Facette

MAGAZINE

INTERNATIONAL ISSUE NO.28, MAY 2023

HISTORY OF GEMS / CORUNDUM TREATMENTS
ASDI-500 / BLACK OPALS / CULTURED PEARLS
AUCTION HIGHLIGHTS / NEW COURSES

SSEF
SCHWEIZERISCHES GEMMOLOGISCHES INSTITUT
SWISS GEMMOLOGICAL INSTITUTE
INSTITUT SUISSE DE GEMMOLOGIE

Dear Reader

After one year with no issue, it is my great pleasure to present you today the newest SSEF Facette. This is already the 28th issue of this annual magazine and it is again packed with our latest findings in research and with updated information about our services and activities.

The reason for the one-year break between the SSEF Facette in 2021 and now is a very memorable one. In summer 2022, the Swiss Foundation of Gemstone Research SSEF celebrated its 50th year anniversary with a glittering gala dinner and a symposium with an impressive line-up of speakers from all over the world. The preparation of this event and the publishing of a coffee-table book to celebrate the 50 years of SSEF took so much time and energy, that we decided to postpone the 28th SSEF Facette, this one, to the year 2023.

In the past few months, the SSEF has continued to grow and as such is now in the midst of a renovation and expansion process to double its lab space in our main location in Basel. Apart from this, we are glad to be able to travel again to venues and shows now that the Corona pandemic seems to have passed. We enjoy very much to meet again our clients in person and discuss with them about issues in the trade and how we can contribute and support them in the challenges they face.

In terms of research and development, the past year was very successful with the development of the first automated screening machine for melée diamonds down to a diameter of 500 microns: that means as tiny as half a millimetre! A truly Swiss precision tool, actually developed and fully produced in Switzerland in collaboration with Unimec SA and the Swiss innovation centre CSEM. More about this next-generation instrument you can read in this Facette. In addition, we have invested much resources in research on corundum, with a special focus on low-temperature heating and on colour modification by irradiation. These issues are complex and require collaboration with other gemmological laboratories and external research facilities. Although we currently do not have the magic key to solve all these issues, we are confident that our step-by-step research contributes to a better understanding and ultimately better protection of the trade against undisclosed treatment challenges.

But finally, we are not only scientists and lost in spectra and trace element data, but gemmologists who are again and again fascinated by the gems and jewels submitted to the SSEF for testing. It is this joy in these products of nature, in their geological and historic provenance, which makes our daily work not a routine job, but an exciting and never-ending journey where so many different facets come to light.

The articles in this issue of the SSEF Facette aim to show you some of the facets of our fascination. I hope that by reading the following pages you are as inspired as we are by the beauty of nature expressed in gems and jewels and by the gemmological science behind it.

Sincerely yours,

Dr. Michael S. Krzemnicki
Director SSEF

COVER PHOTO ▷

Gemstone cutter at work near Ratnapura, Sri Lanka.

Photo: M.S. Krzemnicki, SSEF

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IMPRINT
Annual publication by **Swiss Gemmological Institute SSEF** Aeschengraben 26, CH-4051 Basel SWITZERLAND
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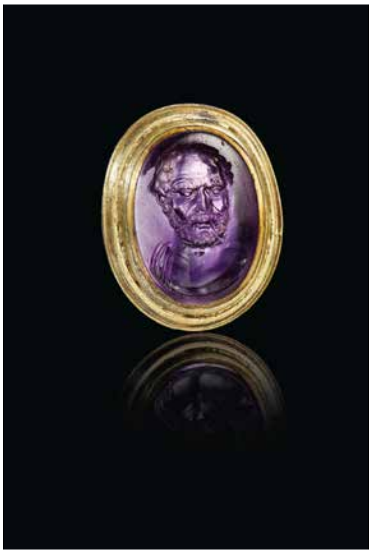
ISSN : 2296-214X | All images ©SSEF unless otherwise stated

UNEARTHING THE PAST: HARNESSING HISTORY IN THE STUDY OF GEMMOLOGY

Gemstones have been used in jewellery for millennia, with their history dating back to ancient civilizations. From Egypt to Mesopotamia, India to China, Europe and the Americas, gemstones have held deep cultural significance and have been treasured for their inherent beauty and mystical properties. In ancient times, gemstones were often associated with spiritual and healing powers, and were used for protection, worship, and adornment.

In ancient Egypt, gemstones such as turquoise, lapis lazuli, and carnelian were used in jewellery to symbolize protection and divine connection. The pharaohs and elite members of society adorned themselves with intricately crafted jewellery, often featuring precious gemstones. Gemstones were also used in burial rituals, with the belief that they would accompany the deceased into the afterlife. In ancient Mesopotamia, gemstones like carnelian and lapis lazuli were used in jewellery as amulets to ward off evil spirits and promote good fortune.

When Alexander the Great conquered the Persian empire in 331 B.C., his domain extended from Greece to Asia Minor, Egypt, the Near East, and India. This unprecedented contact with distant cultures not only spread Greek styles across the known world, but also exposed Greek art and artists to new and exotic influences and materials (including gemstones such as garnets).



◁ **Figure 1:** A Roman amethyst ring with a portrait of Demosthenes. Signed by Dioskourides, circa late 1st century B.C. Price realised USD 1,575,000 at Christie's in 2019. Photo: Christie's.

Romans in particular, adorned themselves with jewellery featuring colourful gemstones and pearls, and it was also common to have gemstones carved into intricate cameos or intaglios (Figure 1), which were used as decorative elements in jewellery. The Roman Empire (27 B.C. – 476 A.D.) was important in gem trading, jewellery manufacturing and new jewellery fashion. The Byzantine Empire, with its capital in Constantinople, persisted as a continuation of the Roman Empire in the eastern provinces throughout late antiquity and the Early Middle Ages and had rulers who treasured many different varieties of gemstones (Figure 2).

◁ **Figure 2:** The Mosaic of Theodora in the Basilica of San Vitale (built 547 A.D.), Italy. Theodora, a 6th-century Byzantine empress married to Emperor Justinian I, is remembered for being one of the most powerful women in Byzantine history and was reportedly a collector of gems and jewellery. Photo: Wikipedia.

During the Renaissance period in Europe, gemstones regained popularity in jewellery as a symbol of wealth, power, and status. Royals and aristocrats commissioned exquisite jewellery pieces adorned with pearls, diamonds, rubies, emeralds, and sapphires, showcasing the opulence and refinement of the wearer. Many of the finest emeralds found in Colombia were traded and sold to the Mughal Empire during the 17th century (Figure 3). In India, gemstones were and still are an integral part of traditional jewellery, believed to bring luck, prosperity, and protection to the wearer.

△ **Figure 3:** Mughal emperor Shah Jahan, the builder of the Taj Mahal, greatly appreciated gemstones such as diamonds, emeralds, pearls and spinels. Excerpt of portrait by Chitarman, dated 1627–28. Source: Met Museum.

In modern times, gemstones continue to be prized for their beauty, rarity, and sentimental value. From engagement rings to statement necklaces, earrings to bracelets, gemstones are used in a wide array of jewellery designs, catering to various tastes and styles. With their rich history and enduring allure, gemstones continue to captivate and fascinate jewellery enthusiasts around the world. Throughout history, the availability, rarity, and desirability of gemstones have influenced jewellery design trends. Equally, it is interesting to study gem treatments and imitations over time as a means of better understanding developments in the global gem industry. Ultimately, the need to identify imitations, treatments, synthetics and cultured pearls led to the emergence of the field of gemmology.

Gemstone sources and their influence on jewellery designs: the example of diamonds

In India, diamond was for thousands of years known as a mark of power and religion. Diamond was also highly regarded as a symbol of strength and wisdom in Buddhism. The Ratnapariksha of Buddhabhatta, a 6th-century Sanskrit lapidary treatise states: "[The one] who wears a diamond is protected against all dangers, be it by serpents, fire, poison, sickness, thieves, or evil spirits." India, and to a lesser extent Borneo, were the only source of diamonds until about 1730, when Brazilian deposits were discovered.

The legends and the mysticism connected to diamonds were appreciated during the Roman Empire (Ogden, 2018). With its fall, and the rise of Christianity in Europe, the situation changed and the appreciation for diamonds was greatly reduced for several centuries. Another reason was the rise of Persia and Islam. As Middle Eastern states gained control over much of the trade with India, their rulers, who had a taste for lavish ornaments, took control of many of the larger and more attractive diamonds coming from India.

As the fear of being accused of heresy and facing persecution diminished in Christian Europe, there was an increased recognition of the virtues of diamonds, and a greater openness to incorporating ideas from classical and Eastern traditions. Beginning in the 14th century, diamonds began to exert their power in the new Western culture of the Renaissance.

Venice became the first European diamond centre from the 13th to the 16th century, as it was at its time one of the most important markets for all kinds of goods from the Orient. At that time, most diamonds reached Venice by the silk route through Persia and Arabia. Diamond trading in Europe later moved to Lisbon and Antwerp which were important sea powers at the time (Ogden, 2018).

In the 18th century, when the Indian diamond mines declined, new and important diamond deposits were found in Brazil. After 1860, Brazilian diamond production rapidly declined, resulting in a great shortage of rough diamonds in the European cutting centres. Fortunately, diamonds were discovered in South Africa in 1870.

The Belle Époque jewellery period (ca. 1870-1914, see Figure 3) could not have thrived as it did without the discovery of diamond deposits in South Africa after 1870- there simply would not have been enough diamonds to supply the growing demand for diamonds during that period. Additionally, the discovery in 1906 of important platinum deposits in South Africa meant that this metal could be more widely used in jewellery at that time. These two examples exemplify well how designs and trends are also influenced by whether a gemstone is available in sufficient supply or not.

△ **Figure 4:** A Belle Époque emerald and diamond tiara, attributed to Marzo (1910s), sold by Christie's for CHF 226,800 in May 2022. Photo: SSEF.

While coloured stones such as sapphires (often used by royalty during the Middle Ages) remained very popular, other stones became more sought-after during and after the Renaissance. There were no ruby mines in Europe however, so royals depended on traders coming back from the East to bring back Sri Lankan and Burmese rubies. It was difficult for explorers to reach the famed Mogok ruby mines in Burma, and many historic rubies were in fact spinels. Long reserved to royalty due to scarce supply, rubies became more used in jewellery during the 20th and 21st century as new mines were discovered on the African and Asian continents.

On the other hand, the arrival of the Spanish in South America marked a big change for emerald and pearl supply in the 16th century. When the Spanish arrived in Colombia and reached Muzo in 1543/1544, intense mining activity over the following decades would produce large quantities of emeralds that would be exported to Europe and Asia (Lane, 2010). Similarly, when Christopher Columbus and others discovered pearls in Central and South America, this generated great wealth for the Spanish crown and triggered what is known as the "Pearl Age" among European royals and aristocrats who were able to source much greater quantities of high-quality natural pearls (Figure 5) (Bari & Lam, 2010).

△ **Figure 5:** The Ermine Portrait of Elizabeth I of England, circa 1585. A testament to the pearl opulence that abounded in the 16th century due to new sources of pearls in the Americas. Image: Wikimedia commons.

Imitations and treatments in history

"*To tell the truth, there is no fraud or deceit in the world which yields greater gain and profit than that of counterfeiting gems*"
Pliny the Elder (Roman naturalist, A.D. 23/24 – 79)

Gemstones have been treated for thousands of years, with evidence of gemstone treatment techniques and imitating gems dating back to ancient civilizations such as the Egyptians, Greeks, and Romans. The practice of treating gemstones to enhance their appearance or properties can be traced back to at least 4,000 years ago (Nassau, 1984). These treatments were often used to improve the colour, clarity, and durability of gemstones or to imitate more valuable gemstones. It is said that the Roman Emperor Diocletian in about 300 A.D. ordered all books describing the fabrication of artificial stones to be burned because this had become a major issue (Nassau, 1984).

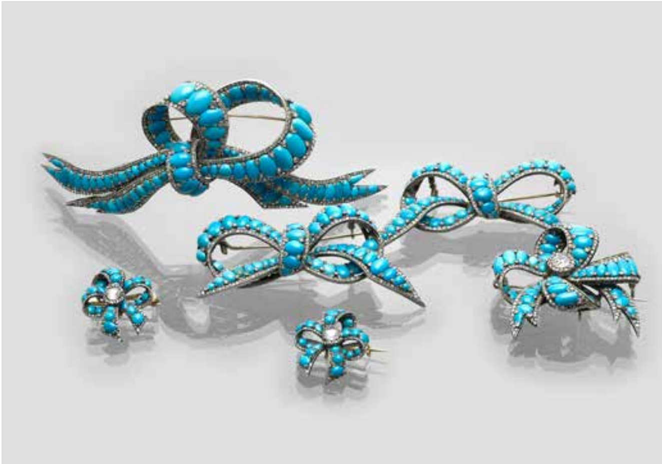
The treatment of emeralds using oil, for example, is nothing new. First reports from Pliny and in the Stockholm Papyrus (supposedly written 400 B.C.) suggested "Smaragdi (emeralds) improve with undiluted wine and green oil, however much they have been naturally stained." (Barney et al., 2006).

One more recent (18th century) example of an imitation is rhinestone, also known as strass. It is a type of imitation gemstone that is created to resemble a diamond and is typically made from materials such as quartz, glass, or plastic (Figure 6). The term "strass" is derived from the name of Georg F. Strass (1701-1783), an Alsatian jeweller who was known for his imitations of diamonds as seen in Figure 6.

△ **Figure 6: 18th century ring with nine antique cut quartz stones imitating diamonds. Photo: A. Castillon, SSEF.**

Another example is fossilized dentine, also known as odontolite, which has been historically used as a turquoise imitation. Since medieval times, French Cistercian monks have used a heating process to turn the material light blue which they thought to be turquoise. These 'stones' were originally set in medieval religious artefacts, but came again into fashion in the early to mid-19th century as can be seen in the set of six antique brooches in Figure 7 (see also Krzemnicki et al., 2011).

The use of gemstone treatments and gem imitations has continued throughout history and is still widely practiced in the modern gemstone industry. However, it is important to note that the disclosure of any gemstone treatments is now required to ensure transparency and consumer protection.



△ **Figure 7: These six "turquoise" brooches are set with 313 light blue stones, the majority of which proved to be fossilized dentine (odontolite), mixed with a few turquoise and glass cabochons. Photo: L. Phan, SSEF.**

The quest to synthetize gem materials

There have been many theories over the centuries over how gems form, and perhaps also of how humans could synthetize them. Theophrastus (about 315 B.C.) believed that "(precious) stones are produced by solidification from fluids, some through the action of heat others of cold" (Caley, 1956). John Mandeville in 1360 suggested that "a diamond is synthesized when two larger ones, one male and one female, come together, in the hills where the gold is. And the diamond grows larger in the dew of a May morning". We know today that diamonds can be synthesized using CVD and HPHT techniques.

The history of synthesizing gem materials dates back to the early 19th century when scientists and jewellers began experimenting with various chemical and physical processes. One of the earliest successful attempts was the synthesis of ruby, which was achieved by French chemist Auguste Verneuil. In 1885 a dealer in Geneva began to sell "Geneva ruby" that is now believed to have been created by flame fusion, the process that Verneuil and others were developing at the time (Nassau, 1969). This was before Verneuil's 1902 announcement of being able to synthesize rubies. It was likely linked to previous work by Frémy and others in Paris. By 1907, several manufacturers were producing synthetic ruby at a rate of 5 million carats per year (Nassau, 1980). This important new supply of synthetic ruby at the turn of the century means that jewels from that period may occasionally contain such stones (Figure 8).

△ **Figure 8:** A Belle Époque ruby, synthetic ruby and diamond fringe necklace. Of scrollwork design, set throughout with old-cut diamonds and variously-cut rubies and synthetic rubies, circa 1910. 87 natural rubies and 4 synthetic rubies. The origin of the natural rubies is Burma (Myanmar), with no indications of heating. Price realised USD 396,500 in 2017 by Christie's. Photo: SSEF.

The emergence of gemmology

Gemmology has its roots in ancient times when humans first began to appreciate the beauty and rarity of gemstones. However, it was not until the 19th century that gemmology as a formal scientific discipline began to emerge.

In the early 1800s, with the rise of scientific disciplines and technological advancements, gemstones started to be studied more systematically. Mineralogists and geologists began to analyse and classify gem materials based on their physical and chemical properties. Pioneering scientists, such as James Dwight Dana, Nils Gustaf Nordenskiöld, and George Frederick Kunz, made significant contributions to the field of mineralogy and gemmology, laying the foundation for the scientific study of gemstones.

The challenges the trade experienced with distinguishing natural and synthetic rubies, and natural and cultured pearls planted the seeds of gemmological research. Whilst it was first thought that UV-light could distinguish natural and cultured pearls in 1921, this turned out to be wrong. By 1927, X-rays and endoscopes were being used to identify cultured pearls (Ogden, 2012). These developments led to the formation of the first gemmological laboratories and gemmology journals that focused on detailed research of gem materials.

New sources of gemstones

The 20th century saw significant discoveries of new gem sources and gem varieties (Figure 9), which has provided jewellery designers with exciting new materials to work with, and for gemmologists to study.

△ **Figure 9:** Some examples of wonderful new additions to the world of gemstones since the 19th century. Photos: SSEF.

The appeal of garnets changed significantly when demantoid garnets were discovered in the Ural Mountains of Russia in 1853. These beautiful and brilliant green gems were widely used by jewellers including Fabergé in St. Petersburg. It was popular in Russia in the period 1875-1920 and in Edwardian jewellery (1901-1915) and continues to be a rare gem used in jewellery today. Tsavorite, the green vanadium-bearing variety of grossular garnet was discovered in 1967 by Scottish geologist Campbell Bridges. He sold his first stones of pure green colour to Tiffany's, who named this new gemstone after Tsavo National Park in Southern Kenya, close to where Bridges had originally discovered it. Tanzanite is another new gemstone variety discovered in the region in the late 1960s.

In the late 1980s, a new type of tourmaline was discovered near Sao José da Batalha in the State of Paraíba, Brazil. This copper-bearing material excels by its vibrant blue to green colour and became known as Paraíba tourmaline; it is considered today one of the most rare and valuable varieties of tourmaline. Similar material would later be discovered in Mozambique and Nigeria.

These and other discoveries have provided designers with access to either previously unknown gem materials or a greater supply of existing gemstones (e.g. Mozambique for rubies, Madagascar for sapphires), allowing them to create unique and innovative designs. The discovery of new gem sources and gem varieties will continue to have a profound impact on the world of jewellery design in future, providing designers with a wealth of new materials to inspire their creativity and elevate their designs to new heights of beauty and artistry.
✶ **Dr. L.E. Cartier**

To learn more about the history of gemstones and jewellery take our ATC Gems & Jewellery course. The course explores the different uses of gems through history, and how these link with different periods of jewellery design. Through this approach, students learn about criteria to identify historic jewellery that contains gems, and gain insights into possible criteria for valuation. Students also learn about fakes and imitations through time, and criteria to identify these. This course is taught in small groups, and will includes extensive workshops, discussions and practical work. For more details see: www.ssef.ch/courses

NEW COBALT-BEARING SPINEL FROM LUKANDE, TANZANIA

◁ **Figure 1:** Series of blue Co-bearing spinels from a new source discovered at Lukande, southeast of Mahenge in central Tanzania, ranging in weight from 2.07 ct to 8.67 ct. Photo: SSEF.

Gem-quality spinel ($MgAl_2O_4$) from Tanzania is well known in the trade for many decades. Most of these spinels are purple or pink to saturated red. Especially famous are pinkish red spinels from Mahenge, which in fact are found at the locality Epanko (or Ipanko), about 7 km south of the small township of Mahenge. In 2007, this deposit produced several giant pinkish red spinels (up to 54 kg) which were later cut into sought-after gems of exceptional quality and size (some larger than 50 ct).

In September 2021, a new deposit of cobalt-bearing blue spinel was discovered near Lukande, which is located about 15 km south-east of Mahenge (Figure 1). Blue spinel there is associated with weathered marble in an eluvial zone buried approximately 1–8 m below the surface from where they are recovered by artisanal small-scale miners. The geological context, combined with field observations and U-Pb dating on zircon inclusions in these spinels indicate that the formation of this deposit is linked to late-stage metamorphic events of the East African Orogeny. This is well in line with other marble-hosted gem deposits in central Tanzania (i.e. ruby and spinel deposits in the Uluguru and Mahenge mountains).

The colour of spinel and, specifically, of cobalt-bearing blue spinel, has been investigated quite extensively in scientific literature. In general, the colour of spinel is due to a combination of transition metals—for blue spinel mainly iron (Fe) and sometimes cobalt (Co). Shigley & Stockton (1984) were the first to attribute Co in addition to Fe as an important chromophore in natural blue spinel.

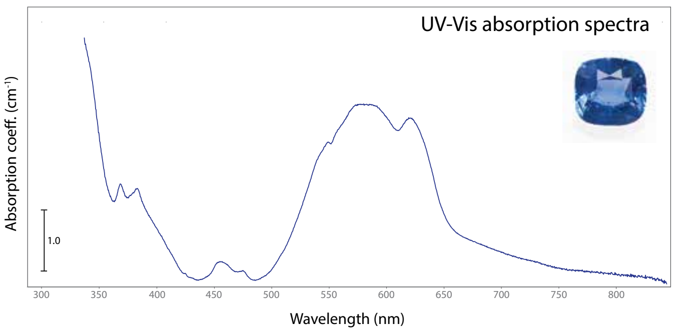
The hue and saturation of the blue colour is not only related to the concentration of the chromophores Fe and Co, but also to their valence state (Fe^{2+} or Fe^{3+}) and their distribution on the two crystallographic sites in the spinel structure. Notably, very low traces of Co may have a strong effect on the blue colour of spinel. Often the amount of Co is so low that it is at or below the detection limit of EDXRF, which is the method commonly used to analyse the chemical composition of gems in gemmological laboratories.

At SSEF, we have analysed about 50 of these new cobalt-bearing spinels from Lukande in the past few months ranging in size from about 2 ct to beyond 10 ct. The blue colour of these spinels results from an interplay of iron and cobalt, with quite a number of them showing an attractive blue colour resulting from distinct cobalt absorption features in the visible part of the absorption spectrum (see Figure 2). Other blue spinels from that same deposit are dominated in the absorption spectrum by iron with only a minor contribution by cobalt. Consequently, these Fe-dominated spinels show a more greyish blue to greenish blue tint.

Interestingly, these new Co-bearing blue spinels from Tanzania can be separated in most cases from cobalt-bearing spinels from Vietnam, Sri Lanka and Pakistan based on their characteristic inclusion features and trace-element patterns. The attractive colours and availability of relatively large sizes have generated significant interest in the gem trade and these new cobalt-bearing spinels from Lukande can thus be considered an attractive new addition to the gem trade.

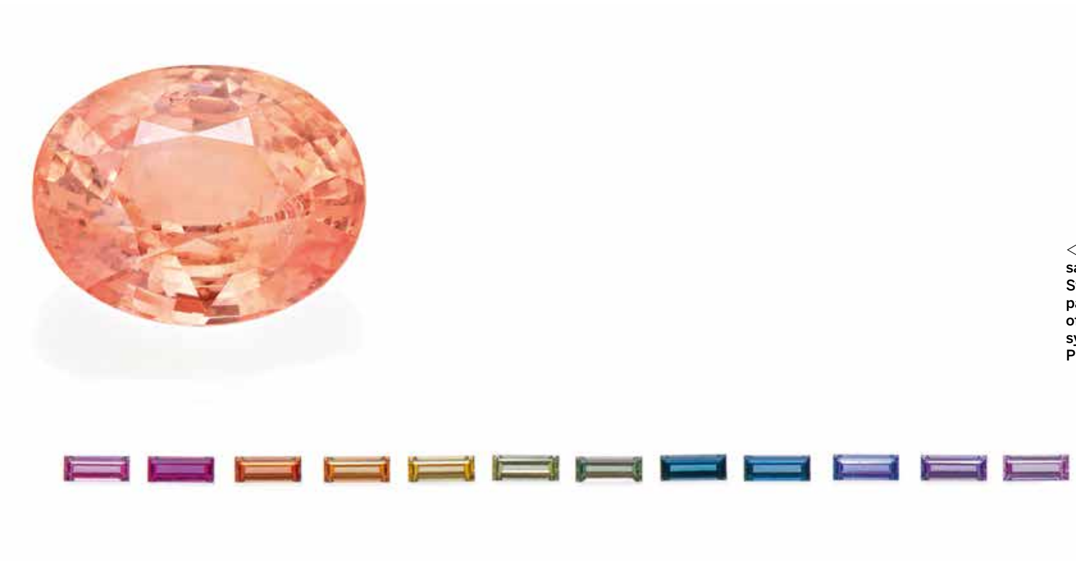
A detailed study about these Co-bearing spinels from Lukande has been published in the latest issue of the Journal of Gemmology (Vol. 38, No. 5) in April 2023.

✶ **Dr. M.S. Krzemnicki**



△ **Figure 2:** Absorption spectrum of a cobalt-bearing spinel from Lukande, Tanzania showing distinct cobalt absorption bands in the centre and smaller iron related peaks towards the ultraviolet (left side of the spectrum). Figure: SSEF.

TESTING OF CALIBRATED COLOURED STONES: A COMPLEX JOB FOR GEMMOLOGISTS



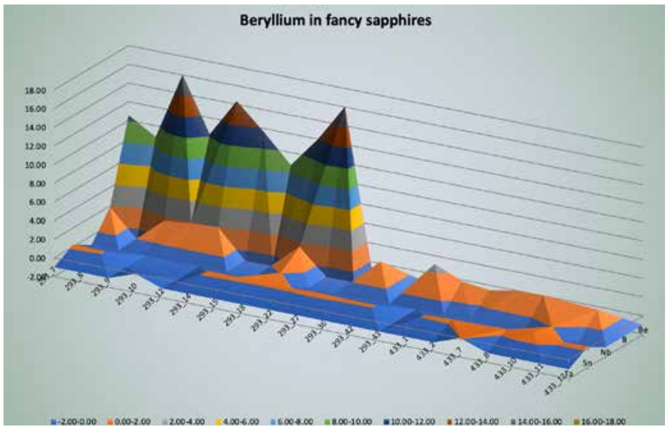
◁ **Figure 1:** Series of tiny calibrated fancy sapphire baguettes tested at SSEF for the Swiss watch industry, compared with a padparadscha of 15 mm diameter. In this series of calibrated small fancy sapphires is hiding a synthetic stone, guess which one it is? Photo: SSEF.

The Swiss Gemmological Institute SSEF is regularly testing batches of tiny calibrated coloured stones for the Swiss watch industry similar to our testing service for melée diamonds. Testing such small coloured gemstones is challenging, starting with the handling of such small stones to analytical restrictions and limitations due to their small size. To be able to provide the industry a gemmological service for such calibrated coloured stones, the SSEF has adopted a specific testing protocol, combining microscopic observation with spectroscopic analyses including trace element analysis by GemTOF mass spectrometry.

Typically, the first and most important request from our clients is to confirm that no synthetic stone is mixed within the submitted parcel of coloured gemstones. Interestingly, we have found repeatedly single synthetic stones in such series of calibrated coloured stones. A challenging task, as we then sort out such a synthetic stone immediately from the rest of the submitted parcel. This shows that our testing provides crucial information to our clients and allows them to be sure that no synthetic stone is set in their prestigious jewellery or watches. Coming back to the question of Figure 1 above, the outermost stone on the right side proved to be a synthetic purple sapphire after testing at SSEF.

In addition to this, we also provide certain information about treatment conditions, always indicating also the limitations of our conclusions due to the small size of such calibrated coloured stones.

Figure 2 shows a concentration-diagram of the trace elements tantalum (Ta), tin (Sn), niobium (Nb), boron (B), and beryllium (Be) measured by GemTOF in a series of calibrated yellow sapphires. The presence of distinct concentration "peaks" of beryllium (on the left side of the diagram) combined with practically no traces of the other displayed elements indicates that the yellow sapphires on the left were treated by beryllium diffusion.



△ **Figure 2:** GemTOF analyses of beryllium and other trace elements of a series of calibrated yellow sapphires. Credit: SSEF.

Testing of small calibrated stones can be very time-consuming and challenging for gemmologists. Due to analytical restrictions, our conclusions are often delivered with some limitations. Still, based on the positive feedback that we receive from our clients, this type of service is highly appreciated as means of safeguarding their quality management and production processes.

For more information about our testing service for small calibrated coloured stones, please contact the SSEF at admin@ssef.ch

✶ **Dr. M.S. Krzemnicki**

PINK SAPPHIRE WITH ORANGE IRON HYDROXIDES IN FISSURES

△ **Figure 1:** Padparadscha or not, that is the question? Photo: SSEF.

△ **Figure 2: The orange brown limonitic compounds as a natural residue in this partially healed fissure is responsible for the slightly orangey hue of the pink sapphire shown in Figure 1. Photo: M.S. Krzemnicki, SSEF.**

Padparadscha is one of the most attractive corundum varieties in the trade and is sought after for its subtle pinkish orange to orangey pink colour. Padparadscha, originally known from Sri Lanka only, is found today also in other deposits such as for example in Madagascar and Tanzania, both part of East Africa and actually once linked with Sri Lanka in past geological times (as part of the supercontinent "Gondwana").

However, it is important to know that not every corundum with an orangey pink colour can be called padparadscha. A detailed description of what factors qualify or disqualify a stone from it being identified as padparadscha has been discussed and harmonised between international gemmological laboratories (LMHC). These criteria are publicly accessible on the LMHC website (LMHC information sheet 4, see www.lmhc-gemmology.org).

Last year, we received again a case, where a client expected a stone to be a padparadscha by judging just its colour (see Figure 1). Meticulous microscopic observation quickly revealed that this stone actually is a pink sapphire which gets its orangey hue only through the presence of brownish-orange ferric-hydroxide, a common natural limonitic residue. Such iron hydroxide can precipitate in fissures and cavities of gemstones when iron-enriched groundwater intrudes into these features (see Figure 2).

The same applies also for certain purplish-red rubies containing similar iron hydroxides in fissures. Although their colour may visually match the best "pigeon blood red" colour, they will not be given this trade colour term by SSEF, as their true colour is purplish red and out of the range to qualify for this colour term. This has been already described in 2017 in our SSEF presentation about "pigeon blood red" and "royal blue" colour terms, accessible on our SSEF website (see https://www.ssef.ch/pigeon-blood-red-royal-blue/).

To conclude, the case of the pink sapphire described in this short note reveals that an observed colour of a gemstone may have various causes and may be distinctly influenced by inclusions. As shown, this may have an impact on its identification (e.g. variety name) and as such finally on its perceived beauty and rarity.

✶ **Dr. M.S. Krzemnicki**

TI-DIFFUSION TREATED SAPPHIRE CABOCHONS

△ **Figure 1:** Five Ti-diffusion treated sapphires examined at SSEF. Photo: SSEF.

Titanium diffusion treatment is known since decades: it can lead to a surface-related blue colour in corundum. Basically, this treatment is a heating process requiring high temperatures in combination with titanium (oxide) as an additive. During the treatment, titanium atoms penetrate into a superficial layer of corundum. By pairing with bivalent iron (already present as a trace element in the corundum structure), a strong blue colour is achieved by intervalence charge transfer (Ti^{4+} - Fe^{2+} IVCT) within this superficial layer in the corundum.

The artificial creation of colour by adding an element (in this case titanium) from an external source has to be fully disclosed throughout the trade and to the final consumer (CIBJO). Even more so, as this sapphire-blue colour layer at the surface of corundum is commonly only a fraction of a millimetre thick and would be completely lost during re-cutting.

Most of the sapphires submitted to SSEF are unheated and of high quality. It was thus a rather rare encounter when we received a series of 5 cabochons (Figure 1), all showing tell-tale signs of surface diffusion by titanium. For faceted stones, the detection of such surface-diffusion treated corundum is usually rather straightforward as they show facet-related variations in blue colour. For the described stones, however, this easy detection was not possible, as no facets were present on these cabochons. Still, we observed many newly healed fissures and characteristic discoid features ("atoll-structures", Figure 2) as a proof of high temperature heating. And the dark blue concentrations at small indentations and blue diffusion rims along flux-filled channels (Figure 3) clearly revealed that these stones had been diffusion treated with titanium stemming from an external source. This was also confirmed by trace element analyses on one of the dark blue spots at the surface. It revealed excessive titanium concentration about 1000 x higher than ever found in sapphires coloured naturally by the same trace elements iron and titanium.

✶ **Dr. M.S. Krzemnicki**

△ **Figure 2:** Disc-like extension features in one of the described cabochons as proof of heating at high temperatures during the Ti-diffusion treatment. Photo: M.S. Krzemnicki, SSEF.

△ **Figure 3:** Diffused blue zone and dark blue spot around small cavity filled with glassy residue in one of the Ti-diffusion treated sapphire cabochons. Photo: M.S. Krzemnicki, SSEF.

NATIVE COPPER INCLUSIONS IN COPPER-BEARING TOURMALINE: A NEW FORMATION SCENARIO?

Gold-coloured platelet inclusions have been reported in copper-bearing tourmaline from Paraíba State in Brazil since the discovery of this highly sought-after gemstone (Fritsch et al., 1990) in the late 1980s. Until now, this extraordinary type of inclusion in tourmaline was mentioned in the literature only occasionally, probably due to its rather rare appearance (Fritsch et al., 1990; Koivula et al., 1992; Brandstätter and Niedermayr, 1994; Hartley, 2018).

A previous study by Koivula et al. (1992) pointed out a possible growth scenario for this type of inclusion as an epigenetic exsolution from the host copper-bearing tourmaline. Epigenetic exsolution means that the inclusion formed after the crystallization of the tourmaline and copper was extruded from the tourmaline into host mineral fractures, instead of being added from external sources. Brandstätter and Niedermayr (1994) also proposed an epigenetic exsolution formation scenario of copper, which seemed for them more plausible than the syngenetic precipitation scenario of native copper on the surface of tourmaline during growth.

In a recent joint research project by SSEF, the microXAS beamline at the Swiss Light Source, the Paul Scherrer Institute, the University of Basel and the University of São Paulo, we investigated a rough copper-bearing tourmaline (elbaite) from Paraíba state in Brazil (Figure 1a). This yellowish-green tourmaline contained plenty of native copper inclusions showing an orangey yellow colour under a reflected light microscope (Figure 1b). The inclusions show a preferred orientation along the c-axis of the host tourmaline and cluster in rather large planar surfaces, which are mostly parallel to each other. Additionally, abundant transparent inclusions showing a similar morphology and orientation as the native copper inclusion were observed in the sample (Figure 1c). As far as we know, this type of transparent inclusion has not been reported previously in copper-bearing tourmaline and we interpreted them as being fluid inclusions because occasionally round (gas) bubbles were found inside these inclusions. To further characterise the native copper inclusions, we used a focused ion beam scanning electron microscope (FIB-SEM) to cut into the tourmaline and expose the cross-section of such a typical native copper inclusion (Figure 1d). The thickness of the native copper (thin film) inclusion is about 150 nm across the entire width of about 3-4 µm.

To the best of our knowledge, such gold-coloured platelet inclusions were so far assumed to be native copper, however without direct experimental evidence so far. In our latest experiment, the characteristic local copper oxidation state of a typical inclusion and the host tourmaline were revealed by using spatially resolved synchrotron radiation x-ray absorption spectroscopy (SR-micro-XANES). The absorption spectrum at the copper K-edge is very sensitive to different redox (and coordination) states of copper. The observed chemical and electronic contrast can be used to construct chemical images depicting the electronic state of Cu (copper "redox-maps") in Fig. 1e of metallic copper (Cu0) distributions on a typical inclusion, which is approximately 5 µm beneath the tourmaline surface. The highest Cu0 composition goes up to only about 30% because it is thin and embedded under the tourmaline surface. The rest of the Cu composition is contributed from oxidised Cu (Cu^{2+}) most probably located in the tourmaline crystal structure. These results are the first and direct proof that the gold-coloured platelet inclusions in copper-bearing tourmaline from Paraíba are indeed native copper in their metallic state.

In combination with additional observations, especially the presence of fluid inclusions of similar morphology as the native copper inclusions, epigenetic exsolution may not easily explain the formation of this type of native copper inclusions. Instead, a syngenetic (epitaxial) growth of native copper during the formation of the host tourmaline is considered a more likely scenario in our opinion. Nevertheless, we cannot fully exclude the formation of such a native copper (thin film) inclusion by fracture filling with fluid after the formation of the tourmaline with the native copper being precipitated from the fluid inclusion. Further detailed research is ongoing, to better understand these fascinating native copper inclusions in tourmaline in the context of the formation of attractive copper-bearing tourmalines from Brazil. This study also revealed that cutting-edge (micro-) analytical methods new to gemmology have a high potential to provide new insights to characterise gemstones and their formation.
✶ **Dr. H.A.O Wang**

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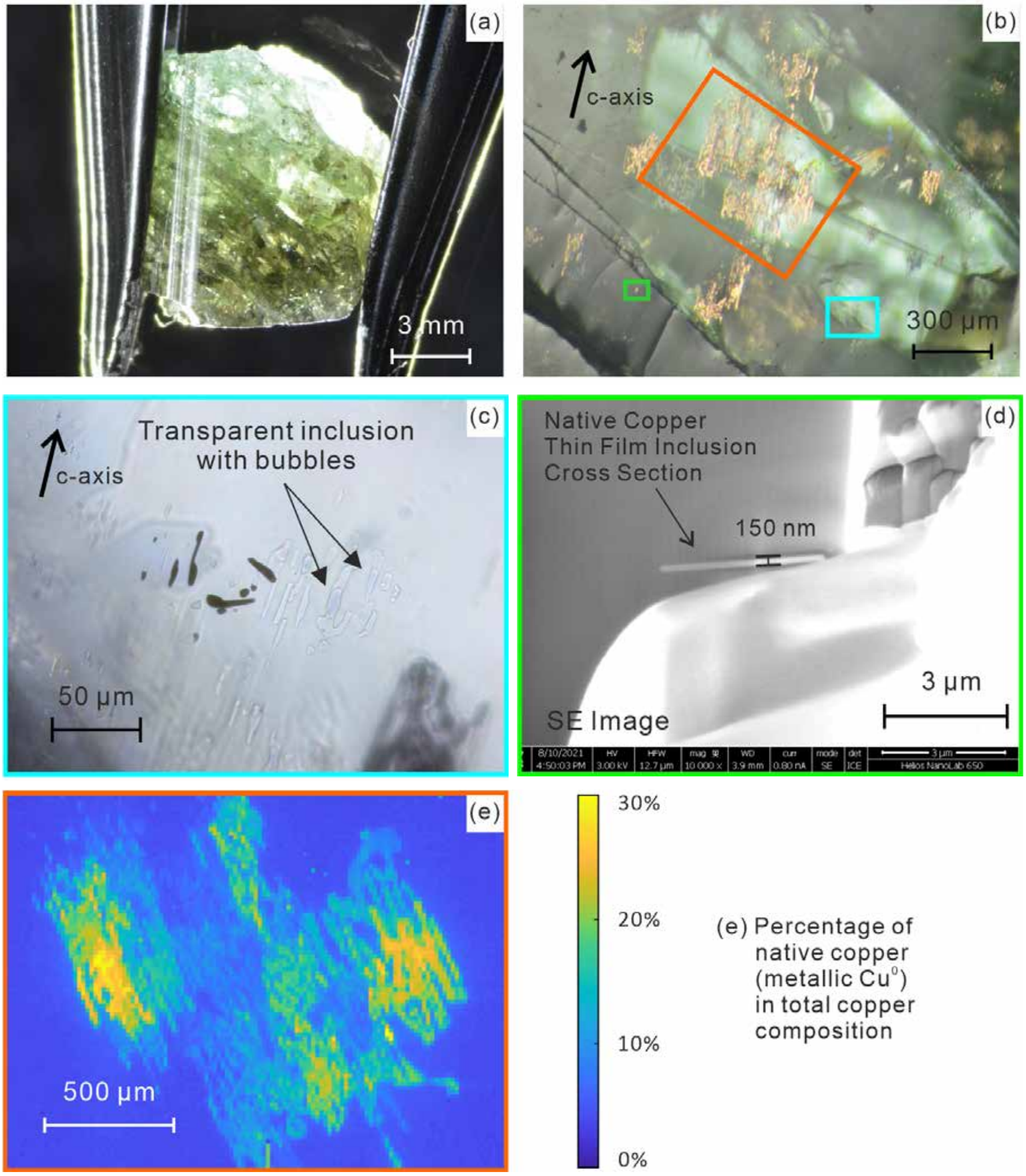


△ **Figure 1:** (a) A Copper-bearing tourmaline from Paraíba State in Brazil. (b) Previously assumed native copper (Cu) inclusions show orangey yellow colour under a reflected light microscope. (c) A cross-section of a selected native copper inclusion was cut by a focused ion beam and imaged by a scanning electron microscope at the Swiss Nanoscience Institute, University of Basel in Switzerland. (d) Transparent inclusions with round gas bubbles are observed in a similar morphology to that of the native copper inclusions. (e) Imaged at the microXAS beamline, Swiss Light Source, Paul Scherrer Institute in Switzerland, a high-spatial-resolution redox map of metallic copper (Cu^0) reveals a direct evidence that the inclusion consists of Cu^0 rather than oxidized Cu^{2+}. The colour scale on the right side indicates the ratio of the metallic Cu^0 speciation to the total Cu. The colour-coded boxes in (b) show the approximate imaging area in (c-e). All microscope photos by SSEF.

GEMTOF QUALITY CONTROL: PARTICIPATION IN 2ND AGE DATING BLIND ROUND ROBIN DATING TEST

Age dating of minerals and their associated rock formations is important in geoscience research in order to be able to reconstruct and understand geological processes and Earth's history. To be able to date a mineral, it is necessary that this mineral incorporates an element/isotope that decays radioactively over time. Uranium is a common radioactive element used for this as it has a fairly long half-life. This allows the dating of minerals that formed a few hundred thousand to a few billion years ago, covering most of Earth's geological past. It also has two different isotopes which decay with different half-lives into different lead isotopes. This provides two independent ages per sample and thus allows for an internal validation of dating results through comparison.

Zircon is among the most commonly dated minerals using the uranium-lead system in geosciences due to its suitability as it has reasonably high uranium concentrations and rarely incorporates lead during crystal growth. An increasing number of laboratories worldwide are doing zircon dating using laser ablation ICP-MS. The International Association of Geoanalysts (IAG) introduced a blind round robin test for zircon dating to enhance accuracies, data quality and improve inter-laboratory comparability. After the first successful round in 2019 and with some delays, the zircon grains for the second round were distributed in autumn 2021 giving the laboratories time until winter 2021/22 to report their results. The final report was released last summer. Blind round robin tests are one of the best methods to ensure and test the comparability and reliability of results produced by analytical laboratories. A batch of the same sample is sent out to each participating laboratory, without the lab knowing the expected result which is only released after all labs have submitted their results. It is also not known which laboratories are participating and all participants are anonymous in the report.

Dating of a zircon inclusion can also provide important clues of the origin of gemstones like sapphires and rubies. SSEF has therefore participated in the second G-Chron zircon dating round robin test to ensure that accurate results are produced by the GemTOF system in place at SSEF.

"Kara-18" blind round robin test

The zircons "Kara-18", named after Karara Station, the nearest geographic feature from the collection site, originate from a large granitic pluton in the Murchison Province of the Yilgarn Craton of Western Australia. The 310 kg of collected rock was crushed and milled to a < 1mm grain size fraction. Zircons were separated from the other minerals by a Wilfley table, a Frantz magnetic and finally a heavy liquid separation. Ending up with 47.4 g of zircon crystals with most being less than 0.3 mm in size (Figure 1). Each participating laboratory received about 90mg for testing. The target value of $^{206}Pb/^{238}U$ age of 2628.38 +/- 0.95 Ma (million years) was provided by analyses in three different isotope dilution thermal ionization mass spectrometry (ID-TIMS) facilities. Homogeneity of the zircon sample material was validated by secondary ion mass spectrometry (SIMS) at the Helmholtz Centre in Potsdam. A total of about 50 laboratories participated in the test and submitted results.

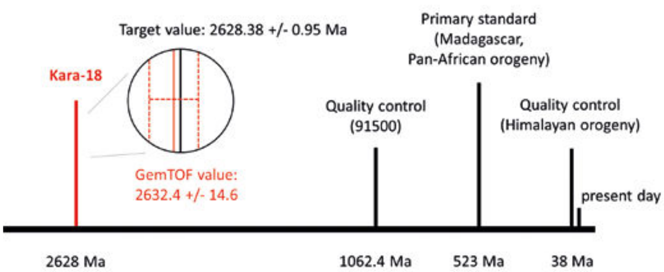
△ **Figure 1:** Image of the Kara-18 zircon grains. Photo: M. Wälle, SSEF.

Accurate age result by GemTOF at SSEF

After having some zircon grains mounted on an epoxy puck at the University of Basel, those zircons were analyzed by our routinely used dating method for zircon inclusions in gemstones. A 523 Ma old zircon from Sri Lanka was used to calibrate the instrument and two other zircons were analyzed as well for quality control.

Distributed over several measurement sessions on different days, around 30 grains of the Kara-18 zircons were analyzed with the GemTOF system at SSEF. This resulted in an average $^{206}Pb/^{238}U$ age of 2632.4 +/-14.6 Ma (mean +/- one standard error) which is in excellent agreement with the target value. This is a remarkably accurate result as these zircons exceed the range of our quality control which goes to 1062.4 Ma and we are normally dealing with zircons in the range of ca. 25 Ma from the Himalayan origin or ca. 550 Ma old ones from Madagascar and Sri Lanka. It is reassuring as our method also works completely fine outside its intended range and this confirms the accuracy of our dating method. We plan to further participate in the round robin U/Pb dating program of the IAG to ensure the high quality of our analytical results in future.

✶ **Dr. M. Wälle & Dr. H.A.O. Wang**



△ **Figure 2:** $^{206}Pb/^{238}U$ ages of the standard and quality control zircons used for age dating with GemTOF in relation to the test sample Kara-18. The insert shows the GemTOF result with the uncertainty overlapping with the target value. Credit: SSEF.

NEW AND ADDITIONAL CRITERIA TO DETECT LOW-T HEATED CORUNDUM

△ **Figure 1:** "Hot" pink sapphire from Ilakaka, Madagascar and clusters of tiny colourless zircon inclusions characteristic and important markers for such pink sapphires. Photo: SSEF.

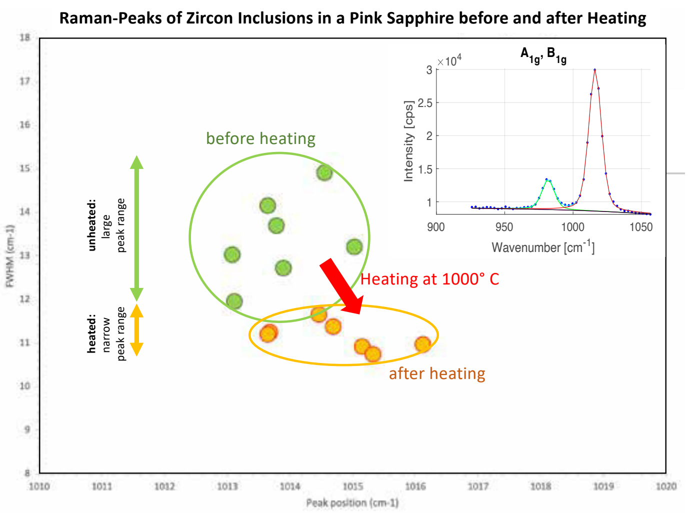
Heat treatment of ruby, sapphire and other colour varieties of corundum is one of the main issues for the gem trade. As such, detecting such treatment is a major task of gemmological laboratories issuing gemstone reports. Unfortunately, and especially lately, the detection of such heating is not always straightforward. This is especially the case when the applied heat is of rather low temperature (< 1000 °C). Such treatment is commonly known in the trade as low-T heating (see also SSEF Press Release from September 2018).

At SSEF, we have seen in the past few months an increasing number of pink sapphires (Figure 1) and other corundum varieties (e.g. ruby, purple sapphire) on which such low-T heat treatment had been applied with the aim to slightly shift the colour to a more attractive and vivid hue.

Unfortunately, traditional detection methods based on detailed microscopy, reaction to ultraviolet light, and infrared spectroscopy is in certain cases not conclusive to tell whether such a stone has been heated (at low-T) or not. Based on numerous heating experiments at SSEF and using new and highly sensitive instrumentation and analytical protocols, we have been able to explore new scientific criteria to separate unheated pink sapphires (and other corundum varieties) from heated ones. These new criteria are mainly based on detailed Raman spectroscopic analyses of inclusions, specifically those which suffer major structural transformations by a heating process (Figure 2).

Consequently, we have recently adapted our testing protocol and are now able to get more unambiguous and conclusive results even for cases which were considered challenging or inconclusive before. On the other hand, however, this also means that considerably more analytical time and effort needs to be invested in the laboratory in our daily operations when testing such stones.

Having said this, it is also important to understand that any result on a gemstone report at the very end reflects the scientific knowledge at the time of examination. As the results of our current research show, scientific gemmological knowledge is constantly evolving. Thus, in certain cases this may result in a reassessment of a previous conclusion because of new and previously unknown or unavailable scientific criteria. Neglecting this fact cannot be a solution for the trade nor for gemmological laboratories.



△ **Figure 2:** Automated curve-fitting developed at SSEF to analyse the shape of the main Raman peak of zircon inclusions in corundum and the effect of heating on the peak shape of zircon inclusions within this sample. Diagram: SSEF.

To conclude, the Swiss Gemmological Institute SSEF applies rigorous testing procedures and is constantly investing in research and state-of-the-art instrumentation so as to be able to identify all sorts of new developments related to gemstones and pearls. We consider it also our mission to inform the trade openly and timely about new research findings and testing criteria, always with the aim to protect the gem trade and to maintain the confidence of the public in gems.

A detailed scientific publication about our latest findings is in preparation and will be published in the Journal of Gemmology.

✶ **Dr. M.S. Krzemnicki**

THE ALLURE OF BLACK OPALS

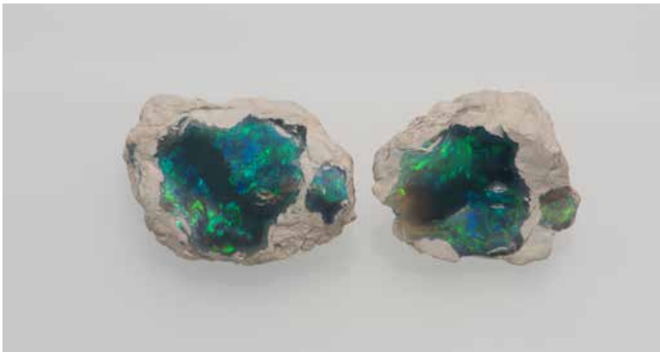
Opal comes from the Sanskrit *upala* and the Latin *opalus*, meaning "precious stone". The Roman naturalist Pliny the Elder (A.D. 23/24 – 79) wrote that: "In the opal you will see the refulgent fire of the carbuncle (red gems), the glorious purple of amethyst, and the sea green of the emerald, and all these colours glittering together in incredible union". It is this multitude of colours – play-of-colour, also called fire- found in opal that has fascinated humans over time.

Although the Romans had assumed that opals came from the Orient and India, all the early material in fact came from the mines near Červenica in present-day Slovakia (formerly Hungary). Australian opals were discovered in the 19th century. Ethiopian opals are found in the Wollo Province and the Shewa Provinces of Ethiopia with large quantities arriving in the market around 2008. Fire opals were first discovered in Mexico in the state of Querétaro in 1870. Mexico is also home to other types of opals, including white, grey, and black opals. Opals were discovered in Honduras in the 1800s, in Nevada (USA) in the 1900s and in Brazil in the 1930s. Following several NASA rover expeditions, opal has even been discovered on Mars!

Opal is a gemstone that is formed over long periods of time using silica that comes from sedimentary rocks (e.g. sandstone) or volcanic ash, and that is dissolved and transported as a silica gel by water. Opal forms when the silica gel seeps into cracks or voids in rocks, such as sedimentary or volcanic rocks, and begins to harden. As the silica gel hardens, it can form microscopic spheres, which may be arranged in a regular, ordered pattern (Gaillou et al., 2008). The size and arrangement of these spheres determines the play-of-colour and pattern of the opal. Sedimentary opals are very common in Australia, whereas Ethiopian and Mexican opals are mostly of volcanic origin (Liesegang and Milke, 2014; Chauviré et al., 2017).

Australia has been the foremost source of high-quality opals since the discovery of opal fields in the late 19th century. There, one can find different varieties such as black opal, white opal and boulder opal. Black opals are known for their deep, rich colours, and their vibrant play-of-colour.

Black opal is a type of opal that exhibits a dark background body colour, usually black or dark grey. It is considered to be the rarest and most valuable type of opal, and is highly prized for its unique and striking appearance. Black opal is typically found in Australia, specifically in the Lightning Ridge region of New South Wales where it was discovered in 1900. It is formed in a similar way to other types of opal, but the dark body colour is due to the presence of tiny dark particles in the silica gel that forms the opal. The dark body colour of these opals helps to visually enhance the play-of-colour.



△ **Rough black opal from Lightning Ridge Australia. Photo: A. Chalain, SSEF.**

Opals are found in a number of locations in Australia. The main deposits all lie within the Great Artesian Basin, the remains of a vast interior sea that covered about a quarter of Australia's current landmass between 100 million and 250 million years ago. A selection of prominent opal fields in Australia include Lightning Ridge and Coober Pedy. Coober Pedy is located in South Australia, and is home to one of the world's largest opal fields and is known for its white and boulder opals. Coober Pedy is one of the hottest and driest areas in Australia, opals were discovered there in 1915.

△ **Opal mining in Coober Pedy at the end of the 20th century. Photo: Prof. H.A. Hänni, SSEF.**

From superstition to haute joaillerie

There is a popular belief that opal brings bad luck to those who wear it, and this belief has persisted for many centuries although the high demand for high-quality opal in recent years suggests otherwise. It is likely a superstition that has been passed down through the ages. The source of this belief is in part due to Sir Walter Scott who blamed a (fire) opal for the death of the beautiful heroine in his 1826 novel Anne of Geierstein. It is thought that this story had a negative impact on how opals were viewed by the bourgeoisie at the time, some going as far to suggest that opals are cursed, yet opal has long also been prized for its beauty and is believed to have many positive associations.

Queen Victoria (1819-1901) and the Art Nouveau movement did much to revive demand for opals. This would also coincide with the discovery of opal deposits in Australia in the 1880s which provided fantastic new material (including black opal) for jewellers to use. The Victorian art critic John Ruskin once fittingly wrote "Everyone knows how capriciously the colours of a fine opal vary from day to day, and how rare the lights are which bring them fully out." The striking beauty and colour diversity of opals was also a source of inspiration for jewellers. Leading Art Nouveau designers such as René Lalique, Henri Vever, Georges Fouquet and Louis Comfort Tiffany would use beautiful opals in their designs.

Australian precious opal can command high prices in the market, and there is thus demand for origin determination. Based on the geological history and formation of different deposits there are trace element chemistry differences that allow for origin determination of opals to be conducted (Gaillou et al., 2008). Apart from silicon, the main constituent of opal (SiO_2 x nH_2O), minor amounts of calcium, potassium, iron, titanium, and traces of manganese, nickel, copper, barium and zirconium, are well known for opals from Australia.

The fascinating world of patterns in black opal

There are many different quality factors that impact the value and rarity of black opal. In addition to factors such as body tone (i.e. degree of darkness) or the dominant diffracted colours (e.g. orange, yellow, green, blue, indigo, violet), patterns are highly sought after by collectors. These patterns can be hard to grade or standardize but are wonderful phenomena to study in black opals (Cody & Cody, 2008). Some of the most desirable patterns found in Australian black opal include: Chinese writing patterns, ribbon patterns, flag stone patterns and floral patterns (see images below).

When admiring these patterns it is hard not to agree with the 18th century English poet James Thomson (who it must be added was not describing opals), which summarises well the fascination many have with opals and their play-of-colour patterns:
"But who can paint
Like Nature? Can imagination boast,
Amid its gay creation, hues like hers?"

At the end of the 20th century, major jewellery houses and designers increasingly began to use opals in their designs. This has led to a stronger demand for high-quality black opals over the past two decades. It seems that the fascination for black opal will thrive for decades to come. We are certainly seeing more and more black opals in the lab today.

To learn more about opals, you can take our free online course on opals: www.ssef.ch/masterclass
✶ **Dr. L.E. Cartier**

△ **Left: An example of a flagstone pattern. Right: An example of a floral pattern. Photo: A. Chalain, SSEF.**

△ **Left: An example of a Chinese writing (or calligraphy) pattern. Right: An example of a ribbon pattern. Photo: A. Chalain, SSEF.**

THE VALUE OF CULTURED PEARLS: EVOLUTION AND CURRENT TRENDS

△ **Figure 1:** A pearl farm on the atoll of Ahe in French Polynesia. Photo: L.E. Cartier, SSEF.

Pearls are often reported as the oldest valuable gem known to humankind, and have been collected for at least 8,500 years (Ainis, et al., 2019). Natural pearls are accidental formations in wild oysters or mussels, and have been considered to be one of the most precious gems in many cultures (Kunz & Stevenson, 1908). In the 19th century, the pearl sac theory was proposed and it later enabled the production of loose round cultured pearls in the 20th century (Nagai, 2013). Production began in Japan with the saltwater Akoya pearl oyster, and this same technique was later expanded to the South Sea pearl oyster (1956 in Australia) and the Tahitian pearl oyster in 1961 (Figure 1). Freshwater cultured production first began in Japan in 1935, but today takes place nearly exclusively in China where production began in the 1960s.

The trade in natural pearls began to collapse during the Inter-war period (1918-1939) and was lastingly hit by news of cultured pearls reaching the market in large quantities in the 1920s. Furthermore, the Great Depression of 1929, subsequent worldwide economic hardship and the Second World War (1939-1945) had a huge impact on luxury goods and natural pearls. At present, cultured pearls vastly dominate the global pearl industry. Natural pearls however remain a valuable niche and have experienced a considerable revival amongst collectors since the beginning of the 21st century when they re-emerged as star jewels at auctions and in private sales.

Cultured pearl beginnings

As if responding to the unprecedented natural pearl rush and depleting wild oyster supplies, English marine biologist William Saville-Kent was the first to successfully achieve culturing loose pearls at the end of the 19th century (Saville-Kent, 1897). In Japan, Mikimoto Kōkichi would apply the Mise-Nishikawa method in 1916 (Taylor & Strack, 2008) and successfully create a new industry, as well as founding the Japanese flagship jeweler Mikimoto. The round cultured pearls were sold by Mikimoto in London from 1919 onwards for 75% of the price of natural pearls (Yamada, 2013). In 1922, The New York Times reported that cultured pearls sold for 30% less than natural ones. In 1928, in a case of alleged fraud, it was stated that cultured pearls had about one tenth the value of the natural material (Ogden, 2012).

Pearl cultivation in Japan was suspended during World War II because of the regulation restricting manufacturing and selling of luxury goods (in order to prepare for war), but grew exponentially once it restarted under the careful protection of the Japanese government (National Diet Library Japan, 1952). Production reached a peak of 125 tonnes in 1967, and overproduction later created a set of challenges for the industry (Müller, 1997). Images of world fashion icons of the era, such as Grace Kelly, Marilyn Monroe, Audrey Hepburn, and Jacqueline Kennedy, showed them adorned with pearls. Middle-class women, influenced by the icons, desired affordable pearls, and cultured pearls from Japan were able to fulfil their demands.

In the last few decades, the huge volume of cultured pearls has highlighted the rarity of natural pearls. The Rockefeller Pearl Necklace sold for $470,000 in November 1998 and was resold in May 2018 for $2 million (Christies, 2018). It may be noted that the resale value of cultured pearls is very low, therefore, their purchases are more of an emotional purchase. On the other hand, the rarity of natural pearls has made them collector items and supports their resale value if they are of sufficient quality. In 1992, an Australian South Sea cultured pearl necklace (16-20mm) sold at Sotheby's New York for $2.3 million, a world auction record for cultured pearls. It is hard to estimate what such a necklace would sell for today, but it is generally agreed that the price for cultured pearls is past the boom period of the 1980s and 1990s when supply was much lower.

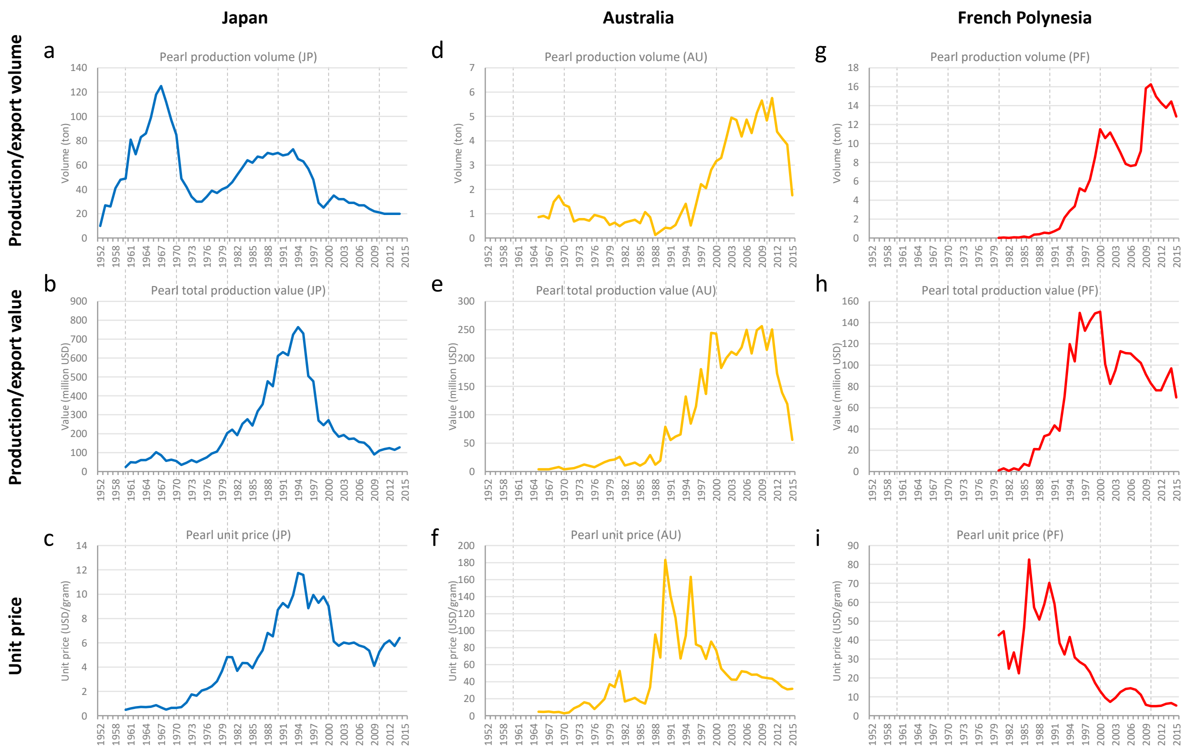
Drivers of the cultured pearl market

This section focuses on marine cultured pearls (Akoya, South Sea, and Tahitian) due to the lack of reliable production and valuation data from China regarding freshwater cultured pearls. Freshwater cultured pearls vastly outstrip marine cultured pearl production in terms of volume, and estimates range between 600 tonnes and over 5,000 tonnes per year since 2005, though figures today would be lower (Cartier & Tu, 2017) (Zhu, et al., 2018). However, the $ value of these gigantic quantities is lower than that of marine cultured pearls. Recent innovation and a focus on higher quality freshwater cultured pearl production in China merit a separate study.

The value of individual cultured pearls is defined by their size, shape, color, lustre, surface condition, and thickness of nacre. However, what are the key macro drivers of the cultured pearl market? Historical data of cultured pearl industries in Japan, Australia and French Polynesia indicates five main factors (Figure 2).

1) Supply volume: The first driver that repeatedly played a big role in history is the supply volume. In Japan, the skewed supply in 1960s-1970s pushed the price. In Australia, the fluctuation of prices in the 1990s was sharply correlated with its supply volume. In French Polynesia, the prices in the 1990s kept decreasing because of the oversupply and this trend has continued to this day.

2) Quality: The second driver is quality. The significant Australian cultured pearl price increase in the 1980s was because of the quality improvement (increase of round/baroque cultured pearls compared with half pearls). The above-mentioned low price in French Polynesian in the 1990s are also because of its poor quality.



△ **Figure 2: Cultured pearl production/export quantity, value and unit price in Japan, Australia, and French Polynesia. a) Production quantity in Japan; b) Total production value in Japan; c) US$ unit price in Japan (Yano Research Institute, 2016); d) Production quantity in Australia; e) Total production value in Australia; f) US$ unit price in Australia (Yano Research Institute, 2016) (Southgate, et al., 2008); g) Production quantity in French Polynesia; h) Total production value in French Polynesia; i) US$ unit price in French Polynesia (Yano Research Institute, 2016) (Tisdell & Poirine, 2008). Figure: A. Sato.**

3) Trends: The third factor were the fashion trends that supported demand. In the 1950s-1960s, the growing supply of cultured pearls in Japan was supported by the boom of cultured pearls advertised by the fashion icons of the era.

4) Macro economy: The fourth driver is the macro economy, which impacts both supply and demand sides. In Japan, the asset price burst in the early 1990s caused the long-lasting recession and the cultured pearl supply plummeted. Around 2010, the Global Financial Crisis impacted negatively both supply volumes and prices in all three production areas.

5) Environment: The last factor is the environment, which biologically has an influence on the pearl oyster ecosystem. In the late 1990s, a disease struck Akoya oysters and 75% of oysters died in Japan. Together with the above mentioned long recession, it caused a significant decrease of the number of cultured pearl farmers in Japan. Climate change is also a growing risk for pearl production worldwide.

In addition to the above five drivers, a couple of additional factors are worth discussing to foresee the cultured pearl market. The first one becoming increasingly important in recent years is linked to sustainability of pearl production and how pearl farmers are affected by global changes (Cartier & Ali, 2012). Global warming and the associated higher water temperature can cause higher oyster mortality and diseases (Tomaru, et al., 2001), and lower quality nacre (Latchere, et al., 2018). Ocean acidification due to higher levels of carbon dioxide in our atmosphere (and thus in the oceans) causes shell nacre malformation and significant decline in shell strength, and pearl nacre may also be influenced (Welladsen, et al., 2010). Climate change is also leading to an increase in tropical storms and could further threaten pearl farms due to rising sea levels (Figure 3). At the same time, consumer interest in sustainable cultured pearls is rising (Nash, et al., 2016), however, the change in consumer behaviour and conservative wholesalers is still not a straightforward trajectory. The establishment of greater traceability in the industry and more awareness of consumers are indispensable. Another factor to be noted in the future of pearl production is the technical advancements in culturing pearls. This includes using new methods to cultivate pearls and experiments including the use of organic nuclei to shorten production times (Cartier & Krzemnicki, 2013). Although it is yet unrealistic, genetic engineering (Katsuhito, 2002) or even pearls grown in vitro could not be excluded in the future (Jayasankar, et al., 2018) (Raghavan, et al., 2019).

△ **Figure 3:** Water levels at the Jewelmer Terramar Four farm in the Philippines show increasing levels of sea water that pose a long-term threat to pearl farmers. Photo: L.E. Cartier, SSEF.

The widely travelled 11th century Persian explorer Al-Biruni was quoted as saying, "the desire of pearls is a thing which is found in all nations." This will continue to be the case, regardless of the highs and lows of pearl supply, demand and fashion trends. As one of the world's oldest gems, inseparable from the human desire to collect jewelry and treasures, we think pearls have a bright future.

✶ **Dr. A. Sato & Dr. L.E. Cartier**

NOTE

This article expands upon a Gem-A student research project by Dr. Akitsugu Sato in 2021 and is a shortened version of an article published in GemGuide in 2022.

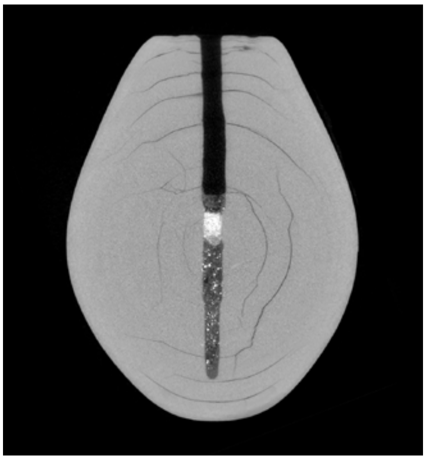
QUEEN MARY PEARL: AGE DATING & DNA FINGERPRINTING

△ **Figure 1: The Queen Mary Pearl set as a pendant in a necklace. This pearl of 41 ct exhibits a delicate slightly grey colour and a very fine and smooth pearl lustre. Photo: L. Phan, SSEF.**

Similar to gemstones which are re-polished over time and thus need an updated SSEF report, we also occasionally receive pearls a second or third time for a new report, for example when the pearl is set in a new jewellery design.

This is specifically the case when a pearl is important and/or of historical provenance. An excellent example for such an update is the Queen Mary Pearl (Figure 1). This beautiful drop-shaped saltwater natural pearl of 41 ct was tested by SSEF already many years ago as an unmounted loose pearl and then later in 2019 after being set as a pendant in a necklace (see also SSEF Facette 2020, No. 26, page 34). Based on the provided documentation, the Queen Mary Pearl belonged originally to Queen Mary (1867-1953), wife of King George V of England (1865-1936). This important pearl was then passed on to the following generations within the royal family until it was eventually sold some years ago.

Last year, we were lucky enough to be able to analyse this pearl a third time, as the saying goes "all good things come in threes". This time, however, the client was specifically keen to know more about the historical background of this pearl, i.e. the species of the pearl-oyster producing this pearl, its habitat, and its age.



◁ **Figure 2: X-ray tomographic section of the Queen Mary Pearl, exhibiting a (half) drill-hole partially with some residues from the former jewellery setting, and several ring structures as is characteristic for natural pearls. Figure: J. Braun, SSEF.**

As it was submitted as an unmounted loose pearl, we were not only able to do a full X-ray tomographic study of the internal structures of this historic pearl (Figure 2), but also to take minute nacre powder samples (about 20 mg in total) from within the pre-existing drill-hole for DNA fingerprinting and radiocarbon age dating analyses. Radiocarbon dating is a scientific method used to determine the age of materials containing ^{14}C, an unstable isotope of carbon. This method was developed in the late 1940s by Willard F. Libby, who received the Nobel Prize in Chemistry in 1960 for his ground-breaking research on radiocarbon dating. Since then, this method has become a standard tool for archaeologists, historians, and geoscientists and is offered by SSEF as a service to our clients since many years. The results of the radiocarbon dating performed at a specialised research laboratory of the Swiss Federal Institute of Technology in Zurich reveals a historic age for the analysed pearl. As it is often the case with radiocarbon dating, the determined age indicates a period in history rather than a precise date. Based on our data, the pearl probably formed between 1707 and 1876 A.D. in coastal waters along the Pacific coast of Mesoamerica. A recent formation in the mid to late 20th or early 21st century, however, can be excluded. In addition, the Swiss Gemmological Institute SSEF in collaboration with the forensic Institute of the University Zurich carried out DNA fingerprinting on the pearl to determine its species, using a method first developed by SSEF for pearls (Meyer et al., 2013) and precious corals (Lendvay et al., 2020). The resulting DNA analysis unambiguously revealed that the Queen Mary Pearl belongs to the *Pinctada mazatlanica* species, commonly known also by the name Panama pearl oyster or La Paz pearl oyster. This species is found off the Pacific coast of Mesoamerica from the Baja California (Mexico) to Ecuador and northern Peru (Figure 3).

△ **Figure 3: Map indicating where *Pinctada mazatlanica* is commonly found. Figure: SSEF.**

Pearl oyster fishing of *Pinctada mazatlanica* began in the Americas long before the arrival of the Spanish in the 15th century, as local indigenous cultures already collected these pearls and oyster shells. Traded and treasured also by European royal courts, these pearls became quickly very fashionable. They were set in historic noble and royal jewellery and remain highly appreciated in the pearl and jewellery trade until today. Having been able to not only investigate in detail the nature of this important pearl scientifically, but actually contributing and confirming the historical provenance of the Queen Mary Pearl has been a fascinating venture and voyage in time.

PEARLS & DIAMONDS: A ROYAL SELECTION

The SSEF is known worldwide as a leading authority in gem testing, and as such we have the great pleasure to scientifically analyse some of the most prestigious and important jewellery before it is offered up for auction or in private sales. Apart from testing the gem materials in such jewellery, we are often impressed to see the ingenuity of jewellers in their designs and craftmanship. This is especially the case when jewellery of historical provenance is submitted to SSEF. In the past few months, we have analysed several historic pearl tiaras and necklace, from which we present in the following a royal selection.

The first pearl and diamond tiara (Figure 1) was presented in 1867 to Maria Vittoria dal Pozzo (1847-1876) as a wedding gift on the occasion of her marriage to Amedeo of Savoy (1845–1890), Duke of Aosta, later crowned King of Spain. This tiara contains 11 drop-shaped natural pearls of partly remarkable size, set together in a classic loop design with a fine selection of colourless old-cut diamonds. It was created by Musy Padre e Figli, court jeweller of Turin, and one of the oldest goldsmiths in Europe. The design can be interpreted as a variation of the Savoy knot, or knot-of-love, a symbol for the House of Savoy and Italian monarchy. This tiara has been designed in a way that it can also be worn as a necklace after a few simple manipulations. Such "dual" use is especially prevalent in noble and royal jewellery, as they can then be adapted to various occasions, such as a coronation, a royal wedding, or just an opulent gala at the royal court.

The second item is a Belle Époque pearl and diamond necklace (Figure 2) by Boucheron. Originally designed as a tiara in 1896, it was shortly afterwards transformed by Boucheron into a necklace and matching ear-pendants (1902). The 32 saltwater natural pearls in this jewellery have been carefully selected and exhibit beautifully matching button- to drop-shapes and a very fine pearl lustre. Their attractive colour subtly ranges from white to light cream. In addition to these qualities, part of these pearls show rosé and green overtones, poetically also referred to as the "orient of pearls". These overtones are an iridescence effect visible on the surface of pearls and contribute greatly to the beauty of the described pearls.

The last item to be described here is the Fürstenberg pearl tiara. This tiara is set with 23 saltwater natural pearls of partly remarkable size in a historic design of the late 19th century. Based on the provided documentation, this pearl tiara was part of the jewels of Fürstenberg, a noble family from Southwestern Germany, hence its name. The pearls in this tiara are characterised by a beautifully matching drop shape and a fine pearl lustre. Their colour subtly ranges from white to light cream. The combination of well-balanced trace elements found in these natural pearls are characteristic of saltwater pearls.

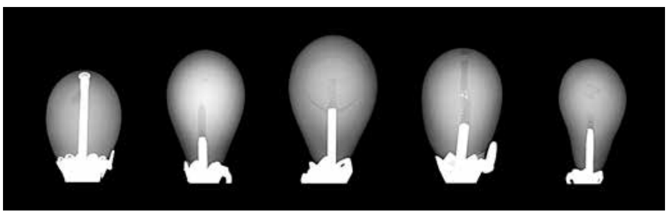
The X-ray analyses of pearls in jewellery is often quite challenging for the analysts at the SSEF. This is especially the case when they are set in a rather rigid tiara with lots of metal mounting and diamonds. We were thus fortunate to have been able to analyse these pearls from the Fürstenberg tiara in a first round when they were detached from the main tiara setting. A selection of these radiographies is shown in Figure 4, revealing characteristic "onion-like" ring structures in these natural pearls. In addition, these radiographies show also different drilling situations, from being half-drilled to fully drilled.

✶ **Dr. M.S. Krzemnicki**

△ **Figure 1:** The pearl tiara of the House of Savoy, which can be also worn as an impressive necklace. Photos: SSEF (top) and Sotheby's (below).

◁ **Figure 2:** Belle époque pearl necklace and pair of ear-pendants by Boucheron. This necklace was transformed from a tiara, originally made in 1896 also by Boucheron. Photo: Luc Phan. SSEF.

△ **Figure 3:** Fürstenberg pearl tiara consists of 23 natural pearls of very fine quality and partly remarkable size. Photo: Christie's



△ **Figure 4:** X-ray radiographies of a selection of the natural pearls from the Furstenberg tiara. Photo: SSEF

ASSEMBLED BLISTERS AND SHELLS USED TO IMITATE PEARLS

△ **Figure 1: Antique pearl necklace with a "pearl" in the centre, assembled from a blister with a polished piece of shell at the base. Photo: A. Chalain, SSEF.**

△ **Figure 2: The intersection line between the nacreous blister (at the top) and the polished shell (at the base) are clearly visible in this assembled "pearl" product. Photo: M.S. Krzemnicki, SSEF.**

Since historic times, natural pearls have been treasured and considered symbols of wealth and beauty. When harvesting (natural) pearls, one may find not only a pearl inside a shell, but also blister pearls and quite often blisters. A pearl has grown completely wrapped in a pearl sac in the mollusc, whereas a blister pearl is a pearl which connected at a late stage to the surface of the shell. Different to this, a blister is just a bulge in the shell surface, and as such much more common. Still, some of these blisters - specifically in nacreous shells – can show a very beautiful lustre and colour, and can be attractive for designers to create a "pearl" like an objet d'art. In some cases, however, this creativity is rather used to "create" an item with the fraudulent intent to mimic a pearl. With historic objects, it is however not always clear to what extent such creations were really fraudulent or just an expression of artistic creativity and skills.

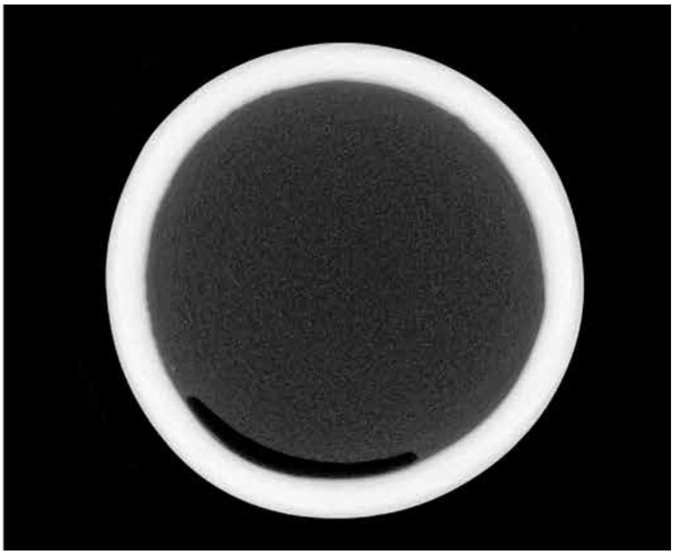
The first item described in this short note we received in the past months was an antique pearl and diamond necklace. This necklace was dominated by a central "pearl" set as a pendant (Figure 1). Radiography and chemical analyses on the smaller pearls confirmed them as saltwater natural pearls based on their "onion-like" internal structures. For the larger item, however, the radiography from the side was much less promising, as only curved layered structures were observed, furthermore with an evident cutting-line separating the upper part of this "pearl" from the base. Microscopic observation finally confirmed that this large "pearl" in fact was an assembled product (Figure 2), made from a nacreous blister at the top with a polished piece of shell as the base.

△ **Figure 3: Pendant made of three curved shell pieces and radiography showing two of these pieces with a grey vertical intersection line where these two parts were glued together. Photo: SSEF.**

The second item we received recently at SSEF was even more fascinating (Figure 3). This pendant was rather large with a maximal length of about 36.50 mm, containing as it seemed a large pearl of slightly baroque drop shape and kept in an "cage" of three metallic branches set with small old-cut diamonds. Originally thought to be a hollow pearl, also known as "soufflure" which sometimes are of exceptional size, it became quickly evident that this object had actually been assembled from three curved shell pieces to imitate a large natural pearl. From the distinct wear marks on the shell pieces, a rather old age might be possible. However, whether this item was truly historic, or made in an antique design with old shell pieces could not be established based on our testing.
Although disappointed by the fact that this item was not a natural pearl, the client was still happy to receive back the full information about this elaborately created objet d'art.

✶ **Dr. M.S. Krzemnicki**

CULTURED PEARL WITH UNCONVENTIONAL BEAD MATERIAL



△ **Figure 1:** Cultured pearl of 24 mm diameter. The X-ray tomography section (right) reveals the unconventional bead material (dark grey) of this cultured pearl. Photo: SSEF

Recently, we received a round pearl for testing which exhibited an excellent surface quality and a remarkable size of 24 mm in diameter. Interestingly, its weight of 60 ct was rather low for such a pearl (resulting in a calculated specific gravity of approx. 1.61 instead of 2.715 considered standard for a pearl). Using radiography and micro X-ray tomography, its identity as a beaded cultured pearl and the reason for this low weight was quickly revealed.

The saltwater cultured pearl contained an unconventional organic bead material, possibly similar to those described in 2013 in an article in the Australian Gemmologist (Cartier & Krzemnicki, 2013: New developments in cultured pearl production: use of organic and baroque shell nuclei. The Australian Gemmologist, Vol. 25, No. 1, pp. 6-13), accessible from the online library on the SSEF website. Nearly transparent to X-rays, this bead material showed no internal structure except a fine granular texture and some empty cavities (black) along the bead/nacre interface. The cultured pearl was undrilled, so the identity of the bead material could not be further tested.

In terms of market acceptance, it might be interesting to see if more such cultured pearls arrive on the market in future. For us, it was the only one in the past few months. Another interesting aspect would be to see the long-term stability of such organic bead material, specifically if the pearl would be drilled and strung on a necklace.

SALTWATER PEARL WITH BARIUM

△ **Figure 1:** Antique pearl necklace with a "pearl" in the centre, assembled from a blister with a polished piece of shell at the base. Photo: A. Chalain, SSEF.

Recently, the SSEF received a button-shaped pearl of 7.5 ct for testing. Based on X-ray radiography and a UV-Vis-NIR reflectance spectrum, the pearl was easily identified as a saltwater natural pearl from the species Pinctada margaritifera. Strangely enough however, this pearl showed a distinct concentration of barium (approx. 350 ppm), an element commonly found in freshwater pearls but only at very low trace levels (about 1 ppm or below) in saltwater pearls. We assume that the presence of barium in this specific pearl might be a residue from a former X-ray radiography performed with an X-ray absorber liquid containing barium. The admixture of barium sulfate to water is applied in medical X-ray radiography since many years with the aim to increase the visibility of internal features.

NOVEL CORAL-ID METHOD USED ON SAMPLES SEIZED BY SWISS CUSTOMS

△ **Figure 1: These precious coral items were seized by Swiss customs between 2009 and 2017, and fully analysed using the novel Coral-ID method of DNA fingerprinting. Photos: B. Lendvay.**

In 2022, an international research group led by scientists from the Swiss Gemmological Institute SSEF and the University of Zurich's Institute of Forensic Medicine (IRM) reported a breakthrough in precious coral jewellery traceability, through the use of a novel forensically validated genetic technique called Coral-ID. Coral-ID is the first reliable and forensically validated method to scientifically identify corals using quasi non-destructive sampling, so that species protected by the Convention on the International Trade of Endangered Species (CITES) can be distinguished from their non-protected counterparts.

Four precious coral species used in the jewellery trade are listed on Appendix III of CITES, and they require species-specific and country-of-origin documentation when being traded and transported across international borders (Figure 2). For the customs authorities that must check the merchandise, the colour of a coral specimen has to date been the main indicator for ascertaining its biological species identity. However, different coral species can have similar colour ranges, and this frequently has caused difficulties when trying to conclusively identify the specific species of coral contained in a jewellery item.

The six taxonomic groups distinguishable by the *Coral*-ID assay. Note that species in the species complexes cannot be differentiated based on mitochondrial markers. Species used in the trade according to [4] are marked with asterisk.

Taxonomic group	Species within group	CITES listed	Primary color of skeletal axis	Distribution area
Corallium rubrum	*C. rubrum* *	No	uniform red to deep orange	Mediterranean Sea, North-East Atlantic [5]
***Corallium japonicum* species complex**	*C. japonicum* *	Yes	dark red with white center [29]	Japan, Taiwan [30]
	C. nix	No	dark red or pink, white center, white tip [31,32]	New Caledonia [31]
	C. tortuosum	No	pale pink [33], white-transparent [26]	Hawaiian Islands [33], New Caledonia [26], Taiwan [26]
Hemicorallium	*H. abyssale*	No	pale pink, darker center [33]	Hawaiian Islands [33]
	H. aurantiacum	No	pale pinkish – orange [26]	New Caledonia [26]
	H. bathyrubrum	No	deep pink to red [34]	North-West Atlantic [34]
	H. bayeri	No	white [34]	North-West Atlantic [34]
	H. ducale	No	dark pink [35]	East-Pacific [35]
	H. guttatum	No	milk white [26]	Hawaiian Islands [26]
	H. imperiale	No	rich pink [35]	East-Pacific [35]
	H. laauense *	No	white [33]	Hawaiian Islands [33], Emperor Seamount [4]
	H. niobe	No	white [36]	Western Atlantic [36]
	H. regale *	No	pale pink [33]	Hawaiian Islands [33]
	H. sulcatum *	No	pink [26]	Taiwan, Japan [5], Philippines [4]
***Pleurocorallium elatius* species complex**	*P. elatius* *	Yes	red to pink with white center [29], orange [37]	Taiwan, Japan, Vietnam [5]
	P. konojoi *	Yes	milky white, pinkish center [37]	Japan, Taiwan, Vietnam [5]
	P. carusrubrum *	No	crimson, orange [26,37]	Taiwan [37]
Pleurocorallium secundum	*P. secundum* *	Yes	pale pink, often almost white [33]	Hawaiian Islands [33], Taiwan [38]
other *Pleurocorallium*	*P. bonsaiarborum*	No	pure white - transparent [26]	New Caledonia [26]
	P. borneense	No	white with pink center [39]	Malaysia [39]
	P. clavatum	No	white [26]	New Caledonia [26]
	P. inutile	No	white [29]	Japan [29]
	P. porcellanum	No	white [29]	Hawaiian Islands [29]
	P. niveum *	No	white [33]	Hawaiian Islands [33]
	P. norfolkicum	No	white [26]	New Caledonia [26]
	P. thrinax	No	white [31]	New Caledonia [31]

△ **Figure 2:** A table of all species relevant to precious corals, including the six major taxonomic groups. References can be found in the article by Lendvay et al., 2022.

The Coral-ID method was tested on a real-world set of samples, comprised of 20 coral-set items (Figure 1) seized between 2009 and 2017 by the Swiss customs authorities. The objects were seized in five separate cases due to the absence of valid CITES documentation during their importation to Switzerland between 2009 and 2017. The samples were obtained from the Federal Food Safety and Veterinary Office of Switzerland (FSVO, Berne). Each object was labelled with a claimed taxon name, which was provided by the importers. Alternatively, if the objects lacked import documentation, they were registered as *Corallium* sp. in the FSVO documentation. Multiple species were found among corals of similar appearance, highlighting the importance of using the new Coral-ID method, which is to avoid misidentification of CITES-listed species as non-CITES listed species, and vice versa. Three of the 20 tested samples were shown to be of species that have not previously been associated with precious coral in the jewellery trade. This further underscores the need for additional scientific research.

CITES and precious corals

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), an agreement signed and regularly updated by the parties of the United Nations, is responsible for monitoring and controlling the trade of vulnerable and endangered species. Trade regulations are codified by national legislation and enforced by local law enforcement authorities. In 1987, Spain made the first attempt to list *Corallium rubrum*, a historically abundantly fished precious coral species, in CITES, but it was rejected by CITES parties. Subsequent proposals by the USA in 2007 to include the *Corallium* genus and by the USA and the EU in 2010 to include the entire Coralliidae family in CITES Appendix II were also rejected. However, China successfully added four species, *C. japonicum*, *C. elatius*, *C. konojoi*, and *C. secundum* (which have subsequently been suggested to belong to the *Pleurocorallium* genus), to CITES Appendix III in 2008, and trade of any specimen or part of these species requires a certificate of origin for customs clearance to be legally traded internationally. Accurate species identification is crucial for implementing CITES regulations. Traditionally, species identification of corallid species has relied on microscopic examination of morphological traits, which can be lost in processed objects. As a result, species identification of precious corals can be difficult or even impossible in processed forms, making a reliable identification method essential for effective implementation of CITES regulations.

Research on coral genetics

Based on our understanding of coral phylogenetics, it is challenging to reliably differentiate certain coral species solely based on DNA analysis. This becomes particularly problematic for species complexes such as *Corallium japonicum* and *Pleurocorallium elatius*, which encompass both CITES-listed and non-CITES-listed species. The Coral-ID assay was designed to cautiously handle the taxonomic uncertainties and provide conservative conclusions regarding the taxonomic identity of an object. In some cases, additional non-genetic information, such as the colour of the object, the distribution area of potential species, and the location of known commercial precious coral fishing grounds, may be considered to make presumptive species identifications.

△ **Figure 3:** A precious coral fishing boat in the port of Su'ao (Taiwan). Photo: L.E. Cartier.

For samples identified as originating from the *Corallium japonicum* species complex, there are three closely related species: *C. japonicum* (CITES-listed), *C. nix*, and *C. tortuosum* (both non-CITES-listed). The red-coloured *Corallium japonicum* is commonly harvested from waters off Japan and Taiwan (Figure 3). *Corallium tortuosum* has a white or pale pink skeletal axis and is found in areas around the Hawaiian Islands, New Caledonia, and Taiwan. Although it is the most abundant precious coral in Hawaiian waters, it is less likely to be fished for commercial purposes due to its small size and usually deformed axis. *Corallium nix* can have a dark red skeletal axis, but it has only been reported from scientific surveys in the Norfolk Ridge (New Caledonia), where commercial coral fishing has never occurred. Therefore, if an object is red and identified as originating from the *Corallium japonicum* species complex, it is presumptively from the CITES-listed *Corallium japonicum* species.

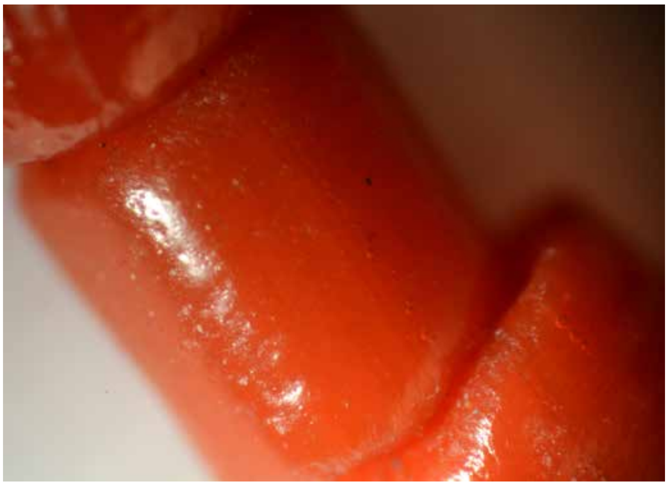
In the case of samples identified as originating from the *Pleurocorallium elatius* species complex, there are three morphologically similar species: the red-pink *P. elatius* and the mainly white *P. konojoi* (both CITES-listed), and the red *Pleurocorallium carusrubrum* (non-CITES-listed). The first two species have been harvested in large quantities from Japan and Taiwan. The latter has been found exclusively in the waters of northern Taiwan, and its material is expected to be mixed in stocks of *P. elatius* in the market. Therefore, if a sample is white or pink, it is presumptively from the CITES-listed *P. konojoi* or *P. elatius*, respectively, while if red, it could be either *P. elatius* or *P. carusrubrum*. Among the confiscated objects we analysed, three objects (Object 1 - pure dark red, Object 2 - red with white parts, and Object 20 - pure white) fell within the *Pleurocorallium elatius* species complex. By combining the genetic results with morphological cues, we may presumptively conclude that Object 20 is from the CITES-listed *P. konojoi*, while Objects 1 and 2 could be either *P. elatius* or *P. carusrubrum*.

Such research shows the importance of carrying out fundamental science and peer-reviewed research on raw materials used in the jewellery industry. Genetic analysis of precious corals is clearly a very useful tool to achieve greater transparency in the trade. In some cases, DNA fingerprinting may not be successful if the coral samples are too old and insufficient fresh DNA is present.
Precious coral identification services are being offered by SSEF in partnership with the Institute of Forensic Medicine at the University of Zurich, which is one of Switzerland's leading forensic institutes. All analyses are carried out in laboratory facilities accredited according to the ISO 17025 standards. Ongoing research is seeking to further elucidate precious coral genetics and allow for more even more conclusive separation of species on a genetic basis.

Detailed information about the use of DNA fingerprinting of precious corals can be found in the following journal article: Lendvay B., Cartier L.E., Costantini F., Iwasaki N., Everett M.V., Krzemnicki M.S., Kratzer A., Morf N.V., 2022. Coral-ID: A forensically validated genetic test to identify precious coral material and its application to objects seized from illegal traffic. Forensic Science International: Genetics 58 (2022), 102663. https://doi.org/10.1016/j.fsigen.2022.102663
✶ **Dr L.E. Cartier & Dr. B. Lendvay**

HAPPY HOUR WITH SODA AND LIME: GLASS IMITATING CORAL

Recently, a necklace was submitted to SSEF for coral testing. Already a first microscopic inspection revealed that this item in fact consisted of numerous tiny glass beads, visually imitating coral very well (e.g. *corallium rubrum*). The most obvious microscopic feature was the presence of air bubbles in these glass beads, typical and characteristic for such artificial glass products (Figure 2). Chemical analysis further confirmed its identity as soda-lime glass, the most prevalent type of industrial glass. Although soda water and lime are often mixed in cocktails during happy hours, our finding about this necklace was not so sparkling and exciting for our client.



△ **Figure 2:** Distinct air bubbles in glass beads imitating a coral necklace. Microphoto (50x magnification): M.S. Krzemnicki, SSEF

DYED QUARTZ IMITATING EMERALD

△ **Figure 1:** Imitation of a rough emerald. Photo: SSEF.

From time to time, we receive some oddities for testing, such as the rough "emerald", reportedly originating from Africa and submitted by a client for testing.

Already a quick visual examination made it clear that this was not an emerald. The surface was dominated by conchoidal fractures and covered partly with dark mica. A closer analytical examination with Raman spectroscopy clearly identified the stone as quartz. Microscopic observation further revealed that a mix of mica and sand was glued to part of the surface of this rough to cleverly mimic natural minerals commonly attached to rough emeralds found in mica schists, e.g. in the Kafubu area in Zambia.

The relatively homogeneous green colour (resembling that of certain Zambian emeralds) of this sample was due to green colour dye found within the fissures and also mixed in with the glue at the surface. We found neither chromium nor any pleochroism in this stone, which are characteristic features typically found in emeralds.

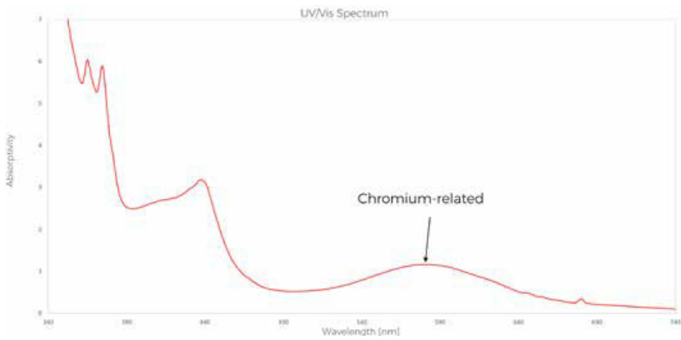
AN INTERESTING CHRYSOBERYL-ALEXANDRITE COMBINATION

The mineral chrysoberyl $BeAl_2O_4$ is an attractive gemstone that shows a wide variation of colours mostly ranging from yellow to green and brownish green to dark brown. These colours are mainly due to the presence of iron and sometimes vanadium as chromophore elements inside the crystal lattice structure. In some rare cases, chromium is present and has a peculiar and interesting effect as it induces a colour change of a certain intensity (weak, moderate, distinct, or strong) when the gemstone is observed under daylight or incandescent lighting conditions. Such a variety of chrysoberyl is named "alexandrite" and was first discovered in the Ural Mountains in Russia. The common observed colours of the gemstone are usually green to bluish green when observed in daylight, and switch to purple and red colours in incandescent light. This term comes from the name of the Russian Tsar Alexander II after whom the gem was named.

The orientation of a rough crystal before cutting is definitely important for any anisotropic mineral, such as corundum and chrysoberyl, as this will strongly influence the final colour of the gemstone. This will influence some optical effects as well, like chatoyancy (cat's-eye effect) and asterism (star effect), and in some specific cases the colour change effect.

As an illustration of this last point, we recently observed at SSEF a very interesting case of alexandrite showing a moderate colour-change from green in daylight to greenish purple in incandescent light (Figure 1). As mentioned before, the cause of the colour change is due to the presence of chromium in the structure of the crystal. So we were quite astonished when the chemical analyses performed routinely on the table of the gemstone were not detecting chromium, but only iron. To understand more the causes of the colour, an absorption spectrum was performed and this additional data showed that chromium was present inside the stone in a sufficient amount to induce a colour change. So, where is the chromium located in this gemstone?

△ **Figure 1:** Alexandrite with a moderate colour change when seen under daylight (left) and incandescent light (right). Photo: L. Phan, SSEF



△ **Figure 2:** UV-Vis-NIR absorption spectrum showing an absorption band induced by chromium. Figure: SSEF.

△ **Figure 3:** Distinct chromium-rich zonation at the culet showing a red colour when observed with an incandescent light source. The stone was immersed in water to minimise reflections. Photo: P. Lefèvre, SSEF

The microscopic observations revealed some common inclusions for a chrysoberyl: healing fissures, milkyness, and a distinct growth zonation (Weeramongkhonlert, 2020). The specificity of this growth zonation was that the area located at the culet on the pavilion was showing a red colour when using a strong optic fibre light (Figure 3). New chemical analyses performed this time specifically on the culet side finally revealed a significant amount of chromium with almost 0,5 wt.% of Cr_2O_3, which is quite a high amount for an alexandrite.

The importance of the orientation of the rough crystal before cutting and the ability of the cutter show here all their importance. If the crystal would not have been properly oriented to get the chromium-rich growth zone at the culet of the final cut gemstone, the colour-change effect would have been strongly reduced, or even not existing at all. And the play of light reflections inside the gemstone due to the numerous facets and the proper angles gives the illusion that the entire gemstone is colour-changing, and not a minority area only.

✶ **P. Lefèvre**

EMERALD OR GREEN BERYL: AN EVERLASTING QUESTION

△ **Figure 1:** Small emerald (left) and large green beryl (right). Although similar in colour, these two gemstones are not belonging to the same beryl variety. Photo: L. Phan, SSEF

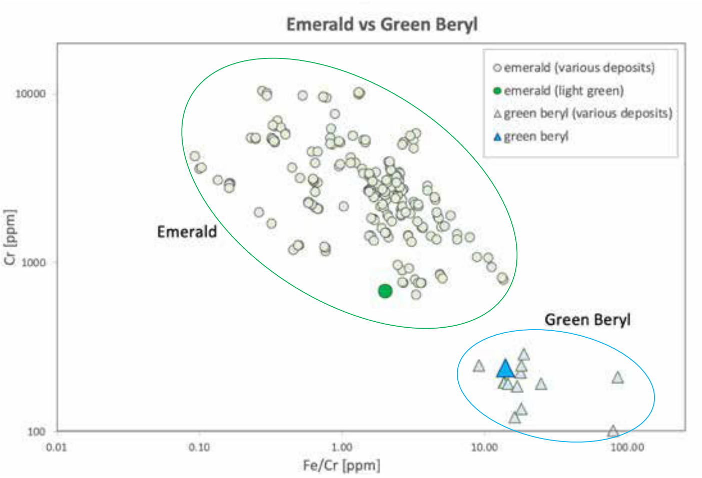
The mineral beryl $Be_3Al_2(Si_6O_{18})$ is known in different colour varieties, such as emerald, aquamarine and morganite, to name a few. By far the most important variety is emerald, known and appreciated since historic times, and especially treasured by Mughal rulers for example. Going by its original definition, the colour of emerald is related to the presence of chromium. However, today it is well accepted that the colour of emeralds is not only due to chromium, but also influenced by the presence of vanadium and iron in the crystal structure of beryl. This explains also certain characteristic colour variations encountered in emeralds from different deposits (e.g. Colombian versus Zambian emeralds). In addition, the concentration of these colouring elements (chromophores) is another important colour factor, mainly controlling the saturation of colour.

As unambiguous as the definition of emerald is in theory, it is always the borderline cases that are challenging: and the question remains whether each beryl of green colour should be called emerald or not. There is quite some literature about this topic (Anderson 1967, Lind et al. 1986, Hänni 1992, Cevallos et al. 2012). Especially, as a gradual transition from emerald to aquamarine exists, documented for example from deposits in Nigeria and Madagascar. It is even possible to find beryl with distinct alternating blue (aquamarine) and green (emerald) colour zones. In addition to this, green beryl exists as a well-established variety name in the trade. This term is used for beryl owing its green colour mainly to iron.

For a laboratory, it is important to develop clear criteria to define a mineral variety beyond the general definition (emerald = green chromium bearing variety of beryl). Only by this is a lab able to consistently separate between different varieties of a mineral, whether this concerns now emerald vs green beryl, ruby vs pink sapphire, or padparadscha vs orange sapphire, to name a few. A detailed description of such criteria used by SSEF was presented a few years ago at international seminars and conferences in Europe, Asia, and the USA, and published in InColour (2020) and in the SSEF Facette (SSEF Facette 2020, No. 26, pages 6-8).

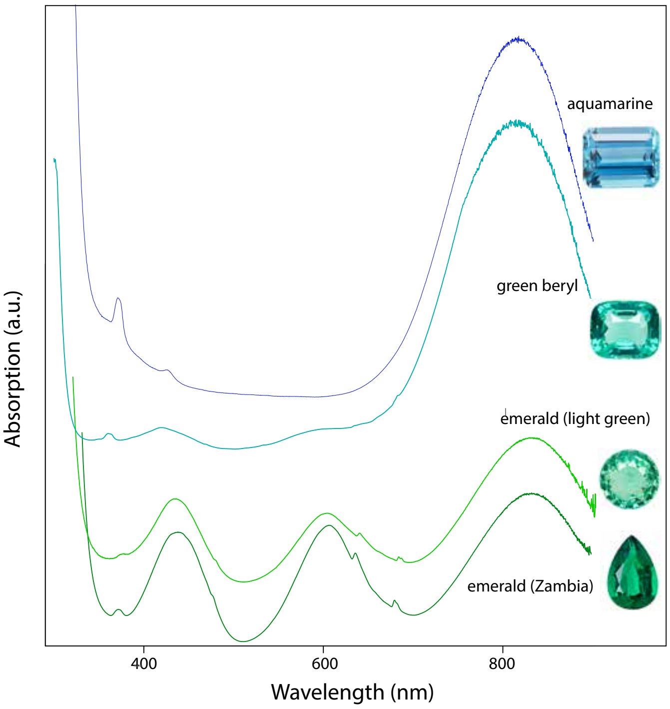
Recently, we had the chance to analyse two stones, which visually showed a similar green colour. A closer look at their trace element composition and absorption spectra however revealed major differences. This resulted in two different beryl variety calls. The smaller stone (on the left in Figure 1) was identified as an emerald, whereas the larger stone (on the right) was identified as a green beryl. These different conclusions were based mainly on their respective trace element concentrations and UV-Vis-NIR absorption spectra (Figures 2 and 3).

The described emerald is rather low in concentration of both chromium (0.098 wt% Cr_2O_3) and iron (0.197 wt% Fe_2O_3), with iron concentration being about twice as high as chromium. In contrast to this, the green beryl contains only traces of chromium (0.035 wt% Cr_2O_3) but much more iron (0.475 wt% Fe_2O_3), i.e. about 14 times more iron than chromium. When comparing these two gemstones with data from our SSEF database (Figure 2), it is evident that the smaller stone (green spot) falls into the group of emeralds (Colombia, Brazil, Afghanistan, Pakistan, Russia, Zambia, and other African sources), whereas the larger stone (blue triangle) fits well with green beryl from Nigeria and Madagascar.



△ **Figure 2:** **Bivariate trace element plot revealing two distinctly separate groups for emerald and green beryl. The described gemstones in this article clearly fall into different groups, with the smaller stone fitting with the emerald group (green spot) and the larger stone with green beryl (blue triangle). Figure: M.S. Krzemnicki, SSEF**

This chemical differentiation into these two beryl varieties is also supported by the absorption spectra of the two described gemstones. The smaller stone (emerald) reveals distinct chromium absorption bands and peaks between 400 - 700 nm and additionally a moderate Fe^{2+} band in the near infrared at about 850 nm, very similar to a typical absorption spectrum of a Zambian emerald. The larger stone (green beryl), however, is very close to a typical aquamarine spectrum, strongly dominated by the Fe^{2+} band in the near infrared. The tiny chromium bands (due to traces of chromium) present in this stone results in a slight shift of its colour to bluish green. Both trace element composition (Figure 2) and the absorption spectrum (Figure 3) clearly indicate, that the larger stone (right in Figure 1) cannot be called emerald, but can be correctly identified as green beryl.



△ **Figure 3:** **Absorption spectra of the two described gemstones compared to a typical spectrum of an emerald (Zambia) and aquamarine. Figure: M.S. Krzemnicki, SSEF**

In summary, there exists a gradual transition between the beryl varieties emerald and aquamarine. As a consequence of this transition, nature may produce stones of such an intermediate chemical composition and colour appearance that make variety identification challenging for laboratories and the trade alike. At SSEF, we use since many years a combination of trace element analyses (mainly of the colouring elements) and absorption spectroscopy to separate between these two varieties, as exemplified with these two real world case studies. As has been shown, even two gemstones of a very similar colour may lead to different variety calls.
✶ **Dr. M.S. Krzemnicki**

BLUE SURPRISE: APATITE AND NOT PARAIBA TOURMALINE

Last summer, the SSEF received a series of nine small blue cabochons ranging in weight from 0.4 to 1.5 ct. The client assumed that these stones were Paraiba tourmalines from a very early production of the Sao José da Batahla mine in the state of Paraiba in Brazil, as they were safeguarded for several decades by a jeweller.

Already doubtful in appearance, these "Paraiba" stones were quickly identified as apatite, well-known to occur in Paraiba-like colours, specifically after they are subjected to heat treatment. Based on the presence of reddish iron-oxide in some hollow channels, it is highly probable that these apatite cabochons were heated. In addition, the fissures (maybe partly induced by the heating process) in these rather included cabochons showed indications of clarity modification by minor to moderate fissure filling. The result was not so thrilling for the client, but at least this Paraiba-mystery could be solved.

A PERFECT MATCH: PARAIBA TOURMALINE AND INDICOLITE TOURMALINE

△ **Figure 1: Submitted as a matching pair of Paraiba tourmalines, our testing revealed that only the left stone is copper-bearing, whereas the right stone was identified as an indicolite tourmaline. Photo: L. Phan, SSEF.**

A few months ago, a client submitted to SSEF two tourmalines of attractive and matching shape, size and colour, both supposedly being Paraiba tourmalines (Figure 1).

Chemical analyses and absorption spectra (UV-Vis-NIR) quickly revealed that their composition and colour cause was much less matching than their visual appearances.

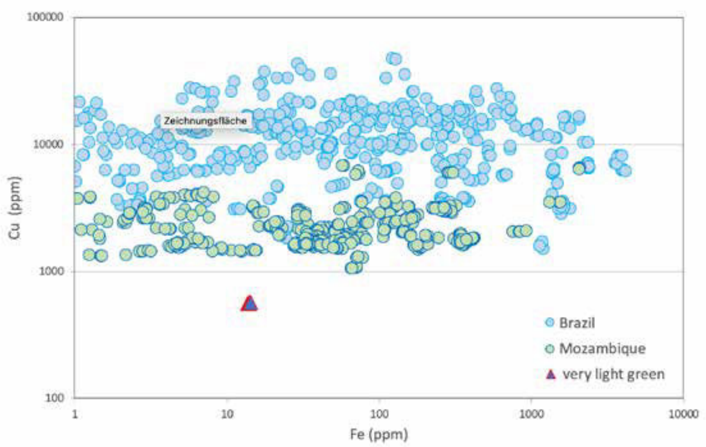
The slightly larger stone of 10 ct (left in Figure 1) contained minor concentrations of copper (CuO 0.24 wt%) but no iron. In contrast to this, the slightly smaller stone of 8.5 ct (right in Figure 1) showed no copper at all but a distinct concentration of iron (Fe_2O_3 2.0 wt%). Absorption spectra confirmed their identity, showing distinct Cu-absorption bands in the left stone but only an Fe-related band at about 710 nm. Both, we and our client were astonished to learn that these two very similar looking tourmalines in fact were a Paraiba tourmaline (left) and an indicolite tourmaline (right). This case demonstrates well that having your gems tested might be very wise before making major buying decisions, specifically in the fast-paced environment of a jewellery show.

SATURATION TOO LOW FOR PARAIBA TOURMALINE

Copper-bearing tourmaline, also known as Paraiba tourmaline in the trade, may come in a range of colours from blue to green. Similarly, the colour saturation of such copper-bearing tourmalines may vary largely, from saturated and vibrant – also known as "electric" or "neon" – to very light coloured. Recently, we analysed a tourmaline from Mozambique of very light green colour, containing only small traces of copper resulting in a weak colour saturation of this stone. When comparing this copper-bearing tourmaline with a large selection of Paraiba tourmalines originating from Brazil or Mozambique, we see that these usually show distinctly higher copper concentrations (Figure 2).

Although this tourmaline is coloured by traces of copper and consequently exhibits weak absorption bands related to copper in its absorption spectrum, the saturation of this stone is considered weak, i.e. too low based on our colour standard to be called a Paraiba tourmaline (see also LMHC information sheet No. 6, https://www.lmhc-gemmology.org/gemstones).

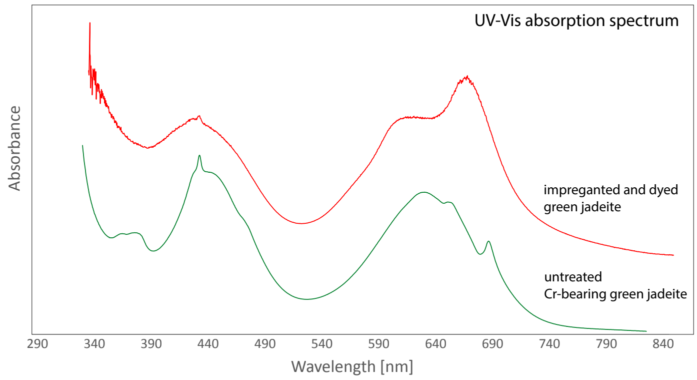
✶ **Dr. M.S. Krzemnicki**



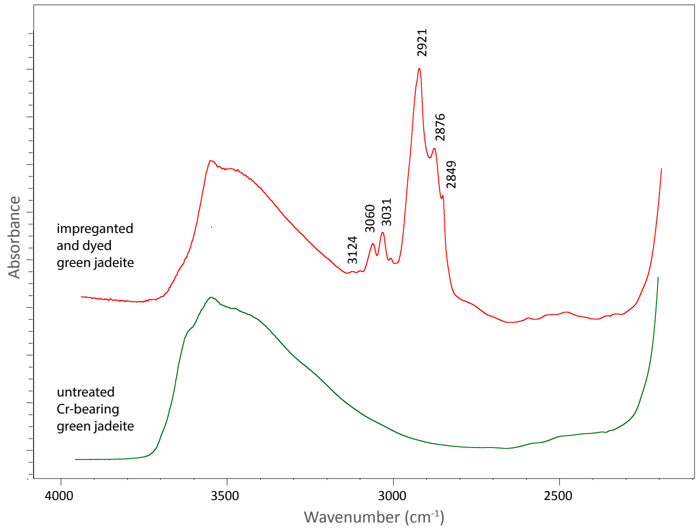
△ **Figure 2: The copper concentration of the described very light green tourmaline (triangle) is distinctly lower (about 550 ppm) than what is common for Paraiba tourmalines from Mozambique (green spots) and Brazil (blue spots). Diagram: SSEF.**

JADEITE: IMPREGNATED AND DYED

△ **Figure 1: Treated jadeite-jade (polymer impregnated and dyed). Photo: L. Phan, SSEF.**



△ **Figure 2: Comparison of absorption spectra of the described jadeite artificially coloured by a green dye (red trace) and an untreated green jadeite coloured by traces of chromium (green trace). Figure: M.S. Krzemnicki, SSEF.**



△ **Figure 3: Comparison of FTIR spectra of the described polymer impregnated and dyed jadeite (red trace) and an untreated green jadeite (green trace). Figure: M.S. Krzemnicki, SSEF.**

Jadeite-jade of saturated emerald green colour is highly valued in Asia. It is therefore not astonishing to see in the market either heavily treated jadeite-jade or even imitations made of different minerals which pretend to be fine quality jadeite-jade of "Imperial green" colour.

An exemplary case was submitted last year, being a ring of 25 mm diameter and showing a vivid green colour as is known in chromium-bearing jadeite. A closer look however revealed distinct colour concentrations in fissures and along grain boundaries which made this quite a dubious item from the start (Figure 1).

The analyses at SSEF confirmed that this ring is a heavily treated jadeite of rather poor quality (many fissures). The jadeite had been first bleached with acids and subsequently impregnated with artificial resin (polymer) and additionally dyed artificially to create the green colour. Chemical analyses showed a rather pure jadeite composition with minor amounts of iron (0.7 wt% Fe_2O_3) but nearly no chromium (only 0.003 wt% Cr_2O_3). The absorption spectrum is distinctly different to chromium-bearing jadeite. It is dominated by three broad bands at about 430, 600 and 675 nm mainly resulting from the green dye, with additionally a small peak at 435 nm from Fe^{3+} (Figure 2).

In addition, the infrared spectrum shows evident peaks related to artificial resin in the range from 2800-3100 cm^{-1} wavenumbers (Figure 3).

In the Asian market, such a polymer impregnated and dyed jadeite -jade is called type B+C jadeite-jade and is of nearly no commercial value compared to an untreated jadeite-jade of similar colour.

DARK PURPLE CHRYSOBERYL

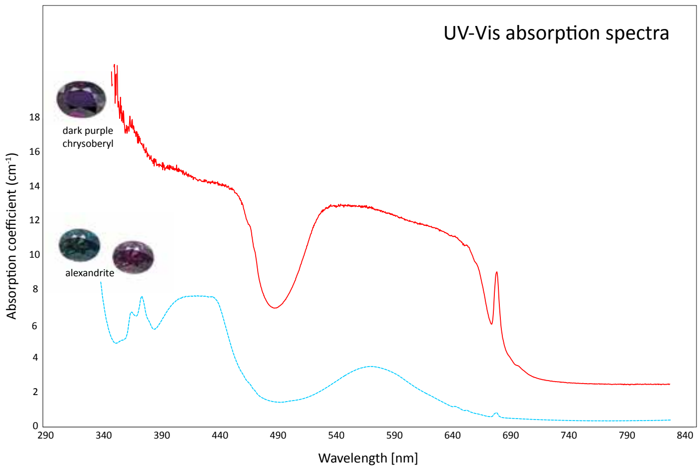
△ **Figure 1: Dark purple chromium-rich chrysoberyl. This gemstone does not show a colour change and thus cannot be called alexandrite. Photo: A. Chalain, SSEF.**

Since about three years, we see at SSEF occasionally chrysoberyl samples of very dark purplish to purplish brown colour, sometimes of quite impressive size (>10 ct). Based on chemical composition, these chrysoberyls show distinct concentration of chromium, but no evident change of colour, thus do not fit the criteria to be called alexandrite (see e.g. alexandrite definition by LMHC, information sheet No. 9, https://www.lmhc-gemmology.org/gemstones). In fact, these stones contain much too high concentrations of chromium - nearly 3 wt% Cr_2O_3 in the chrysoberyl of Figure 1 – to create a colour change effect in these stones when observed under different standard illumination (daylight and incandescent light). The high chromium concentration results in two very dominant chromium-related absorption bands at about 570 and 410 nm in the absorption spectrum (Figure 2). As a consequence, light transmission is mainly restricted to the reddish part of the visible range with some minor contribution by the "transmission window" in the blue-green range, hence the dark purple colour of this chrysoberyl. In addition, the high chromium concentration increases the general absorbance of the stone, thus deepening the colour with a dark tone.

Dark reddish chrysoberyl containing high amounts of chromium have been reported before in literature, mainly from Brazil (Schmetzer et al. 2014, Stone-Sundberg 2014). This rather new material of partly important size is reportedly from East Africa, however the precise location is not known to us so far.

To summarise, the above described properties (no colour change, only dark purplish to purplish brown colour) mean that such chromium-rich stones do not qualify to be called alexandrite and are identified as chrysoberyl on SSEF reports.

✶ **Dr. M.S. Krzemnicki**



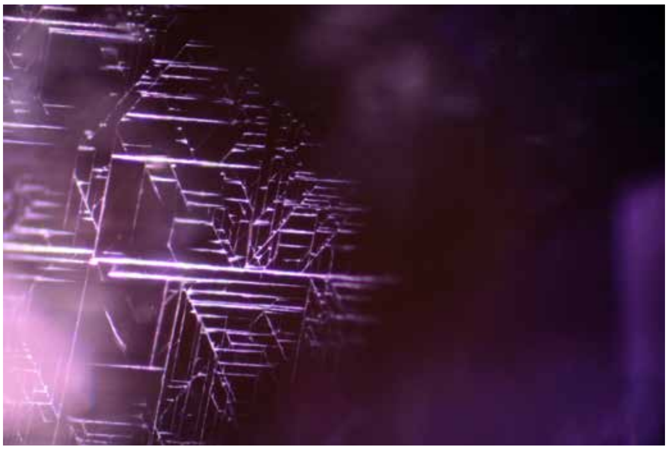
△ **Figure 2: Absorption spectrum of a Brazilian alexandrite (blue spectral curve) exhibiting a distinct colour change compared to the described chromium-rich dark purple chrysoberyl. The spectra have been vertically stacked for clarity. Figure: M.S. Krzemnicki, SSEF.**

PURPLE LOVE

It is always a pleasure for our team to analyse gemstones which are not so common, or sometimes even very rare, but which may compete in beauty and quality (but often not in hardness) with the most prestigious classic gemstones. In the past few months, we had the opportunity to analyse a number of rare and outstanding gemstones of purple colour, some of which are presented in the following.

△ **Figure 1:** Hackmanite of nearly 9 ct showing a vivid purple colour and a fine clarity. Photo: A. Chalain, SSEF.

The first example is a transparent faceted hackmanite from Afghanistan of nearly 9 ct. **Hackmanite**, a variety of sodalite, is known for its striking colour shift from whitish grey to intense purple when exposed to ultraviolet light. Normally, this colour subsequently fades again over time, but can be re-established indefinitely. This property is known in scientific literature as tenebrescence, or reversible photochromism.



△ **Figure 2:** Oriented needle-like inclusions in the described hackmanite. Photo: M.S. Krzemnicki, SSEF.

Hackmanite used as gem material is commonly quite included and of low transparency and thus often cut into cabochons or beads. The described hackmanite submitted recently to SSEF is however a very fine example in size and clarity for this gemstone variety. It showed an interesting three-dimensional pattern of needle-like inclusions (Figure 2) and some small fissures filled with a minor amount of oil.

△ **Figure 3:** our diaspore samples from Afghanistan ranging in weight from 26 ct (left) to 7 ct (right) analysed recently at SSEF. Photo: A. Chalain, SSEF

Diaspore, with a chemical formula of AlO(OH), is known in the gem trade since decades from the Milas District, Mugla Province, in SW Turkey (e.g. Schmetzer & Bartelke, 1979). These stones show an interesting colour change from olive green in daylight to brownish in incandescent light. Purplish pink diaspore has been found first in limited quantities in Mong Hsu in Myanmar (Kyi & Win, 2004) and recently in larger sizes and quantities in the Nangarhar Province in eastern Afghanistan (Nicastro et al., 2020). SSEF received a series of four diaspore for testing (Figure 3), all of similar purplish pink colour and of outstanding clarity. The stones showed a distinct red fluorescence in longwave ultraviolet light due to traces of chromium, and a distinct yellowish chalky reaction under shortwave ultraviolet light, as characteristic for this new material from Afghanistan (Nicastro et al. 2020, Milisenda & Wild 2021). Chemical and absorption spectroscopy analyses confirmed the combination of traces of chromium and vanadium, as being mainly responsible for the purplish pink colour of these stones.

△ **Figure 4:** Exceptional taaffeite of 39 ct analysed recently at SSEF. Photo: L. Phan, SSEF.

One of the most outstanding purple gems encountered at SSEF in the past few months was definitely an exceptional **taaffeite** of 39 ct, reportedly originating from Sri Lanka (Figure 4). Known and sought after as a collector stone, taaffeite, ideally $BeMg_3Al_8O_{16}$, was named after Mr Richard Taaffe, who by chance discovered the first specimen of this mineral in 1945 in a jewellery shop in Dublin (Ireland). Due to its visual appearance, the specimen was offered to him as a spinel and only after his lucky discovery described as a new mineral species. Taaffeite forms a mineral group together with musgravite, another exceedingly rare mineral and gemstone from which it can only be separated by sophisticated analysis. Detailed Raman spectroscopic analyses and trace element analyses (GemTOF) clearly revealed that the described gemstone is a taaffeite, owing its attractive purple colour mainly to iron, similar to purplish spinel (Andreozzi et al. 2019, Lhuaamporn 2022). Interestingly, chromium which is known as a contributing colour cause in pink to purple taaffeite (see also Facette 2021, No. 27, pages 14-15) is present only at sub-ppm level in the described gemstone, thus certainly not contributing to its purple colour. When exposed to longwave ultraviolet light, this taaffeite exhibits a weak green fluorescence, similar as observed occasionally in spinel (Krzemnicki 2023) and commonly attributed to traces of manganese (about 800 ppm Mn in this specimen).

△ **Figure 5: A spinel with a 6-rayed star effect. Photo: L. Phan, SSEF.**

The last purple specimen described in this short note is an exceptional spinel with an attractive 6-rayed star effect submitted recently to SSEF (Figure 5). The star effect, also known as asterism, is a reflection effect on tiny oriented inclusions dispersed in the gemstone. Its visibility and pattern (e.g. 6-rayed or 4-rayed) after having been cut into a cabochon is directly linked to the amount, shape and orientation of these tiny inclusions, often small needle-like solids of fluid-tubes.

The described **purple star spinel** is outstanding in size and weight (40 ct) and has been perfectly cut to show a well-centred 6-rayed star (Figure 5). When rotating the stone in all directions, similar 6-rayed stars are visible at the end of each of the six branches, indicating a complex three-dimensional pattern of inclusions to enable such multiple star effects within one single stone (Figure 6). In addition, our analyses revealed that the colour of this purple star spinel is related to a combination of iron and chromium.

△ **Figure 6: Star effect seen at the end of one of the 6 branches (left), and dense three-dimensional pattern of oriented needle-like inclusions in this star spinel, resulting in multiple star effects on this cabochon. Photos: L. Phan & M.S. Krzemnicki, SSEF**

Light reflection effects on crystal spheres or cabochons have fascinated mineralogists and gemmologists for more than a century (see e.g. Goldschmidt & Brauns 1911: Über Lichtkreise und Lichtknoten an Kristallkugeln, Neues Jahrbuch Min. Geol. Paläntologie). Similar complex multi-star effects as observed in this purple spinel were already described in gem-quality almandine garnet and quartz (Schmetzer et al. 2002, Schmetzer & Glas 2003, Schmetzer & Krzemnicki 2006). To see this effect so beautifully exhibited in a spinel of this size can be definitively considered rare.

The aim to present in this short note this exclusive selection of rare and uncommon purple gemstones was not only to describe their specific gemmological properties, but also to show their beauty and quality, which make them attractive gemstones to fall in love with for gemmologists, collectors and gem aficionados.

✶ **Dr. M.S. Krzemnicki**

AT THE FRONTIER OF RESEARCH: IRRADIATION EXPERIMENTS ON CORUNDUM

△ **Figure 1:** A linear accelerator (LINAC) for radiosurgery by the company ZAP-Surgical. In collaboration with a specialised radiosurgery institution in Switzerland, the SSEF has started last year with its own irradiation experiments on corundum using such a next-generation high-tech device. Photo: ZAP-Surgical.

As is known in the gem trade, the colour of certain gems may be caused or influenced by the presence of colour centres (a type of defect in the crystal structure that can absorb light and thus result in colour, that can be present both in stable or unstable form). Such colour centres can be present and active naturally, or can be created or activated artificially, e.g. by an irradiation treatment. An unstable colour centre may result in a reduction of colour saturation, as in certain yellow sapphires, or in a shift of colour as in certain fancy sapphires of padparadscha-like colour over time (see also article on page 61 in this SSEF Facette). Consequently, SSEF has since many years been testing the colour stability of yellow sapphires and padparadscha sapphires submitted to the lab. More recently we have also started to apply our colour stability protocol to rubies exhibiting a slightly orange secondary hue, specifically but not limited to rubies originating from Mozambique (see SSEF Newsletter from March 2022, https://www.ssef.ch/media/). So far, after having tested hundreds of rubies in the past few months, we have not encountered a single ruby showing an unstable colour after testing.

However, in light of information gathered over the past year from several reliable sources in the trade, it is known that a number of rubies (e.g. of purplish tint) and purple to pink sapphires have been treated by a small number of individuals using cancer radiotherapy equipment to enhance their colour. These stones were usually sold undisclosed. The irradiation treatment can induce a yellowish colour centre in corundum that results in a shift to a more attractive colour hue (e.g. purplish red shifts to red). Based on our latest knowledge, this treatment may induce a notable colour shift which is to some extent unstable. However, the colour will not fully shift back to the original state when exposed to a colour stability test, thus the treatment still results in a colour enhancement when compared to the initial colour of such stones.

△ **Figure 2:** Research samples after a gamma irradiation experiment carried out by SSEF. The rubies used for this experiment have not really changed their colour, whereas the originally pink sapphires have become distinctly orange. Photo: H.A.O. Wang, SSEF.

Our approach to this major challenge to the trade is on two levels. Firstly, by expanding our colour stability testing protocol also on certain rubies (see above), and secondly and most importantly by investing important resources into research on this highly complex issue. For this, we have started a collaboration with a specialised radiosurgery institution in Switzerland, using their linear accelerator (Figure 1) to irradiate well characterised ruby and pink sapphire samples with high radiation doses (Figure 2).

These experiments are still ongoing, but we hope that we find analytical criteria to detect such irradiation treatment applied to corundum. We can already say that we were successful in shifting the colour for some of our samples by our own treatment from pink to orange.

We are confident to be able to update our clients and the trade in the near future about our findings and potential criteria to detect this treatment.
✶ **Dr. M.S. Krzemnicki, SSEF**

SSEF GEMTRACK™: VERSATILE TRACKING SOLUTION FOR THE TRADE

There is growing demand for traceability and transparency—including tracking (from mine to market) and tracing (from market to mine)—of gemstones in the jewellery industry. The Swiss Gemmological Institute SSEF has decades of experience in providing scientific opinions regarding claims of origin (geographical and whether a gem is natural or synthetic) and whether or not a gem has been treated. Gemmological approaches will continue to be important in supporting supply chain integrity and maintain consumer confidence in rare natural gemstones. In addition to existing services, new and combined gemmological techniques (based on unique features within a stone) are being developed to enhance documentation of stones as they journey from mine to market. As such, the Swiss Gemmological Institute has launched successfully our GemTrack™ in January 2019 as a new service to the trade.

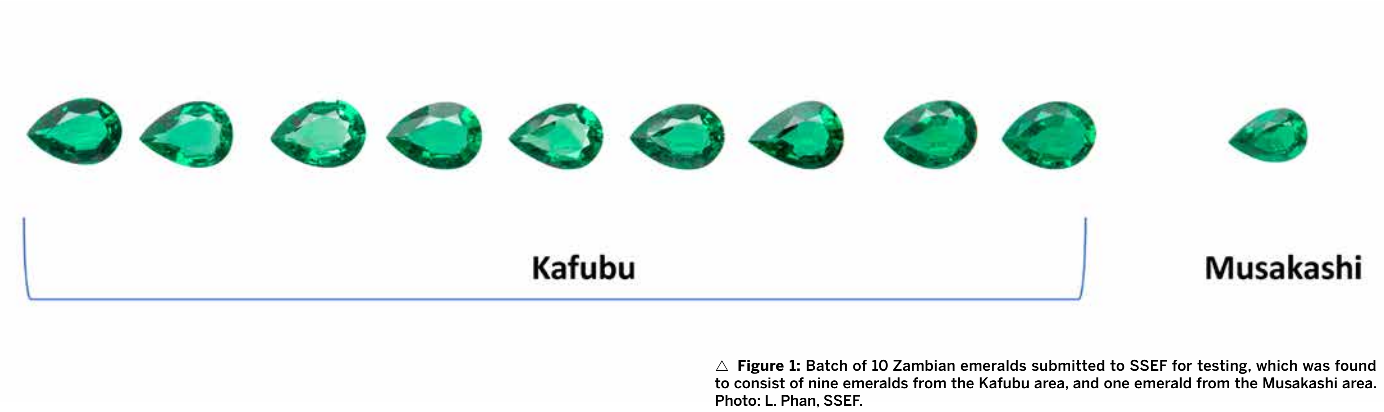
A SSEF GemTrack™ document links a cut stone to a specific initial stone (rough or cut) using gemmological techniques. It is based on a combination of crystallographic, structural, chemical and microscopic analyses that allow for detailed and potentially unique characterisation and fingerprinting of any stone. These same features are later investigated in the stone when resubmitted to SSEF a second time, for example after the cutting and polishing process. Only after this second check, a GemTrack™ document is issued by SSEF.

In the past few months, the SSEF has provided this service to a wide range of clients, from mining companies to gemstone dealers and jewellery brands. The stones were either tracked from rough to cut, from cut to recut, or from loose to set in jewellery.

From the reaction of our clients, we see that they consider the SSEF GemTrack™ a very versatile tracking solution for their specific documentation requirements, but mostly also as a perfect tool to transmit the fascinating journey of a gemstone from rough to being set in jewellery to their customers.

For any further information about our SSEF GemTrack™ service, please check our website https://www.ssef.ch/gemtrack/ or contact us directly at SSEF (phone: +41 61 262 06 40, email admin@ssef.ch).

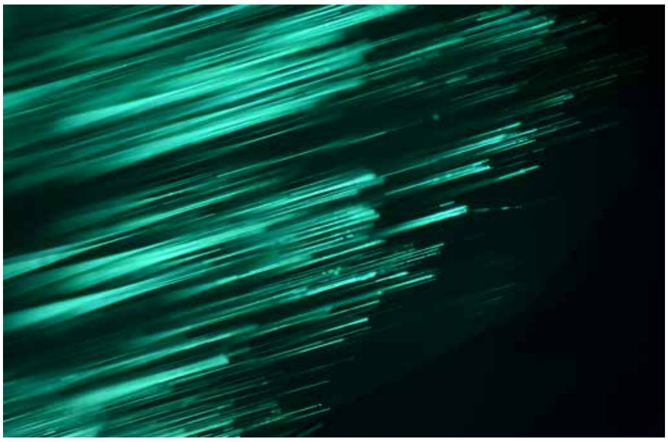
EMERALDS FROM MUSAKASHI (ZAMBIA) AND NOT FROM AFGHANISTAN



△ **Figure 1:** Batch of 10 Zambian emeralds submitted to SSEF for testing, which was found to consist of nine emeralds from the Kafubu area, and one emerald from the Musakashi area. Photo: L. Phan, SSEF.

In 2018, we first reported about new emeralds, reportedly originating from the Panjshir Valley in Afghanistan (SSEF Facette 2018, No. 24, pages 12-13). Some of this new material was of outstanding quality, thus a small but promising new production for the market. Advanced research in late 2021 showed that these "new" emeralds were in reality originating from the Musakashi area in Zambia. Consequently, we informed the few clients who had previously submitted such stones to SSEF about these new findings. In addition, we published a press release (November 2021) and a short article in the Journal of Gemmology (December 2021) about Musakashi emeralds and our findings. The following is a slightly adapted version of the article from the Journal of Gemmology with the intention to give more background information about Musakashi emeralds.

Zambia has been known for many decades as a major source of gem-quality emeralds. Most of the production comes from the Kafubu area, about 45 km southwest of Kitwe in in Zambia's Copperbelt Province. In early 2000, a new emerald source was discovered at Musakashi in the Solwezi District of central Zambia (Zwaan et al. 2005), about 160 km west of Kitwe. However, there has been very limited production from Musakashi until somewhat recently, partly due to equipment problems and legal issues concerning the mining concessions (Klemm 2010; Pardieu et al. 2015).



△ **Figure 2:** Dense pattern of parallel hollow channels in an emerald from Musakashi, Zambia. Photo: M.S. Krzemnicki, SSEF.

Interestingly, Musakashi emeralds are very different in their formation and occurrence from the "classic" schist-hosted Kafubu material. According to Manyepa & Mutambo (2021), Musakashi emeralds are found in "random pockets" related to weathered metasediments that are cross-cut by hydrothermal veins. They are reminiscent of Colombian emeralds, and to some extent those from Panjshir (Afghanistan) and Davdar (China), notably in the presence of spiky three-phase and multi-phase inclusions, as well as fine hollow channels parallel to the c-axis (Figure 2).

△ **Figure 3:** Emerald of 2.4 ct from Musakashi, Zambia, exhibiting excellent clarity and colour. Photo: L. Phan, SSEF

In late 2021, the Swiss Gemmological Institute SSEF received a parcel of 10 emeralds weighing a total of approximately 5 ct (Figure 1; see also SSEF press release November 2021). Whereas nine of these stones revealed classic features of Zambian emeralds from the Kafubu area (e.g. brownish mica flakes, amphibole fibres and rectangular two-phase inclusions), one stone was quite different and showed characteristics consistent with emeralds from Musakashi. Chemical analysis by LA-ICP-MS (GemTOF, see www.gemtof.ch) confirmed a Musakashi origin by comparison to data from reference samples from this locality that were recently added to SSEF's research collection.

The Musakashi emeralds investigated so far by SSEF chemically resemble Colombian stones in many aspects (see also Zwaan et al. 2005; Saeseaw et al. 2014). Their main chromophore is Cr (about 0.42–0.78 wt.% Cr_2O_3), together with V and Fe in similar concentrations (0.15–0.41 wt.% V_2O_3 and 0.22–0.42 wt.% Fe_2O_3). In addition, they contain only low-to-moderate concentrations of alkali elements, and—similar to Colombian emeralds—their FTIR and Raman spectral features show predominantly type I water (Wood & Nassau 1968). This all is very much in contrast to the more Fe-rich emeralds from classic schist-type deposits in the Kafubu area of Zambia. The Kafubu emeralds show a Fe/Cr ratio in the range of 6.5–20, compared to just 0.33–0.84 in the studied samples from Musakashi.

As mentioned above, these new analyses clearly revealed that the emeralds described in 2018 as "new" Afghanistan material (see also Krzemnicki et al. 2021) in fact were originating from Musakashi. This insight is based on additional and new LA-ICP-MS data acquired on references samples hand-picked from the original site in Zambia.

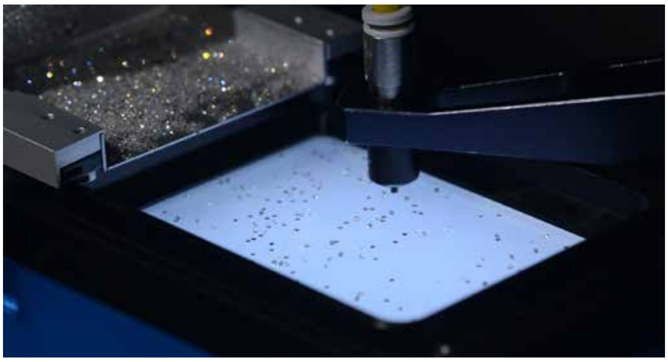
It is often challenging for laboratories to investigate gem material from new sources. Apart from our own field trips to mining sites, we as any lab also depend on obtaining reliable information from trade members and miners (e.g. Manyepa & Mutambo 2021), as accessibility to the deposits is not always possible, especially in difficult times such as during COVID-19. Nevertheless, studying samples from new and lesser-known deposits gives us greater insights into the different formation mechanisms of emerald deposits. This ultimately supports origin determination work, but also means that occasionally we have to update our findings and conclusions when new scientific evidence is pertinent.

Having now seen additional fine-quality Musakashi emeralds in the 2–5+ ct range (Figure 3), we assume that production from there has increased, and that more of these interesting emeralds will appear on the market in the near future.

✶ **Dr. M.S. Krzemnicki**

ASDI-500, WORLD'S MOST PRECISE AUTOMATED SMALL SYNTHETIC DIAMOND SCREENER

△ **Figure 1:** The ASDI-500 was launched in November 2022 at the international GemGenève Gem & Jewellery Show. Photo: SSEF.



△ **Figure 2:** With an amazing precision of one micrometer, the robot of the ASDI-500 pilots the screening of melee diamonds as small as half a millimeter, or 500 microns, hence the name of the device. Photo: SSEF.

The ASDI-500 is an offspring of the ASDI, which was developed in 2014 to support the Swiss watch and jewellery industries in authenticating natural diamonds and screening any undisclosed synthetics or simulants that may have entered the market. The ASDI was a ground-breaking instrument that was the first device that could verify large quantities of colourless diamonds automatically. With the introduction of the ASDI-500 in November 2022 at the GemGenève show, the industry now has access to the first automated authentication device designed specifically for the smallest melee diamonds. Able to screen very large quantities of round colourless polished melee, detecting and extracting synthetics and simulants from among the natural diamonds, the ASDI-500 is the only system operating today that has the degree of precision to handle stones as small as 500 microns (0.5 mm) in diameter.

Developed by the Swiss Gemmological Institute SSEF and UNIMEC SA, a robotics company also headquartered in Switzerland, the ASDI-500 is able to analyse round polished diamonds ranging in diameter from 0.50 to 3.80 mm, operating at an unmatched average sorting speed of 750 stones per hour. Prior to the release of the ASDI-500, no automatized authentication solution was available for very small melee. UNIMEC integrated within the ASDI-500 its extremely fast pick-and-place robot, which has an astounding precision of positioning of 5 microns. This new instrument builds on over three decades of diamond expertise at SSEF.

The ASDI-500 accurately counts and automatically places all tested stones in one of the following bins with very low rates of referral:
• "Natural Diamond"
• "Refer"
• "Simulant"
• "Not analysed"

The ASDI-500 is the first-ever automatic machine to fill the gap between approximately 0.50 mm and 1.00 mm. To an uninformed person, this gap may seem insignificant, but traders and consumers of melee know that it represents millions of diamonds per month and is vital for the Swiss watch industry.

To watch a video of the ASDI-500 and for more information visit: https://www.sattgems.ch/asdi-500

The ASDI-500 is manufactured and commercialized by UNIMEC SA. For further details please contact: marketing@unimecsa.ch

LED LIGHT BOXES FOR STANDARDIZED LIGHTING OF COLOURED STONES AND DIAMONDS

In the past, coloured gemstones and diamonds were often examined in natural daylight, but reproducing such specific lighting conditions was challenging. Some impractical methods had been suggested, like grading only during specific hours or facing northward, especially during cloudy weather. However, modern artificial light sources that resemble daylight have been available for a long time, yet possess specific pitfalls such as: heat, noise, instability of colour temperature, flickering, aging of the diffusor, aging of filters, etc.

A collaboration between SSEF and the Department of Physics at the University of Basel recently resulted in the development of a novel light source for the purpose of colour grading of diamonds and coloured stones (see also SSEF Facette 2021, pages 42-43). Unlike many models that use incandescent bulbs or fluorescent tubes, this new light source utilizes advanced high quality LED light sources to create a natural daylight-equivalent illumination. Its Color Rendering Index (CRI) – a quantitative measure which reflects how close a light source reveals the "true" colour of an object compared to observation under natural light or a standard light source – is 98,4% at daylight (D65), thus exceptionally high and promising for colour grading purposes.

The temperature of daylight ranges from 5000 to 6500 K, and this variation can affect the perception of an object's colour, such as that of a ruby. The colour temperature of a light source plays a significant role in how we perceive the colour of objects. It is thus important to develop standardized lighting conditions.

△ **The light box being demonstrated at SSEF. Photo: SSEF.**

SSEF now offers two cabinets of different sizes for sale. Each cabinet is equipped with a specific light source allowing the user to easily switch between three different colour temperatures. The D65 illumination is provided with a normalized light intensity of 2'200 lux at 20 cm from the source (following the ISO standard 24016 for diamond grading). The other colour temperatures are useful for gemmologists for coloured stone grading and seeking to evaluate colour shifts or colour change (e.g. alexandrite-effect) of a gemstone.

Specific attention was given to designing a diffusor specifically adapted to diamond and gemstone observation. Indeed, whilst most of the available diffusors on the market are bright and will add reflected light on the observed gemstones, our diffusor is roughened with a specific mesh to bring a high comfort of observation. Additionally, our diffusor is made of glass, so that unlike plastic diffusors which alter the colour temperature of the observation light as they age, our diffusor will not change with time.

△ **A comparison of ruby colour under standardized lighting conditions in the SSEF light box. Photo: SSEF.**

The developed light source utilizes advanced LED technology, producing a nearly continuous spectrum of visible light that closely approximates natural daylight. We have sold several such light boxes to members of the trade in recent months, who use this to maintain consistency in their colour examinations of diamonds and gemstones. Our innovative light box for colour grading is available in different sizes and is available through our subsidiary company SATT Gems (www.sattgems.ch).

Small cabinet		
Inner dimensions (lxpxh in cm)	Outer dimensions (lxpxh in cm)	Weight (Kg)
63.5 x 36.0 x 34.0	70.0 x 42.0 x 51.0	10.5
Large cabinet		
Inner dimensions (lxpxh in cm)	Outer dimensions (lxpxh in cm)	Weight (Kg)
95.0 x 65.0 x 72.5	108.0 x 82.0 x 87.5	27

The advantages include:
- New generation of high-quality LED (manufacturer life-time: 10'000 hours)
- No flickering
- 3 colour temperatures
- Electronic touch screen for the selection of the colour temperature
- Home-made glass diffusor specifically designed for diamond and gemstone observations
- CRI 98,4%
- Perfect distribution of the light intensity
- Inner walls of the cabinet in normalized neutral Munsel gray conditions

SEASON HIGHLIGHTS SOLD WITH SSEF REPORTS

Sapphire and diamond pendant-necklace with an unheated Kashmir sapphire of 20.18 ct sold for US$ 2,137,250 at Sotheby's New York in September 2022. Photo: Sotheby's.

Sapphire and diamond necklace and pendants by Reza with 12 unheated sapphires (central necklace sapphire 48.349 ct) of Ceylon origin. Sold for ca. US$ 1,507,000 at Christie's Geneva in May 2022. Photo: Christie's.

Pair of unheated Kashmir sapphires (8.93 ct and 8.76 ct) of 'royal blue' colour mounted in earrings sold at Christie's Hong Kong for ca. US$ 3,186,000 in November 2021. Photo: Christie's.

12.73 ct unheated 'royal blue' Kashmir sapphire sold for ca. US$ 2,634,000 at Sotheby's Geneva in November 2022. Photo: Sotheby's.

28.37 ct unheated Kashmir sapphire mounted in a Harry Winston ring sold for ca. US$ 2,666,000 at Sotheby's Hong Kong in October 2021. Photo: Sotheby's.

Unheated Ceylon sapphire of 28.84 ct set in a ring sold for ca. US$ 461,000 at Sotheby's Geneva in May 2021. Photos. Sotheby's.

Bracelet containing nine unheated Kashmir sapphires (29.89 ct total) sold by Christie's Hong Kong in November 2021 for ca. US$ 2,648,000. Photo: Christie's.

1930s brooch with two unheated Kashmir sapphires weighing 55.19 ct and 25.97 ct. This brooch sold for ca. US$ 3,912,000 at Sotheby's Geneva in May 2021. Photo: Sotheby's.

Harry Winston sapphire and diamond necklace. The sapphire is unheated and of Sri Lankan (Ceylon) origin and a 'royal blue' colour. Sold for ca. US$ 4,717,000 at Sotheby's Geneva in May 2021. Photo: Sotheby's.

126.43 ct unheated Ceylon sapphire mounted in a Harry Winston necklace sold by Sotheby's Geneva for ca. US$ 2,303,000 in May 2021. Photo: Sotheby's.

Burmese sapphire (unheated, 'royal blue' colour) of 20.16 ct in a Cartier ring sold for ca. US$ 2,819,000 by Sotheby's Geneva in November 2022. Photo: Sotheby's.

Kashmir sapphire of 16.46 ct (unheated, 'royal blue' colour) sold at Sotheby's New York in December 2022 for US$ 2,167,500. Photo: Sotheby's.

Unheated Burmese ruby set in a Van Cleef & Arpels brooch sold at Christie's Geneva for ca. US$ 4,572,000 in November 2021.

Ruby and diamond earrings with unheated Burmese rubies (5.19 ct and 5.03 ct) of 'pigeon blood red' colour sold for ca. US$ 3,186,000 at Christie's Hong Kong in November 2021.

Unheated Burmese ruby of 13.02 ct mounted in a ring by Carvin sold in June 2021 at Sotheby's New York for US$ 2,500,500. Photo: Sotheby's.

Unheated Burmese ruby mounted in an F.J. Cooper ring fetched US$ 1,650,000 in April 2021 at Sotheby's New York.

10.13 ct unheated Mozambique ruby set in a Tiffany & Co. ring sold for ca. US$ 1,005,000 in April 2021 at Sotheby's Hong Kong. Photo: Sotheby's.

Ruby and diamond necklace by Faidee containing 38 unheated rubies (total 31.03 ct) from Burma (Myanmar). Sold at Christie's Hong Kong for ca. US$ 773,000 in May 2021. Photo: Christie's.

Star ruby and diamond brooch by Van Cleef & Arpels sold in October 2021 for ca. US$ 454,000 at Sotheby's in Hong Kong. The nine star rubies show strong asterism, are of Burmese (Myanmar) origin, with no indications of heating. Photo: Sotheby's.

Unheated Burmese 4.95 ct ruby mounted in a ring fetched ca. US$ 452,000 at Phillips Hong Kong in November 2022. Photo: Phillips.

Ring with an oval ruby (Burma, no heat, 'pigeon blood red' colour) weighing 7.64 ct sold in October 2022 at Sotheby's Hong Kong for ca. US$ 1,589,000. Photo: Sotheby's.

Ruby and diamond brooch by Chaumet, circa 1928. The rubies are of Burmese origin, with no indications of heating, two with a minor amount of oil in fissures. Sold for ca. US$ 626,000 at Sotheby's Geneva in May 2021.

6.05 ct unheated Burmese 'pigeon blood red' ruby in a ring sold for ca. US$ 3,879,000 in May 2022 at Christie's Hong Kong. Photo: Christie's.

Moussaieff necklace with emeralds weighing from 1.57 to 14.08 ct, of Colombian origin, with a minor to moderate amount of oil in fissures. Sold for ca. US$ 2,973,000 at Sotheby's Geneva in May 2021. Photo: Sotheby's.

Cuff bangle containing five emeralds (from 3.82 to 1.25 ct in weight) all of Colombian origin with no indications of clarity modification. Sold by Sotheby's Hong Kong in April 2022 for ca. US$ 385,000. Photo: Sotheby's.

Sautoir with four rows of emerald beads weighing a total of 572.24 ct. All the beads are of Colombian origin with indications of minor to moderate amount of oil clarity modification. Sold for ca. US$ 401,443 at Sotheby's Hong Kong in April 2022. Photo: Sotheby's.

12.64 ct emerald set in a ring, Colombian origin and no indications of clarity modification. Sold for US$ 976,500 in December 2022 at Sotheby's New York. Photo: Sotheby's.

Emerald and pink diamond earrings with two Colombian emeralds of 7.32 and 6.46 ct (both no indications of clarity modification). Sold at Christie's Hong Kong for ca. US$ 2,041,000. Photo: Christie's.

80.45 ct emerald of Colombian origin, with a minor amount of oil in fissures. Sold at Sotheby's Geneva for ca. US$ 3,510,000 in May 2021. Photo: Sotheby's.

Pair of emerald and diamond pendent ear clips, with two emeralds of 15.73 and 16.71 ct respectively, both of Colombian origin and with a minor amount of oil in fissures. Sold by Sotheby's Geneva in May 2021 for ca. US$ 1,739,000. Photo: Sotheby's.

104.40 ct pear-shaped emerald of Colombian origin, with a moderate amount of oil in fissures mounted in a Harry Winston brooch/pendant combination. Sold for ca. US$ 1,967,000 at Sotheby's Geneva in May 2021. Photo: Sotheby's.

31.99 ct Colombian emerald with minor oil set in a Van Cleef & Arpels necklace. Sold for ca. US$ 1,677,000 at Christie's Geneva in November 2021. Photo: Christie's.

Emerald and diamond bracelet containing twelve Colombian emeralds of 4.18 to 1.43 carat (29.75 ct total) with no indications of clarity modification. Fetched ca. US$ 1,250,000 at Christie's Hong Kong in May 2022. Photo: Christie's.

Chaumet emerald and diamond ring, with a Colombian emerald of 17.80 ct having no indications of clarity modification. Sold for ca. US$ 1,871,000 at Christie's Geneva in May 2022. Photo: Christie's.

Late 19th century natural pearl and diamond tiara / necklace. Sold in April 2021 at Sotheby's Hong Kong for ca. US$ 308,000 Photo: Sotheby's.

JAR pearl and diamond necklace, containing two hundred and fifteen saltwater natural pearls. Sold at Christie's Geneva in November 2021 for ca. US$ 1,875,000.

Pair of saltwater natural pearls measuring approx. 13.45 - 14.90 x 23.00mm and 12.95 - 14.70 x 24.35mm respectively. Sold in November 2021 at Sotheby's Hong Kong for ca. US$ 1,102,000. Photo: Sotheby's.

Van Cleef & Arpels natural pearl (25.13 ct) and diamond brooch sold for ca. US$ 617,000 at Christie's Geneva in November 2021.

Bulgari and Asprey natural pearl and diamond pendent necklace containing saltwater natural pearls ranging from 13.50 to 2.05 mm sold for ca. US$ 417,000 at Christie's Hong Kong in May 2022.

Loose natural Melo pearl weighing 75.61 ct, sold for ca. US$ 95,000 at Sotheby's Geneva in May 2022.

Natural Melo pearl of 138.770 ct (555.08 grains) mounted in a copper necklace by Hemmerle. Sold for ca. US$ 192,000 at Sotheby's Geneva in November 2022. Photo: Sotheby's.

The Rockefeller pearl, a fine Gillot & Co. (ca. 1900) antique natural pearl and diamond pendant. Sold for US$ 700,000 at Christie's New York in December 2021.

Necklace containing sixty-two saltwater natural pearls of 10.90 to 6.05 mm. Sold for ca. US$ 483,000 at Christie's Hong Kong in May 2021.

19th century natural pearl and diamond tiara with 23 saltwater natural pearls. Sold for ca. US$ 2,416,000 at Christie's Geneva in May 2022.

JAR saltwater natural pearl and diamond earrings. Sold for US$ 870,000 at Christie's New York in June 2021.

Natural pearl and diamond tiara/ necklace, containing eleven saltwater natural pearls. Sold for ca. US$ 1,472,000 at Sotheby's Geneva in May 2021.

Unheated red spinel of 21.02 ct of Tanzanian origin, sold by Sotheby's Geneva for ca. US$ 481,000. Photo: Sotheby's.

10.13 ct copper- and manganese-bearing tourmaline from Nigeria, also called 'Paraiba tourmaline' in the trade. It is currently not possible to determine if the tourmaline has been heated or not. Sold for US$ 239,400 at Sotheby's New York in December 2022. Photo: Sotheby's.

Oval jadeite-jade (Fei Cui) type A cabochon of 23.09 ct mounted in a ring, fetched ca. US$ 562,000 at Sotheby's Hong Kong in October 2022. Photo: Sotheby's.

Unheated pink sapphire of Burmese origin weighing 20.39 ct. Sold for ca. US$ 1,896,000 in November 2022 by Sotheby's Geneva. Photo: Sotheby's.

11.54 ct padparadscha sapphire of Ceylon origin, with no indications of heating. Mounted in a ring with diamonds, sold for ca. US$ 610,000. Photo: Sotheby's.

Grandidierite of nearly 7 ct mounted in a ring. Sold for US$ 75,312.50 at Bonhams in Hong Kong in June 2021.

Early 20th century spinel and diamond necklace containing thirty-five unheated pink spinels from Tajikistan. Sold for ca. US$ 563,000 at Christie's Geneva in November 2022.

Paraiba tourmaline and diamond ring. The tourmaline weighs 21.63 ct, is of Mozambique origin and it is currently not possible to determine if the tourmaline has been heated or not. Sold for ca. US$ 532,000 by Sotheby's Geneva in May 2022.

Unheated imperial topaz weighing 54.22 ct set in a brooch. Sold for ca. US$ 564,000 by Sotheby's Geneva in November 2022. Photo: Sotheby's.

Spinel and diamond bracelet containing fifteen unheated Burmese spinels (total weight: 36.20 ct). Sold for ca. US$ 612,000 at Christie's Hong Kong in May 2021.

Unheated Ceylon yellow sapphire (129.08 ct), gem set and diamond brooch. Sold for ca. US$ 151,000 at Sotheby's Geneva in November 2021. Photo: Sotheby's.

Paraiba tourmaline (Brazil) of 14.20 ct with indications of heating. Sold for ca. US$ 805,000 at Christie's Hong Kong in May 2021.

Pink sapphire, sapphire and diamond brooch, with an unheated pink sapphire of 92.01 ct from Ceylon. Sold for ca. US$ 1,774,000 at Sotheby's Geneva in November 2022. Photo: Sotheby's.

Paraiba tourmalines from Brazil,
Mozambique and Nigeria. Photo: SSEF.

COURSES IN 2023 AT SSEF

During 2021 and part of 2022, international travel was greatly reduced, which resulted in a decrease in activity for our courses at SSEF. Nevertheless, we took advantage of this situation and utilized the extra time to introduce free online courses and revamp some of our existing courses. We are pleased that the revamped Scientific Gemmology Course (SGC) that focuses on portable scientific instruments for gemmological analysis has been so well received. Our course on the history of gems and jewellery has also received a lot of positive feedback.
In 2023, we will again be offering a wide range of courses. The SSEF Basic Gemmology Course (09 – 20 October 2023) and the SSEF Basic Diamond Course (23 - 27 October 2023) offer good introductions, and participants can pass the courses after taking theoretical and practical examinations. For more in-depth courses we offer Advanced Training Courses on coloured gemstones, pearls, small diamonds, and the history of gems and jewellery. Finally, the Scientific Gemmology Course (SGC) is an ideal course for those interested in learning about the advanced instruments used in laboratory gemmology today.
As a Gem-A approved practical provider, we also offer ODL Gem-A students the possibility of taking the practical workshops and exams with us in Basel.

ADVANCED PEARL COURSE

This two-day pearl course (06 - 07 November 2023) 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. The last remaining spots are available for the next courses 19 – 23 June 2023 and 20 – 24 November 2023. 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.

ADVANCED GEMS & JEWELLERY COURSE

This advanced training course "Gems & Jewellery: History, Identification and Important Trends" is unique in that it combines the history and significance of gems in historic and modern jewellery. You will learn about all the different uses of gems, and how these link with different periods of jewellery. Through this approach you will learn about criteria to identify jewellery with gems, and gain insight into possible criteria for valuation. This course is taught in small groups, and will include workshops and practical work on a wide range of jewellery pieces. It is taught in collaboration with jewellery historian Kathia Pinckernelle. Learn more about antique jewellery and the use of gemstones through the ages by signing up for the course in 27 November – 01 December 2023.

ADVANCED SMALL DIAMOND COURSE

The SSEF small diamond course (26 – 28 September 2023), which focuses on diamonds of a diameter between 0.5 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

The one-week Scientific Gemmology course focuses on scientific aspects of gemmology, but with the use of portable instruments. This includes learning about techniques and applications of instruments like X-Ray fluorescence spectrometry, UV-Visible-NIR spectroscopy, GemTOF (not portable), Raman and FTIR spectrometry in the field of gemmology, as performed at SSEF with testing setups that we use when we travel abroad for on-site testing. 2023 dates include 03 – 07 July 2023 and 13 – 17 November 2023.

SSEF TAILORED 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 2021 and 2022, a number of companies benefited from such courses that were tailored to specific topics including small diamond quality control, diamond treatments, overview of gemstone treatments and origins, 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.

To be informed of 2023 and 2024 course dates: check our website, follow us on social media (Instagram, LinkedIn, and Twitter) or subscribe to our newsletter (https://www.ssef.ch/newsletter/)

ATC Gems & Jewellery	17 – 20 April 2023
ATC Coloured Stones	24 – 28 April 2023
ATC Coloured Stones	19 – 23 June 2023
Scientific Gemmology Course SGC	03 – 07 July 2023
ATC Small Diamonds	26 – 28 September 2023
Basic Gemmology Course BGC	09 – 20 October 2023
Basic Diamond Course BDC	23 – 27 October 2023
ATC Pearls	06 – 07 November 2023
Scientific Gemmology Course SGC	13 – 17 November 2023
ATC Coloured Stones	20 – 24 November 2023
ATC Gems & Jewellery	27 November – 01 December 2023

CONGRATULATIONS!

The Swiss Gemmological Institute SSEF would like to extend their congratulations to the individuals who successfully completed the courses offered in 2021 and 2022:

Basic Gemmology Course

- Lajos Mazug
- Irina Vikulova
- Sebastiano Sorbello
- Hewad Samir Ghani
- Iman Akhtari
- Alessandro Anghinoni
- Juan Camilo Blanco
- Alessandro Sibilia
- Sullivan Taylor
- Anuschka Waser
- Marina Stomeo
- Tanja Nievergelt
- Marie-France Wullschleger
- Mariko Guillemant
- Riccardo Corticelli
- Arne Kapfer
- Wenqing Zhou
- Sofia Kolmar
- Mahima Verma
- Merel Eland
- Alexandra Jolobova Faure
- Martina Krummenacher
- Michäel Mintrone
- Carole Lachavanne
- Duke Kim
- Audrey Hourquet
- Ryan Briggs
- Riqin Kong
- Violaine Bigot
- Joanne Ryder
- Camille Cuvelier
- Jiaqian Chen
- Marta Hadala
- Anuschka Waser
- Elena Staub
- Shay Kothari
- Stephen Portier
- Chaityam Rathod
- Carole Lachavanne
- Vibhor Saraf
- Davide Busatti
- Andrea Callegari
- Akitsugu Sato
- Wyler Weir
- Elie Chehaibar
- Elise Lambert
- Olympe Fillet
- Songsook Han
- Elena Bravo
- Iryna Omelchenko
- Michella de Carvalho Cruz
- Jiaqian Chen
- Tommaso Peron
- Thomas Weller
- Rossana Ferrarese
- Stefania Suter
- Riqin Kong
- Melissa Wolfgang Amenc
- Akitsugu Sato

Basic Diamond Course

- Ulf Brosowski
- Ionut Cosoveanu
- Corina Quattrocchi
- Anuschka Waser

Advanced Gemstone Course

- Astrid Bosshard
- Archit Rakyan
- Renée König
- Alex Arov
- Marco Massavelli
- Michel Aziz
- Paul Lubetsky

Advanced Gems & Jewellery History Course

- Olympe Fillet
- Elena Staub
- Marie-France Wullschleger
- Marta Mainardi
- Violaine Bigot
- Joanne Ryder
- Céline Mortessagne
- Songsook Han
- Tingting Balmer
- Daline Baumann
- Juliette Cros
- Marion Laurent

Advanced Pearl Course

- Linda Schwieger
- Olympe Fillet
- Violaine Bigot
- Sally Klarr
- Yasmine Bourbouillon Esdras
- Joanne Ryder
- Pei Hsun Wang
- Kathrin Schillinger-Kobel
- Lara Van Oppens
- Maxim Van Oppens
- Noam Lenzini
- Benjamin Guttery
- Carole Lachavanne

Scientific Gemmology Course

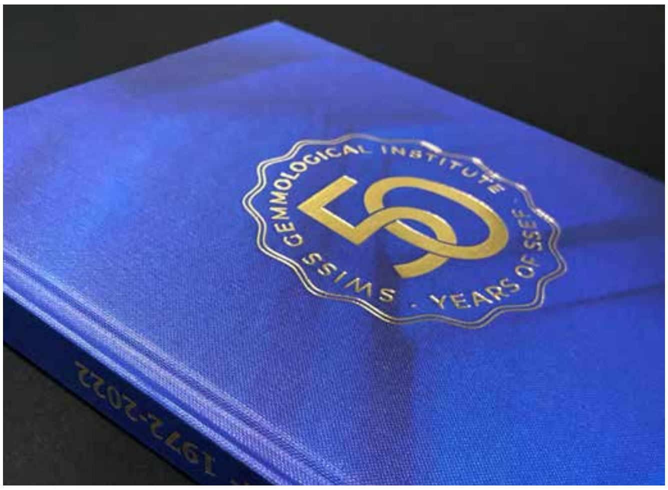
- Max Berent
- Ursula Neuwald
- Stefania Suter
- Reneé König
- Mingyue Yang
- Marc Segers
- Madani Najmudeen
- Martin Mikus
- Ishtiyaaq Ahamed
- Thomas Weller

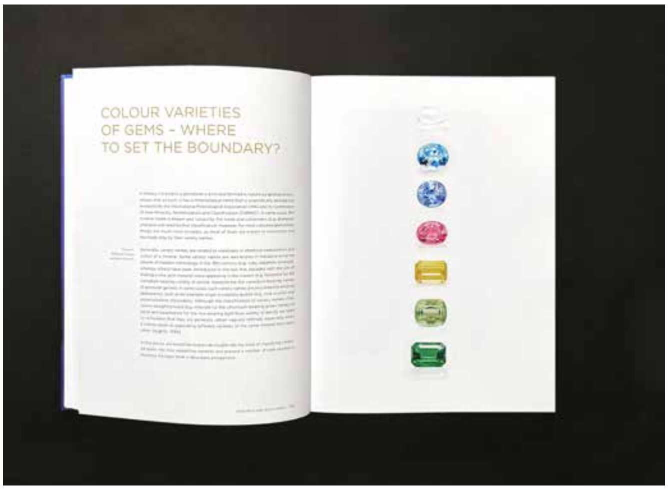
△ Participants in the October 2022 Advanced Gems & Jewellery Course at SSEF.

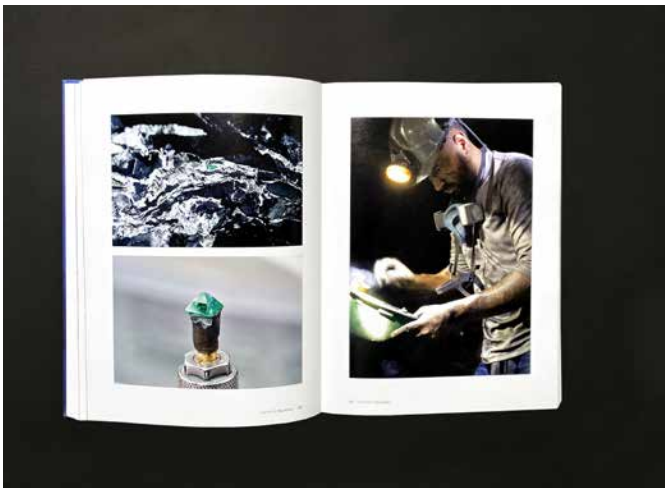
△ July 2022 Scientific Gemmology Course students at SSEF.

BOOK PUBLISHED ON 50 YEARS OF SSEF

To celebrate the 50 year anniversary of SSEF we have published a beautiful book. The book covers SSEF's history along with major research discoveries, photos of expeditions to mines, and a selection of outstanding items tested over the past five decades. To obtain a copy, please contact us (admin@ssef.ch).







ONLINE COURSES: NOW IN TRADITIONAL CHINESE, JAPANESE AND BURMESE AND EXPANDED WITH NEW GARNET, OPAL, SPINEL AND TOURMALINE MODULES

SSEF introduced a collection of online courses in April 2021 named "Understanding Gemstones", which are offered at no cost. Each course is centered on a particular gemstone and provides in-depth knowledge, and students have the flexibility to learn at their own pace through the web-based platform.

Initially these courses were available in English, French, and simplified Chinese, and covered diamonds, emeralds, pearls, rubies, and sapphires. Since 2021, they have become available in traditional Chinese, Japanese and Burmese too.

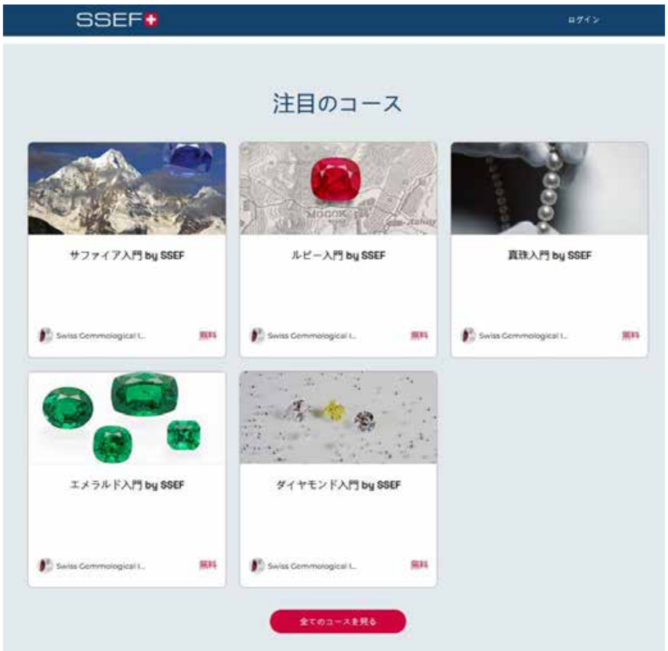
To date, there have been more than 16,000 sign-ups and active students participating on the teaching platforms. Indeed, it was in response to greater demand for such gemmological education and knowledge in Asia that SSEF has decided to roll out courses in three additional languages.

Interest in gems has grown tremendously in recent years and there is strong demand for information about gemstones that have only in more recent decades received more attention. As such, in the spring of 2023 we have launched new course modules on garnets, opals, spinels and tourmalines.

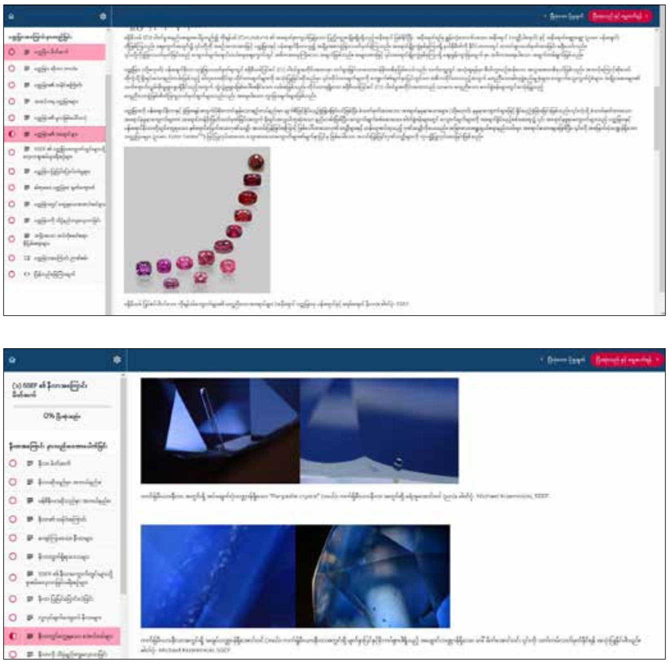
Making gem-learning resources available at no cost to the trade and consumers remains a priority for us. We are pleased to be able to make them even more widely available, and to further connect with the gem and jewellery community in Asia. Wide participation from over a hundred countries shows there is international appetite for gemmological knowledge.

To view all the available free online courses visit https://www.ssef.ch/masterclass

✶ **Dr. L.E. Cartier**



△ Online gem education provided by SSEF in Japanese for free.

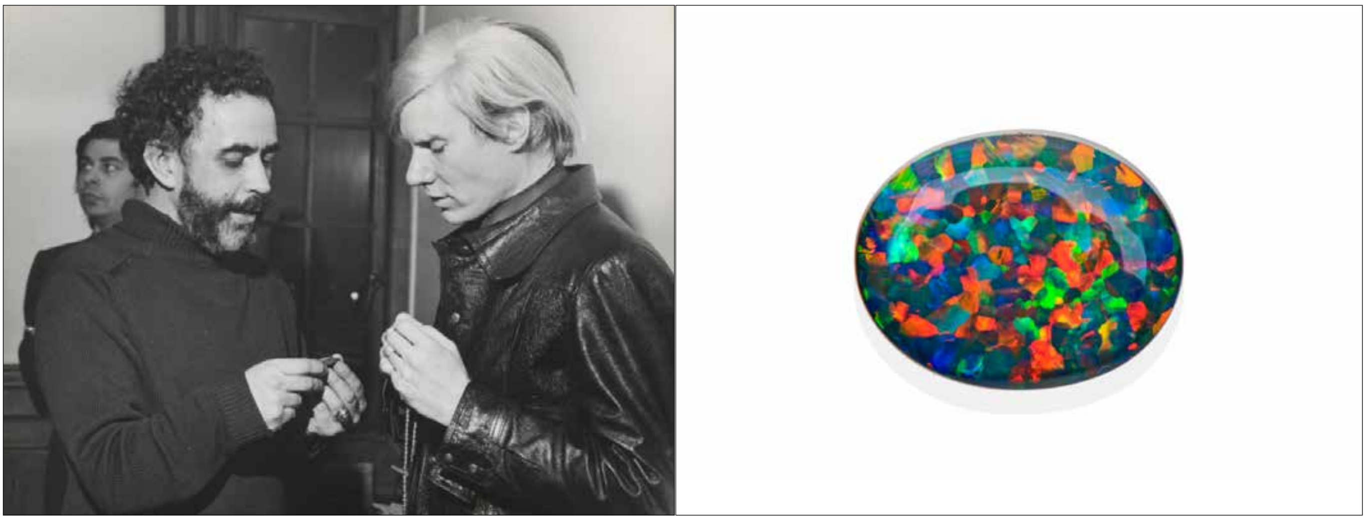


△ SSEF free online courses on ruby and sapphire now also available in Burmese.

△ Paraiba or not? Find out by learning more with our new tourmaline course. Photo: L.E. Cartier, SSEF.

△ Learn all about cobalt-blue spinels and all the other types of spinels. Photo: SSEF.

△ Enhance your knowledge of various varieties of garnets. Photo: SSEF.



△ Did you know that Andy Warhol was a big fan of opals? Learn more about this fantastic gem in our online opal course. Photos: Harrison & Laking Ltd and SSEF.

NEW: SPECIAL LETTER FOR HEAVILY FISSURED GEMSTONES

◁ **Figure 1:** Numerous and distinctly visible fissures in a Colombian emerald after full cleaning. Such a stone would require fissure filling treatment to be made more visually appealing for use in jewellery. Photo: A. Chalain, SSEF.

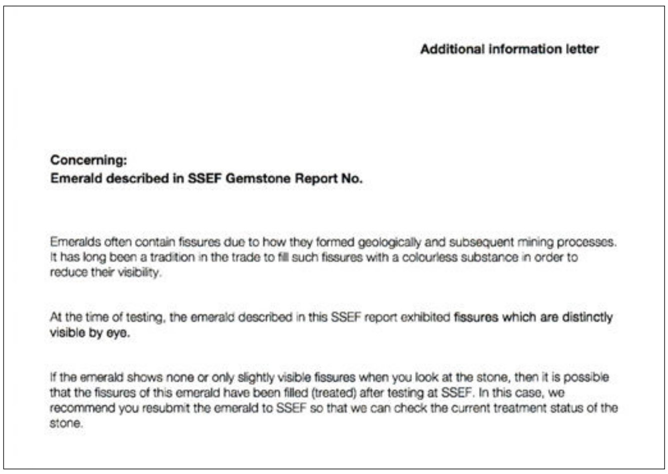
Fissures in emeralds or any other gemstone are often filled with a colourless substance (e.g. oil) to visually enhance their clarity. As long as such a treatment is properly disclosed then this practice is well accepted and in fact has a very long tradition in the trade since ancient times. The Roman scholar Pliny the Elder (23-79 A.D.) already describes oil treatment of gems in the 'Natural History', Book 37 about Gemstones: "Such stones [probably chalcedony], in spite of their varied colours, seem to be green by nature, since they may be improved by being steeped in oil and there is no variety that displays larger specimens" (section translated by Eichholz 1962).

As reported in previous issues of the SSEF Facette (see e.g. Facette 2021, page 36), we often see such gemstones repeatedly over the years, often cleaned and filled again at various stages over time. As part of this, we sometimes see emeralds which contain many distinct and eye-visible fissures which strongly impact the clarity and visual beauty of these emeralds. Usually, these stones have been extensively cleaned before submission to SSEF, which explains the extreme visibility of these fissures. As a consequence of the cleaning, these emeralds are described on our reports with the comment:

"No indications of clarity modification in fissures at the time of testing."

Although this comment clearly highlights the fact that this emerald contains fissures and that the absence of fissure filling material is a valid statement only at the time of examination, we strongly felt the need to inform clients and consumers more about their nature as heavily fissured emeralds.

Since May 2022, we thus add in such a case an additional information letter to the SSEF report (Figure 2), describing the presence of distinct and eye-visible fissures in the emerald (the same applies to other gems). As always, the aim is to protect the trade and consumers from issues, such as undisclosed refilling of fissures in a gemstone without an updated SSEF report indicating the newly present fissure filling material.



Additional information letter

Concerning:
Emerald described in SSEF Gemstone Report No.

Emeralds often contain fissures due to how they formed geologically and subsequent mining processes. It has long been a tradition in the trade to fill such fissures with a colourless substance in order to reduce their visibility.

At the time of testing, the emerald described in this SSEF report exhibited **fissures which are distinctly visible by eye.**

If the emerald shows none or only slightly visible fissures when you look at the stone, then it is possible that the fissures of this emerald have been filled (treated) after testing at SSEF. In this case, we recommend you resubmit the emerald to SSEF so that we can check the current treatment status of the stone.

△ **Figure 2:** Example of such an additional information letter coming along with the SSEF report in the case of a heavily fissured gemstone.

NEW WORDING: REVERSIBLE PHOTOCHROMISM OF FANCY SAPPHIRE

△ **Figure 1:** Fancy sapphire showing a shift of colour from orange to pink as a result of an interesting property known scientifically as reversible photochromism or tenebrescence. Photo: Luc Phan, SSEF.

In early 2018, SSEF published a short note in the SSEF Facette (No. 24, pages 6-7) followed by articles in the Journal of Gemmology (Krzemnicki et al., 2018) and Incolor (Krzemnicki & Cartier, 2019) describing in detail the effect of colour stability testing on certain sapphires of padparadscha-like colour due to the presence of unstable (yellow) colour centres in these stones.

As a matter of fact, when the colour centre in such a stone is activated (e.g. by a strong UV source), its colour is shifting towards a more orange hue (due to a yellow colour centre). On the other hand, when the colour centre is relaxed (e.g. when exposed to a strong light source for a few hours or even sunlight over some time), the colour shifts to a distinctly more pinkish or even pure pink colour hue resulting from the presence of trace amounts of chromium in the stone (Figure 1).

Although the instability of (yellow) colour centres has been known in gemmological science since many decades (e.g. Nassau & Valente, 1987), most laboratories commonly limited colour stability testing to yellow sapphires, not taking into account that a noticeable shift of colour might occur in pinkish orange to orangey pink sapphires, appreciated in the trade as padparadscha sapphires.

Our research findings back in 2018 led to two main immediate consequences:

1) A mandatory colour stability test for any corundum of padparadscha-like colour submitted to SSEF.

2) Corundum of padparadscha-like but showing a colour shift is not qualifying for the variety name padparadscha, but is called fancy sapphire.

This was also unanimously agreed and adapted by LMHC in 2018, see information sheet No. 4 (https://www.lmhc-gemmology.org/gemstones) and many laboratories worldwide.

The ability of certain sapphires of padparadscha-like colour (or any other mineral) to change colour when exposed to sunlight is known in scientific literature **as reversible photochromism** or **tenebrescence**. The colour shift can be repeated indefinitely back and forth when exposing the gemstone to the appropriate light sources (UV lamp, sunlight). Although a colour instability in the strict sense of the terms, this can also be considered an intriguing property of a gemstone, occurring naturally due to specific crystal structure predispositions (colour centres) and may add appeal for collectors of gems.

Consequently, and after discussion with clients and other laboratories, we have adapted since March 2022 a new wording to describe such tenebrescent fancy sapphires on our reports and additional information letter supplied together with the SSEF report.

SSEF

SPECIMEN

Identification: FANCY SAPPHIRE (variety of natural corundum)

Comments: The analysed properties confirm the authenticity of this transparent fancy sapphire.

No indications of heating.
Colour stability test performed: This fancy sapphire exhibits a colour shift known as reversible photochromism (tenebrescence). This is a natural phenomenon that occurs occasionally in fancy sapphires (see additional information letter).

50 YEARS OF SSEF: SPECIAL SYMPOSIUM IN BASEL

△ **Industry leaders and opinion-makers gather to celebrate SSEF's 50th anniversary in the prestigious Hans-Huber Saal of the Stadt Casino in downtown Basel. The day began with a conversation between Max Fawcett (left) head of the jewellery department of Christie's in Geneva and SSEF's Dr. Laurent Cartier (right). Photo: SSEF.**

For 50 years, the Swiss Gemmological Institute SSEF has been the forefront of scientific gemmological research and testing to support a thriving gemstone and jewellery trade. In tribute of both its mission and accomplishments, some 150 industry leaders and opinion-makers from around the world gathered in Basel on September 1 and 2 2022 to celebrate the golden anniversary.

Founded by Swiss trade organisations in August 1972, from its earliest days the independent Swiss Foundation for the Research of Gemstones SSEF and its lab, the Swiss Gemmological Institute, has sought to enhance knowledge, scientific research and transparency in the gemstone and jewellery trades. They did so through the efforts of expert staff and ongoing collaboration with academic institutes and technology developers in Switzerland and elsewhere.

Events organised during the anniversary celebration included behind-the-scenes tours of the SSEF lab and a beautiful gala dinner that rounded out the festivities. But the centrepiece of the gathering was a symposium in the Hans-Huber Saal of the Stadt Casino in downtown Basel. Entitled "Linking Past and Future: Visions for a Thriving Gem & Jewellery Trade," its roster of speakers included representatives from major brands and auctions houses such as Anna Hu Haute Joaillerie, Christie's, De Beers, Gellner Pearls, Sotheby's, The Muzo Companies and Van Cleef & Arpels. Renowned jewellery historian Joanna Hardy, vintage dealer Marianne Fisher and SSEF's director Dr. Michael S. Krzemnicki also shared their insights and expertise.

△ **Photographed during the SSEF golden anniversary celebration (from left to right): Martin Häuselmann, incoming SSEF Foundation Board President; Charles Abouchar, SSEF Board Member; Dr. Gaetano Cavalieri, President of CIBJO, the World Jewellery Confederation; Dr. Michael S. Krzemnicki, Director SSEF; and Marc-Alain Christen outgoing SSEF President. Photo: SSEF.**

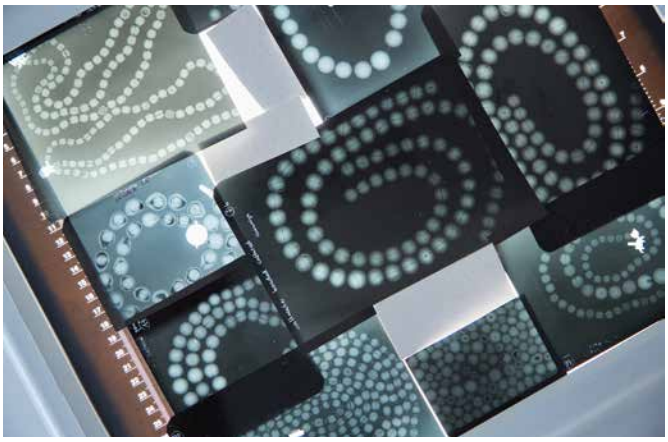
A wide range of themes were addressed including the role of auction houses, emerald mining in Colombia, provenance in the diamond industry, the state of the pearl sector, the power of gems throughout history, the rough-to-jewel journey of the iconic Lesotho Legend diamond, the role of digital in the vintage market, valuation concepts for jadeite, the past and future of gem testing, the process of designing bespoke jewellery and sourcing rare gems.

"For our industry, it is indispensable that we have widely respected and solidly independent institutions, dedicated to scientific research and excellence, and the pursuit of knowledge such as SSEF," said Dr. Gaetano Cavalieri, President of CIBJO, the World Jewellery Confederation, who travelled from Italy to attend the event. "Through tireless work and a readiness to build and share gemmological expertise, it is a cornerstone of the absolutely critical effort to maintain consumer confidence in the jewellery industry."

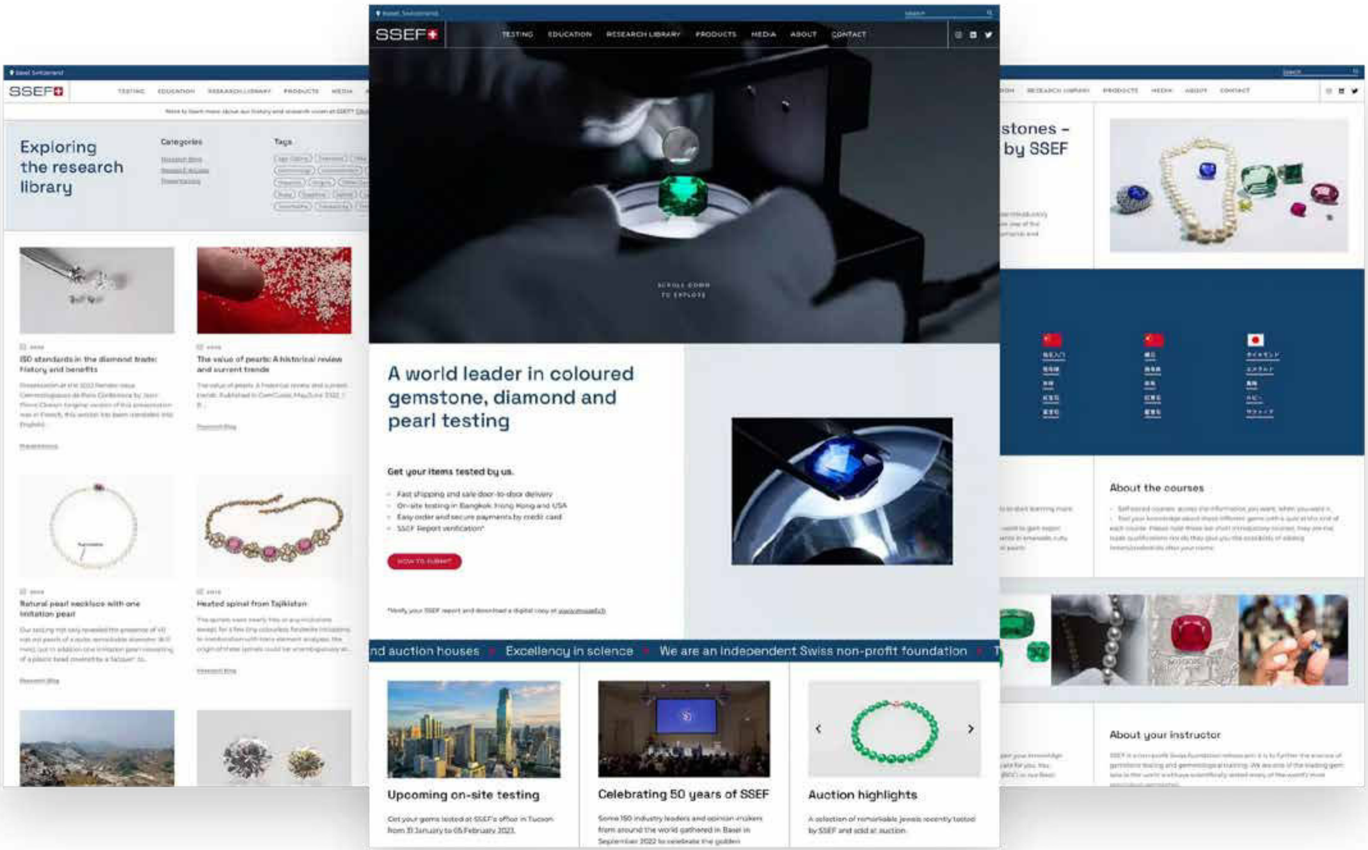
Video recordings of the presentations and discussions can be found here: https://www.ssef.ch/50years/

A special book about 50 years of SSEF was also published, for more details see page 55 of this Facette.

Response to this event has been so positive that SSEF has decided to organize another symposium in 2026 in Basel, as a forum for fostering discussions and the exchange of knowledge and opinion within the trade.



NEW SSEF WEBSITE



We are excited to announce the launch of our new website! www.ssef.ch has been completely redesigned to provide our customers with a better online experience.

Our new website features a sleek and modern design, making it easy to navigate and find the information you need. We've also added features such as:

- Research library with hundreds of research articles
- Videos of the courses that we offer
- Clear and accessible information on available shuttles to send your gems to SSEF
- A digital order form to simplify submissions
- Free online courses on different gems in 6 different languages (more coming soon)

We are confident that our new website will be a valuable resource for our customers, providing them with the latest information on our products and services. We will continue to update the website with new content, so make sure to check back often.

Thank you for your support and we look forward to connecting with you on our new website. Visit us at **www.ssef.ch**

Please let us know if you have any questions or feedback. We would love to hear from you.

SSEF-FERRARI SHUTTLE SERVICES FOR CLIENTS

We are pleased to announce that we will continue to offer special conditions on most regular SSEF-Ferrari shuttles until December 31st 2023.

Until **December 31st 2023**, the Ferrari shuttle to SSEF from the following locations will be **free of charge up to a declared value of goods of 1 million Swiss Francs**. Transport insurance is not part of this offer, and may be charged extra by Ferrari if a client does not have have one.
Europe: Geneva, Paris, London, Italy (only valid for Alessandria, Milan Rome, Valenza), Monaco, Antwerp
Asia: Bangkok (if not normal entry then extra charges apply), Colombo, Hong Kong, Mumbai, New Delhi, Singapore
Americas: New York
Middle East: Tel Aviv

For contact information of the local Ferrari offices please see: https://www.ssef.ch/how-to-submit

IMPORTANT NOTE

For goods with a declared value of more than 1 million Swiss Francs, an additional shipping fee of 0.035% is charged for the amount exceeding this limit, based on the declared value. We remind clients of the need to send an order form with shipments.

SHIPPING FROM MIAMI AND TOKYO TO SSEF

△ Miami. Photo: Adam Thomas (Unsplash)

We are excited to inform you that Miami and Tokyo have been added as on-request destinations for Ferrari shipping services to SSEF, in addition to the existing shuttle service destinations listed on our website. If you need to send your items from a destination that is not included in our current SSEF-Ferrari shuttle service, please contact us directly for guidance on how to proceed.

Ferrari Miami: +1 305 374 5003
Ferrari Tokyo: +81 (0) 3 5524 7760

△ Tokyo. Photo: Louie Martinez (Unsplash)

BANGKOK: SSEF OFFICE EXPANSION AND NOW IN THE 5TH FLOOR

For many years, the SSEF has been offering its on-site testing services in the heart of the gemstone trade in Bangkok, at the Silom Soi 19 Building. Since January 2023, we have relocated within the same building from the 3rd floor to the 5th floor. All contact details, phone numbers remain the same, the only difference is that we are now in a more spacious office in the 5th floor.
Since January 2023, we also have nearly doubled our on-site presence time in January and August to 9 working days instead of only one week (5 working days). As before the pandemic, SSEF will be offering its services in Bangkok
- 22nd to 26th May 2023 (5 working days)
- 23rd August to 1st September 2023 (extended to 9 working days!)
- 10th to 19th January 2024 (extended to 9 working days!)

As always, early application (before the on-site period!) for an appointment is highly recommended. Please contact Alexandra and her team at admin@ssef.ch or by phone +41 262 06 40.

SSEF AT GEMGENÈVE 11-14 MAY 2023

We look forward to seeing you at the upcoming GemGenève show at Palexpo in Geneva 11-14 May 2023. Our booth number is B03. Please join us for an apéro that we will be hosting at the show on Thursday May 11th from 6.30pm to 8.00pm.

2022 was an eventful year as there were two editions of GemGenève that took place. In May 2022, we organized a cocktail apéro at the Villa Sarasin to celebrate 50 years of SSEF joined by friends, clients and other members of the trade.

△ **To celebrate 50 years of SSEF, we came up with a "pearl" cocktail inspired by Cleopatra's banquet with Marc Anthony where she reportedly dissolved a valuable pearl in a glass of wine. Photo: SSEF.**

△ **A cocktail gathering during GemGenève in May 2022 hosted by SSEF in the Villa Sarasin. Photo: SSEF.**

LMHC MEETING IN BASEL

In December 2022, the SSEF hosted the latest meeting of LMHC. The Lab Manual Harmonisation Committee (LMHC) was founded more than 20 years ago at the request of the Gem Industry and Laboratory Conference GILC at a meeting in Basel, but is not formally connected to any trade organization. The LMHC draws on the individual experiences of its members for the purpose of creating a general philosophy for proper nomenclature and disclosure for laboratories as well as to initiate and suggest "preferable" language to be used in the trade.

The goal of the Laboratory Manual Harmonisation Committee is to achieve the harmonisation of gemmological report language and thereafter the revision of this harmonised report language as used by LMHC members (see LMHC information sheets https://www.lmhc-gemmology.org/gemstones).

During the two days in early December 2022 at the 30th LMHC meeting, the gemmological representatives of the seven members of LMHC, that is CGL (Japan), CISGEM (Italy), DSEF (Germany), GIA (USA), GIT (Thailand), GGL (Switzerland) and SSEF (Switzerland) were discussing current issues on treatment detection of gemstones, namely low temperature heating and irradiation of corundum. All participating laboratories openly shared their latest research findings on these issues and discussed options for harmonised testing protocols. As of today, it is a reality that these issues still remain challenging for gemmological laboratories. Consequently, all LMHC laboratories agreed to extend their research about these treatments with the aim to develop harmonised detection criteria with the ultimate aim to support the trade with their expertise.

Apart from these more scientific discussions, a number of minor changes and additions were made on the existing information-sheets, all publicly accessible on the LMHC website: https://www.lmhc-gemmology.org/. In addition, a press release was published in early March 2023, summarising the outcome of this meeting in Basel (see https://www.lmhc-gemmology.org/news).

✶ **Dr. M.S. Krzemnicki**

COLLABORATION WITH ETH ZURICH: COURSE IN ANALYTICAL STRATEGY & INVITED LECTURE

In 2022, the SSEF was again invited to participate as an external expert institution during the course in Analytical Strategy at the Federal Institute of Technology, Zurich (ETHZ), nota bene for the third time in the past few years. This very interactive course is organised since many years by Prof. R. Zenobi and aims to offer students a learning option to develop their own analytical strategies for real-life issues presented to them by external industrial partners.

Based on case studies on rubies tested at SSEF, Dr. Hao Wang and Dr. M.S. Krzemnicki from SSEF presented the students challenging testing issues with a special focus on separation of natural ruby from synthetic ones and detection of ruby treatments.
It was a great pleasure to participate again at this student course at ETHZ and to learn and discuss with the students their suggested analytical procedures and solutions for these ruby issues.

In addition to this, Dr. M.S. Krzemnicki was invited to give a lecture in the seminar "Current topics from Accelerator Mass Spectrometry and its application", organized by the Laboratory of Ion Beam Physics (LIP) at the ETH Zurich. In this talk, he gave an overview about our latest findings in pearl testing, with a special focus on radiocarbon dating on pearls, corals, and ivory. This dating service has developed in collaboration with Dr. Irena Hajdas from the LIP and is offered as a regular service to our clients since several years (see also article about the Queen Mary Pearl in this SSEF Facette, page 23).

KEYNOTE LECTURE AT THE GIT CONFERENCE 2022

Since 2006, The Gem and Jewelry Institute of Thailand (GIT) has been organising a biennial gemmological conference in Thailand. Due to the Corona pandemic, the 7th conference scheduled for 2021 was finally held as a hybrid conference in early February 2022 in Chanthaburi, gemstone trading centre in eastern Thailand.

Dr. M.S. Krzemnicki was kindly invited to deliver a keynote lecture to the attendees at a special corundum symposium during that conference. His presentation was focussing on latest advancements in corundum testing, giving our laboratory view on this constantly developing topic.

Having a strong tie with the GIT since its beginnings, it was for us a great pleasure to be present again at this important gemmological gathering and to contribute to the provided gemmological knowledge with our own research findings.

The proceedings of this conference are accessible on the GIT website: https://git.or.th/en/about/18/149/detail/1844

IGC 2021 PRESENTATIONS

Traditionally, the International Gemmological Conference IGC is holding its gemmological conference every two years. Because of the worldwide CoVid-19 pandemic, it was decided to hold a web seminar in November 2021 and to postpone the originally scheduled IGC conference in Tokyo to October 2023.

During this online conference, 23 scientific talks were presented to participants, of which SSEF was contributing four presentations: These were entitled:

- *Preliminary study of defocused PL measurements of diamonds* by Speich L., Chalain J-P., Krzemnicki M.S., Wang H.A.O., Phan L. & Xaysongkham J.
- *Zircon inclusions in unheated pink sapphires from Ilakaka, Madagascar: A Raman spectroscopic study* by Krzemnicki M.S., Lefèvre P., Zhou W. & Wang H.A.O.
- *Cu-containing thin sheet inclusion in Cu-bearing tourmaline from Brazil* by Wang H.A.O, Grolimund D., Franz L., Mathys D., Schultz-Güttler R. & Krzemnicki M.S.
- *Myanmar gold-lipped cultured pearls* by Tay Thye Sun, Thet Tin Nyunt, Myo Lwin, Tay Zar Linn, Brombach G. & Krzemnicki M.S.

The proceedings of this IGC seminar can be downloaded at https://www.igc-gemmology.org/igc-2021-online

With only a few months to go for the IGC conference in Tokyo, we are very much looking forward to this meeting and to see after the pandemic many of our gemmological colleagues from around the world.

SSEF AT TRADE-RELATED ONLINE CONFERENCES

Since the publication of the last SSEF Facette in May 2021, we were again very active internationally to present our latest research findings and testing standards to a wide audience, be it at scientific conferences, invited lectures, or during webinars.

These included two online conferences, one organized by the Taiwan Gemmological Association, held during the 2022 Taipei International Gemstone Forum and Expo, and secondly the annual conference by the National Association of Jewelers of America (NAJA), exceptionally held as a virtual conference during Tucson Show 2022. At both events, Dr. M.S. Krzemnicki, director of SSEF, spoke about colour varieties of gemstones and presented in detail SSEF standards and procedures to identify such varieties (see also SSEF Facette 2020, pages 6-8).

In addition, Dr M.S. Krzemnicki gave a more general online lecture about the beauty of science in gemstone testing during the Seoul International Jewelery Conference in October 2021.

Furthermore, he was an invited panel guest in 2021 at the CIBJO webinar entitled "A Question of Origin", focusing on the origin of coloured gemstones (https://www.youtube.com/watch?v=OwAvTP6r2wU)

CONFERENCE IN LIÈGE (BELGIUM)

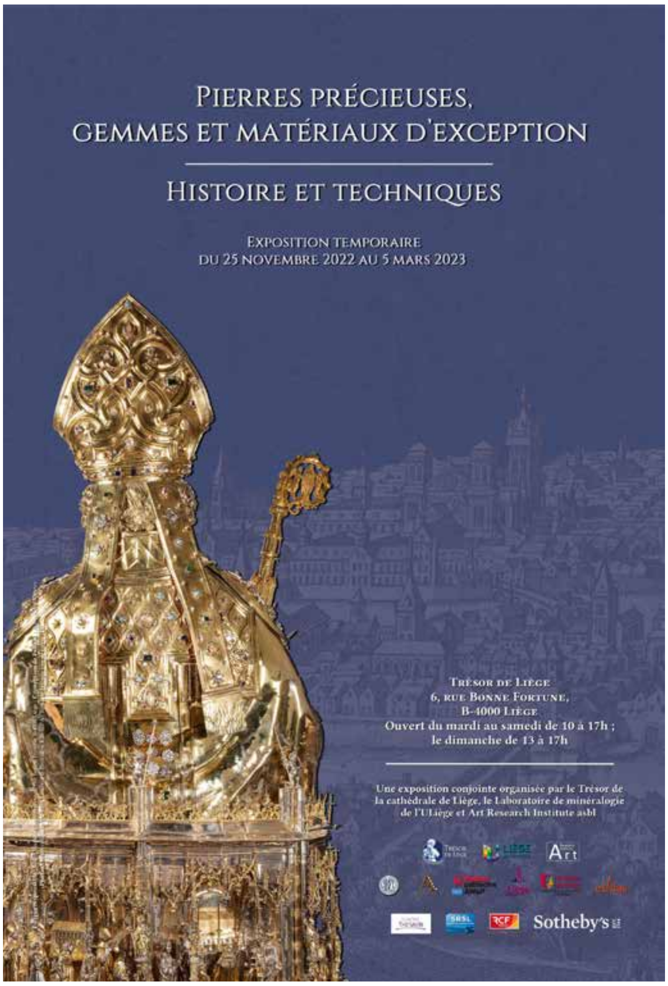
At the end of November 2022, two international study days were organised by a partnership between the University of Liège, the Belgian association of experts (ABEX), and the Treasure of the Liège cathedral in the city of Liège, Belgium. These two days of symposium, named "Gems and heritage, history and techniques" were linked to the start of a temporary exhibition about the use of precious materials and gemstones through the ages.

During this series of lectures, different topics regarding the identification of gemstones, stones, and glass were investigated, as well as the different techniques of testing and valuation. The Swiss Gemmological Institute SSEF was invited for a talk untitled "technical expertise of gemstones", through which our colleague Pierre Lefèvre (Head of Gemstone Testing) introduced the techniques that are used by SSEF to finalise their prestigious reports, including age dating and DNA testing reports. With some practical examples, he showed the different guidelines and analyses (ranging from basic observations all the way to the most sophisticated methods) that are used by gemmologists to finalise their conclusions while testing gemstones and pearls.

In addition to this, there were some well-organised visits of interesting places like the collection of the mineralogy department of the University of Liège, the exhibition "Precious stones, gems and exceptional materials", and the treasure of important cathedrals. These two intensive days were definitely rich in cultural visits and discussions with people coming from different special fields.

✶ **P. Lefèvre**

△ **Crown of the "Holy thorns" of the 13th century for which a detailed study was performed by the mineralogical department of the University of Liège. Photo: Y. Bruni**



△ **Poster of the exhibition linked to the symposium "Gems and heritage, history and techniques" showing the reliquary Chest of Saint Lambert. Composed by A. Alvarez.**

INTERNATIONAL MINERALOGICAL ASSOCIATION MEETING IN LYON

During the daily lab work, gemmologists observe not only features that lead to conclusions on treatment status or origin but we also learn in a more general context about the science of gemstones. With the use of highly sensitive testing methods, such as time-of-flight mass spectrometry (GemTOF, see www.gemtof.ch) we have an excellent opportunity to obtain detailed chemical fingerprints of gem-quality stones, data which may finally support gemmologists in their conclusions. In July 2022, Dr. Wei Zhou happily joined the 23rd General Meeting of The International Mineralogical Association in Lyon (Figure 1). During the gemmological session "Haüy 200 Years On: What News in Gem Research?" she presented a case study on sapphires with a special focus on selected specimens from Kashmir and Madagascar. Her presentation was entitled "Trace elements variation in blue sapphire: Challenge or potential of origin determination?".

△ **Figure 1:** Crown of the "Holy thorns" of the 13th century for which a detailed study was performed by the mineralogical department of the University of Liège. Photo: Y. Bruni

Since more than two decades, SSEF applies laser ablation inductively coupled mass spectrometry (first quadrupole- and since 2016 time-of-flight mass spectrometry) on corundum. By this and the research of other laboratories, knowledge and understanding of ultra-trace chemical composition of sapphires has strongly advanced (see also Abduriyim and Kitawaki, 2006; Wang et al 2016). Based on such studies we know that the "normal" trace element composition (e.g. transition elements) of gem quality sapphires (Figure 2) originating from metamorphic deposits in Kashmir (Zanskar Range, India) and Madagascar (e.g. Andranondambo) can be very similar. Yet, it is interesting to see that the chance of measuring unexpected "exotic" trace elements by using simultaneous multi-element detection (GemTOF) is quite high, and that they may provide important information to us.

△ **Figure 2:** Two sapphires, left one 10 ct, origin Kashmir, right one 11 ct, origin Madagascar. Photo: SSEF.

In the case study presented at IMA 2022, selected sapphires from Kashmir (India) and Madagascar were compared (Figure 2). In general terms, sapphires from Madagascar with "Kashmir-like" velvety appearance often show turbidity and dense growth patterns. In addition, they have the potential to contain numerous "exotic" trace elements at low concentration, among others the so-called high-field-strength elements HFSE (e.g. Zr, Nb, Sn, La, Ce, Hf, Ta, and W) as important geochemical marker of their formation. In comparison to this, sapphires from Kashmir often exhibit distinct bands of turbidity (velvety or "milky" effect) but may also have a rather high level of incompatible elements though generally only Nb, Sn, Ta, W and Ni.

Another useful information is direct (formation) age estimations that can be applied on sapphires by using for example the thorium-lead (Th-Pb) geochronometer. If Th (and Pb) is present as a trace element (directly measured on the sapphire and not on inclusions such as zircon or apatite) it is commonly possible to calculate an approximate geological formation age of the sapphire using established radiometric dating methods. In the presented case study and using this Th-Pb method, a sapphire from Madagascar revealed an approximate age of 510 million years, whereas a sapphire from Kashmir resulted in an age of 24 million years. Both calculated ages are well in agreement with the respective formation ages of sapphires in metamorphic rocks found in Madagascar and in the Zanskar range of the Himalayan Mountains in Kashmir (India). Thus, the presence of thorium (Th) and its use in age dating can also further support the opinion of the origin of a tested sapphire.

The results of this case study show that trace elements may vary considerably in gem-quality sapphires but may reveal important information to gemmologists. To better understand the possible correlation of trace element variations with (internal) zoning features, a more detailed study is planned. However, by using a series of 4-8 LA-ICP-TOF-MS analytical spots (as commonly applied in gem lab analyses), the concentration and homogeneity of trace elements already can be monitored to a certain extent. And this information can be of great help and importance for the origin determination of sapphires.

It is worth mentioning (again) that all this "unconventional" trace element data is obtained and collected as a side effect of our daily gemstone identification work (thanks to GemTOF). In other words, nowadays, by using increasingly sophisticated analytical and data mining techniques, it may no longer be an issue of lacking technical methods to test a gemstone, but there is also a need to be more sensitive and focused in order to find the cherry on top of the cake in the existing data.

✶ **Dr. W. Zhou**

MARC ALAIN CHRISTEN

On the 1st of October 2022, our longstanding president of the SSEF Foundation Board stepped down from the SSEF board after 33 years. During all these many years Marc Alain Christen devoted a lot of time and energy to the SSEF. He actively supported and enabled its development from a small laboratory to the current situation of the Swiss Gemmological Institute SSEF being one of the foremost authorities in gem testing worldwide.

The Swiss Gemmological Institute is a non-profit organisation and part of the Swiss Foundation for the Research of Gemstones (SSEF: Schweizerische Stiftung für Edelstein-Forschung) which was founded in 1972 by Swiss trade organisations and which comes under the aegis of the Swiss Federal Department of Home Affairs.

As president of the SSEF Foundation Board, it was the role of Marc Alain Christen to guide the SSEF in the early years through financially difficult times. However, his main impact has always been his ability to create a deep common understanding between the laboratory team of the Swiss Gemmmological Institute and the SSEF Foundation Board, which was a fundamental requirement so that our common vision for SSEF could flourish so well.

Dear Marc, last August, we celebrated the 50 year anniversary of SSEF and it was a moment of satisfaction for all of us. But we all also felt your pride and joy, when you - still as president of the Foundation Board - concluded your toast on behalf of SSEF at the gala dinner with words summarising all your work for SSEF: "The SSEF Foundation and its Swiss Gemmological Institute are ready for the future; this includes its research, testing and educational activities."

In the name of the whole SSEF team and Foundation Board, I would like to thank you for all your work and dedication to the SSEF. We wish you and your wife Vreni all the best in the years to come with more time for travelling and enjoying private life in Berne and in the cosy chalet in the mountains.

✶ **Dr. M.S. Krzemnicki**

△ **At the 50 year anniversary of SSEF in Basel in September 2022. From left to right: Marc Alain Christen (past Foundation Board president), Dr. Michael S. Krzemnicki (current SSEF director), Prof. Henry A. Hänni (past SSEF director). Photo: SSEF.**

CLOSE-UP: VÉRONIQUE SCHMUTZ

Véronique Schmutz has been working since more than 10 years in the SSEF administration. As all our staff, she has multiple functions and you may meet her at the reception desk of our booth at a jewellery show or talk to her on the phone about different types of inquiries you may have. Her main duties are related to courses, accounting and customer care. She enjoys the multifaceted and international aspect of work at SSEF that includes working with clients from all continents. Although on-site travels to Tucson, Bangkok and Hong Kong can be intense she also relishes the opportunity to explore diverse cultures and engage in enriching experiences during these trips.
Véronique has many other talents and is a very committed and active team member. Among those talents is for sure her passion to make sweet and crispy cookies for the whole team, for which she is famed at SSEF since many years.

Being a mother of two young teenagers, she is experienced and very down-to-earth and easily handles any moment of hustle and bustle or turbulence.

SSEF FOUNDATION BOARD UPDATES

On the 1st of October 2022, Martin Häuselmann has taken over the presidency of SSEF Foundation Board, as successor of Mr. Marc Alain Christen, who was President of the Board since 1989 (!), see also the article on the previous page of this Facette. Mr. Martin Häuselmann, attorney from Bern and Head of Tax and Legal at BDO Bern (Switzerland), has been a member of the SSEF Foundation Board since 2018 (see SSEF Facette 2019, No. 25, page 56). This enabled a smooth and continuous handover within the SSEF Foundation Board.

◁ **Martin Häuselmann**

We, as the SSEF team, are pleased to welcome Mr. Häuselmann in his new role as President of the SSEF Foundation Board and look forward to collaborating with him and the whole foundation board for many years to come.

In addition to this, two new members joined the SSEF Foundation Board in summer 2022, replacing our long-standing former members Nicky Pinkas and Bernhard Berger, who both contributed greatly to the development and success of the SSEF in recent years.

The new members are Christophe Stucki and Dr. Walter A. Balmer, both from Switzerland. Christophe Stucki is a financial expert and is and has been member of executive management in various companies in his professional career. He is not directly linked to the gem and jewellery trade at present, but will definitely bring a lot of financial expertise to the foundation board, which is considered important as the SSEF has grown so much in the past few years.

The second new member is Dr. Walter A. Balmer, entrepreneur in telecommunications, but also a gemmologist and scientist by training with a PhD in Geosciences from the Chulalongkorn University, Bangkok, Thailand (PhD thesis 2011: Gemmological Characterisation of Marble-hosted Ruby Deposits of the Morogoro Region, Tanzania). On field trips to Mogok and Tanzania over the past 15 years, Dr. Walter A. Balmer and Dr. Michael S. Krzemnicki teamed up and have worked on many research projects together. With his arrival at the SSEF Foundation Board, we are glad to welcome a mineralogist/scientist in the board, who is however also very well aware of the practical issues and challenges in the gem trade.

△ **Dr. Walter A. Balmer and Christophe Stucki.**

SSEF ON-SITE IN 2023

In 2023 we will be exhibiting and/or offering our on-site testing services as follows.

Bangkok	11 – 20 January 2023
Tucson	31 January – 05 February 2023
GemGenève	11 – 14 May 2023
Bangkok	22 – 26 May 2023
Bangkok	23 August – 01 September 2023
Hong Kong	14 – 24 September 2023
Bangkok	January 2024
Tucson	30 January – 04 February 2024
Hong Kong	March 2024

DONATIONS

As in previous years, we are grateful for numerous donations we received since 2021 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

Charlie Barron (London), Patrick Flückiger (Geneva), Prof. Henry A. Hänni (Basel).

Gemstone Donations

Prof. Henry A. Hänni (Basel), Koh Choo & Miemie Thin Thut (Bangkok), Joe Belmont (Bangkok), Allen Kleiman (USA), Rainer Schultz Güttler (Brazil), Alexander Leuenberger (Switzerland), Tewodoros Sinthayehu (Ethiopia), Avant Chordia (Jaipur), Dr. Walter A. Balmer (Switzerland), Constantin Wild (Idar-Oberstein), Charles Abouchar (Geneva), Belfont SA (Switzerland), René Kluser (Switzerland), Philippe Honegger (Switzerland), Ulf Brosowski (Switzerland), Max Berent (Switzerland).

Jewellery Donations

Färber Collection (Geneva).

Book Donations

Vivienne Becker (London).

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△ Part of the SSEF team at SSEF's 50th anniversary in September 2022 in Basel.
Photo: SSEF.

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