GAA
Gemmological Association of Australia

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July – December 2015

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In this issue:

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Address for correspondence
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austgem@gem.org.au

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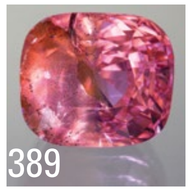
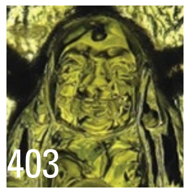
Front Cover:
An early historical chromolithograph dedicated to the European precious opal from Dubník combined with an image of an excellent example of rough precious opal along with its andesite host from the area.
Both images are courtesy of Peter Semrád.

Contents





Foreword

The Australian Gemmologist has featured many articles on "our" opal over the years along with a few on opal from sources outside Australia. In this context, I believe it is essential that an Australian publication such as ours also makes room for information on precious opal from those other sources as well. It is important especially for us here in Australia to recognise that there are now and were in the past, other important sources of precious opal, and for this reason this combined issue features two detailed papers on opal from other countries. I hope these articles will help us understand our own opal production better and allow sensible and balanced comparison with opal from places elsewhere.

Australia is often referred to as the "home of precious opal" however this was not always the case as the first article of this issue, Peter Semrád's "European Precious Opal from Červenica-Dubník – an Historical and Gemmological Summary" will demonstrate. Then there are the "newcomers" to the world of precious opal, an emerging one at this point in time being opal from Ethiopia.

I hope subscribers will find it fascinating to compare the information about the details of "pre-Australian" opals of Europe with those of Ethiopian opal that have flooded onto the market in recent times in: Jeffery Bergman and Barbara Wheat's article "Ethiopian Opals: Facts, Fears and Fairytales."

This issue is also blessed with excellent examples of practical gemmology at work in E. Billie Hughes et. al.'s "Padparadscha or Pretender: Examination of an Unusual Pink-orange Sapphire", Grant Pearson's "Moldavite, a Gemmological Relevant Natural Glass" and finally Grguric, Pring and Zhao's "An unusual occurrence of iron sulphide and baryte in Coober Pedy Opal" – just to add a touch of Australian opal content.

Best regards,

Terry Coldham
Chair – The Australian Gemmologist

Vale Bob Sneed

Bob obtained a Diploma of Pharmacy in 1960. He subsequently completed a Diploma of Botanic Medicine (Herbalism), a post graduate Diploma in Nutrition and a Bachelor of Economics Degree at UQ.

He joined the Queensland Division in 1979 and in 1980 achieved a credit in the GAA Diploma course.

He held the position of President and Education office in the division and served on the state management committee at various times over the years up until the end of 2015.

Bob also taught at TAFE and part time gemmology lecturer.

Served as federal treasurer as part of the federal executive for 4 years (1989-1992) and was federal president for 3 years (1999-2002), he also served on the Editorial committee as treasurer of the Australian Gemmologist with Grahame Brown and Hylda Bracewell for many years. He was made an Honorary Life Member of the association at the Perth conference in 2004.

Bob is survived by his wife Judy, son and daughter and grandchildren.

It is with much sadness that the Queensland division has lost a member and friend to many he will be missed by us all.

GAA 70th ANNUAL FEDERAL CONFERENCE 2016

Organised by GAA Queensland Division

Wednesday 5th May to Sunday 8th May

GAA
Gemmological Association of Australia

CONFERENCE PROGRAMME	
Wednesday 4th May 2016 (Williams Room)	
Full Day (9 am – 5 pm)	**Gem-Ed** (including welcome coffee, morning tea, lunch, afternoon tea)
Thursday 5th May 2016 (Williams Room)	
Full Day (9 am – 5 pm)	**BOSE & E & Gem-Ed** (including welcome coffee, morning tea, lunch, afternoon tea)
Friday 6th May 2016 (Williams Room – Designated Delegates only)	
Full Day (9 am – 5 pm)	**Strategic Planning** (including welcome coffee, morning tea, lunch, afternoon tea)
Saturday 7th May 2016 (Williams Room - on offer w/coffee, m/tea, lunch, a/tea)	
9.30 – 10.00 am	**AG Editorial**
10.10 – 12.00 pm	**Publicity**
12.45 – 1.45 pm	**Treasurer's Report**
1.45 – 5.00 pm	**Federal Council**
6.30 – 11.00 pm	**GAA CONFERENCE DINNER & Graduation Ceremony** 6:30 pm – Racing Bar 7:00 pm – Templeton Room
Sunday 8th May 2016	(Williams Room – on offer morning tea, lunch, afternoon tea)
9.00 – 10.00 am	**Director's Meeting**
10.30 – 11.30 pm	**GAA Annual General Meeting**
11.30 – 12.45 pm	Light Buffet lunch (optional)
1.00 – 5.00 pm	**SCIENTIFIC SEMINAR SESSION (**Holdway Room) **Guest speakers:** Grant Hamid (Hamid Brothers Gem Merchants): THE CORUNDUM CONUNDRUM – weaving a path through the Corundum maze. Tay Thye Sun (Far East Gemological Laboratory) BURMESE AMBER FROM HTI LIN JADE (Full title to be confirmed) Anthony Smallwood (Advanced Gemmological Services Pty Ltd) QUEENSLAND OPAL – *A little history, a little geology and a lot of Gemmology* (Tony will also be guest speaker at the Conference Dinner)

GRANT HAMID WORKSHOP(s): (Classes limited. Morning or afternoon tea provided)
The practical sessions will cover explanation, examination and identification of a range of new stones and treatments including: Diffusion coated star sapphire, diffusion coated synthetic sapphire, synthetic Morganite, glass fracture-filled ruby, blue sapphire and pink sapphire, coated topaz, heat quenched flux healed synthetic ruby and others and any new stones or treatments new on the market.

Venue:	GAA Premises, Suite 1A, 443 Ipswich Rd, Annerley, Qld
Date & Time:	Friday, May 6th Workshop: 2.00 – 4.30 pm OR Saturday, May 7th Workshop: 9.00 – 11.30 am
Cost:	$100.00 per person

REGISTRATION, CONFERENCE QUERIES & PAYMENT FORMS

Visit http://www.gem.org.au
Look under "News & Events" then click on "70th GAA Annual Conference 2016"
OR
Contact: Michelle Selwood at the GAA Qld Office
e-mail: qld@gem.org.au

CONFERENCE VENUE:
Tattersall's Club **Tattersall's Function Centre**
215 Queen Street (Mall, CBD), Brisbane QLD
(Corner of Queen Street Mall & Edward Street, Brisbane CBD)

Report on the Gem-A conference 2015

Grant Hamid shares a joke with the audience.

Andrew Cody shares an Australian opal suite the his audience.

Some of the attentive audience at the Gem-A presentations.

The end of November 2015 saw the Gem A conference being held in London. I was lucky enough to be visiting on other business and because all of the stars were aligned was able to attend for the four days. What an experience. We were treated to many lectures from leaders in their field whom shared so much knowledge. On this star-studded stage were two Australian presenters, Grant Hamid and Andrew Cody. If only I had been able to write faster.

Some of the topics presented were very scientific with lab-based information others were aimed at the 'street' gemmologist and passed on useful information and tools of identification. Whilst all lectures were fascinating, I thought I would briefly describe a few that were of particular interest to me.

- Jorg Gellner, jewellery manufacturer, presented 'A Rap List for Pearls'. Using his extensive knowledge and experience he created a Rap List for pearls which could be used as a guide to grade and value them. It is based on the 4 C's for diamonds but refers to the pearl list as the 5 S's; size, shape, shade, surface spot level and shine. He uses a simple mathematical formula based on percentages. Fascinating and very useful.
- Dr. Adolf Peretti, Gemmologist, presented an enthusiastic lecture on 'Commercially important origins of ruby and sapphire and colour grading. His presentation took us on a virtual tour of mining and faceting showing shades of enthusiasm akin to Steve Irwin and his love and passion of wildlife.
- Dr. Paul Rustemeyer, Chemist and author, presented 'Colour zones and growth phenomena in tourmaline crystals'. What a visual feast this was. His curiosity in the colour zones led him to slice up tourmaline crystals, mostly perpendicular to the C axis, polish each slice until wafer thin, photograph the slices once they were backlit and arrange them, in sequential order, showing a clear growth pattern.
- Grant Hamid, Wholesale Gem Merchant reminded us why it is so important to attend these conferences by updating us with current information on inclusions in both natural and synthetic corundum. He told us an amazing story regarding a piece brought to him for identification after it was purchased at an auction. Be sure not miss this story as he will be telling it again at the GAA conference being held in Brisbane in May.
- Andrew Cody, Australian opal dealer dispelled the myth that opals were 'bad luck'. His photographs were stunning and left no doubt of their allure. His presentation inspired the audience to 'get on board' whether it be doublets, triplets, matrix, boulder or precious opal. As an Aussie retailer I was left wondering why I didn't have more of it in my stores.

Monday saw a day of workshops (fascinating) and Tuesday was play day. A small group of us were treated to a private tour by the curator of the 'Bejewelled Treasures. The Al Thani Collection' at the Victoria and Albert Museum, lunch then on to another private tour of the Crown Jewels at the Tower of London. Just imagine how lucky we were to be visiting these places without the public and being able to, almost, put your nose on the glass containing these jewels. For those of you who have visited the crown jewels you would be aware there are two moving travellators taking you past them. These were turned off so we could study the pieces for as long as we wish. Incredible.

In closing, it was nice to see our fellow Aussies, Grant Hamid and Andrew Cody, who were accent-free I might add, being applauded for their knowledge and professionalism within this very small world-wide industry. Oh, and did you know that there are 50 gems that show asterism and 10 trapiche varieties that show fixed stars.

If you come along to the GAA conference in Brisbane, May 4 – 8, 2016 at 215 Queen Street Brisbane, Tattersalls Function Centre House and you too might learn something you didn't know.

Speakers and their topics (in order of presentation)

Jorg Gellner
A 'Rap List' for pearls

Jean-Pierre Chalain
Retrospective views on the identification of the HPHT treatment at the SSEF.

Dr. Adolf Peretti
Commercially important origins of ruby and sapphire and colour grading (pigeon's blood and royal blue)

Dr. Ilaria Adamo
Demantoid garnet: identification, occurrences and origin determination

Dr. Paul Rustemeyer
Colour zones and growth phenomena in tourmaline crystals

Bill Larson
Gemstones and gem mining in San Diego County, California (this presentation was made by Raquel Alonso-Perez)

Andrew Cody
The astonishing world of opals

Grant Hamid
The corundum conundrum: weaving a path through the corundum maze

Richard Drucker GG FGA
Issues and answers

Martin Steinbach
Asterism: gems with a star. From heaven to you – fascinating and brand new

Fabian Schmitz
Natural vs. synthetic quartz: an overview of differences, colour reasons and identification

Shane McClure GG – Tales from a gem lab – the sublime to the ridiculous

Lynne Cunningham *FGAA*

European Precious Opal from Červenica-Dubník – an Historical and Gemmological Summary

Peter Semrád

Abstract: Currently, with the gem market well supplied with natural precious opal from several countries such as Australia, Mexico and Ethiopia very few in our industry recall that once there was only one major source of precious opal – the European locality Červenica-Dubník (old Hungarian: Vörösvágás-Opálbánya). There are still some who wrongly believe that European opal was some kind of second-class gem with little colour and poor stability. This article sets out to remove any misunderstanding or misconceptions regarding the quality and beauty of European precious opal by providing some colourful flashes that reach out from the past to the present. Whilst tribute is paid to the *locus typicus* of the most commonly occurring opal, light opal, details of the history, geology, opal types, and historic gems from Dubnik are covered.

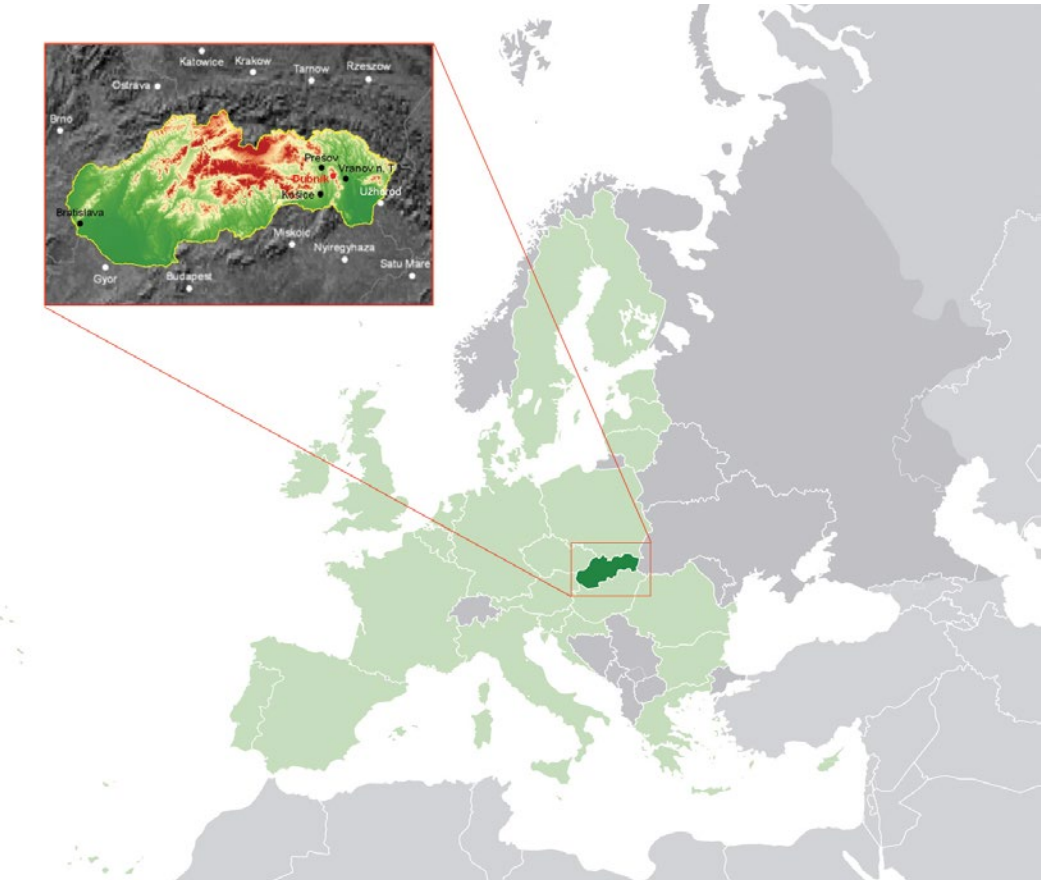


Figure 1. Map of Europe showing the position of Slovak Republic. The position of Dubník can be seen on the insert map of the Slovak Republic.

Location, Geology and Mineralogy, Mining history

Location

The European region for precious opal, Červenica-Dubník (old Hungarian; Vörösvágás-Opálbánya) is situated to the north of the Slanské vrchy Mountains in an area of the Slovak Republic that was, until 1918, integrated into the Kingdom of Hungary (Figure 1). No wonder then that prior to 1918 this European gem had been commonly commercially labeled as 'Hungarian Noble Opal' (Semrád, 2015).

Slanské vrchy Mountain is a neovolcanic mountain chain approximately 10–14 million years old. The main range running from north to south bends slightly towards the east and consists of relatively large adjacent relics of stratovolcanic structures. It is 50 kms long and varies in width from 20 kms in the north to 12 kms in the south. The historical area of Červenica-Dubník, where precious opals were mined is situated in the northern part of the mountains in the transitional zone of the largest volcano – the so-called Zlatobanský stratovolcano (circa 200 km^2) whose name was taken from the Zlatá Baňa village located in its central area (Figures 2,3).

Červenica is a village historically associated with precious opal mining at Dubník. Therefore the name of the locality of opals in relevant literature is often related to the name of this village. Even though local people from nearby villages worked in the mines, most miners came from Červenica. Some modest cultural monuments related to opal mining can be found here (Semrád, 2011). The nearest mining works are 3–4 kilometres from the centre of the village in a direct line towards the north-northeast. They are situated in Libanka-hill where the most potential opal deposits are found. (Figure 4).

Dubník is the name given today to a more or less defunct mining settlement which was established in a valley defined by two elevations historically designated as Dubina (hence Dubník) and Halyky (also Hálky). During the course of the 19th century the settlement grew into a remarkable dwelling and administrative centre for the opal mines, which also included an opal cutting shop. Further opal mining took place within a couple of mining fields in the adjacent or outlying surroundings of the settlement. The most important were Libanka and Šimonka mines. The settlement of Dubník was at that time and is still today, administratively a part of Červenica village.

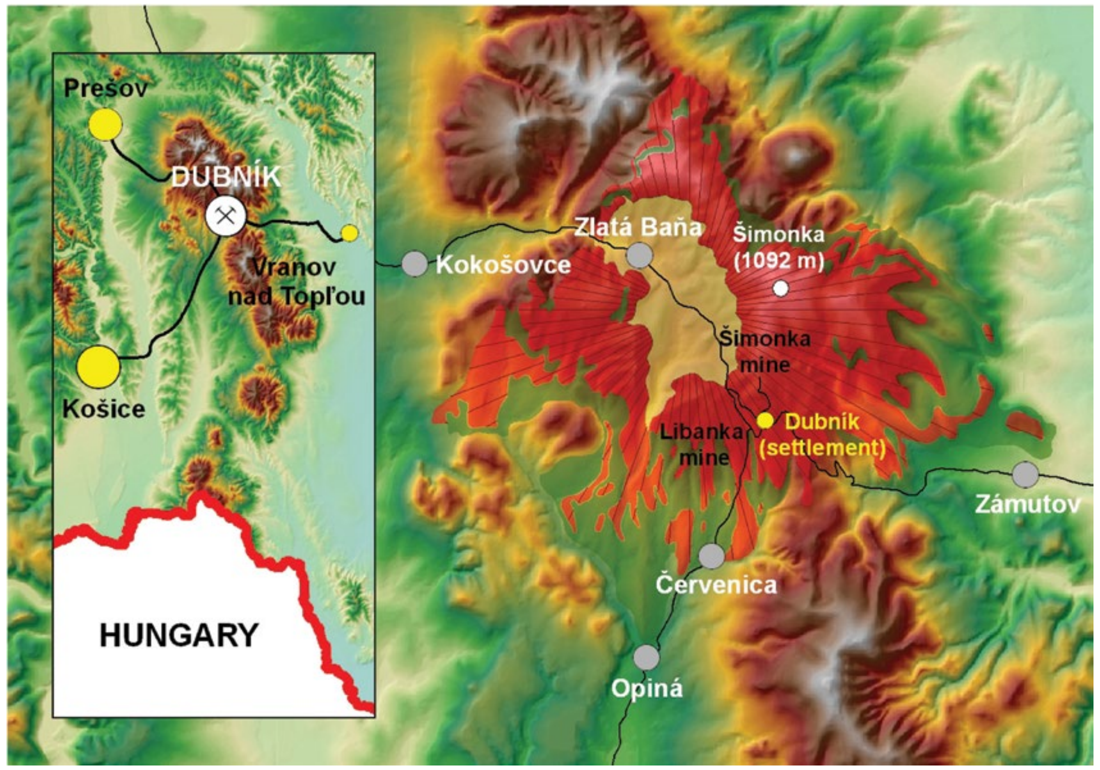


Figure 2. Maps showing position of the locality in the Slanské vrchy Mountain as well as the Zlatá Baňa stratovolcano (yellow – central zone, red – transitional zone, green – peripheral zone). Compiled by the Author.

Figure 3. Aerial view of Zlatá Baňa village from the northwest. Photo Milan Paprčka (www.cbs.sk).

Figure 4. Aerial view of Červenica village from the south. Photo Milan Paprčka (www.cbs.sk).

Geology and mineralogy

The opals occurring in the Červenica-Dubník locality can be classified as "Volcanic Opal" as they are tectonically bound to favourable dislocations in volcanic rocks (Figures 5, 7)– andesites and their pyroclastics – in the transitional zone of the Zlatobanský stratovolcano which is around 10–12 million years old (Kaličiak, 1977; Kaličiak – Repčok, 1987). There were impregnations, veinlets, fragments as well as porous textures identified in the deposits (Kaličiak et al, 1976). Precious opal is found in the host rock either solo in the form of small-grained impregnations or alongside associates in veins, veinlets and pockets that include various macroscopically different types of common opal; namely milky opal, glassy opal, hydrophane and hyalite (all these varieties including precious opal belong to A- type; Flörke et al, 1991).

Precious opal (Figure 8) and the first three common opal varieties mentioned above either intimately grow through each other, one variety continuously turning into the other, or they are arranged in layers forming from one to three cycles. In the latter quite distinct dividing lines between varieties can be observed (Figure 9). Hyalite shows a specific spatial alignment, namely distinctly discordant, as well as a distinctly different habitus in comparison with precious opal, milky opal, glassy opal and hydrophane. It is believed that vapour transport of SiO_2 is likely to have played an important role in the formation of hyalite (A_N-type) whereas in the case of the other four, deposition from solution or a colloid (gel) is strongly in evidence (A_G-type).

Due to the unpredictable nature of the opal distribution within the main opal-bearing structures exploitation was irregular. In the 19th century many geologists and mining engineers had already called these mines 'mines of hope' suggesting that no systematic or sophisticated mining methods had celebrated any success here. Miners thus dug through the host rock with extremely variable volumes of opal mineralisation (Figure 6). The poorest sections yielded only several carats per cubic metre of the rock. However, from time to time miners unearthed thick veins and very rich nests from which they managed to win hundreds to thousands of carats per cubic metre (see text box "The big opal find from 1889").

There are also some ore minerals besides opal occurring in the locality particularly polymorphs of FeS_2 pyrite and marcasite, and a little stibnite. They seem to belong to an older higher temperature stage of the mineral formation processes as the succession shows (Figure 10). The youngest are secondary minerals that can be found chiefly as sulphates, on the walls of old mining works in Libanka-hill.

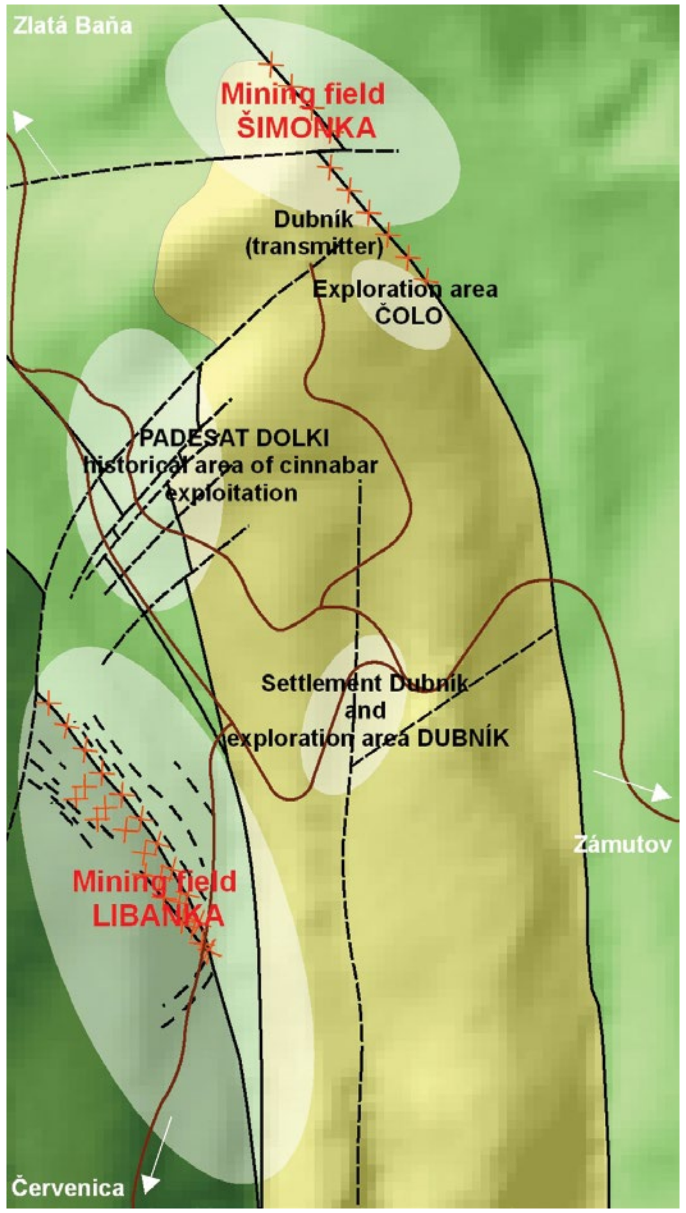


Figure 5. Schematic geological map of the opal deposits in Dubník (colours indicate miscellaneous petrographic varieties of andesites). Remade by the Author (based on the map in Kaličiak et al, 1976).

Figure 6. Stopes around Emilia adit in the mine of Šimonka (80s of the 20th century). Photo by Ervín Némethy.

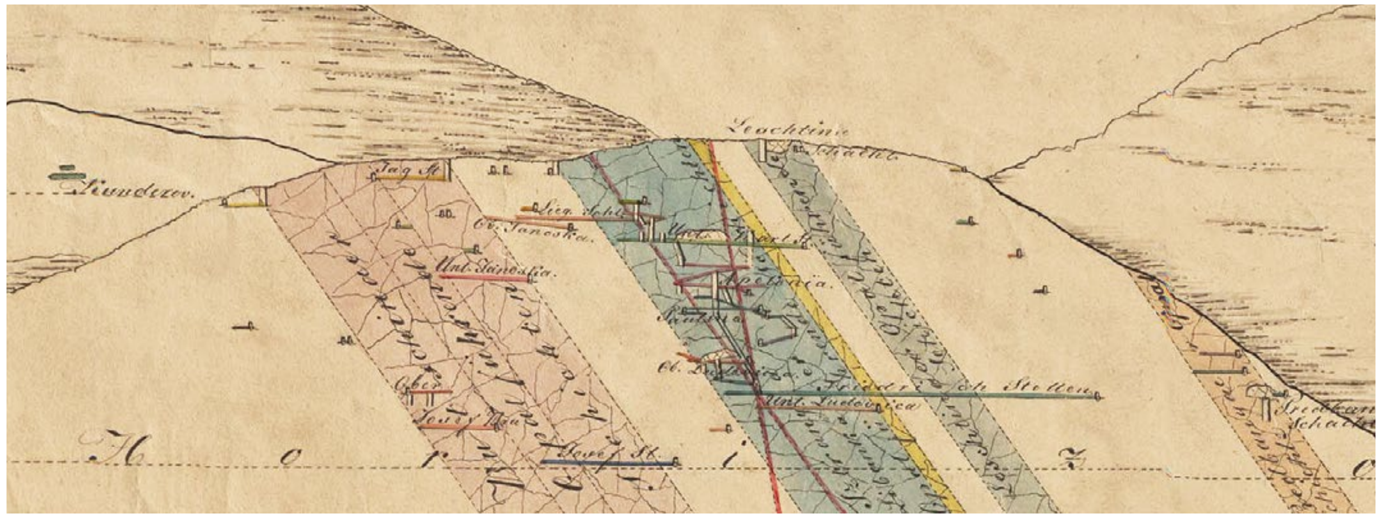


Figure 7. Cross cut showing opal-bearing structures in the area of Libanka (Karl Fail 1852); sign HKG IV, inv. no. 9818). Scan provided by The Slovak Mining Archive in Banská Štiavnica.

Figure 8. An example of raw opal – solid thus suitable for processing. Photo the Author.

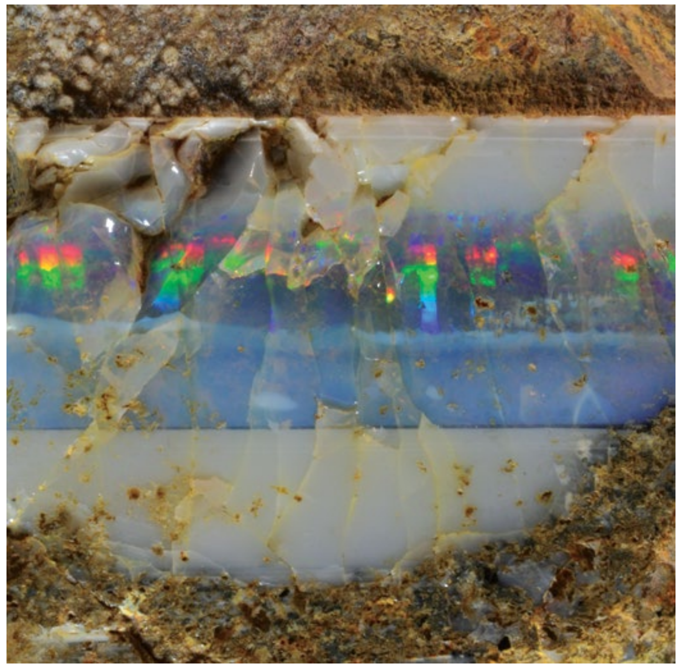


Figure 9. Opal species naturally layered on each other with distinctly sharp boundaries between them. Photo the Author.

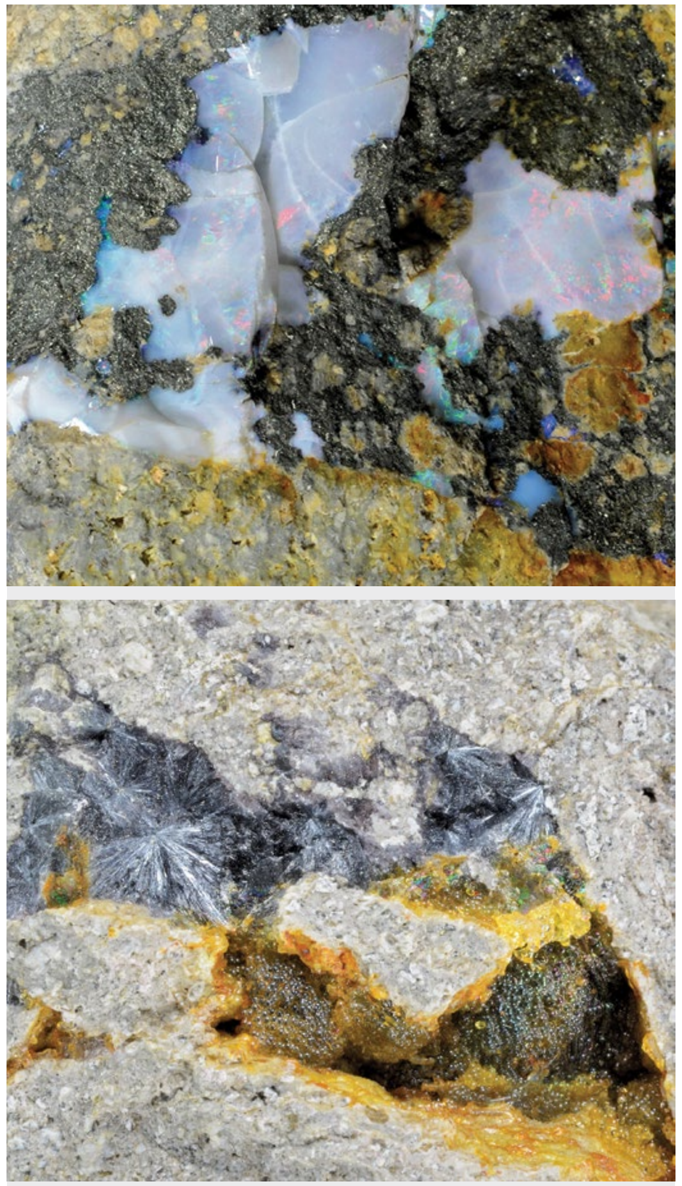
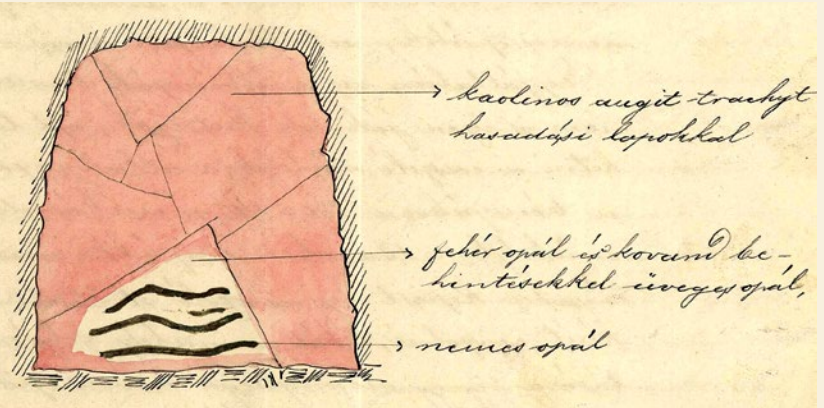


Figure 10. Top: Showing co-occurence of precious opal and iron disulphide (pyrite or marcasite) in andesite. Bottom: Showing co-occuttence of small (<5mm) radial needle-like aggregates of stibnite and hyalite of typical botryoidal habit in andesite. Photos the Author.

THE BIG OPAL FIND FROM 1889

Information about some remarkable past opal finds at Dubník can be found in the reports of officials working for the State. Relevant documents are preserved in the *Hlavný komorskogrófsky úrad* collection (f HKG hereafter) at the Slovak Mining Archive in Banská Štiavnica.

An opal bonanza in the section that was later named Gizela's Chapel (f HKG report no 1490/1889 by J. Veress) - The first precious opals had already appeared at a stope around four metres below the horizon of Viliam adit that belongs to the Libanka mine on 14 January 1889. However, what came a day later (15 January 1889) surpassed all expectations. After blasting and removing some fragments miners uncovered an opal bonanza that was in total 70–80 cm wide, 50 cm high and 25–30 cm thick. The opal mass comprised mainly common opal but still there were also three layers of precious opal with a thickness of 5–12 mm that ran horizontally through the whole find. Such a large opal accumulation could not be recalled even by the oldest miners that had worked at Dubník for thirty-five years. However they did recall that a smaller but as far as the opal quality was considered, more beautiful bonanza was found in 1882. The find amounted to a weight of 200 kg in total. Quite an intensive mining was carried out at the find later on. Although some other interesting finds occurred there, none of them surpassed that which took place on 15 January 1889. The place was named after Gizela Egger, a daughter of one of the leaseholders, whose 24th birthday happened to coincide with the discovery. Many specimens from Gizela's Chapel were put on sale at the World Fair in Paris the same year (Szabo, 1889).



A sketch showing the face where the large opal bonanza was unearthed on 15 January 1889 (József Veress; sign HKG, inv. no. 1490/1889). Scan provided by The Slovak Mining Archive in Banská Štiavnica.Translation.Top line (rose): Tectonically fragmented/brecciated kaolinised augitic trachyt 2nd line (white): Milky and glassy opal with scattered pyrite 3rd line (black & grey): Precious opal

Opal specimens that originated from the area of the large opal bonanza of 1889. Photo the Author.

Mining history

The mines at Dubník were quite likely the first source of precious opal known to consistently deliver material to the international gemstone markets. However, the absence of trustworthy evidence holds us back from recounting who dug out the very first specimen and when that happened. Reliable break through records come only from the turn of the 17th century.

On 14th May 1597 Emperor Rudolf II issued the decree through which he empowered Albert Magnus from Vratislav (Wroclaw) to look for opal and other gemstones within the entire Kingdom of Hungary (Schmidt, 1834). On 5th November 1603 the Emperor urged feudal trustee Stephan Kecer, who was administering the prospective area, not to hamper his workers and representatives looking for opal as well as other gemstones (ibid). *"As far as Hungary is concerned, there is a mine wherein opals are mined. There is not any other like this in the whole world."* (French gem merchant and traveler Jean Baptiste Tavernier, Baron d'Aubonne, 1676).

How the opal deposits were worked at the beginning as far as the owners' rights to mineral resources were concerned is unclear. If they were worked then probably a common fief system was in place. During the course of the17th century local feudal lords lost control over the opal lands and the state (the Habsburg Monarchy) took them under direct administration (Szhegy, 2010). From about the middle of the 18th century everybody who wanted to look for the gems paid a fee to the local state treasury. Later an exclusive rights approach was applied which granted rights to only one company within a permitted area.

In the period 1789–1796 the state attempted to work the opal deposits by its own means (f HKG report no 986/1789 by A. Ruprecht 1789; Németh, 1805). But the endeavor was substantially hampered by never-ending illegal opal digging and trading.

Finally the whole situation ended with a decision to lease the mines. The State authorities, at the turn of the century, correctly determined that the private sector had sufficient courage to cope with illegal opal diggers and sufficient capital for such an adventurous enterprise. After initial difficulties, opting for leases proved to be the correct decision. The early leaseholders were Peter Neumányi, Jozef Rumpler, Obel, Marek Szentiványi and Jozef Brudern (ALZ, 1798; von Zach, 1803; Beudant, 1822).

A rental period of 6 years however proved not to be encouraging for entrepreneurs. Since 1830 the State decided to extend it significantly. From this point the enterprise received an important financial boost through the capital of quite prominent entrepreneurs (Butkovič, 1962, 1970; Semrád – Krchnáková, 2008; Semrád, 2009, 2011): Gabriel Fejérváry and M. L. Biedermann et Comp. (1830–1845), the Goldschmidts (1845–1880; see text box The World Fair in Vienna in 1873), Jozef Bánó and the Eggers (1880–1886) and the Eggers (1886– 1896).

Figure 11. Opal mines around Libanka 1880s. Oil on canvas by Carl Hasch. Photo Naturhistorisches Museum in Wien.

In the period 1896–1918 the mines were again operated by the state (the Austro-Hungarian Monarchy) (Figure 11). However the new entrepreneur failed in converting the gem production into adequate revenue and as such buried the enterprise sooner than was actually necessary (Semrád, 2015). After World War I the opal mines at Dubník passed to the Czechoslovak Republic. Political representatives unfortunately did not manage to instill new life into the mines and therefore after the last unsuccessful try to lease the enterprise to Frenchman H. Bittner-Belangenay exploitation of the gems ceased in 1922/23.

The modern history of the mines begins in the 1990's. After previous decades (1960s-1980s) when unrestrained illegal opal digging developed at Dubník, Jozef Jančok leased from the State (Slovak Republic) a survey area in order to carry out a legal exploration. His activity led to positive results. Some administrative problems however delayed the start of development. Since 2008 Ethiopian opals from Welo locality have been on the market and as such Jančok's project of renewing the opal mining at Dubník became under the circumstances not feasible.

Currently another private company, despite not very favorable circumstances, is trying to get the gem to market. If the company wishes to compete against the present large opal competition from other countries they may have to change completely their commercial strategy. On the other hand they have quite good chances with a project of renewing a part of the underground of Libanka mine for tourism. No doubt that people around the world are eager enough to see historical places from where flowed lovely precious opals to the market (Figure 12).

Figure 12. Left: Entrance portal to the Viliam hereditary adit (2011). Right: Entrance portal to the Jozef adit (2014). Photos the Author.

THE WORLD FAIR IN VIENNA IN 1873

Undoubtedly the peak of popularity of European opal from Dubník has to be the World Fair in 1873 in Vienna. Adolf Louis Goldschmidt, a leaseholder of the opal mines at that time, prepared a breath-taking show for the event that consisted of mineralogical specimens, cut stones and of course spectacular jewellery. Opal cameos with portraits of Emperor Franz Joseph and Empress Elisabeth of Bavaria (Sisi) that were engraved by Guilmare from Paris attracted the most attention. They might have been worn as brooches, medallions or as a part of bracelets. Goldschmidt also put on show an exceptionally sumptuous opal parure that consisted of a choker, a pair of earrings, a bracelet and a brooch. Besides that visitors could admire an opal diadem, semi-parure that included a necklace and a pair of earrings (allegedly featuring dark opals) and another independent pair of earrings where each earring carried an opal of above-average size shaped as a drop. Especially for the gentlemen Goldschmidt showed cufflinks. But there were many other pieces of jewellery (brooches, bracelets and earrings). The very successful presentation of the gems with development of the mines at Dubník even allowed the Goldschmidts to enter the world of the aristocracy. Although since 17th March 1874 only Louis and his descendants were entitled to write their surnames in the form 'Goldschmidt von Libanka', it is undeniable that Louis's parents Salomon Johann Nepomuk and Emilie significantly contributed to this eventuality. References: Szabó (1874), The Morning Post (29.10.1873, p 6) and Semrád (2009, 2011, 2012).

The coat of arms of Adolf Louis Goldschmidt von Libanka and his family granted by the Emperor on 17 March 1874 (Allgemeines Verwaltungsarchiv, Adelsarchiv). Scan provided by Österreichisches Staatsarchiv in Wien

Opal nomenclature, Fashioning, Jewellery

Types of natural opal

Natural opal in accordance with well-established practice in the jewellery industry and a globally accepted nomenclature is currently divided into three types (Smallwood, 1997):

1 – Natural Opal Type 1, 2 – Natural Opal Type 2 (Boulder opal), 3 – Natural Opal Type 3 (Matrix opal).

For completeness, and due to a possible bias against the quality of the material, Smallwood (2012) has proposed to increase the number of classes and to abandon using the word 'type' in combination with a number, substituting the above-mentioned designations with a more generic terminology. He defines types as follows:

Precious Opal (Natural Opal Type 1) **Precious Boulder Opal** (Natural Opal Type 2) **Precious Matrix Opal** (Natural Opal Type 3) **Precious Hydrophane Opal** (a newly proposed class) **Precious Opal Specialities**

A description of each type, as well as information about its occurrence in the locality of Dubník is as follows:

Precious Opal (Natural Opal Type 1)

It is natural opal whose mass has an obvious homogeneous chemical composition throughout. Any precious opal where the whole volume was processed together with other varieties that it associates with thus enabling the cutter to extract whole cabochons of precious opal where possible or to include associates where required to form a whole shape. Material where layers of various opals occur, including precious opal, became commonly known as agate opal or opalagate.

If opal mining was resumed at Dubník, a commercial name for this type would be *Slovak opal* or possibly *Slovak agate opal*, depending on the material – a purely genuine precious opal, or the aforementioned association of several varieties (Figures 13,14).

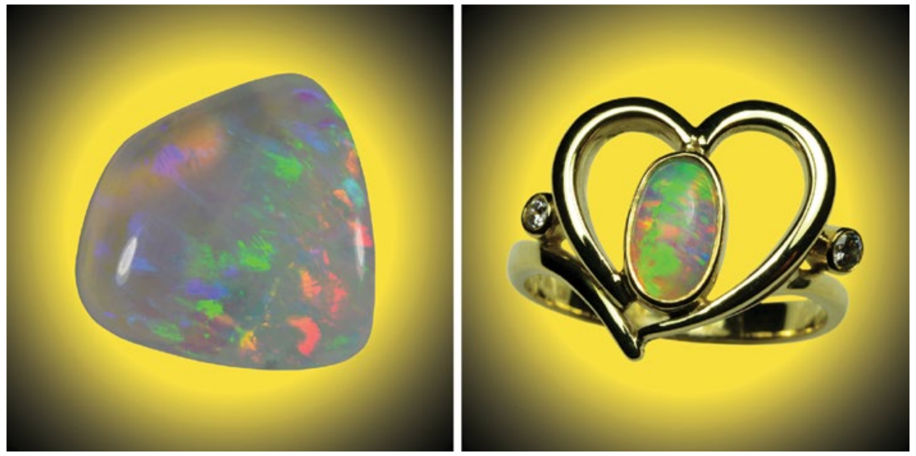


Figure 13. Precious opal (type 1). Normal full precious opal. Left: Freeform cabochon. Right: Set in a ring. Photos the Author.

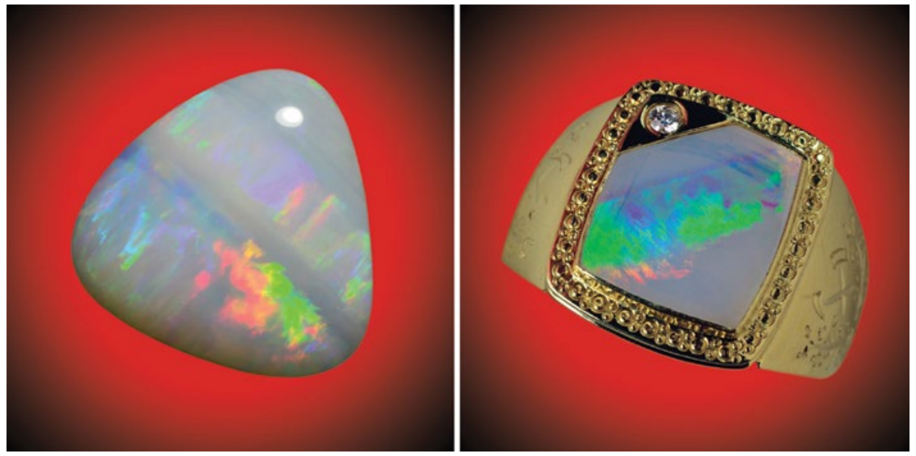


Figure 14. Precious agate opal (type 1). Left: Freeform cabochon. Right: Set in a gents ring. Photos the Author.

Precious Boulder Opal (Natural Opal Type 2)

It is natural opal whose mass is attached on rock (seam boulder opal) or coarsely spread through the rock (matrix boulder opal). Because of the low structural integrity of the opal mass the majority of extracted stones from the deposits at Dubník, with the exception of matrix opal and even though the yield might significantly decrease, were processed by intentionally splitting and cutting out the high-quality parts. If mining is resumed at Dubník, a commercial name for this type would either be *Slovak (andesite) boulder opal* (if 'boulder opal' is considered broadly acceptable), or possibly, and in order to avoid the use of the word 'boulder', *Slovak opal and the rock* (if 'boulder opal 'is considered strictly an Australian opal deposits peculiarity, especially for those found in Queensland see Figure 15).

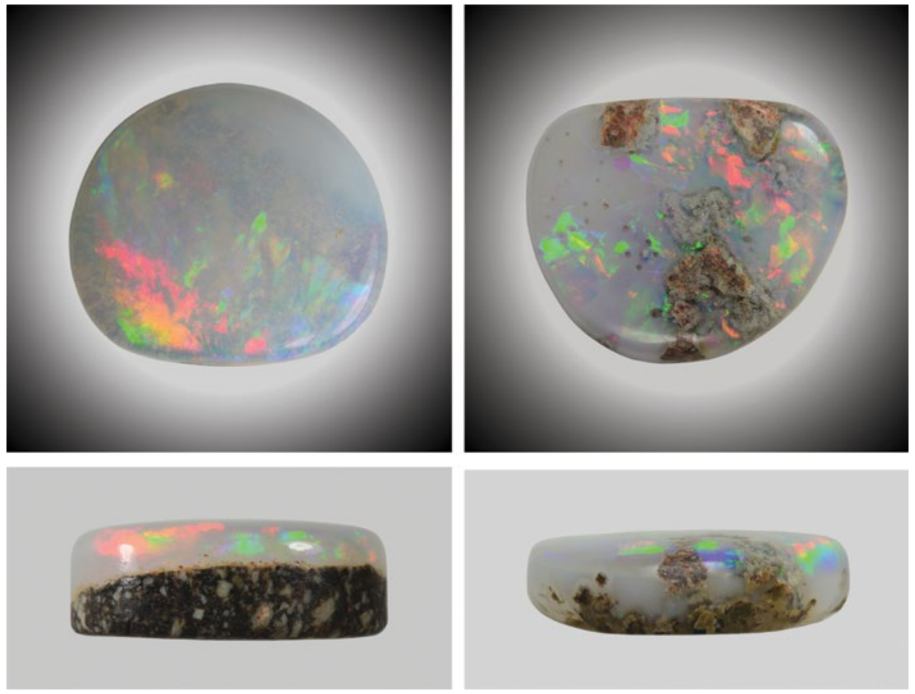


Figure 15. Precious (andesite) boulder opal (type 2) – Left: Top, clean face. Bottom, side view with andesite base. Right: Top, face with inclusions. Bottom, side view. Photos the Author.

Precious Matrix Opal (Natural Opal Type 3)

It is a material where opal is intimately diffused into the pores and fine cavities in the host rock. Due to the significant diffusion of opal throughout the material it is processed solely *en bloc*. A weak point of the matrix from Dubník is that major parts of the andesite hosting opal mineralisation are propilized, i.e. contain FeS_2 in the form of pyrite and marcasite. If any artefact made of the matrix comprising such minerals is kept in inappropriate conditions long term it can eventually disintegrate. An explanation of the problem and potential conservation possibilities were described eg by Kolesar (1996) and recently by Kotlík (2015). If mining is resumed at Dubník, a commercial name for this type would be *Slovak (andesite)* matrix opal (Figure 16).

Figure 16. Two examples of precious (andesite) matrix opal (type 3). Photos the Author.

Precious Hydrophane Opal

It is opal with a POC as well as a high degree of open porosity. This quality means liquids and gases can easily ingress into the opal which results in changes to its optical properties. Hydrophanic opals are quite common at Dubník but only some of them show a POC. This variety was not processed in the past. Hydrophanes were left on heaps or ended up in the hands of curious scholars and collectors as a mineralogical oddity known as *lapis mutabilis* (changeable stone) and *oculus mundi* (eye of the world). Such a material was pulverised and used as pounce (powder) and it cannot be entirely excluded that pulverised opal of low quality was used as sanding material (Figure 17).

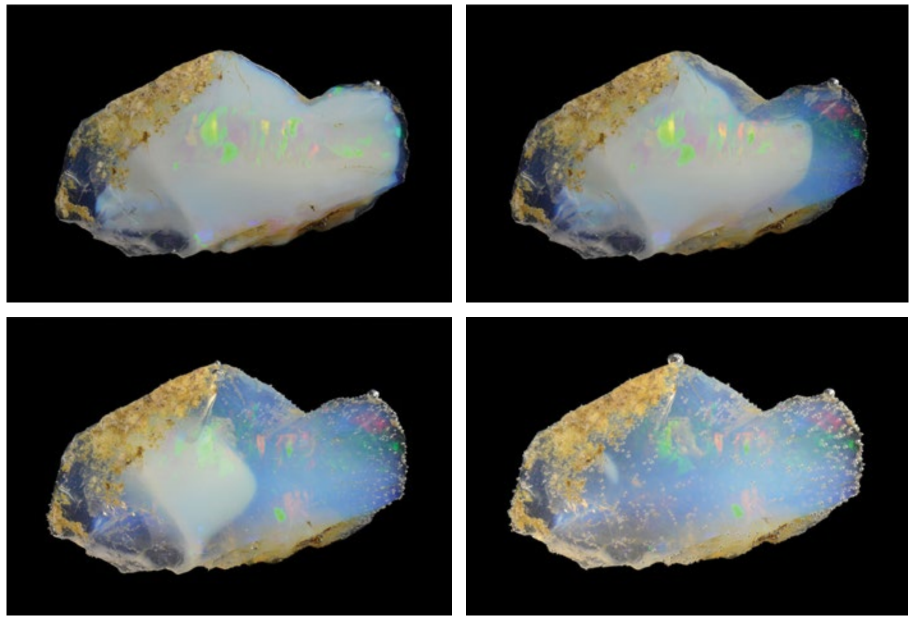


Figure 17. Hydrophane opal. Showing changes with increased absorption of water (top left to bottom right).

Precious opal specialities

It is a class that encompasses opal fossils, opal pseudomorphs as well as specimen opals, ie opals that are considered to be too large as items that can be used in jewellery but where enough reasons exist to keep them more or less as they were found. Unfortunately neither fossil precious opal nor precious opal pseudomorphs (eg famous Australian 'opal pineapples') are known to have occurred at Dubník since the geological setting there is not sedimentary. However, specimen opals can definitely be counted from the locality; the largest known solid opal – baptised as *'Vienna Imperial Opal'* (594g) – belongs to collections at the *Naturhistorisches Museum* in Vienna (see text box).

Common Opal

As mentioned before a couple of varieties of common opal accompany precious opal at Dubník. Some of them which show good optical properties (such as interesting compositional colour(s), transparency or other texture) can be cut and used either for jewellery purposes or in decoration arts (Figure 18).

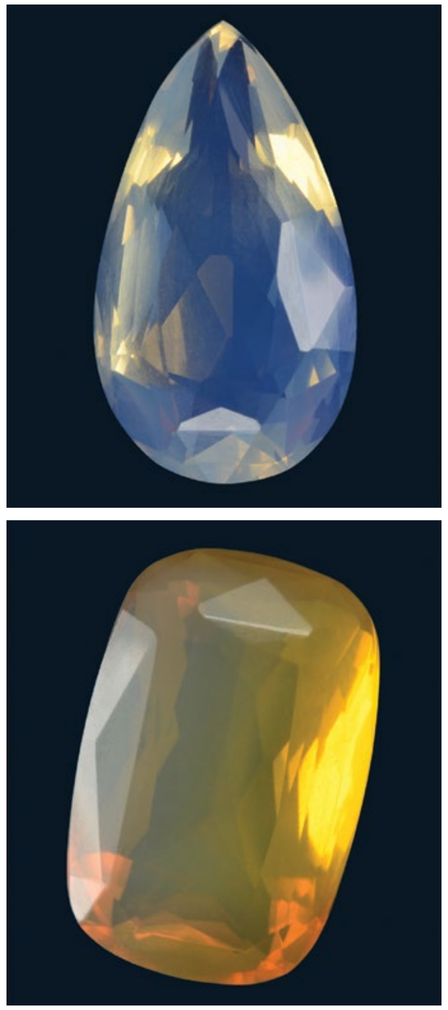


Figure 18. Two examples of faceted glassy opal. The yellow colouration is believed to be due to iron (Fe). Photos the Author.

VIENNA IMPERIAL OPAL

The Vienna Imperial Opal with dimensions of 13x7x7 cm and a weight 594g (2,970 ct) is considered to be the largest known solid precious opal the Dubník locality has ever produced. Literature often relates that this unique specimen was found somewhere in a gully by a merchant named Haupt. The event allegedly took place during the reign of Maria Theresa, (1740–1780), (Lichard, 1867). However, according to some circumstantial evidence this story appears not to be true. An English physician, and a member of the Royal (Academic) Society in London saw in 1668 in one of the display cabinets at the Imperial Majesty Treasury in Vienna, a rather large opal, which might be the one known today as the Vienna Imperial Opal. Amongst other descriptions of items in the cabinet he writes (verbatim) *"An Opal bigger than my hand, as it was taken out of the Mine; and many other fair Opals."* (Brown, 1677). Beudant (1822) describes observations from his study journey in Hungary (1818) and by way of example writes that the large opal had been known in Vienna for more than two centuries. This pushes the finding to the first half of 17th century. Before him Andreas Xaverius Stütz closely described the specimen in his *Catalogus Stützianus*, which he wrote between 1796 and 1805 (manuscript in the library of the *Naturhistorisches Museum* in Vienna). Unfortunately he provides us with neither the finder's name nor the time when it was found. He recorded only a macroscopic description, dimensions (4 3/4" x 2 1/2") and also that rock (earth) preserved in the form of a coating on one side of the opal indicating its origin in the locality. An original Latin text from the Stütz's catalogue was re-written and published by Szabo (1874).

The largest known opal from Dubník the 'Vienna Imperial Opal'. Photo Naturhistorisches Museum, Wien (inv. no. A.y.188).

Body tone and transparency

The macroscopic appearance of the opal body in accordance with the nomenclature is described by tone and transparency (Smallwood, 1997).

Body tone

As far as the body colour of opals from Dubník is concerned, it is possible to say that this locality is a *locus typicus* (typical, originating location) for white or light opals (Figure 19, 20). From time to time opals that feature a body colour ranging from yellow through orange to brown or grey or black are found here, too (Figure 21, 22). However in reality many cases of grey or black actually have only a very saturated brown body colour which optically from above a particular stone appears as dark grey or even black. If this darkness matches with one of the reference levels of tone from N1 to N4, such a specimen can be properly considered as black opal. In fact, it is an apparent body tone that is determined.

The most probable cause for some opals from Dubník being described as dark or black was the anomalous contents of iron in their structure. However Harman – Chovanec (1981) wrote in their study that opals from the locality are very pure, inclusions are minimal and these therefore cannot be considered as pigments. Since no reliable investigations have been done recently, and it is impossible to re-assess the material that Harman and Chovanec worked with, the subject is best left open. The author is currently working with Australian researchers on new analyses to sort this obscurity out.

But the fact remains that dark opals from Dubník, even though occurring only sporadically, are certainly not just a myth. Evidence for this is served with illustrations in this article, historical studies (Delius, 1777; Ruprecht, 1789; Fichtel, 1791; Pulszky, 1847; Szabó, 1853; Szentiványi, 1874; Szabó, 1874; Streeter, 1877) as well as the new book by Semrád (2015). The author recommends to eager researchers interested in further investigations to view jewellery collections with 'exotic' historical specimens in the Naturhistorisches Museum in Vienna as well as those in the Victoria and Albert Museum in London.

Figure 19. Solid raw opal suitable for processing. Photo the Author.

Body transparency

As far as the transparency of opals from Dubník is concerned, it varies significantly Figure 20, 21). Dódony – Takács (1980) who studied the structure of opals from the locality say that it is due to the high variability of the refractive index (voids and pores distinctly variously filled in with air, water, amorphous silica having different RI). Constantini (2005) states "the RI of 13 specimens had a minimum value of 1.449 and maximum value of 1.470 with an average value of 1.457."

Rondeau et al (2004) states "all measurements of density and index of refraction (RI) are in the usual range for opal, with a density of 2.10 (measured on several rough, unfaceted homogeneous samples) and a RI ranging from 1.43 to 1.46. The low RI of 1.43 is measured on white, porous samples."

In scientific circles it is agreed that the formation of precious opal requires an undisturbed environment. However at Dubník sudden changes in viscosity of the precursor in various phases of the formation probably often occurred. Kaličiak wrote about a pulsing source of solutions in which opal was formed (Kaličiak et al,1976).

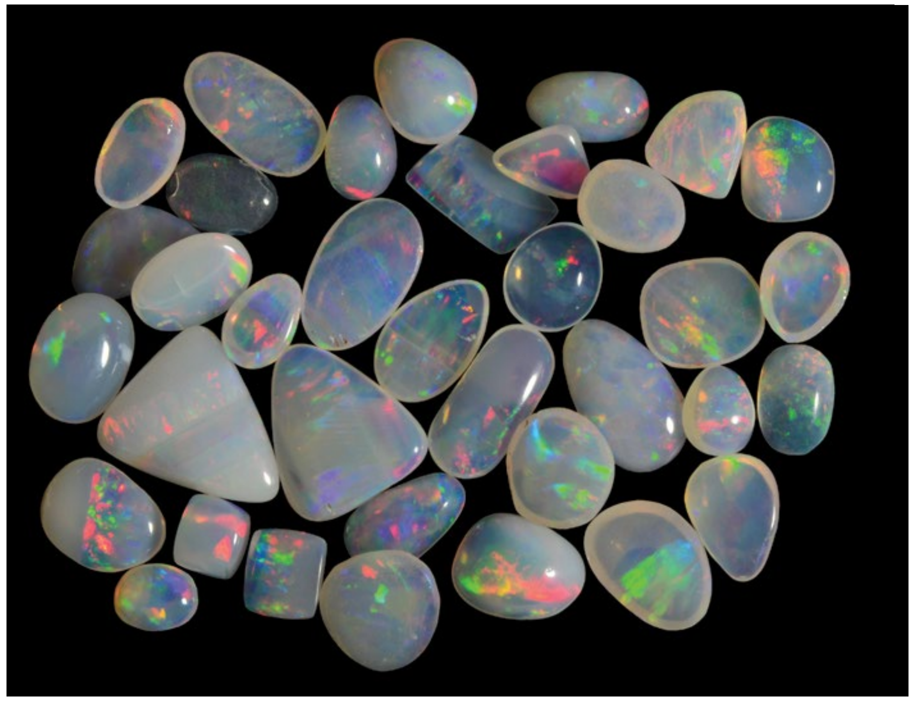


Figure 20. Cut light and crystal opal – typical material from Dubník (locus typicus for this variety). Photo the Author.

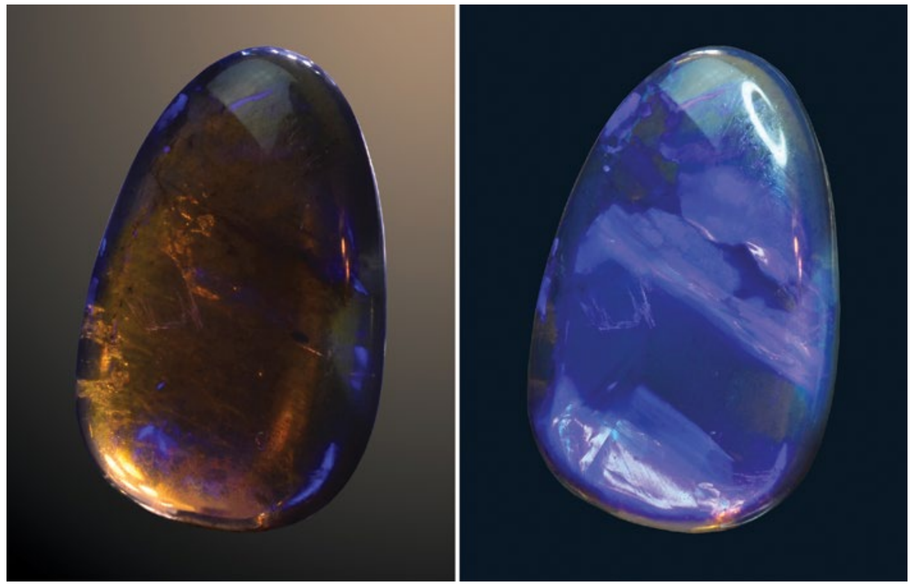


Figure 21. Precious opal (type 1, crystal). Dark blue POC crystal opal with dark brown body colour. Left: Lit from behind Right: Lit from above. Photos the Author.

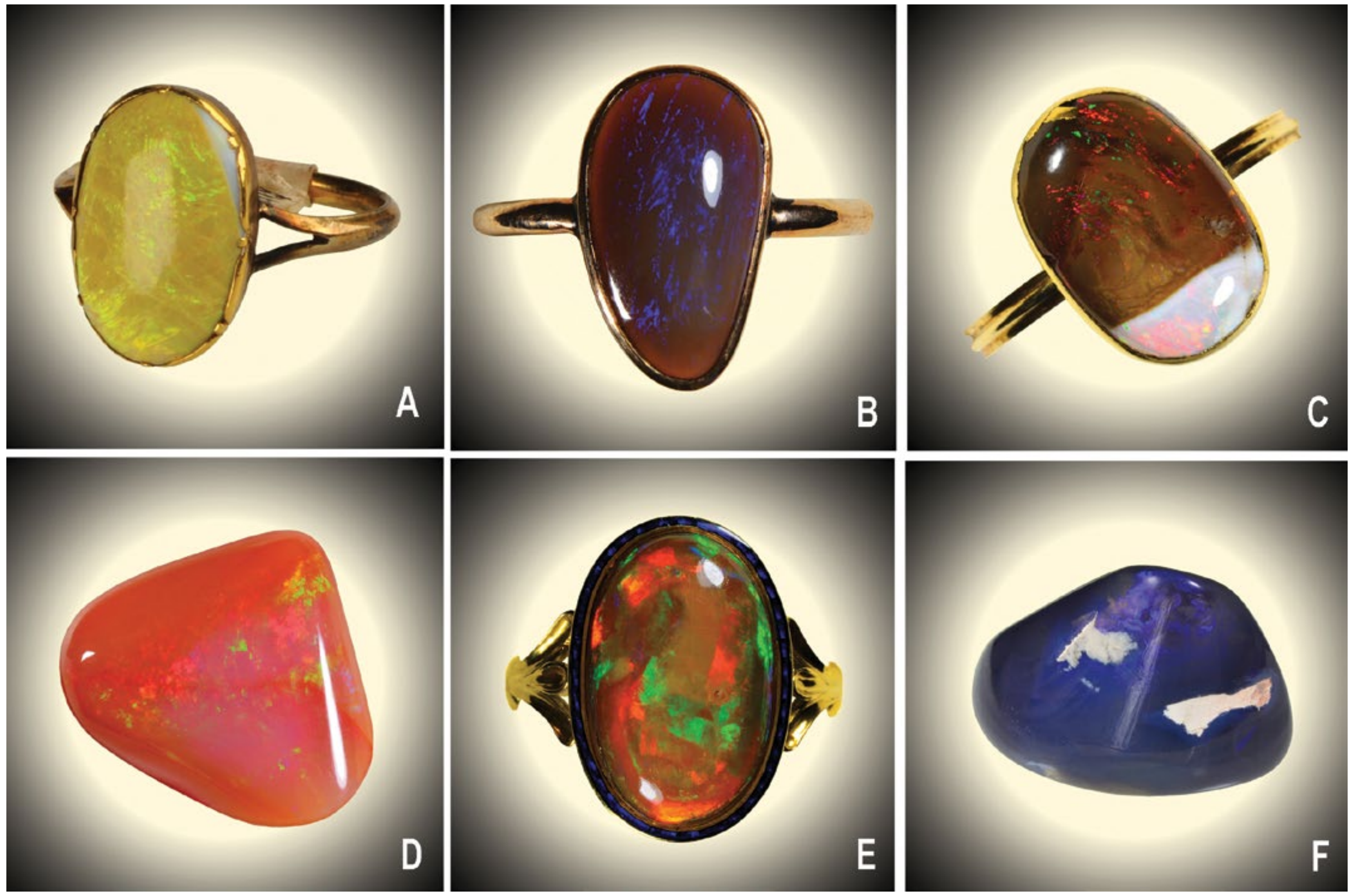


Figure 22. Examples of various body colours found.
A. Dark yellow opal mounted in gold ring. Photo Naturhistorisches Museum, Wien (inv. no. A.y.540).
B. Dark brown opal with blue POC mounted in gold ring (from the legacy of C. H. Townshend). Photo The Victoria and Albert Museum, London (inv. no. 1231-1869)
C. Opal featuring a distinct inconsistency in the body colour (from the legacy of C. H. Townshend). Photo The Victoria and Albert Museum, London (inv. no. 1232-1869).
D. Dark orange opal. Photo the Author.
E. Dark brown opal with multicoloured POC (from the legacy of C. H. Townshend). Photo The Victoria and Albert Museum, London (inv. No. 1226-1869).
F. Dark freeform crystal opal with blue POC. Photo the Author.

Play of colour (POC)

Colourfulness

It seems that specimens with one or two dominant spectral colours, especially those from the end of the spectrum with short wavelengths (violet-green) (Figure 23) occur statistically more often in the locality than first-rate multicolours. (Figure 24)

Brightness

The POC's brightness of most of the opals from Dubník, thus light opals, is affected by the wide variation in haziness of the body. Many specimens demonstrate strong directionality with respect to the brightness of their POC (Figure 25).

Pattern

The majority of opals from Dubník show common Flashfire patterns (Figure 26). But occasionally specimens with 'exotic' patterns also occur: Pinfire, 'Harlequin' (mosaic-like texture thus not genuine Harlequin), Rainbow, Star and Straw.

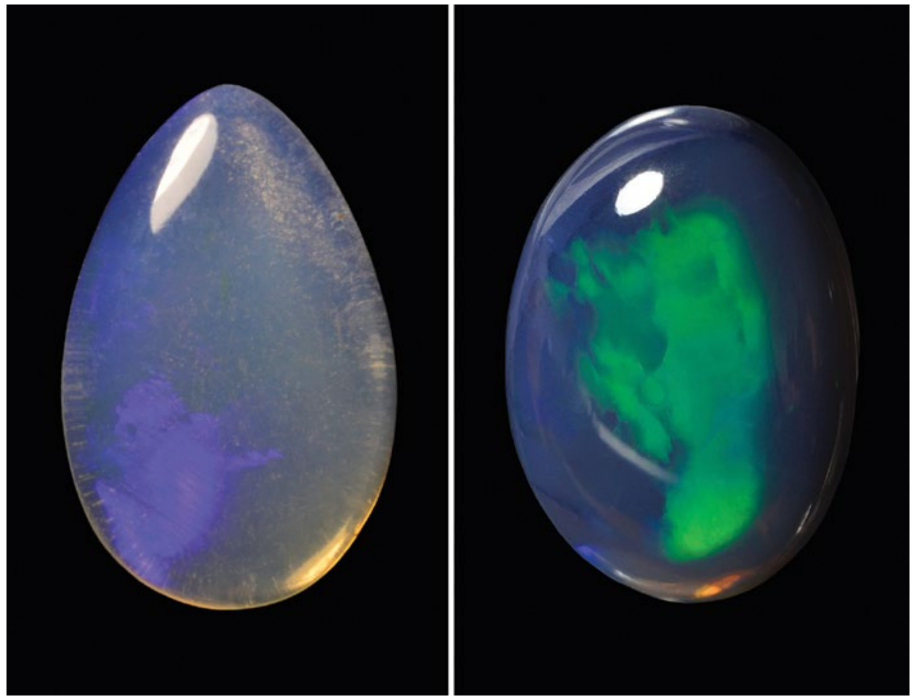


Figure 23. Precious opal (type 1, crystal) with one dominant spectral colour. Left: with blue POC. Right: with green POC. Photos the Author.

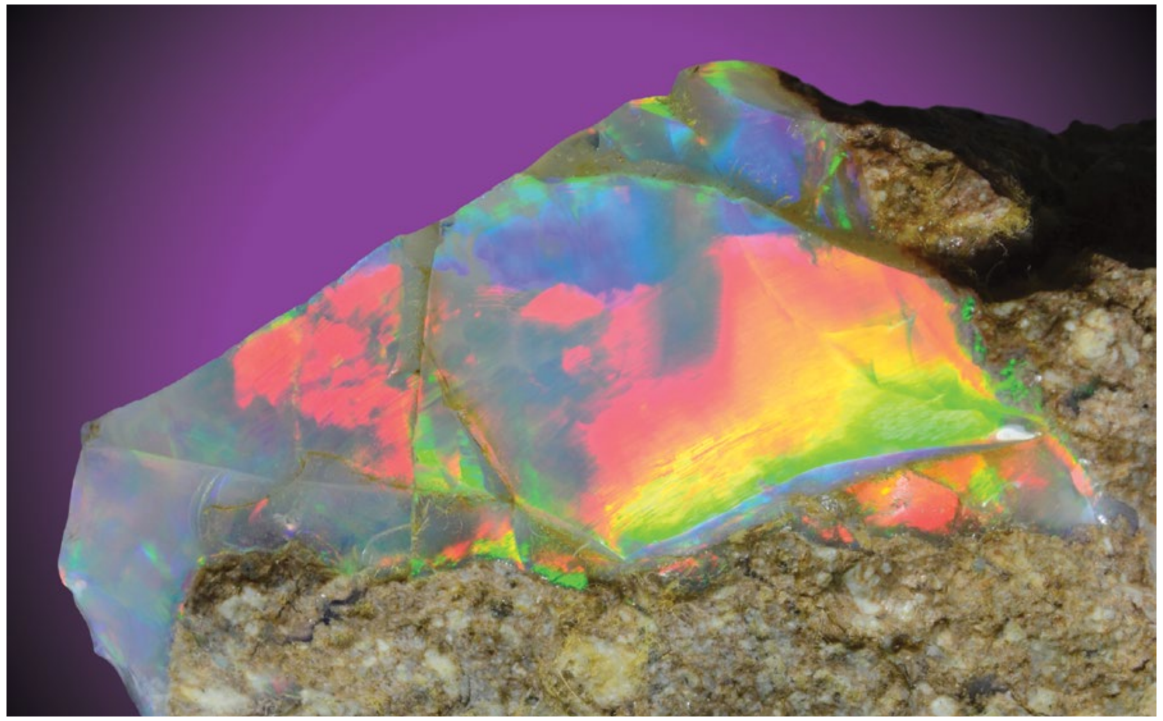


Figure 24. Fine example of multicoloured rough opal still attached to the host andesite. Photo the Author.

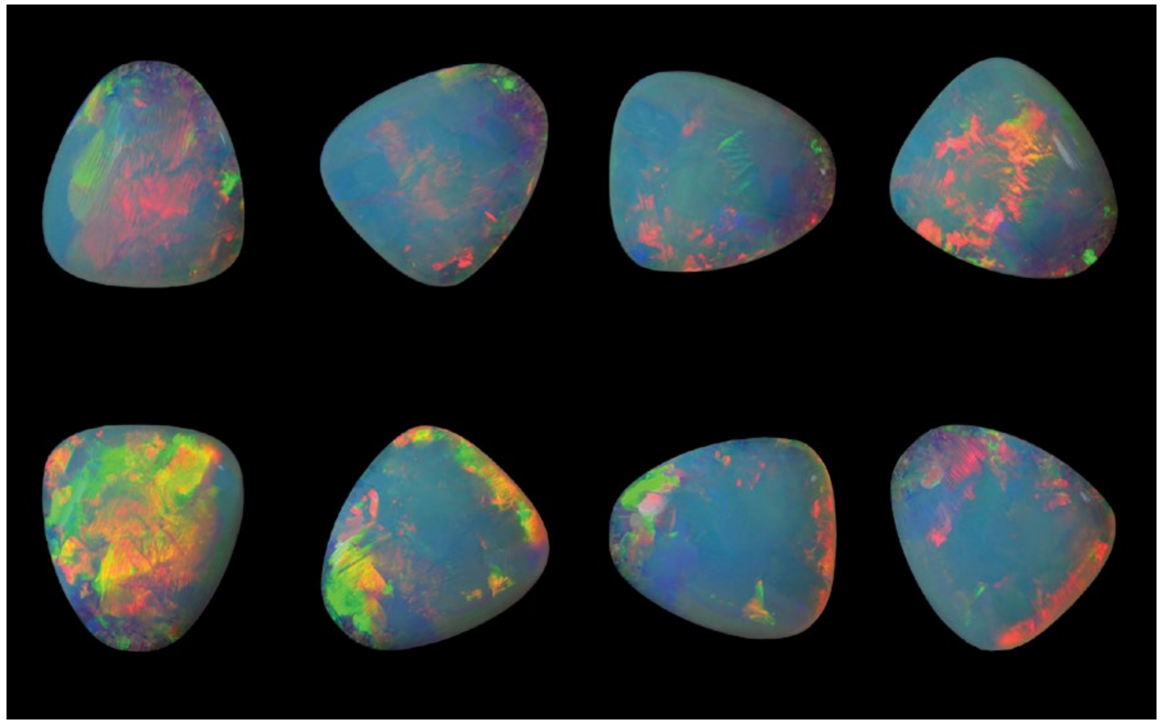


Figure 25. The lighting up and fading out of colour domains in opal as their position against the source of light is changed. The specimen reacts distinctly directionally. Photo the Author.

Figure 26. The majority of stones from Dubník show the most common pattern of POC – Flashfire. Photo the Author.

Fashioning

Descriptions of old equipment (Figure 27), abrasives and polish materials that were used to process opals from Dubník in the past can be found for example in the works of Szlujka (1883), Butkovič (1970) and Semrád (2011).

Cabochon cuts

Most precious opals, if virtually not all of them, were fashioned in the past in a conservative way (Figure 28).

Free forms

They were chosen in the past predominantly in the case of large opals in order to preserve their volume and intrinsic value (Figure 29).

Faceted cuts

Such cuts were in the past very rare. The author identified only one historical faceted precious opal, which was mentioned in an inventory of the collection of Emperor Rudolf II from 1607–1611. (Figure 35).

Engraved gems (glyptics)

Opal cameos and intaglios (Figure 30) even in the second half of the 19th century were considered as unique objects (Butkovič, 1971).

Hardstone carvings

Main parts of objects such as bowls and boxes were made of precious matrix opal that originated at Dubník (Figure 31).

Other treatments

Information on historical treatment of opals from Dubník is very fragmentary. In the past most of the solid gems, in order to reinforce POC, were simply underlaid with something black or colourful material such as silk or feathers if their body transparency allowed this (Lichard, 1867). As far as the matrix is concerned it was soaked in oil and carefully exposed to heat. The mother rock became darker and tiny grains of precious opal therein shone more brightly (ibid). According to Kovalík (1932) the latest leaseholder of the mines Frenchman H. Bittner-Belangenay sold besides non- treated opals also *'Chamäleonsteine'* which were opals allegedly dyed with ink.

Composite opals

The author has seen neither historical nor modern doublets, triplets nor mosaics made of the material from Dubník. In fact these composite products, either on a small or large-scale, seem never to have been made from European opals while the mines were in operation. This is because opal doublets were born only towards the end of the 19th century (Jürgen Schütz, personal communication, 2015; Fischer, 2007). The exploitation in Dubník was then in decline and the enterprise produced mostly cabochons. Opal triplets appeared even some decades later well after opal mining in the locality ceased to exist.

Figure 27. Opal cutters (author: Kornél Divald; year: 1904). Reproduction of a photo provided by Néprajzi Múzeum, Budapest (inv. no. F7008).

Figure 28. Gold ring with opal fashioned into a cabochon with oval outline (from the legacy of C. H. Townshend). Photo The Victoria and Albert Museum, London (inv. no. 1223-1869).

Figure 29. Gold ring with diamonds and opal with multicolour POC cut into a free form. (from the legacy of C. H. Townshend). Photo The Victoria and Albert Museum, London (inv. No. 1220-1869).

Figure 30. Gold ring with an opal cameo in antique style (from the legacy of Leo Merz). Photo Universität Bern (inv. no. DL258), Jürg Zbinden.

Figure 31. Bowl with stem made of matrix opal already mentioned in an inventory of the collection of Emperor Rudolf II from 1607–1611. Photo Kunsthistorisches Museum, Wien (inv. no. KK 1663).

Figure 32. Left: a bottle of opal chips. Right: Opal chips encapsulated in resin. Photos by the Author

But the smallest residual pieces of opal are occasionally employed as 'floating opal chips' in small blown glass bulbs that are filled with liquid (eg glycerine) and sealed or as 'embedded opal chips' in resin (Figure 32). However it seems that the destiny of any chips in the past was most unfortunate. According to Lichard (1867) all opal waste from the processing was finely crushed in order to prevent it from further commercial circulation. Only one hundred years later Butkovič (1971) reported that with the help of new methods almost all material was utilised. He mentioned a successful experiment encapsulating opal chips in methacrylate (note: he meant probably acrylic glass).

Crazing

It is usually said that opals that originated in volcanic rocks are less stable than those that originated in sedimentary rocks. This would automatically make European opals from Dubník not very reliable material. However this is not true. There are many historical stones in private and publicly available collections that show either no significant or very tiny degradation of their structural integrity. Some other aspects should rather be considered than plainly a kind of opal's mother rock. Unfortunately no detailed research was done on European opals as far as the level of their proneness to crazing is concerned. Therefore we can only speculate which factors might play a role in this negative phenomenon. One of them could be open porosity that allows more intensive interaction between the inside of the opal and conditions outside the stone. But if one opal specimen from a particular locality has open porosity it does not imply that other specimens will have it, too. Every locality has good and bad stones. There are also other aspects which might be considered such as the cutter's experience working with opal and awareness of the intended owner of the opal jewellery. What to do and not to do with such beauty. It has to be remembered that the gem, as with any material, has its limits.

Provenance

History shows that the recognition of the place of origin of a particular opal is important not only to collectors and scientists, but also from a commercial point of view (see text box Oriental Opal).

The task of proving the origins of opals, and especially of these from Dubník, can however be extremely difficult. The problem has to be split in two: specimens collected recently and historical specimens.

As far as recently collected specimens are concerned it is important from whom, and especially what guarantee is given for the authenticity of the material. With regard to this it has to be noted that the mines at Dubník have been out of operation for almost a century. Buyers should therefore be very careful with any purchase where they are not provided with enough supporting documentation regarding origin. Regarding historical specimens and artefact which include opal, there are usually no, or only very poor accompanying documents preserved and as such it is in many cases impossible to determine reliably the place of origin of the stone. But with the use of modern laboratory equipment and methods it is possible to make some detailed investigations of the material which can narrow down the options.

ORIENTAL OPAL

Pliny the Elder (1st century AD) mentions a few opal localities in the XXXVII book of his comprehensive work *Naturalis Historia* among which India was allegedly the only country that provided high-quality rough. However, Fichtel (1791) knew from an Austrian gentleman who traded jewels on the Indian subcontinent that opals were sold in the Orient at quite high prices but nobody could pinpoint a specific country there where the opals were mined. The locals rather to the contrary asserted that the opals were imported from the West. Skertchly (1908) referenced *Economic Geology of India* (1881) and noted that although this journal allegedly embraced all important historical as well as more recent data on mineralogical resources of this country, that there was no mention of opal. To this day we do not have any evidence that there were deposits of precious opals in India. It is obvious from the above that as far as the story of the Oriental opal is concerned there are discrepancies. Whether precious opal from Dubník is behind the commercial label of Oriental opal, or opal from another locality, possibly a gem of another kind, we cannot decide unambiguously as clear evidence is missing. Most specialists in the history of gemstones however currently accept the conclusion that the 'Oriental' opal was in reality a precious opal from the European locality of Dubník.

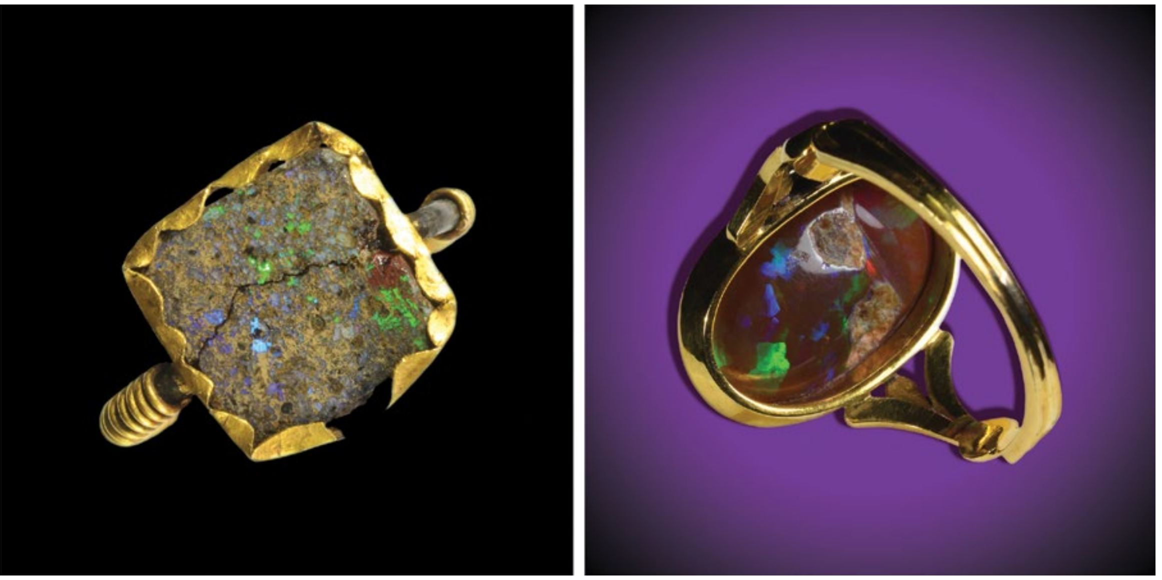


Figure 33. Left: Presence of the mother rock always increases the chances of determining a more accurate provenance for the material. Photo The British Museum, London (inv. no. OA.2874). Right: 'Fingerprints', in this case pits probably with residuals of the mother rock, are always appreciated if the provenance of a stone has to be determined. (This is the underside of the ring in figure 21E) (from the legacy of C. H. Townshend). Photo by The Victoria and Albert Museum, London (inv. no. 1226-1869).

Figure 34. Left: Medieval amulet ring (from the legacy of Sir A. W. Franks). Photo The British Museum, London (inv. no. AF.1000). Right: Medieval ring brooch (purchased from W. Anthony). Photo The British Museum, London (inv. no. 1849,0301.33).

A process aimed at identifying where a particular opal originates from is a bit easier if the assessed material is a combination of opal and the host rock (Figure 33). The type and characteristics of the rock, its alterations, geochemistry and possibly the presence of other minerals than those which are considered to be main constituents can be investigated. If the origin of a solid opal has to be determined, it is more difficult. The key information can only be extracted from the silica, namely from its geochemistry, any inclusions that it contains, and possibly from submicroscopic structures in the opal (Gaillou et al, 2008; Dódony – Takács, 1980, 1986; Harman – Chovanec, 1981). Results obtained from research often point only to the properties of the geological setting that opal was formed in and based on this it is possible by a way of comparison to seek the best concordance with known opal localities.

Modern non-destructive methods open doors to determine the origin of opals mounted in old artifacts. This might be a future challenge pushing the boundaries of our knowledge about the gem further.

Jewellery – famous items

A list of some famous items follows. In some cases there are enough reasons to believe the stones originated at Dubník. In other cases doubts arise if the gems are from the locality. For a preliminary conclusion as far as provenance is concerned, such aspects as the period of production, hallmarks, size of stones, their quantity and macroscopic properties may be considered. A more precise verdict however requires execution of various tests in the laboratory.

Legend

(x) – number of opals mounted on the object
(o) – opal/s of remarkable size with regard to the indicated period
(*) – opal/s of 'exotic' appearance thus not light/white

14–15th century

Binding of Evangeliary of Saint Bernulphus (1) inv. no ABM h3; Museum Catharijneconvent, Utrecht, NL.

Gothic ring brooch (1), a Gothic amulet ring (1) Inv. no 1849,0301.33, AF.1000; The British Museum, London, UK (Figure 34)

Gothic statuette of the Virgin and child (1) Inv. no AP 2002.03; Kimbell Art Museum, Fort Worth, USA

16–17th century

Pendant of Queen of Isabella – Izabela Jagiellonka (16) (o) Inv. no Pig. Jank. 225; Magyar Nemzeti Múzeum, Budapest, HU

Pendant (1) (o), faceted 'Opal of Rudolf II' (1) (o) Inv. no WS XIa 52; KK1825, Kunsthistorisches Museum, Wien, AT (Figure 35 & 36)

Pendant with an opal cameo (with a portrait of Louis XIII or Gaston, Duke of Orléans) (1) (o) Inv. no 791; La Bibliothèque Nationale de France, Paris, FR

Locket with a miniature of Sir Bevil Grenville (10), a pendant (5) Inv. no WB.168, AF.2857; The British Museum, London, UK

Dress ornament (1) (o), a pendant or an earring (6) (the Cheapside Hoard) Inv. no A14097, A14018; The Museum of London, UK

Pendant (8) Inv. no RCIN 51008, The Royal Collection, UK

Dress ornament (8) Inv. no EWA08558, Burghley House, Stamford, UK

Hat badge – the Drake Star/Sun Jewel (20), Pendant – Aberdeen Jewel (5) Inv. no n. a. (private possession, UK)

18–19th century

Badge of the Order of the Golden Fleece (3) (o) Inv. no VIII 2; Grünes Gewölbe, Dresden, DE

Ring with an opal cameo with a portrait of 'Apollo' (1) (o) Inv. no DL258; Antikensammlung der Universität Bern, CH

Collection of rings; Naturhistorisches Museum, Wien, AT (o) (*)

Collection of rings; The Victoria and Albert Museum, London, UK (o) (*)

Brooch with 'Opal of Louis XVIII' (1) (o) Inv. no MNHN 87.44; Muséum national d'histoire naturelle, Paris, FR (Figure 37).

Badge of the Order of the Golden Fleece (3), the Star of the Saxe-Ernestine Order (76) Inv. no RCIN 441170, RCIN 441364; The Royal Collection, UK

Parure of Princess Stephanie of Belgium (303) Inv. no WS XIb 41; Kunsthistorisches Museum, Wien, (Figure 38)

Figure 35. Faceted opal already mentioned in an inventory of the collection of Emperor Rudolf II from 1607–1611. Photo Kunsthistorisches Museum, Wien (inv. no. KK 1825).

Figure 36. Renaissance gold pendant with an exceptionally big opal with regards to the period that the jewel originates from. Photo Kunsthistorisches Museum, Wien (inv. no. WS XIa 52).

Figure 37. Silver brooch with diamonds and the Opal of Louis XVIII (77 ct). Photo Muséum national d'histoire naturelle, Paris (inv. no. MNHN 87.44).

Figure 38. Detail of pendants on necklace and belt that belong to the Neo-Renaissance opal parure of Princess Stephanie of Belgium (jewellers: the Eggers; year: 1881). Photo Kunsthistorisches Museum, Wien (inv. no. WS XIb 41).

Acknowledgements

Establishments

Antikensammlung der Universität Bern Bern, Swiss Confederation http://www.antikensammlung.unibe.ch/

The British Museum London, United Kingdom http://www.britishmuseum.org/

CBS Ltd – Slovakia http://www.cbs.sk/ http://www.SlovenskozNeba.sk/

Kunsthistorisches Museum Wien, Österreich http://www.khm.at/

Muséum national d'histoire naturelle Paris, France http://www.mnhn.fr/

Museum of London London, United Kingdom http://www. museumoflondon.org.uk/

Naturhistorisches Museum Wien, Österreich http://www.nhm-wien.ac.at/

Néprajzi Múzeum Budapest, Magyarország http://www.neprajz.hu/

Österreichisches Staatsarchiv Wien, Österreich http://www.oesta.gv.at/

Slovak Mining Archive Banská Štiavnica, Slovakia

The Victoria and Albert Museum London, United Kingdom http://www.vam.ac.uk/

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References

ALZ (1789) Untitled, In: *Allgemeine Literatur-Zeitung*, No 273, pp 561–562.

Beudant, F. S. (1822) *Voyage minéralogique et géologique en Hongrie pendant l´année 1818* (tome II et III). Paris: Verdière.

Brown, E. (1677) *An Account of Several Travels Through a great part of Germany In: Four Journeys*. London: Printed for Benj. Tooke.

Butkovič, Š. (1962) Náčrt dejín opálových baní na Dubníku. In: *Nové obzory* (Spoločenskovedný zborník východného Slovenska), roč. 4, pp 136–152.

Butkovič, Š. (1970) *História slovenského drahého opálu z Dubníka*. Bratislava: Alfa n. p.

Butkovič, Š. (1971) Dubnícky opál a jeho miesto vo svetovom šperkárstve. In: *ARS*, roč. 5, č. 1–2, pp 181–190.

Constantini, L. (2005) *The Slovak Opal – A rediscovery of the 'Queen of Gems'*. Kežmarok: ViViT.

Delius, Ch. T. (1777) Nachricht von ungarischen Opalen und Weltaugen. In: *Abhandlungen einer Privatgesellschaft in Böhmen, zur Aufnahme der Mathematik, der vaterländischen Geschichte, und der Naturgeschichte*, Dritter Band, pp 227–252.

Dódony, I., Takács, J. (1980) Structure of Precious Opal from Červenica. In: *Annales Universitatis Scientiarum Budapestinensis de Rolando Eötvös Nominanate, Sectio Geologica*, 22, pp 37–50.

Dódony, I., Takács, J. (1986) A vörösvágási nemesopál szinjátéka (Play of Colours of Noble Opal in Vörösvágás). In: *Natura Borsodiensis*, 1, pp 7–19.

Fichtel, J. E. (1791) *Mineralogische Bemerkungen von den Karpathen* (Erster und Zweiter Theil). Wien: Joseph Edlen von Kurzbeck.

Fischer, K. (2007) Composite Opal: Doublets, Triplets, Inlay and Intarsia. In: *Opal – The Phenomenal Gemstone (licensed edition in the English language of extraLapis* No. 10), pp 96–99.

Flörke, O. W., Graetsch, H., Martin, B., Röller, K., Wirth, R. (1991) Nomenclature of micro- and non- crystalline silica minerals, based on structure and microstructure. In: *Neues Jahrbuch für Mineralogie (Abhandlungen)*, 163, 1, pp 19–42.

Gaillou, E., Delaunay, A., Rondeau, B., Bouhnik-le-Cozd, M., Fritsch, E., Cornen, G., Monnier, Ch. (2008) The geochemistry of gem opals as evidence of their origin. In: *Ore Geology Reviews*, Vol 34, No 1–2, pp 113–126.

Harman, M., Chovanec, V. (1981) Mikrotextúry dubníckych opálov a ich vzťah k opalizácii. In: *Mineralia Slovaca*, Vol 13, No 3, pp 209–220.

Kaličiak, M., Repčok, I. (1987) Rekonštrukcia časového vývoja vulkánov v severnej časti Slanských vrchov. In: *Mineralia slovaca*, Vol 19, No 5, pp 401–416.

Kaličiak, M. (1977) *Metalogenetické pomery zlatobanského vulkanického aparátu v severnej časti Slanských vrchov* (dissertation). Košice: Slovenská akadémia vied, Geologický ústav.

Kaličiak, M., Ďuďa, R., Burda, R., Kaličiaková, E. (1976) Geologicko-štruktúrna charakteristika dubníckych opálových ložísk. In: *Zborník Východoslovenského múzea v Košiciach*, pp 7–21.

Kolesar, P. (1996) Konservierung von Pyrit und Markasit. In: *ExtraLapis*, No 11, pp 94–95.

Kotlík, P. (2015) Možnosti konzervace a preventivní ochrany sbírkových předmětů obsahující pyrity. In: *Chemické listy*, Vol 109, No 4, pp 247–253.

Kovalík, A. (1932) *Nerastné bohatstvo Slovenska a Podkarpatskej Rusi*. Trnava: Spolok Sv. Vojtecha.

Lichard, D. G. (1867) Opálové bane pri Červenici. In: *Letopis Matice Slovenskej*, pp 24–32.

Németh, L. (1805) *Reisen durch ungern und einige angränzende Länder* (translation from original in Hungarian by Domokos Teleki). Pesth: Konrad Adolph Hartleben.

Pulszky, F. A. (1847) A vörösvágási nemes opálról. In: *A magyar orvosok és természetvizsgálók Kassa-Eperjessen tartott hetedik nagygyűlésének történeti vázlata*, pp 32–39.

Rondeau, B., Fritsch, E., Guiraud, M., Renac, C. (2004) Opals from Slovakia ('Hungarian' opals): a re-assessment of the conditions of formation. In: *European Journal of Mineralogy*, Vol 16, No 5, pp 789–799.

Ruprecht, L. A. (1789) *Versuch einer Abhandlung über die in der kail. königl. Oberhungari- schen kammeral herrschaft Peklen vorkommende Opal, und Weldt Augen Gebürge, und Andere im Angränzenden Bezirk vorkommende Mineralien* (manuscript). Slovak Mining Archive in Banská Štiavnica. Collection: Hlavný komorskogrófsky úrad, Inv. No. 986.

Ruprecht, L. A. (1789) *Begleitungs Bericht der, über die in der königl. Herrschaft Peklin vorkommende Opalgebürge abgefasten physisch mineralogischen Beschreibung* (manuscript). Slovak Mining Archive in Banská Štiavnica. Collection: Hlavný komorskogrófsky úrad, Inv. No. 986.

Semrád, P. (2009) Opáloví králi: Genealógia rodu Goldschmidt von Libanka, alebo čo vieme o banských podnikateľoch z Dubníka disponujúcich v rokoch 1845–1880 monopolom na ťažbu, spracovanie a komerčné uplatnenie európskeho drahého opálu. In: *Montánna história* (Ročenka o dejinách baníctva a hutníctva), roč. 2, pp 246–297.

Semrád, P. (2011) *The Story of European Precious Opal from Dubník*. Praha: Granit Ltd.

Semrád, P. (2012) *OPAL KINGS – Genealogy of the family Goldschmidt von Libanka* (poster). Praha: Granit Ltd.

Semrád, P. (2015) *Krása drahokamu (Európsky drahý opál z Dubníka) / The Beauty of the Gem (European Precious Opal from Dubník)*. Praha: Granit Ltd.

Semrád, P., Krchnáková, L. (2008) O prenájme opálových baní v Dubníku Gabrielom Fejérvárym v rokoch 1830–1845 vo svetle niektorých menej známych skutočností. In: *Montánna história* (Ročenka o dejinách baníctva a hutníctva), roč. 1, pp 47–59.

Schmidt, F. A. (1834) *Chronologisch-systematische Sammlung der Berggesetze der österreichischen Monarchie* (Dritter Band, Vom Jahre 1579 bis 1606). Wien: Aus der k.k. Hof = und Staats = Aerarial Druckerey.

Skertchly, S. B. J. (1908) *The Story of the Noble Opal*. Brisbane (Queensland, Australia): Flavelle, Roberts and Sankey, Ltd.

Smallwood, A. G. (1997) A New Era for Opal Nomeclature. In: *The Australian Gemologist*, Vol 19, No 12, pp 486–496.

Smallwood, A. G. (2012) *Australian Natural Precious 'Noble' Opal Assessment System Model* (draft 2011–2012). Unpublished manuscript.

Streeter, E. W. (1877) *Precious Stones and Gems, Their History and distinguishing Characteristics*. London: Chapman & Hall.

Szabó, J. (1853) *Jegyzetek az ásvány és vegyipar köréből / írta Londonban az 1851-iki világ iparkiállításon Szabó József*. Pest: László Lukács Ny.

Szabó, J. (1874) A bécsi világtárlat drágakövei (1873) II. In: *Természettudományi Közlöny*, VI kötet, 57. füzet, pp 177–191.

Szabó, J. (1889) A párisi 1889-iki tárlat tudományos szempontból. In: *Budapesti szemle*, 17. évf, 60. köt, 155. sz, pp 161–189.

Szabó, J. (1889) Apró közlemények: Új opállelet Vörösvágáson. In: *Természettudományi Közlöny*, XXI. kötet, 236. füzet, pp 166.

Szeghy, A. (2010) Skonfiškovaná prešovská knižnica a majetok Keczerovcov (Andreja a Gabriela) koncom 80. rokov 17. storočia. In: *Zemianstvo na Slovensku v novoveku* (časť II., Duchovná a hmotná kultúra), pp 123–137.

Szent-Istványi, A. (1874) *Der ungarische Edel Opal* (manuscript). State Archive in Košice. Collection: Štefan Butkovič – personal collection (1788) 1921–1998, Inv. No. 18, sign Op XIII, File No. 8.

Szlujka, G. (1883) A vörösvágás-dubniki opálbánya. In: *Bányászati és Kohászati Lapok*, (Szeptember 15), XVI évf, 18. sz, pp 154–157.

Tavernier, J. B. (1676) *Les Six Voyages du Jean Baptise Tavernier ... qu'il a fait en Turquie, en Perse et aux Indes* (livre second*)*. Paris: Clouzier et Barbin.

Zach von, F. X. (1803) *Monatliche Cor- respondenz zur Beförderung der Erd- und Himmels-Kunde*. Gotha: Verlage der Beckerischen Buchhandlung.

Padparadscha or Pretender: Examination of an Unusual Pink-orange Sapphire

E. Billie Hughes, Chawalit Chankhantha, Andreas Burkhardt, Wimon Manorotkul & Richard W. Hughes

12 February 2016

Abstract: An orangish pink "padparadscha" sapphire was submitted for testing at Lotus Gemology's Bangkok laboratory. Testing showed a number of conflicting features that suggested the gem was a cleverly treated synthetic pink sapphire designed to imitate natural padparadscha.

Figure 1. The 14-ct sapphire that is the subject of this report. Photo by Wimon Manorotkul/Lotus Gemology.

Figure 2. The same stone viewed from the back. One can clearly see the orange color in the fissure, with the pink color from the stone's body. Photo by Wimon Manorotkul/Lotus Gemology.

Introduction

In November of 2015, an orangish pink "padparadscha" sapphire of 14 ct was submitted for testing at Lotus Gemology's Bangkok laboratory. At the time of take-in, the client stated that the gem's origin was Sri Lanka, but the client was unsure of whether or not it had been treated.

Testing showed a number of conflicting features. Large fissures across the stone were filled with unusual orange stains displaying dendrite inclusions, along with needles along twin planes and what appeared to be tiny gas bubbles. Chemical analysis was performed by the Asian Institute of Gemological Sciences' Bangkok lab. The lack of gallium and other features suggested this was a cleverly treated melt-grown synthetic pink sapphire designed to imitate padparadscha.

General properties

Standard gemological testing revealed properties that are typical for corundum, with one exception. The typical ultraviolet fluorescence for padparadscha sapphires ranges from orange to red in both long wave (LW) and short wave (SW), with LW being stronger than SW. However this stone suspiciously showed SW fluorescence equal to that of LW.

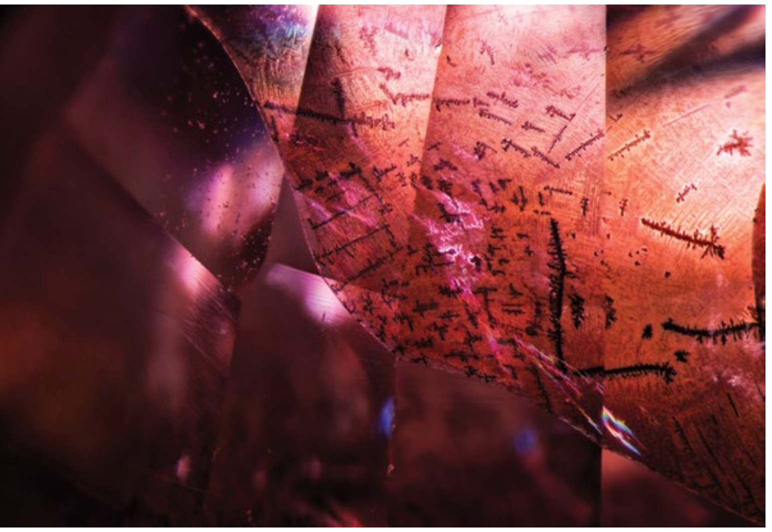


Figure 3. This large orange fissure was the major feature of an otherwise pink sapphire. Photo by E. Billie Hughes/Lotus Gemology.

Figure 4. Another view of the filled fissure with its black dendrite inclusions. Photo by Richard W. Hughes/Lotus Gemology.

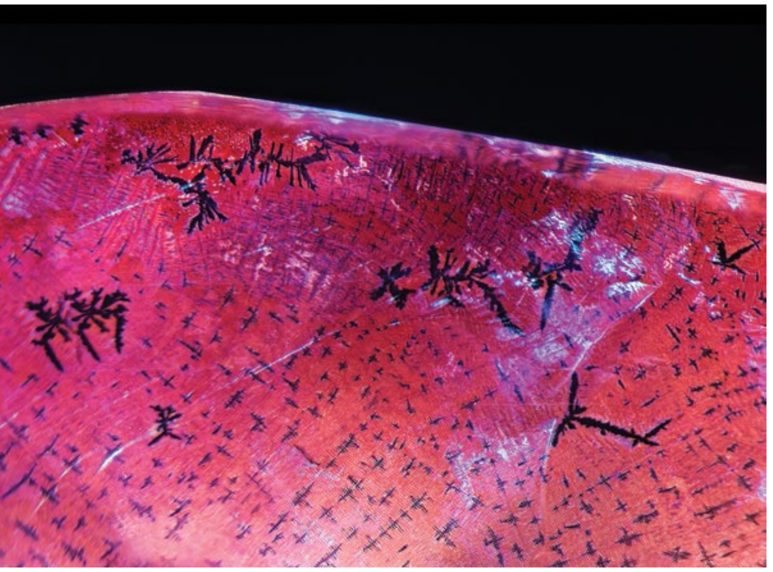


Figure 5. Under magnification, the large fissure displayed a number of unusual features, including black dendrites and a reflective sheen somewhat akin to that seen in glass-filled corundums. Photo by E. Billie Hughes/Lotus Gemology.

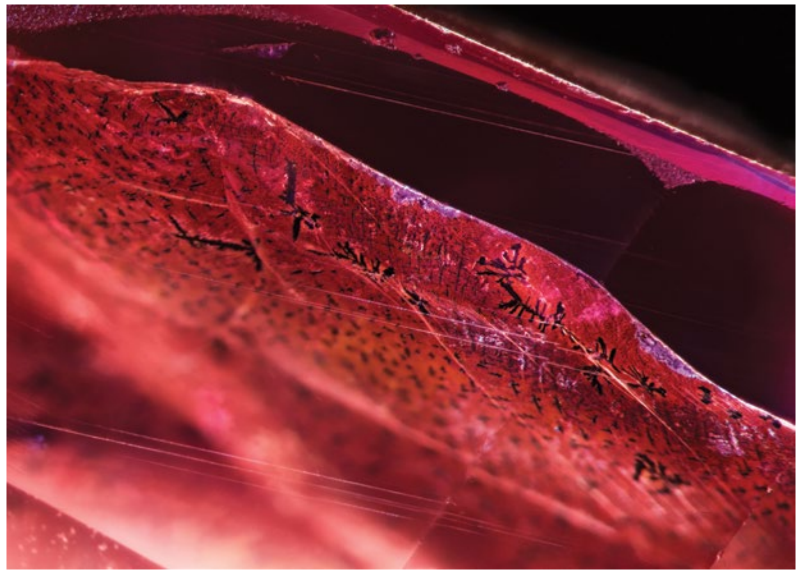


Figure 6. Parallel dislocation needles were seen in a single twin plane just above the fissure. Photo by E. Billie Hughes/Lotus Gemology.

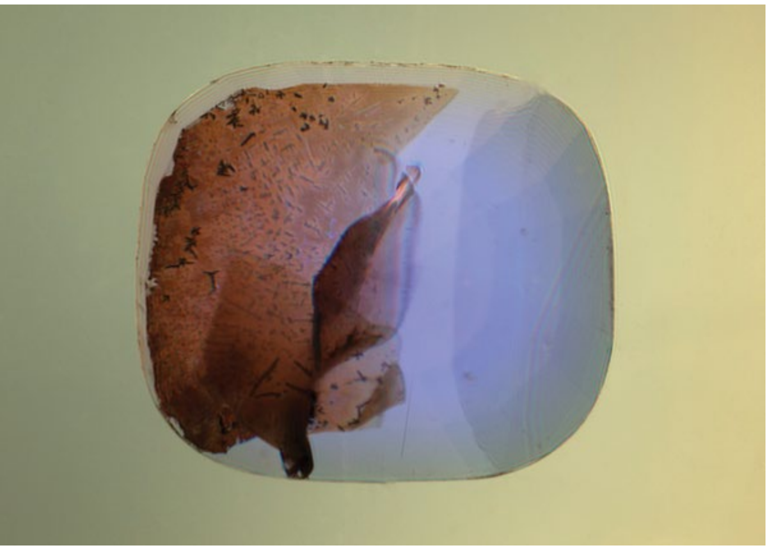


Figure 7. When immersed in di-iodomethane (methylene iodide), the extent of the fissure becomes readily apparent. Adding polarized light reveals Plato-Sandmeier twinning. A dislocation needle can also be seen at the lower center of the stone. Photo by Richard W. Hughes/Lotus Gemology.

Microscopic features

Microscopic examination provided further clues to the stone's identity. The most prominent internal feature was a large orange-stained fissure extending across half the stone (Figure 1). This added an orange color in the otherwise pink stone, superficially causing it to resemble a padparadscha sapphire.

The filling material was also quite unusual, featuring black dendritic inclusions and a glassy surface sheen at certain angles that resembled the filling of lead glass filled rubies and sapphires (Figures 3–5).

Further examination revealed dislocation needles along twin planes (Figure 6). While such needles are typical of natural corundum, on rare occasions they have been seen in synthetic corundums (Eppler, 1964; Hughes, 1997). Immersion between crossed polars revealed Plato-Sandmeier twinning (Figure 7).

More disconcerting was the discovery of two tiny pinpoint inclusions in the pink portion of the stone. These were extremely small, but looked identical to the gas bubbles that are a common feature of melt-grown (Verneuil, Czochralski) synthetic corundums.

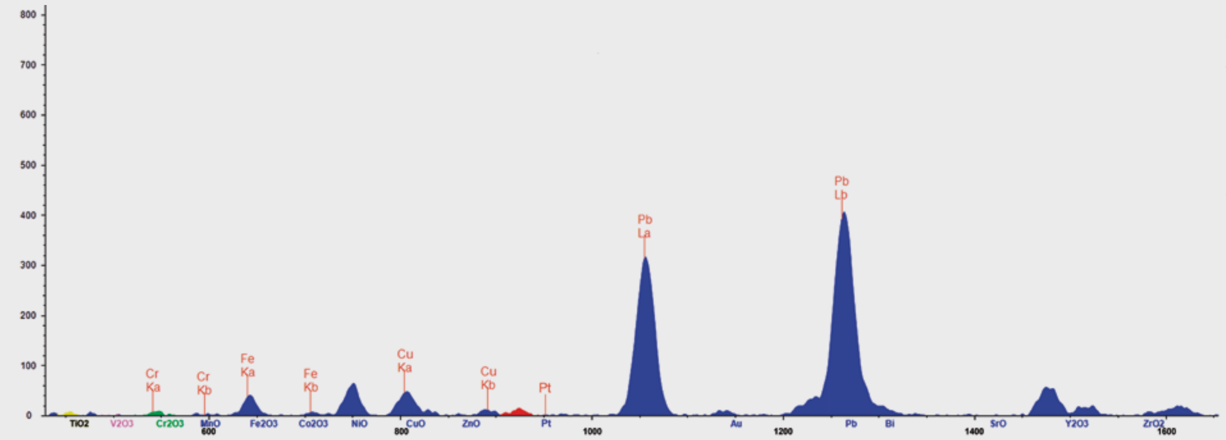


Figure 8. ED-XRF spectrum (45KV) of the fissure revealed unusually high levels of lead (Pb) and copper (Cu).

Advanced testing methods

Non-destructive chemical analysis

The chemical analysis by ED-XRF (Energy-Dispersive X-Ray Fluorescence-Spectrometry) was performed using a Skyray Instrument EDX-6000B spectrometer with rotating table and spin option at AIGS in Bangkok. Full quantitative ED-XRF data with low error rates, high precision and good repeatability are achieved by calibration-curves using certified gem standards. Three different positions were analyzed, with the results given in Table 1.

Two elements are significant in the corundum body, as follows:

- Gallium (Ga_2O_3), which is typically found in all natural corundum, is completely absent; this suggests the stone is of synthetic origin.
- Chromium shows up in concentrations from 340 to 410 ppm (0.035 to 0.041% Cr_2O_3). This produces the pink color.

Two elements of significance were also found in the fissure, as follows:

- While lead was found in tiny amounts (10 ppm; 0.001% Pb) in the non-fracture area, high concentrations of more than 10,000 ppm (1.027% Pb) were seen in the fissure, suggesting it had been filled with lead glass (see Figure 7). Pb-rich glass is commonly used for clarity enhancement of rubies and sapphires (McClure & Smith *et al.*, 2006; Choudhary, 2014; Leelawatanasuk & Susawee *et al.*, 2015).
- Surprisingly, copper was also found in the fissure. We suspect the copper unmixed to form the black dendrites. Artificially created dendrites have also been described in the literature (Fischer, 1991; Johnson & Koivula *et al.*, 2000).

Tungsten (W), platinum (Pt) and gold (Au) are automatically analyzed in corundum measurement routines as well, as they might indicate a synthetic stone made by a crucible growth production (flux, hydrothermal). In this stone, no traces of these metals were detected. Iridium, which is commonly used as a crucible container in the Czochralski process, was also not detected. The presence of low concentrations of chlorine (Cl), potassium (K) and calcium (Ca) in the fissure appear to be components of the glass filler.

According to Muhlmeister & Fritsch *et al.*'s groundbreaking article on trace element analysis of ruby (Muhlmeister & Fritsch *et al.*, 1998), "…the presence of Mo, La, W, Pt, Pb or Bi proves that a ruby is synthetic. Ni and Cu suggest synthetic origin…". While they add the caveat that Ni and Cu could be present in sulfide inclusions in natural rubies, their research strongly suggests that the presence of Pb and Cu by themselves build a strong case for synthetic origin. Adding to this the complete absence of Ga and the conclusion is inescapable: this stone is of synthetic origin.

Table 1. ED-XRF analysis of the gem in three different positions.

Element	Position 1 (body) wt-%	Position 2 (fissure) wt-%	Position 3 (fissure) wt-%
Al_2O_3	99.90	99.42	98.73
Cl	0.000	0.157	0.003
K_2O	0.000	0.010	0.001
CaO	0.000	0.165	0.000
TiO_2	0.000	0.004	0.003
V_2O_3	0.002	0.000	0.000
Cr_2O_3	0.037	0.035	0.041
Fe_2O_3	0.000	0.008	0.001
CuO	0.000	0.006	0.020
Pb	0.001	0.165	1.027
Na_2O, MgO, SiO_2	0.00	0.00	0.00
Sc_2O_3, CoO, NiO, ZnO, Ga_2O_3, W, Ir, Pt, Au	0.000	0.000	0.000

Detection limits: Z/11-14 = 100 ppm, Z/15-92 = 10 ppm (Table 1).

Infrared spectroscopy

The sample's mid-infrared spectrum (Figure 9) showed a series of bands at 2854 cm^{-1}, 2923 cm^{-1} and 2958 cm^{-1}. These bands are due to oil or grease from human fingerprints. The fuzzy and complex bands in the 3500-4000 cm^{-1} region, and the sharp peak at 2354 cm^{-1} resulted from the atmospheric fluctuations such as moisture and CO_2 during the measurement. However, there was an absence of absorption bands related to the hydroxyl group or any hydrous minerals as previously reported in both natural and synthetic sapphires (Volynets & Vorob'ev *et al.*, 1969; Moon and Phillips, 1994; Smith, 1995; Balmer & Leelawatanasuk *et al.*, 2006; Beran & Rossman, 2006; Smith & van der Bogert, 2006).

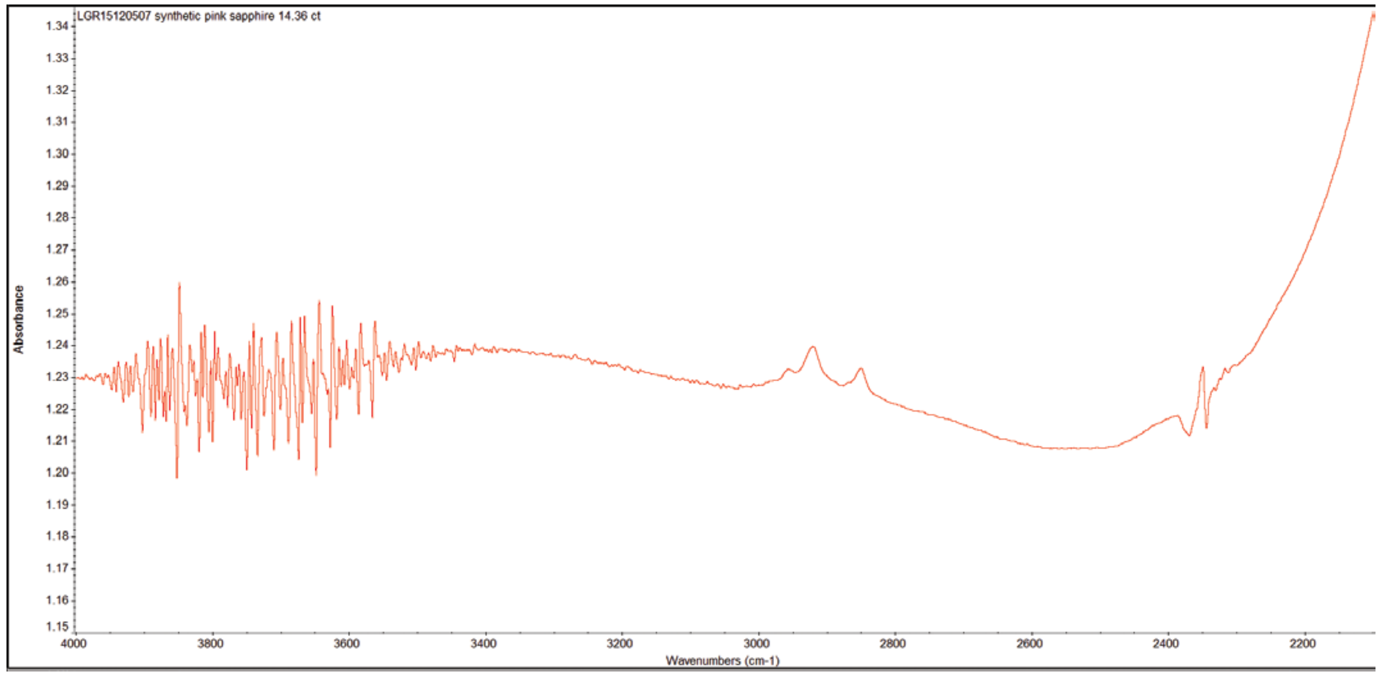


Figure 9. This representative infrared absorption spectrum displays the series of bands due to oil or grease contamination (2800-3000 cm^{-1}), and the atmospheric CO_2 band at 2354 cm^{-1}. FTIR spectrum was recorded in absorbance mode using a Thermo Nicolet iS50 FTIR spectrometer in the range 4000–400 cm^{-1}, with a resolution of 4.0 cm^{-1} and 20 scans. Spectrum: Chawalit Chankhantha/AIGS.

Conclusions

Decades of testing precious stones in the lab have driven home many key lessons. But perhaps none is more important than that of the need to exercise great caution when confronted with a gem that presents contradictory evidence.

The late, great B.W. Anderson once wrote that the most common testing mistake by gemologists was a failure to consider enough possibilities. This was certainly true with this "padparadscha." A hurried look would reveal the orange stains and dendrites in the fissure, and the dislocation needles and twinning would reinforce the view that this was a natural stone. Indeed, some of the junior gemologists who examined it first believed it to be genuine.

But the patient gemologist would reserve judgment, taking note of the unusual UV fluorescence (why is SW equal to LW?), the two tiny pinpoint inclusions (gas bubbles or crystals?) and the twinning (natural or Plato-Sandmeier type?).

Further testing would reveal trace-element chemistry in the pink portion of the stone that lacked gallium. In contrast, significant quantities of Pb and Cu were found in the fissure, with the Cu possibly unmixing as dendrites. The result of the full collection of data is unmistakable—a "padparadscha" unmasked as a cleverly crafted pretender—a Verneuil melt-grown synthetic pink sapphire that had been artificially fractured and then had the fissure filled with a Pb-rich glass with traces of Cu.

References & further reading

Balmer, W.A., Leelawatanasuk, T., Atichat, W., Wathanakul, P., and Somboon, C. (2006) *Update on characteristics of heated yellow sapphires.* Poster, Proceedings of the 1st International Gem and Jewelry Conference, 3 pp.

Beran, A., and Rossman, G.R. (2006) OH in naturally occurring corundum. *European Journal of Mineralogy*, Vol. 18, No. 4, pp. 441–447.

Choudhary, G. (2014) Gem News International: Yellow sapphire filled with lead glass. *Gem & Gemology*, Vol. 50, No. 1, Spring, pp. 92–93.

Eppler, W.F. (1964) Polysynthetic twinning in synthetic corundum. *Gems & Gemology*, Vol. 11, No. 6, Summer, pp. 169–175.

Fischer, G.W. (1991) *Gemstone & Chemicals: How to Create Color and Inclusions.* No city, self published, 74 pp.

Hughes, R.W. (1997) *Ruby & Sapphire.* Boulder, CO, RWH Publishing, 512 pp.

Johnson, M.L., Koivua, J.I. *et al.* (2000) Gem News International: Unusual treated chalcedony. *Gems & Gemology*, Vol. 36, No. 2, Summer, pp. 170–171.

Leelawatanasuk, T., Susawee, N. *et al.* (2015) Green lead-glass-filled sapphires. *Journal of Gemmology*, Vol. 34, No. 5, pp. 420–427.

McClure, S.F., Smith, C.P. *et al.* (2006) Identification and durability of lead glass-filled rubies. *Gems & Gemology*, Vol. 42, No. 1, Spring, pp. 22–34.

Moon, A.R. and Phillips, M.R. (1994) Defect clustering and colour in Fe, Ti: aAl_2O_3. *Journal of the American Ceramic Society*, Vol. 77, No. 2, pp. 356–367.

Muhlmeister, S., Fritsch, E. *et al.* (1998) Separating natural and synthetic rubies on the basis of trace-element chemistry. *Gems & Gemology*, Vol. 34, No. 2, Summer, pp. 80–101.

Schmetzer, K. and Schwarz, D. (2004) The causes of colour in untreated, heat treated and diffusion treated orange and pinkish orange sapphires – a review. *Journal of Gemmology*, Vol. 29, No. 3, July, pp. 149–181.

Smith, C.P. (1995) A contribution to understanding the infrared spectra of rubies from Mong Hsu, Myanmar. *Journal of Gemmology*, Vol. 24, No. 5, Jan., pp. 321–335.

Smith, C.P. and van der Bogert, C. (2006) Infrared spectra of gem corundum. *Gems & Gemology*, Vol. 42, No. 3, Fall, pp. 92–93.

Volynets, F.K., Vorob'ev, V.G. *et al.* (1969) Infrared absorption bands in corundum crystals. *Journal of Applied Spectroscopy*, Vol. 10, No. 6, pp. 665–667.

Corresponding authors

E. Billie Hughes
Lotus Gemology Co. Ltd.
Silom 19 Bldg, Suite 411
45/1 Soi 19, Silom Rd
Bangkok 10500 Thailand
Email: *billie@lotusgemology.com*

Chawalit Chankhantha
AIGS Laboratory
919/1 Jewelry Trade Center,
Level B1 (Unit B24), Silom Rd
Bangkok 10500
Thailand
Email: *charles@aigsthailand.com*

Ethiopian Opals: Facts, Fears and Fairytales

Jeffery Bergman, with Barbara Wheat

Unless otherwise noted all images are by the author.

Introduction

Legend has it that Ethiopia's Queen Sheba adorned herself with precious opal when she visited King Solomon in Jerusalem. The first known evidence of human use of opal dates back approximately 6,000 years (Gebremedhin, K 2014). In 1939, archaeologist Dr. Louis Leakey uncovered opal artifacts in a cave in Nakuru, Kenya dating back to 4000 BC, according to Allan Eckert's book *The World of Opal*. These opals were most likely from Ethiopia (www.opalsdownunder.com 2015).

Facts

In modern times, opal was discovered in Ethiopia in the early 1990s at Mezezo in the Shewa Province. Nodules of a reddish brown volcanic host rock were found containing orange, reddish brown, or "chocolate" brown precious opal, a significant percentage of which was prone to cracking (Filin, S., Puzynin, A., 2009) (Figure 3).

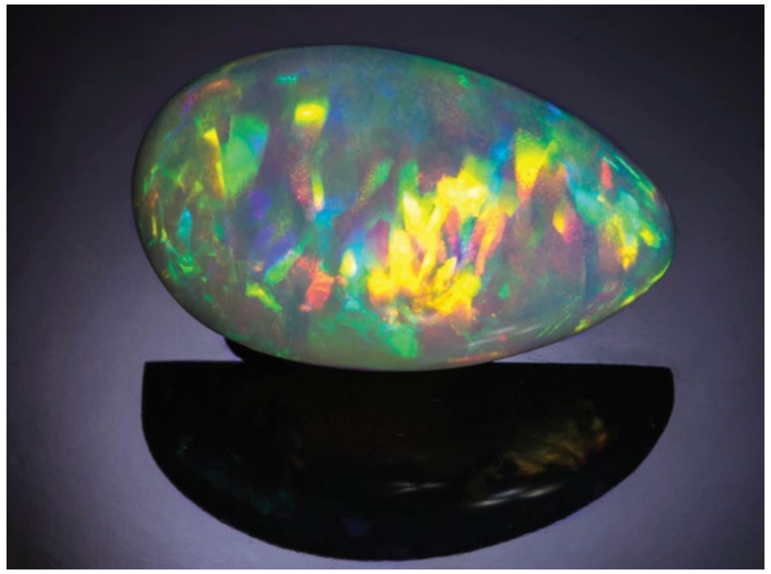


Figure 1. An exceptional Wollo opal from New Era Gems. Photo by Jordan Wilkins.

Figure 3. "Chocolate" opal nodules from Mezezo, Shewa Province. Photo by T. Coldham.

Figure 2. Opal mining areas in Ethiopia.

Figure 4. Assorted Wollo opals courtesy Gilt Co. Ltd.

In 2008, at Wegel Tena in Welo (aka Wollo) Province, large quantities of white and crystal precious opal and occasionally some black material were discovered; reports indicate it is "every bit as stable as the better known Australian opals" (Young, J. 2011) (Figure 4.).

Figure 5. While most Ethiopian black opal on the market is smoke treated, natural black is also available. This material has been reported as non-hydrophane (Kiefert, L., Hardy, P. (2015).

In 2013 at the Stayish mine, Gashena, in Welo province, mostly dark gray and black opal, along with some white and crystal opal was discovered (Kiefert, L., Hardy, P. et al, 2014). This new material is reported to be stable and not hydrophanic (Kiefert, L., Hardy, P. 2015; Weinberg, D. (2015) (Figure 5).

The Ethiopian artisanal mining industry employs more than one million people. The major types of gemstones found in Ethiopia include garnets, emeralds, rubies, and opals. Opal accounts for nearly 98 percent of the precious stone exports of the country (Bekele, K. 2014). The volume of opal production from Ethiopia has been enormous. Combined production for 2011 and 2012 are estimated at 40 tonnes (Bekele, K. 2013). Based on a conservative 20% yield, this could have produced 40 million carats of cut opals.

Twenty-seven countries are reportedly buying Ethiopian opal with India, China and the United States the leading customers (Yonick, D. (2011). One need only walk around a major international trade show to comprehend the overwhelming volume of cut Ethiopian opal now on the market, so much so that it dwarfs what is currently available from Australia (Figure 6). In fact, Ethiopia may now have overtaken Australia as the world leader in opal production.

In 2010, Australian opal miner Peter Blythe wrote: "At the possible wrath of some Australian opal lovers I dare to make this statement. If this field is as extensive as it may well be, perhaps in the future, Australia could lose its dominance in the light opal market. People in our industry must stop using the line 'Australia produces 95% of the world's opal' This is simply no longer true" (Blythe, P. 2011). From the author's experience, Ethiopian opals sell at steep discounts over Australian material of similar sizes and similar appearance. This equates to about 50% less in smaller sizes of the cheapest goods up to as much as 90%

Figure 6. One of the many dealer showcases at the September 2015 Hong Kong show filled with Ethiopian opals in a wide range of sizes and qualities.

Figure 7. Gem grade Ethiopian beads.

Figure 8. Orange, blue and black dyed opal beads, and natural colors.

less in larger and finer qualities. Most of the opals on offer at the Bangkok and Hong Kong September shows fell in the US$10-$50/carat price range, although material as low as $2/carat and as high as $200/carat was available. Many of the best-quality Ethiopian opals "exhibit brilliance on a scale not seen since the early Andamooka, South Australian productions," wrote George Williams, JTV Senior Gemstone Buyer (Williams, G. 2011). Rare and truly exceptional pieces can sport Australian level price tags. Exhibiting in the Fine Gem Pavilion at Hong Kong AWE, A. Kleinman & Company offered a stunning piece at $650 per carat. An 100.11 carat Ethiopian opal was featured in an elaborate jewellery clip named "Paysage d'Opale" from the California Rêverie Collection by Van Cleef and Arpels, Place Vendôme, Paris (Cristol, A. 2016).

The sudden availability of unprecedented quantities of beautiful opal at prices far lower than what the market had come to expect has invigorated demand for opals around the world. This bounty is also quite evident in beads, a product rarely available in Australian goods, but now plentiful in Ethiopian material ranging from low-grade white opal to multi-color dyed beads (Figures 7, 8).

Fears

Historically, opal has been regarded as more fragile than most other gemstones (www.opalsdownunder.com.au 2016). Being relatively soft compared to some other gems also means it can scratch quite easily. It is also known to be brittle causing it to chip quite easily upon only minor impact. But the most bothersome habit is opal's tendency to spontaneously crack or "craze". This dreaded phenomenon is encountered to a greater or lesser extent in opals from every source in the world with, in the author's experience, the possible exception of Andamooka, South Australia (www.gia 2016).

Australian opal's excellent reputation is due in great part to generally minimal cracking or crazing, as well as diligent producers who eliminate problematic material, not allowing it to make it to market. With an over 100-year track record, Australian opals set the benchmark for the trade, a standard by which opals from all other sources are judged.

Early production of material from Mezezo in the Shewa province quickly gained popularity as the world's first chocolate colored opal, but much of it had a bad habit of cracking and/or crazing (Figure 3). News of this material's tendency to self-destruct spread rapidly, and a general fear of Ethiopian opal was instilled in dealers around the world.

Attempts to stabilize Mezezo material even resulted in the issuing of patent #US20110126815 filed on Nov. 30, 2010. This multi-stage process requires a full year to complete, and its effectiveness has never been documented (www.patentorg.com 2016). SSEF laboratory in Basel, Switzerland, examined two resin-treated nodules from Shewa in 2011, and one of them fell apart while it was in the lab's possession (Krzemnicki, M., 2011).

In 2009, *The Australian Gemmologist* magazine reported a stability treatment technique for cabochon-cut Shewa opals involving immersion in anhydrous ethanol in a pressure-tight vessel (autoclave), slowly heating to 80°C and maintaining at that temperature for about a week resulting in supercritical drying. In the second phase of the process, hydrated low- molecular weight silica sols were introduced into the open pores of the opal conducted under pressures of 500 to 600 bar, (i.e. from 500 to 600 times ordinary atmospheric pressure) after a preliminary vacuum treatment of the samples (Filin, S., Puzynin, A., 2009).

Figure 9. Ethiopian opals immersed in water demonstrating their typical hydrophane nature. The photo on the left is after immersion for one minute and on the right after 60 minutes.

Figure 10. Assortment of color-dyed Ethiopian hydrophane opals including smoke treated black.

After treatment, a far lower susceptibility to cracking was reported in this Shewa material, though the editor did note: "Since there is no published standardized test to assess comparative opal-crazing susceptibility, it is difficult to quantitatively demonstrate that these cabochon specimens showed enhanced stability to crazing relative to untreated examples of portions of the same material other than by subjective comparative experience" (Filin, S., Puzynin, A., 2009) Commenting on this complex hi-tech procedure, it was reported in GIA's *Gems & Gemology*, "A stabilization process has been developed to prevent crazing of Ethiopian opal (Filin and Puzynin, 2009), but in our experience this appears unnecessary for translucent opals from Wegel Tena" (Rondeau, B. et al. 2010).

Regarding the toughness issue, Bear Williams of Stone Group Laboratory said: "Widely sold as nice crystal, opal is also tough and stable enough to be treated with smoke and heat and not craze. After treatment, I dropped a smaller, round Wollo opal from seven feet onto a hard tile floor. Most opal, including Australian, would crack; even a diamond might cleave, but this thing bounced back without damage" (Yonick, D. 2011).

GIA has reported similar test results stating "We noticed by accident that Wegel Tena opals could sustain a fall from 1.5m onto a concrete floor with no visible damage, even under the microscope. Repetition of this test on five oval cabochons did not produce any sign of damage. The same experiment with five oval cabochons from the Mezezo deposit and three oval cabochons of white opal from Australia (including one boulder opal) led to breakage of all samples" (Rondeau, B. et al. 2010). Preliminary tests from two respected gemological laboratories indicates opal from Wegel Tena, Wollo, is considerably tougher than Australian opal.

Mike Romanella, partner in Commercial Mineral Company, Scottsdale, Arizona, notes that although the Wollo opal does not have the 100 years of proven history that the Australian opal has, his two-year experience with the material has been positive. "We've seen little crazing in the tens of thousands of pieces we've worked with, and we've had no returns from our customers" (Yonick, D. 2011).

The last great concern is Ethiopian opals' varying degree of hydrophane effect (the ability to absorb water) ranging from insignificant to dramatic (Figure 9). Material from Wollo is reported to gain from 0% weight when immersed in water with up to 50% in a few extreme cases (Bekele, K. 2013). In the author's experience, most of it is moderately hydrophane gaining from 5-15%.

Although there have been some reports of cracking as a result of repeated hydration and drying of Welo material, Stone Group Laboratories conducted rigorous testing and reports: "When many stones were immersed and then left to dry repeatedly (12 times), there was no cracking or change from their original appearance. The laboratory subjected smaller stones to high heat in order to rapidly dehydrate water-soaked stones and found them to be stable even under these conditions" (Williams, G. 2011).

The hydrophane characteristic does cause concerns for consumers who unwittingly allow their hydrophane opals to come into contact with liquids other than pure water. In the author's experience, oils of any type, perspiration included, can permanently reduce or even eliminate the beautiful play-of-color.

The hydrophane effect also presents the opportunity to easily introduce a variety of colored dyes into the structure of the opal resulting in some rather stunning artificial colors, including the coveted black. Vivid pinks, greens and blues are rather easy to spot; oranges and reds can be a bit trickier as they mimic fine naturally colored fire opal from Mexico and Brazil (Figure 10).

Natural black opal was discovered in 2013 at the Stayish mine, Gashena, in the Welo province (Figure 5). This material has a distinctly different appearance from Australian black opal and looks quite similar to the smoke-treated material from Welo. *InColor* Spring 2015 reported: "Preliminary testing at the Gübelin Gem Lab in Switzerland revealed that thus far this new material shows no evidence of porosity, which would therefore exclude it from being categorized as hydrophane" (Kiefert, L., Hardy, P. 2015).

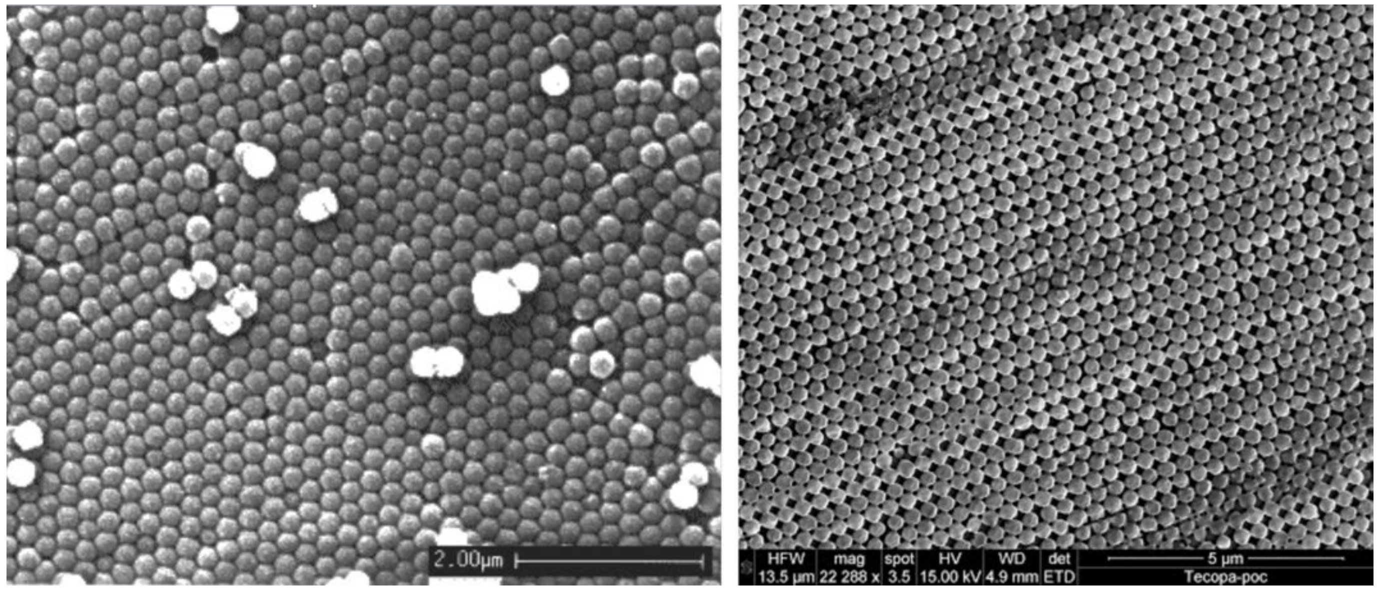
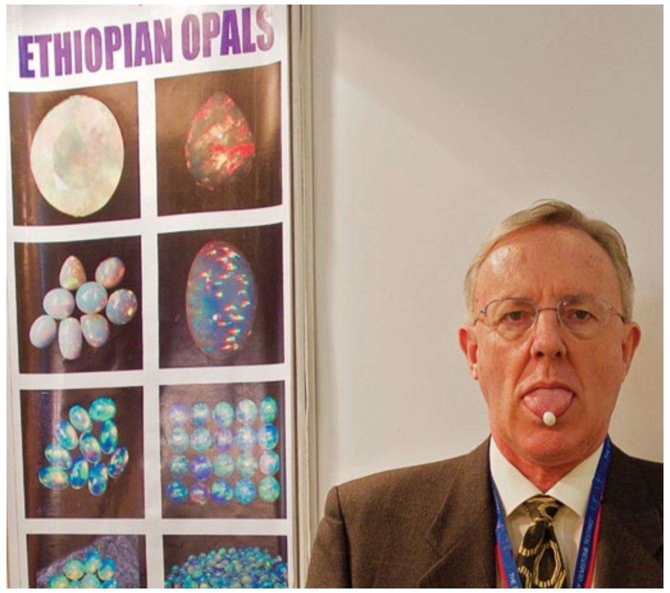


Figure 11. Left: Orderly and tightly packed silica spheres in non-hydrophane waterproof gem quality Australian opal (CalTech). Less tightly packed spheres lacking cement in very porous liquid-absorbing hydrophane opal from Tecopa, California on the right (NHMLAC).

The hydrophane characteristic of Ethiopian opal is due to its internal structure. Typical non-hydrophane waterproof opal is composed of silica spheres orderly arranged in a tightly compacted fashion that does not allow water molecules to penetrate. In contrast, the silica spheres in hydrophane opals are unstructured and random providing ample space for water and other liquids to be absorbed (Figure 11).

Initial fears of crazing after repeated water immersion and drying cycles proved largely unfounded. GIA reported "There was no change in appearance (color, diaphaneity, crazing, or play-of-color) in the samples that were submitted to alternating periods of immersion in water. One customer who wears her opal constantly complained that it became more transparent when she took a shower, swam, or otherwise put her hands in water. She recognized, however, that the opal always returned to its original appearance after some time (depending on the duration of immersion)—which is due to its hydrophane character" (Rondeau, B. et al. 2010).

Some in the trade have suggested re-categorizing hydrophane opal. Reporting for *Rapaport* magazine, Deborah Yonick wrote, "Wollo opal should be recognized as a new type because it can absorb or lose water, affecting transparency and play-of-color when wet, but recovering all its qualities when dry," report researchers. They describe this new Ethiopian opal find as different from the opals of Shewa Province.



Laboratory testing of the Wollo opal revealed most specimens were resistant to crazing after repeatedly being immersed in water and dried out over a period of time. Not only are they stable, researchers say, they're surprisingly tough (Yonick, D. 2011).

Testing for the hydrophane effect is a rather simple matter. GIA suggested, under a microscope "simply place a single drop of water on the surface and observe how the water drop interacts with the opal. After a few seconds of allowing the water to either evaporate or soak into the stone, reexamine the appearance. If the water is absorbed into the stone, that area's refractive index will be slightly different, creating an optical aberration where the drop is placed and confirming that the stone is hydrophane" (Renfro, N. 2013). Another hydrophane opal test protocol affectionately named the KISS method is to simple to touch the opal to the tongue, the degree of absorbency can be roughly judged by just how strongly the stone adheres (Figure 12).

Opal expert and ICA member Francesco Mazzero of Opalinda raised an important point. This weight change could present a problem if one is dealing with a meticulous customs department who insist on weighing opals being imported. From personal experience, in August 2015 the author submitted several samples of Ethiopian opal to the GIA laboratory in Bangkok for examination with a check in weight of 23.57 carats. The check out weight was 23.43 carats, and GIA required the author sign a waiver acknowledging the 0.14 carat discrepancy before release.

The weight difference can be accounted for by the fact that August is mid-rainy season in Thailand so relative humidity is rather high. A few weeks in the air conditioned GIA lab atmosphere with a lower relative humidity induced a drying effect resulting in the weight loss. Shipping from a humid environment like Bangkok or Hong Kong to a dry climate like Madrid, Spain or Tucson, Arizona, could result in a significantly lower weight upon arrival, presenting potential problems if a customs dispute were to develop. Documenting this effect provides dealers with evidence they may one day find useful.

Figure 12. Hydrophane opal test protocol affectionately named the KISS method; if it still absorbs water, it is not waterproof and therefore not polyurethane resin treated. (Photo by Barbara Wheat)

% = weight after 5 minutes immersion in water minus dry weight divided by dry weight x 100.

below 0,01	0,01 to 0,5	0,5 to 2	2 to 4	4 to 10	10 to 20	over 20
practical zero	**very low**	**low**	**medium**	**high**	**very high**	**extreme**

Figure 13. Opalinda recommends opals with a medium hydrophane effect or less for jewelry use.

Figure 14. Top: Two of the three White-based polished Ethiopian hydrophane opals being fully saturated with red wine (left) and coffee (right). Bottom: The two stones after drying along with the untreated control displaying no discoloration after drying.

Mazzero insists on testing all the Ethiopian opals his company sells for the degree of hydrophane effect they exhibit, and has developed a seven-point scale for comparison. Weighing the opal dry, it is then immersed in water for five minutes and re-weighed (Figure 13)

The hydrophane factor is calculated by: wet weight minus dry weight, divided by the dry weight, times 100. For example, a 10.00 carat dry opal weighs 10.10 carat after five minutes of immersion. 10.10 minus 10.00 = 0.1 ÷ 10 X 100 = 1.

In addition to this measurement, Mazzero provides a lab report from Laboratoire Français de Gemmologie documenting the dry weight and the differing weight after immersion in water for five minutes. (Pers Com 2015)

Fairytales

Social media has become a powerful means of disseminating information, both facts and fairytales. In August of this year on the Facebook discussion group Scamologist, with over 7,000 members (at the time), one of the moderators made the statement that "nearly all" Ethiopian opals are resin treated to stabilize them against cracking".

As a former cutter of Australian opal, I've had thousands of stones pass across my dopsticks. In the mid-90s I performed research on synthetic opals stabilized by plastic impregnation that was published in *Gems & Gemology*. (Gem News 1995)

When Welo opals first arrived in Bangkok, I acquired a small selection of rough and cut stones for my personal collection; I do not sell Ethiopian opal.

Being an opal cutter, I have paid close attention to the boom of availability at the Tucson, JCK Las Vegas, Bangkok and Hong Kong shows over the past several years. Armed with my somewhat experienced background, I suspected there was something seriously wrong with the *Scamologist* moderator's statement, and challenged it. Much to my surprise, a prominent Australian opal dealer and industry leader chimed in on *Scamologist* to support the statement writing "most of it has been stabilised with clear polyurethane like materials" and "Most Ethiopian cut opal on the market is undoubtedly stabilised."

Survey

Setting out to find evidence one way or another, I surveyed five dealers in Bangkok's Jewelry Trade Center (JTC). None of them had any resin-treated "waterproof" opals available. I performed a sampling hydrophane test and the results of my rather limited survey were revealed at the 96th GIA Gem Gathering on August 19, 2015 in Bangkok.

Survey Plus

The response on Scamologist was that my study group was too small, saying, "I know many of the traders at the major shows. They stabilise them." It was suggested a more appropriate study group would have been 25 dealers at the Hong Kong and Tucson shows. Since the Tucson show was five months away, I proceeded to carry out "Survey Plus", visiting over 40 sellers of Ethiopian opal at the September 2015 Bangkok and Hong Kong shows. In order to avoid any suggestion of bias, I enlisted former ICA Executive Director Barbara Wheat as overseer of the new and improved survey.

In order to "smoke" out the elusive resin-treated opals, we told each dealer we had a major TV marketing company looking for large quantities of resin-treated waterproof Ethiopian hydrophane opal (which was actually true) and asked if they could supply us with any samples. Every dealer contacted stated that their Ethiopian hydrophane opals were not waterproof and did indeed absorb water. While all were forthright in pointing out which material in their inventory was dyed, not one could provide us with even a single sample of a resin-treated opal. Indeed, none of them had even heard of such a treatment.

Spill the Wine

But back to the Scamologist. One comment was "Imagine if Mr. Bergman's tests were conducted with red wine rather than water. What sort of a mess would he be showing in his results"? Grasping the thorn tree, I did exactly as the Scamologista suggested, and, as I am a glutton for pain, added coffee, as well.

Three of the whitest polished Ethiopian opals I could find were chosen for the experiment since the white base would best contrast staining by wine and coffee. The opals were first weighed, immersed in water until fully saturated then re-weighed in order to determine their relative hydrophane effect. One absorbed about 8% and the other two 14% and 15% of their original weight. The two opals with the greater hydrophane effect were chosen for the test, while the third was kept as a base-color matching control sample.

The opals were allowed to dry until they returned to their original weight, placed in red wine and espresso coffee, and left to absorb the wine and coffee until fully saturated. They were then allowed to dry until they returned to their original weights. There were no visible changes in either of the opals, which had fully absorbed either red wine or coffee (Figure 14).

Figure 15a. Rough Ethiopian opal. Top: Low hydrophanity Ethiopian opal, Centre: Same stones fully dried out, Left: after soaking in wine, Right after soaking in coffee.

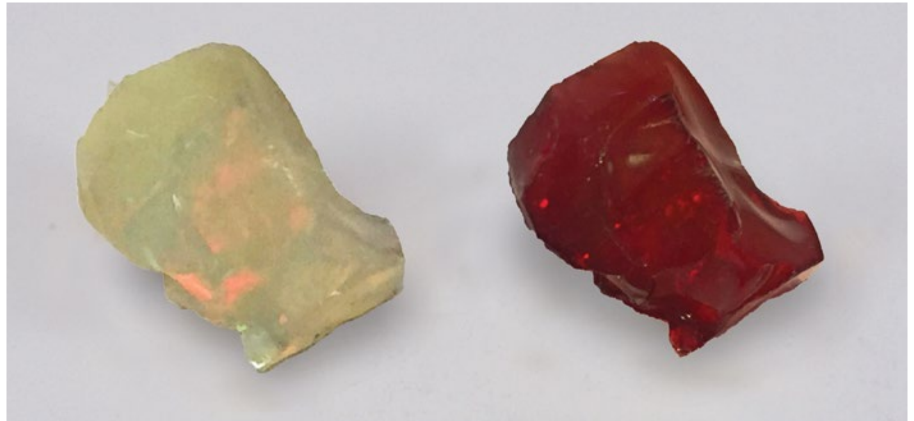


Figure 15b. Left: High hydrophanity Ethopian opal, Right: Same stone fully dried out after soaking in wine.

In similar experiments using rough hydrophane opal, I found that red wine was readily absorbed into material with high hydrophanity (27% weight gain) and the pigment remained after drying (Figure 15 a & b). Wine slightly tinted the surface, but did not change the body color of low-hydrophanity material (6% weight gain), leading me to believe particle size of the colouring compound may play a role. Polishing could be also responsible for creating a surface sealing effect that prevents larger coloring particles from penetrating while allowing small water molecules to saturate the stone. These seemingly contradictory differences between rough and cut material being colored, nor not colored by wine have also been reported by Terry Coldham (Per Comm) and require further investigation.

While the concept of resin treating Ethiopian hydrophane opal initially sounds like a good idea, in practical reality it has yielded unsatisfactory results. Probably the most important point was raised by the GIA, who concluded resin treatment is "unnecessary for translucent opals from Wegel Tena" (Rondeau et al. 2010).

Figure 16. Left: The Ethiopian hydrophane opal before non-branded two-part polyurethane resin treatment. Right: The same stone after treatment that resulted in severe clouding rendering a previously valuable opal worthless.

Treatment detection by gemological laboratories is always a concern to both dealers and consumers. With the discovery of hydrophane opal in Ethiopia, the potential for polyurethane, other resin or oil treatments has certainly increased. According to Shane McClure, the GIA's Director of Identification Services, "GIA has seen some, but not many and I believe most of them were treated with oil" (Sturman, 2015).

I repeated the Ethiopian hydrophane opal resin treatment experiment on cut opals with a non-branded two-part polyurethane resin and a UV cure windscreen repair resin both available in Bangkok. The undesirable clouding developed in both cases and was quite severe with the non-branded two part polyurethane resin rendering the specimen unsalable (Figure 16).

Resin treatment is a concern when dealing with opals from any source, as it is an effective means of reducing the visibility of cracks. In order to be able to fairly compare results, I chose a cracked Australian opal from my collection, purchased a similar size, shape and color Ethiopian hydrophane opal and heated it to induce cracks. Both opals were then immersed in water for 24 hours. The Australian opal demonstrated no weight gain, while the Ethiopian hydrophane opal gained about 8%. Both opals were then kept in a dry environment for 24 hours, with the Ethiopian hydrophane opal subsequently returning to its original weight.

Both opals were then placed in Opticon® Resin No. 224 fracture sealer and heated to 80°C for one hour, then placed in a vacuum to 27mm Hg. This cycle was repeated three times. The opals were then left in the Opticon for 24 hours, removed, cleaned with paper towels and immersed in the hardener solution for 10 minutes, removed and cleaned again with paper towels and left to "cure" for 24 hours before final examination.

The Australian opal showed a slightly noticeable decrease in visibility of the cracks with no change in play-of-color. The Ethiopian hydrophane opal showed a more distinct reduction in visibility of the cracks, although they were still detectable upon close inspection. There was also a greater than 50% reduction in play-of-color (Figure 17).

In addition to this undesirable effect, the Ethiopian hydrophane opal developed an egg-shaped cloud in one half of the stone, as well as hundreds of small snowball-like puffy white inclusions dispersed throughout the stone, barely visible to the naked eye, but readily seen through 10X magnification (Figure 18).

Mikko Åström of M&A Gemological Instruments (which manufactures Raman, FTIR and UV-Vis-NIR spectrometers) provided the following information. (Per Comm).

"An important part of the system provided with each instrument is gemology-oriented software, including libraries of gem reference spectra. These libraries must be absolutely accurate, as many gemological laboratories and individual gemologists rely on them. At M&A each sample inserted into the library is carefully tested with multiple instruments, and in cases where there is any deviation of the data compared to scientific publications, it is abandoned.

Visible spectrum laser Raman technology is often inconclusive due to photoluminescence caused by traces of uranium in opal that masks any Raman peaks generated by polymers. However, FTIR is an effective tool for differentiating most natural opals from their synthetic counterparts. It can detect water in natural opal, which is very uncommon in synthetics. It can also detect polymers used in the manufacturing process of many synthetic opals for stabilizing the material. Similarly, the infrared transmission window of opal happens to be located conveniently at the area where absorption of many polymers, resins and other organic molecules can be detected.

M&A have been trying to find resin impregnated Wollo hydrophane opal from within the market for more than a year, for the purpose of inserting its spectrum into the FTIR-library. This search process has included numerous gem shows around the world including Tucson, Basel and Hong Kong. The sourcing of dyed (artificially colored) hydrophane opal has not been difficult at all, but locating resin-impregnated samples has proved to so far be impossible.

After failing to find a suitable reference sample, M & A made the decision to buy some hydrophane opal and treat it themselves. Rough hydrophane samples were purchased from a seller known to market Ethiopian material. The hydrophane nature of the sample to be treated was confirmed by water droplet test under a microscope (G&G Fall 2013, Nathan Renfro). The sample was cut into two pieces with pliers: one was treated with Hughes Associates Opticon-224 resin, while the other was left intact for reference.

The opal sample was immersed in resin for 6 days at slightly elevated temperature. No hardener was used. The treated stone was then cut free-form, with a faceting machine in order to make sure any polymer related absorptions were recorded from the actual opal material itself and not from any surface contamination. Then another water drop-test was performed before acquiring the FTIR-spectrum. The result revealed the sample had no characteristics of hydrophane nature anymore."

Figure 17. In each image a cracked Australian opal on the left and a cracked Ethiopian hydrophane opal on the right. Left: Fully saturated with water. Centre: Dry. Right: After Opticon treatment. This demonstrates the reduced visibility of cracks, and significant loss of play-of-color in the Ethiopian hydrophane opal.

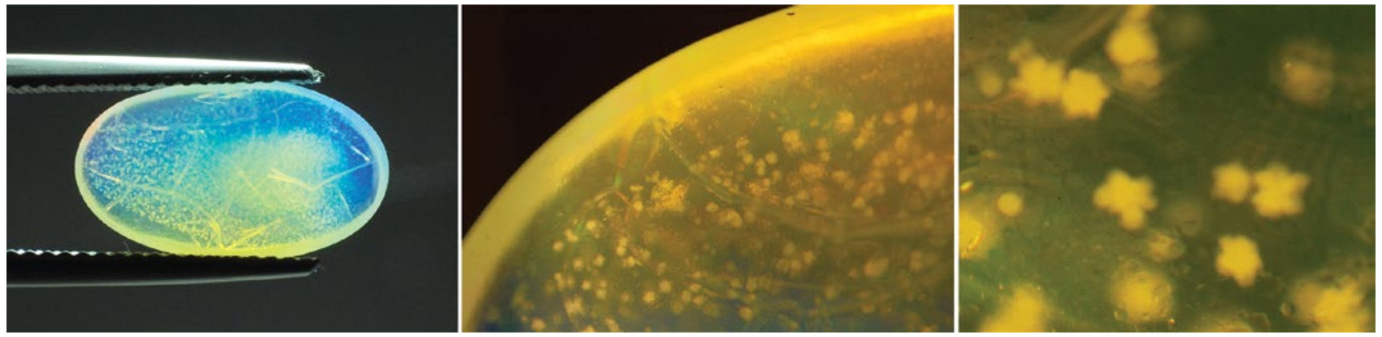


Figure 18. Hundreds of snowball-like inclusions induced by Opticon resin treatment of Ethiopian hydrophane opal Left: under 1X, Center: 20X, Right: 80X.

At Tucson 2016, a reputable dealer in Ethiopian opal was identified as possibly selling resin treated material. Geoscience professor Veronica Poteat visited their booth and randomly selected 38 Ethiopian opals of varying qualities from the dealer's stock for water absorption testing. After 20 minutes in water, all but one had gained weight, empirical proof that 37 out of 38 were definitely not resin treated.

Gemology is about verifiable scientific evidence, not unsubstantiated rumours and hearsay. Touching an opal to your tongue to demonstrate it is hydrophane and not waterproof resin treated is just as scientific as testing it with high-tech equipment. Whilst performing the tongue test, one of the opals stuck so strongly it was actually painful to remove. Under the oversight of author and gemologist Antoinette Matlins, we purchased the opal Professor Poteat identified as not being absorbent, along with 6 others of assorted sizes and qualities. Antoinette Matlins hand delivered them to Alberto Scarani of M&A Gemological Instruments Ltd. for advanced FTIR testing, who reported none showed any sign of resin treatment (Figure 19).

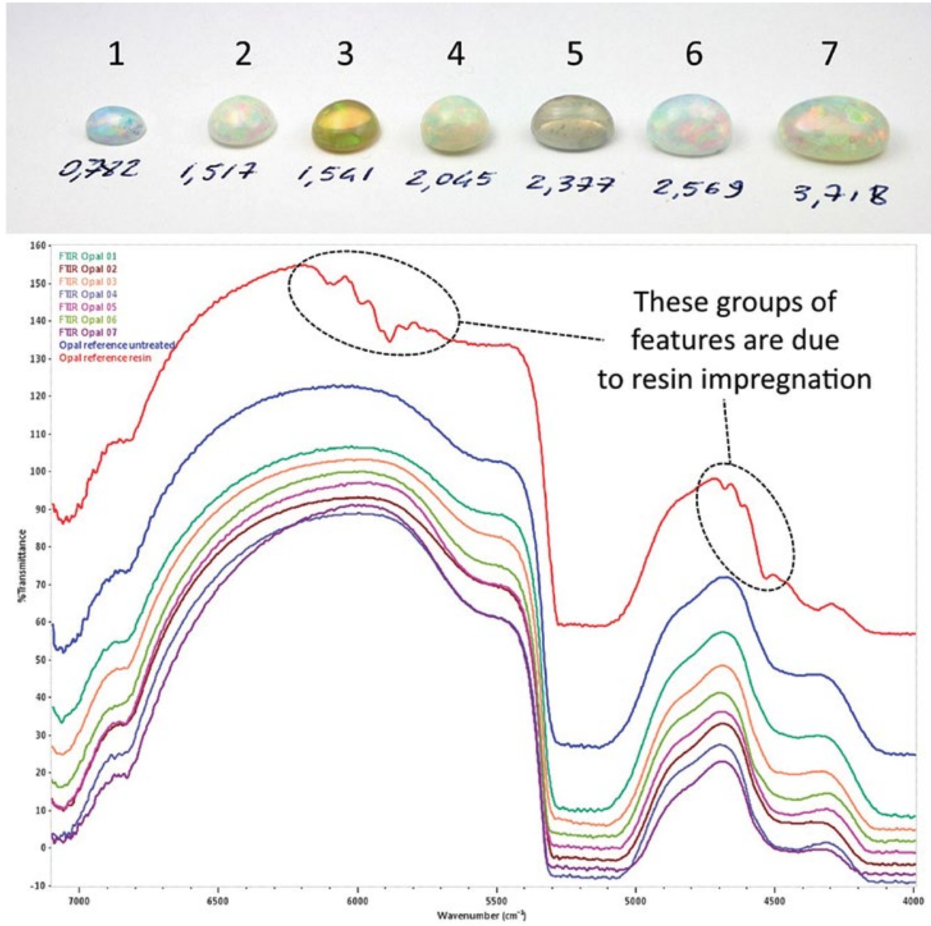


Figure 19. The results of GemmoFTIR testing by Alberto Scarani of the seven Ethiopian opals, including one non-absorbent sample, purchased by the author at Tucson 2016. With comparisons of two reference opals, one untreated and one resin treated.

Conclusion

To quote Bear Williams of Stone Group Laboratories: "Once information is released on a large enough scale that is not confirmed with the rest of the gemological community and it turns out to be incorrect, steps have to be taken so that the confusion does not spread" (Bergman, J. 2016).

In this article, I hope I have demonstrated to a reasonable degree that the vast majority of cut Ethiopian opals on the market are undoubtedly not stabilized. Furthermore, there is overwhelming gemological evidence that they do not need to be stabilized. The widespread presence of polyurethane-resin stabilized Ethiopian hydrophane opal on the market appears to be a fairytale.

Consumer confidence is vital to both the short-term and long-term economic health of our trade. Proper disclosure of all treatments is critical to maintaining economic health. Equally important is avoiding the spreading of unfounded fears of non-existent treatments. Industry leaders bear the responsibility to uphold the highest of ethical standards from both behind the showcase and in the media.

The huge production from Ethiopia has invigorated the opal trade around the world, and undoubtedly taken a chunk out of the Australian opal market share. George Williams, JTV Senior Gemstone Buyer wrote "I have bought and sold opals from all sources for a long time and am thrilled with the variety of body colors, patterns, and especially the brilliance of colors that Welo opal displays. Many exhibit brilliance on a scale not seen since the early Andamooka, South Australian productions. Further, high-dome cabs are available that best show the beautiful play of color in opal (Williams, G. 2011).

Williams concluded: "Welo is as important to the opal business today as the Australian mines were in the previous century. The cornucopia of opal varieties that can imitate Lightning Ridge, Coober Pedy, Andamooka, Mexico or Brazilian opal from this new discovery alone will continue to bring excitement back to this "Queen of Gems" for many years to come."

Suggested Ethiopian Opal Consumer Care Declaration

Most Ethiopian opals will readily absorb any liquids with which they come into contact. Avoid exposure to coffee, tea, wine, oils, perfumes, soaps, dishwashing water and other liquids that could cause permanent and irreversible discoloration. Bead bracelets and necklaces should always be worn over clothing to avoid absorbing perspiration. Do not fear accidental situations such as dropping your opal into a washbasin, glass of wine or cup of coffee, or getting caught in the rain. Absorption is not immediate and requires more time than a quick dip to take effect.

Should your opal accidentally be immersed in water for an extended period of time, remove it and place it in a safe and dry location. The time period for drying out can be minutes to more than a week and will vary depending on stone body type, size and environmental conditions. Do not try and speed up the natural drying process by placing in an oven, under a hot light or hair dryer!

Like most gems, opal should be handled and cleaned with care. Never use a steamer or ultrasonic, keep away from harsh cleaning agents, avoid high temperatures or sudden temperature changes. Only wiping with a clean and dry soft cloth is recommended.

Reference & Further Reading

Bekele, K. (2013) *Report on Ethiopian Opal.* ICA Newsletter, Nov. 2013.

Bekele, K. (2014) *Ethiopia loses more than USD90 Million due to rough gemstones export.* http://www.thereporterethiopia.com Accessed 22/11/2015.

Bergman, J. (2016) *Tanzanite; Facts, Fears & Fakes.* AGA www.accreditedgemologists.org. Accessed 09/01/2016.

Blythe, P. (2011) *Ethiopian opal update.* <http://mineshaft.com.au> Accessed 22/11/2015

Cristol, A. (2016) *Opal in French Jewellery. LGM*, www.gemlabmarseille.com. Accessed 10/01/2016.

Filin, S., Puzynin, A., (2009) Prevention of cracking in Ethiopian opal. *Australian Gemmologist*, Vol. 23, No. 12, 2009, pp. 579–582.

Gebremedhin, K (2014) *Who is benefitting from Ethiopia's global brandname opals?* www.ethiopiabservatory.com accessed 22/11/2015

Gem News (1995) *Gem News, Gems & Gemology* Summer 1995 p. 138

GIA.edu (2016) Opal *Quality Factors.* http://www.gia.edu/opal-quality-factor Accessed 10/01/2016

Kiefert, L., Hardy, P. et al, (2014) *New Deposit of Black Opal from Ethiopia.* Gem News International, Gems & Gemology, Winter 2014, Vol. 50, No. 4 pp. 303-5

Kiefert, L., Hardy, P. (2015) *The Mines of The New Black Opal from Ethiopia. InColor* Spring 2015 Issue 28 pp. 61

Krzemnicki, M., (2011) *SSEF FACETTE* International Issue No.18, Jan. 2011, pp 7.

Mazzero, F. (2015) Opalinda, Personal communication email. 26/09/2015

Opalsdownunder.com.au (2015), *The History of Opal.* Accessed 22/11/2015

Opalsdownunder.com.au (2016) *Opal Facts & Myths.* <http://www.opalsdownunder.com.au/learn-about-opals/introductory/opal-facts-myths Accessed 10/01/2016>

Patentorg.com (2016) *Method of Stabilizing Opals. US 08490612 B2 Patent Summary* www.patentorg.com. Accessed 10/01/2016

Rondeau, B. et al. (2010), *Play-of-color opal from Wegel Tena, Wollo province, Ethiopia.* Gems & Gemology Summer 2010 pp. 90-105

Renfro, N. (2013) *A Useful Technique to Confirm the Hydrophane Nature of Opal.* Lab Notes, Gems & Gemology, Fall 2013, Vol. 49, No. 3

Sturman, N. (2015). *GIA Laboratory, Bangkok personal communication, email. 02/12/2015*

Weinberg, D. (2015) *Australia is no longer the world's only source of black opals.* <https://www.linkedin.com/pulse/australia-longer- worlds-only-source-black-opals-david-weinberg?trk=prof post&trkSplashRedir=true&forceNoSplash=true> Accessed 22/11/2015

Williams, G. (2011) *Ethiopian Hydrophane Opal.* www.jtv.com Accessed 10/01/2016

Yonick, D. (2011) *Ethiopian Opal.* Colored Gemstone, Rapaport Magazine www.diamonds.net Accessed 22/11/2015

Young, J. (2011) *Welo Ethiopia Opal,* www.mindat.org Accessed 22/11/2015

Moldavite, A Gemmological Relevant Natural Glass

G. Pearson

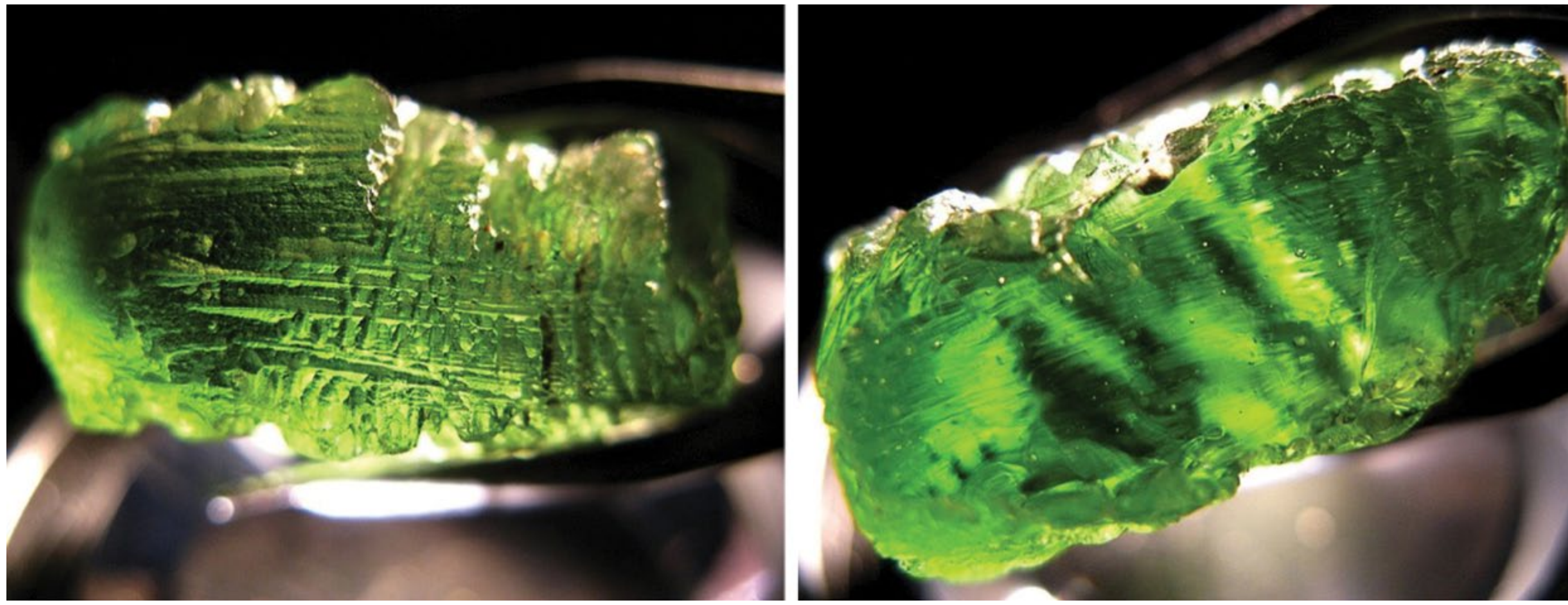


Figure 1. Moldavite. Left: Etched ancient-fracture surface. Right: Fresh backlit fracture.

Natural glass has figured rather prominently in human history, from basic objects of adornment like beads to especially raw materials capable of developing extremely sharp edges simply upon impact and knapping, and invaluable as tools, from weapons like spear and arrow heads to food-preparation flaying and cutting instruments. It has been considered that many of the earlier meso-American native cultures (Maya, Inca, Aztec, Toltec) may have developed so successfully because of an abundant source and a lucrative trade in obsidian, a volcanic glass that could be flaked and worked with skill into intricate edged artifacts.

Moldavite is an unusual variety of natural glass that had long thought to be volcanic or even extra-terrestrial in that it was supposed to be of meteoritic origin. It is found in Bavaria and adjoining countries, notably the Czech Republic, but has been established to be a terrestrial impactite. The name was derived from that of the Moldau (Vltava) River and from the old name of the vicinity, Moldavia. Impactites are objects of terrestrial substance, usually vitreous (glassy), arising from portions of rock or loam violently ejected from an impact site by a meteorite and the energy of impact has melted them upon expulsion. Aerodynamic resolidification of ejectite melts can give rise to a wide range of compositions, structures and morphologies such as the aerodynamically-shaped rimmed buttons, and the boat-like and dumbbell forms of the glassy australites or Australian tektites, which are conspicuous examples.

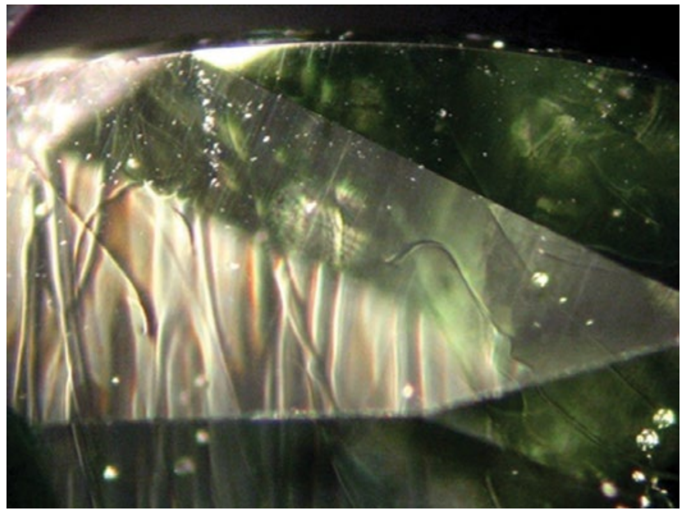


Figure 2. Intense swirl striae and lechatelierite.

However, moldavites, which are small objects of a bright green to olive to yellow-brown colour and transparent to translucent silicate glass, also show a range of unusual shapes that have been sought for talisman and amulet adornment purposes for centuries. Moldavites have been considered to most probably originate as ejectite material from the Nordlinger Ries meteorite crater in Bavaria (Bouska et. al. 1993) formed about 14 MYBP from impact of a meteoritic body estimated to have been about a kilometre across. Their unusual shapes have been subsequently generated by terrestrial erosion attack and differential dissolution of chemically more vulnerable locations on their surfaces by corrosive groundwater over the centuries. Evidence for this can be seen in the differential etch patterns superimposed onto exposed and ancient vitreous fracture surfaces with typically- conchoidal markings (Figure 1) compared to a natural modern vitreous fracture. The resulting textured shapes can be from nondescript to very detailed and delicate, and attractive as well as very fragile, but they have been widely sought for use in craft jewellery and by collectors, especially as complete and undamaged etched specimens.

The chemical non-uniformity that enables development of the unusual shapes and textures by differential dissolution is often evidenced by intense swirl striae revealing minimal mixing of an originally viscous inhomogeneous and only marginally melted glassy mass, (Figure 2).

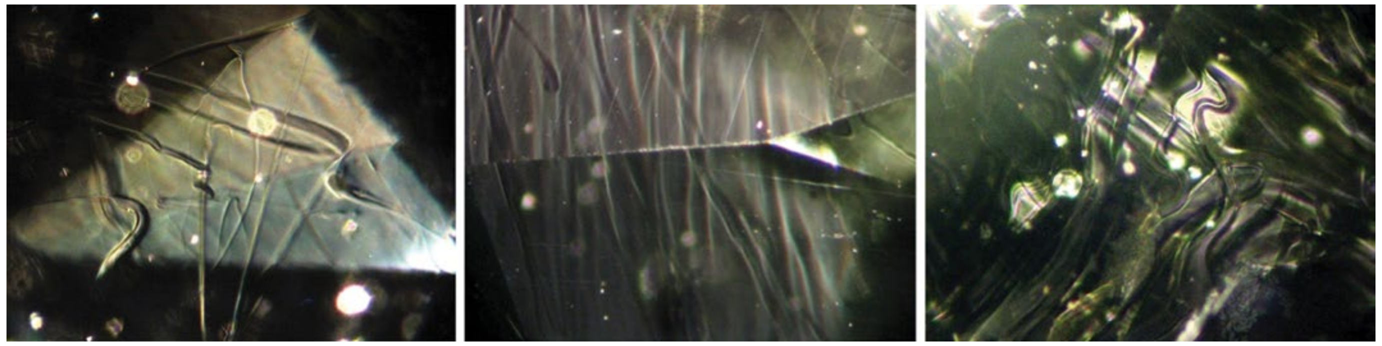


Figure 3. Left: Amorphous silica lechatelierite stringers. Centre & Right: Amorphous silica lechatelierite tangled stringers.

The morphologies of the internal inhomogeneities are quite characteristic and are not seen in ordinary manmade glasses or "pastes". Detection of such characteristic internal features constitutes one avenue by which genuine examples of these natural objects may be distinguished from manmade moulded imitations that are very frequently encountered masquerading as the genuine item. The most easily detected of the internal features are extended twisting fibre-like stringers of lechatelierite or amorphous fused silica, (Figure 3) presumably arising from approximately-equant quartz-crystals or sand-grains in the original ejectite substance. The original rock, surmised to perhaps have consisted of a clay-consolidated sandstone that was rich in quartz particles (and which is often derived from a granite) or even a weathered or intact granite or granodiorite or similar rock, typically containing quartz, feldspars, mica (usually ferruginous, like biotite) and other minor accessory silicates. Quartz has a high melting point, greater than the softening points of almost all other natural silicate based glasses that usually contain components including sodium, calcium, magnesium, potassium, and iron, from inclusion of other minerals such as feldspars, clays, shales and micas for instance. Melted silica is also known to be extremely viscous, even at substantially above its melting point of about 1650°C, much greater than the far more-fluid alkali-rich silica melts of ordinary "soda-lime" glasses, or of natural volcanic magmas giving rise to obsidians that are typically liquid around 900-1200°C. Severe turbulence of the expelled and momentarily airborne molten globule during the impact and ejection event is considered to cause the extreme elongation and twisting and folding of the softened silica grains within their glassy encapsulation, but without significant overall homogenisation of the melted mass.

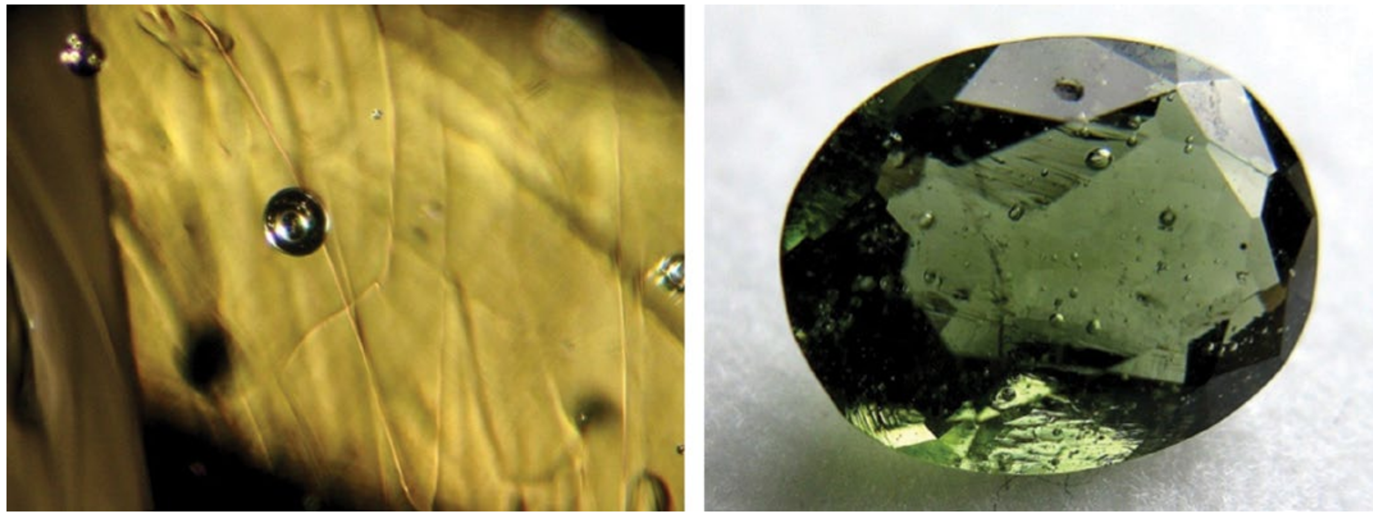


Figure 4. Spheroidised, ovoid gas bubbles indicative of quiescent solidification conditions. Left detail under magnification. Right: In a faceted gem.

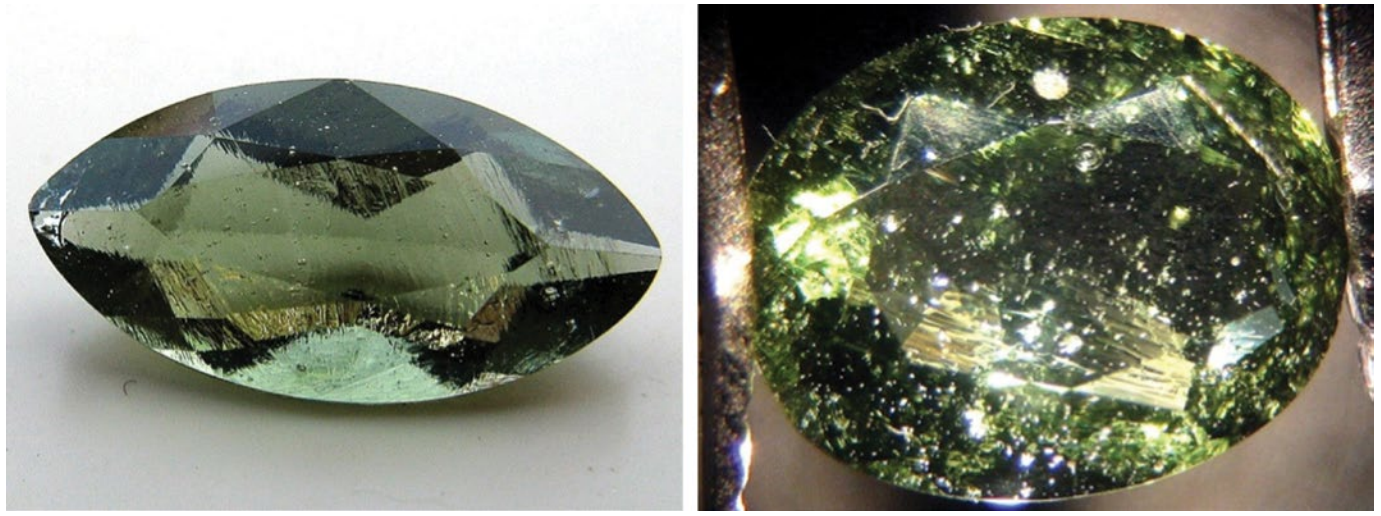


Figure 5. Facetted moldavites from unattractively shaped natural rough material.

Figure 6. Left: Faceted simulant moldavite. Right: KuanYin "carved" & "natural looking" (cast) simulants.

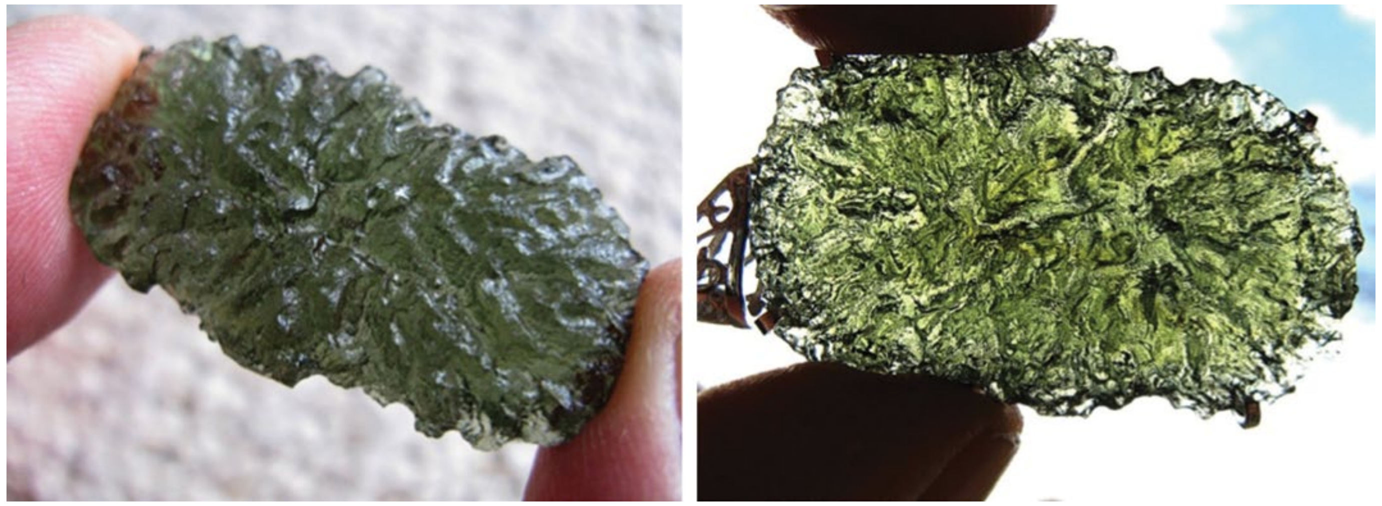


Figure 7. Two views of a simulant complete moldavite "nugget" lacking characteristic natural features.

This results in the extremely extended, tangled and deformed fibre-like lechatelierite structures within a glass matrix, the matrix itself displaying intense swirl striae of varying-composition refractive-index gradients. Resolidification probably occurred under the relatively quiescent conditions after the pasty-molten globule's terrestrial redeposition, enabling entrained and expanded gas bubbles to respheroidise or to become at least moderately oval, which is apparent when specimens are inspected (Figure 4). This is instead of the greatly distorted and disrupted irregular bubble structure that would result from resolidification whilst severe turbulence and plastic deformation was still occurring. After cooling, any natural quench cracking or subsequent geo-mechanical stressing and erosion could fracture some of the internally-strained portions, enabling the fracture surfaces to acquire etch structures from subsequent prolonged groundwater exposure. Erosion and substantial geological transport of many moldavites is known to have occurred from their original formation sites, also consistent with their partial dissolution in water (Bouska et. al. 1993).

It is admitted that it may not be at all impossible to synthetically duplicate such properties and internal structures of a simulant glass with meticulous chemical and particle-size control of the starting materials and suitable mechanical and thermal processing of the carefully melted mix. This would greatly complicate gemmological discrimination between genuine and simulant items. However, it is seemingly unlikely that there would be sufficient financial advantage to undertaking such a closely fraudulent simulation of a relatively lower value material with its limited public demand by such an inevitably much more expensive process. For this reason, present simulants would be expected to not significantly display such convincingly similar inclusion patterns. Being vitreous and therefore of not any discretely defined composition, properties such as RI and SG of both imitation and genuine materials could also be expected to vary, each within a given range, and of course to possibly even overlap with each other.

Less well formed and morphologically less-aesthetically attractive examples of suitable moldavite specimens have been reworked and facetted and polished into gems (Figure 4 Right, Figure 5 Left) and even carved into art objects, so that those with deliberately altered surfaces may no longer display the characteristic etch patterns that might be useful for authentication. Their identification and confirmation requires recognition of alternative characteristic internal features as well as of optical and physical properties consistent with the genuine material such as Refractive Index and Specific Gravity.

Simulants composed of manmade soda-lime silica glass have widely been fraudulently offered as moldavites over the past few years, sometimes for many hundreds of dollars each, although are probably just portions of cast melted bottle or other soda-lime silicate glass which the average person might think would be virtually indistinguishable from the genuine item. They have been encountered as supposed facetted items (Figure 6 Left) as well as supposed carved and polished artefacts (Figure 6 Right) and even sand-cast supposed complete undamaged original moldavite specimens (Figure 7) for jewellery purposes.

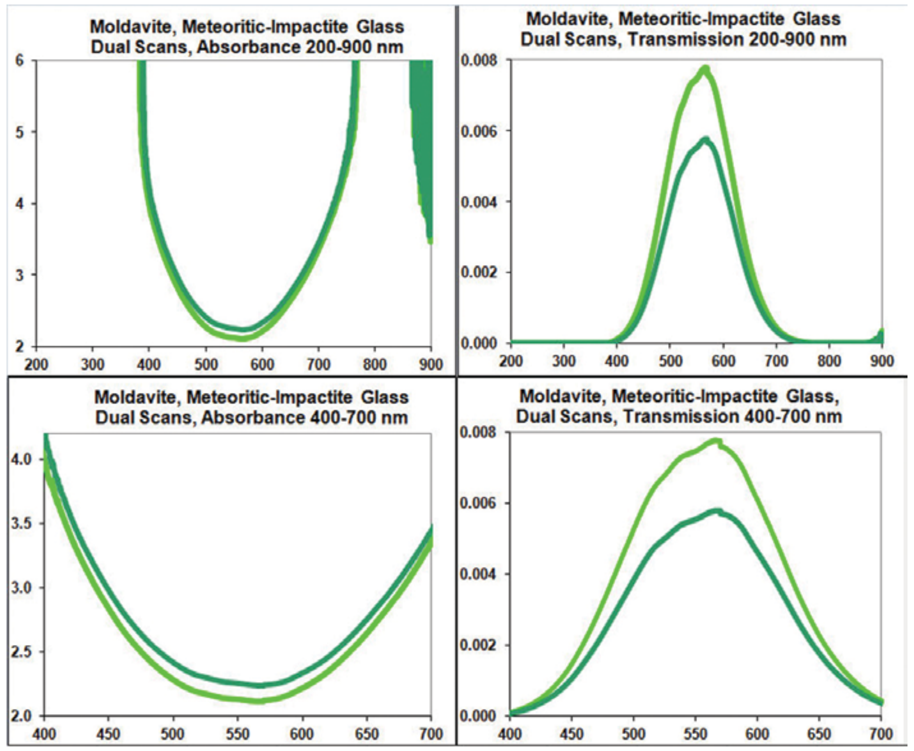


Figure 8. UV-Vis, Green moldavite complementary Absorption and Transmission spectra.

The abundance and availability of such comparatively large and undamaged specimens on the market clearly vastly outweighs the amount of genuine material known to have been collected which is quite limited and very actively sought and valued locally. A reliable approach to distinguishing moldavite from imitation is consequently desirable. Examination by loupe or preferably stereomicroscope of genuine examples of polished and facetted examples, which enables optical access to their interiors, usually reveals evidence of the lechatelierite stringers and striae, sometimes in roiling abundance, as well as occasional remnants of solid foreign particles and also numerous spheroidised gas bubbles of probably entrained air or of decomposition gases formed during fusion, such as of steam and carbon dioxide. A number of facetted examples of "bottle-green" moldavite also have had RI values determined as well as specific gravities relative to water, to compare with values of detected simulants. The UV-Vis spectral absorption and its complementary transmission spectrum of a portion of green moldavite is also included (Figure 8) but shows no distinctive diagnostic features other than just a visible-range mid-spectrum smooth transmission band, attributable predominantly to ferrous iron.

Facetted examples of simulants have been observed to display RI and SG values usually rather outside the range to which the values of the known genuine specimens were confined, as well as their not having the lechatelierite stringers or compositional striae, (e.g. see Figure 6 Left). A number of suspected but pendant-mounted examples of simulants were only able to be RI tested by the "spot" or distant vision technique on small relatively flat protruding polished locations so that precision was less than ideal, but stereomicroscopic examination of the supposedly natural surface revealed a sand-cast texture and occasionally even entrapping residual sand particles (Figure 9). Mounted and set items did not allow SG determinations. A table of selected RI and SG values of several known or suspected simulants as well as of several known genuine moldavites in the writer's possession is included below. Some other reported values of moldavites indicate ranges between 1.478 to 1.530 for RI, and SG between 2.30 and 2.40.

These values should be interpreted in the context of those of pure fused silica (lechatelierite) of RI n_D=1.459, SG of 2.303 (and thermal softening point about 1665ºC), and of "soda-lime glass" from which ordinary windows and bottles are made, of usual RI about n_D=1.518- 1.520, SG about 2.51-2.53 (and with "liquidus" or flow temperature about 1000oC. The liquidus is that value at which flowable molten liquid can exist in equilibrium with the crystalline solid component substance, since glass by definition does not have a discrete melting point). These values apply to manmade container and flat glasses of typical composition about 73-75% silica, 13-14% Na_2O, 9-10.5% CaO, 0.2-4% MgO, 0.15-1.3% Al^2O_3, and only minute traces of other metal oxides. In contrast, the reported composition range from analyses of selected moldavites varies between about 79 to 83% silica, 9 to 11% Al_2O_3, 1.6 to 2.2% FeO, 1.4 to 2.5% CaO, 1.3 to 2.0% MgO, 0.35 to 0.55% Na_2O, and 2.8 to 3.4% K_2O, with only traces of other components (http://www.moldavit.de/UK/info.htm).

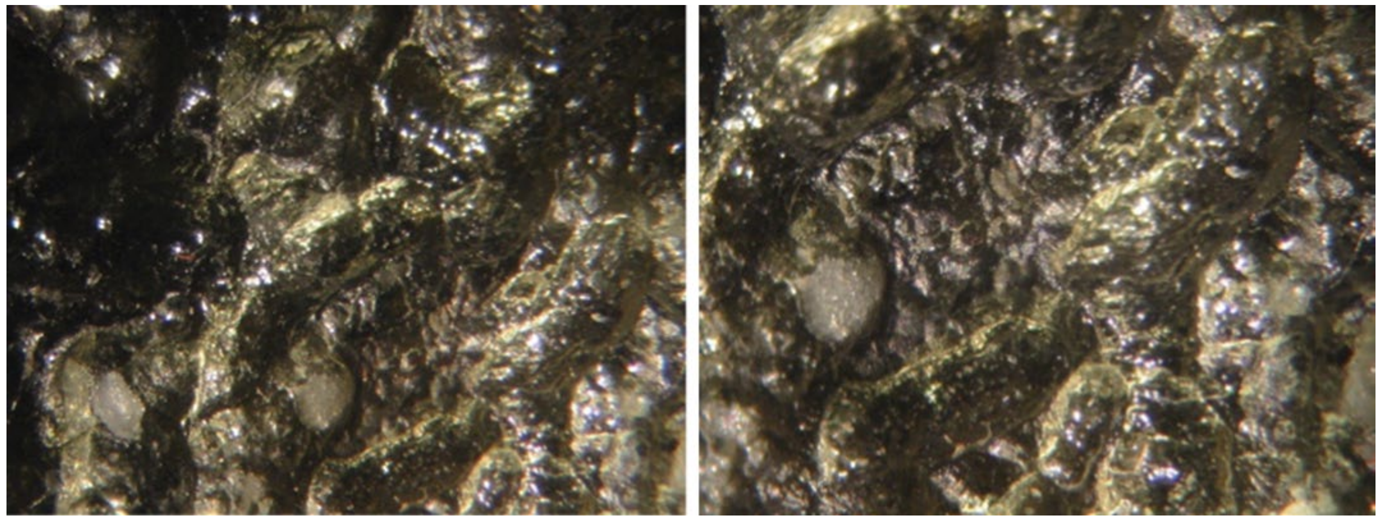


Figure 9. Simulant sand-cast moldavite surface entrapping white sand grains.

Specimen No	Type	Authenticity	Refractive Index	Specific Gravity
1	Mold.Kuan Yin Carving	Simulant	Spot 1.50-1.51	NA
2	Moldavite, Nugget	Simulant	NA	2.512
3	Moldavite, Nugget	Doubtful	NA	2.487
4	Pendeloque Facet	Genuine	1.521	2.505
5	Oval Facet	Genuine	1.490-1.491	2.379
6	Marquise Facet	Genuine	1.481-1.482	2.341
7	Marquise Facet	Genuine	1.488-1.490	2.356
8	Rough, Etched	Genuine	Spot 1.49-1.50	2.390

Figure 10. Purportedly a carved Kuan Yin moldavite, actually a mould and sand-cast glass simulant with absence of lechatelierite stringers. Left: in incident daylight. Right: In transmitted daylight.

The contents of the metal oxides components elevates the RI and SG values well above those of the matrix silica.

At least one large purportedly carved and polished moldavite specimen, with a Kuan Yin figure depicted (Figure 10), showed under the stereomicroscope a number of fine shrinkage wrinkles on the belly just below the navel (Figure 11), obviously indicative of a moulded-casting origin, and certainly not of manual grinding and polishing as originally claimed by the vendor. The large size and apparently intact complete nature of the item was itself an indicator of its doubtful origin since the very few largest reported moldavites ever found were only slightly over a hundred grams (Bouska et. al. 1993). The item has clearly been fabricated from a molten glass.

Another facetted pendeloque stone (Figure 6 Left.), of convincing colour and (spheroidal) bubble inclusion pattern but of doubtful authenticity showed no lechatelierite or striae inclusions and its RI and SG (4, Table) were significantly above the range observed for the known genuine specimens. It was concluded to be an imitation.

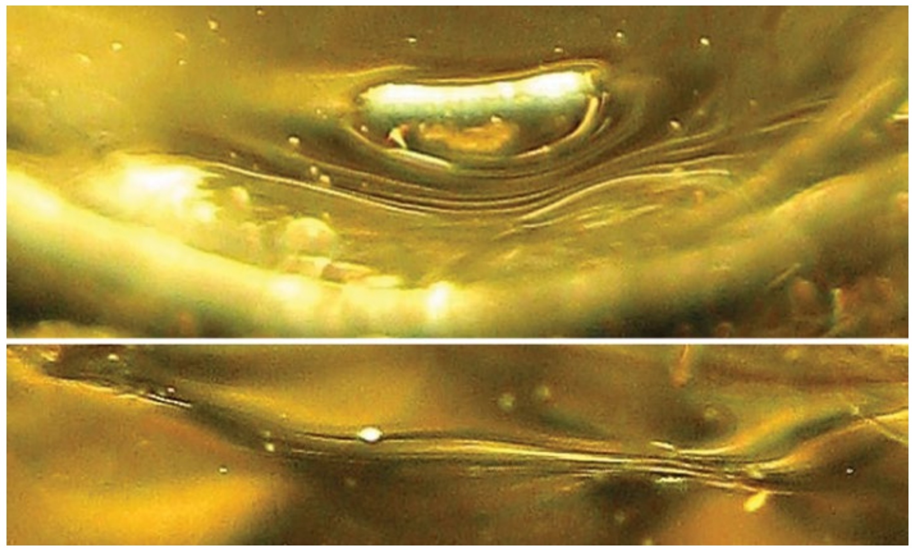


Figure 11. Shrinkage and flow casting-wrinkles at simulant moldavite Kuan Yin navel

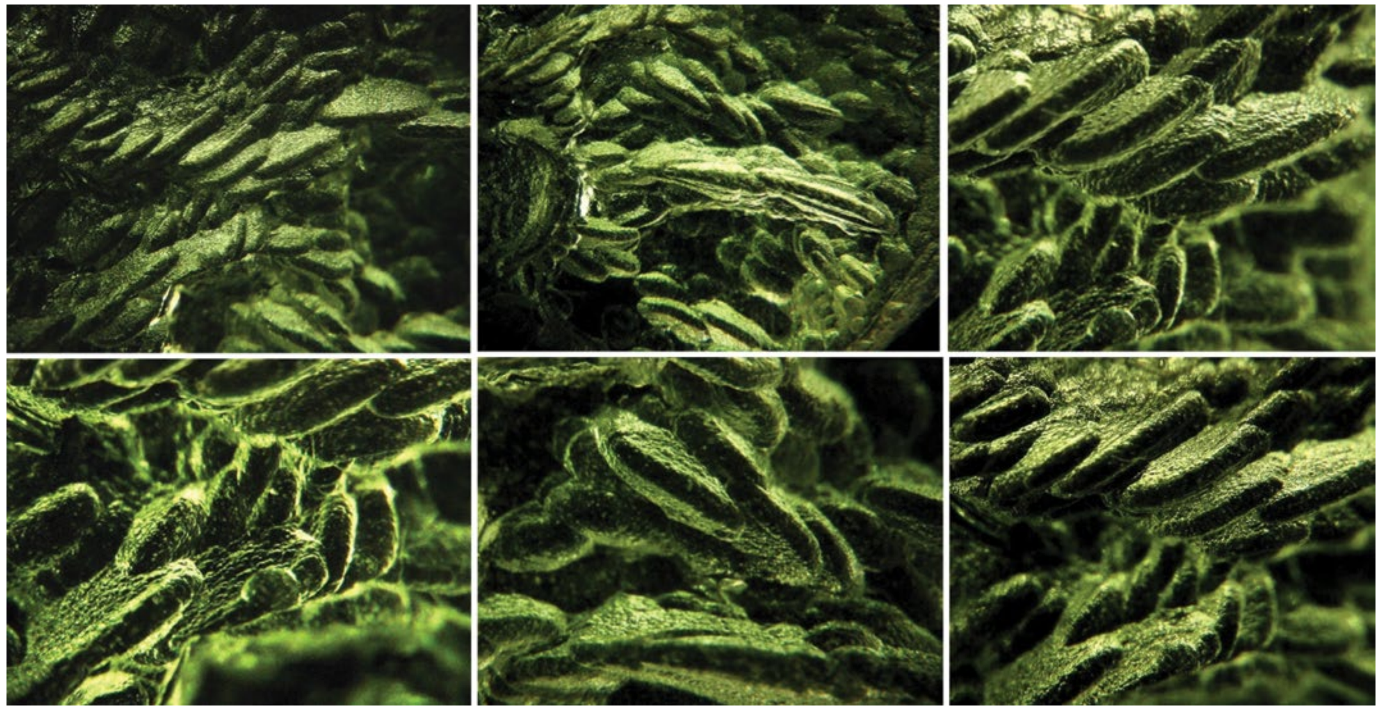


Figure 12. Ordered lenticular internally-pitted pits on etched moldavite natural surface.

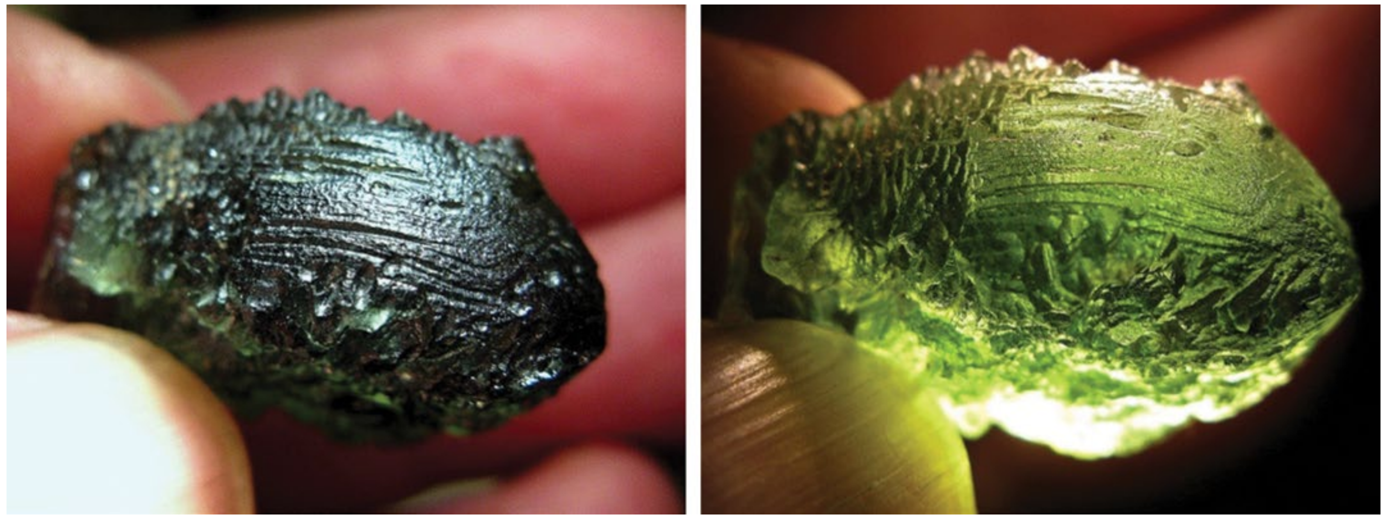


Figure 13. Etch pits on ancient moldavite fracture surface illuminated by both incident (left) and transmitted (right) light.

The structureless and quite irregular sand-cast texture of a simulant (Figure 9) was totally unlike that of the distinctive, well-ordered and repetitive pit-like structure of the natural texture observed on a number of genuine moldavite portions (Figure 12.), although the genuine moldavites retained no evidence of any etch products of residual devitrified substances.

Embedded white sand particles were occasionally detectable in the item's rough surface (Figure 9). The origin of the distinctive ordered pit structure arising from its aqueous weathering dissolution is uncertain but it appears to be consistent and characteristic. The observed pits consisted of aligned but short twisting rows of rounded or lenticular cavities with their own walls then also covered with even more minute rounded and evenly spaced finer pits. These ordered etch-pit structures were also apparent on the ancient conchoidal fracture surfaces of several portions as well, (e.g. Figure 13) and may sometimes be better seen by transmitted and darkfield illumination than by direct incident or oblique illumination with either a loupe or microscope The stereomicroscopic inspection of several examples of weathered-surfaces of Philippines obsidian earlier collected by the writer, and also of specimens of rough "rainbow obsidian" from the Americas revealed no recognisably similar features.

However, inspection of a long-exposed and weathered shard of green Roman glass (Figure 14) reportedly collected very close to the giant statues of the Buddhas of Bamiyan Valley in Central Afghanistan (now destroyed, since 2001), shows a rather similar unusual dimpled pit structure on the glass of the interface (Figure 15), beneath the in-place devitrification layer. The interface also exhibited an attractive brightly iridescent surface layer from a thin translucent film of the hydrolysis and devitrification product that developed while it was buried. The homogeneous composition of the Roman glass fragment and the supposed regular rate of its hydrolysis and devitrification was expected to have generated only an essentially flat and featureless matte interface between the unaltered glass and the leached and devitrified layer. The film of devitrification product is presumed to consist of residual hydrous and amorphous silica and other insoluble products after the soluble metal components of sodium, potassium, magnesium and calcium have been leached out. The actually observed pitting structure was not expected and the reason for its occurrence and development during about two millennia of mostly arid exposure has not been clarified. Similarly, causes for the pitting features on the weathered moldavites' surfaces have not been explained, nor why they are absent from various similarly weathered obsidians of presumably similar compositions. However, this unusual surface texture does presently serve to distinguish between fraudulent cast glass simulants and natural moldavites.

It should perhaps be also noted that very similar although rather thinner devitrification and intensely iridescent layers have also been observed on portions of broken glass containers from at least the White Cliffs opal field in New South Wales, (and elsewhere), after their retrieval from the old dump. Their iridescent devitrification effect is apparent after only a little over a century of arid exposure, rather than of the millennia for the Roman glass. Whether the interfacial pitting structure is also developed is presently uncertain. However, the distinctive natural pitting texture observed on the surfaces of several unworked moldavite specimens is quite different to that of the sand-cast irregular glass-surface of the simulants, and for at least the time being it can serve as a contributory or diagnostic differentiating feature, along with the internal features of the lechatelierite stringers (best observable under stereomicroscopic darkfield illumination). In a parallel sense, it would be interesting to know whether any devitrification layers, iridescent or not, are ever observed on freshly disinterred moldavites but are perhaps removed during cleaning, and whether such devitrification processes are responsible for development of the distinctive pitting textures.

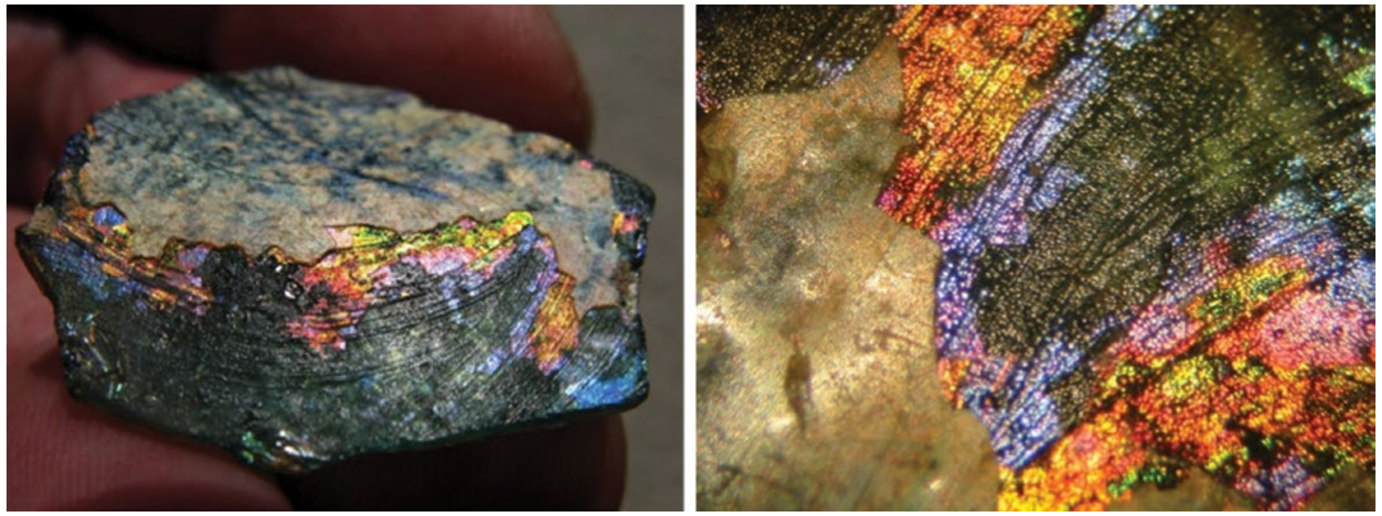


Figure 14. Iridescent devitrifying Roman glass fragment.

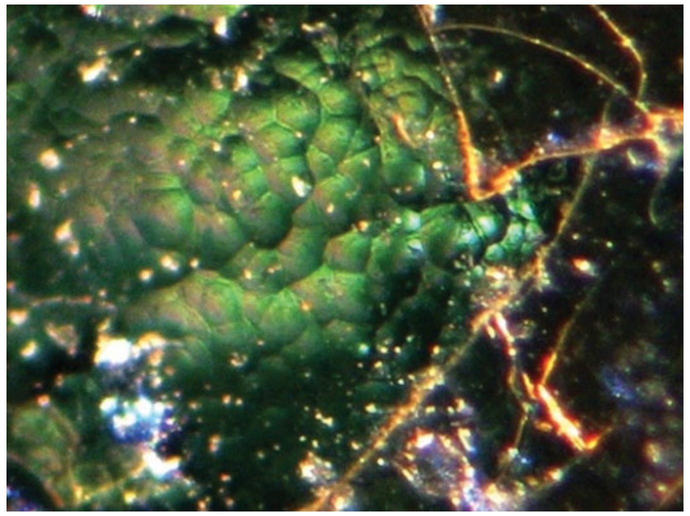


Figure 15. Microbotryoidal pit structure of devitrifying interface of Roman glass shard.

References

Natural Glasses, Vladimir Bouska (et. al.), Pub. Ellis Horwood Limited, Chichester London, (Simon & Schuster International Group) 1993.

Properties and Applications of Glass, Glass Science And Technology 3, H. Rawson, Elsevier, 1980.

"From A Singaporean Gem Laboratory, Moldavite: Natural Or Imitation?" Tay Thye Sun, The Australian Gemmologist, (2007), 23, 76-78.

An unusual occurrence of iron sulphide and baryte in coober pedy opal

B.A. Grguric[1], A. Pring[1], J. Zhao[1]

[1]Department of Mineralogy, South Australian Museum, North Terrace, Adelaide, SA 5000, Australia

Abstract: A single opal fragment from Dora Gully, Coober Pedy was found to contain a part spheroid of radially-fibrous pyrite/marcasite and small inclusions of baryte. Non-destructive characterisation was carried out by SEM-EDS analysis. Sulphide inclusions are rare in Australian opal and are interpreted to represent preserved remnants of an earlier anoxic phase of the Great Artesian Basin.

Background and Sample Description

A single opal fragment containing part of a spheroidal sulphide nodule was submitted to the S.A. Museum in October 2015 by Coober Pedy opal miners Tanja Burk and Dale Price (Tada Opals). This fragment was found on the conveyer of a noodling machine and was mined from dump material at Dora Gully (12 Mile field), Coober Pedy in 2000. Workings in that area were less than 6 metres deep.

The specimen consists of a broken fragment of an opal veinlet approximately 14mm x 10mm across and 3mm thick, with silt/clay inclusions on the selvages. Silt inclusions are more abundant on one selvage and these penetrate approximately 1mm into the body of the opal. The opal is predominantly white potch but contains some thin lamellar domains of green-blue precious opal, aligned parallel to the veinlet margins.

The sulphide spheroid inclusion (1.2 mm in diameter) is located at the fractured edge of the opal veinlet and consists of a pale-brassy yellow to dark-grey sulphide with a splintery, radially-fibrous structure. Approximately ¾ of the original sphere has been broken away leaving part of the spherical cavity encrusted with microscopic Fe-sulphate crystals, but it would appear that the original spheroid was completely encapsulated in opal before being exposed by fracturing. Unfortunately given the mining/recovery method employed, the exact host lithology of the opal veinlet is unknown.

Figure 1: Backscattered electron image of the part fragment of a pyrite/marcasite spheroid in Coober Pedy opal. Note the radially fibrous structure also common in pyrite/marcasite nodules from other occurrences.

Analysis

The small and unique nature of the specimen dictated that destructive testing was not possible. The specimen was examined using a Quanta FEG450 scanning electron microscope equipped with an EDS detector at Adelaide Microscopy. Accelerating voltage was set at 20kV, and the sample was examined at low vacuum obviating the requirement for carbon coating. Backscattered electron images of the sulphide spheroid are given in Figures 1 and 2. EDS analysis showed the chemistry of the sulphide to approximate FeS_2 with no other measurable metal substitution. Precise quantitative analyses was not possible given the unpolished sample surface. On the basis of colour and chemistry the spheroid is thus identified as pyrite and or marcasite. Concentric zonal variations in brightness in the backscattered electron images (Figures 1 & 2) appear to be related to variations in the degree of alteration/encrustation by secondary Fe-sulphates, and probably reflect variations in the porosity of the Fe sulphide.

Examination of the sample in backscattered electron mode also highlighted numerous bright inclusions to 50 microns present amongst the silt/clay inclusions on one selvage of the opal veinlet (Figure 3). These were identified as baryte ($BaSO_4$) on the basis of their EDS chemistry.

Interpretation

This specimen, although not containing commercially valuable gem material, appears almost unique amongst Coober Pedy opals in containing an identifiable pyrite/marcasite spheroid inclusion, and for this reason was set aside by the finders. Other documented occurrences of pyrite/marcasite spheroids or nodules, with identical radiating internal structures, are commonly associated with carbonaceous sediments such as black shales, graphitic slates/schists and coal measures. Good examples up to several centimetres across are described from carbonaceous shales on Millstream Station (Simpson 1948) and in the hanging-wall graphitic slates at the Mount Keith nickel mine (Grguric 2003), both in Western Australia. Reflected light optical and

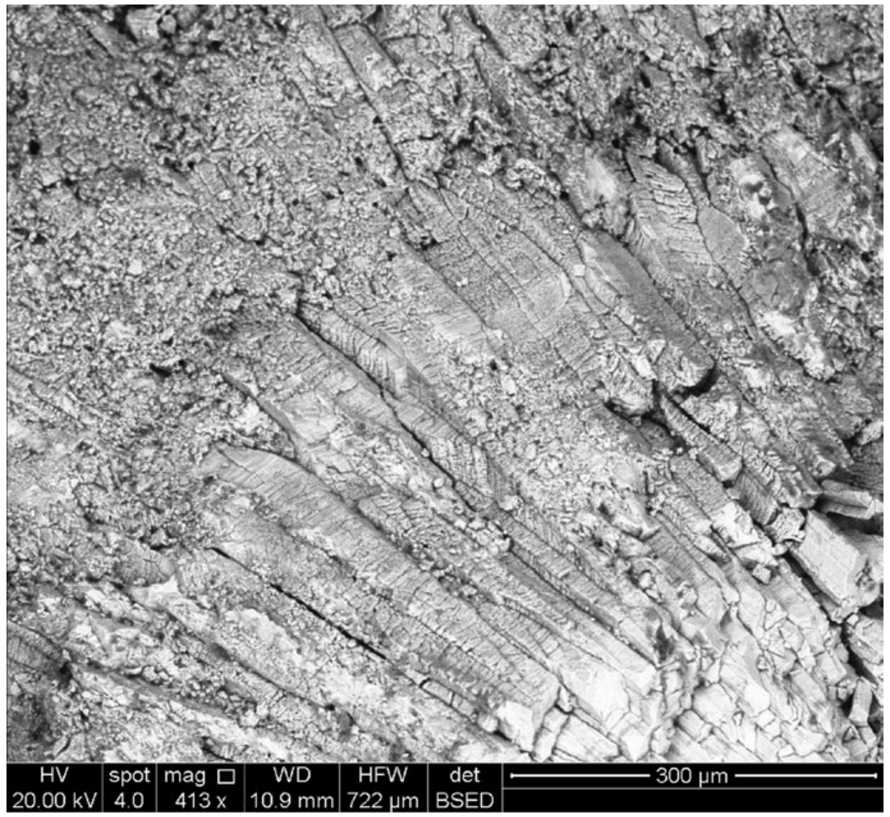


Figure 2: Detail of the microstructure of the pyrite/marcasite spheroid. Backscattered electron image.

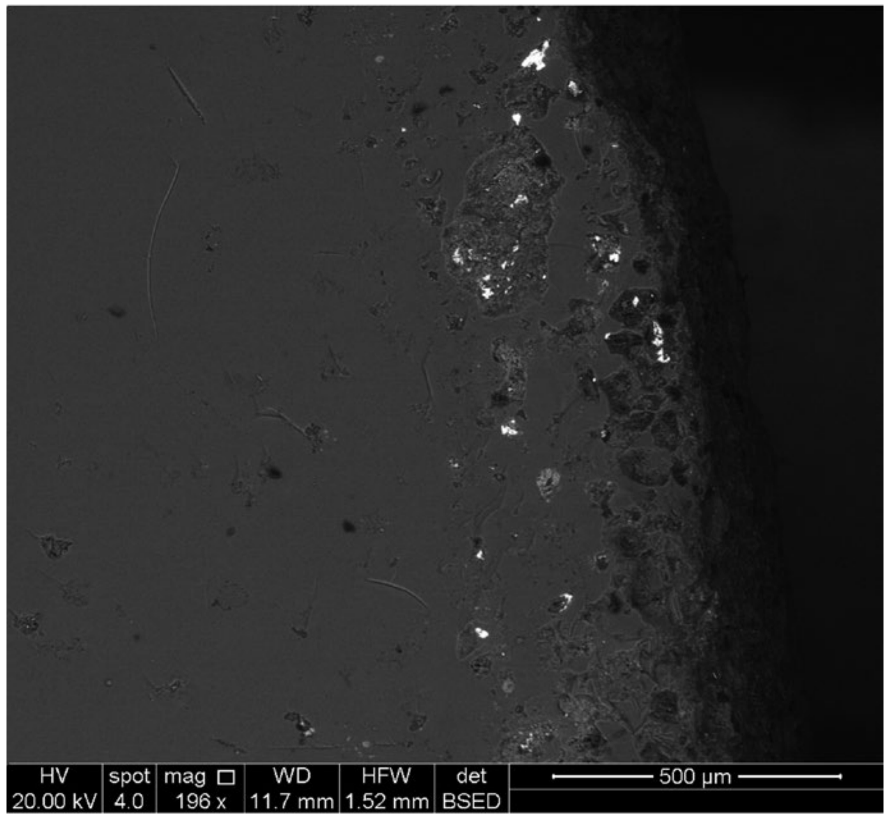


Figure 3: Grains of baryte present as inclusions in opal on one selvage of the opal veinlet show up as bright, white specks in the backscattered electron image. Note associated voids part-filled with clays and Fe-hydroxides.

XRD diffraction analysis of spheroids from other occurrences indicates they may be predominantly pyrite or marcasite, but are typically an admixture of both minerals. The association with carbon-rich sediments suggests formation under highly-reduced conditions e.g. in anoxic basin settings which are favourable environments for sulphate-reducing bacteria. The model proposed by Rey (2013) for the formation of precious opal deposits in the Great Artesian Basin involves an initial shallow, stagnant, anoxic basin during the early Cretaceous which was rich in reduced-facies sediments containing abundant biogenic pyrite, volcanic ash and other volcaniclastics. Later uplift and oxidative weathering of this acid-generating assemblage facilitated mobilisation of silica which was locally reworked by alkaline ground waters to precipitate precious opal. The intensity of prolonged oxidative weathering in central Australia has meant that at the shallow depths currently mined the original reduced, sulphide and carbon-rich sediments are now absent. The former presence of iron sulphides in these sediments is now reflected in abundant secondary sulphates such as gypsum (kopi) and alunite (Rey 2013). It is surmised that the preservation of a pyrite/marcasite spheroid in the Dora Gully specimen represents a rare survivor of the weathering process, and in this case, encapsulation in opal has prevented oxidation. Black opal occurs at Coober Pedy but is rare. This indicates that locally preservation of reduced carbonaceous material also occurs by encapsulation in opal, and also that opal formation commenced before oxidation of the reduced-facies sediments was complete.

To our knowledge, inclusions of baryte as seen in the selvage of the opal specimen, have not previously been documented in Coober Pedy opal. This baryte is probably secondary in origin and derived from the reaction of Ba ions released from weathering of feldspars and volcanic glass with sulphate ions derived from weathering of iron sulphides. The localisation of these inclusions on one selvage of the veinlet suggests it may have been horizontal when formed, with baryte and silt particles settling under gravity into the proto-opal gel from the roof of the veinlet. An SEM search for baryte inclusions in other central Australian opal specimens was not carried out, but would be a worthwhile exercise to determine if baryte is a useful provenance indicator. The white or cream-coloured baryte inclusions are easily overlooked in optical examination but are distinct and bright in backscattered electron images.

Given the importance of sulphide inclusions as rare preserved remnants of an earlier anoxic sedimentary environment, opal workers are encouraged to report any finds of sulphidic material in Australian opal.

References

Grguric, B.A. (2003) Minerals of the MKD5 nickel deposit, Mount Keith, Western Australia. *Australian Journal of Mineralogy, 9(2), pp. 55-71.*

Rey, P.F. (2013) Opalisation of the Great Artesian Basin (central Australia): an Australian story with a Martian twist. *Australian Journal of Earth Sciences,* 60, pp. 291-314.

Simpson, E.S. (1948) *Minerals of Western Australia.* Government Printer, Perth, 714 p.

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2 day course

Prerequisite: Practical Diamond Grading

This course builds on the skills gained in Practical Diamond Grading and takes your knowledge to the next level.

- Grade old diamond cuts and recuts.
- Learn about grading fancy colour diamonds.
- Learn considerations so you can grade set stones.
- Practical experience in visually estimating crown angle, pavilion depth and table percentage – learn to evaluate the cut grade or make of the stone.
- Evaluate brilliance, dispersion and scintillation.
- Cover all the latest treatments/enhancements of natural and synthetic diamonds and detection methods.
- Theory and practical assessment leading to GAA Certificate of Competency.

Diploma in Diamond Technology

Prerequisite: Diploma in Gemmology or equivalent

Show your clients you're serious about Diamonds. Students who successfully complete this course obtain the post-nominal Dip DT.

- Offered part-time over one year.
- Genesis and formation. Chemical and physical properties are covered in depth.
- The process of exploration, mining and recovery.
- Learn in detail the progress of a diamond's journey from mine to marketplace.
- Properties of simulants, synthetics and their detection methods.
- Covers all manner of diamond treatments and their detection methods.
- Independent research into a field of your choice.
- Practical Diamond Grading forms the practical lab work component. All internationally recognised diamond grading systems are covered.

Theory and practical assessment leading to GAA Diploma in Diamond Technology and the post-nominal Dip DT.

Practical Diamond Grading
5 full days or equivalent

The GAA's Practical Diamond Grading Course is the essential asset for all businesses that sell diamonds.

Learn to grade diamonds to international standards for better buying and selling decisions.

- Flexible teaching times (week courses, weekend courses and night courses - State variations). This course also forms the practical component of the Diploma in Diamond Technology.
- Learn about the different internationally recognised diamond grading systems including GIA, CIBJO, IDC and HRD for greater appreciation of their similarities and differences.
- Classes cover both theory and practical lab work with diamond.
- Learn how to estimate the weight and adjustment factors of set and unset diamonds.
- Make visual estimations of proportions of cut diamonds; state the make of diamonds with correct terminology; learn to accurately predict the measured values of the different parts of a diamond that are listed on certificates using only a 10x loupe and back them up using instrumentation.
- Colour grade with master sets and standard lighting, Clarity grade with 10x loupe and/or microscope.
- Considerations when grading a set stone.
- Students also receive theoretical and practical experience in detection and identification of synthetic diamonds, diamond simulants and diamond treatments - fracture-filled diamonds, laser-drilled diamonds plus all the latest treatments/enhancements and detection methods.
- Practical assessment leading to a GAA Certificate.

GAA

Gemmological Association of Australia

Call the Federal Enrolment Officer for more details and dates

1300 436 338

www.gem.org.au

Examination results 2015

Diploma in Diamond Technology

Federal Award

Sutherland Diamond Award
Best all round student in DipDT in Australia
Ashlee Macqueen (NSW)

Distinction
Ashlee Macqueen (NSW)

Credit
Marina Hyasat (NSW)
Debbie Goddard (NSW)

Pass
Nathan Aldous (NSW)
Jiashu William Wei (NSW)

Diploma in Gemmology

Federal Awards

Geoff Tombs Medal
- Best all round student in Gem 2 in Australia
Maria Luisa Chow Chan (WA)

Julia Myers Award
- Best Practical Paper in Gem 2 in Australia
Katherine Harrington (VIC)

State Prizes And Awards
(All award recipients must pass with Distinction)

New South Wales

The New South Wales Trustees Award
- Awarded to the NSW student who submits the best practical paper and who passes with distinction.
Not Awarded in 2015

Nsw Management Committee Prize
- Awarded annually to the Gemmology 2 student attaining the highest pass mark with Distinction.
Andrew Byrne

Victoria

The Howard J. Lem Memorial Prize
- Awarded for the best practical paper in that State.
Katherine Harrington

Victorian State Prize
- This award to be made to the best all round student in Gemmology 2 with the proviso that this student shall not have been awarded a Federal prize.
Sarah Blundell

Queensland

Queensland State Division Prize
- Awarded annually to the student attaining the highest pass mark in Gemmology 2. examination in that State.
Heike Kolberg

The John Andrews Prize
- Shall be awarded to the Gemmology 2 student with the highest pass marks.
Heike Kolberg

South Australia

The Stevenson Award
- Awarded to the student gaining a pass with Distinction for the highest aggregate marks in the State.
Laura Pivovaroff

The Jack Townsend Award
- Awarded to the student in Gemmology 2 with the highest aggregate marks for theory in the state providing a pass with Distinction is achieved.
Laura Pivovaroff

Western Australia

WA F. M. Mardiros Memorial Prize
- Awarded to the top Gemmology 2 student in Western Australia
Maria Luisa Chow Chan

Diploma in Gemmology

High Distinction
Maria Luisa Chow Chan (WA)
Laura Pivovaroff (SA)

Distinction (Order of Merit)
Sarah Blundell (VIC)
Genevieve Fahey (VIC)
Jacqueline McMaster (VIC)
Andrew Byrne (NSW Int)
Heike Kolberg (QLD)
Katherine Kate Harrington (VIC)

Credit (Order of Merit)
Adin Dempster (WA)
Louise Thomas (WA Flexi)
Gabrielle Long (VIC)
Belinda Lippiatt (WA)
Erolyn Willis (WA)
Jacqueline Godfrey (NSW Int)
Yesun Kate Kim (NSW Int)
Linda Ozmen (NSW)
George Ojaimi (VIC)
Laura Springbett (SA)
Margaret Jackson (VIC Int)
Ruzbeh Hosseini (WA)
Vicki Sae Sol Nam (NSW)
Jessica Travassaros (VIC)
Andrew Nealon (NSW Int)
Bernadette Fung (NSW Int)
Edmund Heide (QLD)
Jiao Tan (VIC)
Ben Gregory (NSW Int)
Laura Colgan (NSW Flexi)
Nathalie Kermeen (VIC)
Lynne Cunningham (VIC)
Sharee Leister (WA Flexi)
Benjamin Nicholls (TAS Flexi)
Yue Fong (NSW Flexi)
Michael Lovell (WA Flexi)
Melissa Davies (WA)
Leanne Coneybear (QLD)

Pass
Samanpriya Acharige (NSW)
Gina Barreto Quiroga (VIC)
Korrina Bastion (WA Flexi)
Adrian Butler (SA)
Jessica Byron (WA Flexi)
Erica Combe (VIC)
Nasreen Esfahani (QLD)
Karolina Forssman (QLD)
Nicole Galloway Warland (SA)
Lauren Hall (VIC Int)
Jie Ying Mindy Liang (NSW)
Lisa Littlewood (NSW Flexi)
Natasha Ljubic (NSW)
Lynda Loo (WA Flexi)
Jessica Mar (NSW)
Pierre Meyer (VIC Int)
Samantha Jane Mitchell (NSW)
Jennifer Newby (WA Flexi)
Sonja Newton (SA)
Michael Nugent (NSW Flexi)
Gerard Pagliaro (SA)
Bradley Reid (VIC Int)
Qingya Iris Tu (NSW)
Safal Tuli (NSW Int)
Hanna Veijalainen (QLD)
David Wilson (NSW)
Amanda Woods (VIC Int)
Tea (Ting Ting) You (NSW)
Lalaine Zervos (VIC Int)
Zu Wu Wilson Zou (VIC)
Annabelle Zhang (SA)

Gemmology 1

(Alphabetical order by Division)

New South Wales – In House
Angela Barnard
Adriana Daleris
Meghann Farrell
Wan Yi Ge
Joshua Hill
Sarah Hill
Rebecca Hinwood
Kyle Hoffmann
Marika Kahle
Carman Ka Man Kwok
Yuen Ping Ella Lam
Sarah Matley
Lesley Mountford
Richard Schinteie
Helen Skone
Honglei Helena Su
Claire Swan
Matthew Troilo
Alexandra Wheatley
Wicky Wong
Yeuk Kei Jocelyn Wong
Kai (Gilbert) Xia

New South Wales – Flexible
Monica Casamento
Sabrina Fiorino
Marta Giermanski
Danielle Klar
Samantha Lee Mitchell
Katherine Nguyen
Yi Wen (Heidi) Swanson

New South Wales – Intensive
Andrew Byrne
Bernadette Fung
Emily Gifford
Jacqueline Godfrey
Ben Gregory
Yesun Kate Kim
Andrew Nealon
Nicolas Poix
Si (Vera) Shi
Safal Tuli

Queensland – In house
Felicity Armstrong
Wayne Bradley
Maria Dao
Rayin Haining
Sally Lyon
Maree May
Jenny McLaurie
Niamh Scully
Miranda Simmiss
Christina Wilson

South Australia – In house
Craig Roberts
James Scott
Anna Swarbrick

Victoria – In house
Mina Bahraei (Afra)
Benjamin Broekman
Jennifer Campbell
Michelle Hall
Eddy Heng
Kanchana Hettiarachchi
Fiona Isaacs
Sudha Kariamal
Gerard Kennedy
Sharon Lindner
Kam Hon Ma
Kate MacLeod
Rebecca Senior
Paula Southwell
Yokie Yatagai

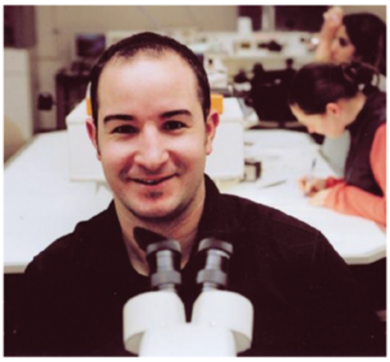
Victoria – Flexible
Gordon Shinewell

Victoria – Intensive
Lauren Hall
Margaret Jackson
Bradley Reid
Paul Rubinstein
Amanda Woods
Lalaine Zervos

Western Australia – In house
Julie Brockman
Teresa Hargreaves
Luis Jorge Pinilla Gallego

Western Australia – Flexible
Jeannine Argus
Stephanie Bright
Elizabeth Brown
Natalee Hibbins
Shirin Yavari

Turn your passion and experience with diamonds into expertise with a formal GAA Diploma in Diamond Technology



- **In-depth** knowledge taught by **industry leading educators**
- Designed by Australian experts for the **Australian market**
- **Hands on** practical and technical knowledge with **lots of support**
- The **practical** diamond grading component of this course will teach you how to grade diamonds to **International standards**
- Grow your industry network and build your **professional reputation**

- This course provides an **in-depth** understanding of **diamonds, simulants and synthetics, treatments and diamond grading**
- Trace diamond's journey from their beginning as **carbon atoms in the earth's mantle** to their final destination as a cut stone or for use in industrial applications.
- Learn to **answer tough questions** and stay 'one step ahead' of the information and mis-information of the world's most popular gemstone.

GAA
Gemmological Association of Australia
Gem-Ed Australia

Call our Enrolment Officer to find out everything you need to know about the Diploma in Diamond Technology

on 1300 436 338 or

email learn@gem.org.au

GAA member cost: Diamond Theory: $2,325. **Practical Diamond Grading**: $2,325. **Easy payment plan:** You can enrol in either course with just a $1,000 deposit.

CLASSES START SOON

Melbourne: THEORY starts 20th April - 25th October. *Wednesday evenings* 6.30–9.00 pm. PRACTICAL: Intensive course *(5 days)* 11th - 15th July, or *Tuesday evenings* 19th July - 2nd October.

Sydney: THEORY starts 3rd May - 25th October. *Tuesday evenings* 6.30–9.00 pm. PRACTICAL: Intensive course *(5 days)* 27th June - 1st July, or 17th - 21st October, or *Monday evenings* 18th July - 10th October.