Winter 2019
Issue 41

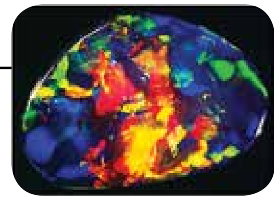
InColor

All About Colored Gemstones

Australian Opal Symposium & Updates

Padparadscha Coloration
Pantone's Color of the Year
Latest Auction Results

A Publication of the International Colored Gemstone Association



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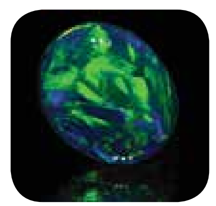

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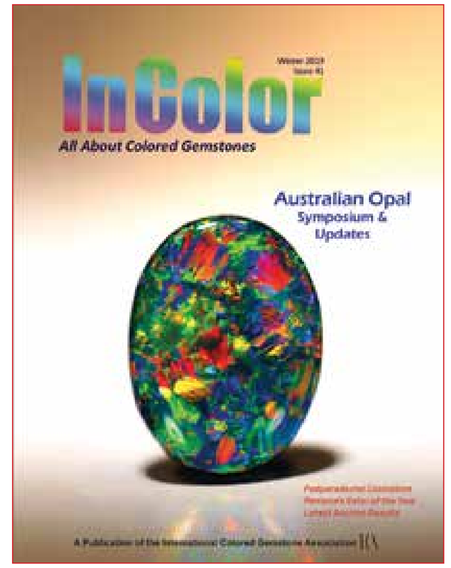

Beautiful 7.01-carat gem black opal recently mined at Lightning Ridge. (Photo and stone courtesy of Cody Opal Australia)

InColor

InColor is the official publication of the International Colored Gemstone Association, ICA.

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2018 – A Very Busy Year for ICA

As we say goodbye to 2018, we can reflect on how significant and busy it has been for ICA. Our Association has been involved in many industry initiatives worldwide, a few that I will mention here.

Just in the past few months, for example, we were invited by Fedesmeraldas and Acodes to be part of the Second World Emerald Symposium in Bogota, Colombia in October. It was quite an impressive event with speakers and delegates from all emerald-producing countries as well as representatives from major consuming nations such as India, China, Thailand, USA, Canada, Germany, Italy, France, UK and Australia.

ICA participation was strong with five Board members and numerous members of the Association from all parts of the globe.

It was remarkable to have together so many leading professionals of our industry not only to discuss the present and the future of emeralds, but also to set standards and priorities for our industry for the coming years.

Needless to say, our gemstone business is often a target for questioning, from its mining operations to overall concerns on its practices and how responsible we really are to the world.

ICA was there not only to present itself and its initiatives to the industry, but to also address questions and to ease any concerns that consumers might have when it comes to *sustainability*. It's important to assure the world that our industry is not only aware of, but also committed to promoting responsible businesses.

Following the participation at the Second World Emerald Symposium, ICA also took part at the World Jewellery Confederation's annual congress that was also held in Bogota. A number of important meetings and discussions were held during both the Symposium and the CIBJO Congress. ICA is actively working together with institutions such as OECD and fellow associations AGTA and CIBJO to further advance initiatives to foster the fair, honest and transparent trade of colored gemstones.

November was also a month of great industry initiatives, starting with the Technological Seminar for the Jewelry Sector held in Rio de Janeiro, Brazil. The event focused on addressing fundamental issues for the development of the sector in Brazil and the difficulties that are preventing the country from growing.

The result was the creation of a document with effective proposals to be presented to the next governmental leaders of Brazil. ICA was not only part of the discussions, but also a co-promoter of the event because it is at the core of ICA's priorities to support discussions, address challenges and brainstorm solutions to facilitate the international trade of colored stones.

At the end of November, ICA was also part of the Guangzhou China International Jewelry & Diamond Conference, a very important invitation from the Guangdong Gems & Jade Exchange. I was able to address the many challenges we face in China and to propose to work together with ICA towards programs for even more successful businesses.

At the Conference, ICA also launched the very first edition of *InColor* magazine in Chinese. This represents a major international link and breakthrough for ICA and China, and the beginning of a new era. I particularly want to thank GGJE and our ICA director in China, Mr. Chen Shen for their great support and efforts in putting this initiative together.

Looking forward to activities in 2019, ICA will begin its first-ever pavilion at the JCK show, which will be held at the Sands Convention Center in Las Vegas in June. Starting with this and continuing with all future ICA trade show pavilions, exhibiting members will be contributing to our recently established project called *Gems Keep Giving Fund*.

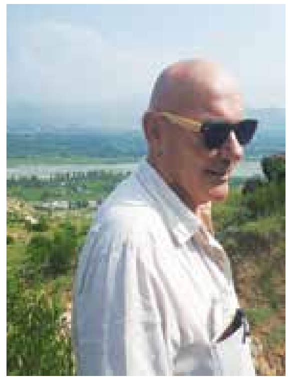
Through this vehicle, ICA will be actively looking to help improve the livelihoods of the many small artisanal miners and their families who account for more than 80% in our industry. They are very important partners in our industry and yet many are living in communities less fortunate than ours.

Money raised in the *Gems Keep Giving Fund* will focus on possible assistance with safety procedures, methods, training, education, social welfare and protection of their environment.

We are also now making plans for even greater participation in the 2019 global promotion and support for the Colored Gemstone Industry.

And finally, I would like to wish you the Very Happiest of New Years! May it be the best ever!

Clement Sabbagh
ICA President



The Bridge to the New Year

The year 2018 is now past, finishing with mixed feelings and results, so let's take a look back at what has focused on all fronts of ethical and responsible mining and sourcing, from all sides of the industry.

The financial markets were quite shaky at year's end, and we also saw slow business overall for the colored gemstone sector. Indicators for the world economy in 2019 are sending mixed signals. A few positive notes were seen in the rebound of world markets following the good news on job creation and car sales last year, and there is no doubt that these positive points are reflected in the gem and jewelry markets.

Looking back at the sector's communication, the terms of *traceability, ethics, responsibility* and *sustainability* have entered the industry's standards and marketing vocabulary. We have seen positive responses from different segments of the industry that want to work together towards adopting relevant guidelines and procedures that benefit the entire supply chain.

Apart from emerald, ruby and sapphire, there has been a rather short supply of raw material for hot colors and stones such as Paraiba tourmaline and red spinel, whose demand continues to rise. Color is doing well—better than the diamond sector, which is entangled with the surge marketing campaigns for lab-grown stones that have somehow affected the consumer market and confidence.

Pantone is the world's leading authority on color in all domains of our lives, and it recently unveiled its choice of 2019 Color of the Year—an orangey-pink tone called *Living Coral*. While common in the online world, in marketing and in fashion, Living Coral is a challenging color for the gem and jewelry industry. Stones in this muted color are not common, and those that exist are difficult to source in large enough numbers to meet the demand.

Having said that, gems that approach the color of the year, including Padparascha, fire opal from Mexico, some opals from Australia, and orangey garnets, among others, are already enjoying strong demand.

Another encouraging sign for the future of the gem and jewelry industry is the noticeable enthusiasm for color by millennial consumers. For those in the entire supply chain—upstream and downstream—who can combine sourcing with responsibility and sustainability, ethics and technical prowess along with good customer service and effective marketing, the future augurs well.

In 2019, the ICA will keep increasing its activities in all fronts, while creating alliances and joint ventures with stakeholders in every corner of the world.

May the colored gemstone world bring you a colorful perspective in your life, full of joy, happiness and success.

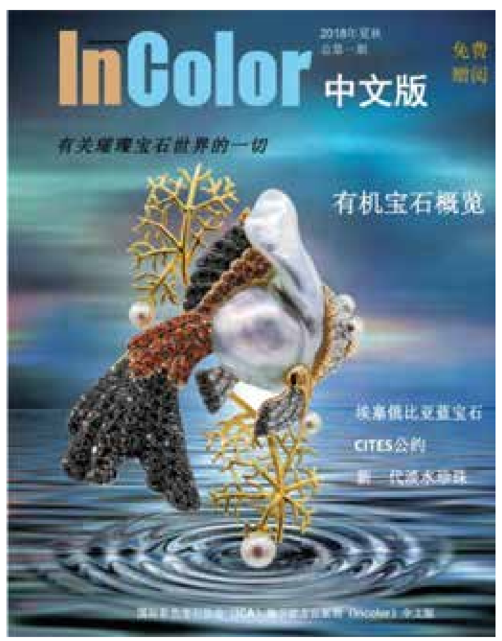
Happy New Year to all!

Jean Claude Michelou
Editor-in-Chief

THE ICA REPORT

Activities of ICA Members Around the World

InColor Chinese-Language Version Launched



Debut of the Chinese-language version of *InColor* Magazine: From Left: Liang Weizhang, General Manager of Guangzhou Diamond Exchange; Wilson Yuen, former ICA President; Zhu Yongsheng, Chairman of GDGJE; Clement Sabbagh, ICA President; Liu Yanhong, Deputy Secretary-General of China Gold Association; Zhou Zhili and Li Zhiwei, editorial board members of the Chinese version of *InColor*.

The Guangdong Gems & Jade Exchange (GDGJE) and the ICA joined together on November 27, 2018 to launch the first Chinese-language edition of ICA's *InColor* magazine at the 2018 International Jewelry & Diamond Conference held in Guangzhou. GDGJE secured the exclusive authorization for the global compilation and distribution rights of the Chinese version of *InColor*, and Guangdong Jin Shi Gold Co., Ltd. gave strong support.

InColor in Chinese is released to readers at no charge and it will be in print and online. Distribution is intended for jewelry and gem trading dealers, retailers, associations, universities, GDGJE's members, trade shows and other relevant gem and jewelry-related venues and events.

Enterprises and individuals are limited to one free subscription and can scan the QR Code featured here to subscribe to the magazine.

ICA Members in Hong Kong

Many ICA members exhibited in the ICA pavilion at the September 2018 show in Hong Kong, while others had booths in different areas at the AWE. They also attended a networking reception held on at the AWE. Overall, the sentiment was that it was a good show.

IN THE NEWS

A look at what's making news in the colored gemstone and jewelry industry.

Ruby Reds in December 2018 Auction

By Richa Goyal Sikri

While the color *red* was challenged in right bank Bordeaux in 2012, some 5,000 miles away in Mozambique, there was a different hue of red emerging that would alter the course of the colored gemstone industry forever. Since the commencement of their operation six years ago in 2012, the Montepuez Ruby Mine (MRM) has grown to become the largest in the world, representing approximately 80% of global supply. It may sound fictional, but observing the frenzy at the latest MRM auction in Singapore, 10-14 December 2018, where 51 companies viewed 90 lots comprised of 685,363 carats of rubies, the statistic is entirely believable.

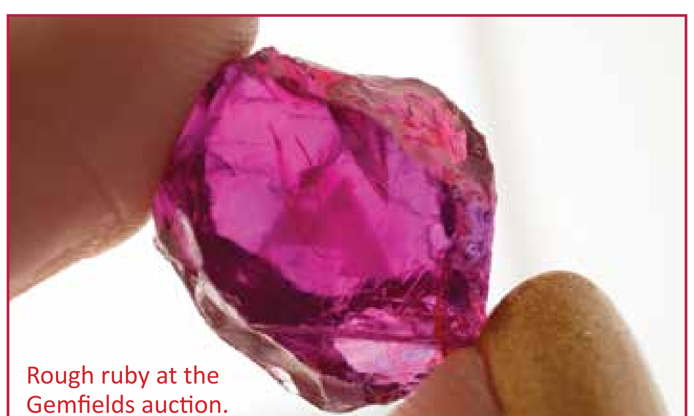
“Our strategy at auction is to divide and conquer. We split into teams, meticulously evaluating each lot. We draw sketches of the stones and, within each lot, have our system of categorization. We have to calculate a price for each stone. Some take more time, such as Lot G that was 118 pieces of rough rubies and we had only 45 minutes in the booth to evaluate,” commented Joe Belmont of KV Gems. “We returned four times and ended up spending three hours with one lot. It's very tough. With rubies, even small mistakes are expensive.”

Unlike emeralds, where there is greater acceptability of inclusions, the standards for rubies are higher. Market demands for eye-clean stones result in a strict criterion for evaluation of rough. The Gemfields grading system helps in many respects, especially in the standardization of color, but bidders still have to consider many factors such as recovery, shape, small bubbles and cracks. Additionally, with rubies, one needs the knowledge of heat treatments. With Mozambique material, in particular, the thickness of the silk is an important aspect to consider. Questions abound like, is the silk located on the face? Can it be burnt with low-temperature heat treatment? How will the stone perform after heating? To help with these questions, some bidders bring their master cutters and specialists for heat treatments.

“This is the eighth auction we attended, and we have bought every single time. If you don't have experience, it is almost impossible to buy. About 90% of the customers are Thai and the rest are Indian,” Belmont continued. “They all have many years of experience in buying rough. If you don't understand what color you will get after cutting, then you are lost. Mozambique rubies haven't been around that long, only ten years, and even before Gemfields, the material was all coming to Thailand. In one lot, some stones are very nice, and some are not so nice, and it is hard when you have to buy the whole lot. Our work continues well into the night as we share notes on the day's assessment and strategize to decide our bid price. It's a delicate balancing act because, beyond recovery and color, we need to consider market dynamics, competition, and our demand pipeline.”

Colored gemstone mining is typically small-scale because the resources are very scarce. Until the discovery of the Mozambique deposit, the other ruby deposit of significance was the heavily mined Mong Hsu in Burma. Rubies from Mong Hsu were included, though, and 99% had to be heat treated to deliver marketable material, so the average price per gram of product was meager.

The industry has never seen a ruby deposit of the scale in Mozambique, and Gemfields' experience from Kagem in grading, standardization of rough, and large-scale mining



Rough ruby at the Gemfields auction.

Gemfields' 11th auction of rough rubies from Montepuez featured 685,363 carats of rubies.

Bidders at the December 2018 Gemfields ruby auction in Singapore

Examining the rubies, one by one.

helped accelerate production. Their auction format was already functional and offered a “plug and play” solution for distribution and sales. However, unlike hard-rock emerald mining in the primary resource, the team had to quickly learn completely different techniques for mining the secondary deposit in ancient riverbeds.

Philippe Ressigeac, of Ressigeac Gems, who worked for Gemfields in Mozambique for three years starting in 2013, explained the complexities involved in evaluating rubies, which can test the mental and financial strength of many in the sector. “Rubies lie exactly between emeralds and diamonds—having the closest value retention to diamonds among all colored gemstones. The rough is less complex than emerald, but the value retention is way higher. While a typical lot of very high quality emerald that will be priced over US$1 million will weigh a few hundred grams, a similar very high quality ruby lot of similar value can be only one stone of 4 grams.”

Ressigeac's experience from mine to market provides an interesting perspective. “As a trader, I find it very difficult to get regular supply of rubies in the open market. Depending on artisanal mining, which by nature lacks consistency, is not easy. Sometimes, during two months, there are no stones, and then some material will appear, all dependent on the pocket the miners hit. While participation in the Gemfields auction requires serious financial planning, if you get one lot, you have enough stock for a few months ahead. I don't know anywhere else you have the opportunity for this scale of supply. Also, as a newcomer to the auction, it was interesting to observe how, despite talk of the market being slow, the results at the last two auctions have been US$71.8 million in June and US$55.3 million in December, which I find incredible.”

Adrian Banks, Gemfields' Managing Director of Product & Sales, noted, “Our latest Singapore auction has yielded yet another compelling outcome, evidencing the ongoing robust demand for Mozambican rubies mined and marketed by Gemfields and Montepuez Ruby Mining Lda.

The 41 Gemfields auctions held since July 2009—30 of Zambian emeralds and 11 of Mozambican rubies—have now surpassed US$1 billion of combined auction revenue, a remarkable benchmark for the colored gemstone sector. We thank our clients, our host countries, our local partners and the Gemfields team for their tireless efforts and support in building the platform that underpins a promising future for our industry.”

The market demand is encouraging for high-quality rubies, and the only source able to deliver right now is the Montepuez Ruby Mine. With consumers preferring higher quality stones, combined with demands for transparent sourcing, the need of the hour is consistent supply. To that end, Gemfields has invested US$13 million in a state-of-the-art sort house, the first of its kind in the colored gemstone business. Once operational in Q1 2019, it will be able to process DMS concentrate produced from 10,000 tons of plant head feed versus the current rate of 3,000 tons per day. Nobody knows how long the deposit will last—perhaps a decade or two. For now, though, it's best if all stakeholders drink up, while there is still wine left in the bottle. *(Photos are by the author.)* ◙

IN THE NEWS

A look at what's making news in the colored gemstone and jewelry industry.

DMCC: Made for Trade

Dubai is firmly established as a leading center for trading international commodities and the world's fastest-growing Free Zone. A *Government of Dubai* Authority, the DMCC regulates, promotes and facilitates trade across a range of goods from gold, diamonds and precious metals to tea, food and industrial materials.

Today, the DMCC is home to more than 15,000 businesses, from start-ups to major multinationals.

On the gem side, DMCC is a hub for diamond trading and is poised to become a hub for colored gemstones as well, according to Ahmed Bin Sulayem, Executive Chairman, DMCC. It is also committed to supporting the UAE Vision 2021 and the National Committee on Sustainable Development Goals. "DMCC is committed to the UN's 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals that outline a vision aimed at targeting the urgent environmental, political and economic challenges facing our world," stated Bin Sulayem.

Partnership building, raising awareness and providing education on topics such as responsible sourcing, gender equality, employee welfare and environment standards all fall within DMCC's sustainability strategy.

A brief video on the DMCC can be seen here:

Scan me

IGT: Capacity-Building in Bangkok

The Institute of Gem Trading (IGT) was established in Bangkok in 2017, with the goal of offering gemological courses taught be experts with decades of experience in mining, cutting and gem trading. IGT's instruction is based on three modular short courses, where students learn the skills of modern professional field gemologists, including grading rough colored gemstones, cutting and re-cutting gems to maximize value, and mastering the trade secrets of the colored gemstone market.

IGT provides hands-on experience where students learn through lectures, videos, interactive demonstrations, sample specimens, workshops, field trips, and seminars by industry leaders such as gem-cutting enthusiast Justin Prim. The 10-day *Gem Cutting and Re-Cutting* class is the first module and costs US$2450. The 7-day second module on *Colored Gem Rough Grading and Analysis* is priced at US$2800, while the third module, *Gem Entrepreneurship Essentials* is in preparation and will be available shortly.

IGT also offers specialized courses for brands and companies designed to update knowledge on changes in the supply path, from mine to market. IGT's *Gem Trading Fundamentals* program provides a complete set of tools to work in the international gemstone trade and its corporate training can be customized to suit the needs of a company.

(Photos are courtesy of Jean Claude Michelou)

IN THE NEWS

A look at what's making news in the colored gemstone and jewelry industry.

Focus of CIBJO 2018 Congress on New Technologies and Responsible Sourcing

The CIBJO 2018 Congress was held in Bogotá, Colombia in October. Its three days of official business was followed two days of steering committee meetings. The final day of the congress was marked by a visit by Colombia's Vice President, Marta Lucia Ramirez. It was hosted by by Fedesmeraldas, the National Federation of Emeralds of Colombia, and CDTEC,Colombia's leading gemological institute.

Addressing the special session of the congress, which also was attended by about 200 members of the Chamber of Commerce of Bogotá's Jewelry Cluster, Ramirez outlined challenges facing Colombia in general and the business community specifically. She pointed to the growing importance and expansion of the Colombian jewelry sector, and paid tribute to representatives of the emerald and jewelry industries.

During the concluding General Assembly session on the final day, CIBJO President Gaetano Cavalieri described the congress as most successful, noting that significant work had been accomplished in driving forward the business and social agendas of the jewelry and gemstone industries, and in particular preparing them for the marketplace of the years ahead.

"As industry leaders, our obligation is to ensure that our sector is able to evolve and adapt in accordance with changing business, technological, social and geopolitical conditions," said Dr. Cavalieri. "Staying in one place effectively means that you are moving backwards, and that is not acceptable. What we have done in Bogotá over the past few days is to examine what is happening around us, and to discuss and implement strategies that will equip our industry for the future."

On the first day of the congress, CIBJO's Responsible Souring Guidance was unveiled. It is intended that the document will achieve the status of a CIBJO Blue Book, coming to serve as a reference for responsible sourcing practices developed and applied by industry organisations and commercial bodies worldwide, while taking into account the challenges of the global jewellery supply chains. Like the other Blue Books for diamonds, colored gemstones, pearls, precious metals, coral and gemological laboratories, it will be a living document, which can be amended and added to as changing conditions require. For that purpose, a Responsible Sourcing Commission was established, with Philip Olden appointed as its president.

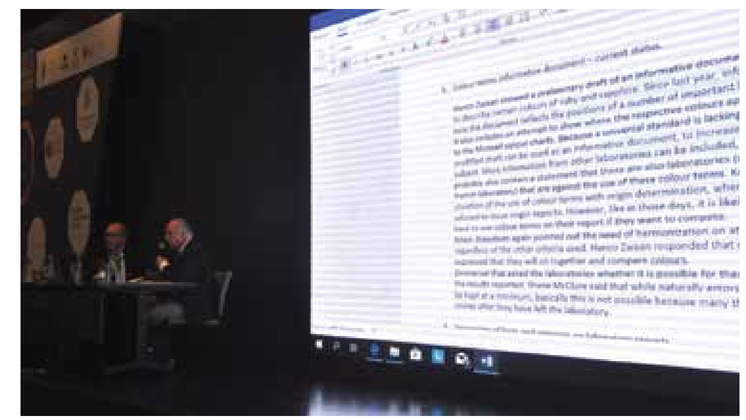
Disruptive technologies were discussed at length during the 2018 CIBJO Congress. Blockchain technology was the focus of a dedicated session, investigating the significance and possible impacts of the new technology in general, and more specifically in terms of its applications in the jewelry and gemstone sectors. These include securely and transparently tracking the movement of merchandise, as it changes hands multiple times during its journey down the chain of distribution, and also the use of digital currencies, which can significantly reduce banking costs and provide financing opportunities for industry members.

Also coming under the spotlight was the use of the social media as a means of marketing products and services in the jewelry industry. In an enlightening presentation during the meeting of CIBJO's Pearl Commission, Kevin Cannon, head of digital marketing at the Cultured Pearl Association of America, showed how a single paid-for posting on Facebook was seen by 1.7 million people, and generated 50,000 clicks, 3,000 shares and more than 800 comments.

Environmental sustainability, particular in the marine ecosystem, received a great deal of attention. CIBJO's Coral Commission, headed by Vincenzo Liverino, reported on its work in promoting research into the re-population of coral reefs, which today are being severely damaged by climate warming and ocean acidification. While precious corals,

The Colombian industry session featured a CIBJO panel, that looked at how responsible business standards can help jewelry producers break into foreign markets. Panel members, from left: Prida Tiasuwan, Vice President of the Thai Gem & Jewelry Association and chairman of the Pranda Group; Edward Johnson, Business Development Manager at RJC; Tiffany Stevens, President and CEO of the Jewelers Vigilance Committee; Charles Chaussepied, Vice Chairman of the RJC; and Steven Benson, moderator. (Photo: CIBJO)

The soon-to-be launched Precious Corals Online Course was at heart of the Coral Commission's deliberations at the Congress. Shown here, Vincenzo Liverino (left), Chairman of the Commission, and Rui Galopim, Vice Chairman. (Photo: CIBJO)



CIBJO's Gemological Commission revealed the results of a survey of gem labs, and how they differentiate reporting of natural, synthetic and treated diamonds. (Photo: CIBJO)

which are deep-water species, are not under the same degree of threat as the shallow water coral reefs, the commission hopes that the profile of precious coral as a luxury item will raise public awareness about the plight of those species that are in danger of extinction.

Among the other subjects receiving close attention was adoption by the jewelry industry of the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas, which were presented and explained by Tyler Gillard, who heads the Responsible Mineral Supply Chain project at the Organisation for Economic Cooperation and Development (OECD) in Paris.

Also discussed at length were the recently revised guides of the U.S. Federal Trade Commission for diamonds, precious metals, colored gemstones and pearls; means of separating professional opinions from measurable facts on gem grading reports; and simplified versions of the CIBJO Blue Books and other guidelines for members of the jewelry retail trade.

The venue of the next CIBJO Congress was also announced. It will be the Kingdom of Bahrain, and will be hosted by the Bahrain Institute for Pearls & Gemstones DANAT in November 2019. ◘

SIHH and Baselworld to Coordinate Their Dates from 2020

From 2020, the Salon International de la Haute Horlogerie in Geneva (SIHH) and Baselworld in Basel, the two major events in the watch industry, will synchronize their calendars. In 2020, the SIHH will be held from 26 to 29 April in Geneva, followed immediately by Baselworld from 30 April to 5 May in Basel. The calendars have been synchronized until 2024.

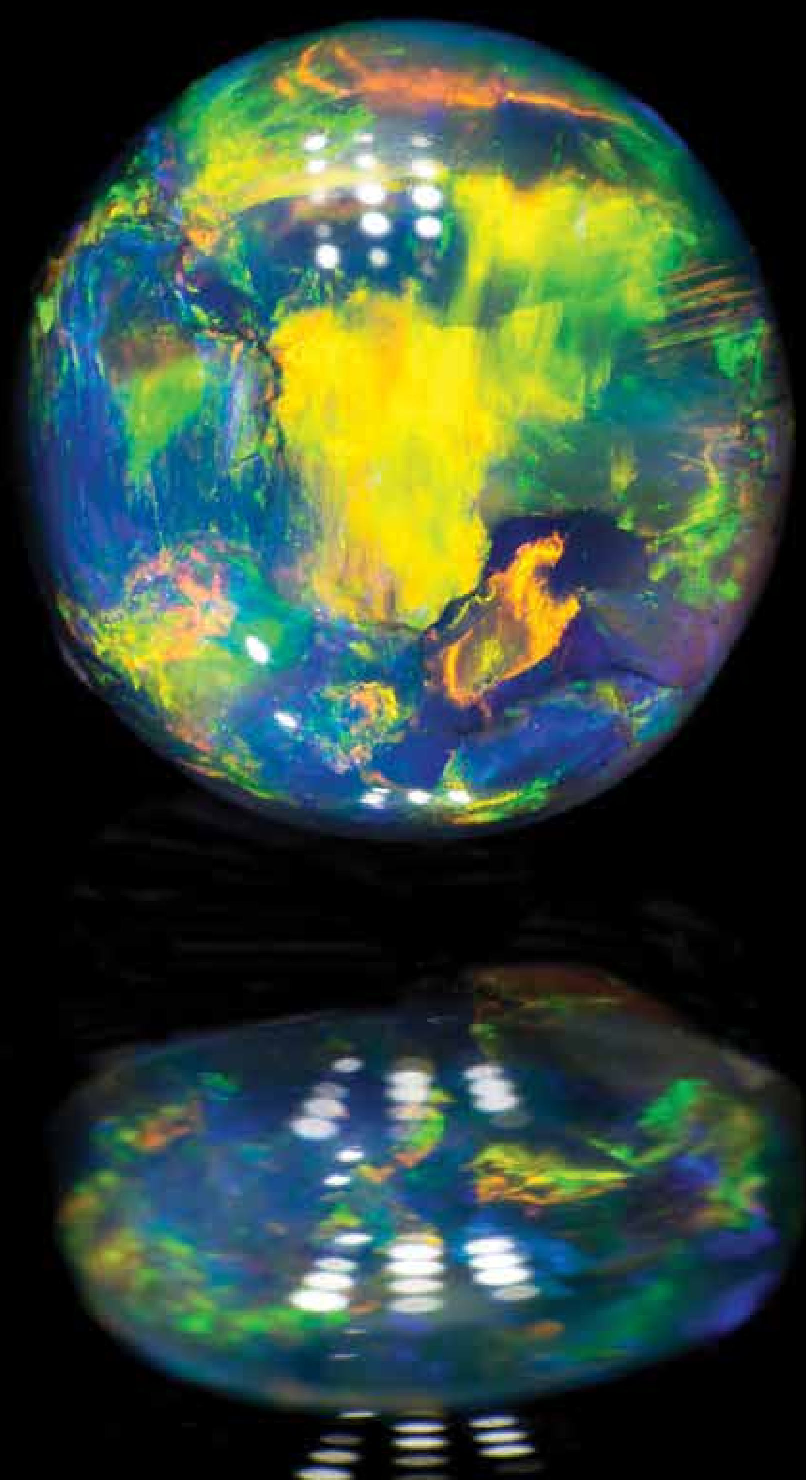
The coinciding of these dates is good news for the whole industry. Until now, the SIHH took place in January, while Baselworld was held in March. This arrangement meant that the professionals, press and clients shared by large watchmaking brands would have to travel to Switzerland twice in the space of just a few weeks. This calendar now coming closer together will be effective as of 2020 onwards.

Fabienne Lupo, President and Managing Director of the Fondation de la Haute Horlogerie, which organizes SIHH, stated: "Our two events have always been different, yet complementary. Resynching with Baselworld will further confirm Switzerland as the foremost destination for watchmaking in the world. This is something we welcome wholeheartedly, as it is in the interests of all."

"Baselworld and the SIHH are working for the industry and its clients. We have sought dialogue with the SIHH and together have found a solution, which benefits visitors, the media, and the entire watchmaking industry enormously," declared Michel Loris-Melikoff, Managing Director of Baselworld. "This partnership between the two most prominent exhibitions in the industry represents a major breakthrough for the future."

For visitors attending both events, and in particular those from other continents, these agreed dates will make their trips to Switzerland far easier. This important and essential breakthrough for the Swiss watchmaking industry is also welcomed by major players in the sector. ◘

The 9th Annual National Opal Symposium



Held in Lightning Ridge over two days in late July 2018, the Australian opal industry came together to learn and share information. The event was well attended with more than 120 representatives from all the major opal fields including, Coober Pedy, Andamooka, Lightning Ridge, Quilpie and Winton, as well as government representatives and academics working in the field.

Opal Fields Roundup and the Science

Alison Summerville of the Queensland Boulder Opal Association talked of the challenges they have on the boulder fields. Among the usual issues of access, high machinery, maintenance and diesel costs, there is also native title and an aging population of miners, while very few younger miners are entering the industry. However the numbers are hopeful.

Currently there are 539 production tenures. 352 are the new Prescribed Mining Claims, which are a maximum of 20 hectares (except in Yowah where they are two hectares). These PMCs are part of new legislation introduced to cut red tape. There has also been a 30% increase in the last three years for exploration permits which number just under 100.

Increased tourism and the demand for experiences, along with the TV series *Outback Opal Hunters* has renewed interest among the next generations and, anecdotally, we are seeing movement downwards in the average age of miners.

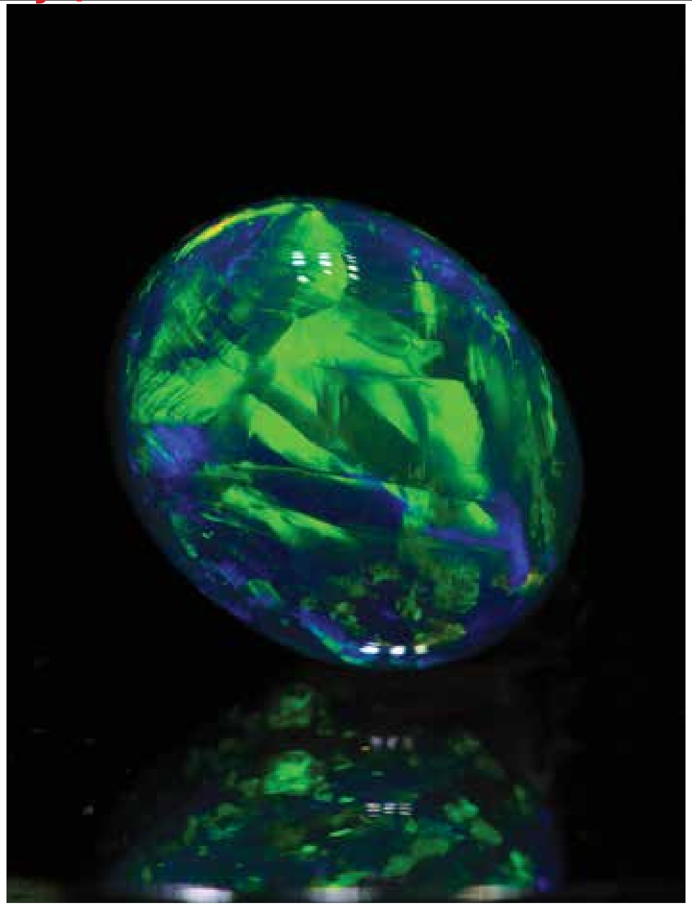
South Australian opal mining is steady with two new areas within the Coober Pedy mining area being made available. Shell Patch was previously not mined due to being an out-of-bounds area around a bore that is no longer in operation and Stuarts Run through which the old Adelaide road runs.

Andamooka is also slated for an increased mining area as a new Indigenous Land Use Agreement is being negotiated with the Kokatha people. Mintabie town—but not the mining field—was slated for closure by the government. Since the Symposium, submissions have been made along with an increased media profile, which will hopefully see a reversal of the recommendation to permanently close the town.

Opal mining in New South Wales is mainly centered on Lightning Ridge and the surrounding fields. Michael McFadyen from the Department of Planning outlined the legislation that covers the area and opal mining. To summarize, it is onerous and at times, contradictory. The mining legislation does not adequately take into consideration small-scale miners and their differing needs from the likes of Rio Tinto and BHP Billiton.

The government presentations made obvious the disconnect between government rules and the reality. The Symposium provided a perfect counterpoint and there was much learning around what was realistic and achievable within the small-scale mining framework. We expect the government officials who attended to have a more nuanced understanding going forward.

Sebastian Deisenberger, President of the Lightning Ridge Miners' Association Ltd (LRMA) discussed the industry point of view in relation to the many changes



Beautiful 3.24-ct black opal.

brought about by the NSW government. Of particular interest is the Voluntary Surrender Scheme, which saw farmers in the mining areas presented with opportunities to sell their farms at market prices back to the state government, thereby alleviating the conflicts between miners and farmers around land access. This has been a successful scheme so far, however, the community is still unsure of the state government's intentions for the land. The LRMA is the most vocal advocacy body for the mining industry at state and federal government levels. Currently, membership is over 900 and continuing to grow.

Jerry Lomax, a miner, former President of the Lightning Ridge Miners Association and now trustee on the Lighting Ridge Management Reserve, updated and explained this reserve. This trust holds the rights to manage the land that the opal fields inhabit. Under the new arrangements, the trustees (which have representatives from local government, from mining and from the community) will manage the land and the access to it.

The hope from this Symposium is that it is clear to the government that not only do we need to allow the trust to manage the opal mining land, but also the farming land (currently owned by the government) that surrounds or is intertwined with it.

The vision expounded by Lomax and supported by the local community is a model of sustainability where farming and mining, as well as the rehabilitation of land, can be managed from a central point. In this model, the Reserve Trust becomes a self-funding entity that does not require

Dr. Annette Condello, Lecturer, Curtin University.

additional funds from either the community or levels of government.

The various aspects of the science of opal, as well as recent paleontological findings were also presented. Papers by Dr. Paul Thomas (not related), Laurie Aldridge, Kurt Steffens, Gary Burton and Lachlan Hart covered water in opal, opal micro-structures, mineralogical exploration and the Griman Creek formation around Lightning Ridge.

Forward to the Future

Gary White, Chief Planner for New South Wales, gave an inspiring talk on the global mega trends for the future and interwove the place that the opal industries and communities inhabit within these trends. It was a talk about

Ruth Benjamin-Thomas addresses the Symposium.

National Opal Symposium Committee, left to right, Jenni Brammall (AOC), Paul Dale (Geological Survey of NSW), Maxine O'Brien (LRMA), Sebastian Deisenberger (LRMA), Kelly Tishler (LRMA) and Ruth Benjamin-Thomas (Black Opal Direct).

big global concepts and then focused on many examples of how our communities can engage and also start to develop strategic plans and visions of our future towns. For many miners in the room who are grappling with rising costs, reduced access and the lack of new miners coming into the industry, Gary gave an alternative way forward. To paraphrase him, "the issues must be re-framed as not just mining issues, but deeper as community issues. Talk about how these affect communities and you are more likely for governments to listen and to help."

This theme of community engagement and promotion was carried through to the next day by Andrew Kemeny of Down to Earth Opals. As past President of the Lightning Ridge Tourist Association, he discussed and took questions about promoting opal and the communities we live in wherever we go. Tourism today is about unique experi-

Local miners at the Symposium.

Magic rough opal.

Delegates at the Symposium.

ences and opal mining towns and their people should be promoting themselves in this way. Justin Thomas of Black Opal Direct, talked more about this promotion through social media and spreading the word via YouTube, Facebook and Instagram and the large volume of searches around the word *opal*. This section was finished off with a presentation by academic Annette Condello who examined the idea of sustainable luxury and the place that opal has historically inhabited.

Jenni Brammall, General Manager of the Australian Opal Centre, also provided an update on this significant project and Dr. Elizabet Smith discussed some of the recent acquisitions of the center as well. To read more on this, see the AOC update.

As a counterpoint to the promotion of our beautiful gemstone, Damien Cody of Cody Opals and Vice President of ICA, along with Terry Coldham, Australian Ambassador to ICA, then discussed the global regulatory environment and corporate social responsibility. Both presentations discussed different aspects of the push to regulate the colored gemstone industry, including the work of the Responsible Jewellery Council, the ICA and other media and governmental stakeholders.

Classification

Tony Smallwood, Gemmological Association of Australia (GAA) lecturer and author of the 1997 *Opal Nomenclature* continued the discussion started by Damien and Terry around the need for suitable standards and the issues we will face if we don't be proactive in formalizing certain aspects of our opal industry.

Left to right: Dr. Paul Thomas, Tony Smallwood and Maxine O'Brien enjoying the Symposium Dinner

Tony discussed that much of the work was done in the 1990s by an active group of traders and gemologists and that we have the basis for a clear and concise classification. New opal finds around the world have impacted our product and the need for a workable classification, which can be accepted and taught, is paramount.

Then, it was my turn to talk about the new revised classification that the GAA and Opal Association (OA) are proposing. Boy was I nervous! My talk, on behalf of these two committees, was on the detail of the revision. For more information on this matter, please see the *Opal Classification* list following this article. At the conclusion, there was robust discussion and the room understood the need for a

Sebastian Deisenberger, President, Lightning Ridge Miners' Association Ltd.

Women who mine.

revised classification. A large majority of participants had no issue with what is being proposed, although the issue of origin was a primary concern for miners.

For anyone working with Australian opal, origin is of utmost importance and, when we see other opal being passed as Australian, we quite rightly get very annoyed. People, particularly those in the mining towns around Australia, want to see origin formally recognized. It was discussed at length and most understood that this was a project separate to classification. It can, however, be part of everything we do as an industry to market our opal.

The Symposium ended with a marketing workshop around what the next steps might look like. To say that everyone participated is an understatement. The entire room was buzzing with ideas and it was gratifying to see all delegates putting their thoughts to paper and sharing them with the room. Without going into the finer details, there was a consensus among most to start looking at a marketing campaign to promote Australian Opal, building on the idea of origin and provenance.

Final Thoughts

While we are small, we have a broad range of experience and depth of knowledge that are not going away too quickly. There are issues with attracting more people to mining, but Gary White showed a creative way to reframe the conversation, as did Andrew Kemeny.

The direct community of Lightning Ridge will benefit from the Reserve Trust and we are hopeful for the surrounding farming land to be included in that Reserve, to future-proof the quality of the land.

The Australian Opal Centre is really moving forward and now with concrete costs and regional dollar benefits being mapped out, it has its best chance yet of getting funded. Imagine a world-class facility to study not only opal, but also the rich dinosaur history of our ancient land!

I think all delegates got a sense of our unique chance to shape how colored gemstones are viewed and regulated globally. By taking the lead with classification, we can be instrumental in providing the road map for other gems around the world.

The next Symposium is due to be held in Coober Pedy in April 2020. International delegates and speakers will be most welcome. *Photos are courtesy of the author unless otherwise specified.*

Opal Classification: The Best Way Forward

By Ruth Benjamin Thomas, Director, Black Opal Direct

The review of opal classification and nomenclature has progressed significantly over the past year. The review is being done by two Committees—the Gemmological Association of Australia Opal Sub-committee and the Opal Association Classification Committee.

We have consulted with, and received feedback from the following stakeholders;

- Gemmological Association of Australia (GAA)
- Jewellers Association of Australia (JAA)
- National Council of Jewellery Valuers (NCJV)
- Lightning Ridge Miners Association (LRMA)
- Queensland Boulder Opal Association (QBOA)
- Coober Pedy Miners Association
- Australian Opal Centre (AOC)
- Miners and Industry professionals via the 9th National Opal Symposium
- CIBJO Colored Stone Steering Committee

What Is Classification and Why Now?

The revised opal classification is a system for categorization only. It is not for the purposes of grading or valuation or for defining origin. This is important as the work being done is to benefit all stakeholders in the process.

The original classification, outlined in the 1997 publication of *Australian Gemmologist* and authored by Anthony Smallwood, was never formally adopted. Since then, the Ethiopian Wello field has opened up as a major source of hydrophane (absorbent) opal, which has very different properties to the Australian material.

- Global industry and consumers are confused, as hydrophane is not generally disclosed.
- Gemological Institutions and laboratories need universal classification to avoid confusion.
- Major gemstone buyers of are requiring full disclosure, but the opal industry does not have a universal classification.
- The revised classification builds on the previous classification and nomenclature and proposes eight separate categories of opal in a universal system to minimize misunderstandings and misrepresentation and to protect the reputation of the opal brand globally.

Eight Categories of Opal

Under the proposed classification there are now eight categories of opal. These categories are determined using a "key" or series of questions.

1. Is the opal natural, has it been treated, is it synthetic or an imitation?
2. Is the natural opal impervious or absorbent?
3. Does the natural impervious opal have play of color or not?
4. Is the natural impervious precious opal homogeneous, on host rock, or in host rock?

Using a flow chart, it then becomes easy to identify to which of the eight categories an opal would belong. The eight categories and their draft definitions are as follows:

Natural Homogeneous Precious Opal: Natural precious impervious opal of substantially homogeneous chemical composition.

Natural Precious Opal on Host Rock: Natural precious impervious opal naturally attached as a layer to the host rock, or where a substantial amount of precious opal is present on the face of the host rock.

Natural Precious Opal in Host Rock (Matrix): Natural precious impervious opal naturally occurring as fillings of pores, holes or between the grains of the host rock.

Natural Common Opal: Natural impervious opal without play of color in its natural state.

Natural Hydrophane Opal (Precious or Common): Natural precious or common opal which is absorbent in its natural state. It may be of homogeneous chemical composition or it could be naturally attached to or occurring in the host rock.

Treated Opal: Natural Opal which has been treated.

Composite Opal: Natural opal which has been manually attached to any material.

Synthetic and Imitation: Any material that simulates or resembles natural opal, but is either manufactured or does not have the chemical formula SiO_2nH_2O.

Ruth Benjamin-Thomas gives a presentation at the CIBJO Steering Committee (Day 2).

THE EIGHT CATEGORIES OF OPAL	NATURAL HOMOGENOUS PRECIOUS OPAL	NATURAL PRECIOUS OPAL ON HOST ROCK
NATURAL PRECIOUS OPAL IN HOST ROCK (Matrix)	NATURAL COMMON OPAL	NATURAL HYDROPHANE OPAL (Precious or Common)
TREATED OPAL	COMPOSITE OPAL	SYNTHETIC & IMITATION

The Way Forward

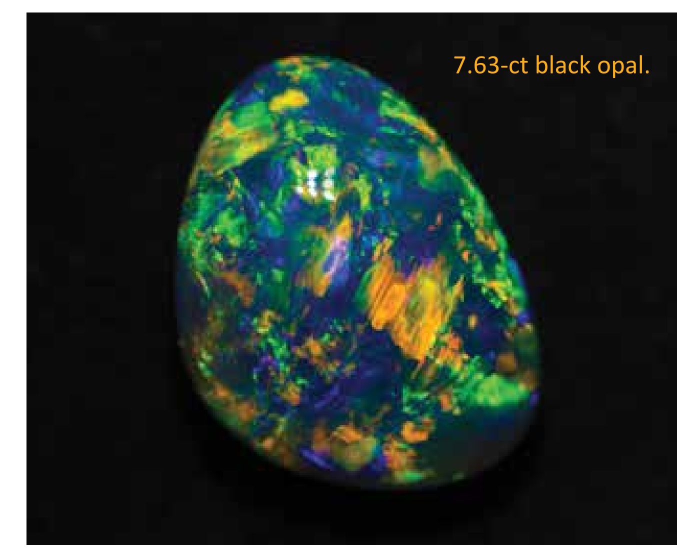
Over the past few months, the working party has stepped back from the detail previously presented to ensure a consensus on the model of the eight categories and the definitions within. We have in principle agreement from all stakeholders to move forward with the structure above.

"This draft classification is considered a living document."

Consultation moved beyond Australia to a presentation by Ruth Benjamin-Thomas, of Black Opal Direct and a Committee Member of the Australian Opal Association to the CIBJO Colored Stone Steering Committee at the CIBJO Congress in held in Bogota, Colombia last October.

There was much discussion around the process and committee members in attendance were provided with this draft documentation. Feedback was positive and those in attendance agreed it was a great step in the right direction. Informally, a subcommittee has been set up to examine the work thus far at an international level.

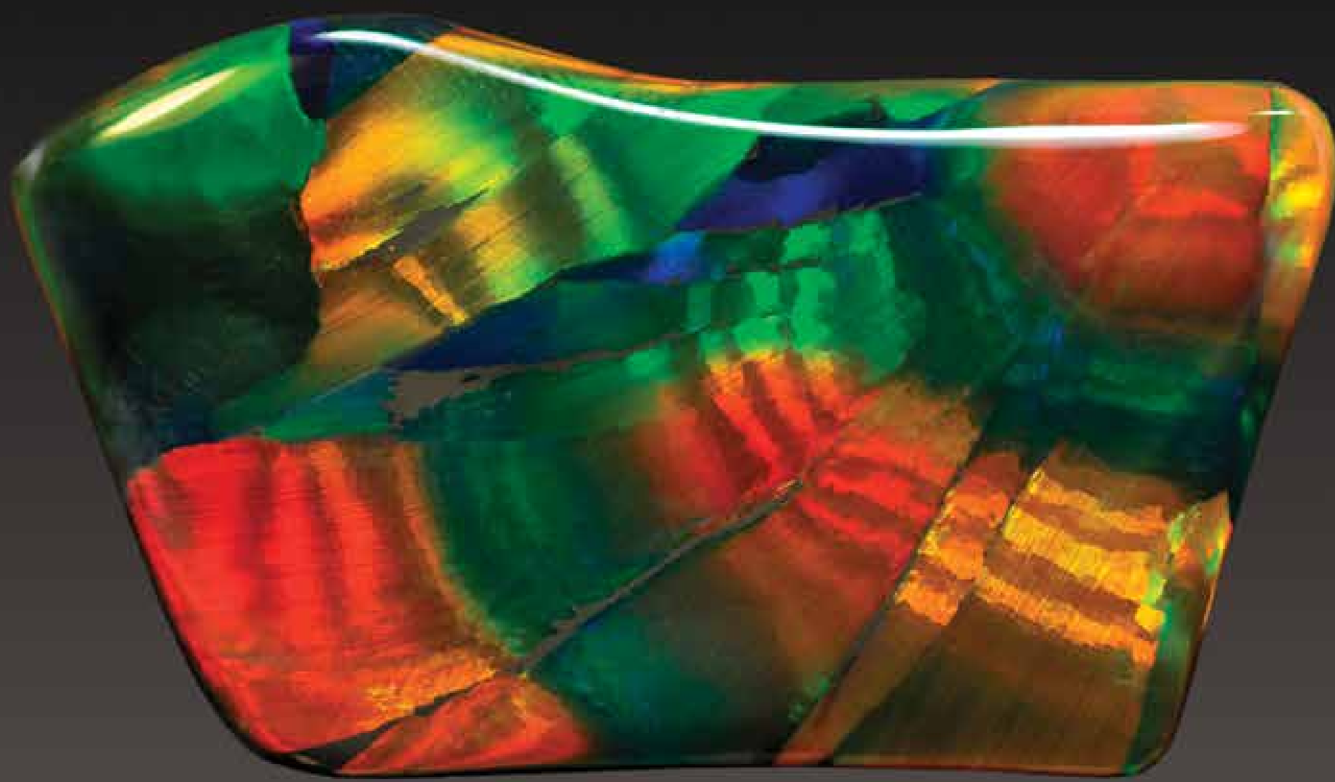
This will be chaired by Ken Scarratt of DANAT Lab with involvement of other steering Committee members. The ultimate aim is an *Opal Guide* issued by CIBJO, which can then be formally adopted and implemented as the only accepted classification for opal globally, enabling industry, gem labs and consumers to have confidence in the disclosure and classification process.



7.63-ct black opal.

The Working group is due to commence working on the detail of each category and to undertake another round of community consultation prior to finalizing the classification this year.

For more information on the revised opal classification, contact Andrew Cody, Cody Opals, or Ruth Benjamin-Thomas, Black Opal Direct.



Australian Opal Mining
A Model for Responsible Mining

By Damien Cody, Dr. Laurent Cartier, John Winch

A New Paradigm of Consumer Expectation

Today's consumers are spoiled with a plethora of choices when buying luxury goods. The Internet has made the world much smaller, with immediate information, communication and commerce capabilities. This is especially the case with jewelry, which is one of the most purchased item categories on Internet shopping. Buyers of colored stone jewelry have loads of information at their fingertips and only a mouse click away.

Many modern day jewelry consumers have added responsible sourcing and sustainable mining to their decision criteria. This is clearly evidenced by the high number of companies that have marketed and articulated their ethical approach and procedures in the sourcing of their gemstones and precious metals and also in their cutting and manufacturing processes.

There have been a number of studies and initiatives in this space, which have spurned this new paradigm for colored gemstone supply. Principle among them was the development of the OECD's *Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict Affected and High Risk Areas.* Originally aimed at specific issues relating to tin, tungsten, tantalum and gold, it has been clarified to include the supply of all minerals including colored gemstones.

The *Guidance* provides detailed recommendations to help companies respect human rights and avoid contributing to conflict through their mineral purchasing decisions and practices. *[www.oecd.org/corporate/mne/mining.htm]*

The Responsible Jewelry Council (RJC) was formed in 2005 by 14 organizations including some of the largest diamond mining and supply companies as well as some famous jewelry brands. It has a member base of around 1100 members. The RJC is currently reviewing their Codes of Practice to incorporate colored gemstones.

RJC Members commit to and are independently audited against the RJC Code of Practices—an global standard on responsible business practices for diamonds, gold and platinum group metals. The Code of Practices addresses human rights, labor rights, environmental impact, mining practices, product disclosure and many more important topics in the jewelry supply chain. *[www.responsiblejewellery.com]*

Opposite page: A spectacular 22.59-ct Lightning Ridge *Peacock Tail* pattern black opal (Photo and stone: Cody Opal Australia)

Figure 1. Opal mine shaft Lightning Ridge.

Figure 2. Tailing out the washed dirt at Lightning Ridge.

Large trade associations such as the International Colored Gemstone Association (ICA) and the American Gem Trade Association (AGTA) have developed Codes of Practice that incorporate responsible and sustainable practices. The World Jewelry Confederation (CIBJO) is formulating responsible sourcing guidelines that, when ratified, will have the status of a CIBJO Blue Book.

Colored gemstones are diverse in species and source distribution. Many are found in under-developed and remote parts of the world. The varying geography, political environments, socio-economic conditions and cultural beliefs all add up to a highly fragmented supply path. This makes the traceability of most gemstones throughout the supply chain extremely difficult.

Opal Mining in the Australian Environment

The Australian opal mining industry goes to extraordinary lengths in bringing Australian opal to the world market in a sustainable and ethical manner, and some would argue that it is the world's most ethically mined gemstone. It benefits from the fact that it is mined in a highly developed, highly regulated and stable country (Figures 1 and 2).

The industry is highly regulated by the overarching Federal Legislation and also State and Regional Acts, which cover a number of issues pertaining to ethics and sustainability. Mining bodies representing the various regions where opal is found will attest to the problems of complying with the ever-increasing layers of complexity.

In this study, we have looked at the various components that make for an ethical, responsible and sustainable mining industry and how the Australian miners measure up.

The elements for this study include:

- Work health and safety
- Workplace conditions
- Native Indigenous land rights and cultural heritage
- Environment protection
- Historical and cultural heritage
- Social responsibility
- Ethics
- Treatments and disclosure

Work Health and Safety

Opal mining operations are subject to a number of prescribed work, health and safety regulations depending on the location. Each of the three states where opal mining is taking place—Queensland (QLD), New South Wales (NSW) and South Australia (SA)—has separate Work, Health and Safety Acts regulated by state government authorities. In NSW, it is compulsory for miners to undertake a safety awareness course every five years. All mine operators must attend a mine operator's workshop.

Figure 3. Coober Pedy.

Figure 5. Rough opal from Mulga Rush Lightning Ridge.

In more than 130 years of opal mining, there have been very few opal mining accidents resulting in fatalities. Our research indicates that in Lightning Ridge where there are around 3000 mining claims, there has been one fatality in the last 20 years. At the other fields, there has been one in Winton Area and four in Coober Pedy in the last 20 years. The Coober Pedy incidents relate mostly to collapses of some of the estimated 250,000 shafts from old workings (Figure 3).

Investigations ensue and valuable lessons are learned from all accidents that are reported. Regular audits are conducted and remedial orders are imposed. Information provided by the regional opal mining associations indicate that, in most mining areas, the audits have resulted in a high degree of compliance with the regulations.

One exception was a 2017 audit by the NSW Department of Planning and Environment, which found a number of breaches among the 124 claims inspected in Lightning Ridge. [*NSW Resource Regulator – Compliance priorities outcomes July – December 2017]* Penalties were applied for non-compliance. All of these breaches were rectified with the exception of one operator who faced having his mining claim cancelled.

In 2017, the Queensland Mines Inspectorate conducted an audit of respirable crystalline silica levels from a wide range of opal mining operations in the Winton area. This involved inspection of both open cut and underground mines. The levels were found to be well within safe levels.

A number of follow-up sampling surveys are scheduled and, in due course, a set of best practices will be formulated that are tailored to suit opal mining. [*Queensland Boulder Opal Association communication November 2018]*

All of the opal mining fields and the various State departments have prepared guidelines for safe practices in relation to respirable silica. The result of the very stringent regulations and the regular audits is a much safer workplace for all involved (Figure 4).

Workplace Conditions

Opal mining areas are covered by State legislation prescribing award pay rates and working conditions. This ensures that workers, whether they are casual or permanent, receive at least the minimum wage prescribed for the type of work and their relevant experience. They also enjoy the protection of safer work environments and compensation in the event of a workplace accident. Workers must be above the minimum age of 16 and receive appropriate training where required. Heavy machinery can only be used by licensed and trained operators.

Most opal mining is undertaken by the mine owners themselves, sometimes with partners. There are very few employed workers. Due to the speculative nature of the production, workers are generally partners who share in the proceeds of any opal discovered (Figure 5).

Figure 4. Gem Black Opal, Lightning Ridge.

Native Title, Indigenous, Land Use and Aboriginal Cultural Heritage

The Aboriginal peoples of Australia maintain the oldest continuous living cultures in the world believed to span some 50,000 years. In fact, opal features in some of the belief systems or *dreamtime stories* that involve the *Rainbow Serpent*, the creator in Aboriginal mythology.

In Australia, Aboriginal Title is referred to as Native Title, which is the recognition by Australian law that indigenous people have rights and interests to their traditional land, which was acquired by the government during European settlement. This is enshrined in the Native Title Act 1993.

The vast landscapes of the Great Artesian Basin (GAB) where Australia's opal deposits are found were roamed by various Aboriginal tribes. Although in large parts of the (GAB), naturally occurring surface water deposits was and is almost non-existent. As a result, some opal mining areas of SA and Qld have little evidence of Aboriginal activity.

Many mining areas especially in Queensland are on Crown Land or Crown Leasehold Land and are therefore covered by Native Title claims. In other areas, there exists Indigenous Land Use Agreements (ILUA) which provide mechanisms for opal miners to negotiate the use of land with authorized Aboriginal Land Councils (Figure 6).

If native title has been granted or a native title application claim has been submitted by a traditional owner group to the National Native Title tribunal, the mining industry must then negotiate and involve the traditional owner group in the process of exploration and mine development.

This also includes traditional owner involvement in the archaeological survey within the activity area. The process and negotiations often result in an ongoing royalty payment or one-off payment to the traditional owner group. In some cases, mining or exploration can be stopped when the cultural and environmental impacts outweigh the benefits for native titleholders.

Figure 6. Ancient Aboriginal water holes carved in the hard cap rock at Koroit Queensland.

Figure 7. A scarred tree, evidence of Aboriginals removing bark to make a shield or a carrying vessel (Coolamon). (Photo: Navin Officer Heritage Consultants)

In addition to the use of the land is the recognition of the native cultural heritage, which includes archaeological, anthropological, contemporary, historical, scientific, social, or spiritual significance. This can extend to Aboriginal traditions that are the intangible aspects of culture (Figure 7).

Each State has legislation protecting Aboriginal cultural heritage and also maintains a central register of Aboriginal sites and objects.

Environmental Protection

The Environment Protection (EP) and Biodiversity Conservation Act 1999 provides a framework for protection of the Australian environment. It established a range of processes to help protect and promote the existing environmental landscapes and the recovery of threatened species and ecological communities.

Most opal mining leases require the miner to pay a substantial bond to ensure that not only does the miner take steps to preserve the environment, but that, after mining ceases, the miner rehabilitates the site to encourage the restoration to its former condition. Failure to comply with an Environmental Act can result in penalties including remediation of damage, court injunctions and criminal and civil penalties.

Some areas have onerous environmental legislation to comply with. Take for example Lightning Ridge that has the following EP acts to comply with:

- Environment Protection and Biodiversity Conservation Act 1999
- Environmental Planning and Assessment Act 1979
- Environmental Planning and Assessment Regulation 2000
- Mining Act 1992
- Mining Regulation 2016
- National Parks & Wildlife Act 1974
- National Parks and Wildlife Regulation 2009
- Protection of the Environment Operations Act 1997
- Protection of the Environment Operations (Clean Air) Regulation 2010
- Protection of the Environment Operations (General) Regulation 2009
- Protection of the Environment Operations (Noise Control) Regulation 2017
- State Environment Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007 (Mining SEPP)
- Biosecurity Act 2015 No 24
- Biosecurity Regulation 2017
- Local Environment Plan

The regulations can require a range of measures depending on the location, including rehabilitation, revegetation, mullock stockpiling, backfilling, geological soil layering, compacted ground rectification, artesian water use limitations, building requirements and weed control.

The Lightning Ridge Miners' Association Ltd (LRMA) has undertaken further studies prior to opening new areas for prospecting and mining. Most environmental assessments by the LRMA are conducted on a collective basis across the entire mining fields.

The LRMA is also running a program of weed eradication of the Hudson pear (*Cylindropuntia rosea*), which is an invasive cactus species of Mexican origin that has infested the region around Lightning Ridge. Its long spines are extremely dangerous to humans and especially native animals such as kangaroos, which often die from a spike from the plant. The spikes can penetrate boots and even car tires (Figure 8). [*Lightning Ridge Miners' Association Communication November 2018*]

Historical and Cultural Heritage

Some older opal mining areas have been proclaimed as culturally or historically significant sites that must be preserved. Old mine workings, camps and equipment are preserved for future generations to experience the hardships endured by the pioneering folk who worked in Australia's remote and harsh desert outback where opal is found.

In the Winton district exists the early mining settlement of Opalton, now a designated fossicking area. Preservation of the main workings is exactly as they were abandoned well over a 100 years ago, with only natural weathering and revegetation re-shaping the past. This preservation is

Figure 8. Hudson Pear spines can puncture tires. (Photo: NSW Department of Lands

largely due to the work of local volunteers from the mining community. The establishment of the Opalton Bush Park has provided facilities for visitors to experience the colorful history of some of the early opal miners from the late 19th century and the harsh conditions they endured in the remote outback (Figure 9).

The older mining areas surrounding the town of Lightning Ridge and the communities of Grawin, Glengarry and Sheepyards were declared *preserved opal fields* in the late 1990s. These preserved fields have a different rehabilitation requirement in that open shafts do have to be made safe, but they do not need to be backfilled; mullock can remain on title. For areas outside the preserved fields, there is a much more stringent requirement for rehabilitation including removing all mullock and backfilling all shafts. In these areas, there are a number of old miner's huts and opal mining sites that are heritage listed (Figure 10).

The newly planned Australian Opal Centre in Lightning Ridge features an exhibit of a number of ingenious mining and processing machines made from whatever scrap materials and resources could be found at the opal fields. This is truly a wonderful tribute to the resourcefulness of the early pioneers at the opal mining fields.

Coober Pedy has also preserved much of its cultural heritage. Miners converted some of their underground mines in to their homes to escape the blistering heat, which is often over 40°C. Many of these camps are preserved along with underground churches and hotels.

Social Responsibility

The outback towns of Winton, Quilpie, Lightning Ridge, White Cliffs, Andamooka, Mintabie and Coober Pedy would simply not exist were it not for the

Figure 9. Old opal mine shaft preserved at Opalton, Queensland.

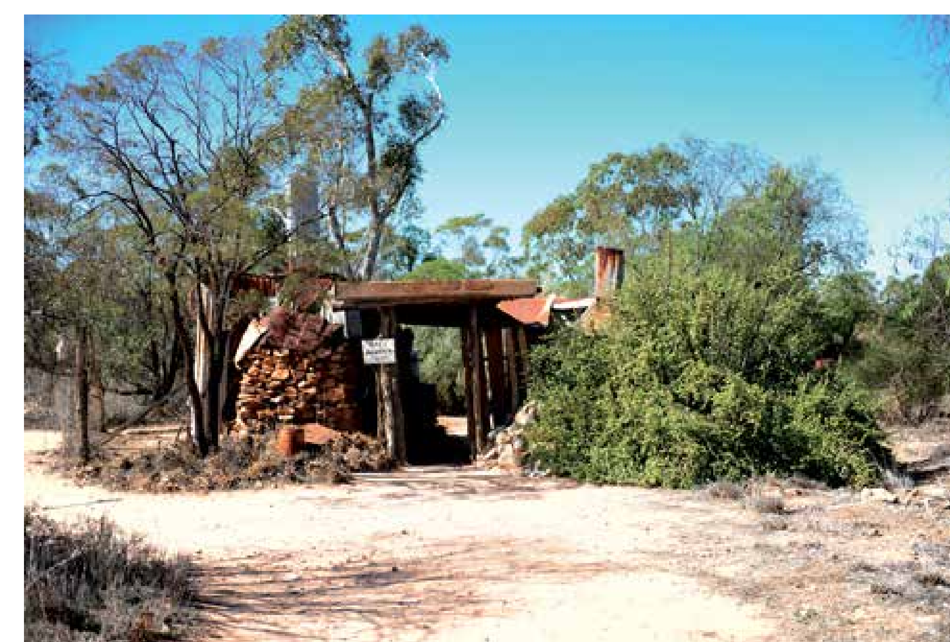


Figure 10. Fred Bodel's mining camp built in Lightning Ridge around 1916.

Figure 11. Split boulder opal rough.

Figure 12. A collection of gem black opal from Lightning Ridge.

opal mining industry. The Australian opal miners and their respective Associations are heavily involved in the development of the local communities. This includes fundraising and active involvement in construction of infrastructure, the flying doctor service, bush nursing, hospital, schools, churches, water supply, communications and many other community needs.

Many post WWII migrants made their way to the opal mining fields. The industry provided rewards for pioneering spirit and hard work regardless of their background, language, skills or education. Today, there are many second and third-generation descendants living and working in these areas (Figure 11).

Some of the infrastructure relied heavily on opal miners for construction and maintenance. Roads are built and maintained, water is often supplied through artesian bores and, in Lightning Ridge, they have built an Olympic-size swimming and diving pools using some of the miner's resourcefulness.

Ethics

Australia has a representative democracy and is well renowned for having a relatively stable government free from corruption and conflicts. It has well-regulated banking and taxation systems together with robust business operating frameworks. International trade across the border is controlled by a well-resourced and efficient Customs Border Force.

Treatments and Disclosure

Solid Australian opal is not readily able to be treated. The exception to this is a porous opalized sandstone from Andamooka known as Andamooka matrix, which can be treated to turn dark and highlight the opal colors.

This material is rarely seen in the marketplace and is fairly obvious to the discerning buyer. Australia has very stringent consumer protection laws that forbid incorrect or misleading descriptions of products.

The Australian Opal Industry has recently proposed a new opal classification and nomenclature for the world's opal. This was presented to the World Confederation of Jewelry (CIBJO) Congress in Bogota in November 2018.

It will be reviewed by CIBJO and the opal industry worldwide before becoming a new CIBJO Opal Guide. Once implemented, it will allow for universal and harmonized descriptions of the opal types and properties, resulting in greater consumer awareness and confidence (Figure 12).

Findings

The Australian opal mining industry has strong credentials as a responsible and sustainable gem mining industry. There appears to be enormous potential for Australia's opal mining industry to make mileage of the appellation of the source and the creditable qualities that go with it. Consumers buying Australian Opal can do so with the assurance that the gemstone they are buying is an ethical gemstone. The industry is an exemplar for many gemstone-mining activities around the world.

Acknowledgements

- Queensland Boulder Opal Association – Robbie Vinnicombe
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- White Cliffs Miners Association – Linda George
- Andamooka Progress Opal Miners Association – Peter Taubers
- Coober Pedy Miners Association – Paul Reynolds

All photos are courtesy of Cody Opal, unless otherwise specified.

Frozen Opal Fluids and Colloidal Crystal Fire: Gem Opal Deposits in the Heart of Australia

By Dr. Simon R. Pecover

Introduction

Australia's Great Artesian Basin (GAB) hosts widespread deposits of opal (Figure 1), and continues to be the major source of high quality gem opal for the international colored gemstone market. Opal mining in the GAB has produced billions of dollars worth of exquisite gems, including *light opal* mainly found in the opal fields of South Australia, *boulder opal* mined in Central Queensland, and *black opal* mainly mined around the town of Lightning Ridge.

Opal in GAB deposits comprises both common potch and rare precious opal, and occurs as replacements of fossils, as in-fillings in ironstone concretions and ferricretes, and as tectonically-generated fault and fracture controlled opal veins. Owing to the numerous varieties of opal, which occur in the sedimentary host rocks of the GAB, a number of contrasting theories have been postulated over the years to try to explain the formation of these important colored gemstone deposits.

Despite there being no consensus on genesis at the moment, what is clear, is that the opal deposits of the GAB exhibit many unique and extraordinary depositional features, and that prospective areas of the basin likely contain substantial remaining resources of precious opal, worth potentially billions of dollars for future supply to the global colored gemstone market.

Chemical and Physical Nature of Australian Opal

Amorphous opal from GAB deposits is composed of hydrated silica ($SiO_2.nH_2O$) containing up to 15% water (Schmidt & Dickson 2017), and comprises colloidal silica spheres, which were formed by the polymerization of silicic acid. Australian opal is commonly referred to as Opal-AG (i.e. *Opal-Amorphous Gel*). However, this term may no longer be appropriate for Australian sediment-hosted opal veins, as complex patterns of viscous opal fluid flow and banding relationships between ordered and disordered forms of opal in these veins, point instead towards an opal fluid state in which high concentrations of colloidal silica spheres were transported through fracture networks as highly viscous non-Newtonian fluids (Pecover 2010, 2012, 2018), and not as stationary gels.

Broadly, there are two major types of opal in GAB sedimentary host rocks: the very common potch and the much rarer precious opal. Australian potch opal comprises a disordered mass of variously sized silica spheres, and/or spheres which have become deformed and elongated (Gaillou et al., 2008; Liesegang and Milke 2018a; Liesegang and Milke 2018b); with deformation of these silica spheres likely to have occurred due to shear flow processes acting upon non-Newtonian highly viscous suspensions of colloidal silica spheres (Pecover 2018). The disordered structure of potch opal prevents it from diffracting white light to produce the colors of the visible spectrum.

In stark contrast to potch opal, Australian precious opal comprises colloidal silica spheres which have been ordered into face centered cubic and/or hexagonal close packed arrays. Silica spheres in these ordered arrays typically range in size from ~150-~440 nm (Sanders 1964; Liesegang et al. 2018b). The packing of different sized silica spheres diffracts different wavelengths of light, with spheres ~200 nm in diameter returning blue light to the eye, while those which are ~250 nm return green light, and those ~320 nm return red light (Figure 2).

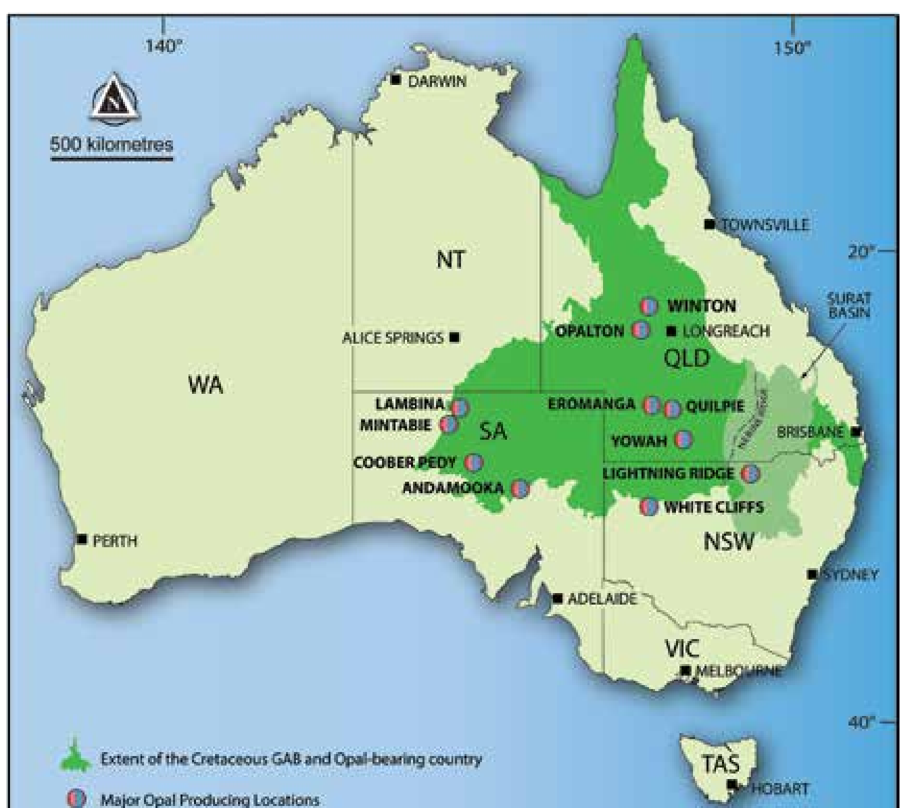


Figure 1. Map showing the location of major opal-producing areas in Australia's Great Artesian Basin.

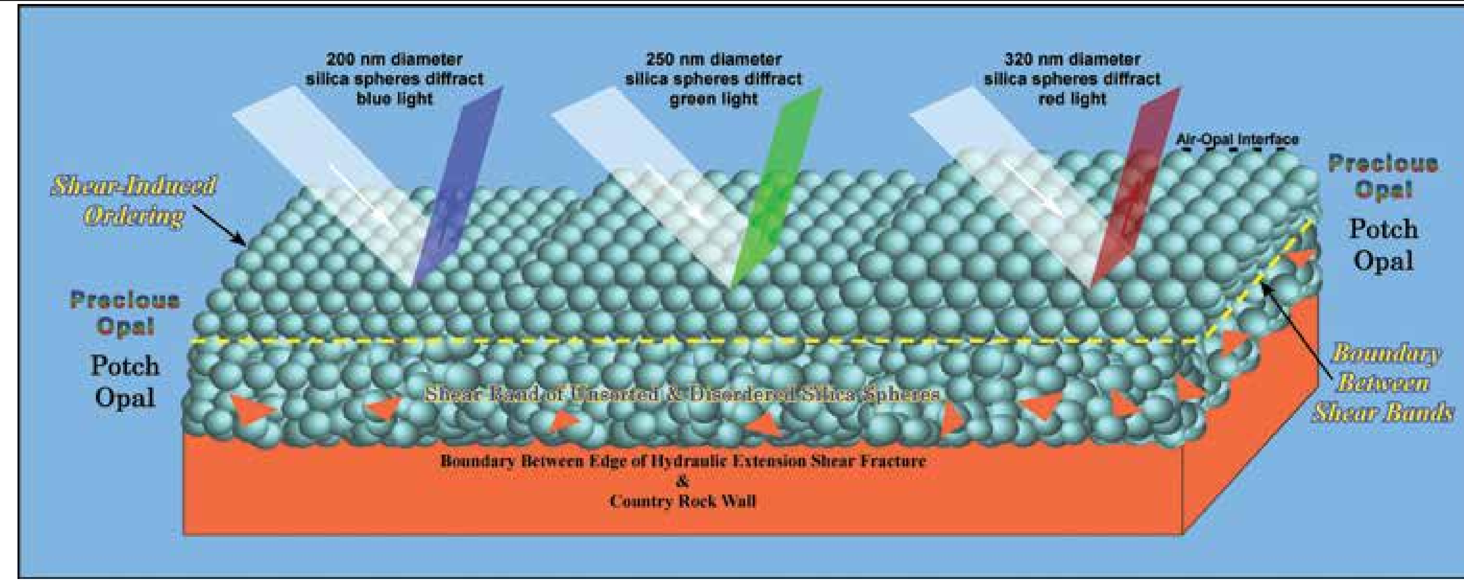


Figure 2. Schematic diagram of light diffraction in precious opal from Australia's Great Artesian Basin deposits.

In many GAB opal veins, the orderly arrangement of silica spheres has also resulted in the formation of distinctive parallel clusters of prismatic photonic colloidal crystals of precious opal (Pecover 2010, 2012, 2018) (Figure 3). These amorphous colloidal crystals are similar to atomic crystalline structures, but are composed of much larger (than atoms) colloidal silica spheres.

The orderly arrangement of silica spheres, combined with dislocations and twinning in these colloidal crystals, facilitates irregularly shaped regions of diffracted light, leading to discreet patches of scintillating color when a magnificent Australian gem opal is rotated before a captivated gemstone buyer (i.e. the so-called *play of color*) (Figure 4).

Ordered arrays of silica spheres in GAB precious opal are also commonly accompanied by fine-grained amorphous silica cements, which fill the spaces between spheres. This combination of silica spheres and silica cement has created tough durable and stable Australian gem opal, which has survived substantively unchanged in the ground since the Miocene (i.e. for the last ~20 Million+ years).

Geological Setting of Great Artesian Basin Opal Deposits

Opal Producing Basins

Gem opal continues to be mined in Australia from numerous deposits occurring in the states of South Australia, New South Wales and Queensland. These opal deposits mainly occur within two Cretaceous sedimentary basins. These include the large Eromanga Basin and the much smaller Surat Basin. Together these basins comprise the bulk of Australia's famous Great Artesian Basin (Figures1, 5 & 6).

Opal deposits occurring in the Eromanga and Surat basins are typically located in specific areas of these basins, where tectonically-generated horizontal compression of very near-surface Cretaceous sedimentary host rocks caused mild warping, which formed low amplitude wrinkles and ridge structures in the Earth's crust at these locations (Figures 7 & 8a) (Pecover 1996, 2007 & 2018). Stratabound, sub-horizontal opal vein deposits occurring in clay-rich sediments within these ridges are commonly spatially associated with, and genetically related to, reverse and thrust faults (these faults form during horizontal compression). Opal-hosting tectonically-generated ridge structures in Central Queensland and NW New South Wales occur as distinctive low elevation geomorphic landforms (e.g. the ridge system on which the town of Lightning Ridge is located; Figure 7); while in the South Australian opal fields similar structures are flatter and less obvious.

Age of GAB Opal Deposit Formation

The age of opal deposits occurring in the GAB has been the subject of much speculation, and some definitive measurement. Speculated ages include Early Cretaceous (~113 Ma: Watkins et al 2011) and Early Cenozoic (~ 60 Ma: Rey 2013).

Measured ages include Miocene (~20 Ma; Newberry 2005) and Late Oligocene to Early/Mid Miocene (~35 Ma to ~20 Ma; Schmidt and Dickson 2017). Age dating by Newberry (2005) and Schmidt & Dickson (2017) is consistent with paleomagnetic dating, dating of alunite, geomorphic studies and mineralogical studies carried out by other researchers across the GAB (Schmidt and Dickson 2017 and references therein).

A broadly Miocene age for GAB opal deposit formation is also in accord with the modeling of paleo-stress fields and the tectonic evolution of the Australian Plate over the past 100 Ma (Muller et al. 2012 and references therein), which likely led to the gentle horizontal warping and associated compressional faulting of the GAB sediments which host the opal deposits (Pecover 1996, 2007, 2010, 2012 & 2018; Horton 2002).

Opal Producing Regions

Historically, each of the three opal-producing states in Australia are considered to produce particular types of opal, such as *light opal* from the South Australian opal fields, *boulder opal* from the Queensland opal fields and *black opal* from fields surrounding Lightning Ridge. While this

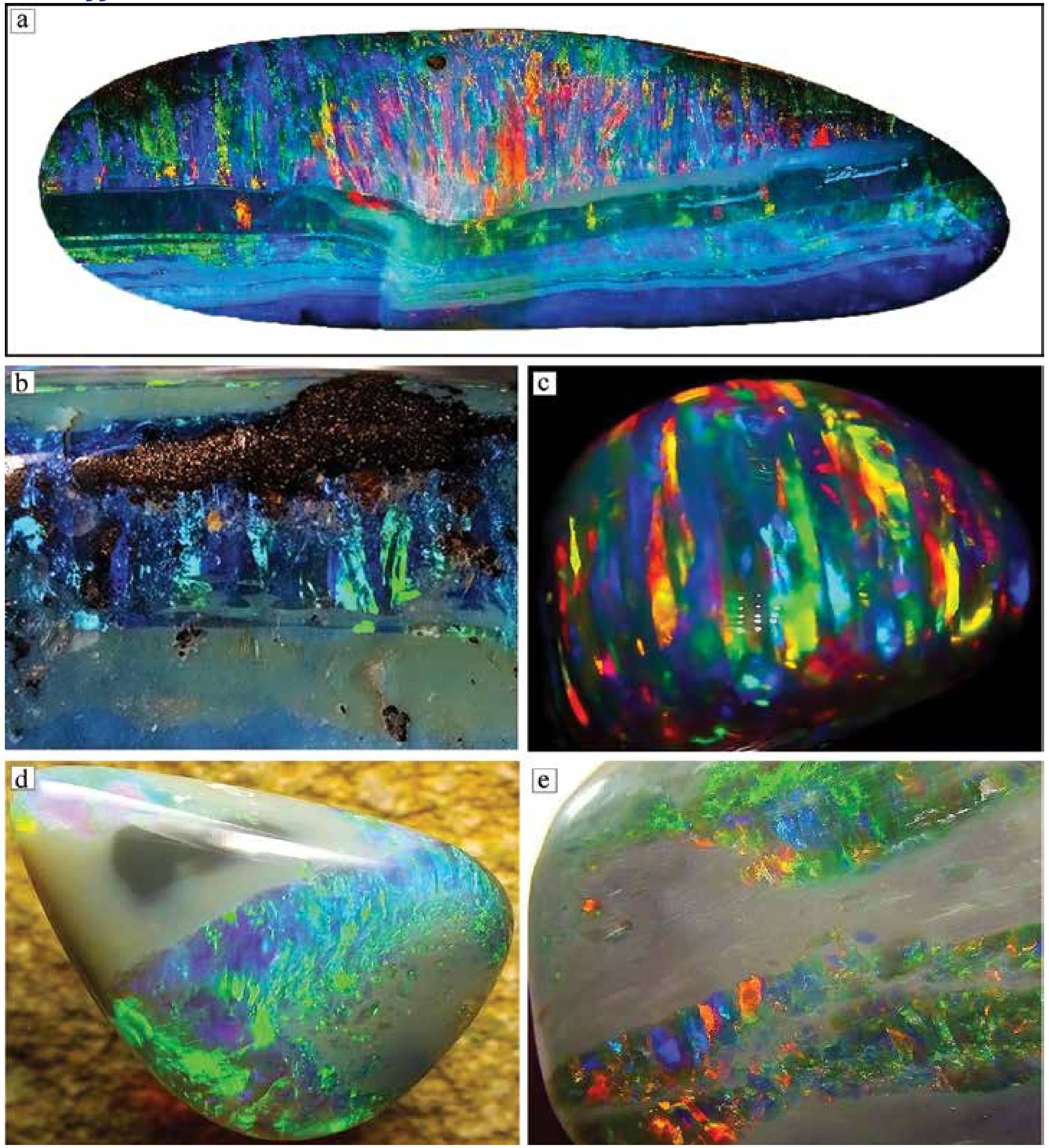


Figure 3. Prismatic photonic colloidal crystals of precious opal, which are postulated to have been formed by shear-induced ordering and epitaxial growth within shear bands undergoing shear thinning. The opals shown are from deposits across the GAB. (a) Shows boulder opal comprising multiple bands of mainly precious opal within which prismatic photonic colloidal crystals of precious opal have grown at right angles to shear banding. (b) & (c) Show close-ups of prismatic photonic colloidal crystals of precious opal in boulder opal (b) and in Lightning Ridge vein opal (c). (d) Shows opal vein with colloidal silica crystals which have been bent and fragmented in response to being sheared. (e) Shows opal vein in which the shearing of bands of colloidal crystals has resulted in disaggregation and fragmentation of crystals, with some crystal fragments having been entrained within adjacent turbulently flowing bands of potch opal. [Pinterest photo in (a); Seda Opals specimens and photos in (b), (d) & (e); Black Opal Direct specimen and photo in (c). The amazing colloidal crystalline opal shown in (c), known as the "Rainbow Serpent", can be viewed on YouTube @ (https://www.youtube.com/watch?v=ZS6i1LEZXIY).]

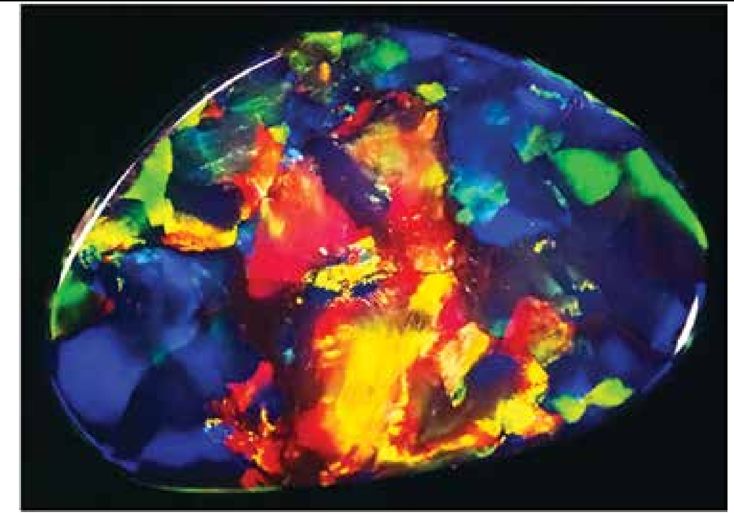
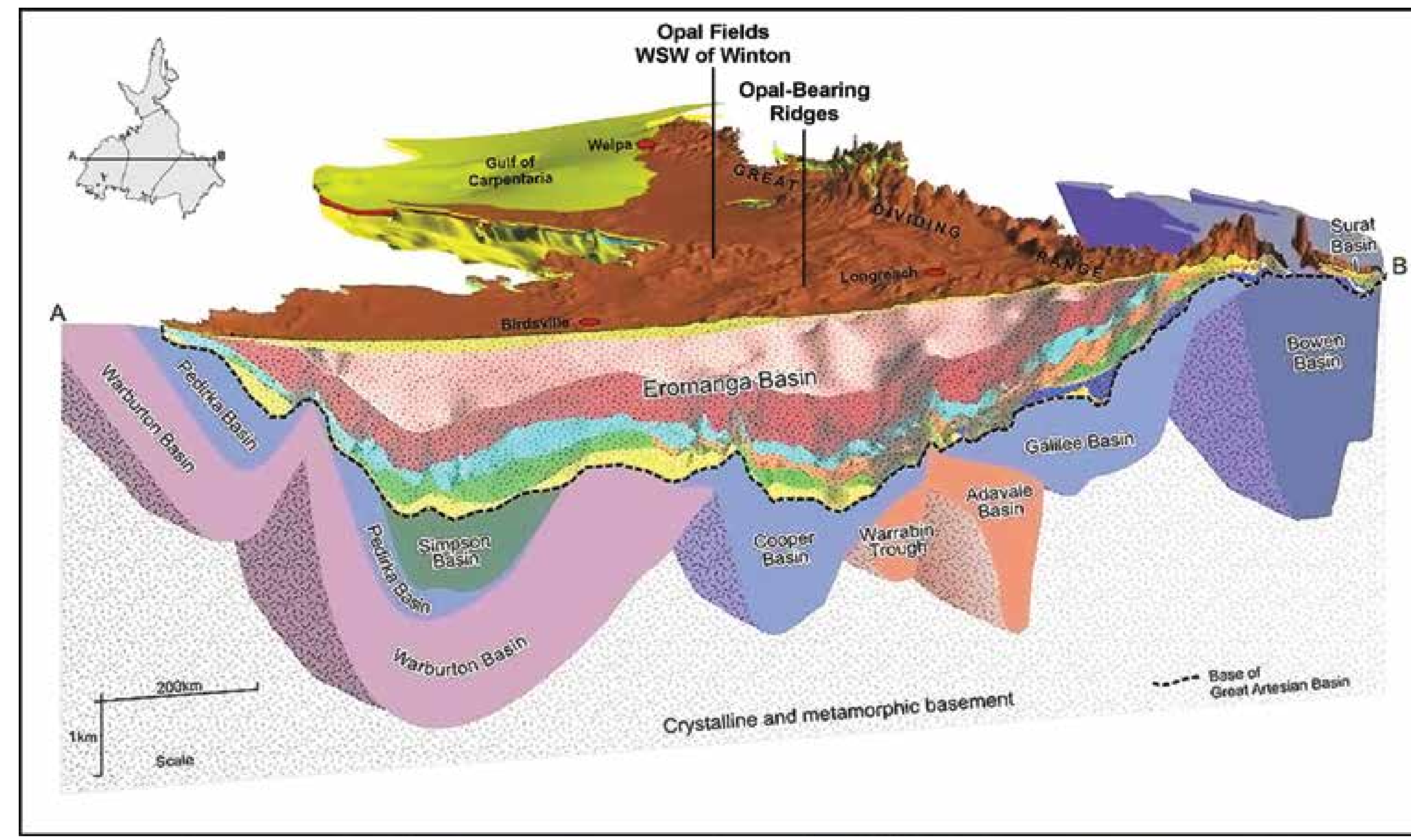


Figure 4. A classic black opal from Lightning Ridge. (Mineral Resources of New South Wales specimen and photo)

Figure 5. 3D representation of the cross-sectional architecture of the Great Artesian Basin. This basin is part of the Great Australian Basin, which contains several basins, including in this illustration, the Eromanga Basin and the smaller Surat Basin. Tectonic horizontal compression formed opal-vein-hosting antiformal ridge structures in the Early to Mid Miocene, mainly throughout the Eromanga Basin in Central Queensland. (Diagram adapted and modified after Figure 1.2 in Smerdon 2012)



demarcation is broadly correct, opal fields in each of the states commonly produce a variety of opal types when considered from a gem grading perspective.

Queensland Opal

Numerous opal fields occur across a wide area of the central region of the Eromanga Basin in Queensland. These opal deposits are hosted by the sedimentary rocks of the Winton Formation (Figure 6), which typically comprise fine to medium-grained feldspathic arenites, siltstones and mudstones. In this geological setting, these sediments were deposited by rivers and streams which flowed across a broad coastal plain bordering the ancient Eromanga Sea during the late Albian to mid-Turonian (102–91 Ma) (Kear and Hamilton-Bruce 2011; Schmidt & Dickson 2017).

In Central Queensland, opal occupies spaces in ironstone concretions and ferruginous septarian nodules, producing a distinctive type of opal known as *Boulder Opal*. The rare accumulation of potch and precious opal in some of these ironstone concretions typically occurred in hollow spaces and fissures after these spaces were formed (Figure 9). Thus, the opal in these concretionary structures is younger than their ironstone hosts (Schmidt & Dickson 2017).

Patterns of opal fluid flow preserved in boulder opal suggests that the opal fluids were injected into the cracks and hollows in these ferruginous rocks under geologically low fluid pressure conditions (Figure 9). Varying amounts of opalized plant and vertebrate fossil remains have also been recovered from Queensland opal deposits (Kear and Hamilton-Bruce 2011).

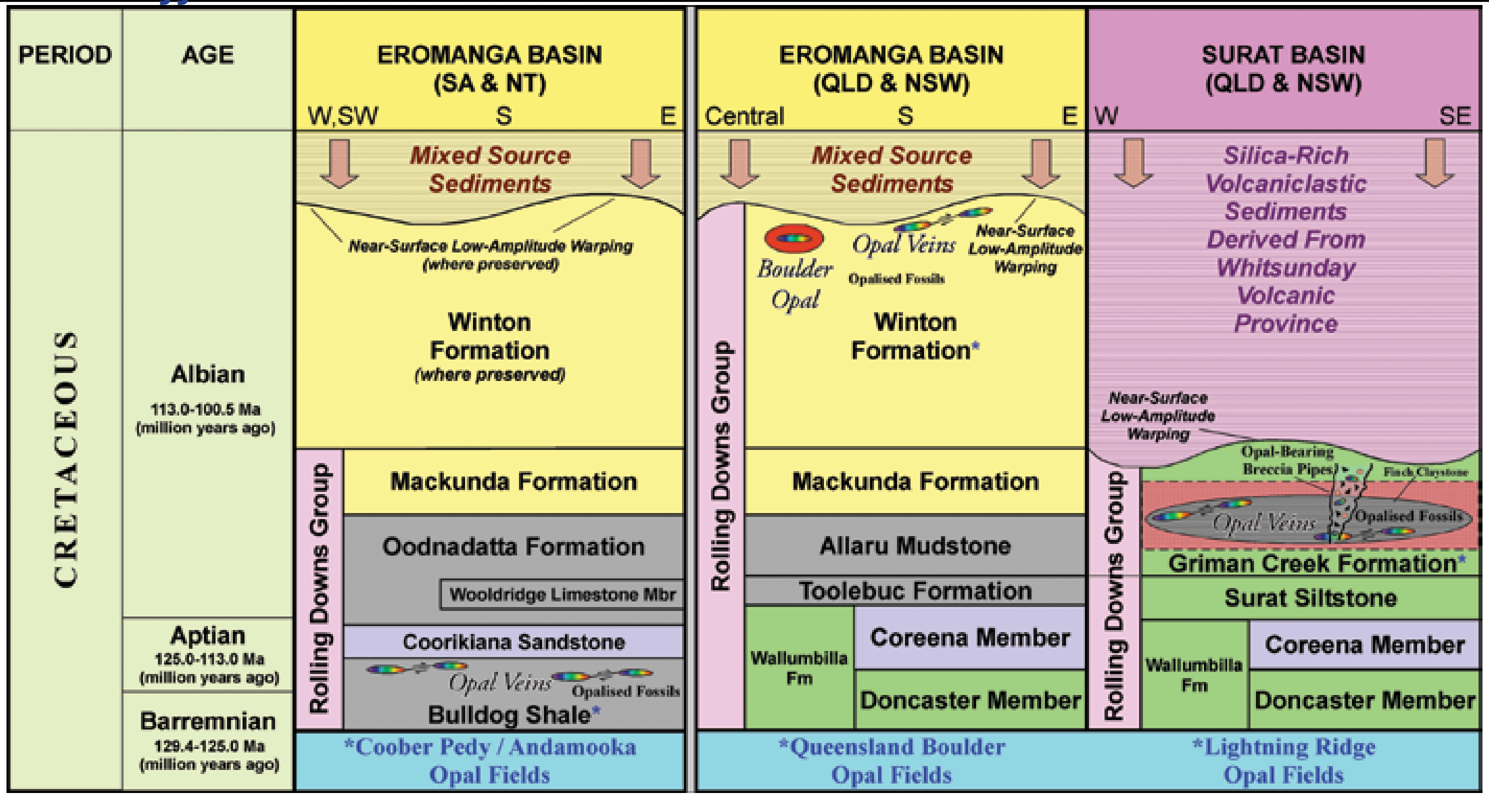


Figure 6. Stratigraphy of Great Artesian Basin sedimentary rocks hosting opal deposits in South Australia, Queensland and New South Wales, Australia.

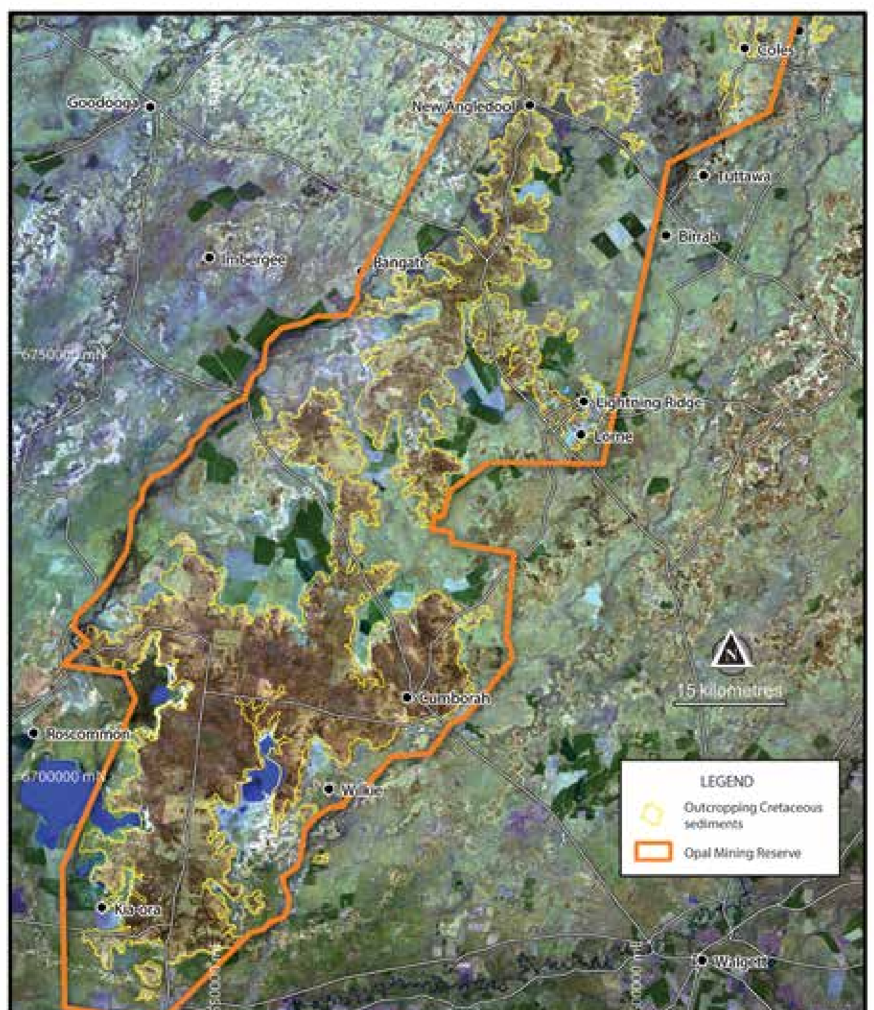


Figure 7. Satellite image of the tectonic ridge system which hosts opal deposits within the Narran-Warrambool Opal Mining Reserve surrounding Lightning Ridge, in NW New South Wales, Australia. The map, *Opal Fields - Lightning Ridge Region*, can be viewed and downloaded at: (https://www.resourcesandgeoscience.nsw.gov.au/__data/assets/pdf_file/0020/236333/Opal_Fields.pdf).

Alternating bands of potch and precious opal are also common in boulder opal, as are mixtures of these two types of opal. Curved patterns of viscous opal fluid flow preserved in boulder opal attest to deposition under turbulent hydrodynamic fluid flow conditions (Pecover 2018) (Figure 9). Figure 9b is an example of a once hollow ironstone concretion that was subsequently filled with an opal fluid, which also trapped a bubble that elongated in the direction of fluid flow. This bubble is *upstream* from opal displaying a parabolic flow pattern indicative of turbulent vorticity fluid flow (i.e. seen to the right of the bubble).

The curvature of opal flow points in the direction of fluid flow, and is indicative of both a velocity profile (i.e. flow fastest in the center of the curve and slowest along the sides due to drag on the fluid) and a fluid pressure gradient along which viscous opal fluid flow occurred (see also Figure 35 for an explanation of this phenomena).

These features demonstrate that the opal in-filling this ironstone concretion was not deposited slowly by bottom-up gravity-driven sedimentation of colloidal silica spheres (i.e. the traditional model), but rather was formed in a very vigorous opal fluid flow hydrodynamic regime, and under conditions likely exceeding local hydrostatic and lithostatic pressures.

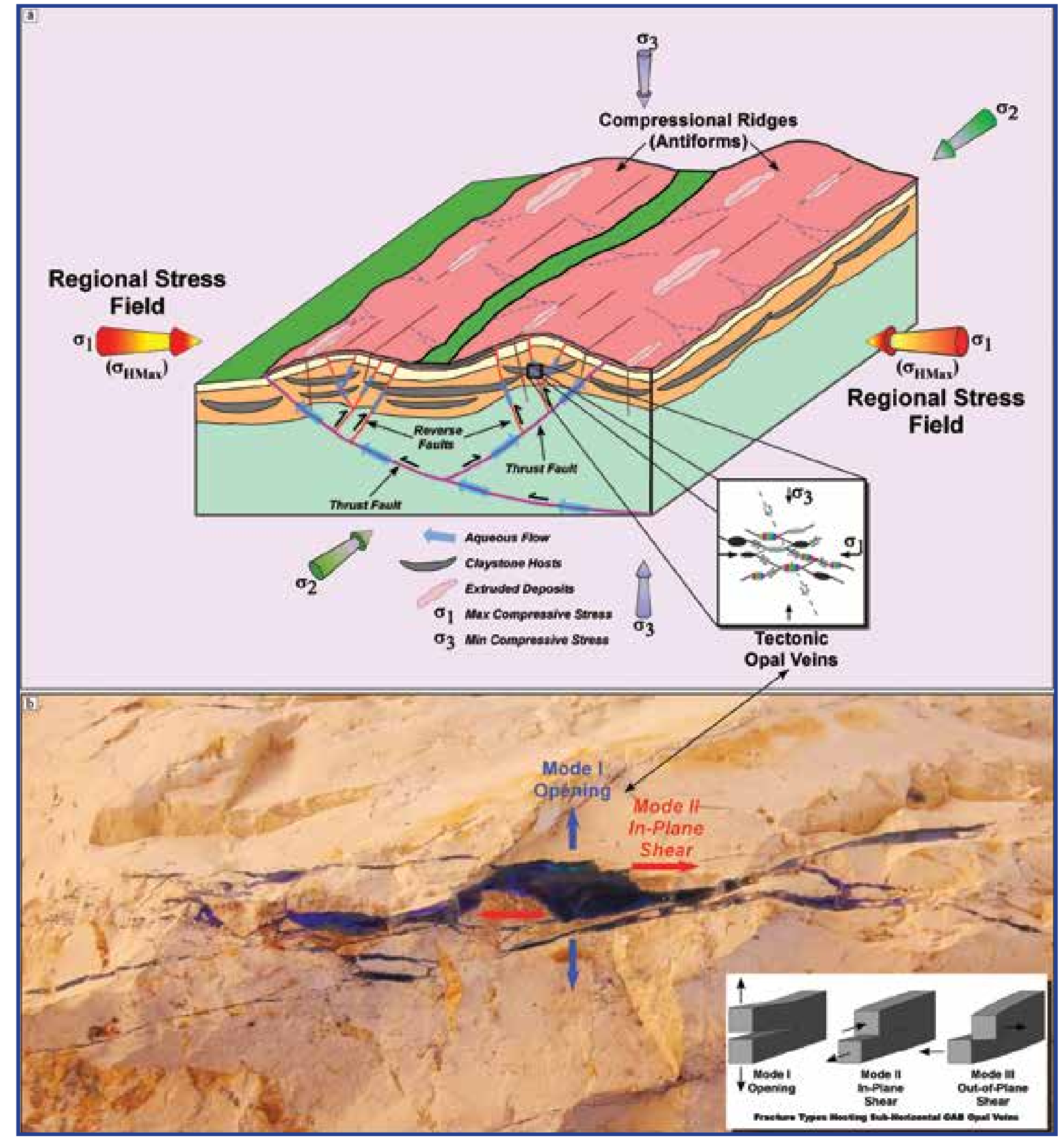


Figure 8. Relationships between stratigraphy, lithology, reverse faults, thrust faults and sub-horizontal opal veins in Great Artesian Basin (GAB) opal deposits. (a) Schematic representation of very near-surface crustal warps which host opal vein deposits in the GAB, where σv = σ3 (Note: The actual structural geology in these ridges is typically far more complex than shown here). (b) Illustrates the modes of fracturing evident in sub-horizontal opal veins at Lightning Ridge and elsewhere in the GAB. The opal vein hosting fractures in GAB opal deposits are typical of hydraulic extension shear fractures. [Tony Cummings specimen and Simon Pecover photo in (b)]

South Australian Opal

Most of the opal mined in South Australia, including at Andamooka and Coober Pedy, is hosted by the marine smectite-rich Bulldog Shale, which is part of the Early Cretaceous Marree Subgroup of the Rolling Downs Group (Figure 6). In these deposits, opal occurs in sub-horizontal and sub-vertical fault and fracture controlled opal veins, as well as opalized fossils. The replacement of carbonate shells of marine molluscs by potch and precious opal also occurs widely in the Bulldog Shale (Figure 10).

Andamooka is known for producing high-quality crystal-type precious opal (Figure 11), but also produces precious opal in which the play-of-color is set against a background of both light and dark body tones. Andamooka is also known for the production of so-called *Matrix Opal* which has replaced carbonate cements, and so-called *Painted Ladies* where opal coats fracture surfaces in quartzite cobbles and boulders (Figure 12). Sub-horizontal opal veins at Andamooka commonly display swirling and parabolic patterns of turbulent viscous opal fluid flow, as well as alternating bands of potch and precious opal (Figure 13).

Coober Pedy is known for large sub-horizontal opal veins which can be many centimeters thick, and which may extend laterally over tens of meters. These generally flat-lying opal veins are commonly found at multiple levels within the Bulldog Shale, spatially associated with reverse and thrust faults. Interestingly, the most productive parts of the Bulldog Shale at Coober Pedy are where opal veins occur in a sub-horizontal zone which is ~5 m above and ~2 m below the boundary between weathered and unweathered Bulldog Shale (Barnes and Townsend 1990). This geological relationship indicates that the opal veins not only post-date the deposition of the Bulldog Shale, but that their formation also likely overprinted the weathered and unweathered portions of this unit; suggesting that these opal veins were not formed by weathering processes (it should be noted, that weathering processes per se are not known to form fault and fracture controlled mineral veins in the Earth's crust).

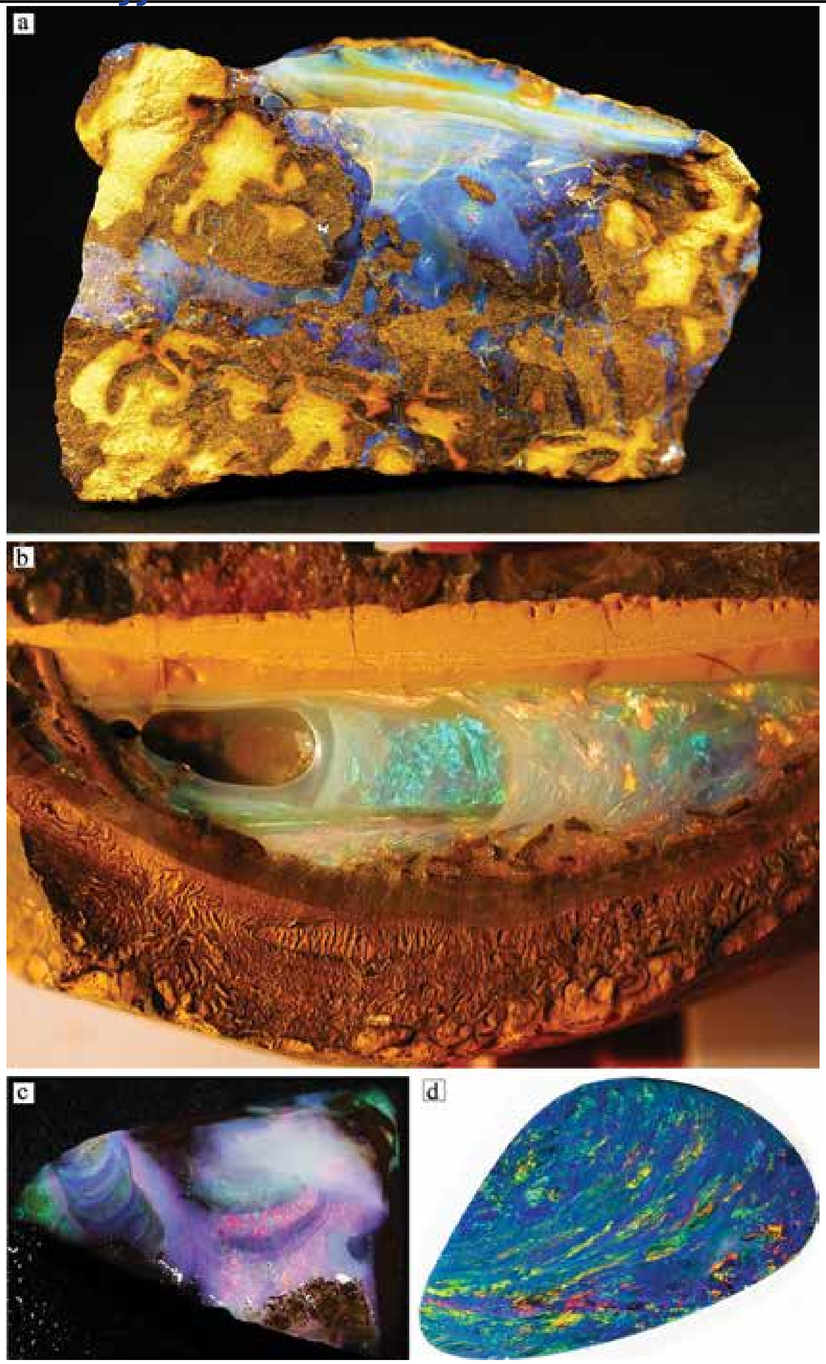


Figure 9. Boulder opal from the Central Queensland opal fields. (a) Shows ferruginised sandstone which has been invaded by opal fluids under low pressure. (b) Shows an ironstone concretion with a once hollow space which has been in-filled by opal fluids. A bubble in the fluid has been stretched in the direction of fluid flow. To the right of the bubble the opal displays a parabolic pattern of fluid flow indicative of turbulent flow along a fluid pressure and velocity gradient. (c) Shows similar patterns of parabolic opal fluid flow in another boulder opal. (d) Shows a gem boulder opal with multiple alternating bands of potch and precious opal which are curved in the direction of opal fluid flow. [Cody Opal specimen and photo in (a); Patrice Rey opal specimen and photo in (b); Seda Opals specimen and photo in (c); Patrik Ujszaszi (Rollingstone Opals) specimen and photo in (d).]

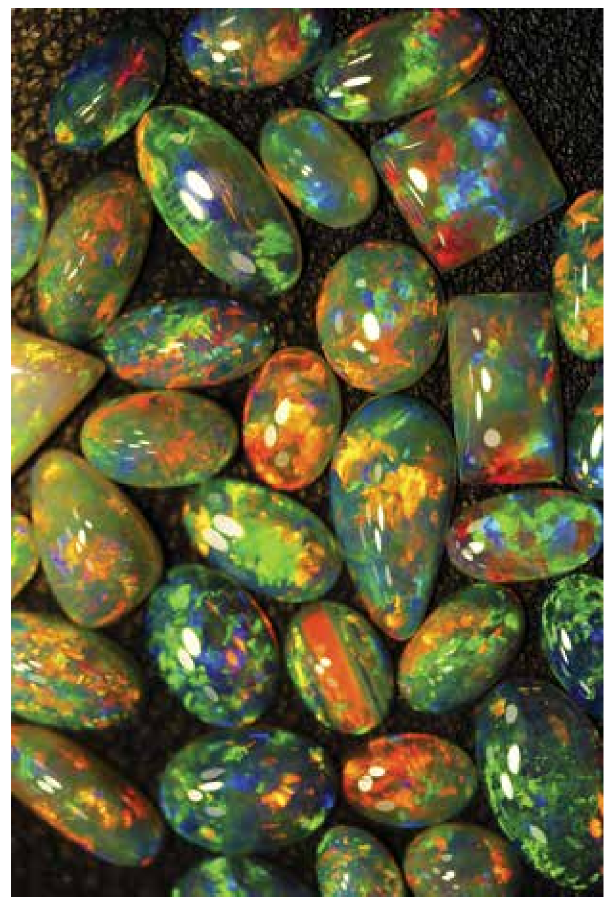


Figure 11. Selection of Andamooka precious opal gemstones showing a variety of colloidal crystalline patterns and structures in these opals. (Cody Opal gemstones and photo)

Figure 10. Opalized bi-valve mollusc fossils from Coober Pedy. Mildly acidic opal fluids invading the sedimentary host rocks containing these fossils replaced their carbonate shells with varying amounts of potch and precious opal. While the molluscs were alive in the Cretaceous (~125 Ma), their replacement by amorphous opal fluids likely occurred in the Miocene (~20 Ma). [Cody Opal (National Opal Collection) specimen and photo]

Figure 12. Specimen of a "Painted Lady" from Andamooka. Bands of potch and precious opal are evident occupying a fracture in a quartzite boulder. [Cody Opal (National Opal Collection) specimen and photo.]

Figure 13. Alternating bands of potch and precious opal in an opal from Andamooka, SA. The wavy pattern evident in this opal is indicative of a combination of fluid flow and shear flow processes which influenced the hydrodynamic and rheological behaviour of highly viscous opal fluids during the formation of this opal. Color bars in this opal contain photonic colloidal crystals of precious opal which have been sheared and fragmented post their crystallisation. [Opal Auctions (Alphaopals) gemstone and photo]

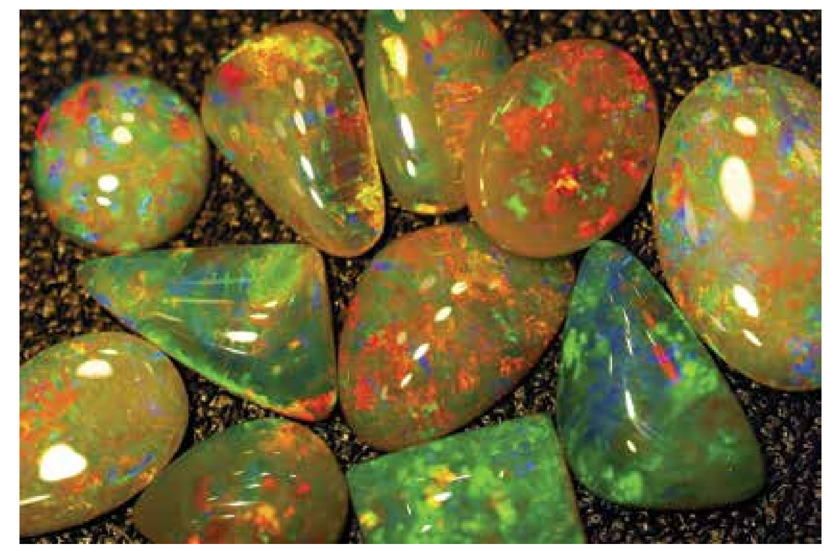


Figure 14. Selection of Coober Pedy precious opal gemstones showing a variety of colloidal crystalline patterns and structures in these opals. (Cody Opal gemstones and photo)

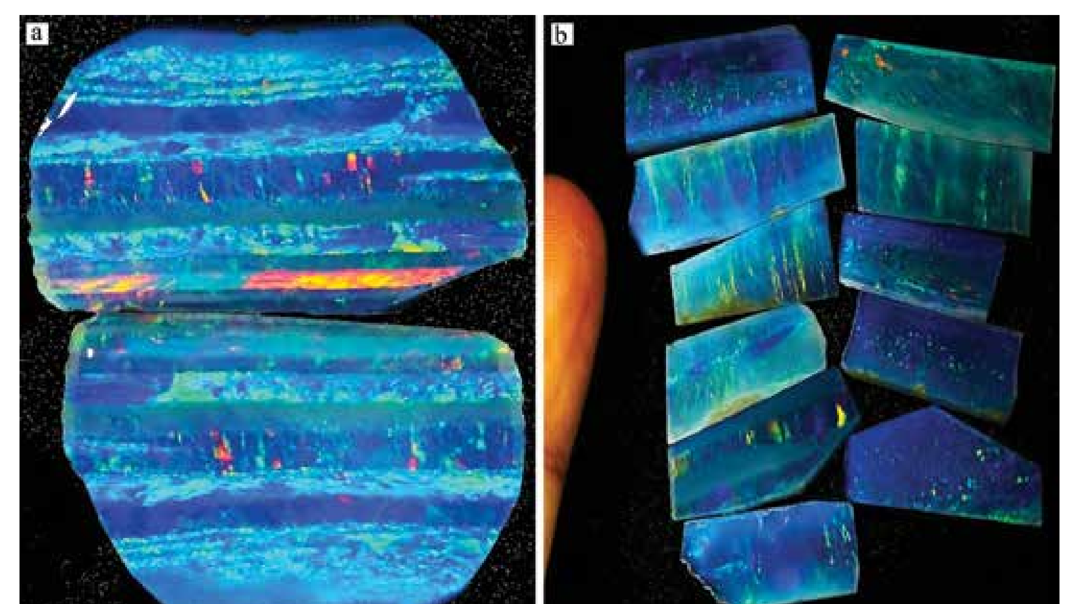


Figure 15. Photos of opal veins showing alternating shear bands of potch and precious opal from Coober Pedy, SA. (a) Shows multiple bands of precious opal in a vein, with some bands containing prismatic photonic colloidal crystals of precious opal which have grown in parallel clusters at right angles to band layering, while in other bands colloidal prismatic growth appears absent or disrupted. (b) Shows a collection of opal veins comprising bands of precious opal in which band-wall-normal prismatic photonic colloidal crystals of precious opal are relatively undisturbed, while in other veins shear and fluid flow disruption in precious opal bands is evident. [Seda Opals specimens and photos photos in (a) & (b)]

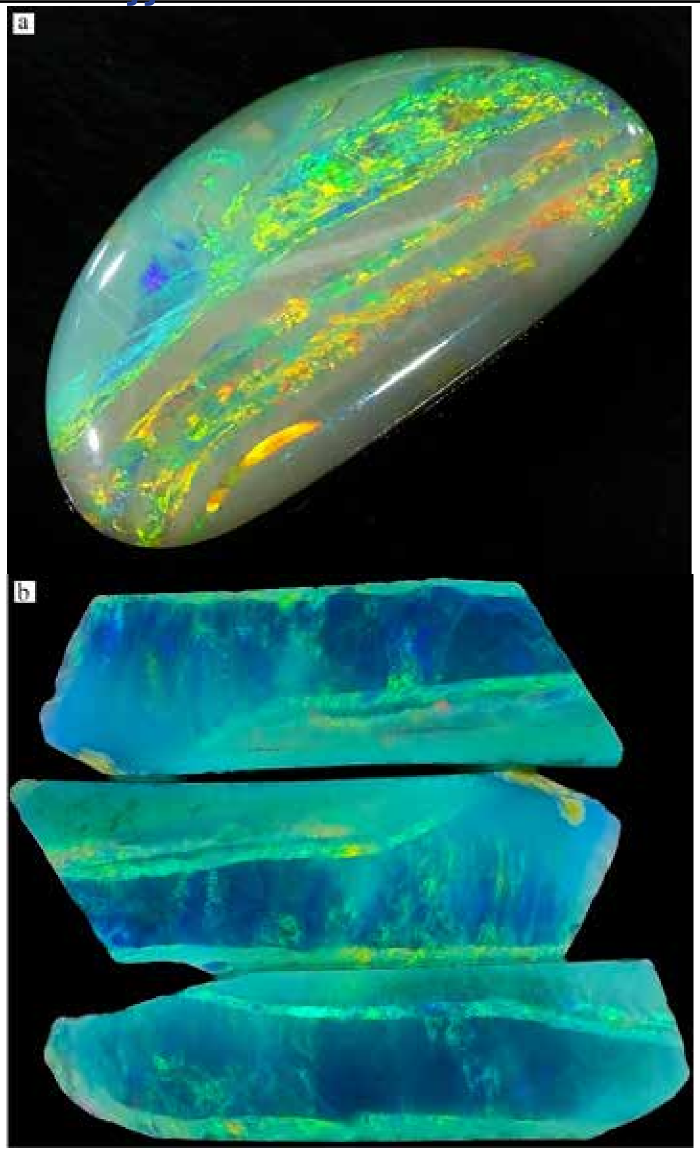


Figure 16. . Photos of opal veins showing alternating shear bands of potch and precious opal from Coober Pedy, SA. (a) Shows bands of precious opal in which the photonic colloidal crystals appear fragmented and sheared. Adjacent bands of potch opal display patterns of viscous fluid flow. (b) Shows slices through an opal vein in which the thickest band of precious opal displays a pattern of parabolic fluid flow which has deformed once band-wall-normal prismatic photonic colloidal crystals of precious opal in the direction of flow (i.e. left to right in the middle slice). [Patrik Ujszaszi (Rollingstone Opals) specimen and photo in (a); Seda Opals specimen and photo in (b)]

Precious opal from the Coober Pedy opal fields typically displays flashes of spectral color set against a light background body tone, commonly giving the gems a somewhat milky appearance (Figure 14). However, precious opals displaying darker body tones, which are less milky in appearance are also produced from the Coober Pedy opal fields. Opal veins at Coober Pedy commonly display alternating bands of potch and precious opal. Bands of precious opal in Coober Pedy opal may also be composed of close-packed parallel clusters of prismatic photonic colloidal crystals of precious opal (Figure 15). When these colloidal crystalline structures are intact they are typically oriented at right angles to banding. Parabolic and vortex patterns indicative of turbulent viscous fluid flow, as well as shearing along bands, is also common in Coober Pedy opal (Figure 16); with turbulent vorticity flow having been imposed on both potch and precious opal at varying times, and in different locations within the opal vein networks during their tectonic evolution.

New South Wales Opal

Opal is mined around the centers of White Cliffs and Lightning Ridge in NW New South Wales (Figure 1). At White Cliffs, opal occurs in sub-horizontal and sub-vertical veins, which occupy hydraulic extension shear fractures within discontinuous lenses of smectite-rich claystone. Lenticular veins of opal at White Cliffs are generally ~3 mm - ~75 mm thick (MacNevin and Holmes 1980).

Figure 17. Selection of White Cliffs, NSW, precious opal gemstones showing a variety of colloidal crystalline patterns and structures in these opals. (Cody Opal gemstones and photo)

Potch opal dominates in the veins at White Cliffs, but this type of opal may pass laterally into veins consisting entirely of precious opal (MacNevin and Holmes 1980). Opal veins comprising alternating bands of potch and precious opal are also common at White Cliffs, as are patterns of turbulent viscous opal fluid flow within the veins. Precious opal from White Cliffs is somewhat similar to opal from Coober Pedy, in that it commonly displays flashes of spectral color set against a light background body tone, giving the gems a cloudy appearance (Figure 17).

Precious opal at White Cliffs also occurs in pore spaces and as fracture coatings in quartzite cobbles. These opalized cobbles are similar to the so-called *Painted Ladies* occurring at Andramooka. Precious opal is also found replacing fossils, including brachiopod and mollusc shells, crinoid stems, reptilian remains, and coniferous wood (MacNevin and Holmes 1980). An unusual form of opal from White Cliffs are structures referred to as *Opal Pineapples* (Figure 18), which are considered to have been formed from the replacement of ikaite ($CaCO_3 \cdot 6H_2O$) crystals by opal fluids (Pecover 2007).

Figure 18. Photo of an "Opal Pineapple," from White Cliffs, NSW. These rare and unusual types of opal are considered to have been formed from the replacement of ikaite ($CaCO_3 \cdot 6H_2O$) crystals by mildly acidic amorphous opal fluids. As such, their formation is the result of the same opal fluid flow processes which have produced opalised fossils and replacements of "Guilielmites" in sedimentary host rocks across the Great Artesian Basin. (Cody Opal gemstones and photo)

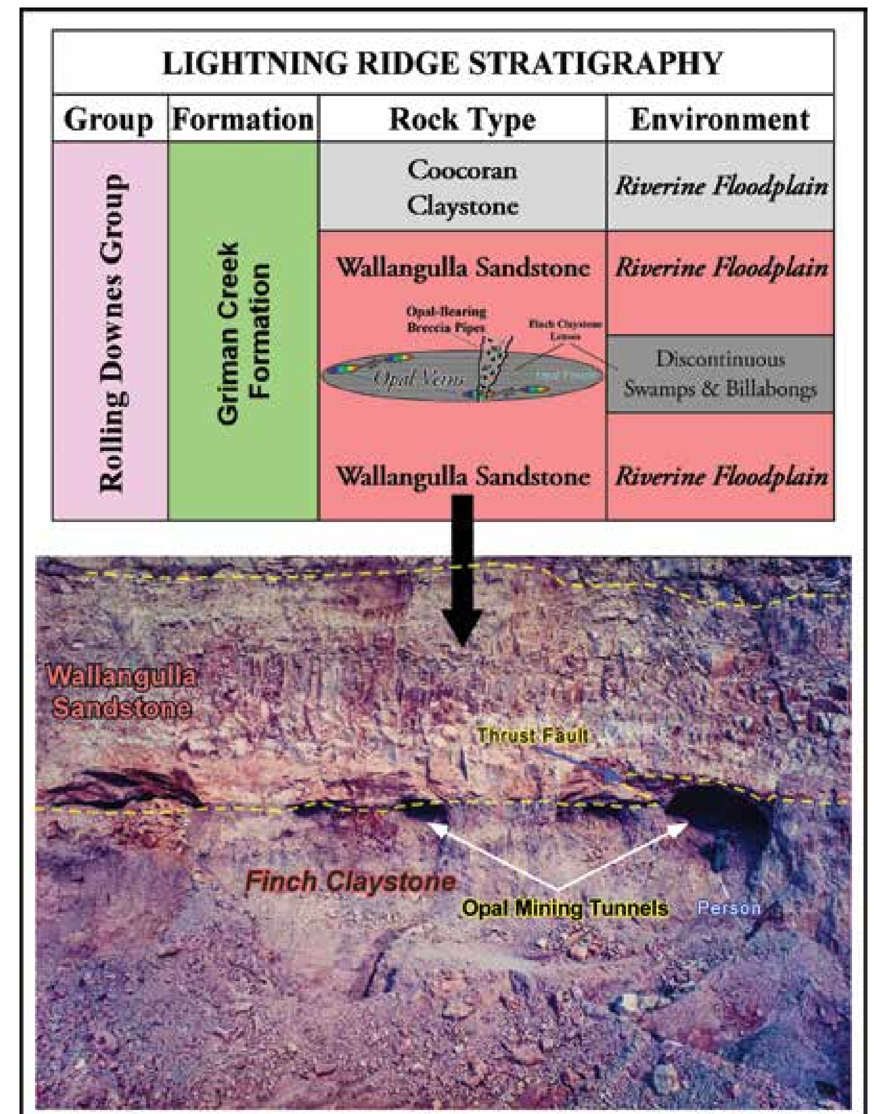


Figure 19. Stratigraphy of sedimentary rocks which host opal deposits around Lightning Ridge and a photo of that layering in an open cut opal mine at the 3 Mile Opal Field at Lunatic Hill, Lightning Ridge. [Simon Pecover diagram; Mineral Resources of New South Wales photo]

Most of the opal mined in deposits surrounding Lightning Ridge is extracted from the Finch Clay Facies unit, which occurs as generally flat-lying discontinuous lenses of grey to buff-colored smectite and kaolinite rich claystones within the terrestrial fluviatile Wallangulla Sandstone Member (Figures 6 & 19). These lenses range from several centimeters to several meters thick, and typically include minor intercalations of sandstone and siltstone. These opal-hosting claystones were formed in small swamps and billabongs, under low energy brackish water marshland depositional conditions (Byrnes 1977), within an overall near-coastal fluviatile sandy flood plain environment in the Albian (~100.5 Ma to ~113.00 Ma) (Figure 6). Given the depositional setting of these claystones, opalized fossils (Figure 20) are common in the Finch Clay Facies unit, and include the replacement by opal of the remains of plants, molluscs, vertebrates and invertebrates (Kear & Hamilton-Bruce 2011).

Much of the opal mined from the Finch Clay Facies unit occurs within sub-horizontal to sub-vertical, tectonically-generated, fault and fracture-controlled opal veins (Figure 21), juxtaposed to the planes of reverse and thrust faults (Figure 22). These opal veins typically occupy hydraulic extension shear fractures; most of which are broadly conformable to the flat-lying bedding of the Finch claystone. Large sub-horizontal opal veins which can be >10 cm thick and extend laterally over tens of meters, have been mined from opal fields around the Grawin/Glengarry area, approximately 40 km SW of Lightning Ridge.

The stress regime which was active when these sub-horizontal opal veins were forming **(**Figure 8), was likely consistent with tectonic conditions where σv = σ3 (i.e. σv, or sigma vertical, refers to the vertical stress direction which normally prevails in the Earth's crust). These opal vein arrays are similar to the laterally extensive and thick opal veins mined around Coober Pedy, Andamooka and Mintabie.

Opal fields in the immediate vicinity of Lightning Ridge township, as well as those to the NW around *Wyoming* and *Jag Hill*, and those to the SW of

Figure 20. Photo of an opalized toe bone of a small dinosaur from Lightning Ridge, NSW. While the dinosaur was alive in the Cretaceous (~113 Ma), the replacement of one of its bones by amorphous opal fluids likely occurred in the Miocene (~20 Ma). [Cody Opal (National Opal Collection) specimen and photo]

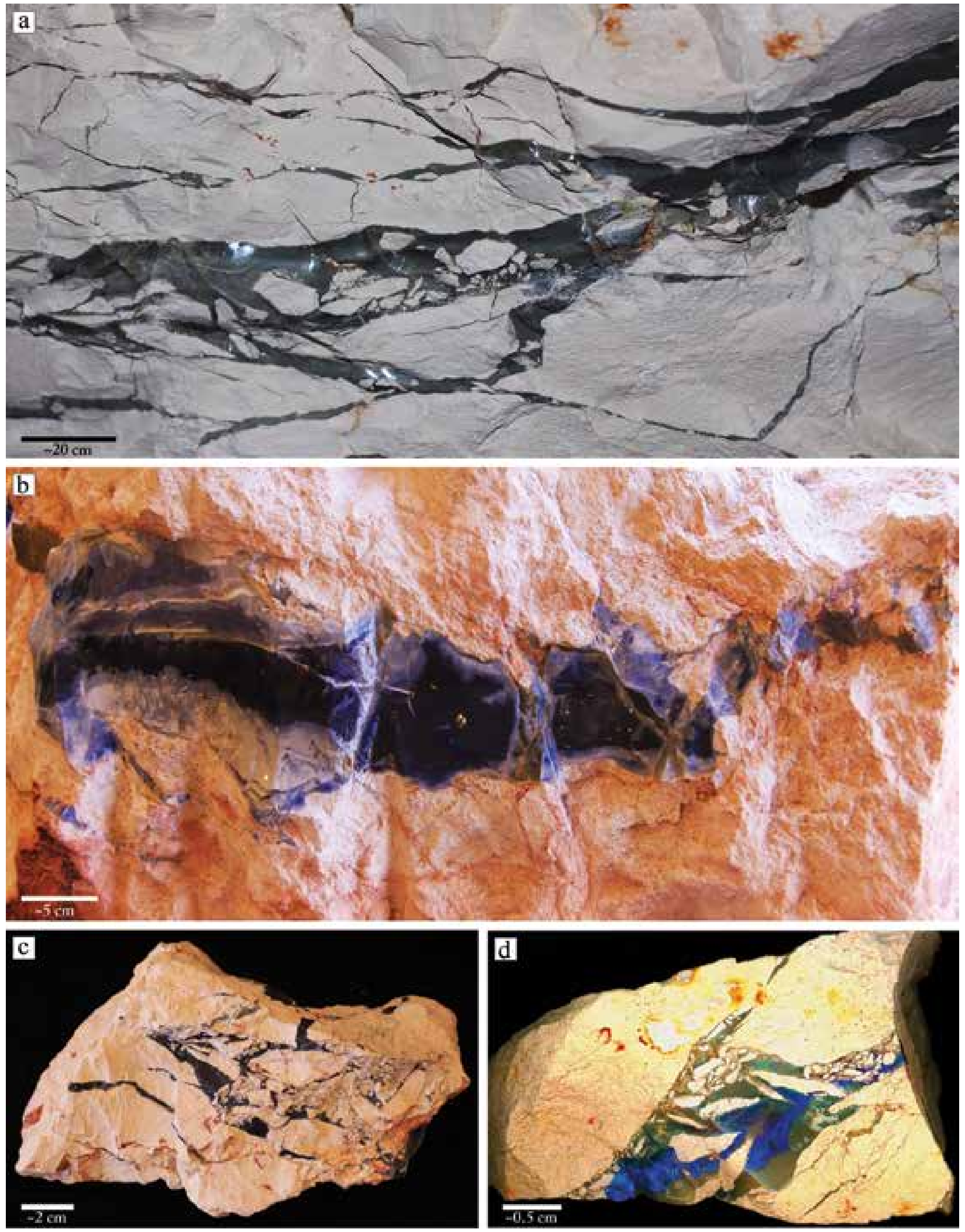


Figure 21. Opal veins comprising mainly potch opal from deposits around Lightning Ridge in NW New South Wales. Scale bars demonstrate that the tectonic processes which formed these opal veins are scale independent (i.e. large-scale features are repeated at smaller scales). (a) Shows opal veins in a thrust fault flat at the Turners Rush Opal Field, NW of Cumborah, and SW of Lightning Ridge. (b) Shows a shear banded sub-horizontal potch opal vein from the Sheepyard Opal Field, NW of Cumborah. (c) & (d) Show opal vein and wall rock breccias, wherein highly viscous opal fluids have supported fragments of wall rock broken-off the sides of the fractures and subsequently entrained in the opal flows. [Simon Pecover photo in (a); Vicki Bokros (Down to Earth Opals) specimens and Simon Pecover photos in (b) & (c); Simon Pecover specimen and photo in (d)]

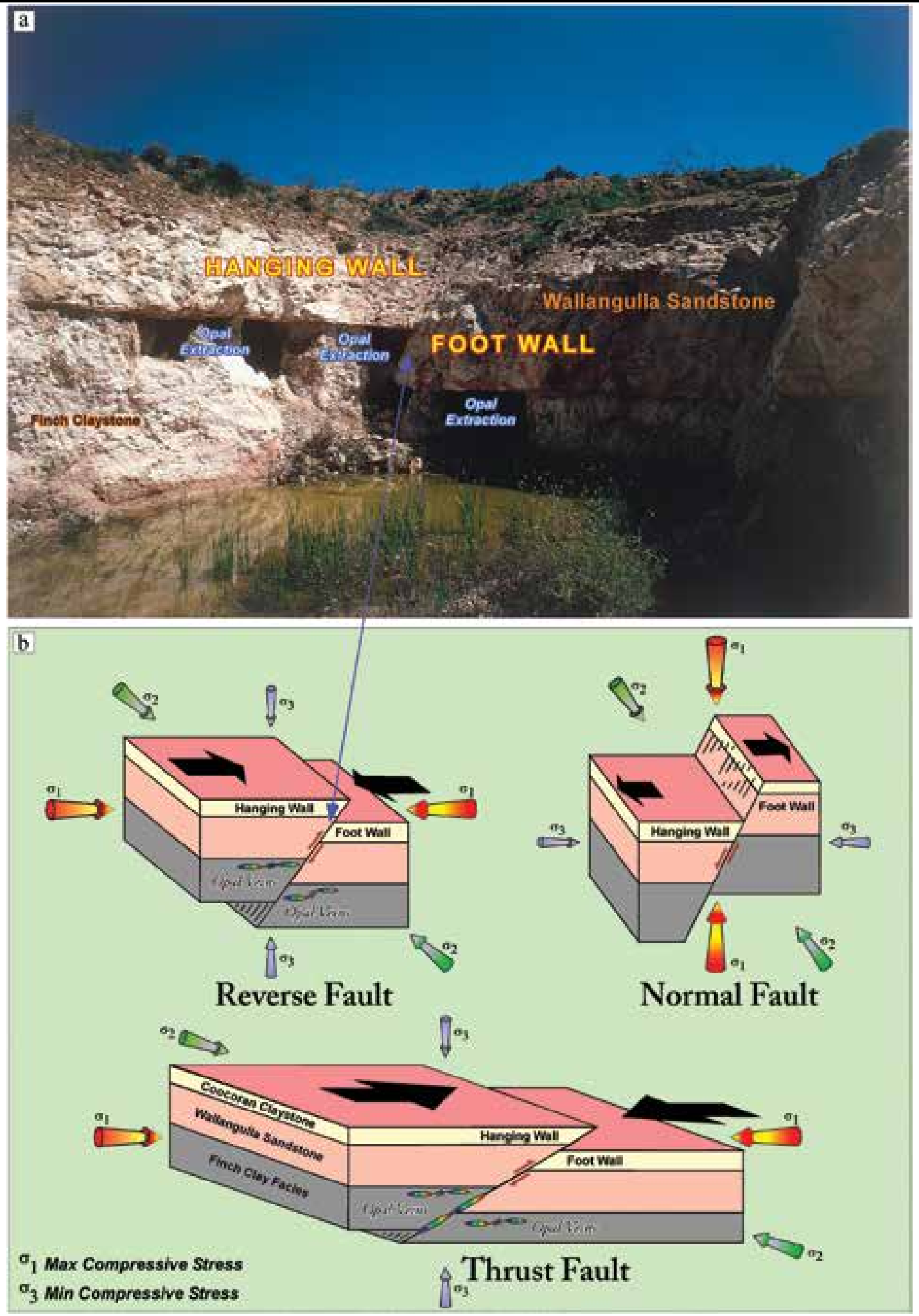


Figure 22. Relationships between stratigraphy, faulting and opal vein occurrence at Lightning Ridge. (a) Reverse fault with extraction of opal on the hanging wall and foot wall sides of the fault plane at the 3 Mile Flat Opal Field. (b) Major fault classes at Lightning Ridge, with sub-horizontal opal veins typically associated with reverse and thrust faults. [Stephen Aracic photo in (a); Simon Pecover drawings in (b)]

Coocoran Lake, produce a form of opal referred to by local miners as *Nobby Opal*. Opal nobbies are typically small (<100 mm), isolated nodule-like masses of opal (Figure 23). Opal nobbies which are connected to thin sub-horizontal opal veins are known locally as *Seam Nobbies* (Aracic 1996), and are commonly sub-rounded to irregular masses of opal which may have been formed within fractures hosting small dilational *jogs* in the planes of thrust fault ramp structures broadly parallel to bedding planes within the Finch claystone.

These types of nobbies commonly contain fragments of wall rocks which are curved and separated by potch and/ or precious opal (Figure 24), suggesting rotation of these opal masses during layer parallel sub-horizontal shearing (Figure 24b). In some cases, rare examples of partially filled nobby opal vein spaces have occasionally been found. These partially filled structures can exhibit horizontal meniscus-like viscous fluid tops and soft-solid-slump features. These features appear to have formed when some of the opal fluid drained from connected leaky fractures after pressurized fluid flow had ceased in these parts of the opal vein network.

Some opal nobbies may also be replacements of carbonate/sulphate concretions or plant fossil remains. A particularly curious type of opal nobby known locally as a *Chinese Hat* also occurs in many opal fields surrounding Lightning Ridge (Figure 25). These peculiarly shaped types of opal commonly exhibit bi-convex cone-in-cone like morphology.

The surfaces of these nobbies are typically striated in a radial pattern away from the apex of the cone; which in situ commonly points downwards. The origin of these nobbies remains enigmatic, although Byrnes (1975) interpreted them as *Guilielmites* (i.e. guilielmite is the pseudofossil name for slickensided soft sediment compaction structures found worldwide in fine-grained sedimentary rocks), which were subsequently replaced by opal fluids moving along fractures sub-parallel to bedding planes.

Angular to sub-rounded fragments of opal found in sub-vertical breccia pipes are also commonly referred to by opal miners' as nobby opal (Figure 26). These sub-angular to sub-rounded opal fragments were likely derived from opal veins that were intersected and sampled by their host breccia pipes (known locally as *Blows*) during their pressurized and fluidized ascent towards the Earth's surface (Figure 26, 28 & 29) (Pecover 2005).

In some places where opal-bearing breccia pipes reached the surface, they also ejected debris which formed aprons and surface-draping deposits around their vents. These deposits (known locally as *Biscuit Band*) have been mined

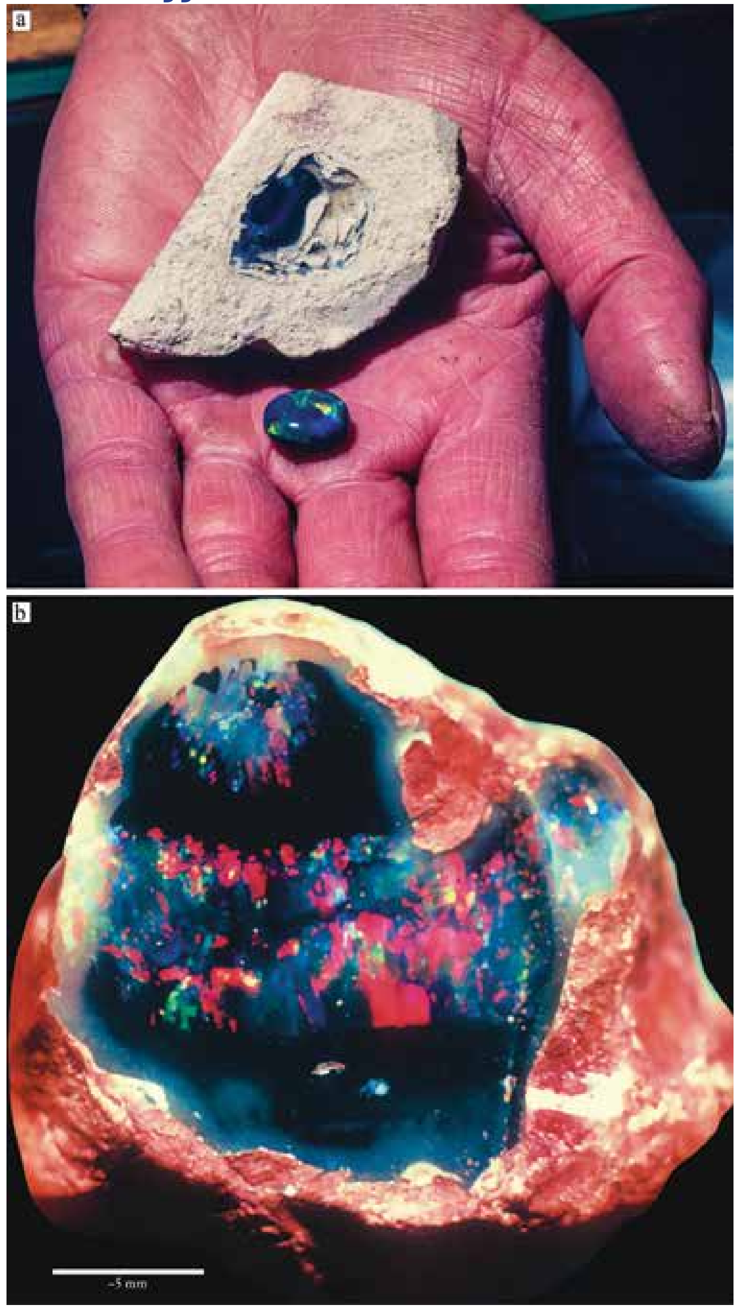


Figure 23. Opal "Nobbies" from Lighting Ridge, which produced black opal gems. (a) Shows internal structure of a "Nobby", as revealed by partially transparent opal infilling the discontinuous fracture space. (b) Shows a classic nobby of precious opal, with photonic colloidal crystals in two distinct groups attached to opposite opal band boundary surfaces. These prismatic colloidal crystals are posited to have grown epitaxially by shear-induced ordering of silica spheres inwards towards a more or less centrally located suture. The proposed mechanism by which this may have occurred is illustrated schematically in Figure 41. [Mineral Resources of New South Wales photo in (a); Len Cram photo in (b)]

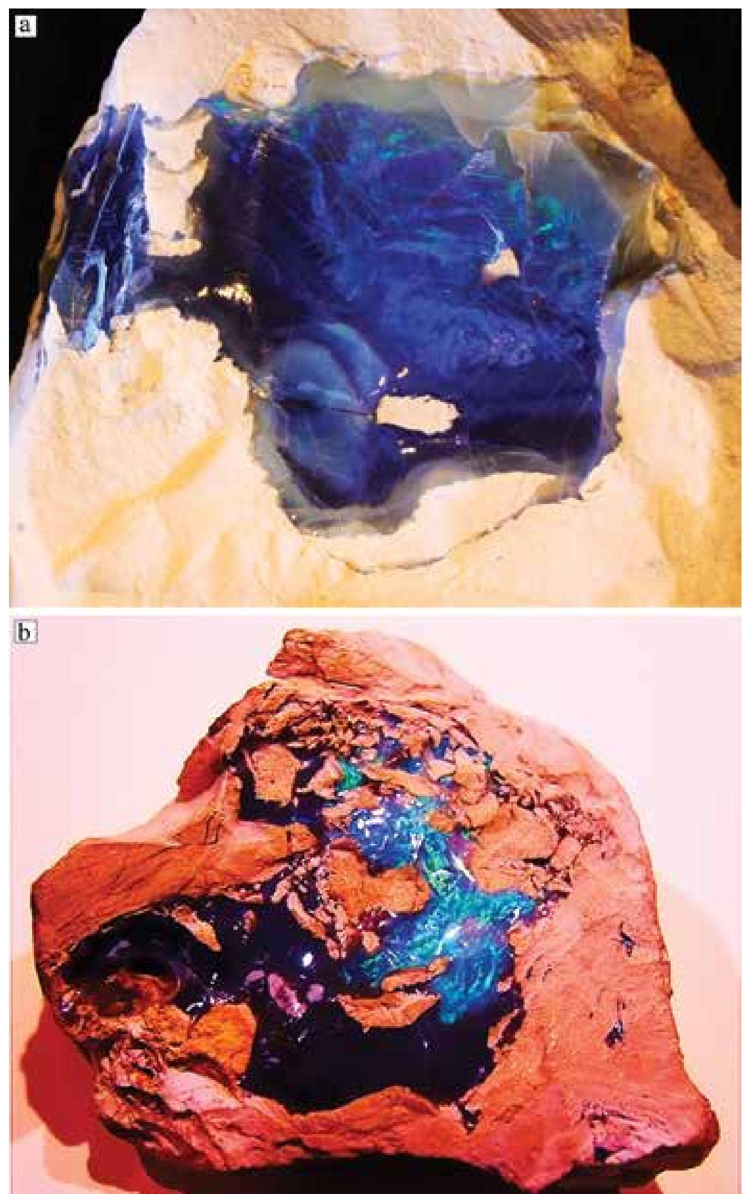


Figure 24. Opal "Nobbies" from Lightning Ridge, formed in discontinuous and isolated tectonic opal veins. (a) & (b) Shows isolated masses of mixed potch and precious opal contained within sedimentary host rocks. Both nobbies show the inclusion of wall rock fragments which have been rotated and entrained within supporting viscous opal fluids. In the case of the nobby shown in (b), the wall rock fragments display curved fracture edges; suggestive of rotation of the entire opal mass during its formation. The opal in both nobbies displays textures and patterns indicative of the viscous fluid flow of intermixed potch and precious opal. The precious opal in these nobbies displays wispy and streaky textures indicative of the flow of shear-fragmented particles of photonic colloidal crystals. The host rock surrounding the potch and precious opal shown in photo (b) has also been substantially indurated with amorphous silica; similar to that seen in samples of "Steel Band". (Note: The opal in (b) has been enhanced to highlight structure.) [Vicki Bokros (Down to Earth Opals) specimens and Simon Pecover photos in (a) & (b)]

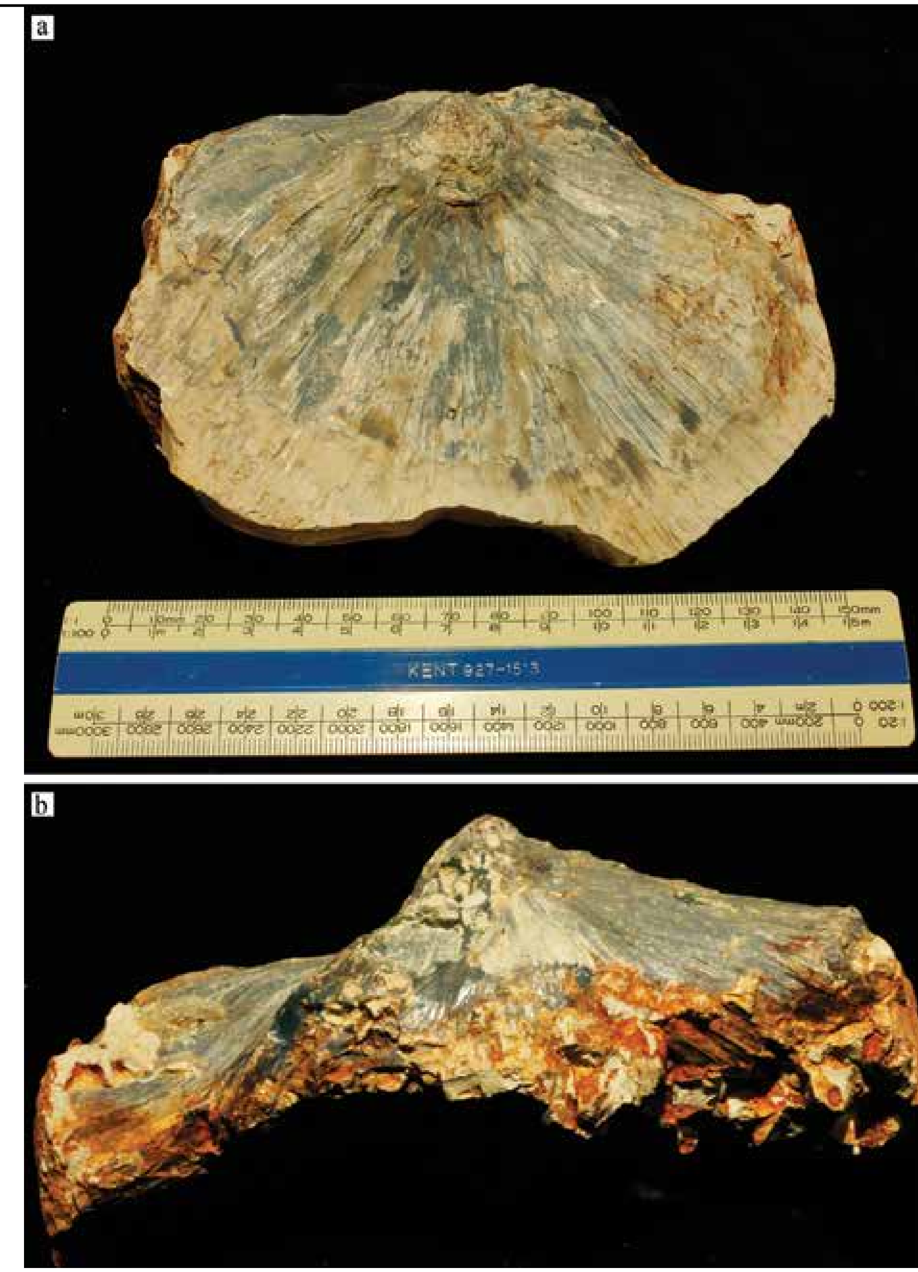
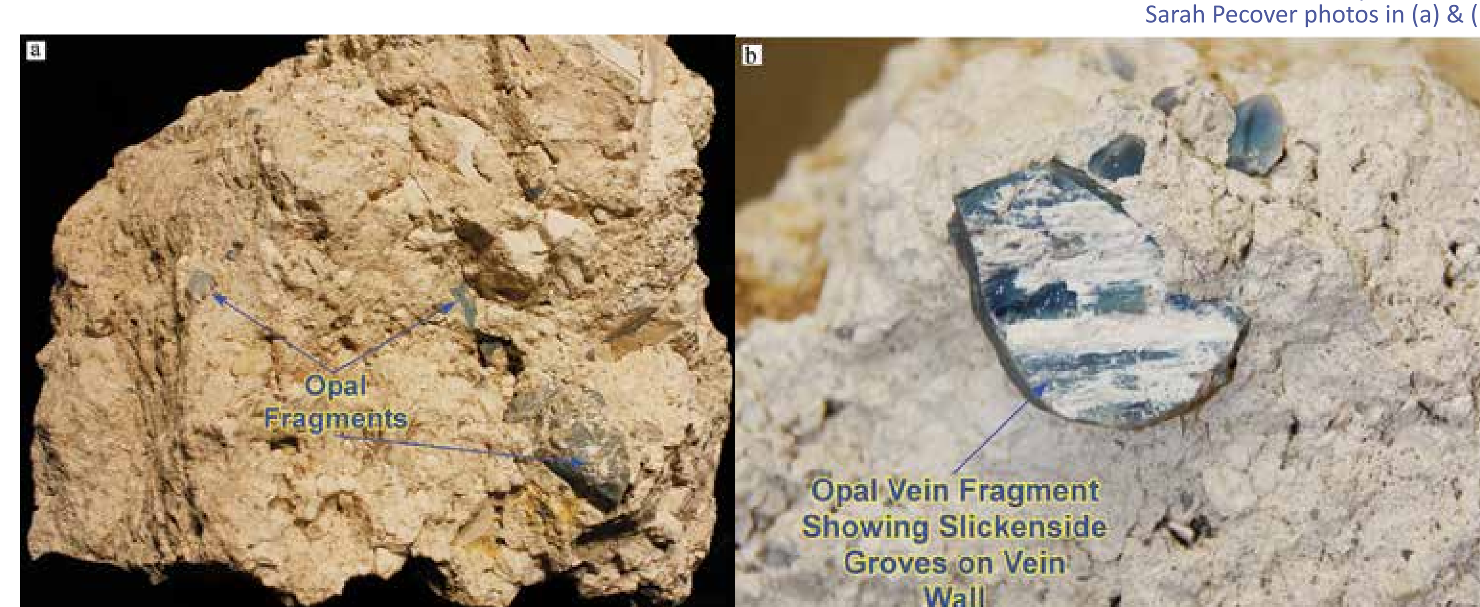


Figure 25. Example of a potch opal "Nobby" known at Lightning Ridge as a "Chinese Hat." (a) Shows striated structure in inclined plan-view. (b) Shows inclined cross-sectional view. [Cody Opals (National Opal Collection) specimen and Sarah Pecover photos in (a) & (b)]

Figure 26. Discreet and isolated fragments ("Nobbies") of potch opal contained within breccia derived from vertical opal-bearing breccia pipes ("Blows") which had passed through and sampled previously formed sub-horizontal opal veins. (a) Shows rounded fragments of opal which have been tumbled about in the breccia during fluidisation. (b) Shows an opal vein fragment which has slickenside groves on the wall of the vein, indicative of shearing sub-parallel to fracture walls during opal vein formation. {Simon Pecover specimens and Sarah Pecover photos in (a) & (b)}



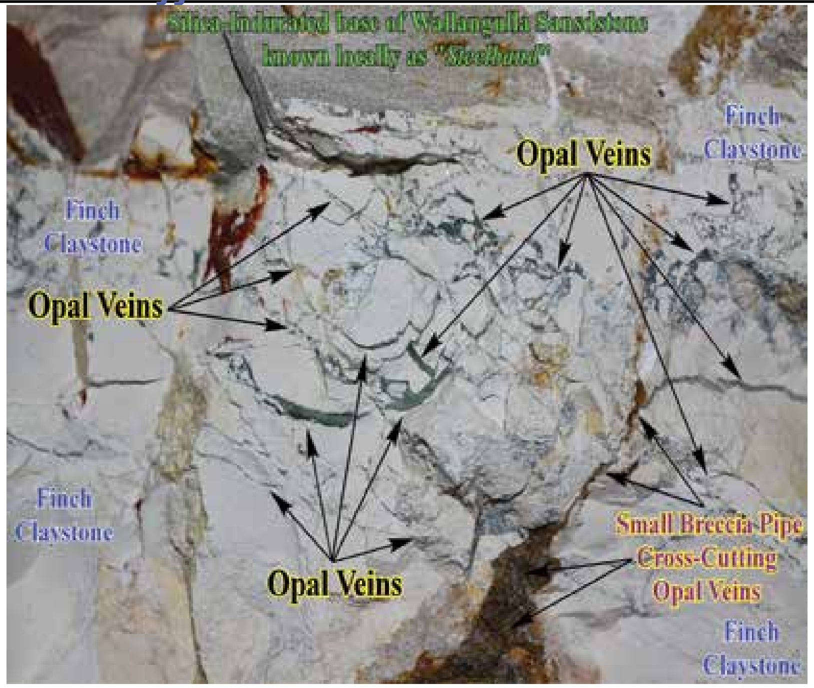
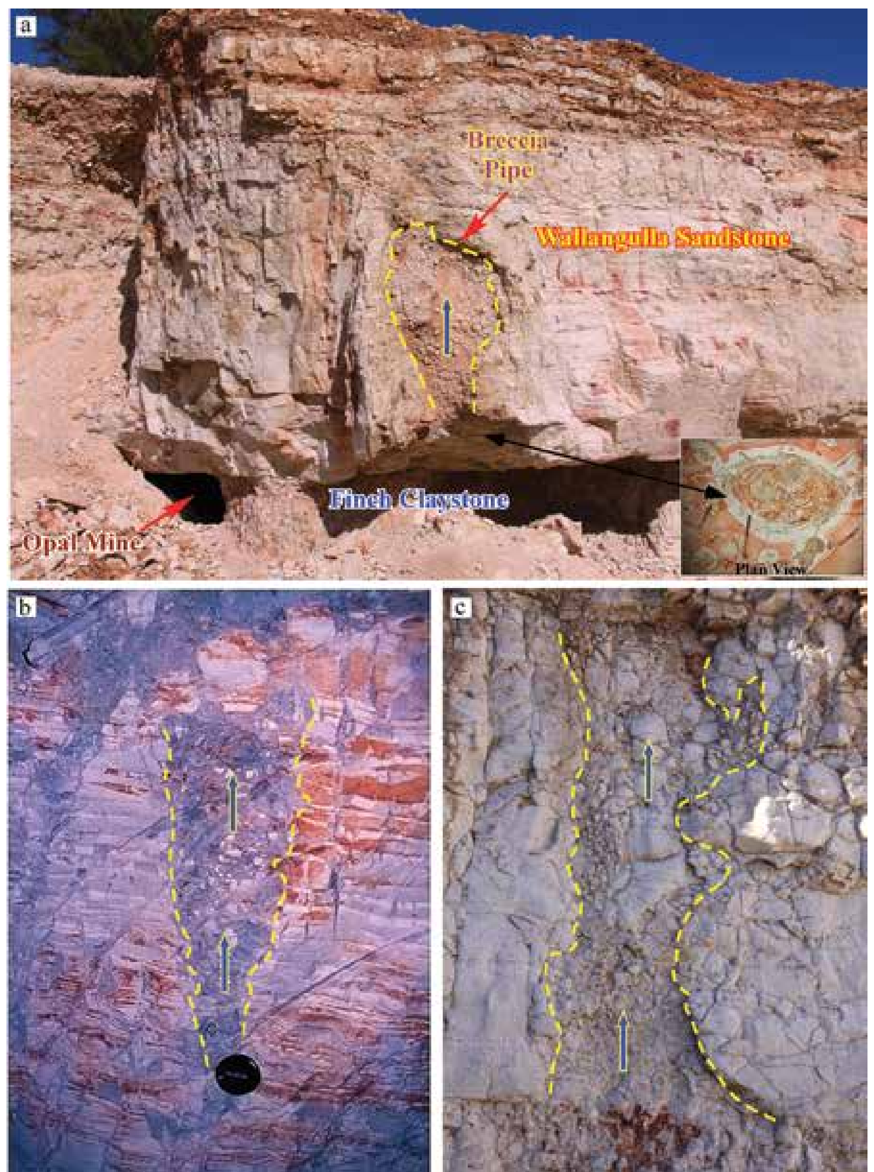


Figure 27. Sub-horizontal opal veins concentrated in the Finch claystone close to the boundary with the overlying Wallangulla Sandstone. The base of the sandstone has been indurated with amorphous silica forming a hard layer known locally as "Steel Band." A small breccia pipe ("Blow") has also begun to intrude the opal vein array. (Tony Cummings opal mine and Simon Pecover photo.)

Below: Figure 28. Breccia pipes ("Blows") which have intruded sedimentary host rocks at Lightning Ridge. (a) Shows a breccia pipe in the Wallangulla Sandstone, which is rooted in the underlying Finch claystone. The insert in the lower right hand side of this photo shows how these structures appear in plan view in the roofs of some opal mines. (b) Shows a breccia pipe cross-cutting Finch claystone in an underground opal mine at the Coocoran Opal Fields. (c) Shows a breccia pipe intruding Wallangulla Sandstone on the side of an abandoned open cut opal mine at the New Chum Opal Field. [Simon Pecover photos in (a) to (c). Mineral Resources of New South Wales plan view photo insert in (a)]



extensively for opal at Lightning Ridge by open-cut methods (Figure 30).

These gem-bearing breccia pipes share some morphological similarities to diamond pipes, except that their formation was not related to volcanic processes, but rather to tectonically-generated fluid overpressure conditions which developed during mild horizontal compression of the Griman Creek Formation rocks at Lightning Ridge.

Precious opal from the Lightning Ridge opal fields, termed *Black Opal*, typically displays flashes of spectral color set against a dark background body tone, which greatly enhances the depth and vibrancy of flashing spectral colors exhibited by these opals (Figure 4 & 31).

However, precious opals displaying lighter body tones and milky appearances are also produced from the Lightning Ridge opal fields. Glassy translucent precious opal termed *Crystal Opal* is also produced from some Lightning Ridge opal deposits (Figure 32).

As in many other GAB opal deposits, opal veins at Lighting Ridge commonly display alternating bands of potch and precious opal (Figure 33). Undisturbed bands of precious opal in these veins may also be composed of close-packed parallel clusters of prismatic photonic colloidal crystals, whose crystalline arrays are also generally oriented at right angles to sub-horizontal banding (Figure 33).

These colloidal silica crystals commonly display extreme length to width ratios, with such crystals likely indicative of initially stable *proto* conditions of precious opal formation in most GAB opal vein deposits (Pecover 2018). However, bands of precious opal in some Lightning Ridge opal veins are composed of masses of highly fragmented

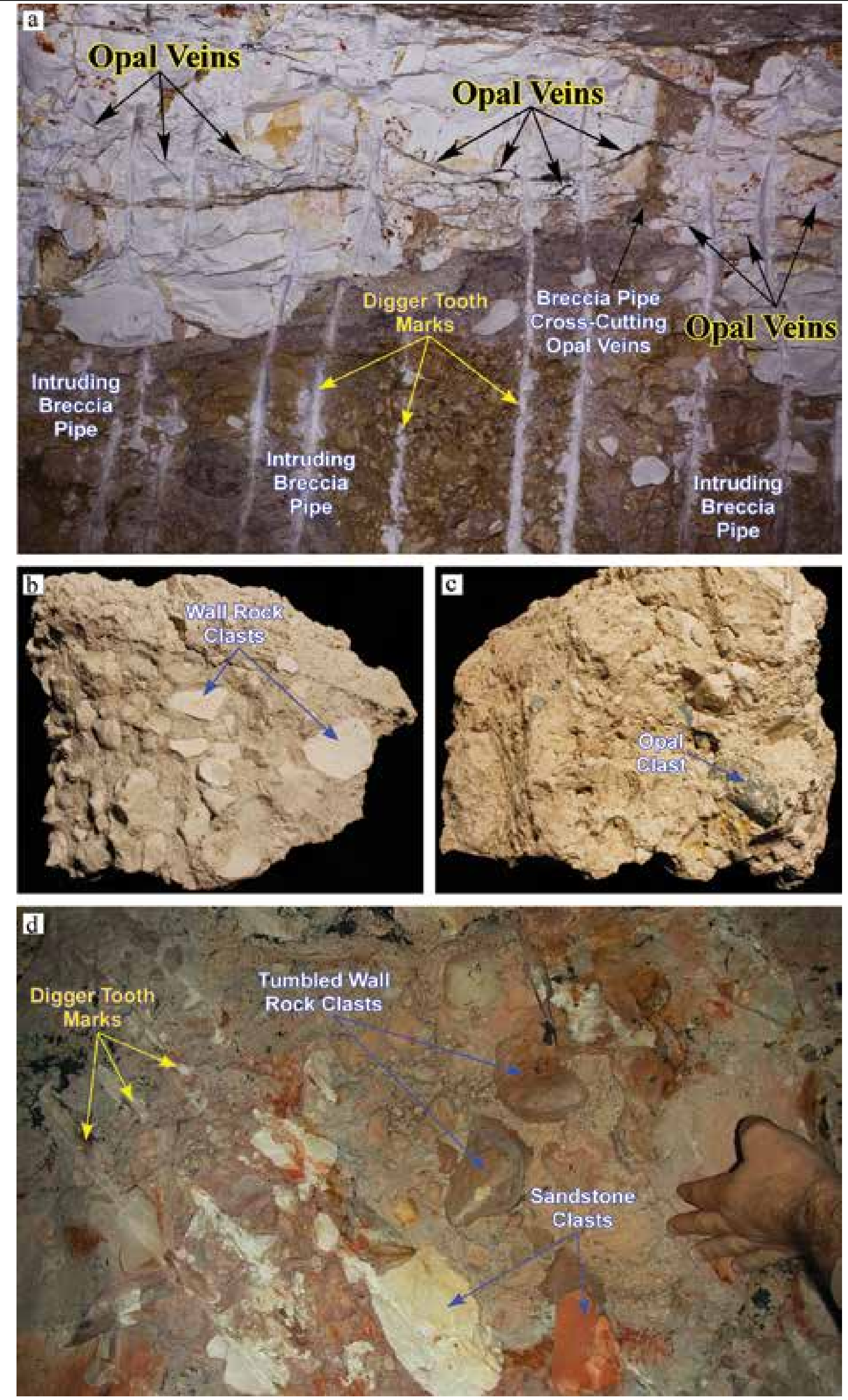


Figure 29. Fragments of country rock which typically fill breccia pipes ("Blows") in most of the opal fields surrounding Lightning Ridge. (a) Shows a breccia pipe intruding sub-horizontal opal veins in Finch claystones (the whitish coloured vertical tooth marks are from the teeth of an underground digger). (b) to (d) Show the clastic fabric of injectite material typically found in breccia pipes at Lightning Ridge. The matrix-supported clastic fabric evident in these photos, comprises fragments of country rock broken-off the sides of pipes, which were mixed together with finer-grained fault gouge material as the entire jumbled mass was injected upwards within the host pipe. Note the fragment of potch opal in photo (c), derived from opal veins which were intersected and sampled by the host pipe. [Simon Pecover photos in (a) to (c); Mineral Resources of New South Wales photo in (d)]

photonic colloidal crystals, which show evidence of having been subjected to turbulent fluid flow post their initial band-wall-normal prismatic proto crystal growth. This imposed turbulent flow has resulted in the formation of chaotic slurries of precious opal crystallites, which appear to have flowed as a kind of crystal *mush* within their respective bands (Figure 34).

Parabolic and swirling vortex eddy patterns indicative of turbulent viscous fluid flow are also common in Lightning Ridge opal veins (Figures 35-38). In some Lightning Ridge opal veins, turbulent vorticity flow imposed on individual bands of both potch and precious opal is evident, suggesting coupled hydrodynamic and rheological evolution of the viscous opal fluids in these veins (Pecover 2018).

In other opals, extreme turbulence and shearing of alternating bands of potch and precious opal has resulted in the mixing of these opal bands, leading to textures and patterns suggestive of alternating hydrodynamic fluid flow and rheological shear flow processes, which has resulted in the formation of unique, complex, and extraordinarily beautiful scintillating plays of color in these types of GAB opal gemstones (Figure 39).

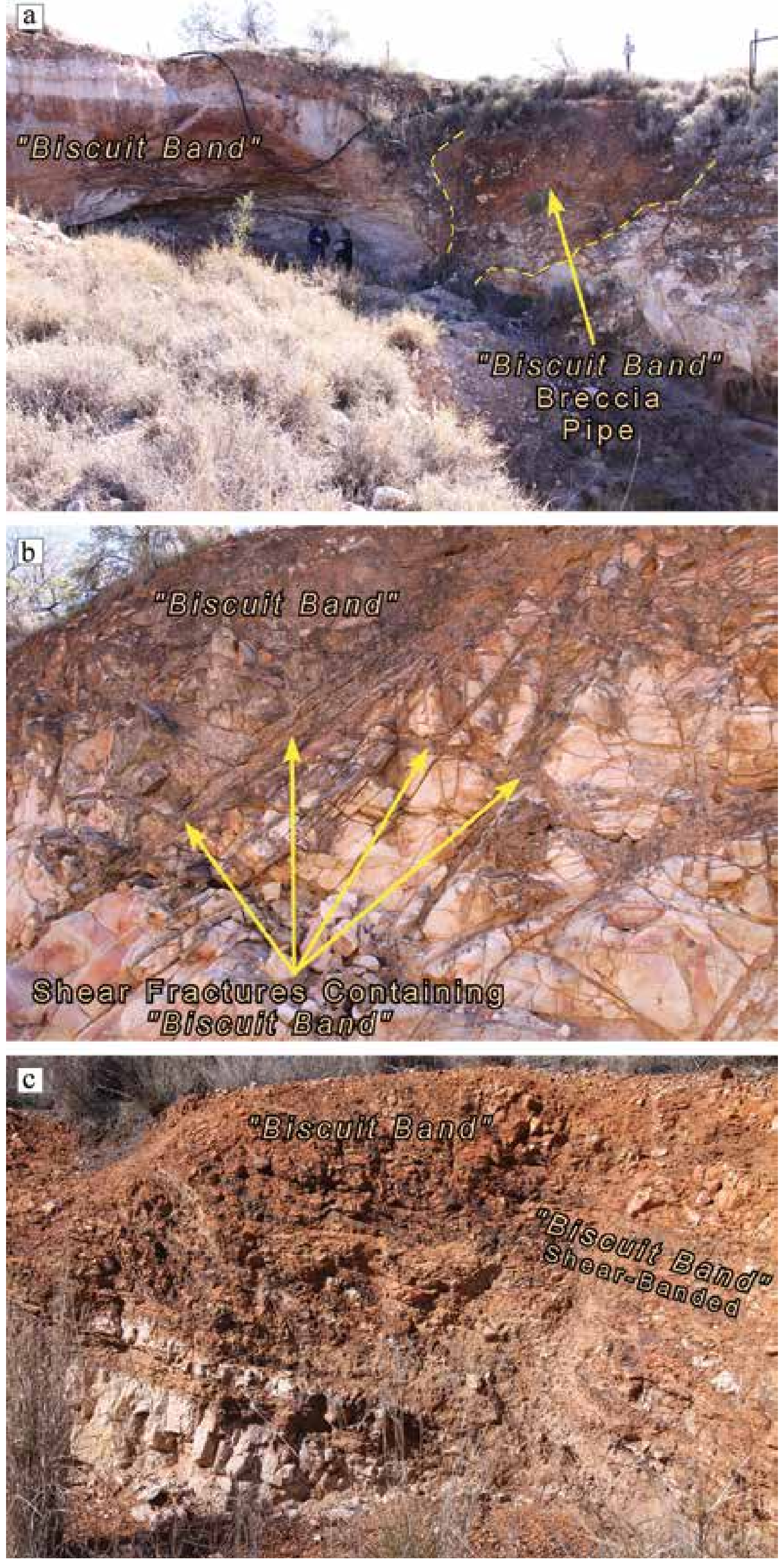


Figure 30. Opal-bearing deposits of so-called "Biscuit Band" occurring in open cut exposures at the 3 Mile Flat Opal Field. (a) Shows this fault gouge material occupying a breccia pipe and adjacent faults and shear fractures, all of which intersect the surface. Where the two men are standing, the biscuit band deposits here produced precious opal worth more than $15 M when mined over 30 years ago (Terry Harcher 2011, pers comm.). (c) Shows surface deposits up to 3 m thick which have been extensively mined for opal in this opal field. [Simon Pecover photos in (a) to (c)]

Formation of Potch and Precious Opal in Great Artesian Basin Deposits

Contrary Views Regarding GAB Opal Vein Formation

Researchers supporting a traditional weathering/sedimentary model of opal deposit formation within mainly Cretaceous sediments of Australia's Great Artesian Basin (GAB), commonly posit that Opal-A colloids within these deposits were formed during basin-wide blanket weathering processes, involving ground waters those chemistry is said to have oscillated between acidic and alkaline conditions (Rey 2013).

These siliceous fluids are also said to have descended slowly through rock fissures, eventually filling pre-existing, and dehydration-generated, open shrinkage cracks and voids (Barnes and Townsend 1990).

Amorphous silica is said to have then supposedly precipitated from these essentially stationary fluids, forming sols in which silica nanoparticles aggregated into colloidal silica spheres which settled passively via bottom-up sedimentation processes under generally hydrostatic pressure conditions (Brown et al. 2004; Smallwood et al 2008; Rey 2013, and references therein; Liesegang and Milke 2014; Dutkiewicz et al. 2015, and references therein).

The common occurrence of layered/banded opal in GAB opal deposits is also claimed to be evidence of bottom-up sediment accumulation processes (e.g. as advocated by Brown et al. 2004 and Smallwood et al 2008), which has partially given rise to the commonly used term *Sedimentary Opal*.

The geology of these deposits shows, however, that much of the opal mined from GAB sedimentary host rocks occurs in stratabound, sub-horizontal, hydraulic extension shear fractures that were filled by vigorously flowing viscous opal fluids as these fractures opened progressively, eventually forming opal vein deposits in all of the opal fields across the GAB (Pecover 1996, 2007, 2010, 2012 & 2018).

Furthermore, the tectonically-driven opal vein formational processes, which occurred in GAB sedimentary host rocks, involving stress, strain and concomitant fluid flow processes, is the way in which most mineral veins are commonly thought to have been formed in the Earth's crust (Bons et al 2012; and references therein).

Coupled Hydrodynamic and Rheological Processes in GAB Opal Vein Formation

Turbulent patterns of viscous opal fluid flow preserved within GAB opal veins, attests to a very vigorous process of opal formation in these rocks

Figure 31. Selection of high quality gem black opal from Lightning Ridge, showing a variety of colloidal crystalline patterns and structures in these opals. (Cody Opal gemstones and photo)

Figure 32. Crystal opal from Lightning Ridge showing a mosaic of colloidal crystalline patterns and structures in these opals. Stone is 34.85 carats. (Cody Opal gemstones and photo)

during which aqueous fluids containing increasingly high concentrations of silica colloids were swept along vorticity, velocity and fluid pressure gradients within fracture networks (Pecover 2018). These fractures were likely formed very rapidly when they opened vertically while propagating horizontally, thereby allowing available over-pressurized opal fluids to rush into the widening gaps and to flow towards the ends of these fracture networks.

It has been recently postulated (Pecover 2018), that low viscosity aqueous Newtonian fluids carrying low volume fractions of silica nanoparticles in these fractures, likely transitioned to more viscous non-Newtonian fluids (Pecover 2010 and 2012) as the concentration of silica nanoparticles increased due to particle collision and jamming within tortuous fracture networks.

Unlike water, which is a Newtonian fluid (i.e. in a Newtonian fluid its viscosity does not change substantially when it is stirred/sheared), non-Newtonian fluids typically become more or less viscous when subjected to shear stress (e.g. sheared Oobleck and Ketchup, respectively).

The rough and tortuous nature of opal-hosting GAB fracture networks appears to have also caused evolving non-Newtonian viscous opal fluids to twist and turn repeatedly, thereby generating eddies, vortexes and complex swirling patterns of viscous opal fluid flow within developing opal veins. Increasing collisions between silica nanoparticles and aggregating silica colloids within these turbulent flows, coupled with particle jamming, could be expected to have increased opal fluid viscosity further, with eventual evolution towards soft solid and glassy rheological states.

Thus, in this opal forming environment, highly turbulent fluid flow conditions in GAB opal veins (Figures 34-40) would have worked against the orderly packing of silica spheres by any means, thereby leading to the dominant formation of potch opal in these veins.

As previously mentioned, an important feature of GAB opal veins is that they commonly display layered or banded structures. This banded structure typically occurs in potch-only veins as well as in veins which show alternating bands of potch and precious opal (Figures 33, 34 & 40). These bands resemble shear bands (Pecover 2018), which are commonly seen in viscous non-Newtonian fluids such as colloidal suspensions undergoing shearing.

In GAB opal veins, soft solid suspensions of silica colloids undergoing shear flow and shear banding would also be expected to exhibit evidence of shear thickening and shear thinning behavior, in response to imposed shear strains (Pecover 2018). Furthermore, in this rheological environment, initially generated shear banded layers of opal would also likely have all formed locally at about the same time in any given part of the fracture network.

This process is contrary to the traditional bottom-up, temporally-separated, layered sedimentation model of GAB opal vein formation, proposed by Brown et al. (2004) and Smallwood et al (2008).

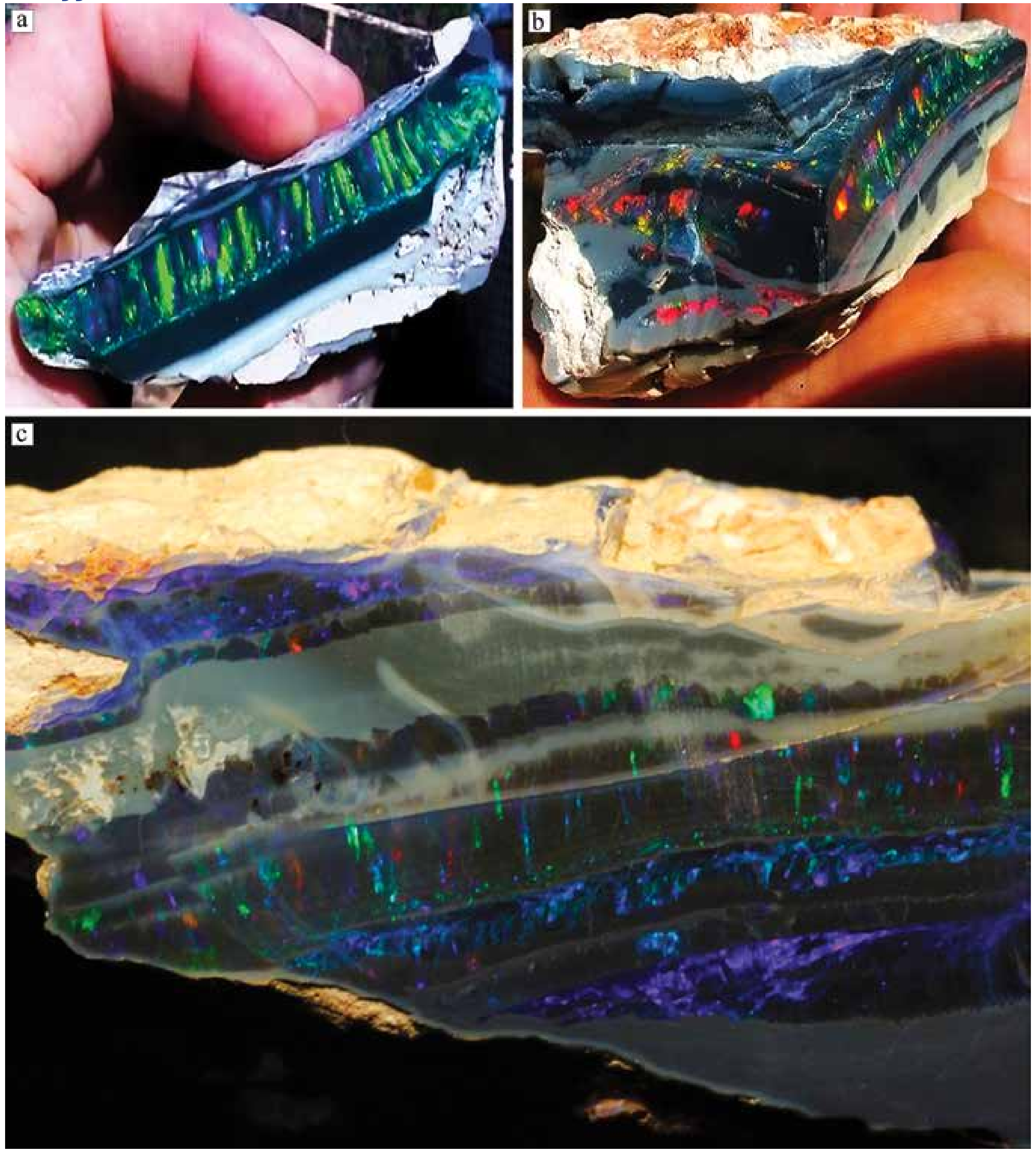


Figure 33. Shear bands of precious opal comprising relatively undisturbed prismatic photonic colloidal crystals displaying extreme length to width ratios, arranged in close-packed parallel clusters. (a) & (b) Show prismatic colloidal crystals of precious opal which have mainly grown at right angles to shear band boundaries. These crystals are posited to represent initial conditions of shear-induced ordering of silica spheres in bands subjected to just enough shear to allow crystals to grow epitaxially under relatively low and stable shear flow conditions. These crystals are therefore posited to be "proto" crystals of precious opal, and to be the forerunners of precious opal occurring as chaotic slurries of broken crystal fragments in those shear bands which have been progressively deformed by on-going shear and fluid flow. (c) Shows classic alternating bands of precious opal separated by bands of potch opal. From bottom to top the first two bands of precious opal display the effects of shear flow after initial crystallization, while the next (and thickest band/color bar) shows that the prismatic crystals have remained relatively undisturbed. Crystals in the next three bands show digit-like features. The topmost band of precious opal displays a chaotic flow pattern of fragmented opal crystals similar to the bottommost band. This suggests that shear strain was greatest at the edges of this opal vein, closest to fracture wall boundaries. [Unknown owners of specimens in (a) & (b); Black Opal Direct photos in (a) & (b); Cody Opals (National Opal Collection) specimen in (c); Sarah Pecover photo in (c)]

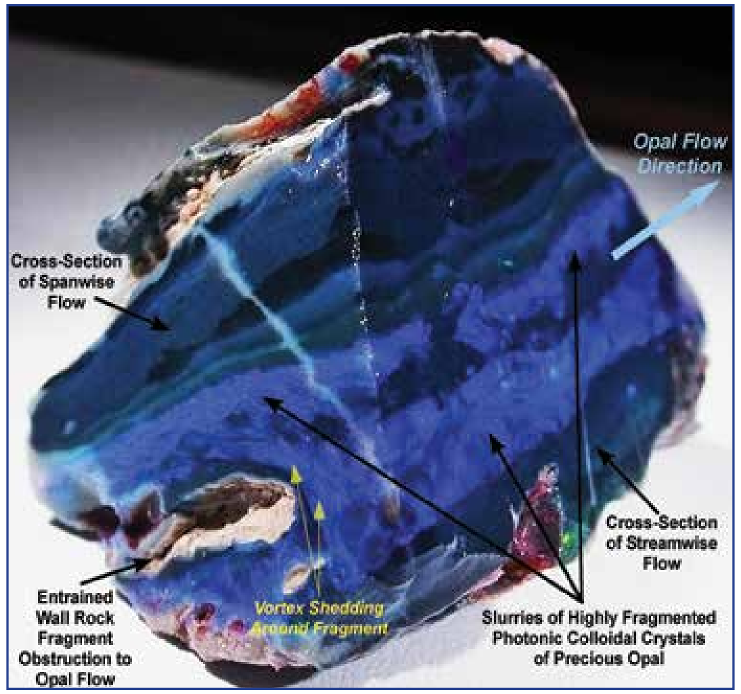
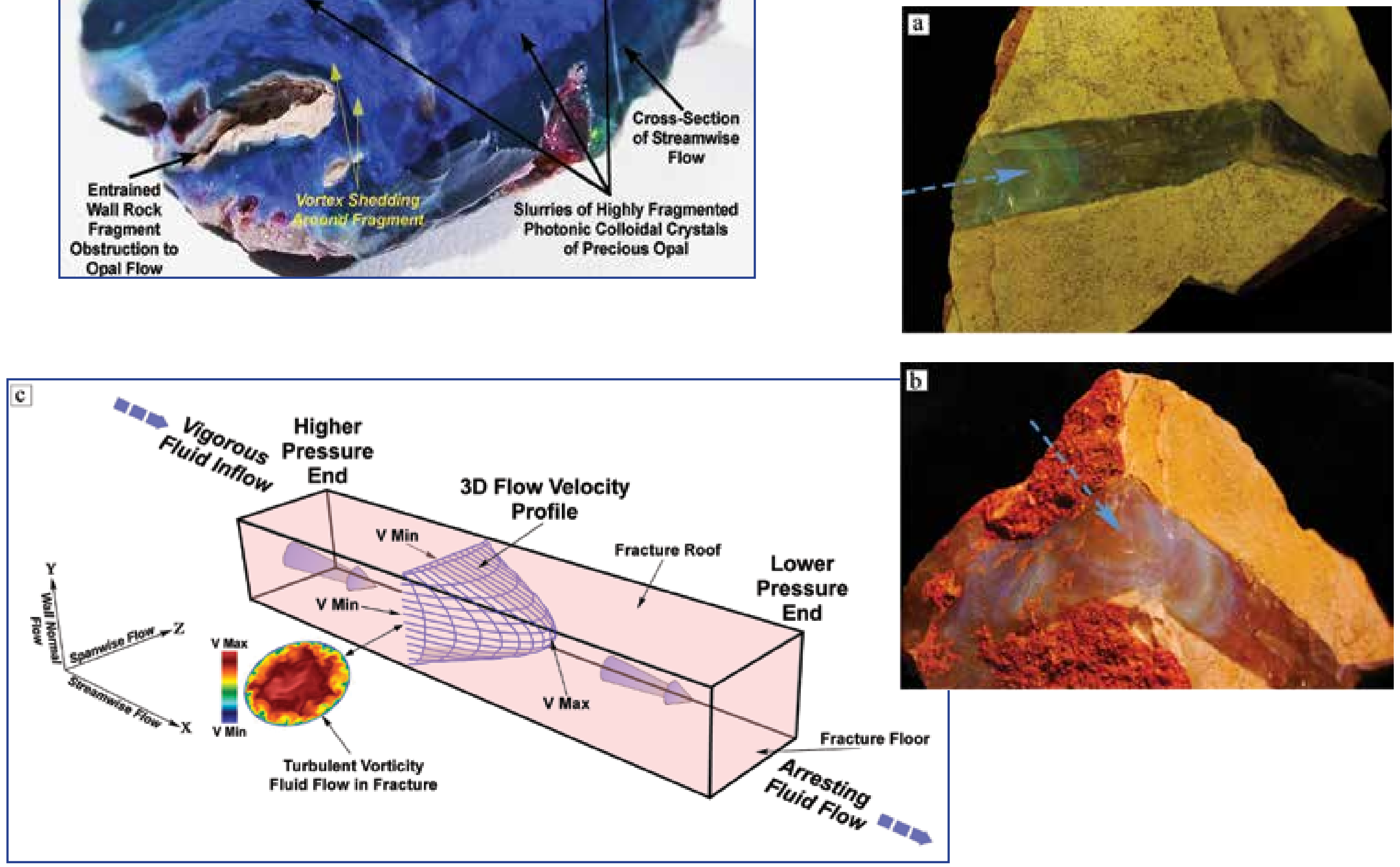


Figure 34. Example of substantial shear flow fragmentation of colloidal crystals of precious opal evident within discreet bands in the one sample; seen in cross-sectional views across streamwise and spanwise directions of opal fluid flow. Bands of precious opal exhibiting flow disruption and vortex shedding around an entrained wall rock clast are evident in the spanwise flow direction. Patterns of turbulent flow are also evident in the bands of potch opal on either side of these precious opal bands. (Seda Opals specimen and photo)



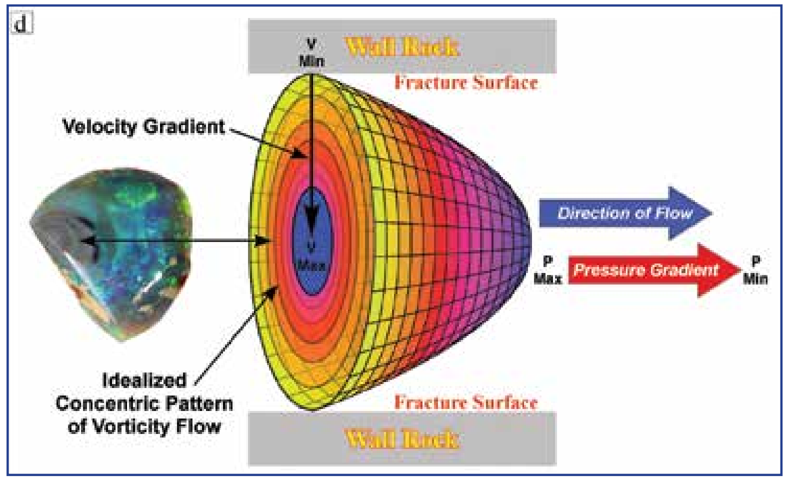


Figure 35. Paraboloid patterns of turbulent viscous opal fluid flow through relatively straight-walled fractures. The parabolic shape is indicative of the relative velocities of flow; with flow fastest in the center of the opal vein, and slowest along the sides of the host fracture, where drag along the fracture wall has slowed down the flow. Blue arrows point in the direction of flow. The blunt torpedo-like shape of the parabolic velocity profile is indicative of turbulent fluid flow conditions. (a) Shows in plan-view, a parabolic pattern of viscous opal fluid flow within an opal-filled fracture from the Mulga Rush Opal Field, SW of Lightning Ridge. (b) Shows the same opal vein which has been rotated to show the flow structure in cross-section, and which reveals a concentric pattern of flow. (c) & (d) Show schematic models demonstrating how the paraboloid patterns of viscous opal fluid flow in the Mulga Rush tectonic opal veins is posited to have been formed. [Simon Pecover specimen in (a) & (b) and Sarah Pecover photos in (a) & (b) ; Seda Opals specimen and photo in (d). Simon Pecover schematic drawings in (c) & (d)]

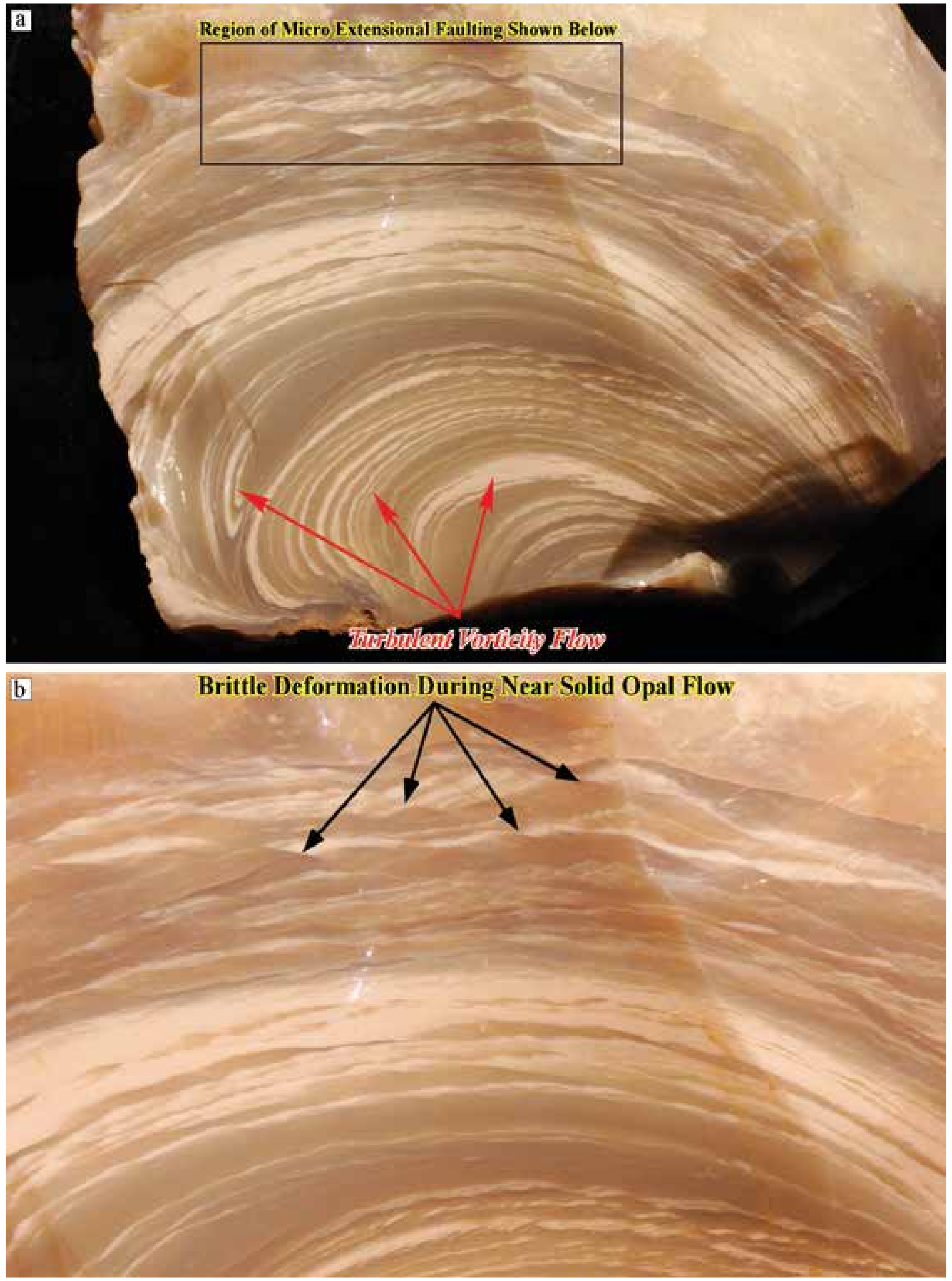


Figure 36. Pattern of turbulent fluid flow which has deformed banded potch opal from Lightning Ridge. (a) Shows curved patterns of turbulent flow indicative of turbulent vorticity flow. (b) Shows that deformation has been partly accommodated by brittle fracture deformation within individual bands; via the formation of micro extensional normal faults, as these bands were stretched and became elongated to accommodate increasing strain. The textures and flow patterns evident in this opal, demonstrates the concomitant ductile and brittle fracture deformation processes which were at work during its formation. [Cody Opals (National Opal Collection) specimen in (a) & (b); Sarah Pecover photo in (a) & (b)]

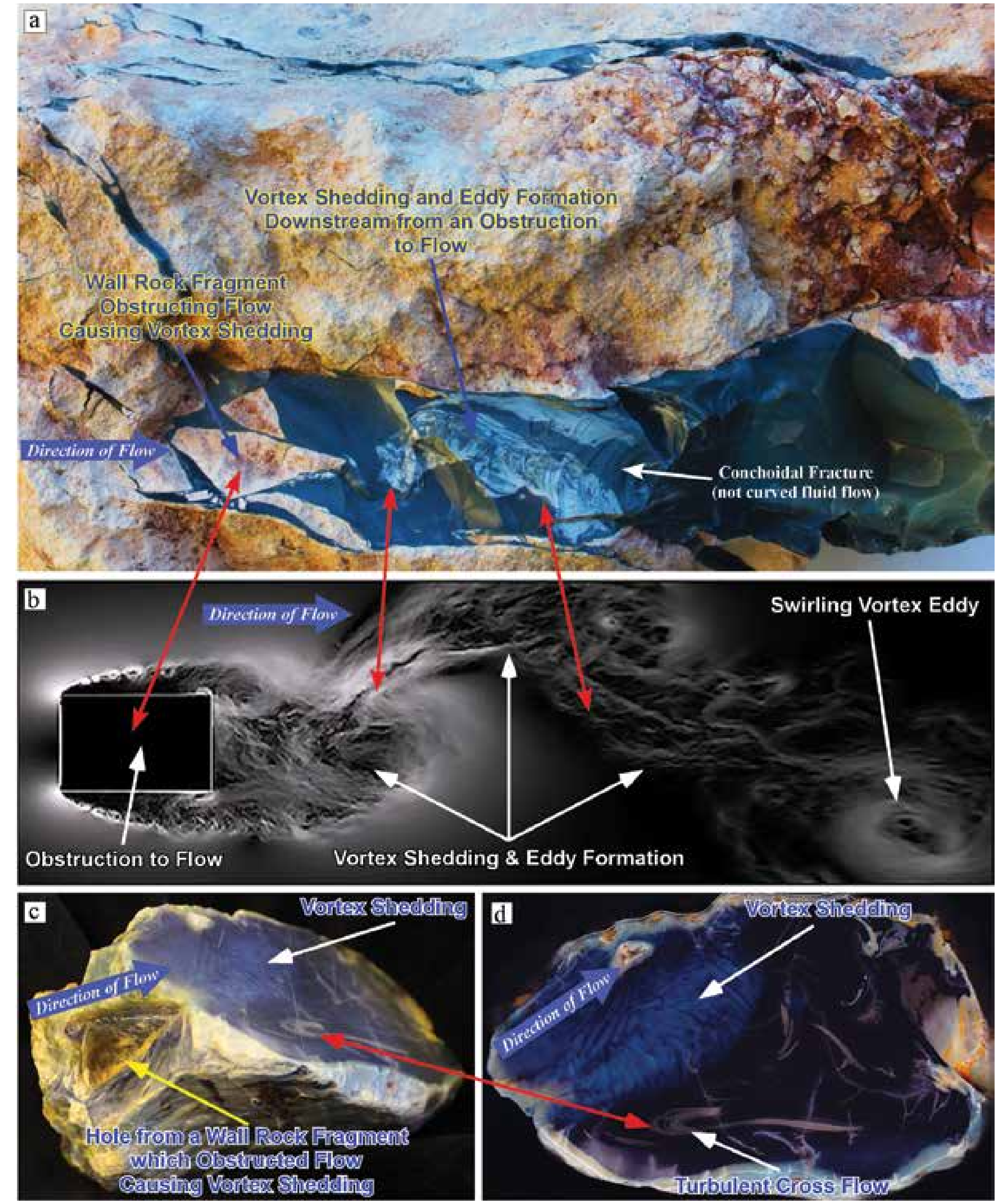


Figure 37. Patterns of turbulent fluid flow in potch opal veins. (a) Shows a hydraulic extension shear fracture in a sandy claystone that has been filled wall-to-wall with potch opal forming a vein. This specimen from the Mulga Rush Opal Field NW of Cumborah, shows evidence of at least two types of viscous potch opal (i.e. gray and whitish colored) flowing together through the opal filled fracture. The whitish colored opal displays a pattern of vortex shedding downstream from a triangular-shaped fragment of country wall rock entrained in the flow. (b) Shows a computer simulation modelling vortex shedding and eddy formation downstream from an obstruction to fluid flow which is remarkably similar to the pattern of flow shown in the opal vein in (a). (c) & (d) are the same opal vein specimen, which displays a similar pattern of vortex shedding and eddy formation on the lee side of a once tetrahedral shaped wall rock fragment (opal cutters commonly refer to fragments of country rock caught-up in opal veins as “Sand”). [Simon Pecover specimens in (a),(c) & (d); Sarah Pecover photos in (a),(c) & (d); Fluid Dynamics Simulation screen capture image from F.Xavier Trias (2014), @ https://www.youtube.com/watch?v=c8zKWaxohng in (b)]

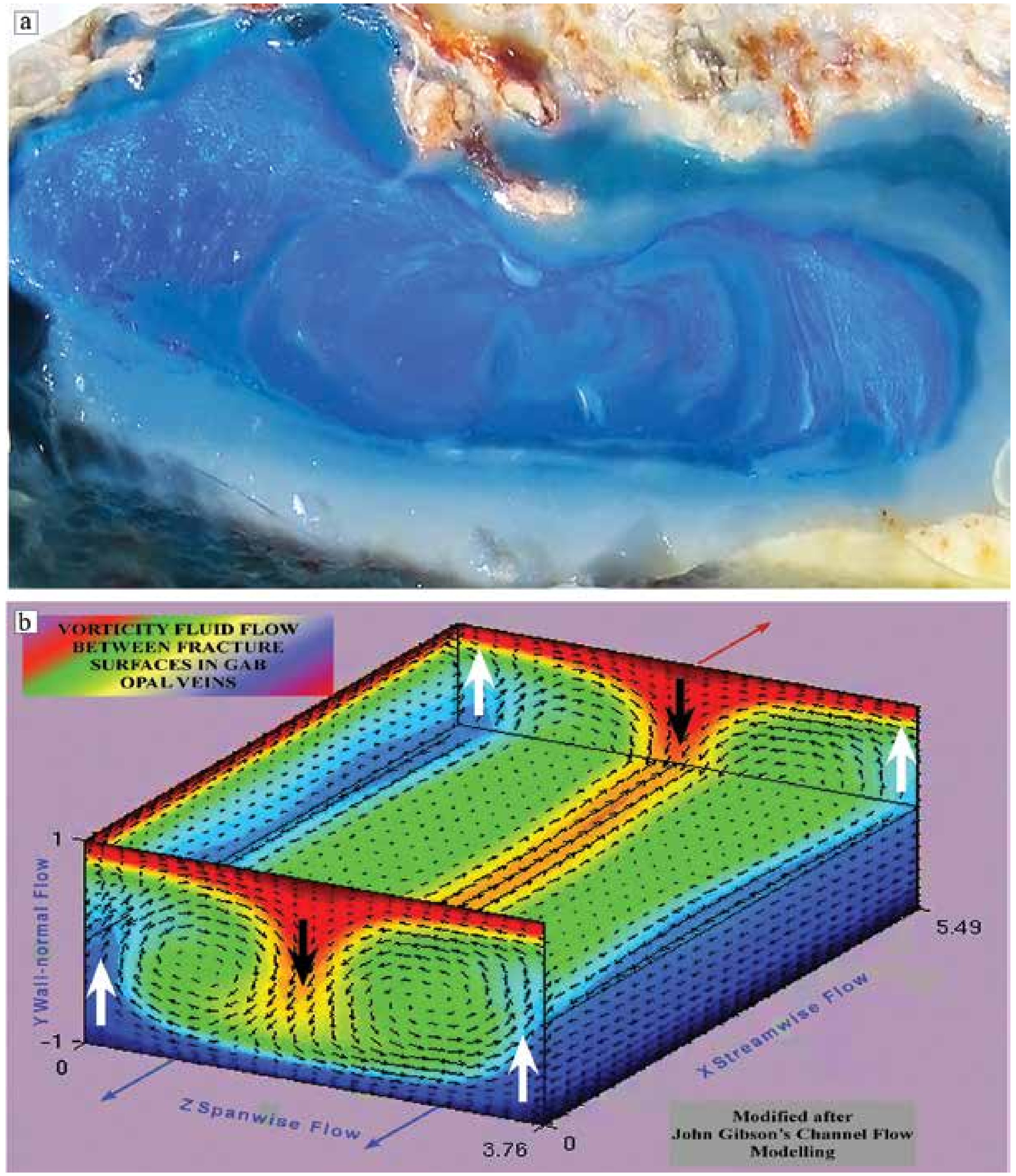


Figure 38. Pattern of viscous opal fluid flow through the long axis of an opal vein from Lightning Ridge. (a) Shows a cross-sectional view of the distorted concentric flow pattern of viscous opal which moved through the vein. The opal in this vein consists of concentric alternating bands of potch opal and precious opal. The precious opal comprises tiny fragments of broken photonic colloidal crystals which have formed flowing slurries, in a somewhat flattened helical vortex fluid flow pattern through the vein. (b) Shows a schematic model demonstrating how the pattern of viscous opal fluid flow evident in the above opal vein may have been formed, as the opal fluid moved through the host fracture. [(Patrik Ujszaszi (Rollingstone Opals) specimen and photo in (a); Diagram adapted from the work of John Gibson @ (http://channelflow.org/dokuwiki/doku.php?id=gibson) in (b)]

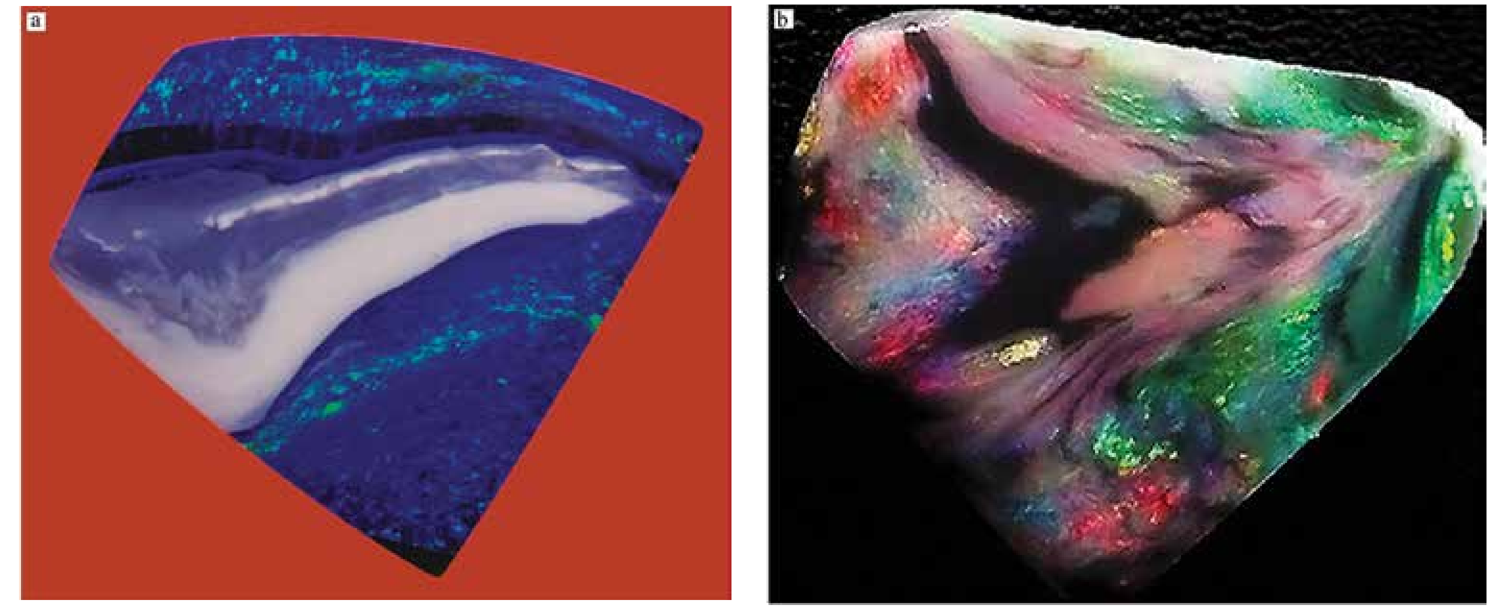


Figure 39. Opals displaying extreme deformation and distortion of once parallel shear banded layers of potch and precious opal. (a) Shows flowing crystal slurries of fragmented precious opal turbulently streaming along fluid pressure and velocity gradients concomitantly with distorted bands of potch opal. (b) Shows a fluid flow folded structure of bands of potch and precious opal, which have been sheared into a complex pattern of turbulent vorticity opal fluid flow. [Len Cram photo in (a); Seda Opals specimen and photo in (b)]

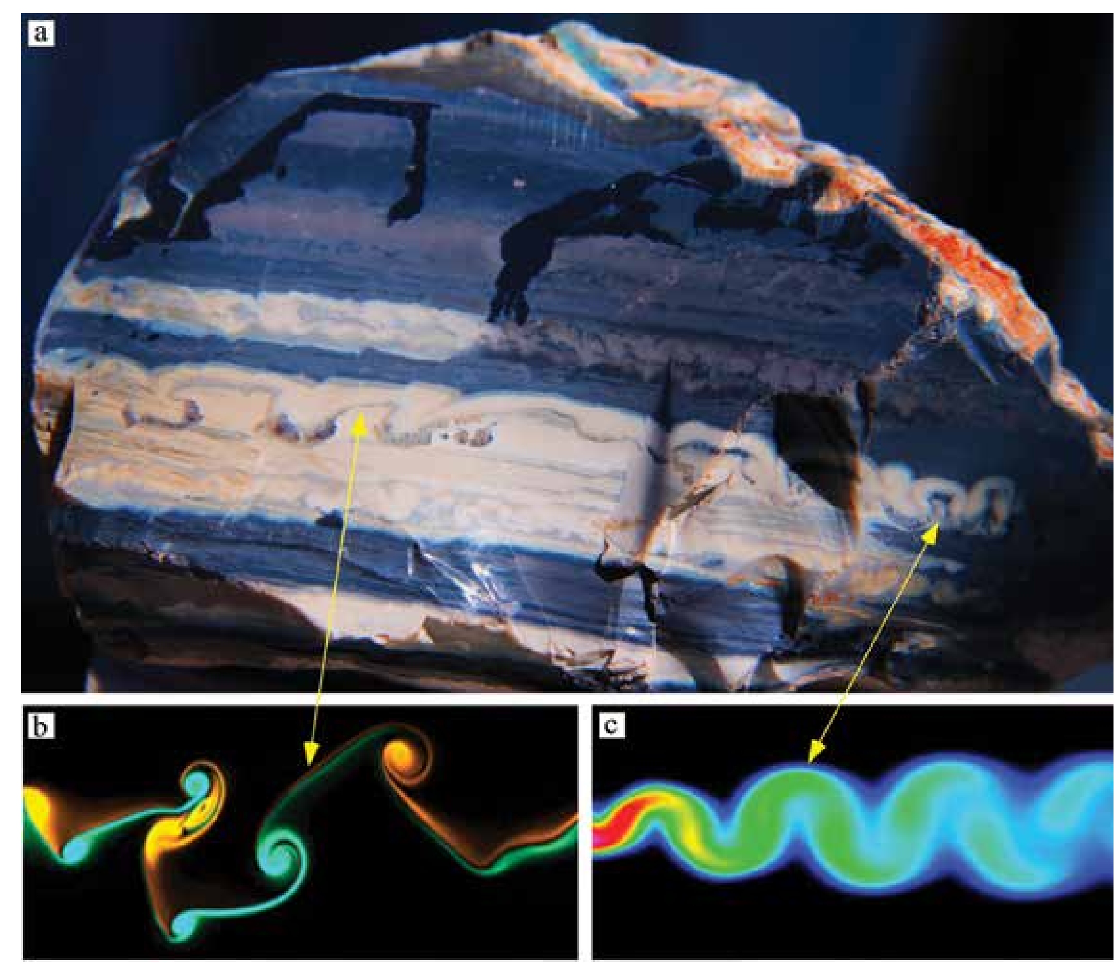


Figure 40. Patterns of turbulent viscous fluid flow within individual shear bands of potch opal. (a) Shows heterogeneous turbulent fluid flow occurring simultaneously within multiple individual bands of potch opal. Complex flow patterns consistent with vortex shedding are evident within a number of parallel shear bands in this opal. Flows which are transitional from small widely-spaced eddies to more closely-spaced tightly contorted eddy flows can be seen in some bands. However, other bands in this opal show no obvious macro textural evidence of contorted flow or patterns of vortex shedding, but instead show finely banded structures (b) & (c) Show a computer simulation modelling vortex shedding and eddy formation during fluid flow, which is remarkably similar to the pattern of flow shown in the shear-banded opal vein above. [(Specimen whereabouts unknown (a); Simon Pecover photo in (a); Physics Graphics Von Karman Vortex Street animation of vortices fluid flow @https://www.youtube.com/watch?v=f3LmjJ1N7YE in (b); DolfynNet Von Karman Vortex Street turbulent intensity animation @https://www.youtube.com/watch?v=QouhxL-qfo0 in (c)]

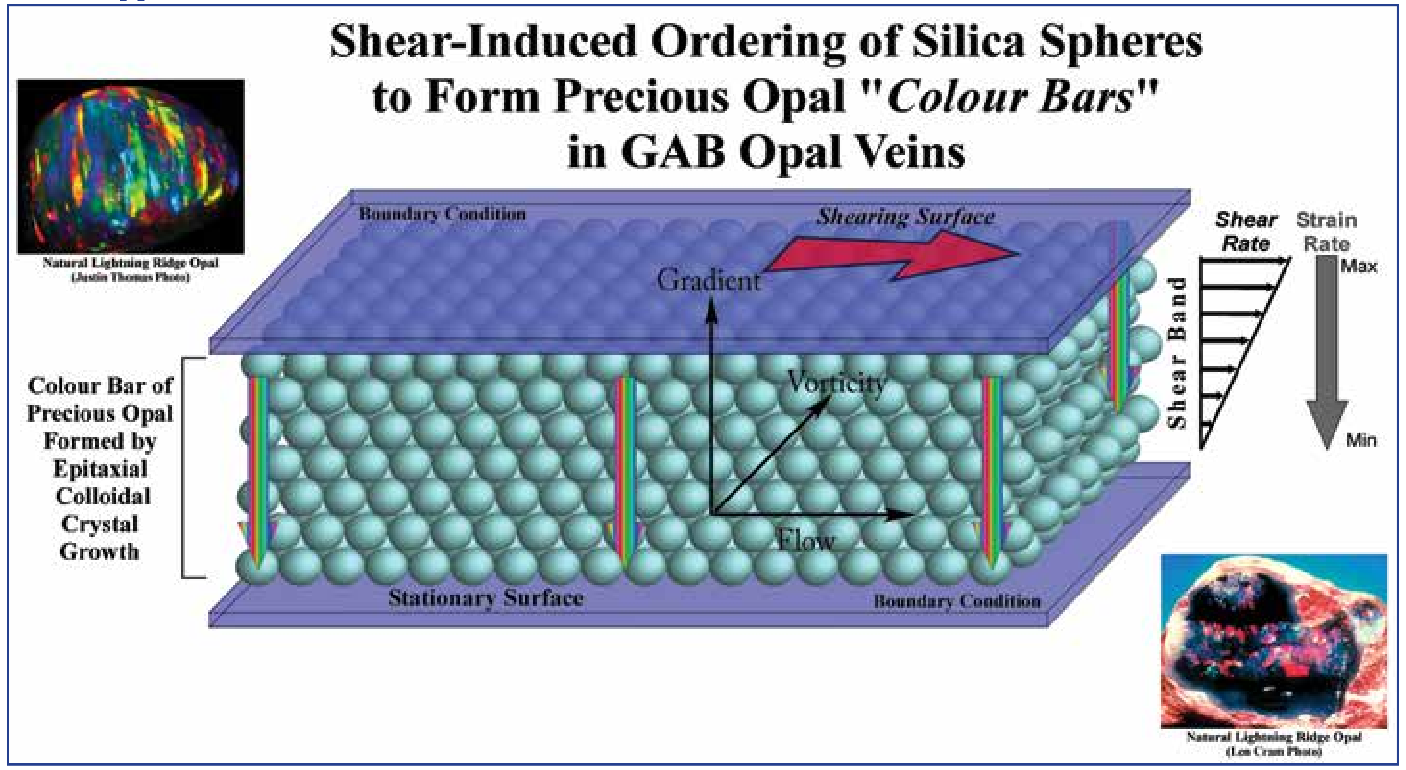


Figure 41. Shows a 3D schematic model of boundary-driven shear-induced ordering of colloidal silica spheres posited to have formed discreet bands of precious opal in tectonically-generated opal veins hosted by Great Artesian Basin sedimentary rocks. This type of shear-induced ordering and colloidal crystallization is consistent with the research of Shereda et al. (2010). Prismatic photonic colloidal crystals of precious opal displaying extreme length to width ratios, arranged in close-packed parallel clusters are evident in the opal samples shown. The photonic colloidal silica crystal structure of the gem shown in the top left-hand corner, is a feature of the opal known as the "Rainbow Serpent," which can be viewed on YouTube @ (https://www.youtube.com/watch?v=Z-S6i1LEZXIY). The colloidal crystalline structure evident in the opal shown in the bottom right-hand corner suggests growth on two opposing fronts towards a centrally located suture, consistent with Shereda et al (2010). [Simon Pecover schematic diagram; Justin Thomas (Black Opal Direct) specimen and photo in top left; Len Cram photo in bottom right]

Thus, it is reasonable to posit, that shear thickening behavior in particular shear bands likely favored the formation of potch opal within which flattened and stretched colloidal silica spheres were increasingly jammed into densely packed masses incapable of diffracting white light to produce spectral colors. Figure 40 shows compelling evidence of preserved turbulent fluid flow within individual bands of potch opal, which could not have been formed by the passive, gravity-driven, bottom-up, sedimentation processes advocated by Brown et al. (2004) and Smallwood et al (2008).

In contrast to potch opal formation, shear thinning of non-Newtonian opal fluids along the boundaries between shear-thickened potch opal layers, may have favored the segregation of undeformed silica spheres in these lower viscosity fluids and their shear-induced ordering into face-centered cubic and/or hexagonal close packed lattices during evolving shear flow conditions (i.e. at low rates of shear, perhaps equivalent to when paint is brushed onto a surface); thereby also facilitating the epitaxial growth of light diffracting prismatic photonic colloidal crystals of precious opal in discreet shear bands (Figures 33 & Figure 41) (Pecover 2018).

However, given the highly turbulent conditions which appear to have dominated the tectonic opal vein forming environment in GAB sedimentary host rocks, it is perhaps not surprising that precious opal is so rare in Australian sediment-hosted opal deposits. There is also abundant textural evidence in GAB opal veins, that bands of potch opal alternating with bands of precious opal (known as *Color Bars*) were deformed post their initial formation. This suggests oscillating hydrodynamic and rheological conditions, which has led to some very unusual overall patterns of turbulent vorticity flow and macro deformation features in GAB opal veins (Figure 39).

The tectonic opal vein forming environment in GAB opal deposits was likely consistent with the following physical conditions:-

- Lithostatic and hydrostatic pressures corresponding to a very near-surface crustal environment, at depths ranging from 0 m – ~50 m, and
- Fluid overpressure conditions of <2MPa (i.e. ~200-300 psi; extrapolating from Philipp 2012; Pecover 2018), and

A stress regime prevailing at the time of sub-horizontal opal vein formation, consistent with conditions where $\sigma v = \sigma 3$ (e.g. see Figure 8a), and

- Concomitant development of Mode I, II, and possibly III hydraulic fracturation within mainly sub-horizontal fracture networks (e.g. see Figure 8b), and
- Temperatures of <35°C (Vysotskii et al. 2013), and
- Progressive evolution of aqueous opal fluids, from Newtonian to highly viscous non-Newtonian fluid and soft-solid glassy states (Pecover 2018), and
- Oscillating hydrodynamic and rheological fluid flow and shear flow conditions (Pecover 2018), and
- Eventual sudden freezing of all hydrodynamic and rheological activity in response to a termination of the prevailing stress field and a rapid drop in fluid pressure and flow velocity, thereby virtually instantly preserving patterns of opal fluid flow in the veins; followed by dewatering and final solidification.

Concluding Remarks

The GAB is probably the most productive and prospective gem-opal-bearing geological system on Earth. The potential of this opalized system to underpin the discovery of major new gem opal resources to support future large-scale opal mining is substantial.

While gemstone resource estimation is notoriously difficult, likely in-ground opal resources in the GAB, worth potentially billions of dollars (Pecover 2007), could greatly expand the amount of high quality gem opal available for sale throughout the global colored gemstone market into the future.

Even though the Australian Opal Industry is somewhat late in following the resource development and marketing model of the global diamond Industry, the immense and minable gem opal resources in the GAB appear capable of supporting a similar economic model to that of the diamond Industry going forward.

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Dr. Simon Pecover is an Australian gemologist and a mineral deposit research geoscientist, and Managing Director of Pan Gem Resources (Aust) Pty Ltd. His gemstone research work has included the study of high-grade lahar-type sapphire deposits in Eastern Australian Tertiary basaltic volcanic terrains and the study of tectonically-generated fault/fracture-controlled opal vein deposits occurring in Australia's Great Artesian Basin.

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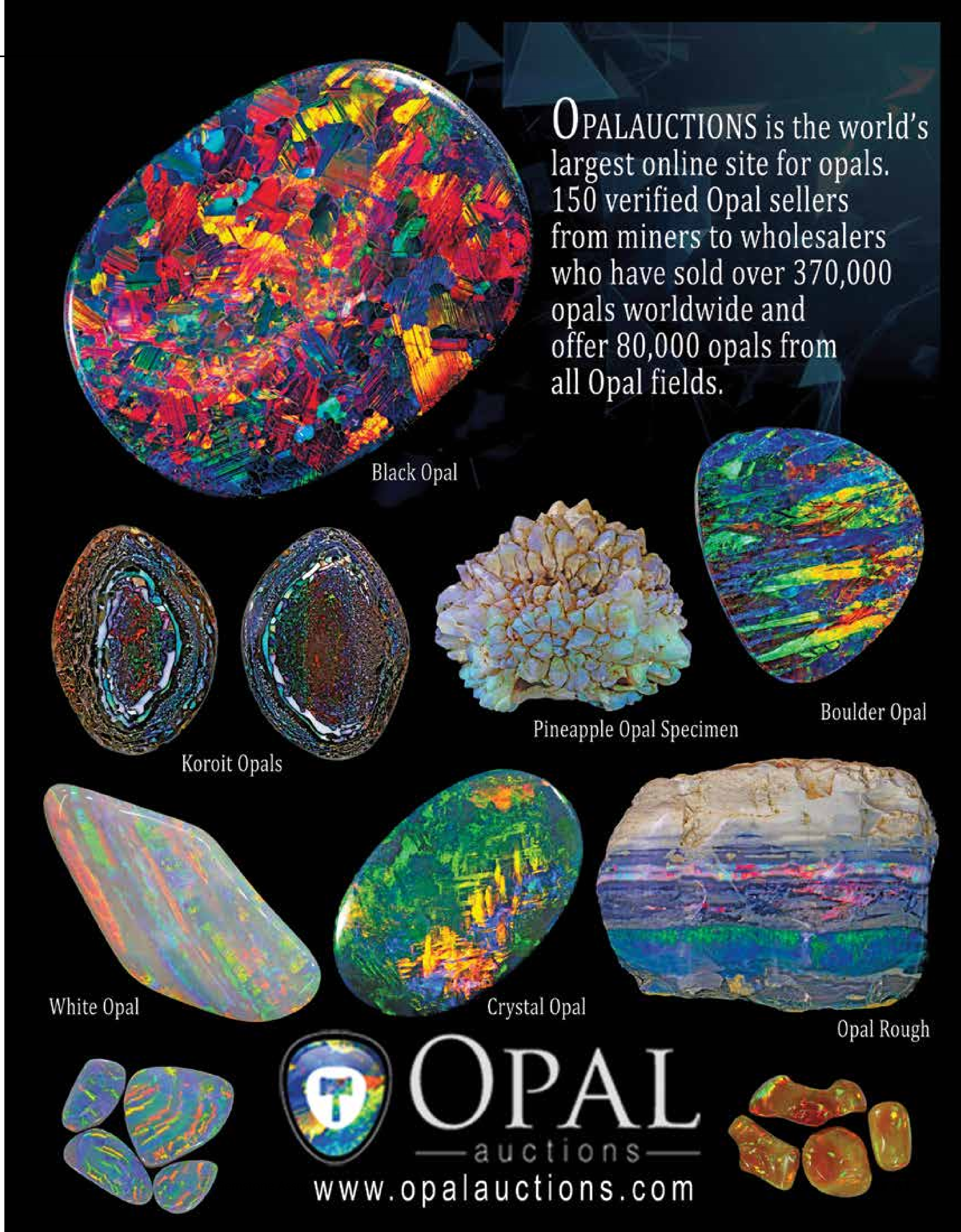

Water in Opal – What Can It Tell Us?

By Paul Thomas, Laurie Aldridge and Anthony Smallwood

Introduction

Opal is a hydrous silica composed of predominantly silicon dioxide and water. The chemical composition of opal is normally described by the general formula $SiO_2.nH_2O$. The formula indicates that opal contains water and the value of 'n' is variable so the water content is variable and is known to range widely. Such a simple formula hides many of the important characteristics of how water is contained in opal, the variability in the water content and states of water, which are intricately involved in the formation of opal and may influence properties of the opal as a gemstone.

The understanding of the states of water in opal is therefore of importance. The way in which the water is contained provides clues to the mechanisms of the formation of opal. The water contained may also be used as a probe to help elucidate the complex microstructure beyond the sphere array structure in which precious opal, in particular, is described. This article will outline the types of water present in opal that displays play-of color (POC) and how these types have been determined using chemical and physical laboratory characterization techniques.

Why Does Opal Contain Water?

In order to understand and characterize the types of water that are present in opal, the first step is to have a basic model for the formation of opal. The origin of the silica remains disputed, but it is generally agreed that opal formation is based on a dissolution-precipitation mechanism with water as the medium (Iler 1979). For opal to form by this diagenetic process, the first step must be dissolution of silica through the weathering of silica bearing minerals:

$$\text{Mineral dissolution} \rightarrow Si(OH)_3O^-,\ Si(OH)_2O_2^{2-} \quad (1)$$

$Si(OH)_3O^-$, $Si(OH)_2O_2^{2-}$ species are the individual silica species formed in solution on the weathering of silica-rich minerals. As the dissolution process proceeds, more silica is dissolved until the solution becomes saturated, or even supersaturated. A supersaturated solution is a solution where the water contains more dissolved silica than it should be able to dissolve and that is energetically favorable; so the solution is in a *meta-stable* state and is ripe for precipitating the silica. In a super-saturated solution, the silica species react together in a process of polymerization to produce larger species:

$$2Si(OH)_3O^- \rightarrow {}^-O\text{-}Si(OH)_2 - 0 - Si(OH)_2O^- + H_2O \quad (2)$$

This polymerization process continues until colloidal particles are formed. The chemical process can be described by the generalized reaction:

$$nSi(OH)_4 \rightarrow nSiO_2 + 2nH_2O \quad (3)$$

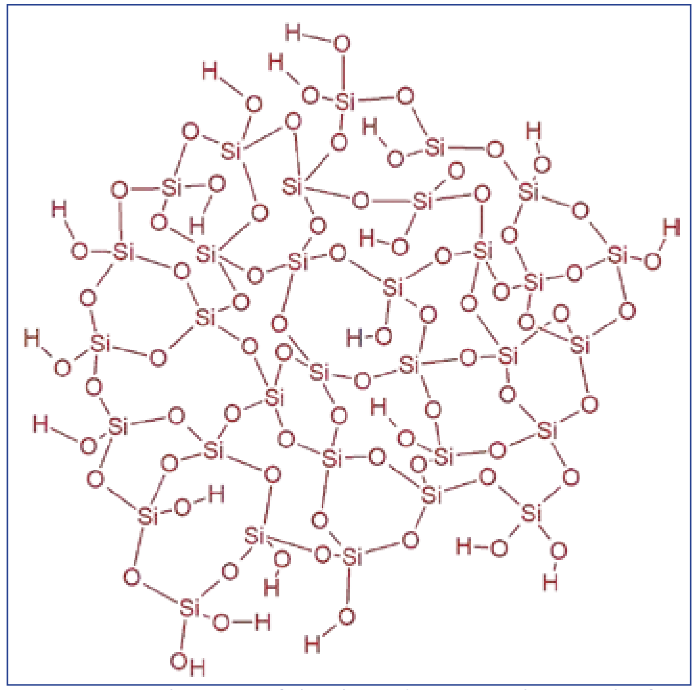

Figure 1. Schematic of the three dimensional network of polymerised silica which forms the sphere particles in the colloid initially formed by precipitation.

This generalized equation does not give a visual impression of how the silica is bonded. As silica has a valence of 4, each silica atom bonds to 4 oxygen atoms, which form the Si-O-Si bridges between the silicon atoms. As there are 4 of these bridges per silicon atom, a three dimensional network is formed as outlined in Figure 1.

The silica network continues to grow as long as the supply of silica continues, resulting in the formation of colloidal particles in the water. This growth process continues until, in the formation of precious opal, a monodispersed colloid of large spherical particles (circa 200 to 400 nm with a size variation that should be less than 5%) is formed (Iler, 1979). The colloid then concentrates and the spherical particles "crystallize" to form an ordered array of silica spheres. An example of such an array is shown Figure 2.

The final step in the formation of the opal is the cementing of the spheres with a silica cement as, prior to this step, the opal will remain porous allowing the diffusion of water through the array.

The cementing process binds the spheres together through the precipitation of silica in the voids between spheres. The microstructure in Figure 2 is therefore only observed if this silica cement is etched away using hydrofluoric acid.

The microstructure observed in Figure 2 is responsible for the POC in opal. The POC is based on the diffraction of light off ordered arrays of monodispersed silica spheres (Sanders, 1968; Darrah et al, 1976). The size of the spheres defines the color of light that is observed as diffraction is based on the path length that light travels between the planes of spheres and the color by the wavelength of light. The larger the spheres, the longer the path length light can travel, and hence the longer the wavelength of light that is observed. In the white light spectrum, blue is at the short wavelength end of the spectrum and is observed for smaller sphere sized opal (200 to 250 nm in diameter), while at the long wavelength end of the spectrum, red is observed for larger sized sphere (roughly in the range 250 to 400 nm).

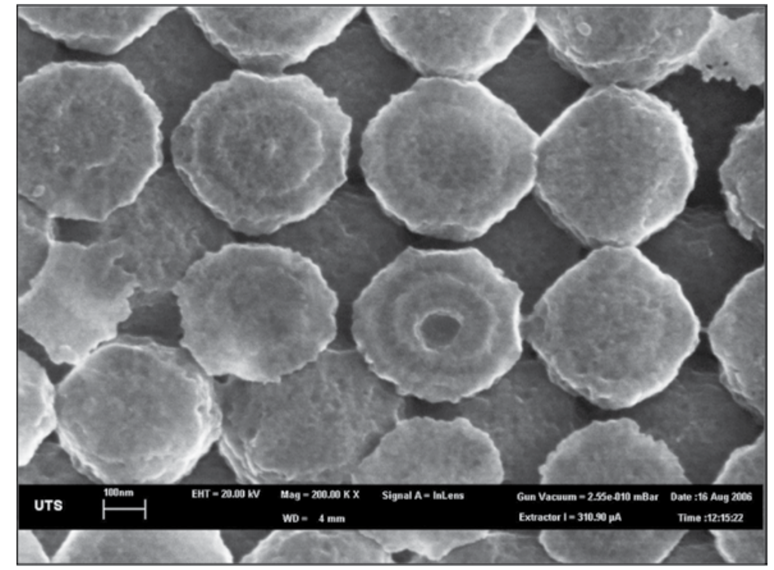

Figure 2. Coober Pedy play-of-color opal showing ordered arrays of spheres after etching with hydrofluoric acid. (Smallwood et al, 2008a)

Opal-A and Opal-CT

The three-dimensional silica network at the atomic scale is composed of SiO_4 tetrahedra (Figure 1) that are bonded together in a random network as is the case for opal-A (amorphous) or with a more ordered network (but not highly ordered) as in opal-CT (cristobalite-tridymite). X-ray diffraction (XRD) is a useful tool for the discrimination of opal-A and opal-CT. The tetrahedra in opal-A are randomly stacked and only a broad hump or halo is observed (Figure 3(a)). On the other hand, opal-CT is partially crystalline and contains a partially ordered arrangement of silica tetrahedra which produce definite peaks in the diffraction pattern corresponding to the ordering exhibited by cristobalite (C) with tridymite stacking faults (T) (Figure 3(b)). In fact, X-ray diffraction formed the original basis for the nomenclature of opaline silica (Jones and Sanders, 1968; Langer and Flörke, 1974).

The three-dimensional network defines the atomic scale structure of the silica, but not the microstructure, which results in the POC. The structure of opal at the atomic scale does, however, influence the amount of water contained in the opal and the type of water present. We will first discuss the amount and then we will address the types of water present in opal.

Water Content of Opal

As the formation of opal is a dissolution-precipitation process, water becomes trapped in the opal as it is being formed. Opal can therefore contain significant amounts of water, from 2% to 20%, but typically the quantity of water contained in opal is 6% to 10%. Measurement of the amount of water in opal is usually carried out by thermogravi-

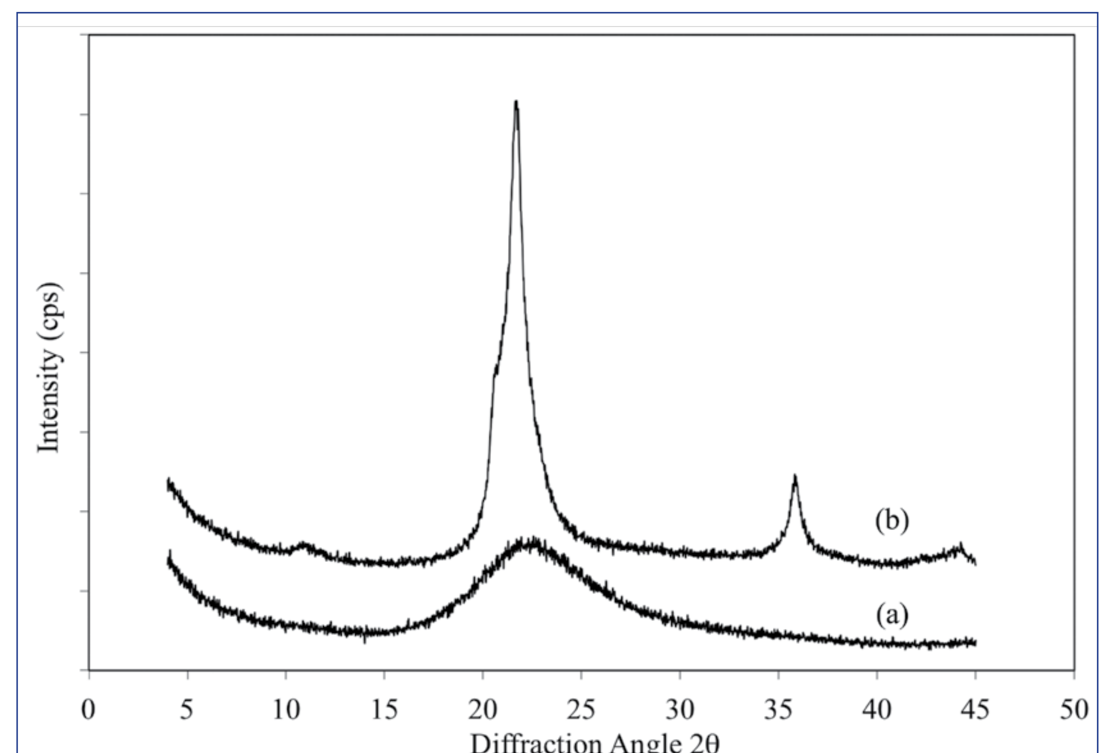

Figure 3. X-ray diffraction pattern of (a) opal-A from Coober Pedy and (b) opal-CT from Tintenbar. (Smallwood et al, 2008b)

metric analysis (TG) where a sample (typically 20 to 50 mg) is heated at a constant rate (typically 1°C/min) to 1000°C to drive off the water. The amount of water contained can then be determined from the mass change. Some typical data is shown in Figure 4 and total water contents using this technique are listed in Table 1 along with their XRD classification.

The total amount of water is an important measure as it is the basis for the status of opal as a hydrous silica with the notional formula of $SiO_2.nH_2O$. Measurement of the amount of water provides a value for 'n', but it does not in itself help to understand how the water is contained in the opal. In order to understand how water is contained in opal, the types of water need to be identified and characterized.

Types of Water in Opal

The formation mechanisms are important in defining how water is contained in opal. As opal is formed through the polymerization of silica in water, two generic types of water are, therefore, contained in the structure, molecular water and bound silanol water. Molecular water is literally water molecules that are physically contained or trapped in the opal while silanol water is water that is chemically bound in the form of Si-OH groups in the opal network at internal or external surfaces. The types of water are schematically shown in Figure 5 and are discussed below.

Molecular Water

Molecular water is literally molecules of water molecules physically contained in the opal. Due to the nature of the formation process, molecular water is contained in a number of environments within the opal. These are identified in Figure 5 as *bulk*, *surface adsorbed* and *cage* water. The presence of molecular water in opal has given rise to the term opal-A_G or amorphous gel-like opal as opposed to hyalites which are also amorphous, but contain negligible quantities of water and have the designation opal-A_N or network-like opal (Langer and Flörke, 1974). We will limit the discussion to opal-A_G and will simply refer to these types of opal as opal-A.

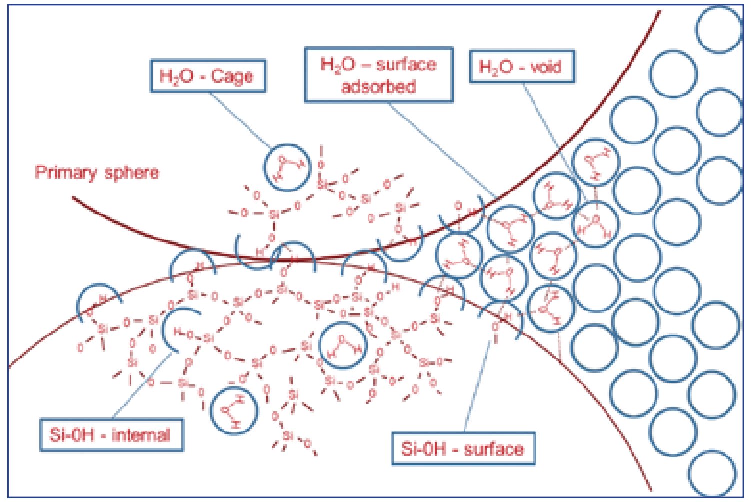

Figure 5. Schematic of the environments of water in opal. (After Langer and Florke, 1974).

(i) Bulk water. Bulk water is defined as water where large quantities of molecules are trapped together in voids or inclusions in the opal. This type of water has all the characteristics of liquid water as each water molecule experiences an environment where they are surrounded by lots of other water molecules. Although bulk water can be contained in large inclusions, most of the bulk water is contained in defects in the arrays or in the voids or spaces between spheres. As spheres do not tessellate when packing, voids may occur between the spheres. If these voids are not infilled by the silica cement, the voids are likely to be filled with water. An example of this phenomenon is shown Figure 6 where a micrograph of an un-etched fracture surface of a Coober Pedy opal is shown.

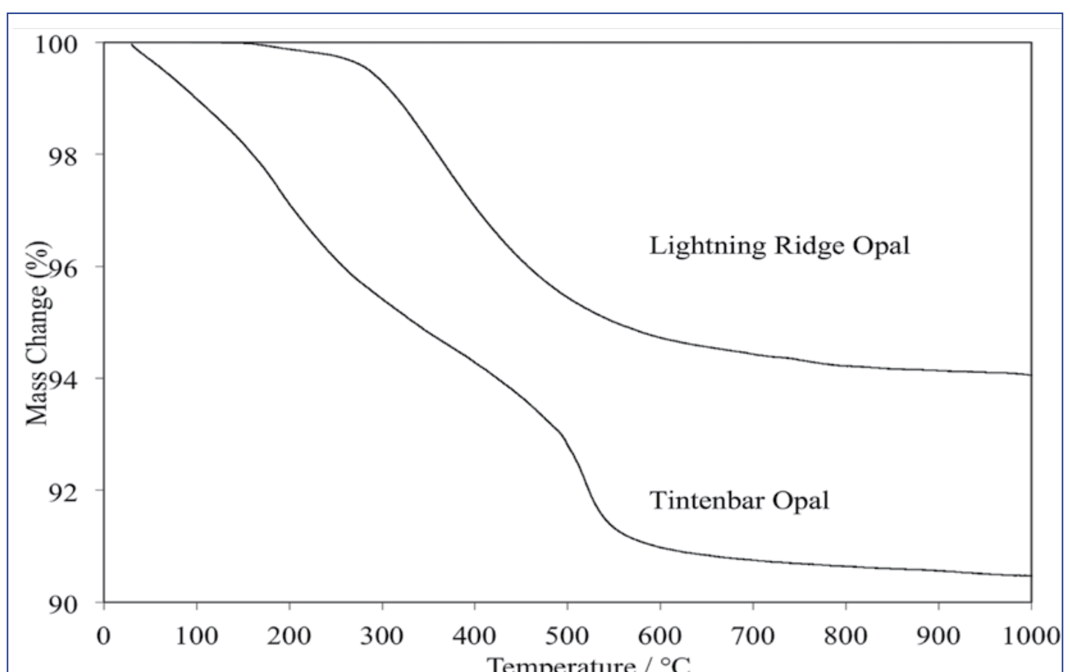

Figure 4. Mass % (TG) curves representing the mass change during heating resulting from water loss from a Lightning Ridge potch opal containing 5.9% total water and a Tintenbar crystal opal containing 9.5% water. (Smallwood et al, 2008)

Origin	XRD Classification	Water Content / %
Andamooka Black Boy	A	6.90
Andamooka Honey Opal	A	6.11
Argentina Lemon Opal	A	5.33
Brazil Lemon Opal	A	5.32
Brazil Light Opal	A	5.80
Coober Pedy 14 Mile	A	7.05
Coober Pedy 9 Mile	A	6.60
Coober Pedy Alans Rise	A	6.82
Coober Pedy Olympic	A	6.90
Ethiopian Fire Opal	CT	7.05
Ethiopian Shewa Brown POC	CT	9.09
Ethiopian Shewa Colourless	CT	12.86
Ethiopian Wollo Lumps	CT	8.04
Indonesian Java Faint POC	CT	3.01
Lambina	A	6.74
Lightning Ridge Sun Flash	A	5.88
Mali Lemon Opal	CT	5.14
Mexican Orange	CT	9.91
Mexican POC	CT	8.36
Mintabie Grey POC	A	6.01
QLD Boulder Blue POC	A	6.05
Slovak Opal	A	8.39
Tintenbar POC	CT	9.10
White Cliffs	A	6.52

Table 1. Water contents of opals determined using thermogravimetric analysis by heating the opals to 1000°C at a rate of 1°C/min supported on a balance in a furnace. The type of opal (opal-A or opal-CT) is listed based on XRD pattern. (Unpublished data)

As bulk water contained in the opal has the properties of liquid water, it can be frozen by cooling to below 0°C. Once the opal has been cooled to sub-zero temperatures and the water has crystalized, the crystallized water can be melted again by heating to above 0°C. This type of crystallization-melting process has been carried out using the technique of differential scanning calorimetry (DSC) where, on heating the frozen water, the melting process can be followed and is observed as a negative peak in the scan since the melting of water is endothermic (it takes energy to melt the crystals). The size of the peak is proportional to the amount of crystallizable water present in the opal. DSC curves are shown in Figure 7 for a variety of opals from Australia and a Mexican opal (Thomas et al, 2013).

Two aspects of the DSC curves help to characterize the opal. The temperature at which the water melts indicates size of the void or capillary in which the water is contained (the lower the temperature, the smaller the void or capillary)

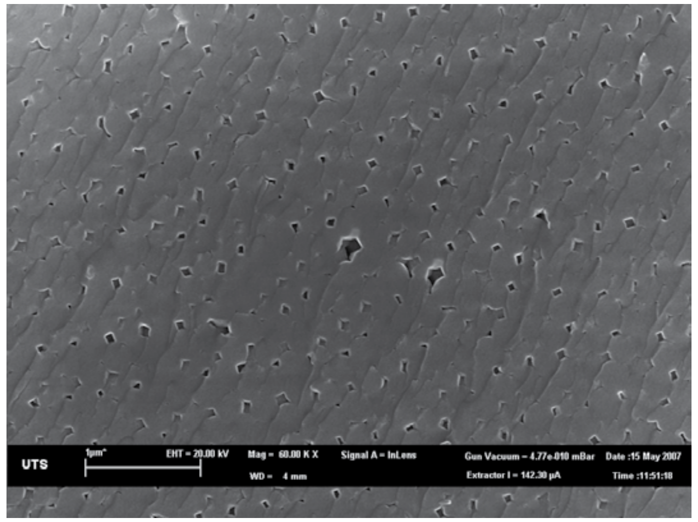

Figure 6. SEM micrograph of the fresh fracture surface of a precious play-of-color Coober Pedy opal (without etching) showing distinct arrays of voids between spheres. (Thomas et al, 2013)

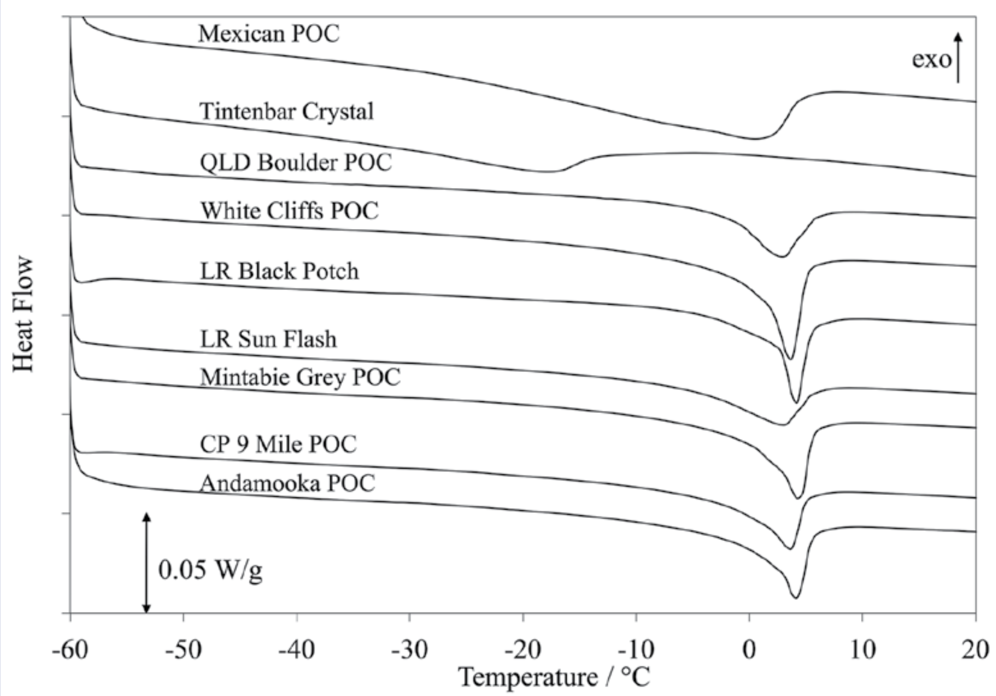

Figure 7. DSC curves showing the melting behavior of bulk water in specimens of opal. (Thomas et al, 2013)

and the area of the peak is proportional to the amount of crystallizable water (Landry, 2005). The data in Figure 7 can be separated into two groups, the opal-A group and the opal-CT group (although only two opals are included in the latter group). For opal-A—opal that is sourced from the Great Australian Basin (GAB)—the melting begins around -10°C, but most of the water melts around zero, which suggests that the water is contained in relatively large pores (estimated to be in the range 8 to >50 nm in diameter based on the method outlined in Landry (2005)), which is consistent with the voids shown in Figure 6.

For opal-CT from Tintenbar, all of the water melts below zero in the range -40 to -10°C suggesting that the pores are much smaller (we have estimated them to be of the order of 2 to 8 nm in diameter using the method of Landry (2005)). The opal from Mexico has characteristics of both capillary water and void water. The small size of the pores, which contain water in the opal-CT, are smaller than the voids between spheres. This suggests that the pores are more like capillaries and are formed during the polymerization of the spheres themselves. Figure 8 is a schematic of the types of cavity, which contain the water in opal.

Based on the area of the melting peaks, the amount of crystallizable water ranges from 10% to 25% (Table 2), although that range has been expanded in recent work on going in our laboratories. This suggests that the between 75 and 90% of the water is not crystallizable and is contained elsewhere in the opal.

(ii) Adsorbed water. The second type of molecular water contained in opal is adsorbed water. Adsorbed water is molecular water that is physically adsorbed to the silica surface. Adsorbed water does not have the characteristics of bulk water as it is not as free to diffuse and is interacting with silanol (Si-OH) groups in the surface.

As adsorbed water is interacting with the solid surface, the water does not freeze and so is not crystallizable. The effect of the surface on the water molecules is not limited to the water molecules directly adsorbed to the surface, it also influences water molecules adsorbed to water molecules adsorbed to the surface. The thickness of the adsorbed layer has been estimated by experimental studies on synthetic mesoporous silicas and is estimated to be circa 1.1 nm (Landry, 2005).

Potentially, a significant portion of the water can be adsorbed, but this type of water is difficult to identify and therefore quantify. The proportion of this type of water will increase for smaller pores as the surface area to volume ratio of the capillary pores increases with reducing pore diameter. Based on the size of pores contained in the opal-CT determined from the data in Figure 7, it is estimated that opal-CT has a greater proportion of this type of water than opal-A.

It should also be noted that, if the pores are less than 2 nm in diameter, the water contained in the pores is just adsorbed water. If the pores are less than 1 nm in diameter, they are approaching the size of the water molecules and water therein contained can be considered to be cage water.

(iii) Cage Water. The third type of molecular water is cage water. This is water that is trapped in the three- dimensional silica network (Figure 5). As in the case for adsorbed water, cage water is also difficult to identify directly. Experimental comparisons between opal-A and opal-CT suggest that opal-A has more cage water than opal-CT. Work currently being carried out by our group on the diffusion rates of molecular water using quasi-elastic neutron scattering (QENS, where neutrons hit the water molecules to determine their mobility in a similar fashion to a cue ball hitting the pool balls). QENS has shown that the mobility of water in opal-A is greater than that of opal-CT (water molecules move on average faster in opal-A).

This greater mobility is ascribed to isolated molecules in cages. If the molecules are isolated they are freer to move. If the water molecules are bonded to other water molecules or silanol groups (this type of bonding is known as *hydrogen-bonding* and is the way that water molecules interact with each other), they are less free to move and so have less mobility. This difference can also be seen in near-infrared spectrum of the water in opal (Chauviré B. et al, 2017). Peaks in the spectrum are sharper and more skewed to higher wavenumber when they are less associated with other water molecules or silanol groups (Figure 9). Greater interaction between water molecules results in broader peaks, which are extended to lower wavenumber.

Sample	Total Water content (mass loss at 1000°C) as a % of opal mass	Crystallizable water present as a % of opal mass	Crystallizable water as a % of total water content
Andamooka POC (SA)	6.7	0.63	9.4
Coober Pedy (CP) 9 Mile POC (SA)	7.2	0.74	10.2
Mintabie Grey POC (SA)	6.3	0.89	14.1
Queensland (QLD) Boulder POC	6.5	0.56	8.6
Lightning Ridge (LR) Black Potch (NSW)	6.1	0.67	10.9
Lightning Ridge (LR) Sun Flash POC (NSW)	8	0.58	7.3
White Cliffs POC (NSW)	6.6	0.96	14.5
Tintenbar POC (NSW)	9.1	1.16	12.8
Mexican Fire Opal	8.8	2.05	23.3

Table 2. List of water contents of the opal samples characterized, which were used to determine the percentage of crystallizable water present in the opal as a percentage of the total water content. (Thomas et al, 2013)

Silanol Water

Silanol water is water that is chemically bound in the silica network. Silanol water corresponds to the presence of broken bridges in the silica network (Adams et al, 1991; Brown et al, 2003; Langer and Flörke, 1974). Silanols can be found at both internal (e.g. capillary pores) and external surfaces or as isolated broken bridges in the 3D silica network (Figure 5). Each Si atom has a valance of 4 and is therefore bonded to 4 oxygen atoms. In pure silica, each of these oxygen atoms is bonded to another Si atom creating the 3D network (Figure 1).

The process of opal formation is a "condensation reaction" as described by Equation 3 above, but the process is imprecise and depends on the pH. The higher the pH, the more likely there are to be broken Si-O-Si bridges, and the more silanol (Si-OH) or bound water present. The proportion of broken bridges can be determined from ^{29}Si nuclear magnetic resonance (nmr) spectroscopy as this technique

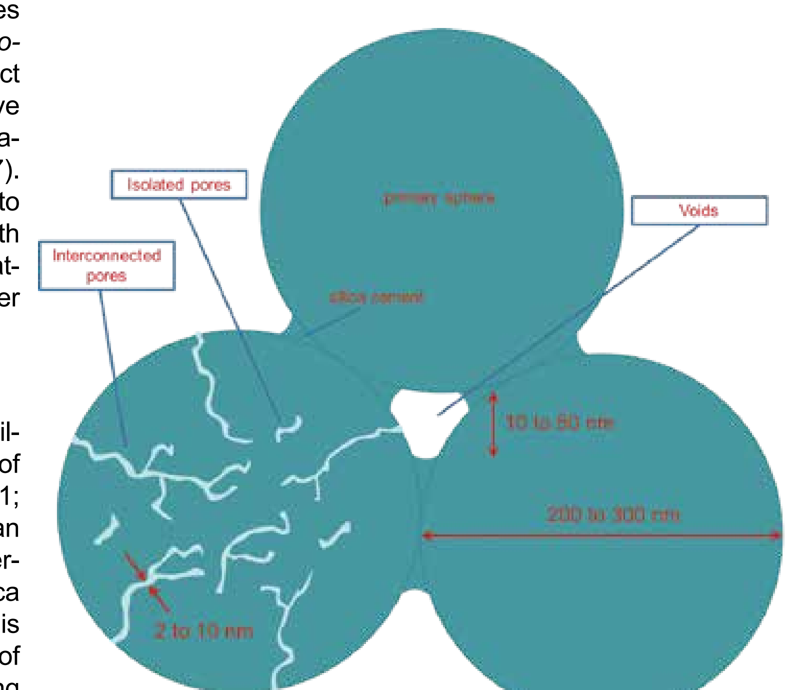

Figure 8. Schematic of the voids and capillaries that contain crystallizable water. The crystallizable water in opal-A is contained predominantly in the voids while, for opal-CT, the water in predominantly contained in capillary pores.

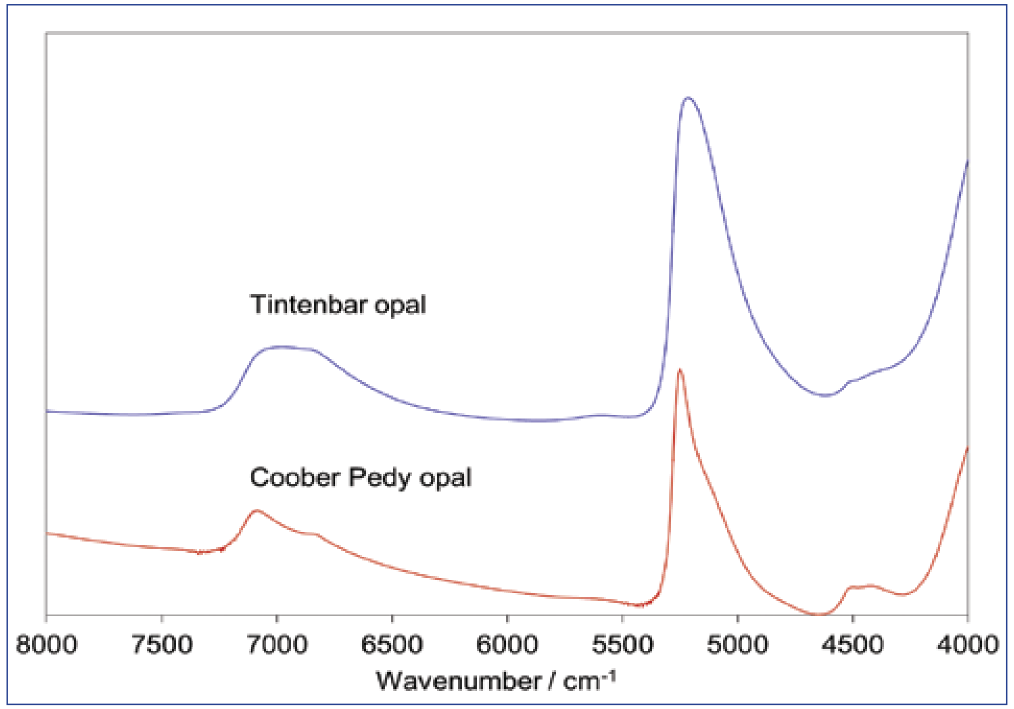

Figure 9. Near infrared spectra of a Coober Pedy and a Tintenbar opal showing the characteristic differences in the water contained in these opals. (Unpublished data)

is sensitive to the environment of the atoms and can detect how many bridges (or broken bridges) are present per Si atom. Figure 10 shows the ^{1}H cross polarization ^{29}Si nmr spectra (i.e. it accentuates the Si-OH functionalities present) of opal-A from the GAB and opal-CT from Tintenbar and Mexico. It is clear that the peak at -102 ppm is bigger for the opal-CT specimens indicating that these opals have a greater amount of silanol water per silicon atom. These results correlate with the greater capillary porosity of opal-CT and suggest that the environment is key to the type of opal that is formed.

Opal-A is formed in sedimentary rocks of the GAB. These sedimentary rocks are kaolinite rich and have the potential to ion exchange with the pore waters thus reducing pH. Opal-CT, on the other hand is normally found in weathered tuffs and at closer proximity to weathered rocks that are the source of the silica, resulting in an elevated pH and a greater proportion of silanol groups.

General Remarks

Two types of water have been identified in opal, molecular water and chemically bound silanol water. These types of water can be subdivided further into water contained in the silica network (cage water and internal silanol water) and water that is contained in capillaries and voids in the opal (surface adsorbed and bulk water and surface silanols). The presence of these types of water results from the formation mechanism of opal, i.e. opal is formed through the dissolution and re-precipitation of silica.

The atomic structure and the microstructure of the opal can be influenced by the environment in which the opal is formed. Certainly, there are significant differences between the water contained in opal and the morphological type of opal (i.e. whether the opal is opal-A or opal-CT) and in the total water content (opal-A is generally found to contain less water than that of opal-CT).

Both the molecular water and the silanol water in opal can be differentiated between opal-A and opal-CT. The molecular water in opal-A is contained in voids between spheres or is distributed through the silica cage network while, in opal-CT, the molecular water is contained in small capillary pores. Opal-CT is observed to contain more silanol or bound water than opal-A. These differences suggest differences in the environment in which the opal is formed and from the perspective of the proportion of silanol groups in opal-CT. Opal-CT is expected to be formed at a higher pH than opal-A, though still within the bounds suggested by Iler (1979), i.e. a pH of 8 to 10.

The presence of water and how water is contained has been implicated in the physical properties of opal as well. Water has been linked to whitening and crazing of opal through water loss (Pearson, 1985; Aguilar-Reyes et al, 2005; Rondeau et al, 2011). Understanding the microstructure and the states of water in the microstructure of opal can therefore help to understand the mechanism of crazing and hence has the potential to help identify stones that might be susceptible to crazing. At this stage, the correlation is based on water content, but the more information we attain from characterizing the water content and the types of water in opal, the closer we will be to achieving the goal of being able to identify susceptible material.

Finally, not only does opal provide us with the aesthetic pleasure of the beauty and uniqueness of the gemstone and the magnificence of the chemical and physical processes that underpin the formation of this beautiful gem, opal and its dissolution-precipitation mechanism of formation has also helped to identify the presence of water on Mars (Milliken et al, 2008). Opal is helping to understand the environment of Mars. Understanding the nature of the water in terrestrial opal will aid the understanding of the formation of Martian opal and the environment in which it is formed. Opal is out of this world!

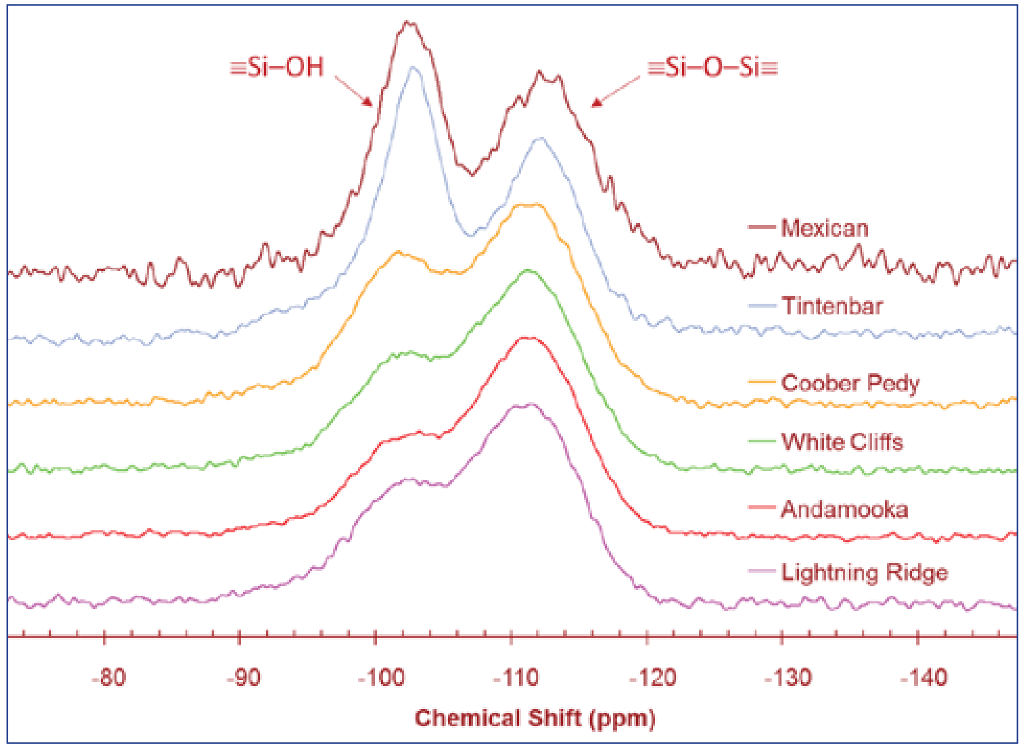

Figure 10. 1H cross polarization 29Si nmr spectra for opal-A specimens from the GAB and opal-CT specimens from Tintenbar, NSW and Mexico. The peak at -102 ppm indicates the proportion of silanol (Si-OH) water present. (Brown et al, 2003)

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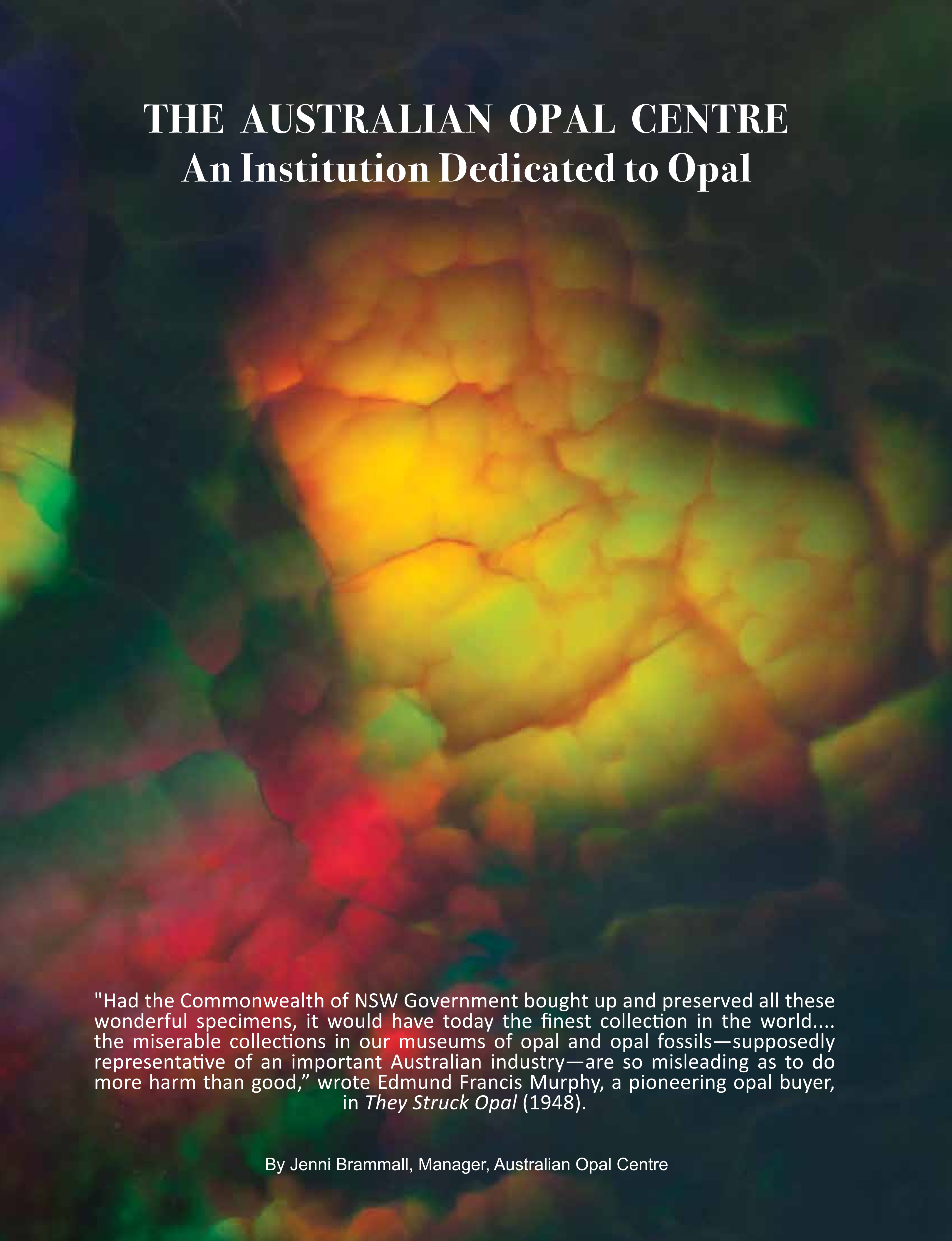


THE AUSTRALIAN OPAL CENTRE
An Institution Dedicated to Opal

"Had the Commonwealth of NSW Government bought up and preserved all these wonderful specimens, it would have today the finest collection in the world.... the miserable collections in our museums of opal and opal fossils—supposedly representative of an important Australian industry—are so misleading as to do more harm than good," wrote Edmund Francis Murphy, a pioneering opal buyer, in *They Struck Opal* (1948).

By Jenni Brammall, Manager, Australian Opal Centre

Opal is Australia's National Gemstone, with each of Australia's major opal fields having its own distinctive geology, opal types, fossils, landscape, natural and cultural heritage. This panoply of treasures, unique in the world, is the consequence of a freakish combination of geological conditions (Rey 2013). Gemstone laboratories and industry participants, educators and opal enthusiasts look to the Great Southern Land for knowledge and leadership on all matters opal.

Yet there is no Australian institution dedicated to opal science, art, heritage and culture; no center for opal-related education, training or industry development; no public collection of the country's magnificent national gemstone. Despite the passion and hard work of opal industry members over many years, Edmund Murphy's words still ring true.

An Australian public institution dedicated to opal is long overdue and at the Australian Opal Centre, industry and community members are together making it happen.

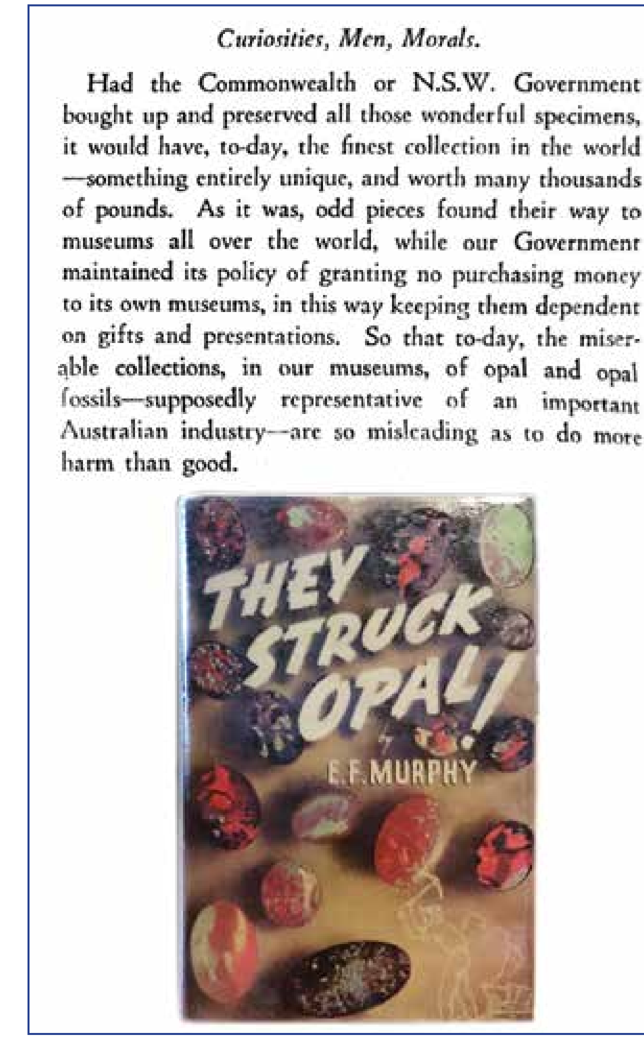
The Australian Opal Centre has already assembled the world's premier public collection of opalized fossils from the Age of Dinosaurs. It has become the leading repository for relics of the history and heritage of Australia's outback opal fields, has one of the world's most complete collections of opal-related publications, is a key provider of opal-related knowledge services and has well-advanced plans to construct a building that will be a 21st century architectural icon and a long-awaited center of excellence for opal.

History

The history of the Australian Opal Centre has been recorded elsewhere (Brammall 2015), so will be recounted here only briefly. The project was conceived in the late 1990s by community members who sought to develop a not-for-profit, high quality, high profile attraction based on opal and opalized fossils, with education, research and community functions. Initial research and planning was supported by several government and community entities.

Esteemed Australian architects Glenn Murcutt and Wendy Lewin were appointed to design the new facility. Murcutt is the only Australian to have received the Pritzker Prize, sometimes referred to as the *Nobel Prize for Architecture*. A building by Murcutt and Lewin in an Australian opal field would become a 21st century architectural icon.

In 2004, with local government seed funding, Lightning Ridge Opal and Fossil Centre set to work in earnest. It obtained accreditation as a public museum, endorsement as a recipient of tax-deductible donations in Australia and established Australia's first dedicated public collection of opal and opal-related items.



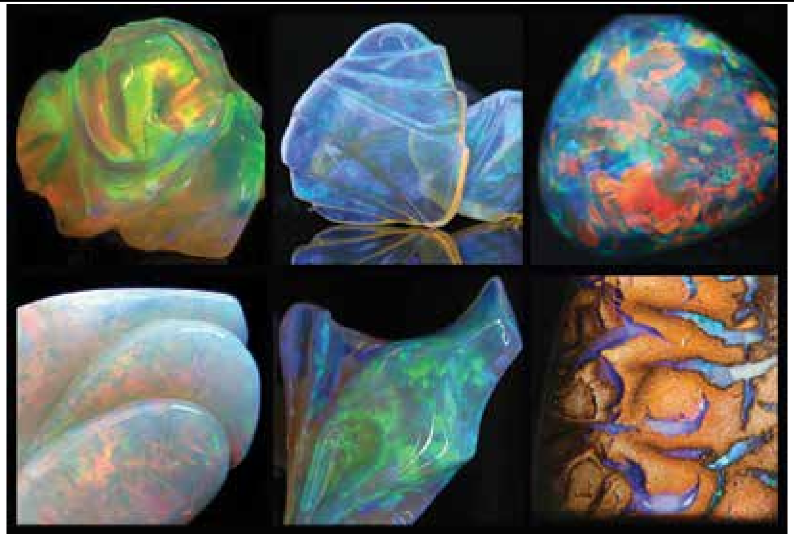
Curiosities, Men, Morals.

Had the Commonwealth or N.S.W. Government bought up and preserved all those wonderful specimens, it would have, to-day, the finest collection in the world—something entirely unique, and worth many thousands of pounds. As it was, odd pieces found their way to museums all over the world, while our Government maintained its policy of granting no purchasing money to its own museums, in this way keeping them dependent on gifts and presentations. So that to-day, the miserable collections, in our museums, of opal and opal fossils—supposedly representative of an important Australian industry—are so misleading as to do more harm than good.

E.F. Murphy, *They Struck Opal* (1948).

Australian opal treasures: black opal (left) and 100 million-year-old opalized theropod dinosaur tooth. (Photo, right: Robert A. Smith).

Opposite page: Close-up of highly unusual opal pattern within a piece of opalized wood, one of thousands of opal-related items in the Australian Opal Centre collection. (Photo: Robert A. Smith)



Australian opal: crystal, black, light and boulder matrix.

Opalized fossils donated to the Australian Opal Centre through the Australian Government's Cultural Gifts Program. Clockwise from top left: yabby button (crayfish gastrolith), freshwater snail, plesiosaur tooth, dinosaur toe bone, pine cone, lungfish tooth plate, dinosaur pelvic bone, crocodile tooth, naticid or 'moon snail'. Magnifications vary; individual items from 8mm to 50mm across. (Photos: Robert A. Smith)

The AOC's Black Opal Heritage Shed: learning hub by day (top left and right), outdoor cinema venue by night (bottom, during a screening of SPARK).

The AOC's small public exhibition space welcomes thousands of visitors each year. It displays highlights from the AOC collection and a scale model of the planned new AOC building.

U.S. Consul General Valerie Fowler (right) visiting the AOC's Morilla St showroom with Vicki Bokros, gemologist, opal dealer, AOC past president, AOC Founder and Life Member.

A site was surveyed and acquired on the historic Three Mile opal field. A functional brief was developed and the design and engineering team got to work. Development consent was sought and obtained, and a business plan was developed.

Membership was taken up by hundreds of individuals and businesses across Australia and the world, including opal buyers, sellers, processors, wholesalers, retailers, jewelers, writers, photographers, designers, scientists, educators and others inspired by the concept. Donations to the collection came in from around Australia and the world: opalized fossils, opal specimens, books, artworks, historical materials.

In 2007, the Lightning Ridge Opal and Fossil Centre became the Australian Opal Centre, as the national significance of its collections, themes and purpose became clear. At around the same time, local government seed funding ended and the organization was forced to become self-funding.

A small exhibition space and museum shop were fitted out in rented premises. AOC Morilla Street was opened in December 2008 by the Governor of NSW, Her Excellency Professor Marie Bashir, and has since been open to the public six days per week. Schools and tour groups asked to visit. Journalists, publishers, professional bodies, film crews, authors and designers started to get in touch, seeking education, information, images and expertise.

Raising the multi-million dollar budget required for the new AOC was clearly going to be a marathon rather than a sprint. Meanwhile, larger premises were needed to host groups, diversify revenue generation and provide more storage.

In 2011, the AOC built its Black Opal Heritage Shed. The shed contains a display of vintage opal mining machinery, facilities for lectures, group visits, AOC and community events and a gallery space for exhibitions. While fundraising continues, the AOC is building its audience, activities and income, working from its exhibition space, Black Opal Heritage Shed and other locations.

Current Activities

A remarkable museum collection

Crowning the AOC collection is the world's most diverse collection of rare opalized fossils—thousands of them, including many of incredible beauty and scientific significance. Many of these extraordinary fossils have been donated through the Australian Government's Cultural Gifts Program. Opal-related geological items in the collection are another valuable resource for research and exhibition.

A collection of opal books and publications, one of the most comprehensive in the world, forms the foundation of the future AOC research library. These, together with artworks, artifacts and archival materials, remain in storage awaiting construction of the new AOC. Other major collections, committed for donation, remain in the custody of current owners until the Centre has appropriate facilities for storage, protection and access.

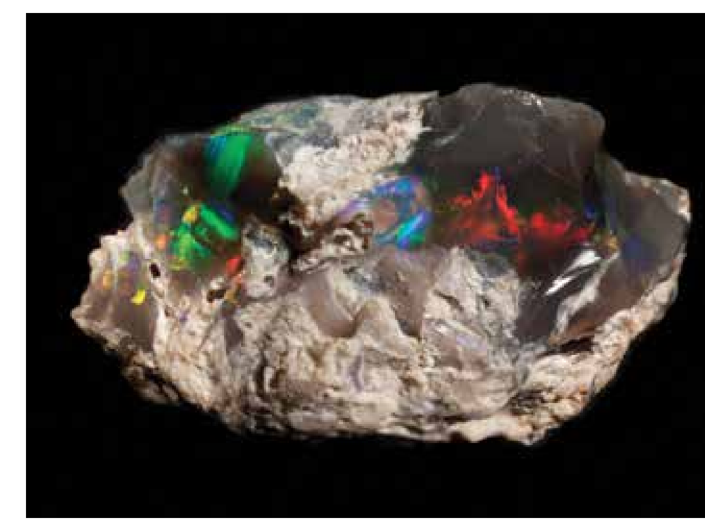
Other collection items are as varied as the diffraction apparatus used by John Sanders in the early 1970s to reveal the microstructure of precious opal, historic opal jewelry items, and Harold Hodges' infamous opal denture.

The Centre will, in future, invite major donations of precious opal, to create a stunning showcase of opals from all Australian opal fields and comparative material from other opal-producing nations. This collection will be a tribute to all who contribute to it. Acquisition of the AOC opal collection will commence after funding is secured for the new AOC building, to ensure appropriate security, environmental, storage and exhibition conditions for the collection.

Opal pendant/brooch worn by Major Lady Winnie Mackenzie, the first woman to be commissioned by the Australian Army Medical Corps. Donated to the AOC by P. Garry through the Australian Government's Cultural Gifts Program.

The AOC holds the world's most scientifically significant collection of opalised fossils. Access is provided for scientiic research and a curated highlights are on public display; the bulk of the collection is in storage, awaiting display and interpretation in the new AOC building.

Nicola Williams with an item of historical significance: the diffraction apparatus used by scientist John Sanders in the 1960s and 70s to reveal the microstructure of precious opal.



Rough black opal in the Australian Opal Centre collection. (Photo: Robert A. Smith)

Weewarrasaurus pobeni, one of several recent new dinosaur discoveries to emerge from the AOC's collection and research collaborations. Two small opalized jaw fragments (largest 26mm), discovered in a parcel of rough opal and donated to the Australian Opal Centre by Michael Poben through the Australian Government's Cultural Gifts Program, were found to represent an entirely new species. (Photos: Robert A. Smith; Artwork (reconstruction): Jim Keuther)

The Australian Opal Centre collection is a gift to the people of Australia and the world, from the donors who have gifted these treasured items to the AOC in perpetuity. The collection continues to grow in size and significance.

Scientific research

The Australian Opal Centre fosters scientific and cultural research in collaboration with other institutions. The AOC's collection of opal-related specimens is sought out by researchers in geology, gemology and paleontology.

The AOC participated in an Australian Research Council (ARC) Linkage Grant scientific research project involving institutions in Australia and Sweden, and assisted the ARC-funded Opal Project at the University of Sydney, which resulted in important publications such as Rey (2013).

Paleontological research on AOC collection items is thriving. The AOC's Dr. Elizabeth Smith and Manager Jenni Brammall, both vertebrate paleontologists, collaborate with other researchers to facilitate exciting new discoveries in paleontology and geology (Bell et al. 2016, 2017, 2018, 2019; Brougham et al 2017; Hamilton-Bruce and Kear 2010; Kear & Godthelp 2008). Most recently, the AOC collection gave the world *Weewarrasaurus pobeni* (Bell et al. 2018), the first new dinosaur species to receive a scientific name in New South Wales in almost a century.

Fossil Dig

Since 2014, the Australian Opal Centre has run an annual Lightning Ridge Fossil Dig co-hosted by the Australian Geographic Society.

Members of the public pay to join scientists from the AOC and University of New England, Armidale, to search for opalized fossils and enjoy privileged access to sites, materials and expertise in opalized fossils, opal mining and opal itself. New fossils are added to the AOC collection and participant fees provide an important income stream. Dig participants learn about and purchase opal, and many continue as AOC champions and volunteers, contributing a range of professional skills.

Participants in the annual Lightning Ridge Fossil Dig, hosted by the Australian Opal Centre.

Federico Fanti, geologist (University of Bologna, Italy) and National Geographic Emerging Explorer, in an opal mine during the Lightning Ridge Fossil Dig. This research produced the first absolute dating of Lightning Ridge's opal deposits, via radioactive decay of zircon crystals (Bell et al 2019). (Photo: J. Pickrell)

Education and training

The Australian Opal Centre is becoming a hub for education and training in opal science, art and industry skills. In conjunction with the Gemmological Association of Australia, it is developing a suite of opal-related courses for enthusiasts and professionals, for both online delivery and face-to-face delivery at Lightning Ridge. Consumer education about opal and opalized fossils is currently provided in the AOC's public display space.

AOC Founder Kylie Gutry at the 2017 Lightning Ridge Fossil Dig, with Dig particant and AOC Life Member Greg Banks.

100 million-year-old opalized pine cones found during the 2018 Lightning Ridge Fossil Dig.

Paleontologist Dr. Phil Bell and AOC Founder Kirsten Cowley discovered conjoining pieces of a rare opalized aspidorhynchid fish scale during the 2018 Lightning Ridge Fossil Dig.

Rough opal collected in the field by AOC Fossil Dig participants.

An underground mine visit provides vital insights into both the geology and the industrial/social history of opal and fossil discoveries at Lightning Ridge. Guide Stephen Henley with Fossil Dig participants.

Lightning Ridge Fossil Dig participants enjoying special access to a miners' processing site to search for opalized fossils.

Fossil Dig participants also enjoy a rare opportunity to examine and discuss rough, cut and set opal with local opal experts.

2018 AOC Fundamentals of Opal Carving class with instructor Andrew Kemeny.

The first course in the AOC's *Opal Practical Studies* series, *Fundamentals of Opal Carving*, has run successfully for three years and, by November 2018, was booked out for 2019. Other courses are in development.

Lectures and educational tours are provided for special interest groups including fossil clubs, jewelers, gemologists, valuers, historians, engineers and others. Educational displays about opal are in development for use in teaching, trade shows and retail settings. Readers may contact the AOC to request information or tell the AOC what courses they would like to see offered.

The AOC provides opportunities for students from the University of New England (UNE), Armidale, to gain work experience in its fossil collection and each year, and UNE runs a vertebrate paleontology intensive school at the AOC's Black Opal Heritage Shed.

School groups visit the Australian Opal Centre from up to several hundred kilometers away to learn about opal, opal mining, opalized fossils, Australian prehistory and the environment. Programs emphasize hands-on discovery. Every student receives a little sample of rough opal with play-of-color—seeds sown in the minds and imaginations of a new generation. Even students across the world can benefit, as when the AOC provided images and information for *Scholastic Math*, a middle-school classroom magazine distributed throughout the USA.

A Field Study Centre is on the drawing board to provide accommodation and facilities for visiting student groups. A site has been donated by an AOC supporter and conceptual designs have been prepared and government approval obtained. The project will recommence when construction funds are secured.

Opal carving by Ting Ting Lau, student in the AOC's 2018 Fundamentals of Opal Carving class.

School students discover opal, fossils, the natural world and opal fields at the Australian Opal Centre.

An exhibition of pottery by Graeme Anderson made using clay from the opal mines.

Planned Lightning Ridge Field Study Centre, to provide accommodation for visiting student groups. (Design and rendering: DWP Architects)

Cultural programs

Australian Opal Centre cultural activities include lectures, exhibitions and other events. AOC-hosted lectures by visiting gemologists, paleontologists, geologists, jewelers and photographers always receive enthusiastic attendances.

The AOC has initiated and hosted numerous exhibitions of artworks inspired by opal, the opal fields and opal people, even exhibitions of *opal clay* pottery made using clay from the opal mines.

The AOC also contributes to or participates in collaborative cultural projects. It contributed to *Migration Memories,* an Australian National University and National Museum of Australia research project and exhibition, as well as to *Brilliant Ideas*. Led by the Australian Society for the History of Engineering and Technology, it documented the invention and adaptation of opal mining machinery by miners, engineers and fabricators and produced a permanent display, an exhibition booklet and a set of portable exhibition panels.

An exhibition by Swedish artist Linda Persson, on work done while visiting Lightning Ridge and the AOC, was selected for *Momentum*, the Nordic Biennial in Moss, Norway.

In 2015, the AOC-supported OPALessence (play.with.colour), an installation at the world-renowned Vivid Sydney festival, sharing opal color and pattern with 1.5 million festival goers and up to 1.2 billion people worldwide.

And, in 2016, the AOC developed SPARK, a community arts project culminating in a cinematic presentations of opal and opal-field life, so successful that it has since been screened three times weekly, six months per year, as cinema under the stars.

Information services

The Australian Opal Centre is called upon daily to provide information about opal, opalized fossils, the opal industry and related subjects.

A fossil identification service is provided for miners. Inquiries are received from members of the public, journalists, publishers, filmmakers (including the producers of the recent hit *Outback Opal Hunters*), educators, government and other organizations. The Centre provides information, images and fact-checking services for books, newspaper, magazine and journal articles, as well as television and film productions. AOC representatives are invited to present at conferences including GAA Federal Conferences, National Opal Symposia, paleontological events in Australia and Canada, and diverse other gatherings.

Industry development

The AOC aims to foster a sustainable opal industry in Australia. It increases public awareness of opal and the opal industry through publications, public programs and work with journalists, filmmakers and others. It makes submissions and supports lobbying by miners' associations and

Opal color and pattern en large in the historic Rocks precinct of Sydney, in the AOC-supported installation OPALessence at the Vivid Sydney Festival. Inset: information about opal was available by scanning a QR code at the site.

An exploration drill in use to prospect for indications of opal at Lightning Ridge. (Photo: H. Deisenberger)

Hydraulic digger in an underground opal mine at Lightning Ridge. (Photo: M. Goodwin)

Fred Bodel's camp, one of the oldest remaining dwellings on the Lightning Ridge opal fields, during a visit to the Australian Opal Centre by Her Excellency Marie Bashir, Governor of NSW and Sir Nicholas Shedadie.

other industry bodies. It seeks to inspire young people to pursue opportunities in the opal industry. It participates in and supports events such as the National Opal Symposium.

It supports opal-related initiatives of other organizations, for example: contributing to a presentation on Australian opal for the Gemstone Industry Laboratory Conference at Tucson in 2014; providing images and information for important papers such as Smallwood (2014); providing design services and educational seminars for the successful 2014 Great Australian Opal Tour run by the Gemmological Association of Australia (GAA) and National Opal Miners' Association (NOMA). The AOC sent manager Jenni Brammall to the First Changsha Mineral and Gem Show to support the Australian Pavilion, coordinated by the National Opal Collection, to give presentations about opalized fossils and Australian opal to the public, and as a keynote speaker on opalized fossils.

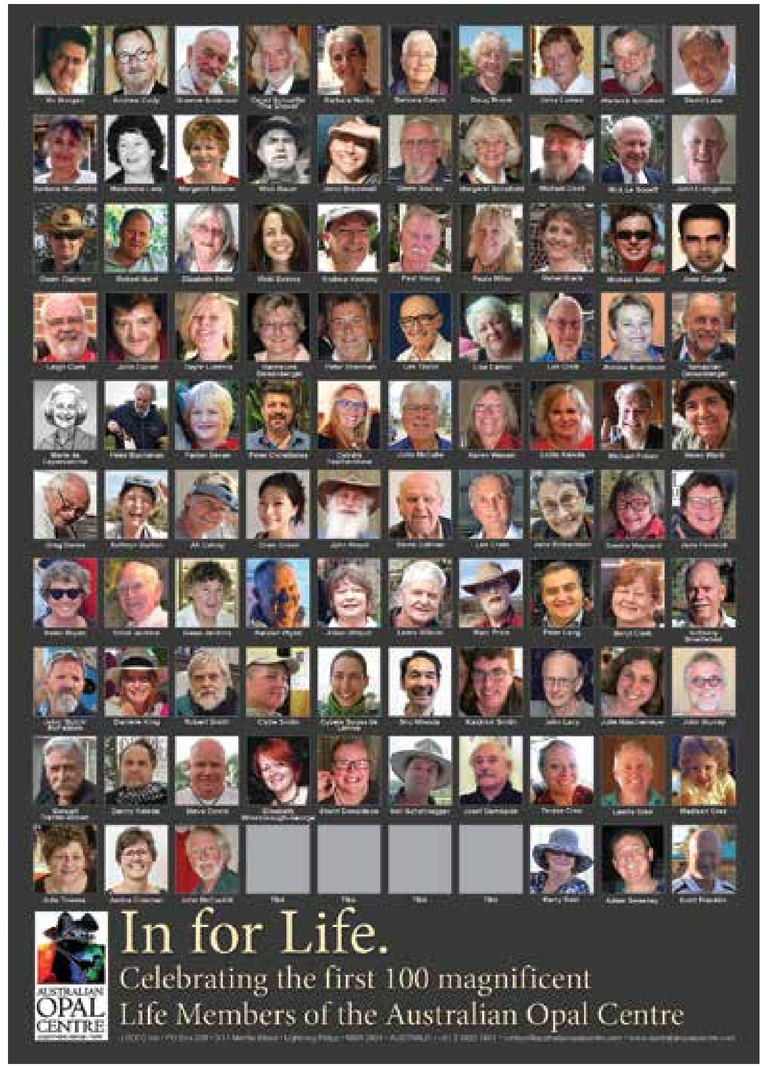
Currently, the AOC is part of the working group developing a new opal classification for international adoption, spearheaded by the GAA and the Opal Association.

In the future, the AOC will seek to redress the paucity of information readily available about the nature, extent and value of the opal industry in Australia. Excellent work conducted previously by other industry bodies must be revisited, updated and reformulated to provide current data and benchmarks for future industry analysis.

Educational materials about opal are being developed by the AOC for use at trade shows and by opal sellers. Future plans include a certification services for opal, further collaboration with other industry organizations, and support for industry coordination, development, training, marketing and promotion.

Opal field heritage

"…the remnants of the hundreds of miners' dreams… make Lightning Ridge a truly living historic village, the likes of which councils spend millions of dollars trying to recreate," mused Bob Pelchen, plain air painter, Morwell, Victoria. Australia's opal fields are rich with natural, cultural and industrial heritage. The AOC works to document and protect opal field heritage, often in collaboration with Lightning Ridge's Miners' Association, Tourism Association and Historical Society. It has acquired two historic miners' camps and supports practical initiatives to preserve and provide access to on-field heritage.



Life Members and Founders have been integral to the establishment and growth of the AOC and its activities.

Authentic opal mining landscapes are essential firstly for mining activity and secondly as places of historic, cultural and scientific significance, vital for their long-term economic and cultural benefits. The living heritage of the opal fields and industry also includes the stories of their people.

In its new building the AOC will celebrate this heritage and provide secure storage for collections and archives belonging to the AOC, available also to other organizations needing such facilities.

Membership

LROFC Inc currently has about 800 members. Members contribute to the vitality of the organization and are part of its growth and future. Higher levels of membership receive additional recognition and rewards.

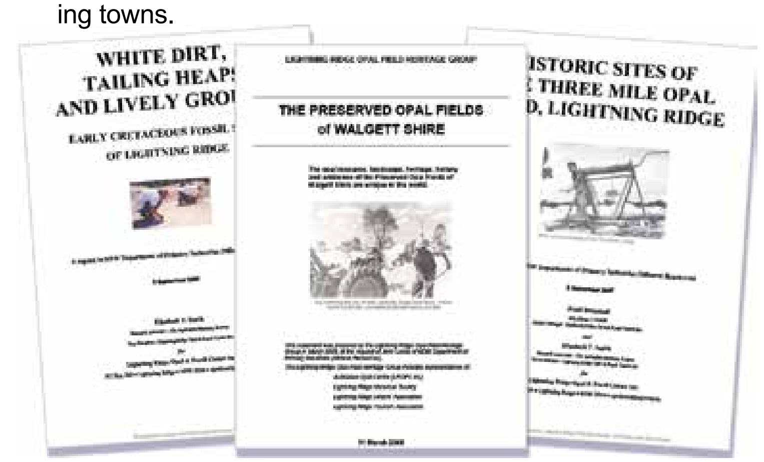
The planned new Australian Opal Centre building: self-powered, largely underground and to be constructed on a historic opal field. Architects Murcutt + Lewin. (Rendering Candalepas Associates)

Business activity and fundraising

The Australian Opal Centre is a self-funding not-for-profit enterprise. With no government or other recurrent funding, revenue generation and fundraising are vital. The organization's main income sources are its programs, fundraising initiatives, merchandise, membership fees and donations. To enhance its financial sustainability the AOC is expanding its opal-themed education programs and other specialist products, services and experiences.

Cost of construction and fit-out of the new AOC building is estimated at AU$34 million. In mid-2017, the AOC Founders Campaign was launched, offering opportunities for up to 148 benefactors called *Founders* to contribute to the new AOC and leverage the balance of required funds from Australian state and federal governments. By December 2018, more than 70 Founders, including many luminaries of the opal industry, together had committed almost AU$1 million to the project and secured a local government commitment of AU$2 million. New Founders are sought and inquiries are welcome.

Among other fundraising events for the Building Fund, the most notable was perhaps a walk from White Cliffs to Lightning Ridge—686 kilometers—retracing the footsteps of opal industry pioneers to raise funds for the new AOC building and reinvigorate friendships between the opal mining towns.



The AOC documents opal field heritage and advocates for its importance both to the continuation of opal mining activities and on economic, tourism and cultural grounds.

Towards a new AOC

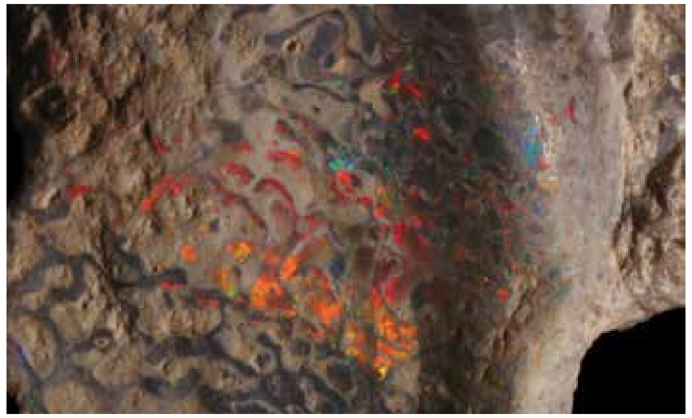
The Australian Opal Centre is currently limited by the size and disposition of its facilities. To achieve its potential, it must realize the 100-meter long, two-story, largely underground building designed by world-renowned architects Murcutt + Lewin. Insulated by the Earth, ventilated passively, generating 100% of its own power and collecting its own water, this innovative building, its remarkable contents and programs will be famed worldwide.

- The new Australian Opal Centre will contain:
- The world's premier public collection of Australian opal, opalized fossils and related materials
- Spectacular permanent and temporary exhibitions
- Scientific testing and research laboratory (gemology, paleontology and other aspects of opal science)
- Research library and archives
- Collection storage and curatorial facilities
- Facilities for conferences, exhibitions and events
- Lapidary and jewelry teaching workshop
- Discovery room for education programs
- Gift shop and café
- High-security vault for certification and on-consignment sales of high-end Australian opal
- Underground courtyards and gardens
- Offices and amenities

Construction and operations will produce major beneficial outcomes through direct and flow-on employment generation, training, economic and cultural development. The project has been lauded by high-profile supporters such as Dame Marie Bashir, former Governor of NSW who, in 2011, hosted a reception at Government House in Sydney in support of the AOC and celebrating Black Opal as the gemstone emblem of NSW.

In 2013, excavation of the development site, creating a 100-meter long, two-story deep cutting, instantly conveyed the scale of the project. The overburden was used to fill three disused open cut mines, creating multiple community and environmental benefits. The site and its viewing platform are themselves an attraction on local bus and self-drive touring routes.

(Was, or is, there opal in the hole? We don't know yet! The excavation stopped just short of the opal-bearing levels.



Bone microstructure preserved faithfully and spectacularly in gem opal, in a piece of opalized shell from a turtle that lived 100 million years ago. Griman Creek Formation, Lightning Ridge. Donated to the Australian Opal Centre by S. Miltenburg under the Australian Government's Cultural Gifts Program. (Photo: Robert A. Smith)

The site will be over-excavated and refilled prior to construction.)

In 2017-18, the AOC completed further vital planning and management documentation, raised almost a million dollars in commitment from its Founders, and received an impressive $2 million commitment from the Walgett Shire Council.

Late in 2018, it submitted bids for NSW ($7.5 million) and Australian ($9.5 million) government funding for Stage 1 of a two-stage build, to deliver a viable, operating facility that will generate revenue while fundraising continues for Stage 2. Timing of construction depends upon Australian government investment in this remarkable Australia resource and industry, and on further support from visionary benefactors who, through the AOC Founders campaign, can create an extraordinary legacy at the Australian Opal Centre.

The new AOC will be a place of dazzling treasures, knowledge, learning, discovery, creativity, community, enterprise, economic and cultural development. Inquiries are welcome from readers who would like to be part of the next chapter of the Australian Opal Centre story.

Acknowledgements

The author thanks Australian Opal Centre members, management committee members (past and present), Founders, donors, volunteers, advisers, research associates, granting bodies, member organizations and other supporters; the AOC design and engineering team; Walgett Shire Council; and the miners, cutters, carvers, designers, jewelers, buyers, sellers, collectors, artists, writers and opal enthusiasts who bring opal to the world. We acknowledge the Yuwaalaraay, Yuwaalayay and Gamilaraay custodians of the land in the Lightning Ridge district and pay respects to Elders past and present.

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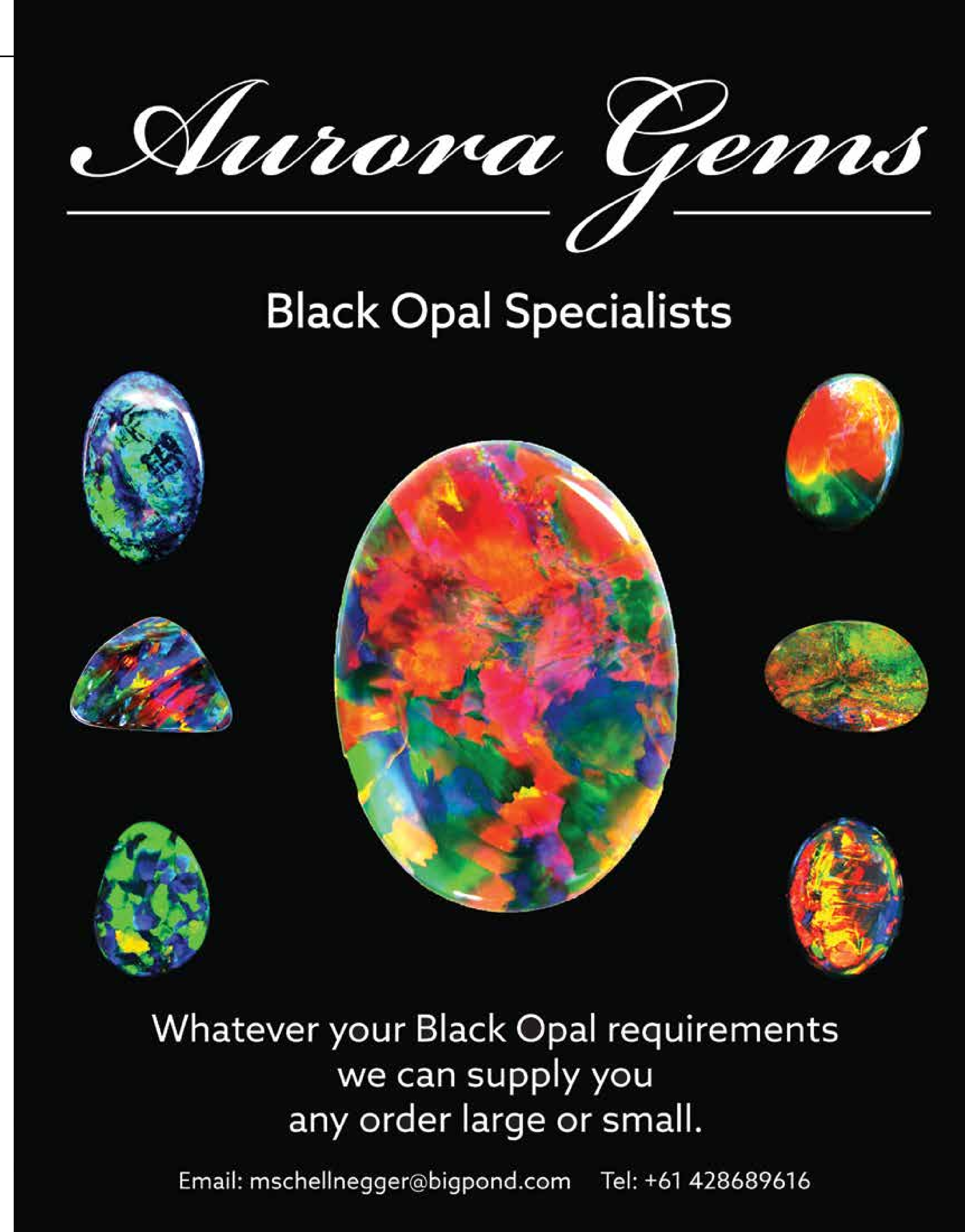
(All photos are courtesy of J. Brammall unless otherwise specified.)

The Australian Opal Centre (AOC) is a not-for-profit facility dedicated to opal-related research, education and training, heritage and arts, travel, cultural and economic development. Based in the classic opal-producing locality of Lightning Ridge in western New South Wales and representing all Australian opal types and locations, the AOC has developed scientific, educational and cultural programs and an astonishing collection of opal-related items over the past decade. It plans to construct a magnificent new facility to provide an international focal point for opal-related knowledge and activity. ◙

AUSTRALIAN OPAL CENTRE
LIGHTNING RIDGE · NSW



Mastering *Opal* with the Innovative Reference Sets

When the finalists were announced for the prestigious JNA Awards 2018 in the category of *Industry Innovation of the Year,* it was no surprise that the *Opal Master Reference Sets*, created by Andrew and Damien Cody of Cody Opal, were among them. The two brothers received their *Honouree Award* at a gala dinner in Hong Kong in September 2018.

By Cynthia Unninayar

The innovative Opal Master Reference Sets, released in January 2018, have been a great success, "with 55 of the 60 sets sold mainly to gem labs, gemology education institutes and appraisers," says Andrew Cody. "As a result of the strong demand, Cody Opal is contemplating the manufacture of a second series of the sets."

Along with the Master Sets comes a handbook to interpret the Sets, which is nearing completion. "There were some delays with the preparation of some areas of the content since the newly proposed 'Opal Classification' was nearing completion," adds Damien Cody, noting that he expects 1000 copies to be available in the early part of this year.

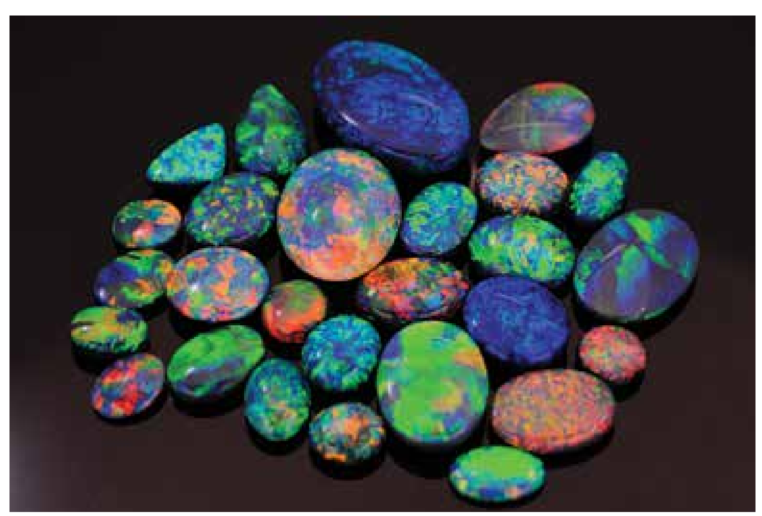
The handbook, in English, contains about 200 pages and will be presented in a loose-leaf binder so that, as new finds or information becomes available, it can be updated. Later in 2019, a Chinese version will become available.

The idea to create the Master Sets came about after long discussions with representatives of several gemological institutions and the trade, who felt that a Set of this kind would be an important tool for education, identification, classification and grading purposes.

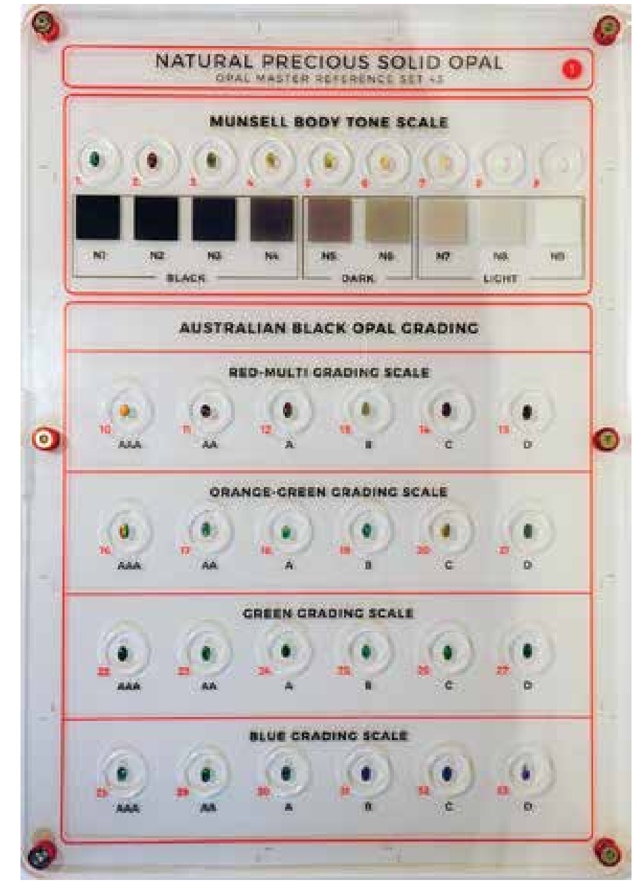
"While opal is of one of the world's most important gemstones in the market, it is probably the gemstone that is understood the least," explains Andrew. "Without a reference guide, gem labs resorted to non-standardized terminology, which often resulted to an arbitrary, and somewhat inaccurate, description of opal. Even educational institutes

James Courage (center) presents the Honouree Award to Damien Cody (left) and Andrew Cody for their Opal Master Reference Sets, a finalist in the *Industry Innovation of the Year* category of the prestigious and highly respected JNA Awards.

The packaged Master Sets. Each of the 60 sets is comprised of nine boards/trays featuring a total of 216 sample stones.



Collection of gem black opals from Lightning Ridge, Australia.



Master Set tray showing natural precious solid opal and the Munsell scale.

Tray featuring samples of natural precious opal on host rock. Each acrylic board is secured with tamper-proof screws and holographic security labels.

Comparing and identifying opals for the Master Sets and then assembling the Sets is a long process.


Artificial and treated opals are also included in the Master Sets.


Natural opals on their acrylic boards being used.

"If there was a scale of difficulty in the appraisal and understanding of gemstones, diamond would rank #1, the easiest, and opal would be #10, the most complex…" - Richard Liddicoat,

were inconsistent with their course notes, to the detriment of consumer bodies, governments and trade associations that were demanding full and frank disclosure."

"On top of this, large amounts of new *hydrophane opal* material were appearing in the market, along with artificial and simulated opal. Altogether, these caused confusion, not only for consumers, but for the opal market as a whole," explains Damien.

With the positive responses from a cross-section of the industry, the Cody brothers launched into their Master Sets. After two years of research and development, they came up with 60 Sets, each comprising nine boards and 216 sample stones. Almost 13,000 stones were carefully selected, cut and graded from all of the opal mining localities around the world to complete it.

The gems are displayed on acrylic boards to depict the important aspects of opal identification, classification, locality, type, grading and morphology.

Each Set is individually numbered and the boards are secured with tamper-proof screws and holographic security labels. In addition to the handbook used to interpret the Opal Master Reference Sets, an *Augmented Reality* feature brings to life video footage of opal and the mining fields where it is found.

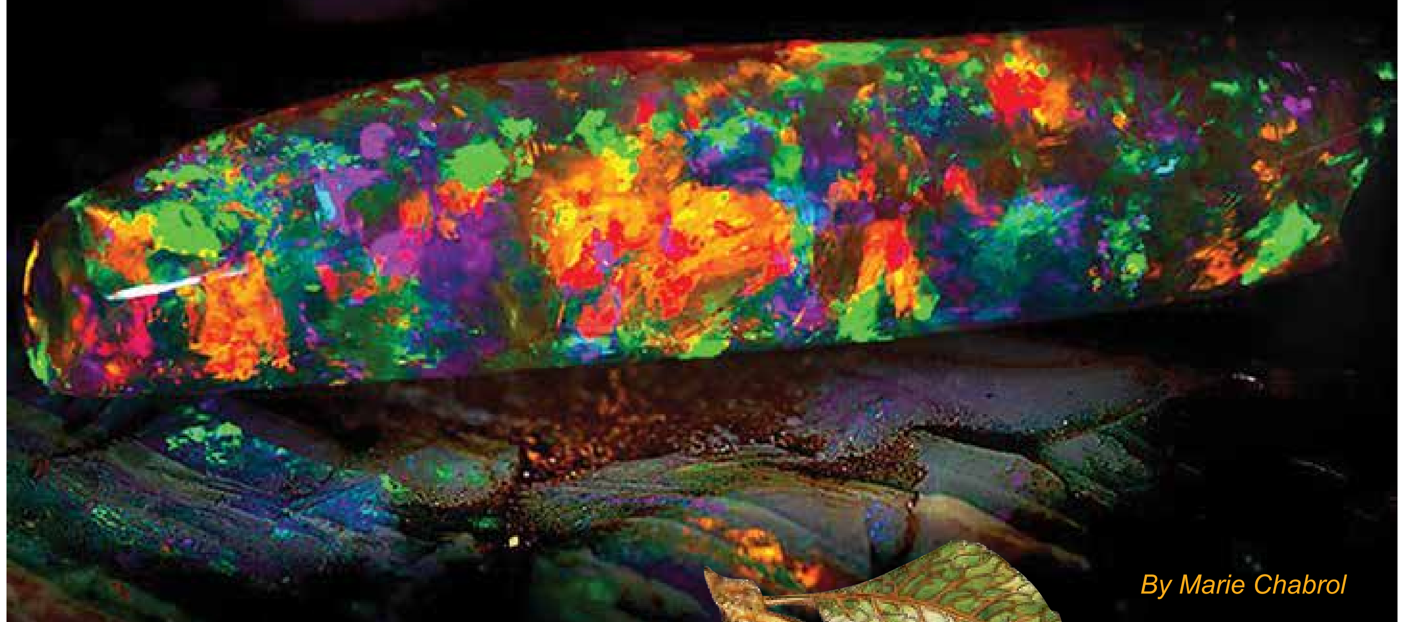
"The sets are a great teaching resource and also a useful tool for identification, classification and appraising opal. It will also simplify the process of ordering an opal by color, type and quality," Damien says. "And, on a more functional note, appraisers and dealers now have a reliable guide for assessing the quality and value attributes of the opals they are selling or buying, in the case of the customers."

"And, since consumers today are demanding better and more transparent information, and the trade needs to be on top of their game," concludes Andrew.

The Opal Master Reference Sets are certainly a tool to help the trade to be on top of their game when it comes to opal from around the world.

Example of a treated opal in the Master Set.

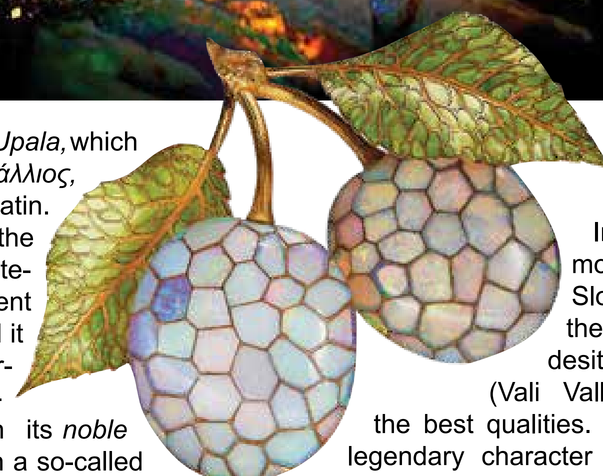
Opal – A Colorful Love Affair



By Marie Chabrol

The name *opal* comes from the Sanskrit *Upala*, which means *gemstone*. It will become *ὀπάλλιος*, *opállios* in Greek then *opalus* in Latin. Although opal has been well known since the 19th century, it has an older story that is mysterious and even devilish, going back to ancient times. The Greeks and Romans attributed it with magical and powerful virtues. Its colorful changes and reflections raised a questions and even fears. This silicate known in its *noble* variety (with colorful effects) exists also in a so-called *common* version (without colorful effects). Opal is found in many regions of the world, in different shades and effects. This is certainly wherein its magic lies!

Among the ancients who talked about opal is Pliny the Elder (23-79 BC) in his famous *Natural History*, translated by Litré in 1877. He described this stone presenting *the subtle fire of the carbuncle, the purplish brilliancy of the amethyst, the sea-green of the emerald; and all these colors shine there, wonderfully melted.* He also related an anecdote about Roman Emperor Antoine, who banished Senator Nonius when he refused to give him his opal ring, valued at 2 millions sesterces. Pliny added that opal in general is like *a color drawing on that of the flower called heliotrope (...), a rugged surface, details that stop the eye.*



He noted that the Indians used colored glass that imitated opal.

In antiquity, opals came mostly from present- day Slovakia. Until the end of the 17th century, the andesitic lavas of Cervenitsa (Vali Valley, Slovakia) provided the best qualities. In the Middle Ages, the legendary character of Robert the Devil (it could have been inspired by the father of William the Conqueror) described this stone as *diabolical*. In 1075, the bishop of Rennes calls it the *stone of thieves*. But a legend dating back to the Black Death epidemic is primarily responsible for its bad reputation.

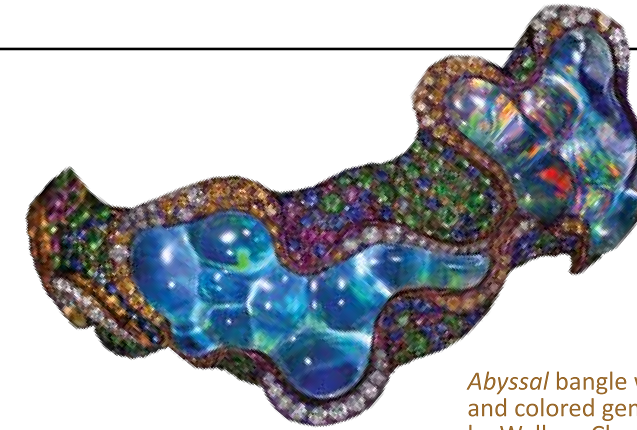
Isidore Kozminski wrote in his 1922 book, *The Magic and Science of Jewels and Stones,* that opal was the favorite gemstone of Italian jewelers, who used it often. Others insisted that opals worn by those stricken became suddenly glowing, and that the gem's luster entirely disappeared with the death of the wearer. Opal then became associated with the death of the victim and an object of dread.

Photos

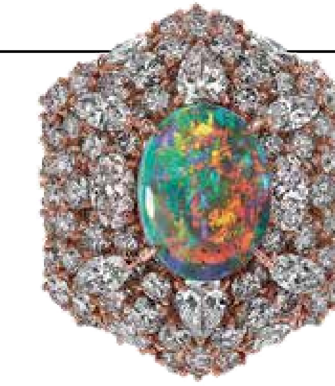
Top: *The Virgin Rainbow Opal,* found in 2003 in Coober Pedy, is thought to be the most expensive opal in the world (est. US$1 million). It is displayed in the Adelaide South Australian Museum. (Photo: Adelaide South Australian Museum)

Center: Enameled gold brooch with opal marquetry. Signed Rene Lalique, circa 1900. Sold at Christie's for CHF212,000. (Photo: Christie's)

Left: Yellow gold *Sabrina* bracelet set with tsavorite garnets, blue zircons and opals by Paula Crevoshay.



Abyssal bangle with opal and colored gemstones by Wallace Chan



Fascinante opal ring, in pink gold, diamonds and opal by Victoire de Castellane, Dior Joaillerie

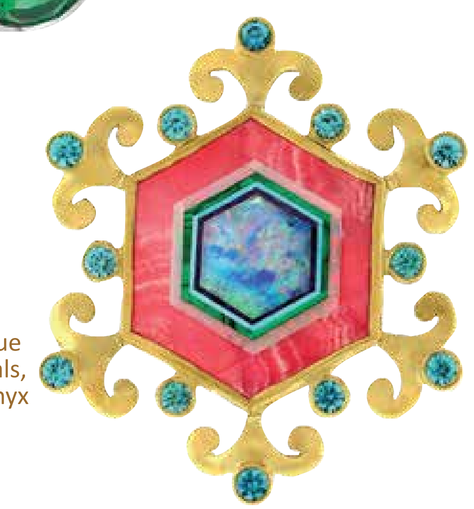
A 108-ct Mexican fire opal is accented by diamonds, sapphires and amethysts in white gold by Naomi Sarna.

The discovery of opal in Australian mines gave opal back its letters of nobility. In 1849, German geologist Johannes Menge found the first opals. But the discovery of similar stones in Queensland (1869) allowed the advent of an industry that we know today. When these stones arrived on the market, they quickly provoked commercial jealousies. Hungarians declared them to be fake because they presented extremely intense colored fire. And, the opals of Slovakia, more milky, tend to fade very quickly.

Yet, Australia saw a rapid increase in opal discoveries: Quilpie (1871), White Cliffs (1890), Opalton (1896) and Coober Pedy (1915). At the same time, descriptions of opals came from around the world: the Gold Opal from Hungary (brownish-greenish to yellow) by Ernst F. Glocker in 1847; the Quincite (pink common opal) by Pierre Berthier; the Forcherite (yellow orangy, from Austria) by M. Aichhorn in 1860, etc.

In Europe, opals were appreciated at the end of the 19th century, especially in London where they provided joy to Queen Victoria. By wearing them regularly, she promoted these stones throughout the Commonwealth and to her international counterparts. In France, the actress Sarah Bernard believed the gems had magical virtues.

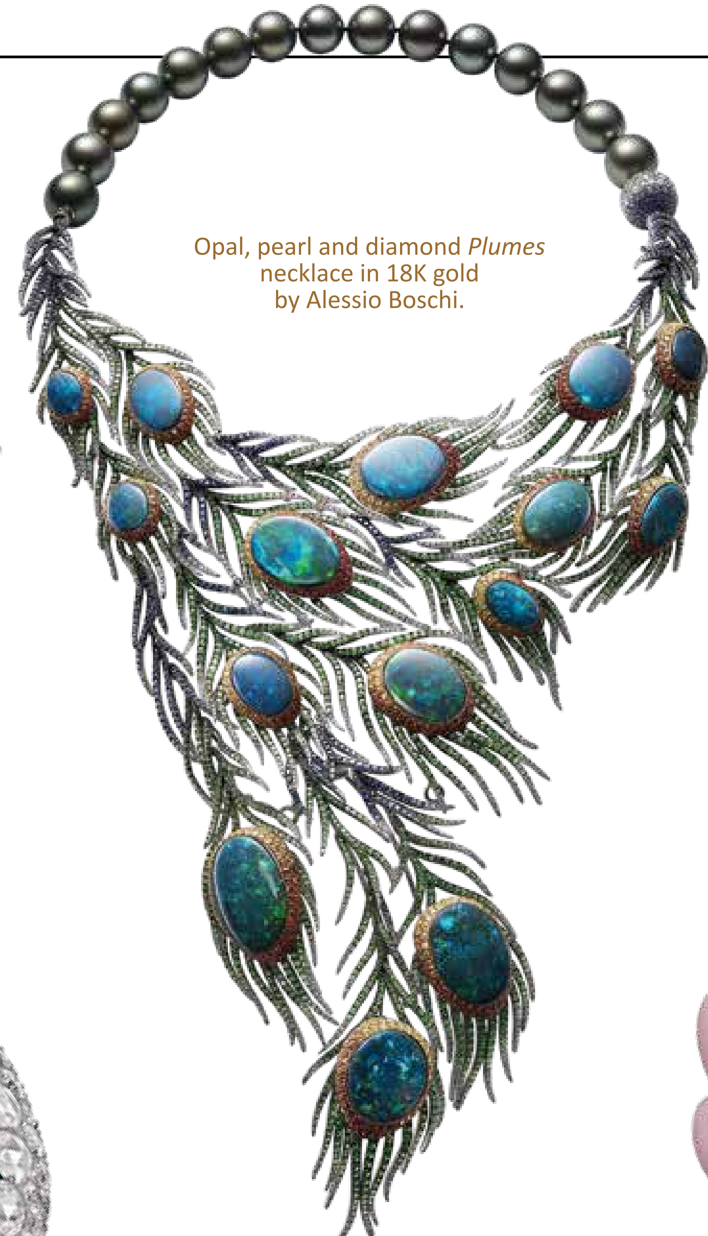
The 16.65-ct black opal *Maelstrom* ring with sapphires, tsavorites and diamonds in 18K gold by David Morris.



Yellow gold brooch with blue zircons, rhodochrosite, opals, turquoise, malachite and onyx by Paula Crevoshay.

Sapphire and 22.08 Mexican fire opal blackened gold cuff by Lydia Courteille.

Austrian brooch from the 1940s in platinum, opals, diamonds, rock crystal, enamel, aquamarine and pearls. (Photo: Sotheby's)



Opal, pearl and diamond *Plumes* necklace in 18K gold by Alessio Boschi.

Brooch in pink opal in white gold, with two round sapphires, pear-shaped tanzanites, and round mint tourmalines by Chaumet.

Silver and gold ring with a Peruvian blue opal and diamond by Tai Vautier Jewelry.

Gold ring with an 11.77-ct black opal by David Morris.

India Collection gold ring with pink opals and white diamonds by de Grisogono.

Gold bracelet with Australian opal, haüynes, andradite, hessonite garnets, yellow sapphires by Lydia Courteille.

Petit Panache ring, in black opal, gold and diamonds by Victoire de Castellane, Dior Joaillerie.

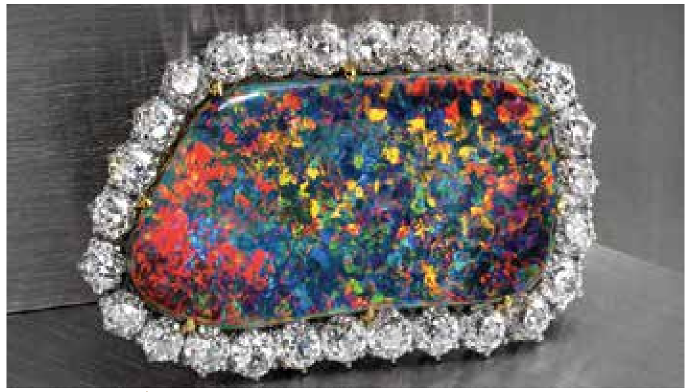
Enameled gold necklace with opal and pearl signed Georges Fouquet, circa 1900. Sold by Christie's for more than CHF300,000. (Photo: Christie's)

Aurores Boréales gold modular ring that can transform into two jewels, with Australian opal, Ethiopian opal, sapphire, Paraiba tourmaline, tsavorite garnet and aquamarine by Pamela Hastry/Morphée Joaillerie. (Photo: Marie Chabrol)

Colorful Symphony gold watch with an Australian opal dial with diamond, emerald (2.8 ctw) and Ceylon sapphire (5.56 ctw) accents by Piaget.

Titanium ring set with diamonds and opal by Arunashi.

Opal, sapphire and diamond *Sea Anemone* rings in 18K gold by Alessio Boschi.



Set in a 19th-century brooch is a 48.80-ct black opal offered in 2017 at a Bonhams auction (unsold, estimated at US$200-300,000). (Photo: Bonhams)

At the same time, the advent of fantasy literature and the birth of the Art & Crafts and Art Nouveau movements highlighted these gemstones in jewelry. Opal enjoyed immense success with creators such as Lalique, Fouquet, Sybil Dunlop and Dorie Nossiter.

But then, the birth of the Art Deco movement significantly reduced its appeal. It was not until new deposits were discovered that opal regained its luster. In the 1970s came opals from Peru, also called *opals of the Andes*. These gems are blue, green, yellow, pink, translucent or opaque and without iridescence. The opals from Ethiopia in the mid-1990s (the first stones were in 1994 from the Menz Gishe District) also revived interest for this material.

In high jewelry, Dior's Victoire de Castellane first used opal, for which she has a real passion. Almost all the collections she has signed for the house since 1999 include them. Australian or Ethiopian, the stones chosen by the gemstone department all have incredible colors and almost supernatural fires. The major international high-end jewelry brands as well as smaller designers incorporate opal in their lines. In 2010, the 26th edition of the Biennale des Antiquaires officially signed the big return of this gem. Boucheron, Cartier, Bulgari, Chaumet, Harry Winston, Anna Hu, Wallace Chan, Van Cleef & Arpels, David Morris and Feng J. regularly place opal in creations, each one more spectacular than the previous. And, one of the most beautiful watch dials ever produced was opal, signed Yves Piaget in an unforgettable wristwatch in the 1970s.

There are no two identical noble opals. And designers understand and appreciate this mystery. Even though opal is a fragile gem and requires special attention in the manufacturing stages, its colorful love affair with admirers around the world continues. *Photos are courtesy of the designers mentioned unless otherwise specified.*

Emerald 18 Makes Its Mark in 2019

For designers and manufacturers of high-end jewelry, the sourcing of high-quality colored gemstones is most often a headache they'd rather do without. Ideally, they'd work with reliable gemstone cutters who can guarantee a consistent and unvarying supply of gemstones that is tailor-made for their jewelry lines and designs. But they also know that such cutters and suppliers are almost impossible to find.

Newsflash from Israel. A new company called **Emerald 18 Ltd.** was formed last year in response to the jewelry and luxury market's growing demand for standard-sized, high-quality round and sharp-edged emeralds of precise proportions. Emerald 18 is the joint, cooperative platform of Hargem Ltd. and H. Stark & Co. Ltd., two of Israel's leading colored gemstone manufacturers and traders that have been operating since the late 1960s.

"Emerald 18's core business is the production and marketing of meticulously prepared assortments of high quality, African-sourced emeralds," says Ehud Harel.

The firm's assortments, or lots, are composed of stones in sizes ranging from 1.75 mm to 4.00 mm, with sizes supplied in increments of 0.25 mm (i.e. 1.75-2.00-2.25 mm etc.). Each lot is composed of stones of—always—consistent and uniform dimensions, color, height and brilliancy. In addition, Emerald 18 has gained fame with its production of micro-cut round emeralds for micro settings, ranging in sizes from 0.90 mm to 1.7mm, with a 0.05 mm tolerance.

"We've spent a lot of time and effort to understand what demands today's jewelry manufacturers and designers have. To reflect the consistency and quality of our production, we have adopted the term 'Quality Cut,' and consequently made it our trade mark!" Harel explains. "Stone setters love working with 'Quality Cut' emeralds. They experience almost no breakage and therefore can utilize the entire lot bought. That makes a significant difference in the final cost of a set piece!"

Naturally, such precision cannot be achieved without applying advanced decision-making and production technologies. "We have the technological backing of Sarine Technologies, in which our companies are major shareholders," explains Hanoh Stark.

"In practice, our production methods can be likened to those of the diamond specialists who supply precision-cut small diamonds to the luxury industry. Not only do the cut, color, size and brilliancy need to be consistent, but also the angles of the facets, the height and depth of the stone. Our 'Quality Cut' emeralds provide that!"

"Effectively, the employment of our in-house Sarine Technologies girdling robot and other proprietary decision-making software and instruments also result in stones that weigh significantly less, often 25% less than traditionally cut stones of similar sizes, thus making Emerald 18's stones highly economical and affordable," Stark emphasizes.

"The key to this business model is that almost 100% of our production is marketable and salable," Harel notes. "Of course, we continue to offer single stones in a variety of shapes, sizes, weight and categories."

For more information, please contact us at:
office@emerald18.com

The Emerald 18 team, from left: Emanuel Shalev, Emerald18 Marketing Manager, Hanoh Stark and Ehud Harel.

Royal cut emerald

Quality-cut emeralds

Rough Zambian emerald.

Padparadscha-Like Fancy Sapphires with Unstable Colors: Coloration Mechanisms and Disclosure

Dr. Michael S. Krzemnicki and Dr. Laurent E. Cartier

In 2017, padparadscha-like fancy sapphires from the Ambatondrazaka area in Madagascar appeared on the market, partly of exceptional size and clarity. Some of these stones show a distinct change of color over time shifting from a distinct pinkish orange to just pink in the course of weeks (Krzemnicki, 2018). Research by SSEF over the past two years on the color stability of such stones has provided further insight into coloration mechanisms and applicable nomenclature to ensure full disclosure.

Color instability of certain corundum varieties (mainly yellow sapphires) is not new to gemologists and the trade (Nassau & Valente, 1987). For many years, SSEF has systematically applied a fading test (with the consent of the client) to determine the color stability of yellow sapphires. Based on recent research, color stability testing is performed also on sapphires of padparadscha-like color to be able to separate padparadscha of stable color from fancy sapphire showing instable color.

Padparadscha sapphires are generally described as exhibiting a pinkish orange to orangey pink color of moderate to low saturation (Crowningshield, 1983; Notari, 1996; LMHC, 2018). Originally known from alluvial deposits in Sri Lanka, today this attractive variety of corundum is also mined in Tanzania (Johnson and Koivula, 1997) and Madagascar (Milisenda et al., 2001), with additional production coming from a deposit discovered in late 2016 near Ambatondrazaka, which has also been a source of important blue sapphires (Perkins and Pardieu, 2016; Krzemnicki, 2017; Pardieu et al., 2017). This Ambatondrazaka area has produced both padparadscha sapphires of stable color and padparadscha-like sapphires of unstable color.

Coloration Mechanisms and Color Stability

As these new padparadscha-like fancy sapphires arrived on the market, it became clear that the color of these stones with unstable colors can be restored after a short exposure to UV light (similar to most yellow sapphires with unstable color), so that they become pinkish orange again (at least until they start to slowly fade out again in daylight).

In other terms, the stable color of these stones is in fact pink (chromium-related) and the superposed unstable color is yellow (due to an unstable yellow color center), resulting—if activated—in an overall orange to pinkish orange color of the stone (Figure 1).

The reason for this quite distinct color change (instability) is very similar to those of yellow sapphires of unstable color (Figure 2). Their subtle padparadscha color is, in fact, a mix of a weak chromium-related absorption (resulting in a pink color) superposed by broad absorption bands due to yellow color centers.

In cases where such a color center is not stable, it results in the observed shift of color from pinkish orange (color center active) to pink (color center inactive). Spectroscopically speaking, the color shift results from a distinct reduction (fading out) of a yellow color center, as can be seen in absorption spectra before and after fading tests.

Testing and Disclosure of Unstable Color

Based on current scientific knowledge, the color stability of gemstones can be quite easily tested—even by a well-trained gemstone dealer. Before testing, the color of the gemstone has to be very well defined (e.g. with Munsell color charts or other Color Scan systems). The stone is placed on a metallic reflecting plate and then exposed during approximately three hours to a very strong fiber optic light source (halogen). After this, the color is again meticulously determined.

Any noticeable change/shift may also be confirmed by UV-Vis spectra taken before and after the fading test. To check restoration of color with UV radiation, the stone is subsequently placed table down directly on a strong UV light source (in a dark box) and exposed for about ten minutes to UV radiation. Again, thecolor needs to be meticulously determined to check if any change has occurred.

In cases where this tenebrescent shift of color is only minimal, it can be neglected and does not need specific attention. Some of this more recent material from Ambatondrazaka Madagascar, however, has shown a very marked shift of color from (slightly pinkish) orange to pure pink (Figure 3), which in our opinion requires specific

Figure 1: Fancy sapphire recently found in Madagascar showing an unstable color, shifting from pinkish orange (padparadscha-like) to pink after a fading test. (Photo: SSEF)

Figure 2: Yellow sapphire of >50 carats with unstable (reversible color), seen before fading test (left), after fading test (middle), and after exposure to UV radiation (right). (Photos: J. Xaysongkham, SSEF)

Figure 3: Fancy sapphire from Ambatondrazaka (Madagascar) showing pink color (actually the chromium-related stable color of this stone), which shifts to pinkish orange after activation of the yellow color center, and subsequently returns to pure pink after fading (back to stable color). (Photos: V. Lanzafame, SSEF)

disclosure. Stones from Sri Lanka and Ilakaka (Madgascar) may also show such color instability, but in general much less frequently.

Summary

In summary, these orange to pink fancy sapphires of unstable color—so far mostly observed from this new source in Madagascar—can still be very attractive in color and size, but should not be named as padparadschas. The color shift they show is certainly a challenge for the trade dealing with padparadscha sapphires.

In November 2018, the Laboratory Harmonisation Committee (LMHC) announced that the term padparadscha may not be used if the color of the stone is not stable and shifting out of the padparadscha color range (e.g. shifting to pink) by a color stability test. The updated Information Sheet No. 4 for padparadscha sapphires can be downloaded on the new LMHC website (www.lmhc-gemmology.org).

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PANTONE'S COLOR OF THE YEAR LIVING CORAL

Pantone's Color of the Year for 2019, Living Coral emits the energizing aspects of color found in Nature. From coral reefs to the beauty of orangey-pink gemstones, it is a color that we will be seeing a lot of this year. Among the gemstones that evoke this warm color and related shades are garnet, padparadscha sapphire, quartz, opal, rhodochrosite, tourmaline, and more, as well as enamel and, of course, coral.

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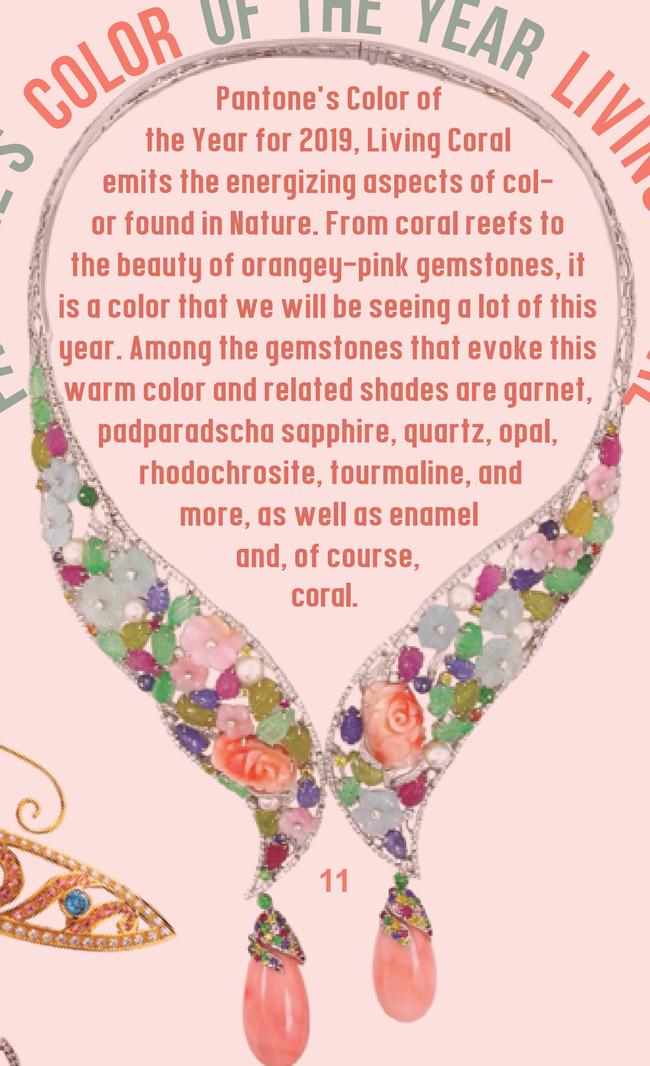

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1) Elke Berr; 2) Lydia Courteille; 3) Gemolithos; 4) Masriera; 5) Green G; 6) Carla Amorim; 7) Zorab Creation; 8) GiGi Ferranti; 9) Emily Zhang/Different Gems; 10) FancsV; 11) Blue River; 12) Stuller; 13) Alessio Boschi Jewels; 14) Arya Esha; 15) Le Vian; 16) Gumuchian; 17) Omi Privé. *Design and text by Cynthia Unninayar.*

L'ÉCOLE – SCHOOL OF JEWELRY ARTS

Explaining, sharing and revealing the soul of these exceptional crafts.

Founded in 2012, L'ÉCOLE School of Jewelry Arts is the world's first introductory school for the general public. It is located in the heart of the Place Vendôme, the cradle of Parisian jewelry-making, in an 18th-century mansion that embodies the French artistic style. L'ÉCOLE was created with the support of Van Cleef & Arpels, with the aim of unveiling this secretive, but fascinating world. Dedicated to jewelry in its entirety, it is intended for enthusiasts, lovers of beauty, the curious and anyone who desires to become an enlightened connoisseur. L'ÉCOLE is a unique experience: sharpening your eye, honing your sense of taste, revealing an art and initiating you into a culture.

Some 20 courses are offered by L'ÉCOLE in French or English, arranged around three broad themes: Savoir-Faire, the Art History of Jewelry and the World of Gems. Courses last for two to four hours and can be chosen in any combination.

The courses are intended mainly for adults and are given by at least two instructors. Whatever their length, all courses are carefully scripted to keep students on the edge of their seats. Each course is open to a maximum of 12 students to ensure that each of them can derive full benefit from the experience and try out the techniques.

L'ÉCOLE includes:

- a design studio to learn the techniques of gouaché;
- a jewelry workshop to try out the jeweler's gestures;
- a gemology workshop to handle stones;
- a lacquerwork and enameling workshop;
- two classrooms dedicated to courses about the art history of jewelry;
- a lecture hall;
- a library further your understanding.

Upon arrival, students from all over the world are greeted by their instructors and the staff of L'ÉCOLE. This quality time creates bonds between students before the classes begin. No special knowledge or manual skills are required.

Since opening, L'ÉCOLE has welcomed more than 27,000 students in Paris and abroad.

Once a month, L'ÉCOLE organizes an evening devoted to revealing the secrets of the world of jewelry. Each lecture brings together 75 people and two experts. Curiosity and dialogue are the watchwords for these exceptional occasions. The President of L'ÉCOLE and the lecturers start by welcoming the attendees at a cocktail reception.

Artistic activities play an essential role in children's education and development. L'ÉCOLE invites a young audience to develop its creativity while discovering a new world. This initiative offers a playful and educational experience, enabling children and adolescents from 5 to 16 to explore the creative professions. Devised with this audience in mind, the Creative Workshops have been developed in a spirit of transmission and sharing.

L'ÉCOLE, School of Jewelry Arts is not only about hands-on teaching from the best specialists. Its resources stretch beyond those exceptional encounters. By consulting books in the library or watching online videos, students broaden the knowledge acquired in their classes. To further their knowledge of jewelry, some 20 videos are available to date on L'ÉCOLE's YouTube channel.

L'ÉCOLE's library is open to students wishing to consult its numerous rare books and specialized works, classified by theme: Jewelry maisons, history, great collections, watchmaking, fashion, the jewelry arts and savoir-faire, mineralogy and gemology, plus exhibition catalogs.

It also organizes library chats, which offer a chance every three months to talk with an author about her or his book. The discussions happen during lunch hour, with a simple format: one hour, one book, one author. Each session finishes with a book signing, and the possibility of purchasing the book at L'ÉCOLE.

Overseas Training

L'ÉCOLE School of Jewelry Arts travels regularly to meet its students and offer them, in their country, a complete set of courses and lectures.

Tokyo. For its first trip abroad in July 2013, L'ÉCOLE settled in Japan for two weeks: 660 students from all horizons—art lovers, watchmaking enthusiasts and devotees of precious stones—took part in various classes at the emblematic Tokyo Station Hotel. It was an opportunity to discover and share L'École's identity, values, heritage and expertise. L'ÉCOLE returned to Tokyo for an exceptional two-day session on May 30 and 31, 2016. Next dates: February 22 to March 8, 2019 at Kyoto University of Art & Design, Gaien Campus in Tokyo.

Hong Kong. In November 2014, L'ÉCOLE opened its doors at the PMQ Design Centre in Hong Kong, where students from the entire region (Hong Kong, China, Taiwan, Singapore and Korea) took part in classes on Savoir-Faire, Art History of Jewelry and the World of Gems. L'ÉCOLE returned twice to Hong Kong in March 2016 and September 2017.

New York. Following a highly successful first trip in June 2015 at the prestigious Cooper Hewitt, Smithsonian Design Museum, L'ÉCOLE returned to Manhattan in January and October 2016 and October 2017 for a series of lectures. Next date: October 24 to November 9, 2018.

Dubai. After the success of its first trip in November 2017, L'ÉCOLE returns to the Dubai Design District from March 29 to April 13, 2019.

Museum Sponsorships

Musée des Arts Décoratifs (Paris)—Jewel Gallery. The Jewel Gallery displays 1,200 pieces of jewelry that offer an exceptional panorama of the history of jewelry from the Middle Ages to the present day. It presents a remarkable illustration of the mission of the Musée des Arts Décoratifs, encouraging access to and understanding of its collections for the widest possible audience. With the same emphasis on education, L'ÉCOLE is supporting publications about the Museum's jewelry collection. In October 2016, a first book *Flora* was published, followed by *Fauna* in September 2017 and *Figures & Faces* in March 2018.

Musée d'Art Moderne de la Ville de Paris. The school of Jewelry Arts supported the catalogue of *Medusa: Bijoux et Tabous*, an exhibition that looks at the jewel from a new point of view, from May 19 to November 5, 2017. The catalogue was published by Éditions Paris Musées.

Scientific and Humanities Research

L'ÉCOLE, School of Jewelry Arts is committed to supporting museums with research and teaching. In line with its educational mission, it has naturally sought to partner with various additional cultural projects. It has embarked on partnerships that reassert its commitment to traditional and innovative savoir-faire and creativity. Partnerships in France and Japan bear witness to L'ÉCOLE's basic missions: spreading culture, transmission and education.

Muséum National d'Histoire Naturelle (Paris). Developing the scientific research undertaken by the museum's instructors and researchers, L'ÉCOLE sponsored the cutting of identical replicas of the 20 most famous diamonds sold by Jean-Baptiste Tavernier to Louis XIV in December 1668. These replicas are now displayed in the library of L'ÉCOLE, as part of the permanent exhibition *The Fabulus Destiny of Tavernier's Diamonds.* In partnership with the Muséum, L'ÉCOLE also produces educational videos (Emeralds, Biominerals, etc.), available free on L'ÉCOLE's website and YouTube.

Université de Rennes 2. Over three years, L'ÉCOLE has financed a doctoral thesis at the university's Art History and Criticism Research Unit on the subject of Jean-Baptiste Tavernier (1605-1689), a major figure in the history of jewelry, explorer and merchant who was at the origin of many public and private collections of gems in the West.

Educational Sponsorships

École Boulle, École Supérieure des Arts Appliqués et du Design (Paris). Founded in 1886, L'Ecole Boulle trains its students in high-level craft skills. L'ÉCOLE sponsors the gemology training course for its jewelry students.

Kyoto University of Art & Design (Japan). The Kyoto University of Art & Design provides artistic education to the young talents of tomorrow.

L'ÉCOLE also offers its jewelry students an opportunity to measure themselves against professionals in a competition entitled: *Modern Fairy Tales: Enchanting Jewelry for the 21st Century.*

Special Exhibitions in Paris

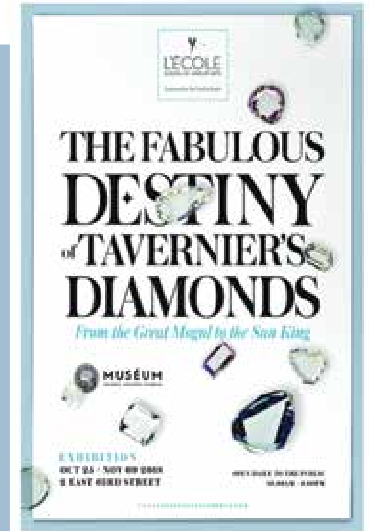
Since January 2017, L'ÉCOLE welcomes exhibitions twice a year in Paris to allow the public to discover jewelry and art objects. These exhibitions always present an original perspective and remarkable expertise. They also sometimes travel around the world as part of Nomadic Schools.

Harumi Klossowska de Rola, *Retour d'expédition*, January 23 to February 10, 2017. Returning in spirit from the confines of the world, but not from her beautiful animal obsessions, Harumi Klossowska de Rola presented a new collection of jewelry and objects in January 2017. L'ÉCOLE will again organize an exhibition around her work during L'ÉCOLE in Tokyo from February 22 to March 8 2019.

Daniel Brush, *Cuffs & Necks,* October 13 to 31, 2017. For its second exhibition, L'ÉCOLE honored the polymorphous American artist Daniel Brush. The exhibition allowed the French public to discover the creations of an artist who defines himself beyond any category. Artisanal and experimental, timeless and multi-directional, the work of Daniel Brush touches jewelry, drawing and sculpture, with a passion for materials and unique shapes, taking inspirations from Noh theater to pre-Colombian art. The pieces exhibited at L'ÉCOLE focused on the colliers de chien of the book *NECKS* alongside a series of cuffs, while offering insight into Daniel Brush's rich creative universe, including paintings and other objects produced by the artist in recent years. This exhibition will be displayed again as part of L'ÉCOLE in New York from October 24 to November 9 2018.

Precious Art Déco Objects from the Prince and Princess Sadruddin Aga Khan Collection, April 4 to 25, 2018. For the first time in France, L'ÉCOLE presented a selection of works of art from an exceptional collection of Prince Sadruddin Aga Khan. The precious boxes that make up this collection were offered to his wife Princess Catherine Aleya Beriketti, and represent real masterpieces of inventiveness, creativity, fantasy and technical prowess. Cigarette cases, kits, compacts and other precious objects of gold enriched with ornamental stones or precious stones, adorned with mother-of-pearl, lacquer or translucent enamel, sometimes enhanced with Asian or Western-inspired miniatures, were displayed at L'ÉCOLE in a scenography highlighting the many Chinese, Japanese, Persian and European influences of Art Deco.

The Yves Gastou collection, *Men's Rings*, October 5 to November 30, 2018. Yves Gastou, key figure in the life of Saint-Germain-des-Prés in Paris and antique dealer for over 30 years, collects men's rings. 500 of them will be showcased at L'ÉCOLE, ranging from the rings of 17th-century Venice doges to American biker rings of the 1970s, from ancient Egyptian rings to 19th-century "memento mori" skull rings, from 18th-century enameled rings to rings by contemporary artists. In parallel with this unprecedented exhibition, L'ÉCOLE is pleased to support the publication of the book *Men's Rings* published by Albin Michel.



L'ÉCOLE organizes exhibitions presenting original perspectives and remarkable expertise.

Teaching Staff

The School of Jewelry Arts is made up of some 40 instructors: jewelers, designers, mock-up makers, art historians, gemologists, enamelers and a lacquer master. These experts have an enthusiasm for sharing their know-ledge and have all been trained to be excellent teachers. While they operate in their specific field of expertise, they are all attentive to transmitting their knowledge in a spirit of experimentation and dialogue.

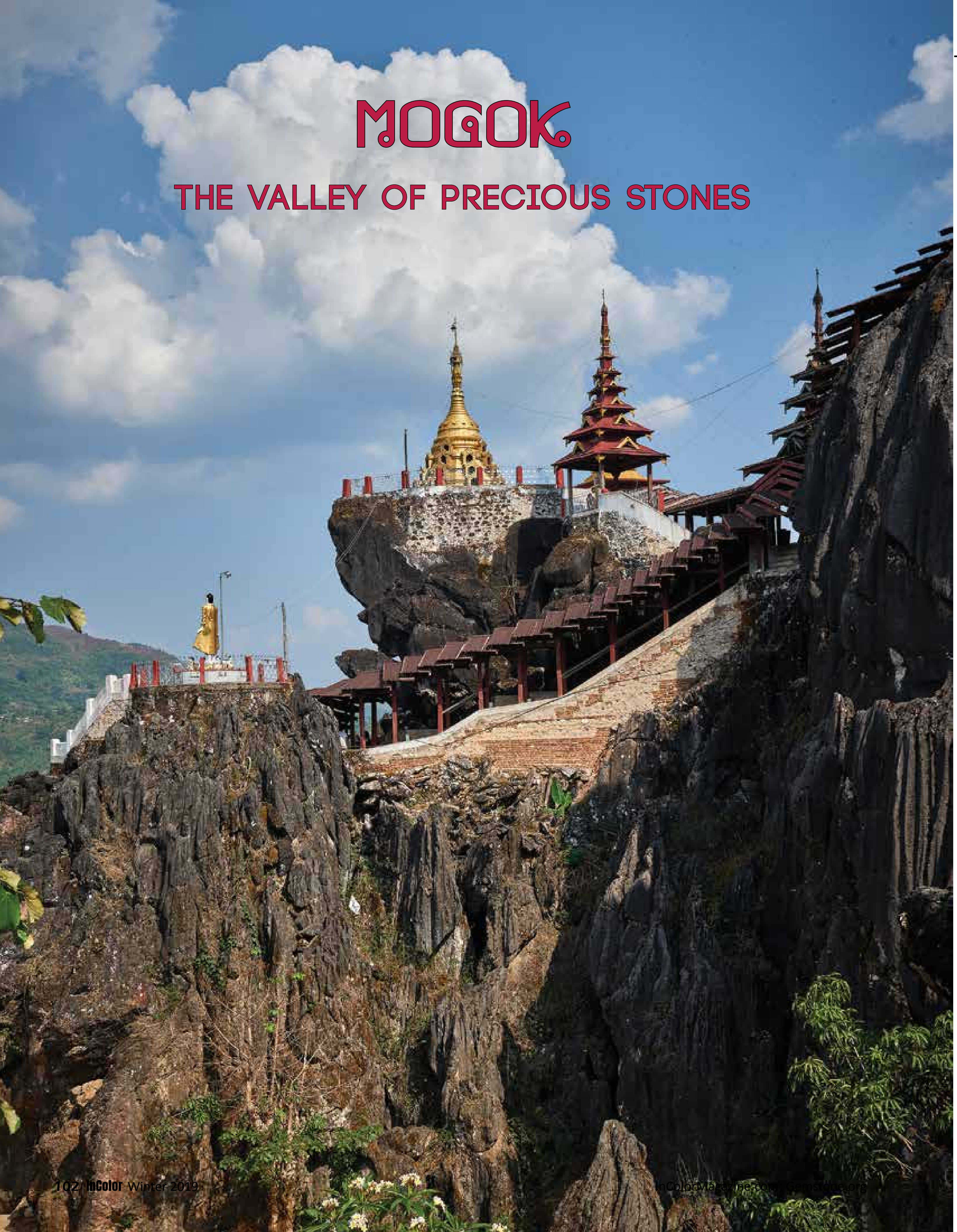
Expert jewelers, *Mains d'Or™* from Van Cleef & Arpels' workshops, they introduce each participant to jewelry-making techniques. The model-makers, designers, lacquer master and enamelers are graduates of the leading schools, and these experts guide students through the first stages of creating a jewel.

Gemologists, geologists and stone buyers all have vast knowledge of the world of gems and are passionate about sharing their expertise.

Art historians are graduates of the University of Princeton (USA) and L'Ecole du Louvre (Paris). Their experience, enthusiasm, taste for transmission and passion for jewelry predestined them to embody L'ÉCOLE's teaching.

L'ÉCOLE, School of Jewelry Arts
22, Place Vendôme - 75001 Paris
www.lecolevancleefarpels.com

Photos are courtesy of L'ÉCOLE.



MOGOK

THE VALLEY OF PRECIOUS STONES

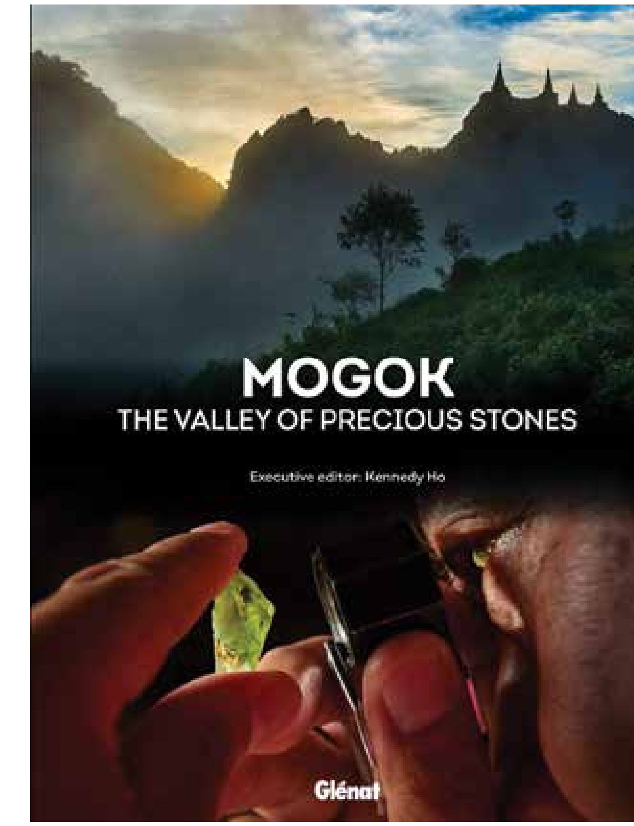
Book Review by Adrien Trivier, GG, FGA, SRBG

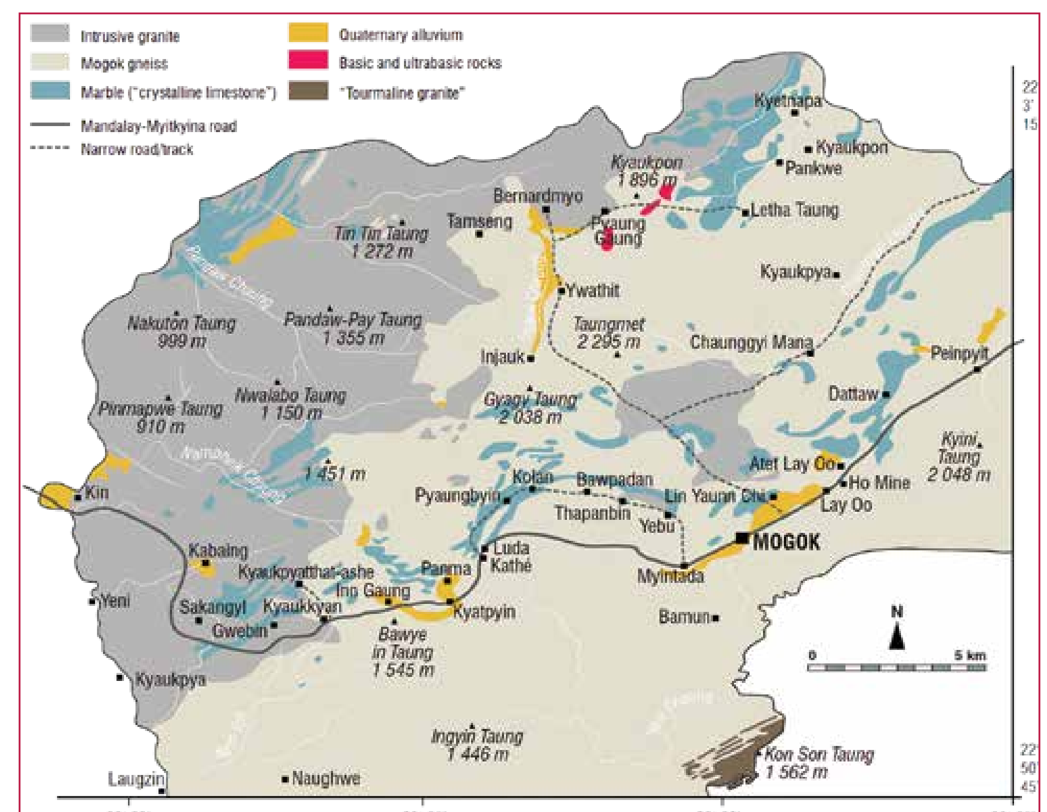
Connoisseurs of gemology know Mogok as the mythical and eternal valley of precious stones "lost in the mountain of the Shan country" at several hours drive from Mandalay over an unsafe remote road. A few years ago, as a tribute to this famous Burmese valley, Kennedy Ho, one of heirs to a Sino-Burmese family that has been active in gem trading for two generations, and also chairman of the Asian Institute of Gemological Sciences (AIGS), started a project for this beautiful book with a team of renowned gemologists and scientists.

Dr. Emmanuel Fritsch is a geologist, professor and researcher of physics at the University of Nantes in France. He also directs the Degree of Gemology (DUG) in Nantes. In the first chapter, he describes with simple words how the area was influenced 50 million years ago by the collision between India and the Asian plate that created the Mogok metamorphic belt and its great diversity of minerals. He also explains how the different gems were formed.

Franck Notari is the director and co-founder of the GGTL laboratories in Geneva, head of scientific research at the AIGS and also senior lecturer at the DUG of Nantes University. Notari explains the particularities of the right chemistry balance between the chromogenic elements that gave some rubies their perfect red hue and luminescence, making them so rare and desirable.

Candice Caplan, archeo-gemologist at the GGTL Laboratories in Geneva and Egyptologist, is passionate about antique jewelry, history and legend. She gives an overview of the Mogok valley from the first Neolithic settlement to present day, telling the passing of the secret and unreachable city of Capelan. *[Also called Capellan, now identified as Mogok.]* The city is the historical provider for the Silk Road of spinels and rubies that created the symbol of power and spectacular jewelry for the grand maharajas of India and the crowned heads of Europe.





Photos

Above: Cover of the book *Mogok - The Valley of Precious Stones,* edited by Kennedy Ho. (Photo: Jean Baptiste and Sandrine Rabouan)

Left: Geological map of the Mogok region. (Image: Emmanuel Fritsch)

Opposite page: The Kyauk Pya That pagoda is built on top of jagged ridges of blackened karst. Stupas and temples are often built to offer thanks for all the gems-bearing surroundings. (Photo: J. B. Rabouan)

View over the town of Mogok at night. (Photo: J. B. Rabouan)

Bubble in mixed liquid gas of CO_2, H_2S and COS in a Mogok ruby. To realize this micrograph, the author had to polish the sample as close as possible without making the inclusion explode. He took 27 pictures with different depths of field, which were then combined to create an image with a greater depth of field. (Photo: F. Notari)

The Ho family in 1964 in Burma. (Photo: J. B. Rabouan)

Photos

Left: Women selling gemstones at the *Cinema Market*, which is held in the eastern part of Mogok every morning from 8 am to 10 am. (Photo: J. B. Rabouan)

Center: In the street of Mogok during the ceremony to celebrate childen's entry into the monastery. (Photo: J. B. Rabouan)

Bottom: Independent miners working with very limited means at a sapphire mine. (Photo: J. B. Rabouan)

Dr. Thomas Hainschwang (Ph.D in physics, University of Nantes, co-founder of GGTL Laboratories in Liechtenstein) talks about the diversity of colors in Mogok sapphires. From the rarest blue found in the valley to the extremely rare vanadium color change—from green in daylight to almost red in incandescent light—that is almost exclusive to this region.

A talented photo reporter, Jean Baptiste Rabouan is passionate about ethnography and gemology, and he is also a permanent contributor to photo-reporting magazines. His wonderful ethnographic approach to Mogok, with breath taking pictures, shows the life of the hidden valley at different periods of the year, allowing the reader to visualize Mogok's life and environment.

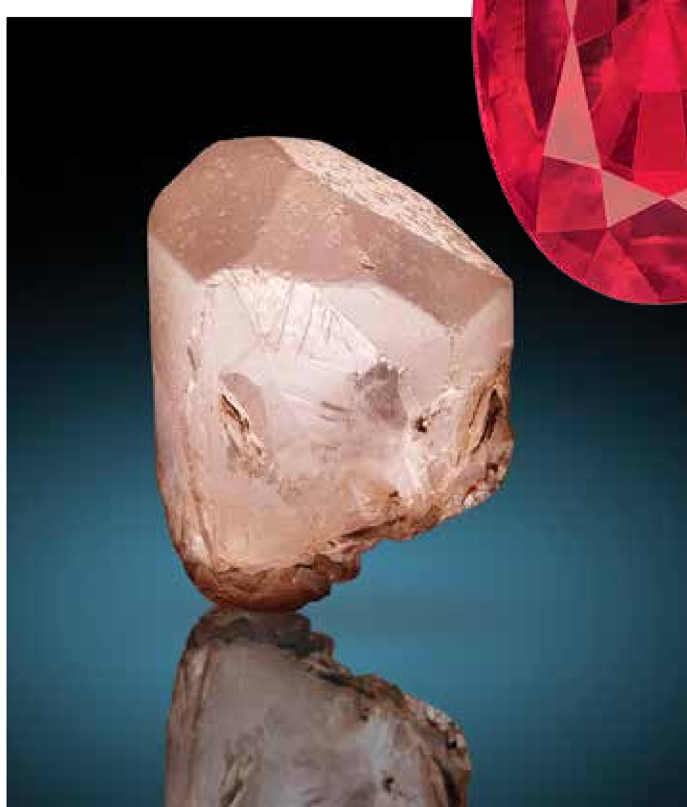
Kennedy Ho took a unique opportunity, during a period of stability between 2016 and 2017, to obtain all the permits and an exceptional "green light" to explore the mines. The making of this book required five consecutive trips to the area to collect all the data and pictures necessary to finalize the book. The last trip took place in March 2018 during the 800-year anniversary of Mogok, which was open exceptionally for few days to very few foreign visitors.

This remarkable team started a study of the valley, visiting various mines and gemstone markets. They wrote the story of Mogok from a new approach and under a different angle exploring indepth the local population, while making an overview of the mineralogy of the valley—one of the richest gemstone occurrences of the world. Although Mogok is particularly famous for its rubies and sapphires, many other gems are also mined, including spinel, peridot and some extremely rare gems such as poudretteite or Kyawthuite. Kyawthuite is an orange gem composed of bismuth and antimony. A 1.61-carat cut stone is known as unique and the only piece listed until now.

Left to right - Candice Caplan, Emmanuel Fritsch, Kennedy Ho, Franck Notari and Thomas Hainschwang in Mogok. (Photo: J. B. Rabouan)

A magnificent > 20-ct ruby, certainly one of the most beautiful stones mined in Mogok. (Photo: Frank Notari)

Classical *Landscape* inclusion in an unheated Mogok sapphire. (Photo: T. Hainschwang)



Exceptionally rare Poudretteite crystal of 17.14 carats. (Photo: N. Jarusinthanakorn)

This book is not only a fantastic book about gems, but a real compilation of scientific reference collected *in situ* and studied in a gem laboratory and a university, offering some totally new information.

It also pays homage to small-scale miners, who sometimes risk their life for the gems. For centuries, they have been mining the valley to find the most beautiful gems on Earth, but today they are threatened by fast growing mechanized techniques and large-scale mining.

The different backgrounds and complementary nature of the authors provide unique knowledge that combines science, history and ethnography.

Whether a gem lover, gemologist, photographer or a passionate traveler, *Mogok - The Valley of Precious Stones* is a must-have book in every connoisseur's or aficionado's personal library.

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The Most Sought-After Jewels from the Fall 2018 Auctions

By Marie Chabrol

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Now that the Christmas season is over and we begin 2019, we are already sure that the New Year will bring many beautiful jewelry-related events and even some nice surprises.

Lest we already forget 2018, however, last year offered many opportunities to celebrate the industry. Among them were the November and December auctions that often met high expectations. Although some lots may not have found buyers, most of the featured items achieved particularly honorable scores, with many setting new world records. Among the highly followed events was Sotheby's sale of the incredible Bourbon-Parma collection, more precisely the lost jewels of Queen Marie-Antoinette.

The final results came just before Christmas and they are extremely eloquent. For the fall auctions (November and December), Poly Auctions and Tiansheng Auctions realized US$16 and US$38 million, respectively. Over at the two market leaders, Sotheby's and Christie's, sales exceeded US$160 million US$250 million, respectively.

With a total yearly score US$492 million only for jewelry, Christie's confirms its first-place status for the 25th consecutive year. Moreover, the Paris office, which is not, for obvious fiscal reasons, the most important place in Europe in this sector, achieved more than US$5 million with remarkable success on signatures such as René Boivin or Suzanne Belperron. Note also that Sotheby's made the bold decision to reopen jewelry sales in the French capital. Finally, the Parisian departments have recently changed their faces with the nominations of Violaine d'Astorg (Christie's, April 18) and Magali Teisseire (Sotheby's, July 18) as these two institutions want to recreate a real jeweler's center in France where the Place Vendôme remains, for many buyers, a guarantee of quality and know-how.

Let's start with the undisputed stars of sales: corundum, especially Burmese *Pigeon Blood* rubies, along with sapphires from all sources, but particularly those from Kashmir, which continue to dazzle the hearts of collectors worldwide. Four major rubies sold during the year, including: a 24.70-carat for US$11 million (Sotheby's); a 10.04-carat for more than US$7 million, or UD$720,000 per carat (Christie's Hong Kong); a 7.06-carat for US$1.5 million (Poly Auctions); and an 8.06-carat for more than US$2 million (Tiancheng). For sapphires, *The Peacock Necklace* set featuring 109.08 carats of the finest quality Kashmir gems sold for almost US$15 million, beating the world record for price per carat of over US$137,000.

There were a number of unusual lots that reached incredible prices, mainly fine pearls and jade. By the end of 2018, all eyes were on the Geneva sale of the Bourbon-Parma collection. As expected, these remarkable historical gems and jewels all achieved significant prices but we must highlight the Marie-Antoinette pendant in gold, silver, diamonds and a fine pearl measuring 15.90x18.35x25.85mm. It sold for US$36 million, establishing a record for a fine pearl and for an antique jewel.

Photos

1. An exceptional and highly important natural pearl and diamond jewel. Sold for CHF36,427,000 / US$ 36,165,090 at Sotheby's Geneva, 14 November 2018. World Records for a Natural Pearl, and for an Antique Jewel. (Photo: Sotheby's)

2. *The Peacock Necklace* featuring diamonds and Kashmir sapphires. Sold for US$15 million at Christie's. (Photo: Christie's)

3. A spectacular ruby and diamond ring. Sold at Sotheby's Hong Kong, 3 April 2018, for HK$86,392,500/US$11,007,268 ($445,638 per carat). (Photo: Sotheby's)

4. The 8.01-ct fancy vivid blue pear-shape diamond on a Mousaeieff setting. Sold by Christie's for US$20 million. (Photo: Christie's)

5. The 8.06-ct natural unheated Burmese Mogok *Pigeon's Blood* ruby and diamond ring sold for more than US$2 million. (Photo: Tiancheng)

6. This 10.04-ct Burmese *Pigeon's Blood* ruby achieved a final price of US$7 million at Christie's Hong Kong. (Photo: Christie's)

7. A 7.06-Ct Burmese *Pigeon's Blood* ruby and Diamond Ring sold at Poly Auctions for US$1.5 million. (Photo: Poly Auctions)

8. The *Winston Pink Legacy*, 18.89-ct vivid pink diamond, sold by Christie's to Harry Winston for US$50 million. (Photo: Christie's)

9. The 29.53-ct D IF Type IIa, excellent polish diamond ring. Sold at Tiancheng for more than UD$3,4 million. (Photo: Tiancheng)

10. A 51.52-ct, Harry Winston diamond ring. Sold for US$ 3,98 million ($77,154 per carat) at Sotheby's New York, 4 December 2018. (Photo: Sotheby's)

11. A 3.47-ct fancy intense blue diamond ring. Sold for US$ 6,66 million (US$1,92 million per carat) at Sotheby's New York, 18 April 2018. (Photo: Sotheby's)

12. An 8.08-ct fancy vivid blue cushion-cut diamond on a Bulgari ring. Sold by Christie's for US$18 million. (Photo: Christie's)

13. The *Ai Diamond*, a 5.00-ct fancy vivid blue diamond ring.Sold for HK$108.4 million/US$13.8 milliion (US$2,7 million per carat) at Sotheby's Hong Kong, 3 October 2018. (Photo: Sotheby's)


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Photos

14. This *Laughing Buddha* jadeite and diamond pendant sold for more US$920,000 at Tiancheng. (Photo: Tiancheng)

15. Magnificent jadeite, ruby and diamond pendant necklace sold at Poly Auctions for US$2.3 million. (Photo: Poly Auctions)

16. A 10.48-ct D color IF Type IIa diamond. GIA Report. Sold at Poly Auctions for US$1.5 million. (Photo: Poly Auctions)

17. A 32.06-ct unheated Burmese sapphire and diamond ring sold for more US$730,000 at Tiancheng. (Photo: Tiancheng)

18. Impressive lavender jadeite bead and emerald necklace sold at Poly Auctions for US$2.7 million. (Photo: Poly Auctions)

For jade, Asia is where this gem is truly appreciated. At Tiancheng and Poly Auctions, 90% of the jadeite lots found buyers, including an incredible lavender jade necklace that reached US$2.7 million. The green jadeites were extremely appreciated and five pieces appear in the top ten results of the two houses: pendants, bracelets and necklaces realized prices from US$600,000 and US$2.3 million, truly honorable results.

We end with diamonds because these stones, both colorless and colorful, continue to command very high prices, most notably the colored gems: blue, pink, yellow, green, red and orange—on one condition, though, and that is the colors must be *vivid*. The Winston Pink Legacy, a stunning 18.89-carat vivid pink diamond sold at Christie's (Geneva) for over US$50 million. Harry Winston acquired this stone whose per-carat price was a record at nearly US$2.7 million. Clearly, investors have great interest in these gems, whose prices continue only to rise.

For blue diamonds, it seems essential to mention *The Ai Diamond,* a 5-carat fancy vivid blue diamond that sold at Sotheby's for almost US$14 million. Again at Christie's, a 8.01-carat fancy vivid blue IF on a Moussaieff mount, sold for US$20 million (US$2.5 million per carat) and an 8.08 carat fancy vivid blue, on a Bulgari jewel exceeded US$18 million, for $2.2 million per carat.

We finish with two colorless Type IIa diamonds that easily seduced buyers. At Poly, a 10.48-carat Flawless D diamond reached US$1.5 million and at Tiancheng, a 29.53-carat DIF diamond sold for almost US$3.5 million.

Every year, in Spring and Fall, the global auction houses display rare stones, with wonderful provenance that we might have thought had disappeared. This Spring 2019 undoubtedly won't be an exception to. Maybe we'll see more emeralds and why not more opals? It remains up to jewelry connoisseurs and investors to look carefully, and perhaps set new world records. ◙

The 62nd Bangkok Gems & Jewelry Fair – Color and More

The gem and jewelry industry in Thailand is one of the most important sectors in the nation's economy, employing more than 1.2 million people, and generating more than US$12.8 billion in 2017. A witness to the economic importance of the industry, the Bangkok Gems & Jewelry Fair (BGJF) is organized and supported by Thailand's Department of International Trade Promotion (DITP) under the Ministry of Commerce.

By Cynthia Unninayar

A model wears an emerald and diamond parure by Beauty Gems, during the opening ceremony of the 62nd BGJF, in a gown by Thai designer Tipayaphong Pusanaphong. (Photo: BGJF)

"The Bangkok Gems and Jewelry Fair is an important marketing tool to promote the industry's capabilities and support Thai manufacturers to expand their businesses abroad while networking and trading with partners from Thailand and other countries," explains Mr. Sontirat Sontijirawong, Thailand's Minister of Commerce. "At the BGJF, new brands and designers have an opportunity to showcase their unique creations to target buyers from around the world, while the number of exhibitors joining the Bangkok Gems & Jewelry Fair as well as those expressing interest in participating in the fair has been rising every year."

Sontijirawong went on to state that the industry has been experiencing robust growth. "In the first seven months of 2018, from January to July 2018, exports of gems and jewelry, excluding unwrought gold, saw an increase of 6.93% compared to the same period in the previous year. Moreover, the industry is projected to continue its steady growth into the coming year."

In 2017, high-growth products were gemstones (+12.42%), pearls (+28.34%), silver jewelry (+14.74%), precious metal and metal-plated items (+90.19%). Products that saw a negative growth were diamonds, gold jewelry, imitation jewelry, and other precious metal pieces.

It should also be noted that a significant share of Thailand's gem and jewelry industry is third-party production that Thai manufacturers carry out for many foreign brands, including a number of well-known global luxury brands. These pieces are mainly crafted in gold, diamonds and gemstones, but the nation is also the world's second largest supplier of silver jewelry, just behind India.

Handcarved silver plate by Phoenix Silver. (Photo: Cynthia Unninayar)

Selection of the new sapphire species, dubbed "Gold Sheen" sapphire offered by Genuine Gems & Jewellery (Photo: Genuine Gems & Jewellery)

Held 7-11 September 2018, the 62nd edition of the BGJF featured more than 900 exhibitors, with 800 from Thailand. The majority were gem dealers, while silver manufacturers and equipment sellers also occupied a significant portion of the show, with diamond dealers and jewelry makers of all sorts making up the rest. Many exhibitors indicated that the event was slow, while others seemed happy, both in terms of sales and contacts made. This seems to be the new norm for trade shows these days.

This edition of the BGJF took place under the theme "Heritage & Craftsmanship," with the aim of highlighting Thailand's cultural heritage. Beautiful Thai designs with international touches shone a spotlight on Thailand's position as a major actor on the global gems and jewelry stage.

One of the most spectacular examples of Thai craftsmanship was the extravagant fashion show entitled the "Queen of Jewelry." The show was dedicated to the royal projects of Her Majesty Queen Sirikit, who dedicated her life to promoting arts and culture as well as helping her subjects generate income. The fashion show highlighted jewelry from Thai manufacturers, which showcased exquisite collections in high fashion, from gold jewelry made by artisans using ancient techniques of jewelry making to contemporary gold and silver jewelry, many including precious colored gemstones with intricate designs.

As in previous years, the "Niche Showcase" featured five niche jewelry trends: *Metro Men*—jewelry for the modern man as well as LGBT individuals; *The Moment*—jewelry for special occasions such as weddings and auspicious events; *Beyond Jewelry*—Lifestyle and decorative products with precious stones and materials; *Heritage & Craftsmanship*—jewels and products that mix heritage and craftsmanship such as those featuring reinterpreted folk wisdom of the four regions of the

Ruby and diamond necklace and earrings by The Best Gems. (Photo: The Best Gems)

A selection of ceramic-based synthetic stones used in a range of designs in silver and gold was displayed by the brand Siamite, of the Formica Group. (Photo: Cynthia Unninayar)

Heart-shaped 488.48-ct kunzite offered by ABC Stone Co. (Photo: Cynthia Unninayar)

Ceramic and silver "Cat" rings by Rosy Jewellery. (Photo: Cynthia Unninayar)

Enamel and silver necklace by Good After Nine Jewelry. (Photo: BGJF)

Geode and silver ring with gold accents by Goldlip Jewelry. (Photo: Goldlip Jewelry)

A model wears a 24K gold and gem suite by Prima Gold, during the opening ceremony of the 62nd BGJF, in a dress created by Thai designer Tipayaphong Pusanaphong. (Photo: BGJF)

country into four contemporary jewelry collections; and *Spiritual Power*—pieces that reflect spiritual beliefs such as Thiti Jewelry combining ancient beliefs related to silver and pearl jewelry in contemporary design.

A special "Jewelers" exhibition featured a number of Thai designers who participated in the Designers' Room and Talent Project, with a range of creative products. The "Creative Jewelry Project Exhibition" showcased 40 designers of whose innovative techniques attracted much attention, as did those in the special "Innovation and Design Zone," with products made from non-traditional elements.

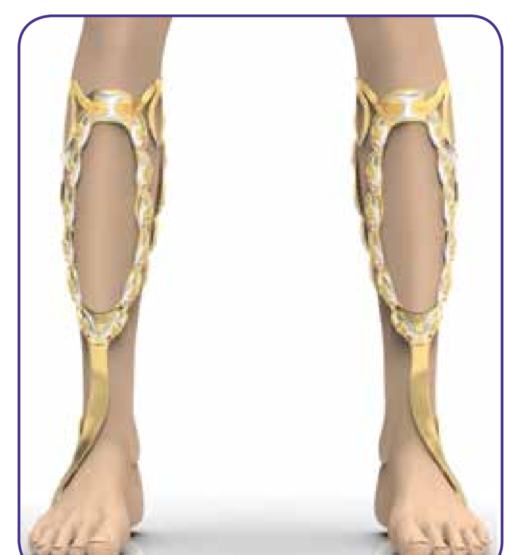
Finally, an expanded "New Faces" section provided an opportunity for 150 new exhibitors from 18 provinces in Thailand to show off their creative works.

Thousands of trade visitors from around the world visited the five-day show, which was opened to the public at large during the last two days. Show officials indicated that the reason for opening to the general public was two-fold. First, it allowed local people to see the creativity of Thai (and other) exhibitors, and secondly, some 20% of sales were generated during the final two days of the show.

Thailand's gem and jewelry industry enjoys several tax advantages to help its competitiveness. A number of tax-free zones include production facilities, where foreign companies benefit from a strong infrastructure, easy access to raw material suppliers and a highly skilled workforce.

BGJF exhibitors are also exempt from paying the value-added tax (VAT) when importing their goods for the show. VAT is paid only after the show and only for products that are sold. This greatly eases the paperwork and costs for overseas exhibitors who import and then re-export their unsold products, which remain untaxed. (bkkgems.com)

Pranda Jewelry celebrated its 25th anniversary during the 62nd BGJF with the brand's many friends. Shown here: Left: Prida Tiasuwan, Pranda Board Chairman; Cynthia Unninayar; Prapee Sorakraikitikul, Vice Chairman; Victor Tuzlokov, renowned gem cutter.



Photos

Left top: The expanded "New Faces" section provided an opportunity for 150 new exhibitors from 18 provinces in Thailand to showcase their creative works. (Photo: Cynthia Unninayar)

Left center: Among the most popular gems at the show was Paraiba tourmaline, as shown in this suite featuring cuts of Paraiba and sphene by Azizi. (Photo: Cynthia Unninayar)

Left bottom: These gold-plated silver "leg" jewels were crafted by Guy Chaturachinda, from Stormer Industries, and were featured in GIT's *Gems Treasure Showcase of Jewelry* from the "Contemporary Design Project." (Photo: BGJF)

GIT 2018

During the 62nd edition of the BGJF, the Gem and Jewelry Institute of Thailand (Public Organization), also known as GIT, organized its 6th International Gem & Jewelry Conference (GIT 2018) entitled *Global Gem Sourcing & Trading.*

The conference took place on September 10, and featured a roster of well-known speakers in the sector. Focusing on branding was Ms. Bryna Pomp, Curator of the Museum of Arts and Design (MAD) in New York, whose presentation was entitled *Successfully Developing a Product Strategy and a Brand Identity in a Competitive Global Marketplace.*

Gemstone specialist and author, Mr. Richard W. Hughes gave a very informative talk at the history and beliefs surrounding *Jade*. Mr. Prida Tiasuwan, Vice President of The Thai Gem & Jewelry Traders Association spoke on *Thailand's Gem & Jewelry Industry and Its Potential for Being the Global Gems & Jewelry Hub.*

Associate Professor Visut Pisutha-Arnond, Academic Advisor to GIT, talked on the *Provenance of Gems: An Identity Challenge.* Mr. Zaheer Azizi, President of Thailand-based Azizi Enterprises, offered a detailed look at *Paraiba Tourmaline: From Mine to Market.*

Ms. Bryna Pomp, Curator of the Museum of Arts and Design in New York, talks at GIT 2018. (Photo: Cynthia Unninayar)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