fee of 0.035%
Example 1: declared 100'000 SFr > shipping costs: 275 SFr
Example 2: declared 1'000'000 SFr > shipping costs: 590 SFr

ON REQUEST SHUTTLE GERMANY - SSEF

call Ferrari contractor office **Germany**
(Gerhard Enz GmbH) **+49 711 4598 420**

Costs: 240.- Swiss Francs per round trip and an additional liability fee of 0.035%
Example 1: declared 100'000 SFr > shipping costs: 275 SFr
Example 2: declared 1'000'000 SFr > shipping costs: 590 SFr

For all other destinations, please contact us. Pricing and conditions for shuttles may be subject to change.

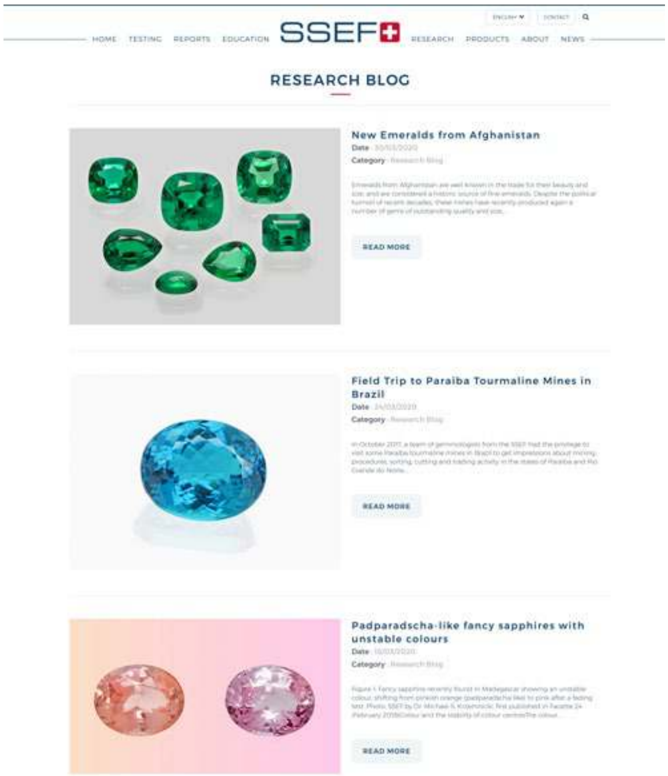
SSEF SOCIAL MEDIA AND RESEARCH BLOG

We have launched social media accounts on Instagram, LinkedIn and Twitter to keep you updated of gemmological news and service updates from our side. We look forward to connecting with you online, and do reach out to us with any questions or comments. We have also started a research blog on our website (www.ssef.ch/research-blog) that highlights important research from the past few years. We hope these resources are useful to you in expanding your gemmological knowledge.

Instagram
https://www.instagram.com/ssefgemlab/

LinkedIn
https://www.linkedin.com/company/ssefgemlab

twitter
https://twitter.com/ssefgemlab



LIBRARY UPDATED

In our mission to share gemmological research and provide educational resources to the gem and jewellery industry we continue to upload research articles authored or co-authored by SSEF researchers to our website, that now reaches over 400 articles. This Library of Publications also includes a wide range of presentations that we have given over the years at different conferences and venues. All files are available as PDF copies. This library contains most of our research that has been published since 1974 and will be continuously updated.

SSEF has been central to a number of important discoveries and developments in gemmological research in the past five decades. A selection of related important publications are now available online. For example:

- Ferroaxinite – another new gem from Sri Lanka (1982)
- Identification of fissure-treated gemstones (1992)
- Raman spectroscopic applications in gemmology (2001)
- GemLIBS: a new analytical instrument to analyse beryllium in orange sapphires (2004)
- About the platelet peak of HPHT-treated diamonds of type Ia (2009)
- DNA fingerprinting of pearls, corals and ivory (2018)
- U–Pb Dating of Zircon and Zirconolite Inclusions in Marble-Hosted Gem-Quality Ruby and Spinel from Mogok, Myanmar (2020)

Visit www.ssef.ch/library to access all these papers

TWO NEW LASERS FOR RAMAN SPECTROSCOPY APPLICATIONS

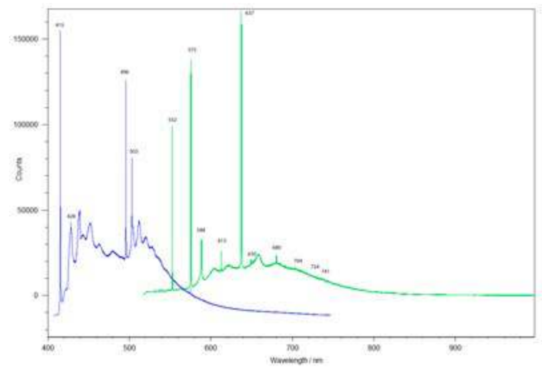
Since December 2019, the SSEF's Raman spectrometer is equipped with two new lasers and one additional grating system with 2400 lines. This is an essential step forward in our research and our client testing services. These new generations of solid-state lasers are less expensive, better performing and more stable.

The main excitation wavelength that we use is certainly the 514.5 nm (emitting green light), for its universal potential. In addition to the old 1800 lines grating system we can now run analyses with a 2400 lines grating system, which provides a shorter scan range but a higher resolution; such enhanced gemmological applications are currently under investigation at SSEF.

Using a 514.5 nm wavelength is also essential for SSEF because we started our first Raman and photoluminescence (PL) analysis in 1996 and in 1999 respectively using this wavelength laser, and all spectra are forming a unique database of analyses. It is noteworthy that at SSEF all PL applications are calibrated on the same diamond Raman line width since 1999. This provides us, and our clients, with an incomparably consistent database.

In addition to the new green laser, we now can easily run our analysis with a 405 nm (blue) solid state laser which is now indispensable for diamond PL applications, especially but not limited to low temperature characterizations of CVD synthetic diamonds. Using this excitation wavelength, we mainly use the 2400 nm grating system for its high resolution and since its narrow scan range is covered by the green laser scan range. The diamond department can use both wavelengths for diamond PL applications. Our team is now working on merging of the 405 nm PL spectra with our 514 nm PL reference database.

Having now two lasers on our Raman spectrometer, we will also be able to easily differentiate PL and Raman peaks by switching from one laser to the other. ***J.-P. Chalain**



△ **Figure 1:** Low temperature (minus 196°C) photoluminescence (PL) spectra of a treated yellow diamond (irradiated and annealed). The blue curve is the PL spectrum obtained by excitation of the 405 nm laser (PL 405) and the green curve is obtained by excitation via the 514.5 nm laser (PL 514). For clarity, both spectra are shown on the same X scale (in nanometres). The Y scale (in number of counts) of the blue curve is slightly offset to show the presence of the NV° optical centre in the two spectra and their difference of intensities. Noticeable peaks in nm on the PL 405 spectrum (in blue) are 415 (N3); 428 (Diamond Raman peak); 496 (H4); 503 (H3); 575 (NV°) and on the PL 514 spectrum (in green) 552 (Diamond Raman peak); 575 (NV°); 588; 613; 637 (NV^-); 650; 680; 704; 724; 741 (GR1°).

ASDI ACHIEVES 100% ACCURACY IN DPA'S ASSURE PROGRAM

Last year, in the SSEF Facette No. 25, we were reporting on the ASSURE Program, an initiative of the Diamond Producer's Association (DPA) which aims to evaluate devices checking the authenticity of diamonds. In May 2019, in the context of the DPA ASSURE program, the SSEF's Automated Spectral Diamond Inspection ASDI device was evaluated by UL Verification Services Inc., an independent neutral third-party.

The ASDI successfully passed 100% of the tests. This means that all stones categorised by the instrument as 'diamonds' were indeed natural diamonds, all diamond simulants were correctly sorted out, and all synthetic diamonds were correctly referred for definitive testing.

As with any other instrument evaluated in the frame of the ASSURE program, the ASDI device was rigorously tested under a strict protocol. The testing sample was composed of 1,000 natural diamonds, 200 diamond simulants and 200 synthetic diamonds, including stones created through HPHT and CVD, some of which were especially processed for the ASSURE program.

Although the ASDI can test stones as small as 0.85 millimetres (0.002 carats), the test sample was only composed of stones with a diameter ranging from 1.0 millimetre to 3.8 millimetres.

The ASDI passed all tests unfailingly, screening out all stones of the testing sample at a speed of more than 6,500 stones per hour. The detailed report is available on the DPA's ASSURE Program website (see: https://diamondproducers.com/app/uploads/2019/05/1906500S-B-ASDI.pdf).

The ASDI device was the very first such instrument available in the market in early 2013 to tackle the challenge of synthetic melees. We are thankful to DPA for its ASSURE Program initiative, as it has provided us the opportunity to demonstrate the capability of ASDI technology.

We are also thankful to ASDI's customers who proved us their confidence in buying the ASDI device. They became pioneers in automatically checking the authenticity of small diamonds. In counterpart, we are now delighted to prove to them, by the intermediate of an external independent and neutral third-party that still 5 years later, the ASDI device is accurate, highly efficient and fast. Today, these proven specifications are placing the ASDI device in the top rank of automatic devices for screening colourless small melees batches. *** J.-P. Chalain**

NGTC VISITS SSEF

In May 2019, the SSEF was honoured to welcome a high-ranking delegation from the National Gemstone Testing Center (NGTC) of China in our SSEF premises in Basel, Switzerland.

This delegation was led by Jie Ke, deputy director at NGTC, Lixin Yang, director of standardization office, and Hua Chen, director of technology development and foreign cooperation, joined by Jun Zhang and Jun Su also from NGTC.

During the meeting, we had a lively and interesting discussion about gemstone testing procedures and standards. Although SSEF and NGTC are two entities which are different in size, structure and legal status, i.e. SSEF as a fully independent non-profit organisation and NGTC as Chinese state-level organization and national authority for gems & jewellery testing and inspection, we easily found that we both share common ground and the same philosophy with regards to a scientific approach and that we are both striving for international harmonisation in testing protocols and nomenclature. * **Dr. M.S. Krzemnicki**

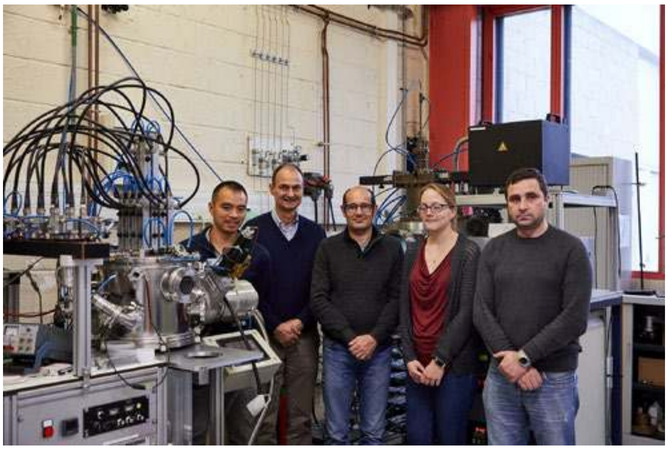
△ **NGTC delegation led by Jie Ke, Lixin Yang and Hua Chen with Jun Zhang, Jun Su at SSEF. Group photo additionally with Jessica Han, Jonathan Jodry (Chair of ISO Technical Committee 174 Jewellery & Precious Metals) and Michael S. Krzemnicki, Jean-Pierre Chalain, Wei Zhou and Hao Wang from SSEF. Photo: L. Phan, SSEF.**

SSEF VISITS DIAMOND LAB IN PARIS

On the 6th of November 2019, members of the SSEF diamond department visited the Centre National de Recherche Scientifique-CNRS, Laboratoire des Sciences des Procédés et des Matériaux - LSPM, at the University of Paris 13 in Villetaneuse. This globally renowned laboratory is famous for its expertise in growing extremely pure CVD synthetic diamonds.

In 2007, after a first visit of the LSPM, we received a few CVD samples free of NV centres that they had grown.. For SSEF, these samples provided first evidence that not all CVD diamonds will show an orange fluorescence (NV centres fluoresce orange). More than a decade ago, this last observation was then a starting point for launching the ASDI research programme for an automatized screening of small diamonds.

Some 13 years later, in spite of the excellent results of the DPA Project Assure tests of the ASDI device (see article on page 57), we are still challenging this machine. Hence a new research project with LSPM that we have initiated.



△ **Figure 1:** SSEF colleagues visiting the LSPM laboratory in France. From left to right: Ly Phan, Jean-Pierre Chalain, Jocelyn Achard (LSPM), Laura Speich and Ovidiu Brinza (LSPM). Photo: SSEF.

GEMMOLOGY TALKS IN CHINA

At the very end of 2019, our senior gemmologist Dr. Wei Zhou was invited by Prof. Dr. Yu Xiao Yan for talks based on the topic 'International Gemstone Testing' at the Gemmological Institute of the China University of Geoscience (Beijing). Over 100 people attended, mostly students and researchers actively working in the gemmological field. After a 3 hour presentation, Dr. Zhou also took the opportunity to visit the institute, which is her alma mater for her bachelor degree and considered to be one of the best institutions in China for gemmological education and research. With the developments of China's jewellery market, enhancing exchanges and cooperation with Chinese scientific institutions will give both them and SSEF interesting and meaningful opportunities.

▷ **Figure 1:** Dr. Wei Zhou of SSEF visiting the gem lab with Prof. Dr. Yu after having given presentations at the China University of Geoscience in Beijing, China.

SEMINAR TO CELEBRATE 40TH ANNIVERSARY OF GAHK

In September 2019 during the Hong Kong Jewellery Show, the Gemmological Association of Hong Kong GAHK celebrated its 40th anniversary with the seminar 'Scientific Research, Professional Practice and Knowledge Creation'.

Since many years, the SSEF has supported the educational mission of GAHK and has participated in numerous GAHK conferences and contributed with publications in their GAHK Journal of Gemmology. It was thus a great pleasure and honour for Dr. Michael S. Krzemnicki of SSEF to be invited as speaker at this landmark event in the Hong Kong Convention Center, together with a line-up of eminent fellow colleagues of the gemmological community.

These included Prof. Mimi Ouyang (Honorary Chairlady of GAHK), who presented new jadeite from Guatemala, Dr. Dietmar Schwarz (former research manager at ICA GemLab, Thailand), speaking about spinel, Dr. Pornsawat Wathanakul (former director GIT, Thailand), presenting new findings on the cause of blue colour in sapphire, Prof. Yang Mingxing (China University of Geosciences, Wuhan), explaining the Chinese grading standard for turquoise, and Prof. Dr. Qi Lijian (Tongji University of Shanghai) who presented research on beaded freshwater cultured pearls. As representative of SSEF, Dr. Michael S. Krzemnicki (director SSEF) discussed challenges and strategies applied at SSEF when separating gems into their colour varieties, based on a presentation given earlier at the European Gemmolgical Symposium in Idar-Oberstein (Germany).

As usual, this GAHK seminar was not only informative, but for us also a moment to network and socialize with our friends from Hong Kong and beyond in Asia.

Finally, we would like to congratulate the Gemmological Association of Hong Kong for their 40th anniversary and the many achievements accomplished in these years and for sure, we wish them a bright and successful future. *** Dr. M.S. Krzemnicki**

△ **Figure 1:** Dr. Michael S. Krzemnicki speaking during GAHK seminar. Photo: GAHK.

SSEF AT SGS CONFERENCE 2019

△ **Figure 1:** Part of the invited speakers of the annual SGS Conference 2019: From left to right: Michael Hügi, Richard W. Hughes, Prof. Henry A. Hänni, Dr. Michael S. Krzemnicki, Hans Pfister, Helen Molesworth, Roland Schluessel and Dr. Lore Kiefert. Photo by Daniela Bellandi, Gold'Or.

In April 2019, the Swiss Gemmological Society (SGS) held their annual conference in Meisterschwanden overlooking the beautiful lake of Hallwil in Switzerland. As in the past, the conference was well attended with about 90 society members and guests. For this year's conference the main topic was jade: its mineralogy, deposits, historical and cultural significance, quality assessment and its trade.

Invited speakers included Prof. Henry A. Hänni (GemExpert GmbH and former director of SSEF) who introduced the mineralogical characteristics and classification of jadeite-jade and nephrite-jade, Helen Molesworth (Gubelin Academy, Switzerland), who gave an extensive overview on the history of jade from Prehistoric times until today, Richard W. Hughes (Lotus Gemology, Bangkok), who spoke about the cultural significance and use of the historically important 'mutton-fat jade' (nephrite-jade) of Khotan in Western China, and Roland Schluessel (Pillar & Stone International Inc., USA), who focused on trade aspects of Burmese jadeite-jade and the complexity of its quality grading.

In addition to this, a broad range of further topics were presented, including from SSEF Dr. Michael S. Krzemnicki who gave a summary about current research at SSEF and exceptional cases tested in recent months, Dr. Bertalan Lendvay, research associate of SSEF, who presented his findings about genetic (DNA) analysis on pearls and coral used in jewellery, and Dr. Myint Myat Phyo, SSEF associate in Asia, about inclusions in spinel from Mogok, Myanmar (see Phyo et al., Journal of Gemmology 2019).

In addition to the presentations, the participants had plenty of time for discussions and networking. As in the past, the social event was again the highlight of the conference, bringing the participants together on a boat trip and a dinner followed by dancing.

The Swiss Gemmological Society SGS is a very active association and provides many options to access relevant and up-to-date gemmological knowledge and networking opportunities for jewellers and gemmologists in Switzerland and beyond.

For more information, please check the SGS website https://gemmologie.ch/en/

SGG SSG

Schweizerische Gemmologische Gesellschaft
Société Suisse de Gemmologie
Società Svizzera di Gemmologia
Swiss Gemmological Society

EGS 2019 IDAR OBERSTEIN

In May 2019, the German Foundation of Gemstone Research (DSEF Gem Lab) celebrated their 50th anniversary by organising the 7th European Gemmological Symposium (EGS) in Idar-Oberstein (Germany), a small town in western Germany that has been known globally as a gem-cutting and trading centre since more than 150 years.

For this event, Dr. Michael S. Krzemnicki, director of SSEF, was invited as a guest speaker together with fellow gemmologists from all over the world. The two-day event, perfectly organised by our German friends, allowed the interested public to gain the latest information about gem and pearl research and testing, but also to learn more about the fascination linked to sourcing exceptional gems in remote areas (by Hans-Jürgen Henn, Henn GmbH) and how to grow synthetic diamonds for jewellery (Dr. R. Chudelka, Ziemer Swiss Diamond Art AG). In a special ceremony, Prof. emer. Dr. H.A. Hänni, former director of SSEF, received a medal of honour for his life-long research in gemstones and for his support to the DSEF organisation and publication Zeitschrift der Deutschen Gemmologischen Gesellschaft.

The presentation by Dr. Krzemnicki entitled 'Red Ruby or Pink Sapphire, That's the Question - Where is the Boundary Between Colour Varieties of Gems?' focused on challenges and strategies applied at SSEF when separating gems into different colour varieties. As the naming of colour varieties is currently again much in discussion in the trade and trade organisations (e.g. CIBJO) alike, we present in this Facette (on pages 6-9) a more detailed review of this topic.

Furthermore, a PDF file with this presentation which was given also in Hong Kong (GAHK and Gem-A Seminar September 2019) and Tucson (GILC 2020) has been uploaded to our SSEF website: www.ssef.ch/presentations *** Dr. L.E. Cartier**

△ **Figure 1:** Speakers of the 7th European Gemmological Symposium, 25-26th May 2019, Idar-Oberstein (Germany). Photo: DSEF.

TRACEABILITY PANEL AT GEMGENÈVE 2019

In May 2019, GemGenève and the Art Law Foundation (Switzerland) organized a conference and panel on traceability in the gemstone trade (https://artlawfoundation.com/fda-events/gemstones/), attended by interested participants from the gem trade, jewellery brands and media. As part of this event, Dr. Michael S. Krzemnicki was an invited speaker and gave a keynote lecture about traceability from a gem lab's perspective (available online https://www.ssef.ch/presentations/. In his talk, he focused on the challenges, options, and opportunities to trace and track gemstones within the supply chain, and the importance of gemmological laboratories to independently confirm and track gemstones over time. Specifically, he presented the GemTrack service, a tracking option for any gemstone from rough to cut and even mounted in jewellery based on advanced scientific testing at SSEF (see also article about GemTrack in this Facette, pages 12-13).

The talk and the following panel led to an intense and fruitful discussion among the present speakers and participants about this timely issue, to be continued as all agreed. *** Dr. M.S. Krzemnicki**

CIBJO CONGRESS IN BAHRAIN

△ **Figure 1:** Udi Sheintal (president of CIBJO diamond commission) and Jean-Pierre Chalain (vice-president of CIBJO diamond commission) at the congress in Bahrain. Photo: Steve Benson, CIBJO

The 2019 CIBJO congress took place in November the city of Manama, in the Kingdom of Bahrain. The pre-congress launched the CIBJO participant members' work on the 16th of November and the official congress ended on the 20th. The opening ceremony was introduced by HE Shaikh Khalid bin Abdulla Al Khalifa, the Bahrain Deputy Prime Minister who also serves as Chairman of Mumtalakat, the country's sovereign wealth fund, under which operates the Bahrain Institute for Pearls & Gemstones - DANAT, the host of the congress.

Beginning of 2019, CIBJO President Dr. Cavalieri launched a new committee with the aim of providing structure to the growing international market of synthetic diamonds. The 'Laboratory Grown Diamond Committee' met several times last year and its chairman Wesley Hunt presented a first draft of the 'Laboratory Grown Diamond Guidelines' to the congress. It was decided that the continuation of this work will be put under the umbrella of the Diamond Commission.

More information on the 2019 CIBJO congress at: http://www.cibjo.org/congress2019/ * **J.-P. Chalain**

WORLD PEARL SYMPOSIUM

Taking over the role of the Pearl & Gem Testing Laboratory founded in 1990, the Bahrain Institute for Pearls and Gemstones - DANAT organized a World Pearl Symposium which took place in Manama (Bahrain) on the 14th and 15th of November 2019, just prior to the CIBJO congress.

The symposium was opened by Dr. Gaetano Cavalieri, CIBJO's president, and Noora Jamsheer CEO of DANAT.

This exceptional event gathered pearl experts from all over the world. Local pearl experts, researchers and dealers also provided the audience with many interesting information on the importance of the legendary natural pearl market of Bahrain. On the last day, Jean-Pierre Chalain gave Dr. Michael S. Krzemnicki's talk: 'New Frontiers in Pearl Analysis: Age Dating, DNA Fingerprinting, and Novel Radiographic Methods'. This presentation is available at: https://www.ssef.ch/presentations/

More information on the World Pearl Symposium at: https://www.danat.bh/pearlsymposium/

GEM-A CONFERENCE 2019 IN LONDON

The annual Gem-A conference organised by the Gemmological Association of Great Britain is one of the most memorable gemmological conferences that take place. It's a great mix of insightful gemmological talks and great conversations with Gem-A members over the space of a few days in London. The 2019 edition took place on a rainy weekend in November (2-3 November 2019) in a beautiful location overlooking the Thames and house of parliament.

Dr. Laurent E. Cartier was invited to give a presentation on diving for diamonds in the Sewa River in Sierra Leone. His talk covered miners who dive artisanally for diamonds in Sierra Leone, as it's quite a unique way of recovering diamonds. He also shared findings on the history of diamond mining in Sierra Leone, exploration and mining techniques in Sierra Leone, the types of diamonds that are found and what 'ethics' could mean to such miners and our industry.

Speakers and conference attendees got the opportunity to visit the impressive Houses of Parliament (House of Lords and House of Commons) on a guided tour on the Saturday evening before the gala dinner. The traditional gala dinner took place in the Stranger's room of the House of Commons

On the Monday after the conference, a range of workshops took place at Gem-A headquarterrs at Ely Place in central London. Dr. Cartier gave a well-attended hands-on workshop about new types of cultured pearls found in the market.

Unfortunately, the Gem-A conference will no longer be taking place on an annual basis (but rather biannually), but the wait will make it all the more memorable! Thank you to Gem-A for your kind hospitality, and we look forward to much more future collaboration between SSEF and Gem-A.
*** Dr. L.E. Cartier**

Gem-A
THE GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

△ Alan Hart (gracious host and CEO of Gem-A) announcing the raffle results during the much-awaited Saturday evening dinner in the House of Commons in London. Photo: L.E. Cartier.

△ Divers on the Sewa River in central Sierra Leone. These divers works on a seasonal basis and recover diamond-rich gravels from the bottom of the Sewa River. Photo: L.E. Cartier.

SSEF AT IGC IN NANTES (FRANCE)

The 36th International Gemmological Conference IGC was held last August in Nantes, France at the impressive La Cité Nantes congress centre. This biannual conference brings together many of the world's leading research gemmologists, and is by invitation only. It was organised under the lead of Prof. Emmanuel Fritsch of the University of Nantes. SSEF was involved as a conference sponsor and assisted in both the IGC website and the conference proceedings. Dr. Michael S. Krzemnicki sits on the executive committee of IGC, and Dr. Laurent E. Cartier was at the end of the IGC Nantes conference voted in as a delegate of the International Gemmological Conference.

A pre-conference excursion took place from the 24th to the 26th of August 2019: the megalithic treasures of Brittany and a freshwater mussel farm. A post-conference excursion took place from September 1 to 4: 'Hidden Paris', exploring little known private and public collections of gems and jewelry, including the historical 9 ct pink Grand Condé diamond in Chantilly.

The conference which took place over 4 days had 12 sessions of talks on a wide variety of gemmological research topics including diamonds, coloured gemstones, pearls and new scientific methods. The conference also included a number of posters which were a source of fruitful discussions during the poster sessions and coffee breaks. SSEF researchers presented a total of 4 papers during this IGC conference. Dr. Hao Wang presented new findings on 'Multi-element analysis of gemstones for country of origin determination'. Dr. Michael S. Krzemnicki gave a talk entitled 'Age dating applied as a testing procedure to gemstones and biogenic materials'. Jean-Pierre Chalain shared results of recent diamond research in 'Study of a recut HPHT synthetic diamond: colour vs size vs SWUV transmission'. Lastly, Dr. Laurent E. Cartier highlighted ongoing research by SSEF in collaboration with the University of Zürich on 'DNA fingerprinting of precious corals and pearls'.

The full abstract proceedings (236 pages) of the IGC conference in Nantes can be downloaded as a PDF from the following website: https://www.igc-gemmology.org/igc-2019

Furthermore, the PDFs of SSEF presentations given at IGC 2019 can all be downloaded on https://www.ssef.ch/presentations/

△ **Figure 1:** Jean-Pierre Chalain sharing recent diamond research results at the IGC conference in Nantes. This was somewhat of a homecoming for him as he studied in Nantes for his DUG many years ago. Photo: R. Serov.

△ **Figure 2:** Dr. Michael S. Krzemnicki with Dr. Ahmadjan Abduriyim at IGC 2019 in Nantes. Photo: R. Serov.

△ **Figure 3:** IGC participants also had the opportunity to visit Nantes' Machines de l'île and encounter the grand elephant there. Photo: L.E. Cartier, SSEF.

EUROPEAN CONFERENCE ON MINERALOGY AND SPECTROSCOPY

In September 2019, a team of three SSEF researchers attended the 9th European Conference on Mineralogy and Spectroscopy in Prague, Czech Republic. This scientific conference has been run every four years since the inaugural meeting in Italy in 1988. This year, it was organized by Prof. Jan Cempírek from Masaryk University together with his colleagues. It was hosted in a intricately painted room in the Brevnov Monastery in Prague, which was founded in 990 AD (Figure 1).

During the three-day scientific meeting, we listened to presentations about a wide range of topics including theoretical and experimental mineralogy and spectroscopy, geochemistry, crystallography, as well as specific topics such as HPHT experiments, uranium minerals and gemmology. Among many interesting talks and discussions, SSEF members contributed four oral presentations in the gemmology session.

Dr. Tashia Dzikowski-Hutter is a gemmologist at SSEF and she presented an overview about the current challenges in distinguishing natural from synthetic rubies in routine laboratory testing of gemstones. She highlighted selected comparisons of natural inclusions and confusing inclusions in synthetic rubies, such as flux residues, platinum flakes and gas bubbles. In order to tackle the difficulty and provide more evidence in gemstone testing, she applied trace element analysis using GemTOF, and discussed cases where elemental concentrations and the presence of exotic elements play important roles in identifying synthetic rubies.

Dr. Hao Wang, research scientist at SSEF, presented a novel multi-element analysis method for origin determination of Paraíba tourmalines. Gem-quality tourmaline is often free of inclusions under an optical microscope, making the comparison of trace elements for origin determination very important. His presentation focused on multi-element and statistical analyses in order to cluster Paraíba tourmalines samples with similar elemental composition. By comparing 30+ elemental concentrations of more than 1000 measurements, this method successfully separated Paraíba tourmalines from Brazil, Mozambique and Nigeria. Importantly, this method does not need to have the user-input origin information as a pre-requisite, therefore making the clustering more objective.

Dr. Myint Myat Phyo, a former PhD student at SSEF and the University of Basel (Switzerland), gave two presentations related to her PhD thesis on the topic of gem-quality rubies and spinels from Mogok, Myanmar. She presented a detailed and comprehensive record of inclusions found in spinel, which is highly sought-after in the gemstone market. Her work filled a gap in existing inclusion studies in Mogok spinel and is expected to provide complementary information on the origin determination of spinels. In her second talk, Myint emphasized the U-Pb dating of zircon and zirconolite inclusions in gem-quality rubies and spinels from Mogok. She recorded a wide range of ages found in those inclusions. The young ages, which may point to the formation of ruby and spinel in Mogok, are determined to be about 22 million years old. In her work, a zirconolite inclusion in Mogok ruby was characterized for the first time. We would also like to congratulate Myint for her work being recognized by the conference scientific committee; as a result she received a 'Best Student Presentation' award! * **Dr. H.A.O. Wang**

△ **Figure 1:** Painting-decorated ceiling of the conference room in the Brevnov Monastery. Photo: H. Wang, SSEF.

△ **Figure 2:** Dr. Myint Myat Phyo received her 'Best Student Presentation' award. Photo: H. Wang, SSEF.

OECD FORUM ON RESPONSIBLE MINERAL SUPPLY CHAINS IN PARIS

The Organisation for Economic Cooperation and Development (OECD) in Paris organises an annual forum on responsible mineral supply chains, taking place in 2019 from April 23rd-26th at OECD headquarters. The OECD Due Diligence Guidelines for responsible supply chains of minerals are widely accepted as the most important standard for companies to follow, and also includes diamonds and coloured gemstones. The OECD forum is the leading event worldwide bringing companies and stakeholders together to exchange on CSR, mineral legislation, sustainability, traceability and discuss experiences and initiatives.

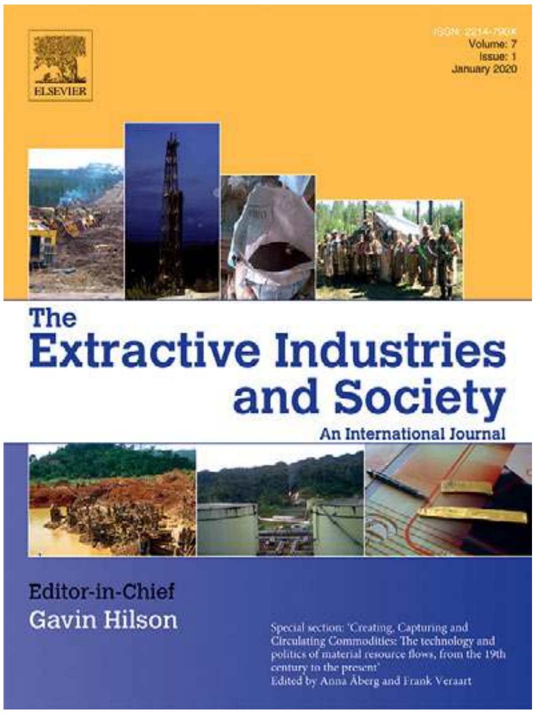
Together with Patricia Syvrud (University of Delaware), Dr. Laurent E. Cartier was invited to organise and present research at a side-session event on coloured gemstones and sustainable development. This was an excellent opportunity to discuss issues and opportunities in coloured gemstone supply chains and present latest transparency and traceability intitiatives for the coloured gemstone supply chain. Lastly, educational opportunities (such as the University of Delaware's MMS programme) were addressed, as were the outcomes of research projects linked to the Gemstones & Sustainable Development Knowledge Hub (www.sustainablegemstones.org).

JOURNAL SPECIAL ISSUE ON GEM SUPPLY CHAINS

The Extractive Industries and Society is a leading academic journal published by Elsevier that focuses on research related to the socio-economic and environmental impacts of mining and oil and gas production on societies, both past and present. Dr. Laurent E. Cartier was invited by the editor Prof. Gavin Hilson (University of Surrey, UK) to guest edit a special section on coloured gemstones and sustainable development.

The vast majority of existing research on coloured gemstones has focused on the material properties and sources of different gem varieties (e.g. in scholarly journals Journal of Gemmology and Gems & Gemology), but there is very little research available on supply chains and issues linked with the extraction, processing and trade of gem resources. The coloured gemstone industry has undergone great transformations in the last few decades. Although it has always been a global trade, it has now become a globalised and highly interconnected industry. This growth has also become associated with considerable sustainability challenges and an urgent need to examine the social and environmental impacts that come with the production, trade and consumption of coloured gemstones. As ethical certification mechanisms and a push for traceability seeks to bring more transparency to the industry (Hilson, 2014; Cartier et al., 2018), it is evident that more field research is required to map the issues the sector is facing and the special section sought to address some of these gaps in research.

The special section of the journal was published in early 2020. It features 7 papers including an introduction by Dr. Cartier. The first three papers critically explore: the gem industry in Namibia and its challenges; how the provenance of gemstones can be harnessed through the 4 P framework of place, product, price and promotion; and CSR practices in the emerald mining sector in Colombia. The final papers focus on: an ethnographic study of the global emerald trade; the phenomenon of gem rushes and the role of artisanal small-scale miner (ASM) driven migration in gem regions of Madagascar; and the growth of the Thai gem industry and the role of women in the sector. Interested readers can contact Dr. Cartier for access to articles.



PEARL FORUM AT INHORGENTA

Inhorgenta Münich organises an annual Pearl Forum. The aim of the forum is to share pearl industry developments with a wider audience. The focus for 2020 was on sustainability. Speakers this year included Andy Bardon (National Geographic, USA) who spoke about the need for inspirational storytelling when tackling sustainability themes. He shared images and video footage from a National Geographic & Waitt Foundation research expedition to French Polynesia to research the impacts of pearl farming on fish populations a few years ago. Justin Hunter (J. Hunter Pearls, Fiji) spoke from a pearl farmer's perspective on the need and challenges for sustainability when cultivating marine cultured pearls. Dr. Laurent E. Cartier offered an overview on sustainability issues within the pearl farming sector, research initiatives and how pearling can address certain marine conservation challenges. Last but not least, Jennifer Heebner (CPAA, USA) shared her insights on how accountable and credible sustainability messaging for marine cultured pearls can be used as a tool to engage with a wider consumer audience.

△ Dr. Laurent E. Cartier speaking at Inhorgenta in February 2020 on sustainable pearls. Photo: A. Bardon.

SSEF IN TUCSON

SSEF was pleased to be exhibiting for the first time at the AGTA GemFair in Tucson in February 2020. SSEF was providing coloured gemstone express testing services to US-based and international clients. The Tucson shows are an ideal moment to also connect with the international gem community and come across new finds for our gemmological research.
The Tucson shows were also the opportunity to share recent research by SSEF to the wider gem community. Dr. Michael S. Krzemnicki spoke about 'Harmonization of Color Terms' at GILC -Gemstone Industry & Laboratory Conference- organised by ICA on February 3rd in Tucson. This was an important event and opportunity to discuss with the trade and other labs the possibilities and challenges of harmonizing colour terms for gems.

Dr. Laurent E. Cartier was invited to give a talk at the Accredited Gemologists Association AGA Conference who talked about 'Traceability of Gemstones and Pearls – Challenges & Opportunities'.
We look forward to returning to Tucson in 2021!

△ **The SSEF on-site team in Tucson on a morning sunrise hike in the Arizona desert.**

GEMGENÈVE 2020

Gemgenève (5- 8 November 2020) is a boutique international Gem and Jewellery Fair. Initiated and organised by a small group of traders, this international show unites some of the most prestigious and reputed international gem companies. The SSEF has been exhibiting since the first edition in 2018 and will be present with a booth at GemGenève in 2020, where we will offer our testing services for coloured gemstones.

SSEF ON-SITE 2020

In 2020 we will be exhibiting and/or offering our on-site testing services as follows. Please note that the COVID-19 situation has meant that many shows and on-site testing events have been postponed or cancelled. We are closely following the situation over the coming months and this calendar may be further adapted:

Tucson	4-9 February 2020
Hong Kong	postponed
Baselworld	postponed
Hong Kong	postponed
Bangkok	17-21 August
Hong Kong	9-19 September 2020
GemGenève	5-8 November 2020
Other locations	on request

CLOSE-UP: DR. HAO WANG

Dr. Hao Wang is a research scientist at SSEF and started to work for us in the summer of 2015. At that time, we were actively exploring options to acquire a laser-ablation ICP mass spectrometer for the SSEF laboratory, to complement our long-standing collaboration with the University of Bern (Prof. T. Pettke) and the Federal Institute of Technology (Prof. emer. C. Heinrich and his research group) for trace element analyses on gemstones from clients and for research.

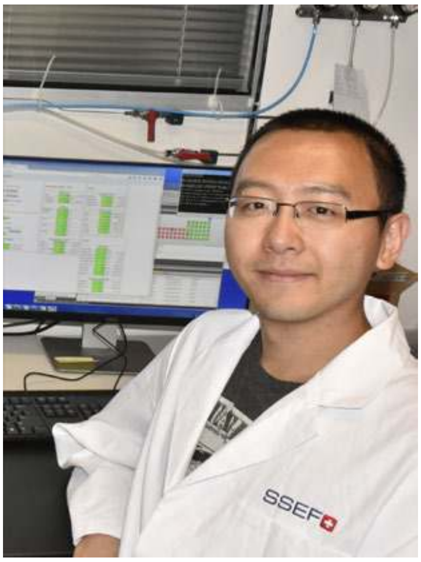
Rarely the wording "in the right place at the right time" has proven to be so fitting and true as with Hao Wang, who spontaneously applied at SSEF just after successfully finishing his PhD and Postdoc studies at the world-renowned ETH Zurich in the research group of Prof. Detlef Günther, focussing on novel methods in trace element analysis using mass spectrometry.

Since then, Hao Wang has not only evaluated and successfully integrated the GemTOF (laser-ablation-inductively-coupled-plasma time-of-flight (TOF) mass spectrometer) in our analytical setup and procedures, but has also guided our SSEF analytics team and students from the University of Basel in the use and application of this highly sensitive multi-element detection method. In addition, he is strongly involved in our research at SSEF, spanning from biogenic materials (e.g. pearls, ivories, corals), coloured gemstones (mainly origin determination) and diamonds (inclusion studies), all finally highly relevant to our expertise and excellence in gemmological testing.

Furthermore, he is developing new statistical machine-learning tools for our database, to extract relevant information from multidimensional analyses (e.g. chemical and isotopic data) with the aim of giving gemmologists robust decision-making support as a backbone for their findings and conclusions.

He is a regular speaker at scientific conferences worldwide and is keen and interested to dig for gems, be it in the gravels of an alluvial deposit or deep in a shaft within hard-rock pegmatites such as in the hills of Paraiba in Brazil.

As if this were not enough, he also is a very active team member and - as a frequent and passionate hiker – has probably visited more scenic places in Switzerland than many of our Swiss staff members will ever do. We are very happy to have amongst our team Dr. Hao Wang as an inspiring and dedicated scientist and teammate. *** Dr. M.S. Krzemnicki**



TEAM ACHIEVEMENTS

We are pleased to share news that Michael Rytz (gemmologist at SSEF) succesfully completed his Master of Science in Geosciences at the University of Basel in March 2020 under the supervision of Dr. Michael Krzemnicki. Michael Rytz's master thesis project focused on the chemical characterisation of chrysoberyls from different origins using LA-ICP-TOF-MS. His research fits in nicely with ongoing research on origin determination of gems at SSEF. We want to congratulate him warmly on completing his studies.

Furthermore, we are thrilled that Dr. Myint Myat Phyo has completed her PhD entitled `Mineralogical, gemmological and petrological study of the Mogok Stone Tract in Myanmar with a special focus on gemquality ruby and spinel'. She successfully defended her PhD in September 2019 at the University of Basel's Institute of Mineralogy and Petrography. Her supervisors were PD Dr Michael S. Krzemnicki and Prof. Dr. Leander Franz (University of Basel). We look forward to continuing our research collaboration with Dr. Myint Myat Phyo on Burmese gemstones and the formation of gems in the Mogok Stone Tract in future.

FOUNDATION BOARD AT SSEF FOR SCIENTIFIC GEMMOLOGY CRASH COURSE

As a non-profit foundation under the aegis of the Swiss Federal Department of Home Affairs, the SSEF is supervised by a foundation board consisting of the following members: M.A. Christen (President, Bern), Charles Abouchar (Geneva), Bernhard Berger (Geneva), Horst Edenhofer, Martin Häuselmann (Bern), Adrian Meister (Zürich), Nicky Pinkas (Geneva), Frederic Torroni (Geneva), and Ronny Totah (Geneva).

In October 2019, the SSEF team invited the SSEF Foundation Board including board candidate Melissa Wolfgang Amenc (Geneva) to visit the SSEF laboratory for a short and intense crash course in analytical gemmology. The aim was to provide our Foundation Board members with the latest updates in our scientific know-how and our analytical procedures. These can be definitively considered key factors in order to continuously keep up with the newest developments and challenges in the gem and jewellery trade and to stay at the forefront of research.

Our Foundation Board members, all with years of experience in the trade and hands-on expertise in evaluating gemstones were very keen and interested students. As such, both the SSEF team and Foundation Board members mutually benefitted from this event, based on the plenty of questions and the lively discussions that emerged out of this course. Questions addressed were for example:

- How do we finalise an origin on coloured gemstones?
- Why is it that origin discrepancies of different labs occur more often for sapphires than for rubies ?
- What are the testing procedures at SSEF?
- How is age dating carried out on pearls or gemstones?

And many more...

To make that day even more memorable, the course finished at the Kunstmuseum Basel with a private tour through the exhibition Gold & Glory – Gifts for Eternity, in honour of the millennium of Basel Cathedral (see article in this Facette, page 45), and a delicious dinner in the Hotel Krafft overlooking the Rhine river.

As this was such a successful event, we cordially invite interested clients and jewellery & gem trading companies to visit us for such a crash course in analytical gemmology. For more details, please contact admin@ssef.ch, keyword 'crash course'. *** Dr. M.S. Krzemnicki**

FRÉDÉRIC TORRONI NEW IN THE SSEF FOUNDATION BOARD

The SSEF team would like to welcome Frédéric Torroni, our new member of the SSEF Foundation Board since September 2019. With Mr. Torroni (F. Torroni SA in Geneva), the SSEF has found a strong and committed new board member, who by his personality and long-established experience in the gem trade is an ideal fit for our Foundation board. We look forward to collaborating fruitfully with him as part of the SSEF board for many years to come.

TEAM EVENT IN BERN AND BASEL

On December 11th 2019, the SSEF got together for the annual team event. It began by heading to Bern to visit Switzerland's beautiful capital. We started by a guided tour of the exhibition 'Rocks of the earth, meteorites, diamonds and co.' at the Natural History Museum of Bern. This was also an opportunity to learn more about the many other treasures that nature other than gem and diamonds. We had the unique chance to go behind the scenes and explore the museum's collection in the basement with a guided tour by the curator. Lunch took place in a lovely Italian restaurant overlooking the river Aare, in which many Bernese people swim in summer.

We continued by a guided culture and history tour of Bern's old town which, with its well-preserved medieval centre, was included on UNESCO's listing of World Heritage Sites in 1983. The day finished with a cooking workshop in Basel that focused on a range of delicious recipes – including cooking at -200°C with liquid nitrogen- followed by a group dinner all together (see team photo on page 73).

△ **The old town of Bern overlooking the river Aare. Photo: M. Schmitt, SSEF.**

DONATIONS

As in previous years, we are grateful for numerous donations we received in 2019 from many pearl and gemstone dealers around the world. These donations not only support our research but also add to our collection of specimens to be used in our courses, with the aim to educate the participants and to give them the opportunity to learn gemstone & pearl testing on a wide variety of untreated and treated materials.

PEARL DONATIONS

Antoinette Matlins (USA), Laurent Cartier (Basel), Bertrand Ternat (Conch Pearls Ltd., Hong Kong), Henry A. Hänni (GemExpert, Basel)

GEMSTONE DONATIONS

Imam Faris (Imam Gems (Pvt) Ltd., Sri Lanka), Rodrigo Giraldo (Bogotá, Colombia), Groh & Ripp (Idar Oberstein, Germany), Sebastian Hänsel (Basel), Gebr. Henn K.G. (Idar Oberstein, Germany), Auktionshaus Ineichen Zürich AG (Zürich, Switzerland), Anna Hügli (Basel, Switzerland), Esther Hunziker (Péclard Suisse SA, Zürich), Peter Loosli (Peter Loosli AG, Switzerland), Alexander Leuenberger (ALine GmbH, Switzerland), The Muzo Companies (Colombia), Andrew Rimmer (Opsydia Ltd., UK), Prof. Dr. Rainer Aloys Schultz-Guttler (Universidade de São Paulo), Mie Mie Tin-Htut (Silken East Co. Ltd., Bangkok), Aung Kyaw Zin (SP Gems, Myanmar), Enzo Liverino (Torre del Greco, Italy)

PUBLICATIONS

Cartier L.E., 2019. Gemstones and sustainable development: Perspectives and trends in mining, processing and trade of precious stones. The Extractive Industries and Society, Volume 6, Issue 4, 1013-1016.

Cartier L.E., 2019. Laser inscription and marking of gemstones: an overview of options. Incolor, 43, 66-69.

Cartier L.E., Krzemnicki M.S., 2019. Traceability & Blockchain for Gemstones – an Overview. Published in Journal of the Gemmological Association of Hong Kong GAHK, 2019, Volume XL, 22-25.

Cartier L.E., 2019. A brief review of traceability and blockchain for gemstones. GemGuide, September/October 2019, 2-4.

Cartier L.E., Krzemnicki M.S., Lendvay B., Morf N., Meyer J., 2019. DNA fingerprinting of precious corals and pearls. Abstract Proceedings of 36th International Gemmological Conference, 154-156.

Chalain J.-P., Phan L., Krzemnicki M.S., Pausch J., Steinacher M., 2019. Study of a recut HPHT synthetic diamond: colour vs size vs SWUV transmission. Abstract Proceedings of 36th International Gemmological Conference, 35-37.

Dzikowski-Hutter T.J., Krzemnicki M.S., Lefèvre P., Zhou W., Wang H.A.O., 2019. A Gemmological Approach to Distinguishing Natural from Synthetic Rubies: LA-ICP-TOF mass spectrometry provides new insights. The 9th European Conference On Mineralogy And Spectroscopy, Prague, Czech Republic.

Hänni, H.A., 2019. Gemstones of the garnet group – about mixed crystals and solid solution. J.Gemmol.Assoc. Hong Kong, Vol. XL, 36-49.

Hänni, H.A, Parenzan, C., 2019. A brief study of three reported "coconut pearls" from South East Asia. Journal of Gems and Gemmology (Wuhan, China), Vol.21, Nr.3, 42-47.

Hänni, H.A., Milisenda, C.C., Wang, H.A.O, 2019. Tourmalin mit Coltan ore inclusion – an example of auto-irradiation. 36th International Gemmological Conference IGC, Nantes. 102-103.

Hänni, H.A., Milisenda, C.C., Wang, H.A.O., 2019. Turmalin mit Coltan Einschlüssen- ein Beispiel von natürlicher Selbstbestrahlung. Z. Dt. Gemmol. Ges. 68, 3-4, p. 55-60

Hänni, H.A., Parenzan, C., 2019. "Kokosnuss-Perlen" Artefakte mit einer langen Geschichte. Z. Dt. Gemmol. Ges. 68, 3-4, p. 49-54

Hänsel S., 2019. Grossular from Tanzania with Uncommon Inclusions. Journal of Gemmology, 36(6), 500-501.

Krzemnicki M.S., Cartier L.E., 2019. Padparadscha-like Fancy sapphires with Unstable Colours: Colouration Mechanisms and Disclosure. InColor, No. 41, 92-94.

Krzemnicki M.S., Butini F., Butini E., De Carolis E., 2019. Gemmological Analysis of a Roman Sapphire Intaglio and Its Possible Origin. Journal of Gemmology, 36(8), 710-724.

Krzemnicki M.S., Cartier L.E., Hughes R.W., Leelawatanasuk T., Kiefert L., Choudhary G., McLure S., Milisenda C.C., Gambini E., Kim S., Schwarz D., Dunaigre C., Horikawa Y., 2019. Sapphires Heated with Pressure – A Research Update. InColor, Spring 2019, 86-90.

Krzemnicki M.S., Cartier L.E., Lefèvre P., Zhou W., 2020. Colour varieties of gems: where to set the boundary? InColor, 2020 Winter, 45, 92-95.

Krzemnicki M.S., Wang H.A.O., Phyo M.M., 2019. Age dating applied as a testing procedure to gemstones and biogenic gem materials. Abstract Proceedings of 36th International Gemmological Conference, 48-50.

Panczer G., Riondet G., Forest L., Krzemnicki M.S., Carole D., Faure F., 2019. The Talisman of Charlemagne: New Historical and Gemological Discoveries. Gems & Gemology, 55(1), 30-46.

Phyo M.M., Wang H.A.O., Guillong M., Berger A., Franz L., Balmer W.A., Krzemnick M.S., 2020. U–Pb Dating of Zircon and Zirconolite Inclusions in Marble-Hosted Gem-Quality Ruby and Spinel from Mogok, Myanmar. Minerals, 10, 195; doi:10.3390/min10020195.

Phyo M.M., Bieler E., Franz L., Balmer W.A., Krzemnicki M.S., 2019. Spinel from Mogok, Myanmar—A Detailed Inclusion Study by Raman Microspectroscopy and Scanning Electron Microscopy. Journal of Gemmology,36(5), 418-435.

Wang H.A.O., Krzemnicki M.S., Bueche S., Schmid R., Braun J., 2019. Multi-Element Analysis of Solid-State Inclusions in Diamonds. Abstract Proceedings of 36th International Gemmological Conference, 176-178.

Wang, H.A.O., Chalain, J.P., Phan L., Krzemnicki, M.S. 2019, Multi-Element Analysis of Inclusions in Diamond using a novel technique LA-ICP-TOF –MS. The 70th Annual Diamond Conference, Warwick, UK.

Wang, H.A.O. et al, 2019, Multi-Element Analysis of Gemstones For Country of Origin Determination Using LA-ICP-TOF-MS. The 9th European Conference On Mineralogy And Spectroscopy, Prague, Czech Republic.

△ SSEF team in December at our annual team event. Photo: SSEF.

Swiss Gemmological Institute SSEF

THE SCIENCE OF GEMSTONE TESTING™

Aeschengraben 26
CH-4051 Basel
Switzerland

Tel.: +41 61 262 06 40
Fax: +41 61 262 06 41
admin@ssef.ch

www.ssef.ch