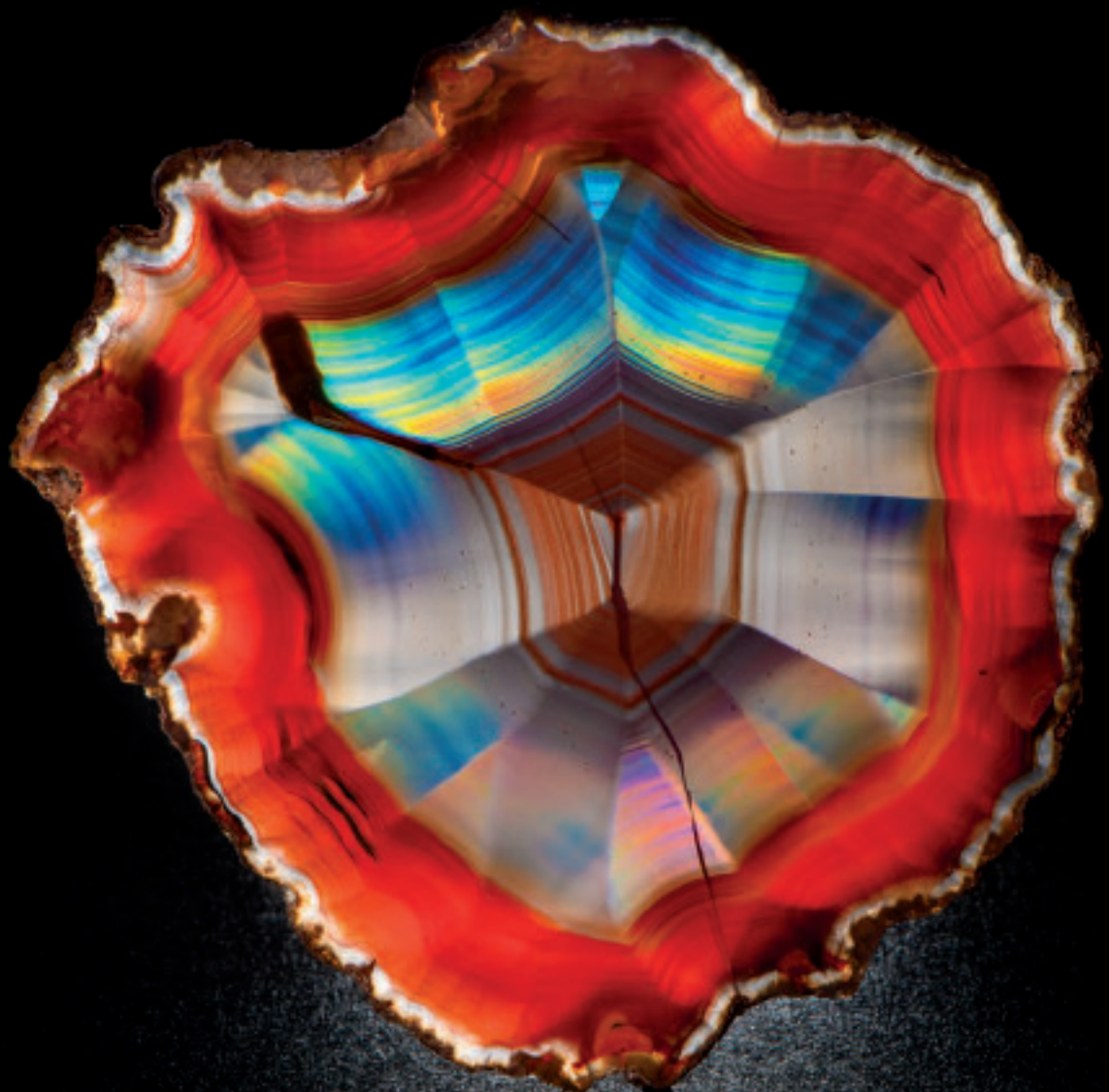
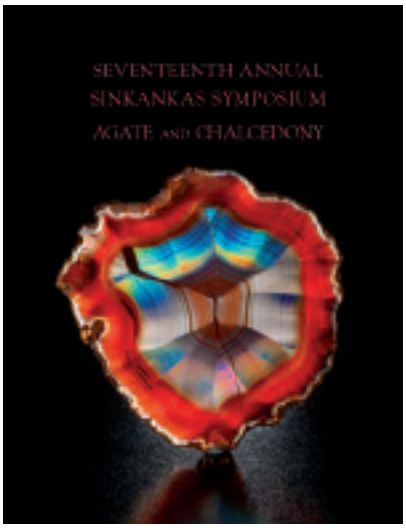
SEVENTEENTH ANNUAL SINKANKAS SYMPOSIUM

AGATE AND CHALCEDONY





FRONT COVER

Iris Agate (90.2 x 86.1 mm), from Chihuahua Mexico. Photo by Robert Weldon, courtesy of Si and Ann Frazier.

BACK COVER

Laguna Agate (162.2 mm), detail, from Ojo Laguna, Chihuahua, Mexico. Photo by Robert Weldon/GIA, courtesy of Kristalle.

SEVENTEENTH ANNUAL SINKANKAS SYMPOSIUM AGATE AND CHALCEDONY

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Seventeenth Annual Sinkankas Symposium – Agate and Chalcedony

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SEVENTEENTH ANNUAL SINKANKAS SYMPOSIUM
AGATE AND CHALCEDONY

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Dedication

This symposium and proceedings are dedicated to Si and Ann Frazier, who have devoted their lives to the study of the science, history and beauty of agate and chalcedony. Si was a popular speaker at the Sinkankas Symposium and author of past Sinkankas Symposia articles.

Roger L. Merk (1948–2015) was the original organizer of the Sinkankas Symposium. We are grateful for his leadership, generosity, and passion over the years.

Acknowledgments

Conference Organizers: Donna Beers, Clare Conway, Dona Dirlam, Lauri Everette, Caroline Nelms, Lisbet Thoresen, and Robert Weldon.

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Special Thanks to

GIA's Clare Conway, Lauri Everette, and Caroline Nelms for hosting, and Kevin Manley for video editing.

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Ann Frazier for continuing the support she and Si have invested in this event since the beginning.

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Mike Dow and Cynthia Emblem, of DPI Direct, Poway, California, for producing the beautiful full color printed proceedings for this year's symposium and the previous six and for creating a website portal to make them available to bibliophiles anywhere in the world.

Very special thanks to all speakers and authors for sharing their knowledge of agate and chalcedony.

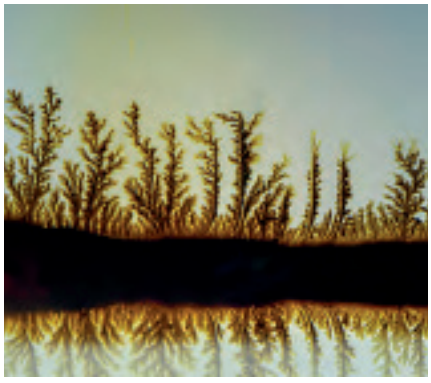
Flamingo (10.2 x 5.2 x 2.4 cm), 1903-08. Agate, rose diamonds, gold. Workmaster Henrik Immanuel Wigström (1862–1923), for Fabergé firm. Royal Collection Trust, United Kingdom, RCIN 40465. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Facing page: Crazy Lace Agate. Chihuahua, Mexico. 61.22 ct. 162.2 mm. Photo by Robert Weldon/GIA. Courtesy of Kristalle.

SEVENTEENTH ANNUAL SINKANKAS SYMPOSIUM
AGATE AND CHALCEDONY (Virtual)

April 24 – June 7, 2021

Hosted by
the Gemological Society of San Diego and the Gemological Institute of America



PROGRAM

Format: Eight pre-recorded presentations available for online viewing on demand via the Sinkankas Eventbrite website portal.

Timothy Adams
Fabergé's Work with Agate and Chalcedony

Patrick Dreher
Dreher Carvings of Agates and Chalcedony

Peter Heaney
The Complex Mineralogy of Agates

William Larson
Collecting Crypto-crystalline Quartzes: A Conversation with Bill

Çiğdem Lüle
Chalcedonies of Anatolia: From Neolithic to Modern Day

Nathan Renfro
The Microworld of Agate and Chalcedony

George R. Rossman
Cause of Color in Agate and Chalcedony

Robert Weldon
Challenges of Photographing Agates

SPEAKER and AUTHOR BIOGRAPHIES

TIMOTHY ADAMS is an independent art historian with an expertise in historical goldwork. His specialty is the work of Carl Fabergé, jeweler to the Russian Imperial Court. Tim has an extensive 30-year background working in the fine jewelry industry for companies such as Bailey Banks & Biddle and Tiffany & Co. He has lectured internationally and is currently curating an exhibition for the Catalina Island Museum and the Houston Museum of Natural Science called *Fabergé at Sea,* which opens in May 2021.

Tim is a contributor to GIA's *Gems & Gemology* journal and serves on its board of editorial review board. He is also the curatorial consultant for the Decorative Arts at the Bowers Museum in Orange County, and has taught art history courses at San Diego State University.

PATRICK DREHER is a fifth-generation master gemstone carver, born in 1970 and still located in Idar-Oberstein, where the tradition of cutting gemstones reaches back for more than 500 years. Patrick grew up in this sphere of influence and spent countless hours in the carving workshop of his famous father, Gerd Dreher.

In 1988, he was officially apprenticed to his father, laying the foundation for his future as a master gemstone carver. For more than 30 years he has been producing original gemstone sculptures, and his art objects are on display in famous museums and private collections all over the world. For the last 20 years he has given many lectures internationally on gemstone carving.

Patrick is a member of the board of trustees of the German Gemstone Museum in Idar-Oberstein and a member of the board of directors of the Federal Association of the Gem and Diamond Industry in Germany.

As a hobby, Patrick devotes himself with passion to the subject of Fabergé, as it is closely linked to his own family's history. He specializes in animal carvings of Fabergé, and experts often seek his knowledge.

SI AND ANN FRAZIER devoted their lives to the world of geology, mineralogy, and gemstones. Si studied geology with an emphasis on mineralogy and petrology at the University of California, Berkeley. Together, he and Ann collected minerals and gems extensively and owned Frazier's Minerals and Lapidary in Berkeley from 1965–1981. After closing the shop they divided their time between writing, teaching, traveling for their business, and displaying at gem and mineral shows.

For more than 40 years, they wrote for both rockhound magazines and professional publications. Si taught geology, mineralogy, petrology, geology of ore deposits, and gemology at San Francisco State University and occasional courses related to gemstones and minerals at San Francisco City College, College of Marin, University of California at Berkeley Extension, the Revere Academy of Jewelry Arts, and Oakland Technical High School.

DR. PETER J. HEANEY is a professor of geosciences at Penn State University. His scientific interests have focused on "mud and gemstones." As an environmental mineralogist, he has investigated the ability of soil minerals to remove toxic metals from surface and ground waters, using a range of X-ray and electron probes that offer crystallographic insights into metal sequestration. He and his graduate students have developed techniques that provide real-time, atomic-scale perspectives of the substitution of deleterious dissolved metals, such as chromium, cesium, and lead, into the structures of manganese and iron hydroxides. His group also has designed environmental cells that allow time-resolved observations of crystal growth in aqueous solutions using synchrotron X-radiation.

In addition, Peter has published papers on unusual optical effects in gem materials, such as chatoyancy in tiger's-eye and iridescence in agate, rock crystal, hematite, and goethite. As a Visiting Scientist at the National Museum of Natural History with Dr. Jeffrey Post, Peter also has collaborated in studies of the Hope diamond.

Professor Heaney served as the president of the Mineralogical Society of America in 2008 and was a central organizer of events to celebrate the centennial anniversary of the MSA in 2019. He received an A.B. in history and science from Harvard University in 1984 and a Ph.D. in Geosciences from the Johns Hopkins University in 1989. He joined the Penn State faculty in 1998, and he has authored more than 140 mineralogical publications.

WILLIAM F. LARSON became interested in gems and minerals at a very early age when he combed the hills of San Diego County with his father and Josephine Scripps and John Sinkankas in search of fine crystals. He earned an advanced degree in geological engineering from the Colorado School of Mines.

In 1968, Bill and then-partner Ed Swoboda purchased three gem mines in the Pala mining district—the Tourmaline Queen, Stewart Lithia, and Pala Chief, whose histories date to the 1800s. Bill stepped onto the international stage in 1972 when an extraordinary strike established his company and the Pala mining district as one of the world's premier sources of tourmaline.

As president of Pala International Inc., Bill heads one of the industry's leaders among gemstone import, lapidary, and mining operations internationally. In a joint venture with his wife, Bill and Jeanne Larson own The Collector, a retail shop located in Fallbrook that showcases fine colored stones, jewelry, and *objets d'art*. Today, Bill travels the world as a guest lecturer, media spokesperson, and authority on minerals and gems, the mining industry, and colored stone pricing.

DONA LEICHT and her husband, Wayne, are the owners of Kristalle, a retailer of gold and mineral specimens established in Laguna Beach, California, in 1971. Over the years, they have field collected all over the United States. (One of their first dates was at a quarry in Pennsylvania—in the rain.) The Leichts also learned about minerals through the microscope. As members of the Baltimore Mineral Society, they studied micromounting under the tutelage of the late Paul Desautels of the Smithsonian Institution. Dona's articles have appeared in *Rocks & Minerals*, *Lapis*, *Mineralien-Welt*, *Mineralogical Almanac*, and other publications.

DR. ÇIĞDEM LÜLE is a mineralogist and award-winning gemologist. She is the founder of Kybele LLC, a consulting firm based near Chicago. Çiğdem's scientific background and gem trade and market experience in Turkey, the United Kingdom, and the United States form the basis for the broad range of services provided to clients. Çiğdem is considered one of the pioneers in archaeogemological research, with an emphasis on origin investigation. She lectures on various aspects of gemology, archaeogemologym and mineralogy worldwide. She specializes in mineral and gem appraisal services as an independent appraiser. Her consultation services also include developing tailored education for the gem professionals, appraisers, gemologists, and gemology students. She is a contributing editor to the GemGuide and the technical advisor to the World of Color communication system. Çiğdem is also a consultant to the ColorCodex color referencing system developed by ColorCodex LLC in New York. In 2016, she was awarded the prestigious Antonio C. Bonanno Excellence in Gemology Award. She is also the proud recipient of the Catriona McInnes Medal of 2019

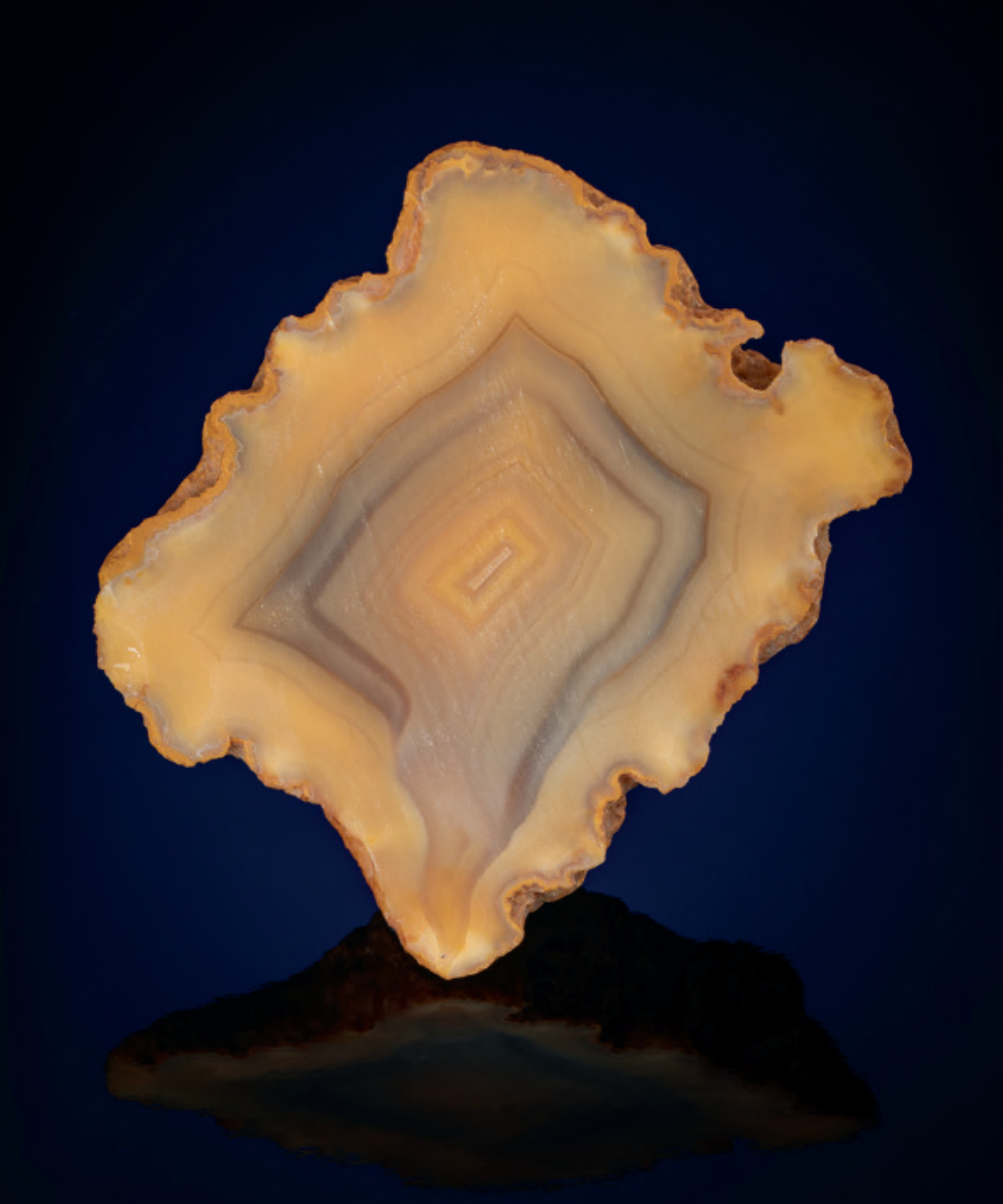
NATHAN RENFRO developed an interest in minerals during his teenage years in western North Carolina. He explored the rich geology of his home state, with particular interest in the pegmatite bodies of Mitchell County, searching for minerals such as beryl, kyanite, garnet, magnetite, feldspar, and mica. In 2006, Nathan obtained a bachelor's degree in geology and education from Appalachian State University, where he was a recipient of the Outstanding Senior Teaching Geology Major award. In 2007, he received the William Goldberg Diamond Corporation scholarship and enrolled at GIA. As manager of identification (colored stones) at the GIA laboratory in Carlsbad, he has authored or coauthored several articles and served as a member of *Gems & Gemology's* editorial review board. Nathan is also a lapidary and designer, with a focus on contemporary cutting techniques, freeform shapes, and improving the optical performance of traditional cutting styles.

DR. GEORGE R. ROSSMAN is Professor of Mineralogy in the Division of Geological and Planetary Sciences at the California Institute of Technology in Pasadena. His principal research interests deal with the use of spectroscopic probes to study minerals. His work addresses the origin of color in minerals, methods for micro-phase identification, the long-term effects from the exposure of minerals to background levels of natural radiation, and X-ray amorphous minerals, including biominerals and weathering products. An important application of his studies concerns the role of low concentrations of water and hydroxide in nominally anhydrous solids. He and his students develop analytical methods for OH analysis and examine the mode of incorporation of hydrous components in solids and their role in modifying physical and chemical properties. George was the recipient of the Mineralogical Society of America's inaugural Dana Medal in 2001, the Richard P. Feynman Prize for Excellence in Teaching at Caltech in 2004, and the Friedrich-Becke Medal of the Austrian Mineralogical Society in 2005. Rossmanite, a species of the tourmaline family, is named after him. George joined the Caltech faculty in 1971. He received a B.S. in chemistry and mathematics from Wisconsin State University, Eau Claire, where he graduated summa cum laude. He holds a Ph.D. in chemistry from Caltech. George has authored or coauthored more than 320 publications in the mineralogical and chemical sciences.

LISBET THORESEN is an independent researcher specialized in integrating gemology, archaeology, and archaeological science, or archaeometry, into the study of ancient glyptic (carved gems). Since 1990, her research has focused on the identity, sources, and transmission and trade of gem minerals used by ancient gem cutters as well as techniques of production, including the application of intentional treatments. She is also interested in the historiography of ancient literature on topics related to natural history and geography. These topics have informed her lectures and essays authored or co-authored for journals and books including *Journal of Gemmology,* conference proceedings and workshops, and a contribution to Richard Hughes's opus *Ruby & Sapphire: A Gemologist's Guide* (2017). Previously, from 1983 to 2000, Lisbet worked in all aspects of the preservation, archaeometric research, exhibition planning, and conservation of antiquities as Associate Conservator at the J. Paul Getty Museum in Malibu, California.

ROBERT WELDON is director of GIA's Richard T. Liddicoat Library in Carlsbad, California, leading a team of librarians and subject matter experts. He is positioning the library to not only be a critical archive for researchers and students, but also a significant content producer for the Institute. He pursues writing assignments at gem localities and often leads gem photography projects in those global locations. Weldon has visited gem sites in Myanmar, India, East Africa and southern Africa, Colombia, Bolivia, Brazil, Russia, and other sources. He speaks Spanish and German fluently and is a well-known public speaker on gemological subjects. Robert is the recipient of the 2020 Antonio Bonanno Award for Excellence in Gemology. He has reported extensively on gemological issues for over three decades. He was a senior editor at *JCK,* and later *Professional Jeweler* magazines before returning to GIA in 2006.

Weldon's photography is published in international gemological, jewelry, and consumer publications and in several books, including *Splendour & Science of Pearls,* which he co-authored and edited. *A Rough Guide for Artisanal Miners* is an educational booklet which he has also lectured on and delivered to artisanal miners in Tanzania and other East African countries. His photographs have appeared on more than 30 covers of GIA's scholarly publication, *Gems & Gemology,* where he has published a number of peer-reviewed articles on subjects such as the Museum of London's Cheapside Hoard, Botswana's diamond industry, the Chivor emerald mine, the gemstones of the Taj Mahal and the Mughals, and the extraordinary carvings from the Dreher family.



Panama Canal Agate (66.52 mm). Photo by Robert Weldon, courtesy Si and Ann Frazier.

In Memoriam: Claren "Si" Frazier (1933–2020)

Dona Leicht

WHEN NEWS REACHED ME about the passing of Si Frazier, well, all I could do was sigh. When you realize that a well-respected man within the mineral community has departed the scene, a long, long sigh is a natural response after screaming "Oh, no!"

All of us had been used to seeing Si, along with his wife, Ann, at almost every major mineral event. At this year's Tucson Show his absence was noted by many. In recent years Si had been noticeably showing signs of his declining health. He had been in a hospital and care facility since early January and passed on 25 February 2020.

I often wondered how his given name of Claren ended up as "Si" for most of his life. It appears to be one of life's little quirks. We know that his grandfather was named Silas—his father was also a Claren—a popular country-western song with lots of references to "Si" may have played a part, but in the end junior Claren was "Si" for the rest of his life, and no one argued the point.

Si's parents, Claren and Loraine Frazier, owned a ranch in Sonoma, California. During explorations around the area Si discovered some quartz crystals, and his future path was almost predestined. The area was also prolific with Native American arrowheads, and Si said that it was the jasper Miwok Native American arrowheads that he collected that were still among his favorite pieces.

When his parents relocated in Susanville where both worked for the Naval Ordinance Station, Si was moved into the city of Berkeley to live with his uncle while he attended middle and high schools.

Scott Williams (another of the famous faces in the mineral world) operated Minerals Unlimited on Durant Avenue in Berkeley, and thirteen-year-old Si became Scott's first part-time employee! Yes, by his early teens Si was already well versed in mineralogy.

Si entered the University of California, Berkeley, where a degree in geology was probably a walk in the park for the young mineralogist. (Yes, I would call him that well before the degree.) During those years he met a fellow student who was studying anthropology. Si married Ann Talburt in September 1961. At the university Si was in the Air Force ROTC—that tidbit surprised me. I just could not picture him in a uniform. Back in the day, there was such a thing as the draft, and in 1956 Si was drafted into the army. After his stint in the service, he joined the Naval Reserve. Now that I have the vision, which uniform did he look the best wearing? I asked Ann, but she never saw him in uniform!

Photo: Rock Currier.

Scott Williams sold the business in 1954 and moved to Arizona where Minerals Unlimited continued, as did Si, under Ralph Merrill. After graduation from Berkeley (Si in 1960 and Ann in 1961), they spent an entire year traveling around Europe in a 1952 Volkswagon "bug"; they remembered that year as one of the best of their

Photo by Wendell Wilson.

lives. And, of course, they were gathering rocks and minerals along the way (about 7 tons!). Si had by this time convinced Ann that collecting rocks was way more fun than collecting pottery sherds—and there went the career as an archeologist; but, as Ann was to discover, collecting those rocks really was fun! Upon returning from Europe, Si enrolled for a master's degree and began teaching (geology, mineralogy, crystallography, ore geology, and petrography) at San Francisco State University.

Minerals Unlimited had moved back to Berkeley, and in 1964 Si and Ann purchased the business, placing an emphasis on gemstones and jewelers' supplies. Si was still teaching, but by 1971 the store was doing so well that he quit. They began to travel to acquire gemstones and gem carvings from Idar-Oberstein for the store, as well as minerals and books. Europe had always been their favorite destination, and Si said he had little desire to drift into Africa or South America. In 1980 they closed the store and concentrated on selling at shows and doing part-time teaching at schools such as San Francisco City College, College of Marin, Oakland Technical High School, Revere Academy of Jewelry Arts, and the Berkeley extension. As if this weren't enough, he also gave lectures to various societies around the world.

Those first pieces of quartz Si found as a young boy would come to be the focus of a life-long writing project on quartz—the mineral and the gem. In just a matter of years the Fraziers built a personal collection of quartz, agate, jaspers, and books—anything with that quartz connection. A great disappointment is that this epic work was not completed. In between, however, Si and Ann wrote more than two hundred articles for periodicals such as *Lapidary Journal, Rocks & Minerals, Gems & Gemology,* and many more.

Each year the Sinkankas Symposium is held at the GIA headquarters in Carlsbad, California. Each symposium has a central theme, and the Fraziers' articles were included in the annual programs. John Sinkankas was a huge mentor for Si, and I can only imagine their conversations about minerals and rare books. The $2 copy of Dana's second edition Si bought in the early days turned into one of his collecting interests that eventually took over just about every room in their apartments. The $500 they paid for a first edition Dana years later pushed Si into the "serious antiquarian book collector" category. John also taught Ann bookbinding, which, considering the depth of the book collection, was a handy skill.

The 2020 Sinkankas Symposium was scheduled for this past May, with Agates and Chalcedony as the topic. The entire program was to have been dedicated to Si and Ann Frazier. Unfortunately, like so many events, the symposium was cancelled because of the coronavirus.

The number of professional organizations of which Si was a member is impressive: Mineralogical Society of America, Gemological Association of Great Britain, the German Gemological Association, Friends of Mineralogy, and numerous local and U.S. societies. When the Geo-Literary Society was formed in the 1980s, Si became a member and was eventually president. The society still meets once a year in Tucson. Si was a past director of the American Gem and Mineral Dealers Association, which was news to me because I never knew it existed.

Was Si a collector possessed? I'm sure he would have laughed and admitted to it. We are back to those pesky silica minerals, and the Fraziers' personal collection is

Si and Ann. Photo by Jim Parrish.

abundant in agate and jasper. His favorite agate was the iris agate found in the Berkeley Hills.

A 1952 article in *American Mineralogist* by Dr. Francis T. Jones about iris agates so intrigued Si that he followed all of Dr. Jones' (Stevens Institute of Technology, New Jersey) writings until the professor died at age ninety. Part of their extensive quartz collection is cut agates, jasper, and other quartz varieties. Si tried to compile a complete history, locality, and additional notes about each piece. This alone is a major task that took years of work and is ongoing.

And then there is the actual quartz collection, which is huge but the flats and drawers are arranged by type, locality, habit, inclusions, and just about any other thing about that particular crystal—with all handwritten labels! You get the picture now? Si sitting among his thousands of books, examining every quartz specimen, writing labels and notes, perhaps enjoying a cup of tea (or more likely a latte) —an 1850 library scene recreated in their not-too-modern condo.

In earlier days Si could be found behind the saw cutting agate slabs, an activity that was almost mindless but gave him enormous enjoyment. All connections to the lapidary equipment were severed after a move to a high-rise apartment. (I can see that the neighbors would have little patience with the sound of a cutting saw.)

And so went the life of Si Frazier, with Ann by his side for nearly sixty years. I have never heard a bad word about Si. He was so eager to share his knowledge, loved talking to collectors who showed a genuine interest, and enjoyed visiting with old friends at shows and being surrounded at home by the books and specimens he devoted his life to acquiring. There was not a day that Si failed to learn something new about mineralogy or rare books. He had no unbearable ego about just how important he was within the mineral world. That alone was deserving of the affection and love that we had for Si. He was a mentor to so many young collectors, many of whom I have talked with during this writing. That almost hidden sly sense of humor, his infinite patience, and his intense interest that never waned—Si, you are one for the ages. How lucky we all are to have known you; and that makes saying goodbye so hard. We won't forget ...

Agate and Chalcedony Objects by Fabergé

Timothy Adams

THE ST. PETERSBURG jeweler Carl Fabergé was appointed Supplier to the Russian Imperial Court by Emperor Alexander III in 1885, which gave him unlimited access to gems and minerals from the Ural and Caucasus Mountains as well as Siberia. He used this vast array of stones to create unique pieces that blended precious metals, enamel, and stone into luxury objects, which were must-have gifts at the turn of the twentieth century.

The Fabergé firm soon became the largest jewelry house in Russia, and one of the leading jewelers in Europe. Headed by Carl Fabergé, it employed over 500 jewelers, enamelers, engravers, and stone carvers, as well as designers and a sales staff. Founded in the capital city of St. Petersburg, branches were subsequently opened in Moscow, Odessa, Kiev, and London. By the end of the nineteenth century, it became fashionable to give small whimsical gifts, often carved from semi-precious

Figure 1 (above). Two views of a Brown Agate carved shell *bonbonnière* set with a gold and enameled 1756 coin of Empress Elizabeth Petrovna bordered by rose-cut diamonds (3.8 cm). Made by Fabergé workmaster Mikhail Perkin c. 1890. The McFerrin Collection, Houston Museum of Natural Science, Texas, inv. 311.

Facing page. A kiwi tilts his head at the viewer. Carved in agate, with gold feet and beak, eyes set with rose diamonds, by Fabergé workmaster Henrik Immanuel Wigström (1862–1923). Royal Collection Trust, United Kingdom, RCIN 40342. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

stones but of high quality and unique design. Fabergé was the master of this genre of gift, often called an *objet de fantaisie*. Figure 1 is an example of a small gift often presented to say thank you for a kindness, or for no special occasion at all, just out of admiration. It is a carved agate snail shell *bonbonnière* containing sweets, applied with an Empress Catherine II coin and further ornamented with gold and enamel.

The Ural and Caucasus mountain ranges, as well as the vast expanse of Siberia, are a cornucopia of gems and minerals. A variety of gemstones from the chalcedony family are abundant there, such as agate, jasper, onyx, heliotrope, and carnelian in all their various colors. They were used by Fabergé for their unique qualities and colorful patterns. He was not interested in the value of the material as much as how it would work with the overall design of a piece. The material was used if it had the right color patterns and texture.

Fabergé's workshops produced a wide variety of stone and enameled Easter Eggs for the holiest of Russian Orthodox holidays, from small egg-shaped pendants and *bonbonnières* (figures 2 and 3) to the legendary Imperial Easter Eggs made for the Emperor to present to his mother, the Dowager Empress Maria Feodorovna, and to Empress Alexandra (figures 4 and 5). Thinly carved banded agate was used because its translucent quality allowed light to illuminate the striations of color in the stone. A banded agate cup with a gold handle from the British Royal Collection (figure 6) exemplifies the delicate balance between metal and stone that Fabergé designers achieved. Not emphasizing one material over another allows for aesthetic harmony of design, as seen in the agate case from the Cleveland Museum of Art (figure 7).

Fabergé jewelry and timepieces often used chalcedony and agate stones, which were especially popular at the turn of the century. Two cabochon blue chalcedonies highlight a brooch and watch set, circa 1904 (figure 8). They are set with rose-cut diamonds to add an understated, subtle sparkle, and the watch is detachable. Moss agate with its "gardens" of dendritic inclusions created a natural landscape for the Fabergé designers to frame in precious metals. In a brooch and watch set created with cut and polished pink moss agate pieces (figure 9), one sees four landscapes that can be gardens on land or undersea. They are graduated

Figure 2. Chalcedony egg pendant (3.18 cm h. × 2.22 cm dia.) produced by Fabergé workmaster Mikhail Perkhin (1860–1903). Virginia Museum of Fine Arts, Richmond. Bequest of Lillian Thomas Pratt, 47.20.126. Photo by Travis Fullerton © Virginia Museum of Fine Arts.

Figure 3. Striated agate *bonbonnière* carved as an egg mounted with gold and green, white and orange enameling (6.4 cm). Made by Fabergé workmaster Mikhail Perkhin c. 1899. The McFerrin Collection, Houston Museum of Natural Science, Texas, inv. 143.

Figure 4. 'Memory of Azov' Easter Egg (9.3 cm l. × 7.0 cm dia.). Made by Michael Perkhin, workmaster for Fabergé firm, 1891. The egg is carved from heliotrope, the fittings are cast and chased gold, silver and non-precious metal, set with precious stones. The Armoury Chamber of Moscow Kremlin Museums, MP-645/1. Courtesy of The Moscow Kremlins Museums.

in size and mounted in rose gold, each framed in rose-cut diamonds. The watch itself is mounted with a pink-toned moss agate to match its rose-gold case. Using rose-cut diamonds, instead of a more brilliant-cut, allowed the diamonds to accent the piece without distracting from the overall aesthetic effect. This was a hallmark of Fabergé's designs.

The most prolific use of chalcedony and agate stones by the Fabergé firm was in their small hardstone carvings of animals. Fabergé worked early on with the Imperial Peterhof Lapidary Works, and by the 1890s he was collaborating with artisans in the major stone carving centers of Ekaterinburg in Russia and Idar (now Idar-Oberstein) in Germany. The stone carvers worked from designs and plaster casts supplied by Fabergé. Moritz Stern and Dreher from Idar were suppliers to Fabergé and supplied high quality carvings. But according to Franz Birbaum, Fabergé's head designer, the work from some (lesser skilled) carvers was not up to Fabergé's high standards, so they were passed on to Stern or to Carl Woerffel's shop to be recut and polished.

Carl Fedorovich Woerffel owned a stone-cutting factory and bronze foundry in St. Petersburg. His expertise was in supplying gemstone objects to Fabergé, where they would often be mounted in gold and applied with enamel and gemstones to be fashioned into cigarette cases, bowls, vases, or animal figurines. By the early 1900s, the demand for hardstone-cut flowers, figurines, and small animal carvings was increasing. Fabergé was unable to fulfill all the orders, even though he had his own stone carving shop. In 1915 Fabergé purchased Woerffel's factory to meet the demand, but even more to control the quality of work.

Queen Alexandra, the wife of England's King Edward VII, was the sister of the Dowager Empress Maria Feodorovna of Russia and a great admirer of Fabergé's work. She especially loved his small animal carvings. One observer of her collection said, "The Queen loves agate animals and has a magnificent collection." Indeed, she had over 100 animal carvings.

The largest order Fabergé received for carved animals came in 1907 from Edward VII, who wanted stone portraits of his favorite horses and dogs. The commission included all the animals on his country estate at Sandringham. This involved modeling cows, bulls, pigs, hens, and birds. It was such an important commission that Fabergé sent his two most skilled

Figure 5 (facing page). Renaissance Easter Egg, produced in agate, with gold, polychrome enamel, rose-cut diamonds and rubies. The last of the Faberge Easter Eggs, made by workmaster Mikhail Perkhin, 1894. Fabergé Museum, St. Petersburg, 05.05.1894.

Figure 6. Cup made from banded agate, mounted with gold and three sapphire cabochons (6.2 × 7.3 × 5.3 cm). Made by Erik August Kollin (1836-1901), masterworker for Fabergé firm. Royal Collection Trust, United Kingdom, RCIN 23090. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Figure 7. Agate cigarette case with gold mounts, interior gold cigarette restraints and a sapphire cabochon thumpiece (overall 6.7 cm). Produced by Erik Kollin, workmaster for Fabergé firm, this elegant box is made from a patterned agate resembling tortoise shell. Cleveland Museum of Art, gift of Howard F. Stirn, 2009.23.

Figure 8. Chalcedony bow brooch and pendant watch set in platinum and gold with rose-cut diamonds and two cabochon-cut blue chalcedony stones (length 4.7 cm). Made by Fabergé workmaster Albert Holmström c. 1904-1908 The McFerrin Collection, Houston Museum of Natural Science, Texas, inv. 479.

Figure 9. Moss agate brooch and pendant watch set in gold mounted with rose-cut diamonds four pieces of cut and polished moss agate (length 9.7 cm). Attributed to Fabergé St. Petersburg branch c.1890-1900. The McFerrin Collection, Houston Museum of Natural Science, Texas, inv. 77.

Figure 10. Animal figurine (5.1 × 6.5 × 2.2 cm). Portrait model of 'Caesar,' Edward VII's wire-haired fox terrier, produced in 1908. Carved in white chalcedony with cabochon ruby eyes, brown enamel and gold collar, which has a gold bell attached, inscribed "I belong to the King." Royal Collection Trust, United Kingdom, RCIN 40339. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

animal sculptors, Boris Froedman-Cluzel and Frank Lutiger, to Sandringham to create models. They spent several months carving wax models, which were examined and approved by the King himself. He insisted that there be no duplicates, and the chalcedony and agate stones were to match the color of the animal being carved.

Once the wax models were completed, they were sent to St. Petersburg and placed in the hands of the highly skilled carvers Peter Derbyshev and Peter Kremlev. Once the carving was completed, the piece was sent to the Fabergé's goldsmith workshop, headed by Henrik Wigström, for a final polish, and to add gold feet and eyes of precious stones.

Edward VII's favorite dog was a wire fox terrier named Caesar (figures 10 and 11). He was modeled in chalcedony with ruby eyes, and his gold collar bears the engraving "I belong to the King." Caesar's character and energy are naturalistically captured by the modeler in the dog's stance.

Figure 11. King Edward VII and Caesar 1908 (27.8 × 20.3 cm). Gelatin silver print by Byrne, Francis & Co. Ltd. The King is standing next to Caesar, who is on a stone ledge beside him. Caesar achieved worldwide fame in 1910 when he joined the funeral procession of his master. Royal Collection Trust, United Kingdom, RCIN 2107402. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Figure 12. Animal figurine (4.4 × 10.5 × 3.6 cm). A portrait model of a Clumber spaniel, 'Sandringham Lucy,' c. 1907. Carved in pale gray chalcedony, with cabochon ruby eyes. Royal Collection Trust, United Kingdom, RCIN 40442. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Figure 13. Animal figurine (5.4 × 6.8 × 1.5 cm). Agate carving of a borzoi, with ruby inlaid eyes, c. 1908. Borzois were bred exclusively for the Russian court. Royal Collection Trust, United Kingdom, RCIN 40030. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Figure 14. Animal figurine (4.6 × 8.4 × 6.7 cm). Doe and three baby rabbits, c. 1907, carved from a single piece of agate with subtle color variation ranging from pale orange to reddish brown, the eyes are inlaid with rose diamonds. Royal Collection Trust, United Kingdom, RCIN 40409. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Figures 15a,b. Animal figurine (5.2 × 3.8 × 3.5 cm), frontal and three-quarter views. Chimpanzee, carved from from a single piece of agate, eyes inlaid with peridot, 1900. The carving exploits the bi-colored material, with the brown color of the body contrasting the pale bluish gray of the face and left arm around the elbow.Royal Collection Trust, United Kingdom, RCIN 40375. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Figure 16. Animal figurine (4.2 × 5.9 × 4.0 cm). Bulldog carved from semi-transparent banded agate, with rose diamond eyes. The curving bands of the stone accentuate the dog's rippling musculature and vitality; his tail is raised and the posture is assertive, yet playful. Royal Collection Trust, United Kingdom, RCIN 40273. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

The Prince of Wales, later King George V, had a Clumber spaniel named Sandringham Lucy (figure 12). Fabergé's artisans carved her of chalcedony and added cabochon ruby eyes to bring her to life. One of Queen Alexandra's favorite Borzois was carved of agate. In the selection of the material for this royal pet, the transluceny and luster of the stone complements the breed's distinctive color markings and luxurious coat.

A clutch of rabbits huddled together (figure 14) and a seated chimpanzee with arms folded (figure 15) show the charming nature of these hardstone animals. The modelers' observations of these animals over weeks of study allowed the artists to capture each animal's innate character and then translate it into stone.

Many different farm animals were modeled by Fabergé workmasters, along with mice and other rodents, but whether they were pampered pets (figure 16) or animals of the hedgerow (figures 17–21), the color variations and patterns of the material selected for the carving always elicited the personality of the animal: they were unique portraits.

Figure 17. Animal figurine (5.2 × 5.6 × 2.4 cm). Cockerel, c. 1908, carved from carved from carnelian, with rose diamond inlays for the eyes, and cast gold for the feet. Royal Collection Trust, United Kingdom, RCIN 40447. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Figure 18. Animal figurine (3.5 × 4.1 × 2.1 cm). Seated pig scratching his ear, c. 1908, carved from carnelian with a brown sard-colored posterior and curly tail, eyes inlaid with rose diamonds. Royal Collection Trust, United Kingdom, RCIN 40015. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Figure 19. Animal figurine (0.9 × 5.2 × 3.8 cm). Four piglets carved from agate and chalcedony in various colors, attached to a gold mount, c. 1896-1903. Mikhail Perkhin, workmaster for Fabergé firm. Royal Collection Trust, United Kingdom, RCIN 40038. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Figure 20. Animal figurine (5.7 cm l.). She-goat carved from strongly banded agate, c. 1900. She stands with her head turned to the left and tail uplifted; the eyes are inlaid with diamonds. Sotheby's Russian Art Auction, held April 21, 2010, Lot 137, from the estate of Frances H. Jones.

Figure 21. Animal figurine (6.2 × 5.2 × 5.8 cm). Dormouse, c. 1910, carved from bluish gray and orange to brown-colored agate, with platinum and gold elements, eyes inlaid with sapphires. Royal Collection Trust, United Kingdom, RCIN 40261. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Figure 22. Animal figurine (7.8 × 15.7 × 5.7 cm). Crow, c. 1907, carved from jasper and obsidian, the eyes are inlaid with aquamarines, the feet are silver-gilt. Henrik Wigström, workmaster for Fabergé firm. Royal Collection Trust, United Kingdom, RCIN 13756. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

A winsome dormouse (figure 21) was added to the collection around 1910. It features a clever use of precious metal threads for the whiskers and golden strands representing a tasty meal of grass (or straw) held in the rodent's paws.

A crow made of jasper and obsidian (figure 22) illustrates how the Fabergé lapidaries might combine two different materials to achieve a more naturalistic color variation than might be obtained from a single stone. This technique is known as "mosaic sculpture."

Knowing of Queen Alexandra's fondness for these Fabergé animal figurines, her friends and family often gave them to her as gifts. Fabergé's London branch made sure it had a nice selection of animals to choose from just for this purpose. The Fabergé repertoire was not limited to farm animals or domestic pets. Exotic creatures were added over the years. Primates including chimpanzees were popular subjects (figures 15a,b, and 23). They were carved with expressive faces and poses from single pieces of agate.

Figure 23. Animal figurine (7.5 × 6.2 × 7.6 cm). Chimpanzee, c. 1910, carved from a single piece of agate, eyes inlaid with peridots. Royal Collection Trust, United Kingdom, RCIN 40377. Royal Collection Trust / © Her Majesty Queen Elizabeth II 2021.

Figure 24. Animal figurine (4.13 × 7.3 × 2.86 cm). Eagle, 1899-1908, carved from banded agate, with diamond-set eyes and feet of gold. Henrik Wigström, workmaster for Fabergé firm. Virginia Museum of Fine Arts, Richmond. Bequest of Lillian Thomas Pratt, 47.20.257. Photo by Travis Fullerton © Virginia Museum of Fine Arts.

Figure 25. Animal figurine (11.75 × 6.99 × 4.13 cm). Ostrich, c. 1900, carved from banded agate, eyes inlaid with demantoid garnets, feet of gold, quartzite plinth. Virginia Museum of Fine Arts, Richmond. Bequest of Lillian Thomas Pratt, 47.20.262. Katherine Wetzel © Virginia Museum of Fine Arts.

An eagle and an ostrich (figures 24 and 25) in the Lillian Thomas Pratt collection at the Virginia Museum of Fine Arts, exemplify how the carvers carefully chose the colors and patterns of the stones to suit the subject. A series of agate and carnelian fishes in the Cleveland Museum of Art (figure 26) illustrates how Fabergé's masterworks exploited the endlessly nuanced and variable colors and patterns to be found in the microcrystalline quartzes.

Fabergé rarely produced human figures carved in hardstone. In fact, only around 50 were made, and Emperor Nicholas II was known to have a collection of 21. His brother Grand Duke Michael received one from his wife Natasha on their first wedding anniversary. Their first year of marriage had been spent sailing on their yacht, the *Zarnitza*. As a remembrance of this honeymoon period, she bought a hardstone

Figure 26. Animal figurines (overall 3 cm). A set of three carnelian and agate fish. Produced by Erik Kollin, workmaster for Fabergé firm. Cleveland Museum of Art, gift of Howard F. Stirn, 2009.30.

Figure 27. Statuette of a Sailor (12.07 × 6.03 × 3.18 cm), after 1890, milky quartz, aventurine, onyx or chalcedony, lapis lazuli, sapphires and gold. Virginia Museum of Fine Arts, Richmond. Bequest of Lillian Thomas Pratt, 47.20.268. Photo by Travis Fullerton © Virginia Museum of Fine Arts.

Figure 28 (right). Statuette of a Russian peasant girl (15.9 cm), c. 1910, by Peter Carl Fabergé, signed: C. FABERGÉ. Carved from jasper, purpurine, nephrite, jade, with sapphire inlays for the eyes. Metropolitain Museum of Art, New York, 54.147.107, gift of R. Thornton Wilson, in memory of Florence Ellsworth Wilson, 1954.

figure from Fabergé's London shop in the form of a sailor (figure 27). On the sailor's cap was engraved the name of their yacht. It was carved from white agate, with lapis lazuli accents; his eyes are sapphires and his face and hands are carved in aventurine quartz.

A popular theme for Fabergé hardstone figurines were everyday Russian people, painters, carpenters, street peddlers, and village peasants. The Metropolitan Museum of Art in New York has a Fabergé hardstone peasant girl (figure 28) in a red dress and scarf made of purpurine, a man-made deep red glass that is easily cut and polished. She is also carved from jasper and jade, with blue sapphire eyes.

Most of these figurines are caricatures of Russian types, and not actual portraits. An exception would be the portrait of N.N. Pustynnikov, the bodyguard of Empress Alexandra Feodorovna from 1894 to 1917 (figure 29). In 1912 Emperor Nicholas II commissioned Fabergé to make hardstone portrait figures of two bodyguards who were assigned to protect his wife, and his mother the Dowager Empress Maria Feodorovna. The figure of Pustynnikov, now in a private collection, is carved from nephrite, gray jasper, black chalcedony, brown obsidian, and cachalong. His medals are gold and enamel. He and the other bodyguard, A.A. Kudinov (figure 29), are the only known hardstone figures to be portraits of actual people. Both men posed for designers in the workmaster Henrik Wigström's studio. Next a wax model was created and sent to the lapidary shop to be made in polychrome stone.

The last example of a masterpiece in hard stone carving by Fabergé is the portrait of the famous gypsy singer Varvara "Varya" Panina (1872–1911; figure 30).

Figures 29a–d (facing page and this page, below). Four views of a portrait figure of Kamer-Kazak N.N.Pustynnikov (1857-1918), personal body guard to Empress Alexandra Feodorovna. Human portraits were among the rarest of figurines produced by the Fabergé firm. This lifelike carving measures 19.05 cm tall and is composed of multi-colored hardstones including different varieties of microcrystalline quartz. Photo by Walter Hill, courtesy of Stair Galleries, New York.

Figure 30 (right). Portrait of Varya Panina carved from multi-colored jasper, aventruine quartz and purpurine. Collection of A La Vieille Russie, New York.

She was a deep contralto and very popular in Moscow, where she started singing in a restaurant. Once she was given the chance to sing on stage, her fame spread to St. Petersburg. There she became popular with the leading literary figures of the time such as Leo Tolstoy and Anton Chekhov, as well as members of the Russian Royal Family. Fabergé uses a green and red striped jasper to form her skirt, and a variegated red and cream jasper to create the illusion of an embroidered shawl. This shows the carver's careful attention to detail in selecting just the right stone to create an impression of verisimilitude. These small human stone mosaic figures are as rare as the Imperial Easter Eggs.

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Iris Agates and Cantor Dusts: The Textural Complexity of Agates

Peter J. Heaney

Abstract

Agates are most famous for their concentrically colored bands, which often are geometrically intricate. Commonly, this polychromatic layering will enable a skilled collector to trace a given agate to its locality with high fidelity. Imprinted on these pigmented bands, however, is yet another type of pattern—a repetitive microfabric with respect to the quartz crystals that compose the chalcedony within an agate. Although this silica texturing is much subtler than the bright colors imparted by metal oxide inclusions, it gives rise to the diffraction effects responsible for the rainbows of iris agate. Moreover, the crystalline defects often occur as a hierarchical fabric characterized by the fractal qualities of a so-called Cantor dust. This presentation will describe the curious nature of the Brazil twins that populate agates as oscillatory waves at length scales of nanometers, microns, tenths of millimeters, and centimeters.

Introduction

OVER THE PAST CENTURY and a half, scientists have accomplished a feat of dubious virtue: Of the 30 materials identified as "important gemstones" by Hurlbut and Kammerling (1991; table 1), all can be grown synthetically. Even lab-created diamond, which seemed an unlikely commercial threat 30 years ago, can now be produced in large crystals at sufficiently low cost as to exert major impacts on the diamond market (e.g., Grynberg et al., 2014; Taylor and Lewis, 2018). Surprisingly, agates—one of the most abundant gem materials in terms of both geographic distribution and sheer tonnage—have remained impervious to humanity's efforts to reproduce them. Single microcrystals of prismatic quartz were first synthesized by a German geologist in the mid-nineteenth century (Schafhäutl, 1845), and mass manufacture of large hydrothermal quartz crystals was powering industries such as General Electric one hundred years later (Byrappa and Yoshimura, 2008). Undoubtedly, the copious availability of natural agates has depressed both the prices of these exquisite gems and, by extension, the motivation to duplicate them. The barrier to synthesizing agates, however, goes beyond the lack of economic incentive. The textures of nanocrystalline agates are highly idiosyncratic, and their growth processes likely involve chaotic behaviors that lie at the fringes of our understanding. This contribution focuses on the nature of the intricate microtextures that are idiomatic to agates.

The Nature of Banding in Agates

In his 1887 book titled *Chips from the Earth's Crust,* John Gibson offers a popular survey of what was known about "Scottish pebbles" at that time. After acknowledging the mysterious nature of their formation, he observes:

> Dr. Reusch [German author of an 1864 overview of agates] has shown how the agate structure may be strikingly reproduced artificially. He took an

Figure 1 (facing page). Laguna agate, Mexico (75.53 ct., 53.75 mm). Courtesy of Kristalle, photo by Robert Weldon/GIA.

irregularly-shaped cavity, and introduced into it a thin cream of plaster of Paris, which, after shaking round, he poured out, thus leaving a thin coating of the material lining the interior. This was repeated with different coloured creams of plaster, until the entire cavity was filled up; and on cutting through the nodule thus formed, the concentric layers of different coloured plasters exactly reproduced the appearance of a banded agate.

Neither Gibson nor any gemologist today would regard a polychromatic ball of gypsum as an acceptable simulant for agate! Although distinctive colorful banding is what attracts most collectors to geodes—and often pins agates uniquely to their localities (figures 1 and 2)—layering with variegated pigmentation is not an essential character of an agate. Many agates exhibit no coloration beyond the diffuse blue Rayleigh scattering that occurs when white light interacts with particles that are nanometers in size. Iris agates in particular are more desirable in the absence of distracting pigmentation.

Nevertheless, concentric banding of the silica matrix itself is diagnostic of even non-pigmented agates, and an examination of these bands by electron microscopy reveals a complexity that is virtually without peer among gem materials. The quartz within agates is a variety known as chalcedony, and chalcedony differs from the

Table 1. Important Gemstones from Hurlbut and Kammerling (1991)

Andalusite	Nephrite
Beryl	Opal
Calcite	Peridot
Chrysoberyl	Quartz
Corundum	Rhodochrosite
Diamond	Rhodonite
Diopside	Serpentine
Feldspar	Sodalite
Garnet	Spinel
Hematite	Spodumene
Idocrase	Topaz
Iolite	Tourmaline
Jadeite	Turquoise
Lapis lazuli	Zircon
Malachite	Zoisite

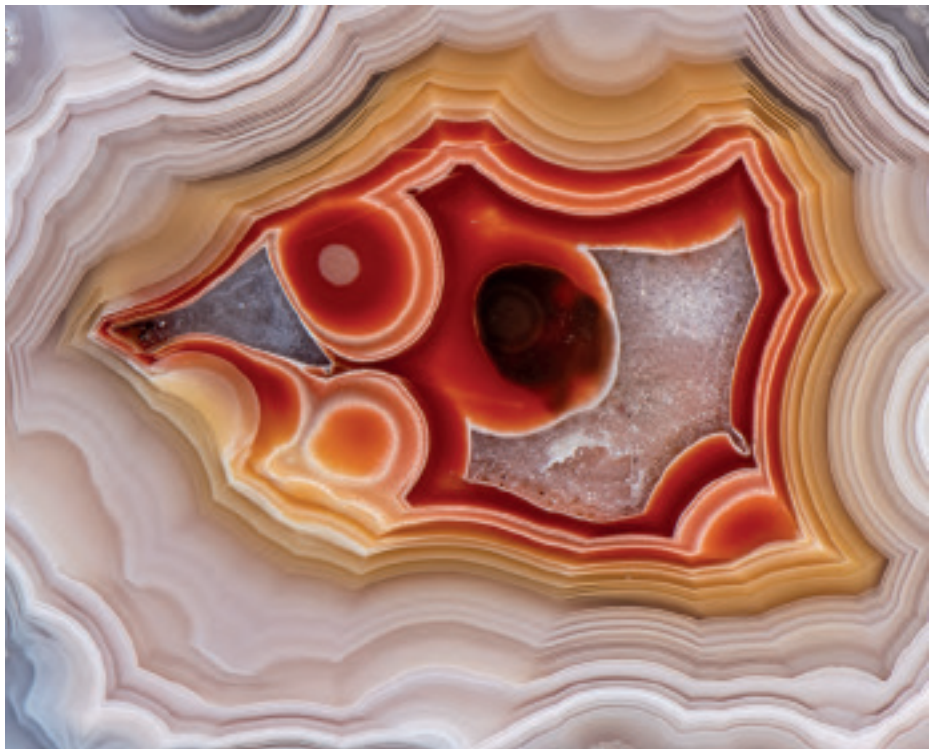

Figure 2. Laguna agate (detail), Ojo Laguna, Chihuahua, Mexico 129.59 g. 70.85 mm. Courtesy of Kristalle, photo by Robert Weldon.

Figure 3. A 248.70 g rock crystal quartz, probably from Arkansas. Photo by Robert Weldon; gift of Serena Lam.

large, prismatic quartz crystals formed hydrothermally (from Hot Springs, Arkansas, for example; figure 3) in several ways. First, the individual crystallites that compose chalcedony are typically less than 0.1 micron in size. A single human hair is on the order of 100 microns in diameter, and thus the quartz that comprises chalcedony actually is nanocrystalline, even though by convention we often describe chalcedony as "microcrystalline quartz." Second, the crystallites in chalcedony are aligned to make fibers (figure 4), and those fibers extend along a different crystallographic direction than the prism direction of Hot Springs quartz crystals. Formally, we say that Hot Springs–type quartz is elongate along the *c*-axis, whereas chalcedony fibers are oriented perpendicular to the *c*-axis (Michel-Lévy and Munier-Chalmas, 1892).

Third, the chalcedony fibers are twisted about the growth axis (Lacroix, 1900; Frondel, 1978), whereas most prismatic quartz grows straight. A close look at some of the chalcedony fibers in figure 4 reveals a spiraling quality like a barber's pole about the cores of the fibers, and this fiber twisting gives rise to a characteristic zebra-stripe (or Runzelbanderung) when chalcedony is viewed with crossed polars in a petrographic microscope (figure 5). Fourth, the

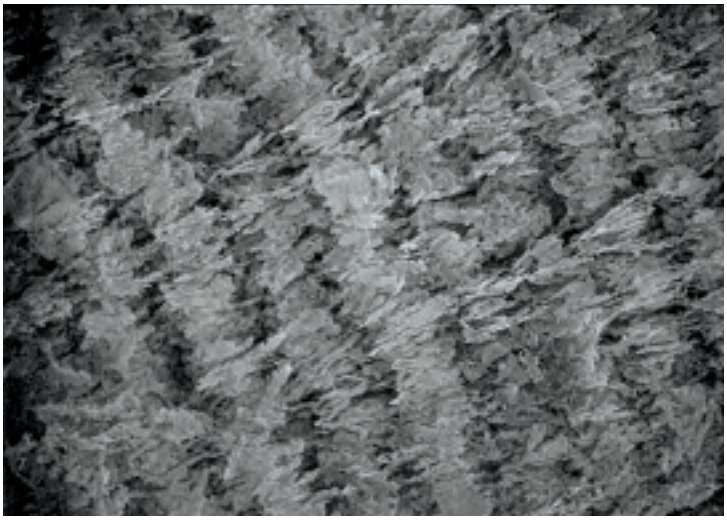

Figure 4. An image of an etched iris agate showing the chalcedony fibers that make up an agate, taken with a scanning electron microscope.

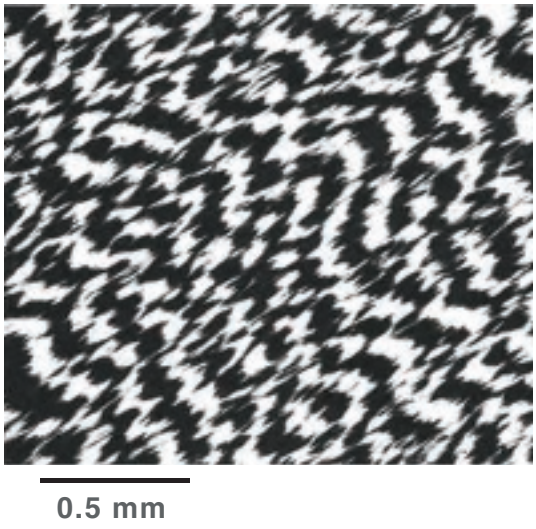

Figure 5. Extinction bands along chalcedony fibers, as seen with crossed polars in a petrographic microscope, reveal that the helical pitch is correlated among adjacent fibers. From Heaney et al. (1994).

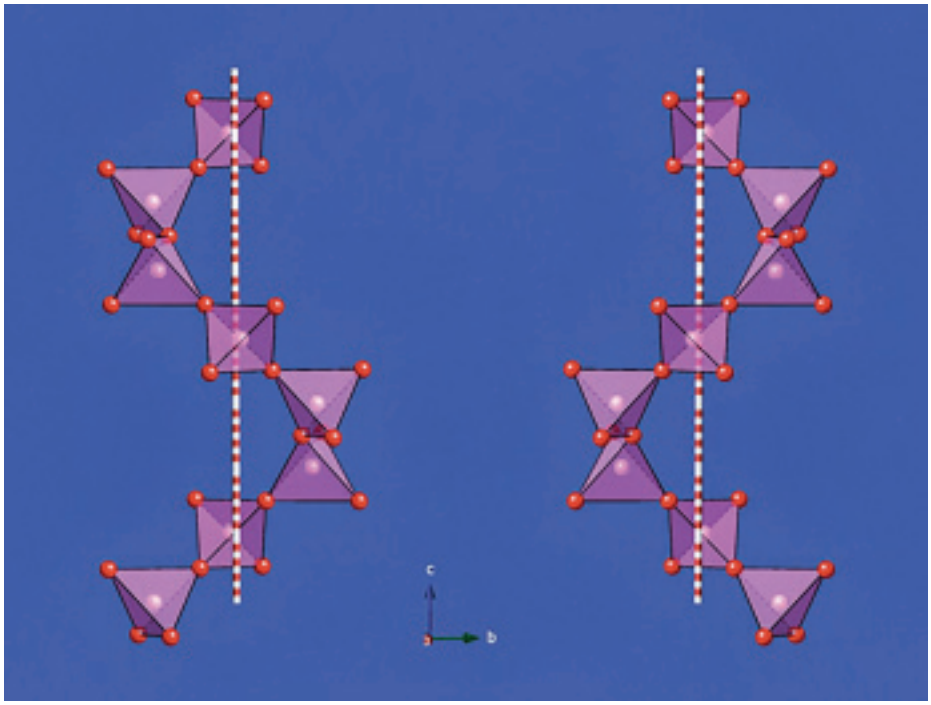

Figure 6. Chains of silica tetrahedra (Si: pink balls; O: red balls) that comprise the atomic structures of left-handed quartz (left) or right-handed quartz (right). Drawing made with CrystalMaker.

nanocrystalline quartz in chalcedony is intimately intergrown with moganite, which shares the same chemical composition (SiO_2) with quartz. Moganite was first identified as a new mineral and christened "lutecite" by Michel-Lévy and Munier-Chalmas in 1892 based on light optical microscopy, but it was wrongly discredited in the 1920s. Rediscovered as "moganite" by Flörke et al. (1976, 1984), it was finally approved by the International Mineralogical Association in 1999. The amount of moganite relative to quartz in agate depends strongly on the age of the agate, since moganite is less stable and over time will convert to quartz (Heaney and Post, 1992; Petrovic et al., 1996; Moxon and Ríos, 2004).

Brazil Twinning

The chalcedony in agates differs from Hot Springs prismatic quartz in yet a fifth way: It contains extremely high concentrations of a crystalline defect called a Brazil twin. Twins within minerals refer to regions of a crystal that are related by a symmetry operation, such as a rotation or a mirror reflection. In quartz, Brazil twins are regions in which the atoms are related by reflection in a plane parallel to the *c*-axis. The crystal structure of quartz consists of silicon (Si) atoms that are each surrounded by four oxygen (O) atoms to make a tetrahedron—the Platonic solid built from four equilateral triangles. These chains may be either left- or right-handed (figure 6). If, as with a regular wood screw, the threads spiral away from the viewer in a clockwise direction, the chains are right-handed; counterclockwise spirals generate left-handed screws.

As can be seen in figure 6, left- and right-handed chains are related by mirror reflections; like your left and right hands, no amount of rotating will superimpose one exactly on the other. When different portions of the same crystal of quartz contain silica chains of opposite handedness, we call those different regions "Brazil twin domains," and the boundary separating them "Brazil twin walls." Brazil defects can form as a crystal grows, or alternatively they can be induced in a fully grown quartz crystal by applying stress (Frondel, 1962; Fazio et al., 2018). Energetically, it is equally favorable for quartz to crystallize either with left- or right-handed chains, and the atomic structure of left-handed quartz interlocks very well with the atomic structure of right-handed quartz (Grimmer and Delley, 2012). Thus, separate nuclei of left- and right-handed quartz crystals growing within hydrothermal solutions may eventually incorporate within a single crystal.

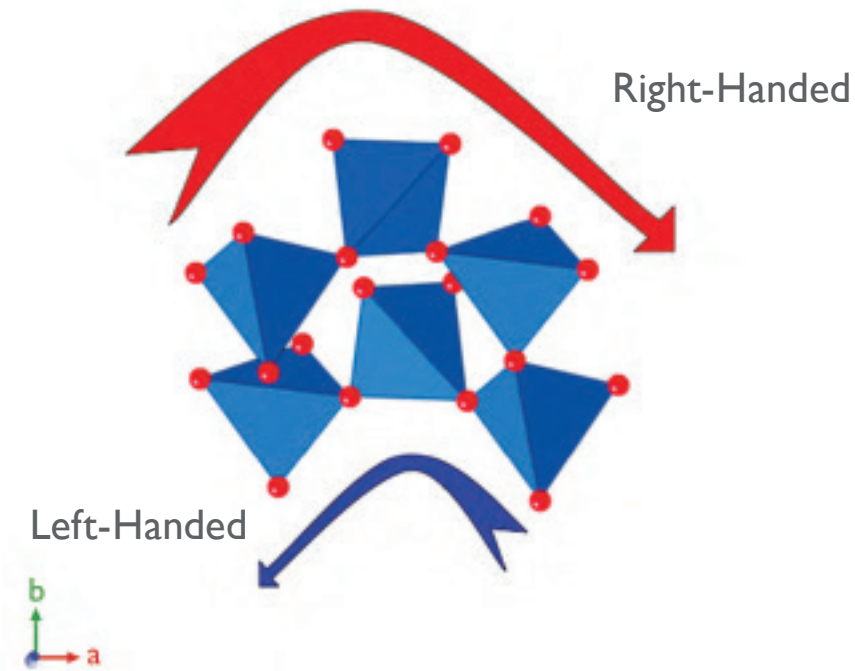

Figure 7. Reversing handedness of silica tetrahedra chains in the structure of moganite, which has a different unit cell than quartz.

Brazil twins are observed in nearly all natural quartz crystals. They are especially common in amethyst, which in turn is abundant in the geodes of the Paraná traps of Brazil, hence the name of the twin. I have examined seemingly perfect rock crystal quartz from localities like Hot Springs using transmission electron microscopy, and before long one always stumbles into a Brazil twin boundary. But even in amethyst, the density of these defects is low enough that one can count the number of twin walls per unit area. In chalcedony, the Brazil twinning is so intense that it is impossible to measure twin wall densities in the usual way. When the Brazil twinning is so concentrated that the handedness of the spiraling chains reverses with every unit cell (figure 7), a new crystal structure is generated—that of moganite (Miehe and Graetsch, 1992).

As seen in figure 6, the spiraling silica chains in quartz run parallel to the crystallographic *c*-axis. Most prismatic, Hot Springs–like quartz crystals grow fastest in the direction of these helices and thus along the *c*-axis (figure 3). Chalcedony fibers, by contrast,

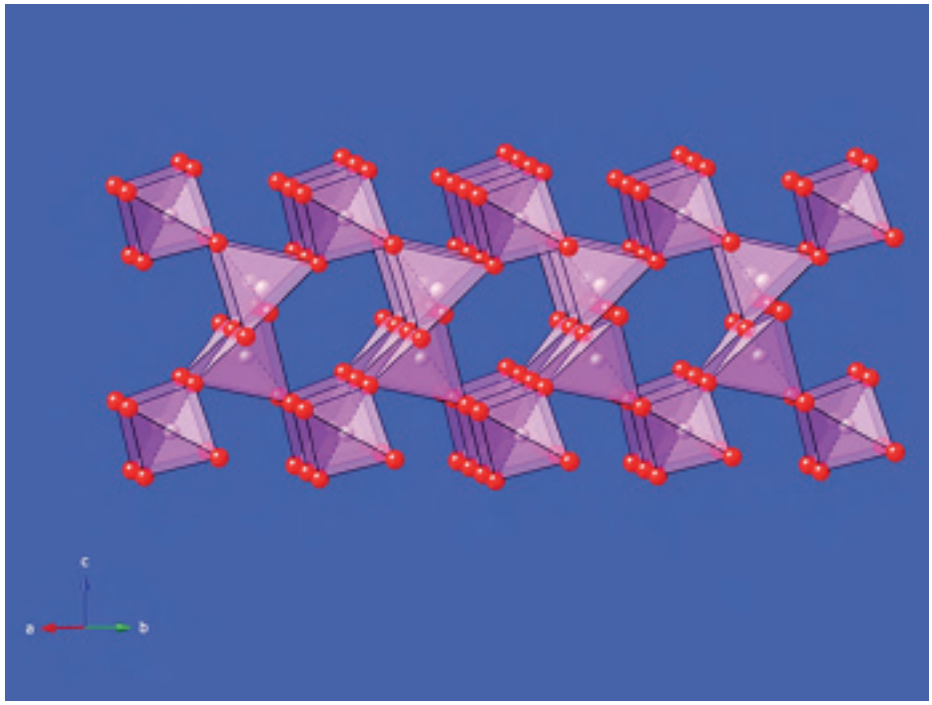

Figure 8. A view of the atomic structure of quartz along the [110] direction, perpendicular to the c-axis of quartz. Chalcedony fibers are elongate parallel to this [110] viewing direction.

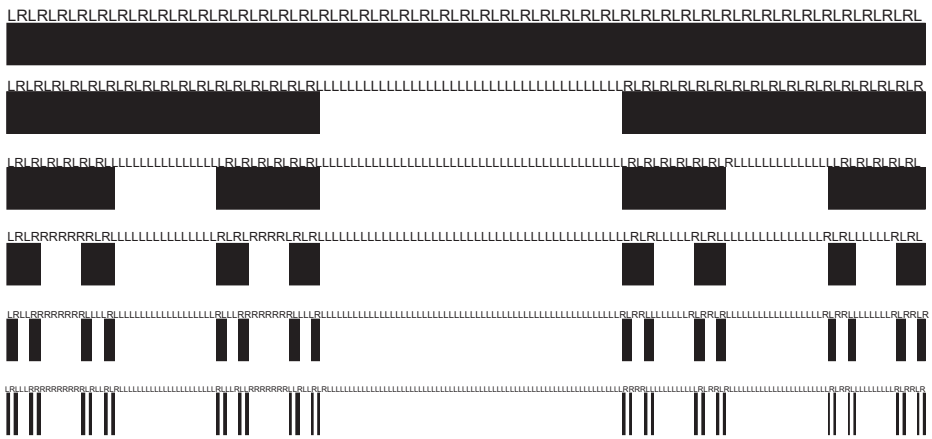

Figure 9. A Cantor dust of left-handed and right-handed Brazil twin boundaries (left and right, respectively).

are elongate perpendicular to the spiraling chains, in what is known as the [110] direction. Silicate minerals tend to grow most rapidly in the direction of their tetrahedral chains, but there are secondary silica chains in quartz along this [110] direction (figure 8), and apparently these linear [110] chains outcompete the helical chains along the *c*-axis during the growth of chalcedony. Heaney (1993) has proposed that chalcedony fibers grow from the exterior towards the interior of the cavities via these [110] silica chains, generating excessive Brazil twinning in the process, perhaps because of changes in the state of silica polymerization in the parent fluid. (See for example, figures 1 and 2.)

Cantor Dusts

The German mathematician Georg Cantor (1845–1918) was a professor at the University of Halle, and he is regarded as a founder of set theory. He was particularly enamored of paradoxical sets whose dimensions (D) do not conform to the usual whole numbers by which Euclid described points (0), lines (1), planes (2), and solids (3). Instead, Cantor devised ingenious sets whose dimensions were fractional, dubbed "fractal dimensions" by Benoit Mendelbrot in 1975 (Peitgen et al., 1992). Cantor analyzed a set devised by the British mathematician H.J.S. Smith constructed in the following way: Start with a line segment with a length of 1. Remove the middle third of that line segment. Next, remove the middle thirds of the two residual line segments. Keep removing the middle thirds of line segments ad infinitum (figure 9). The resulting array—called a "Cantor dust"—has a dimension that is more than a point but less than a line; its fractal dimension works out to 0.631 (Shirali, 2014). Varieties of Cantor sets appear over and over in chaotic dynamical systems in mathematics. Amazingly, they also are concealed in the banding patterns of agates. How?

Imagine that the line segment in figure 9 represents a regularly repeating series of Brazil twin boundaries. If the repetition occurs at the scale of the unit cell, then the top line is a schematic illustration of the mineral moganite. Now suppose that we remove all Brazil twin boundaries from the middle third of this line segment. That leaves the middle third of the line segment as entirely either left-handed (as shown in the illustration) or right-handed. We repeat the removal of Brazil twin boundaries in the residual line segments and continue indefinitely. What emerges is a hierarchically banded

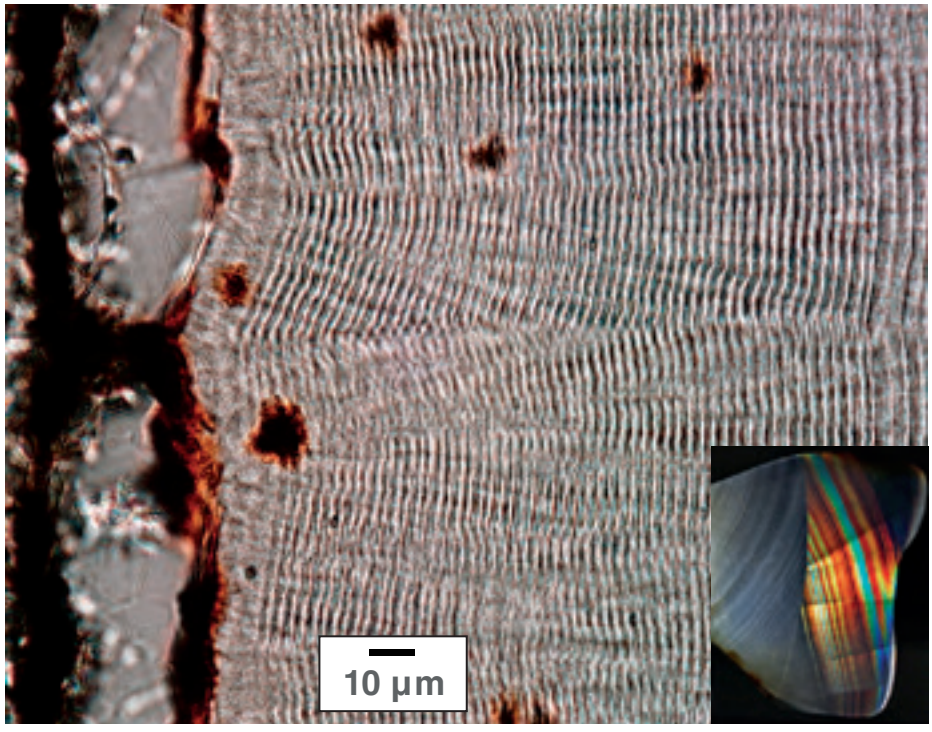

Figure 10. Petrographic thin section of Brazilian agate viewed in plane light showing repetitive iris bands. **Inset:** Iris agate photo courtesy of Dave Ault.

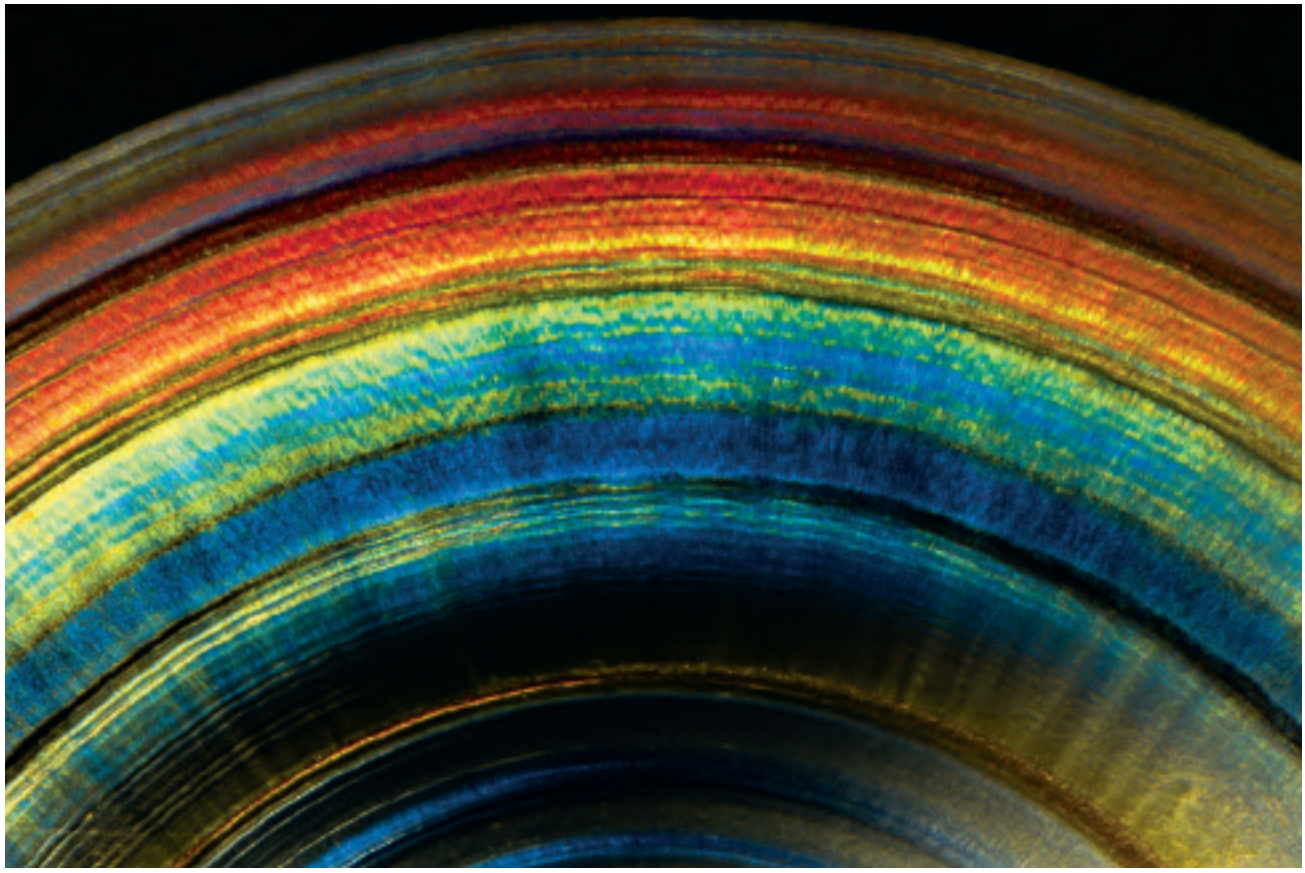

Figure 11. An iris agate from Nipomo, California, shows vibrant diffraction colors. Photomicrograph by Nathan Renfro; field of view 11.51 mm. Courtesy of the John Koivula Inclusion Collection.

alternation of Brazil-twinned quartz and untwinned quartz. Like Russian dolls, every time we magnify the illustration, we observe the same nested pattern.

This symmetrically tiered oscillation in Brazil-twin density—symmetrical with respect to magnification rather than rotation or reflection—is exactly what one observes within the banding of agates. At the nanometer scale (10^{-9} m), agates contain moganite (Brazil-twinned at the unit-cell scale) alternating with quartz (no Brazil twins). At the micron scale (10^{-6} m), we see bands of intensely Brazil-twinned nanoquartz alternating with coarser-grained defect-free quartz. As seen in figures 10 and 11, this micron-scale banding gives rise to the iris agate effect first described by Brewster (1813). Frondel (1985) reports over 15,000 successive iris bands within an individual specimen, and Heaney and Davis (1995) demonstrated that these stripes correspond to undulations in Brazil twin defect density.

We can demagnify twice more (figure 12), and the same agate (from Brazil) reveals oscillations in Brazil twin densities at the 100-micron scale and again at the centimeter scale. Of course, not all agates exhibit this hierarchy of defects so beautifully. For instance, many agates do not contain a coarsely crystalline quartz druse as the final crystallization stage in the interior, and others do not exhibit regular iris banding over thousands of sequences to create an iridescent grating. On the other hand, systematic examination of agates in hand samples, in thin sections with light petrographic microscopy, and at the nanoscale by transmission electron microscopy, does reveal that subsets of these hierarchical textures are quite common.

Implications?

Does the embodiment of Cantor sets in agates tell us anything about how they form? The grand divide in models for agate formation is the debate between epigenesis and syngenesis (Shaub 1989). Epigenesis (epi = "after" or "over") implies that agates formed following the deposition of the vesicular host

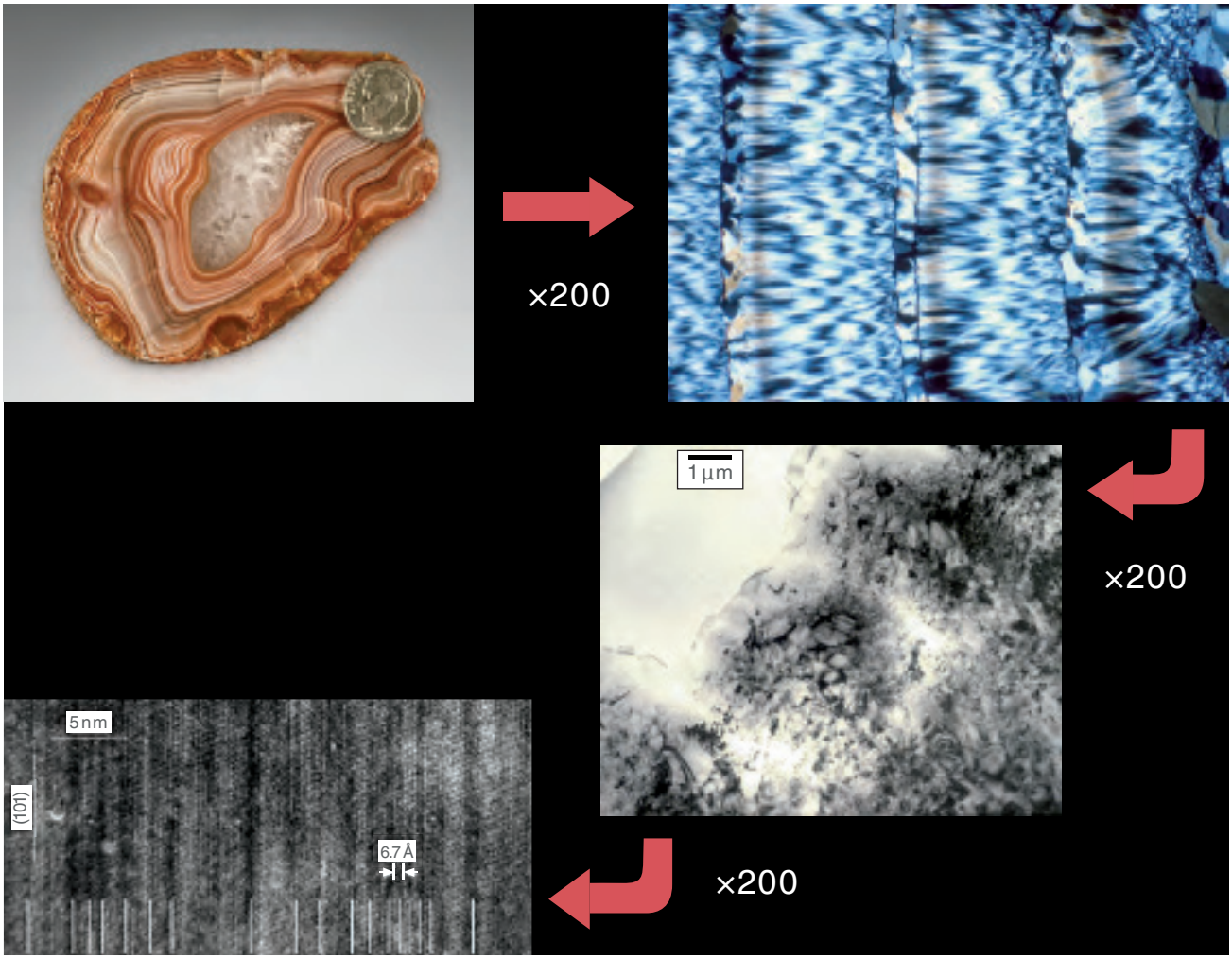

Figure 12. Successive magnifications of a single agate (USNM #83325 from Brazil) yield regular oscillations in Brazil-twin density over four length scales. The high-resolution transmission electron microscopy image at lower left is courtesy of Huifang Xu (Xu et al., 1998).

rock from fluid infiltrations that may have been greatly separated in time, whereas syngenesis (syn = "together") posits a roughly contemporaneous formation of agate and host rock—or at least that the agate formed via a single geological process. Unfortunately, the textural cyclicity observed in agates does not rule out either mechanism without ambiguity. Microbands within mesobands within macrobands are known in rocks deposited epigenetically by time-controlled cycles. For example, cave stalactites form from the evaporation of calcium carbonate–rich fluids, and cyclic banding at different scales related to seasonality has been observed in their layered sequences (e.g., Genty and Deflandre, 1998). Banded iron formations likewise exhibit multiple scales of banding that are likely related to temporal cycles (Cloud, 1973), though the genetic significance of this layering remains hotly debated.

On the other hand, chemical reactions far from equilibrium also are known to produce self-organized patterns within closed systems (Nakuzi and Steinbock, 2016). Most famously, Liesegang rings occur when a gel containing a weakly soluble salt reacts with a different salt solution to form concentric bands. Although this process seems more likely to explain the precipitation of the metal oxides that pigment agates than the Brazil-twinned banding described here, the similarity of Liesegang rings to those seen in agates has convinced many scientists that complex non-linear crystallization dynamics underlie agate formation (Wang and Merino, 1995; Howard and Rabinovitch, 2018).

Regardless, when the day arrives that some scientist or inventor proclaims that agates finally have been synthesized, the assertion will falter in the absence of hierarchical microtwinning of quartz. Like Reusch's rainbow-colored ball made from plaster of paris, a lab-created banded nodule may look like an agate, but unless it is sprinkled with a Cantor dust, it is not the real thing.

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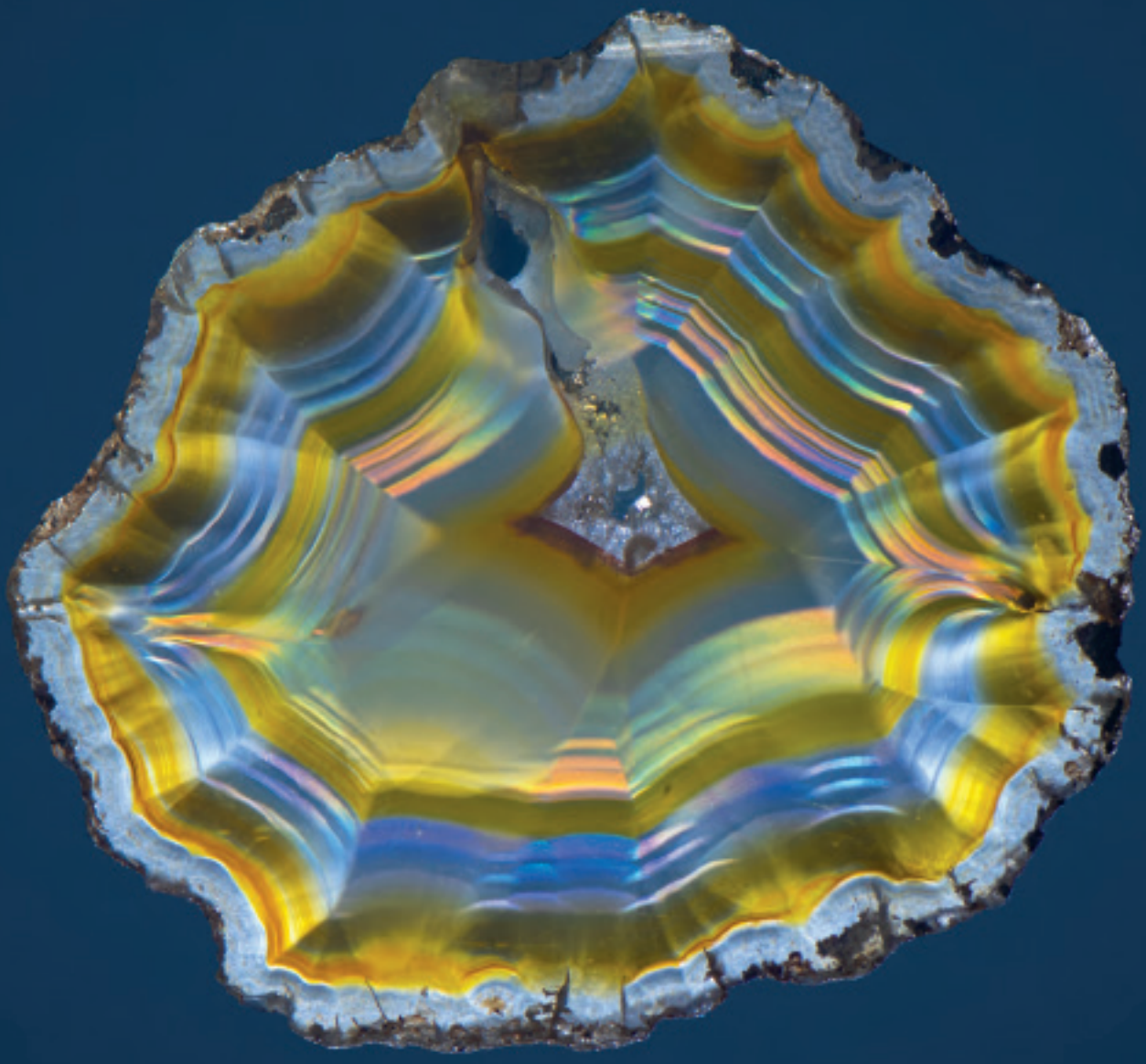


Iris Agate from the William Larson Collection. Photo by Robert Weldon.

Collecting Cryptocrystalline Quartz

William Larson

With photographs by Mia Dixon

I STARTED NOTICING AGATES when I was about six years old on the shores of Lake Minnetonka, where I found small agate pebbles on the beach. I distinctly remember breaking a small agate with a larger rock but this one had a small vug. It was not only colorful but also sparkled from tiny crystals: I was hooked (figure 1).

We moved from Minnesota to California when I was eight. My parents planned the trip through Yellowstone, and all along our route were gas stations advertising Montana agates. Whenever we stopped, we would look at the bins of rough and sliced specimens. I still have the one I was allowed to buy, a fifty-cent purchase of moss agate (figure 2).

Once we settled in Southern California, I certainly favored crystallized specimens. But I soon met one of my mentors, Miss Josephine Scripps (figure 3), who took a shine to young people. She called us her "monsters," and we would go out and dig for various crystals. One of the things I did was to study her extensive collection, which contained perhaps 2,000

Figure 1. This 9.5 cm butterscotch chalcedony from Indiana is Bill Larson's first self-collected mineral, collected at age six.

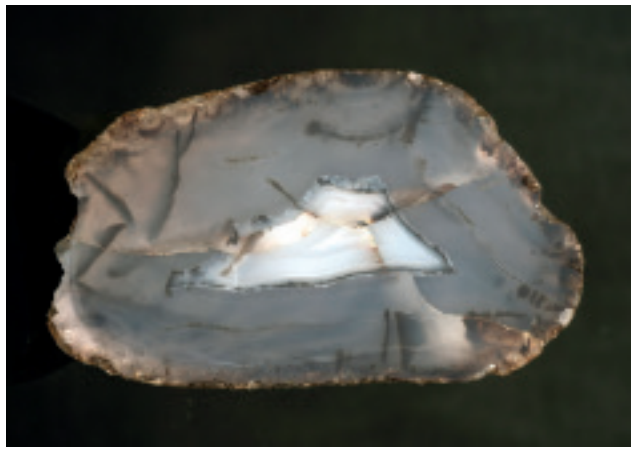


Figure 2. A moss agate from Montana purchased by Bill Larson at age eight when the family moved to California.

Figure 3. Josie Scripps in the 1970s.

Figures 4a–c.

a (top left): A 16.43 ct chrysocolla from the Globe-Miami mining district in Arizona.

b (top right): A 34.98 ct chrysocolla with druse.

c (bottom): A 9.5 × 7.5 × 3.5 cm chrysocolla from the Globe-Miami mining district in Arizona.

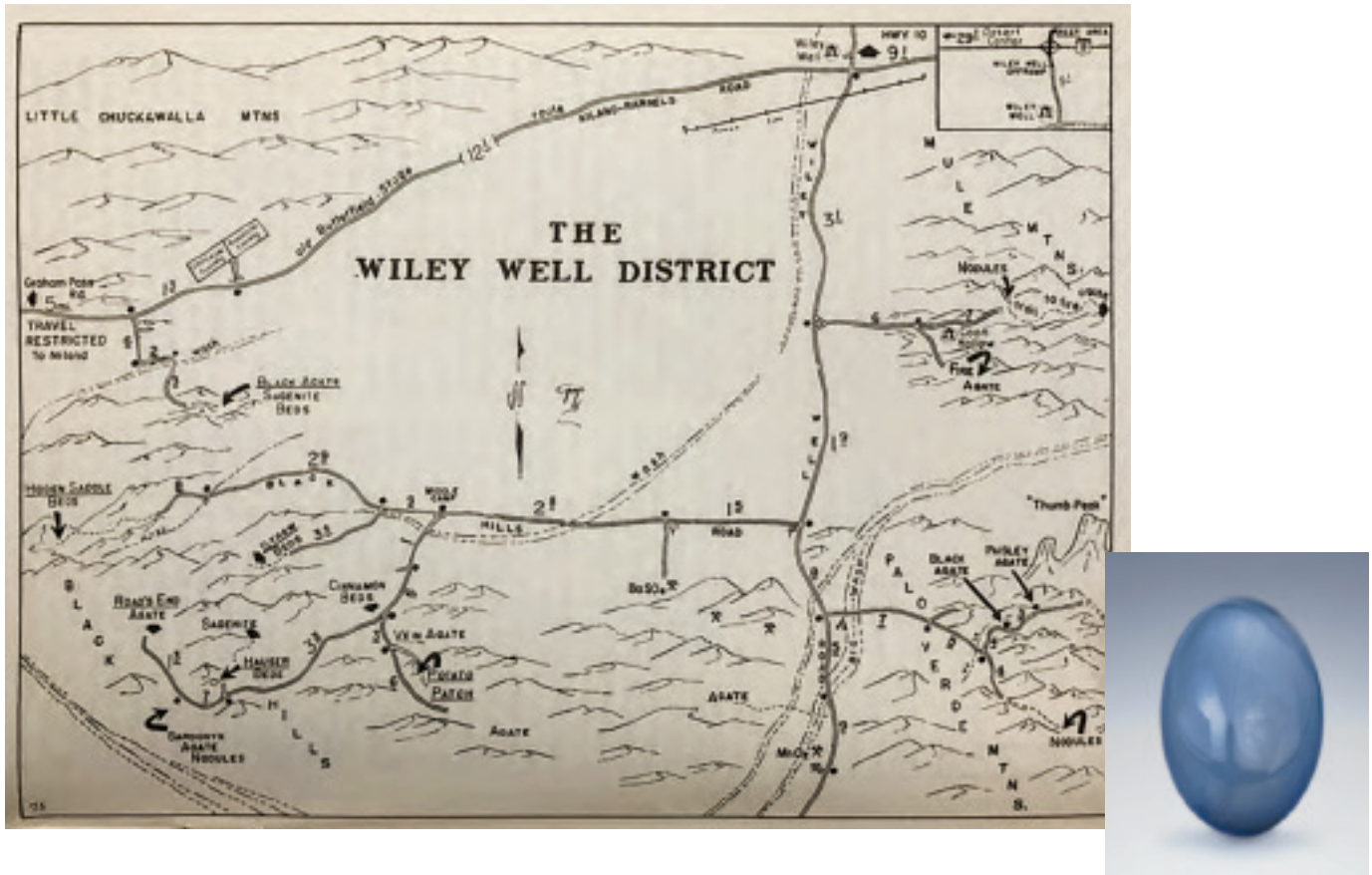


Figure 5. A map of "heaven for rockhounds" like Bill Larson, when he was a youngster. This page from the 1971 second edition of Mary Frances Strong's Desert Gem Trails shows rock collecting areas in the Wiley Well District of Riverside County, California, which have been popular since the 1930s. They include the Hauser geode beds and the old Colorado River Pebble Terrace. **Overset image:** A Mojave Blue Chalcedony cabochon that Bill purchased at a rock shop when he was a child. The fine color quality of this quartz variety first found at a now-defunct Mojave Desert locality for which it was named is still highly prized by rockhound hobbyists.

pieces. One cryptocrystalline quartz soon became one of my favorite minerals: chrysocolla. It still is! (Figures 4a–c.) Josie had several large examples from the Inspiration mine in Arizona, as well as cut pieces. Their blue was indeed gorgeous.

Of course, geodes with beautiful agate patterns were easy to see at various fairs. Josie and my parents arranged many collecting trips to Wiley Well (figure 5), a well-known area for collecting geodes in Southern California, so I did get exposed to these, though I was partial to the ones that had vugs with crystals.

We would visit the Mojave Desert in search of small opals or just for the scenery. On some of these trips we were shown "Mojave Blue" at the rock shops we visited. It is a very fine blue chalcedony. While we never got to dig any, we did get a few very fine pieces of rough. So my cryptocrystalline collection continued to grow, albeit at a slow rate compared to my crystal collection.

Fire agate from Arizona and later from Mexico was very popular during my early years collecting, so these became interesting to learn about, with their great play of colors.

After high school I attended Colorado School of Mines. During these four years I ignored collecting most anything that didn't have crystals. After graduation I went back to grad school but was drafted into the army. This was 1968: I was traded around in Fort Ord from infantry to secretary school, until I wound up in the craft shop, part of the Special Services, teaching lapidary and jewelry making. Now I had to learn all the agates, chalcedony, and jaspers that could make nice jewelry-size cabochons for beginners. All the varieties I had ignored as a crystal enthusiast were now important to have on hand. My "students" were returning GIs from Vietnam. They would often ask for specific types of agate such as bloodstone, moss agate,

Figure 7. A 6.5 cm iris agate specimen.

or onyx to make a cabochon, so I needed to know where to stock these items from my various donation sources. And how to cut them. I read all I could on the subject of cutting cabochons. This gave me much more interest and even some expertise in knowing what were considered fine samples of the rather vast world of cryptocrystalline quartzes.

Color is always one of the attractions for mineral enthusiasts, so when I first saw fine vibrant green chrysoprase from Australia, I was an immediate fan. Sadly, this material was out of my price range on army pay.

After becoming a full-time mineral dealer in 1970, I would often purchase mineral collections that

Figure 8. This agate snail (approximately 7 × 4 cm) from Black Rock Desert, Nevada, dates back to the Miocene Age, 5–23 million years ago.

contained various interesting agates specimens. So it was necessary to became more knowledgeable for unusual types such as snakeskin agate from Oregon or iris agates (figure 7), those super-thin agates that would exhibit beautiful colors from diffraction grating.

Visiting museums is one of the best ways to expand your mineral knowledge. Beyond the plethora of crystals I was exposed to, there is much from the cryptocrystalline world: eye agates, the rare specimens from South America, pseudomorphs of agate after shell from any number of worldwide localities, each with its own distinctive signature for the locality (figure 8).

There are also antiquarian chalcedony pieces in the form of seals and religious objects, great jewelry pieces, and also utilitarian implements. I had a very rare opportunity to acquire an especially remarkable ancient object, an Babylonian axe-head (figures 10a, b), all the more special because it had an extraordinary provenance, complete with documentation that only enhances its intellectual value (figures 9a, b).

It is truly fascinating to handle historical objects that can be attributed to a cultural context, and in many cases even sourced to the locality where the raw material was mined. More historical agates were often seen in Native American artifacts—arrowheads, for instance. Some flints and chalcedonies were exquisitely worked, especially for ceremonial purposes.

Quartz Family Minerals

Pliny the Elder (23–79 A.D.), in his "Natural History," also discusses the agate. However, he notes that the discovery of the stone in numerous places other than Sicily seems to have detracted from its popularity. Besides Sicily, Pliny mentions Crete, India, Phrygia in Asia Minor, Egypt, Cyprus, the Oeta Mountains, Mt. Parnassus, Lesboa, Messenia, Rhodes, and Persia, as places where agates were known to occur in his day.

Neither Pliny nor any of the other ancient writers states definitely that the agate was cut into gems; however, some cut stones have come down to us from very ancient times. Some of these date back as far as the Mycenaean age of Greek culture.

AXHEAD FASHIONED FROM AGATE

A Sumerian ceremonial axhead engraved with a three-line inscription. (Morgan Collection, American Museum Natural History, New York.)

So far had the lapidarists progressed in the art of cutting and polishing agates, even at that early date, that some were engraved with mythological figures.

In early times, agates were used for many objects, such as bottles, cups, and bowls, a few of which have survived to our time. One of the best examples, cut from a single agate, measures twenty-eight and a half inches in diameter. This piece fell into the hands of the Crusaders, who carried it to Europe. It is now preserved in Vienna. Probably the most striking object ever worked from agate is a two-handled wine cup, with a capacity of more than a pint, carved over on the outside with Bacchanalian subjects. History states that this cup was made for the Emperor Nero, and that, after passing through many hands, it was presented in the ninth century

Figure 9a (this page). A description and plate of the axe head pictured below (figures 10a and b). from an early 20th century monograph on quartz minerals published by the American Museum of Natural History (AMNH). This passage describes the ancient cultural history of quartzes and their sources as described by the first century AD Roman naturalist, Pliny the Elder. In this article the caption indicates an early dated attribution of the axe-head to the Sumerian civilization.

Figure 9b (facing page). A scholarly article about the Babylonian axe-head was published on April 6, 1905, in the bulletin of the American Museum of Natural History. The cultural attribution of the axe-head in this article assigns the date of manufacture to the later dated Bablylonian empire. It came to the museum as a gift from J. Pierpont Morgan.

Figures 10a, b (below, this page and facing page). Two views of the Babylonian axe-head previously in the collection of the AMNH. It bears an inscription on one side (a). The ivory colored discoloration is typical of agates that have been exposed to longterm burial.

An Ancient Babylonian Axe-Head.

By Prof. J. Dyneley Prince and Dr. Robert Lau.

AUTHOR'S EDITION, extracted from BULLETIN

OF THE

American Museum of Natural History,

Vol. XXI, Article VI, pp. 49-52. Plate VI.

New York, April 6, 1905.

Article VI.—AN ANCIENT BABYLONIAN AXE-HEAD

By Prof. J. Dyneley Prince and Dr. Robert Lau.

Plate VI.

In the Tiffany Collection of gems belonging to the American Museum of Natural History is a remarkably perfect and very ancient Babylonian axe-head of pure agate. This object was originally obtained by Cardinal Borgia while at the head of the Propaganda and was subsequently offered by the Countess Ettore Borgia to the British Museum for sale, whence it was returned to her, owing to the Museum's lack of funds to purchase it at that time. It was then acquired by Count Michel Tyszkiewics for the sum of 15,000 lire (Italian), who kept it until his death, when it was purchased by Mr. George Kunz, of Tiffany & Co., of New York, by whom it was added to the Tiffany Collection, which was later presented to the American Museum of Natural History by Mr. J. Pierpont Morgan.

The axe-head is interesting, not only because of its extreme beauty as an artistic production, which undoubtedly entitles it to its very prominent position in this unique collection of gems and rare coins, but also because of the inscription in archaic Babylonian characters, with which its obverse side is embellished. A discussion as to the probable age of this object must depend, first, on the nature of this inscription, and, secondly, on the character of the agate of which the hammer is made.

The dimensions of the Morgan axe-head are as follows: Length, 13.7 cm.; width over the handle-perforation, 3 cm.; length of the back, 1.7 cm.; width of the back, 1.9 cm.; diameter of the perforation, 0.9 cm.

There can be no doubt that the axe-head was a votive object presented to some temple in Babylonia. It is unfortunate that the place where it was originally excavated is not known, as in that case much might be learned regarding the date of the object, which now depends entirely on deduction. This is not unique as a votive axe. A fragment of a similar axe in imitation of lapis lazuli, 6.75 x 4.25 x 1.5, was found at Nippur, in Southern Babylonia, by the recent American Expedition to that site. This Nippur axe shows an inscription of seven lines, which may be transliterated and translated as follows:

Figure 11. An 8 cm agate chimpanzee carving by Gerd Dreher.

Starting in 1971, I would visit Idar-Oberstein to sell our rough tourmaline. There I was exposed to the vast history of this European cutting center built around centuries of cutting agates. They had perfected so many cutting ideas and styles, from simple cabochons to fluted cabochons, cameos, spheres, eggs, and bowls to complex carvings, some of which were lifelike animals. Idar has an exciting world of agates.

Over the years my collections increased in size, especially when we saw something different. I had obtained three Dreher carvings in the early 1980s from Borsheims in Omaha when they bought part of the David P. Wilber Dreher collection. After their special shows were ended, the owners were happy to exchange out three Drehers. This was exciting, although it took more than 30 years before we got into collecting Drehers.

Figure 12 (above). An agate lily carved by Dreher (Idar Oberstein, Germany) measuring 110 × 148 × 70 mm.

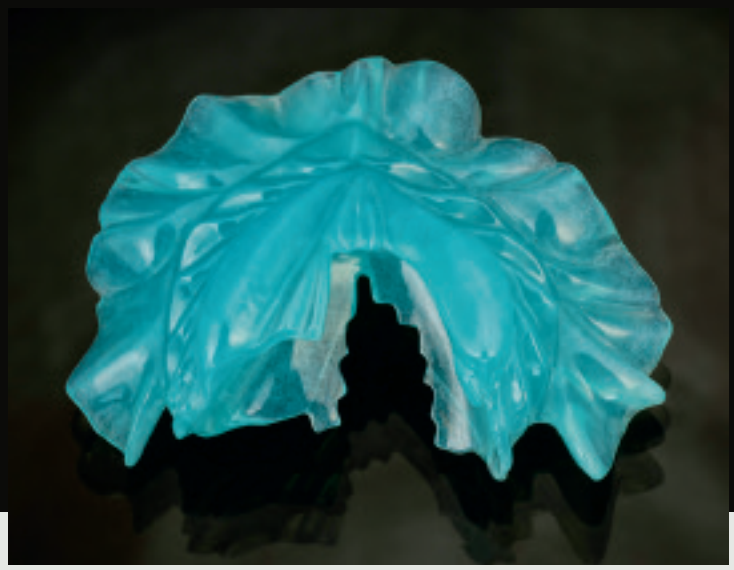


Figure 13 (right). This Glenn Lehrer carving is a 53.549 ct chrysocolla from Arizona measuring 4.5 × 2 cm. It now sits in a brooch designed by Paula Crevoshay and Glenn Lehrer, called "Georgia's Dream."

I credit my sons Will and Carl for reintroducing me to this wonderful family. We started in Idar with two cryptocrystalline quartz toads, one in multi-colored jasper and one walking toad of Brazilian agate. Over the next several years we added many more Drehers (figures 11 and 12), several in exotic cryptocrystalline quartz species including chrysoprase and chrysocolla. Some of these are on display today at GIA.

Glenn Lehrer is another master carver whose beautiful pieces complement the gem mineral to show them off to best effect (figure 13).

Chalcedonies of Anatolia: From Neolithic to Modern Day

Çiğdem Lüle

Chalcedony as a Gem Material

VARIOUS COLORS AND PATTERNS of chalcedony have been used as gem materials for thousands of years. Chalcedony is a microcrystalline quartz and includes many varieties based on their color, pattern, and phenomena. It is commonly found in almost every geography and is one of the more affordable gemstones today. There are a number of interesting traits known about chalcedony, some of which are not often understood. It is one of the oldest gems used since prehistoric times, after shell and bone, mostly in bead form and engravings. Beads of extensive sizes, colors, and patterns are still a very popular choice within the gem trade at almost all levels.

It is possible to trace back the use of chalcedony not only in history but also in prehistory, thanks to archaeological research. Chalcedony was revered by many cultures and civilizations through the millennia, although the reasons behind this popularity remain the subject of investigation and debate. Was it used because it was readily available? Was it used because it was a perfectly suitable carving material? Was there a meaning or cultural trait attached to it that is not known or understood today? Many more questions can be asked. Perhaps there is not just one answer but a combination of them.

Archaeological and anthropological researchers suggest that one of the strongest reasons human beings used personal adornment was self-expression (Baysal, 2019). Whether as a status symbol or for pure pleasure, ornaments from simple beads used on clothing to intricate gold jewelry have been a fundamental aspect of human existence. Considering that the Anatolia region of modern-day Turkey has always been one of the most populated geographies since the Stone Age, looking into chalcedonies of this region and their use in different eras might provide a perspective on gem chalcedony today.

Where is Anatolia?

The Republic of Turkey extends from the westernmost tip of Asia to Eastern Europe. The peninsula that is surrounded by the Black Sea, the Marmara Sea, the Aegean Sea, and the Mediterranean is the part called "Anatolia," and the small portion in the west within the European continent is known as the Thracian Peninsula.

Anatolian settlements and civilizations prior to modern Turkey are numerous, and more are still being discovered. The geography offers not only a passage from Asia to Europe but also major rivers and fertile

Facing page, top. Engraved scaraboid with Aphrodite riding a goose (11 × 27 × 21 mm). Greek, about 400 BC. Engraved in blue chalcedony in a simplified scarab form that was characteristic of Graeco-Persian sealstones produced in the east; iit eventually replaced the traditional scarab form in the Greek homeland. J. Paul Getty Museum, Villa Collection, Malibu, California, 81.AN.76.36.

Facing page, bottom. Pendant Brooch with Cameo of Enthroned Virgin and Child and Christ Pantokrator (Overall: 72 × 55 × 16 mm; Cameo: 38 × 32 mm). Byzantine, late 1000s–1100s (cameo), 1100s–1300s (mount). Intricately carved in blue chalcedony; gold mount with pearls, emeralds, garnets, sapphires, and a sardonyx intaglio. Metropolitan Museum of Art, New York, 2007.9. Purchase, Acquisitions Fund, Christopher C. Grisanti and Suzanne P. Fawbush, Austin B. Chinn, and Katharine R. Brown Gifts, Gifts of Marx Freres, J. Pierpont Morgan, and Mrs. Frank D. Millett, by exchange, and funds from various donors, 2007.

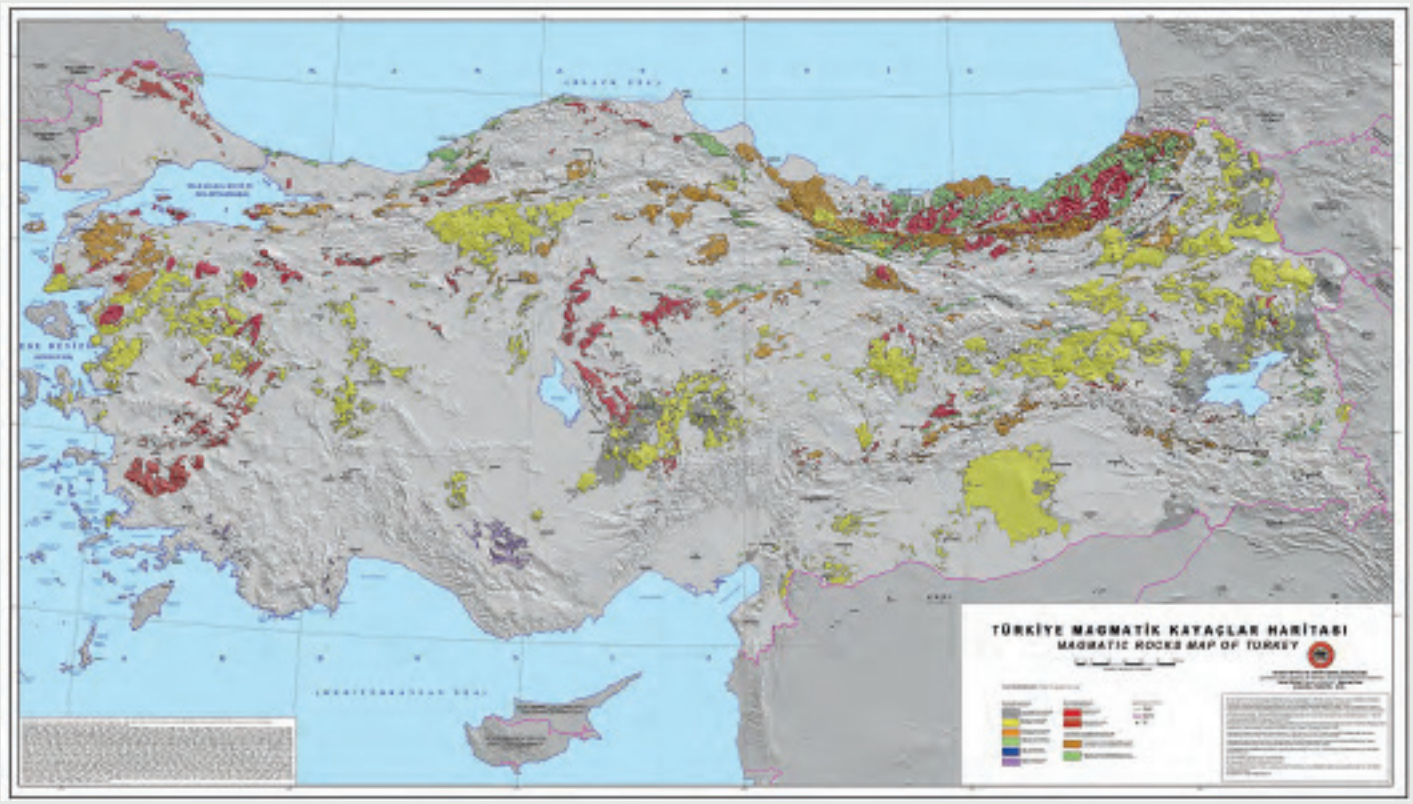
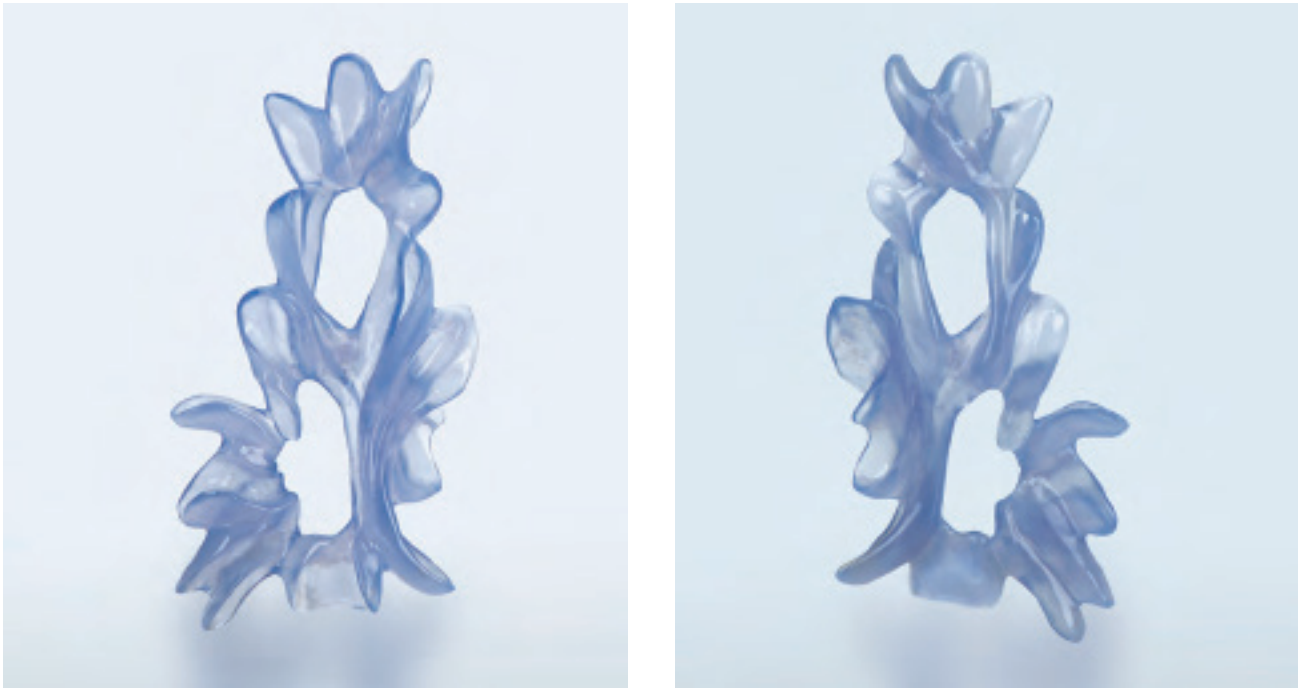


Figure 1. Magmatic rocks map of Turkey. This map shows igneous and volcanic activities and related structures in Turkey. Most chalcedony and agate findings are close to these sources, either as a direct product or a product of secondary hydrothermal activity. Source: General Directorate of Mineral Research and Explorations of Turkey.

Table 1. A general archaeological timeline of Anatolia.

Paleolithic Age	500,000–11,000 BC
Mesolithic Age	11,000–7000 BC
Neolithic Age	7250–5400 BC
Chalcolithic Age	5400–3250 BC
Bronze Age	3250–1200 BC
Iron Age	1200–550 BC
Classical Age	550 BC–330 AD
Medieval Age	330–1299 AD
Ottoman Age	1299–1922
Modern Turkey	1923–Today



Figures 2a, b. Anatolian blue chalcedony carving by Meg Berry, front and back view. Photos by Orasa Weldon.

soil, and hence the earliest human settlements favored the place. This is partially due to Anatolian geology. It is complicated, as it consists of a few major tectonic plates and dotted with several small volcanoes that are technically still active (not in our day, but as recently as a few thousand years ago) (figure 1). Based on this very basic overview, it is easy to see why it has also been rich in minerals and metal ores that have been mined for thousands of years.

Timeline

It is imperative to look into the timeline to understand the use of microcrystalline quartzes in Anatolia. With the increasing numbers of new and interesting chalcedony finds in the region, the ancient sources are still known and mined (albeit small in scale). Table 1 outlines a timeline of prehistoric and historic eras in Anatolia in the broadest sense. Please note that such classifications might differ from one continent to another.

The Paleolithic, Mesolithic, and Neolithic ages are commonly known as the "Stone Age" and provide us very little hardstone personal ornaments. Most probably due to limitation in cutting and polishing technology, the only ornaments, mostly in bead form, were made of shells, bones, and soft rocks such as serpentine or limestone. As we get closer to the end of the Stone Age, we see chalcedony and quartz type of materials used for personal ornaments. One of the earliest human settlements, Çatalhöyük, has been excavated in Middle Anatolia and revealed such items with a few rare carnelian beads (Reagan, 2005). Carnelian in particular has been excavated in bead form at contemporaneous excavations in Anatolia and triggers the question of acquiring the reddish brown color by heating gray or colorless chalcedony (Baysal, 2019).

The use of chalcedony in forms other than beads manifests itself as engraved seal production more in the Chalcolithic Age when people started using metal tools. Engraved stones were mainly utilized as personal seals, and therefore hardstones such as chalcedony would be an appropriate option for intricate engraving both for rings and also in cylindrical form to be drilled and strung. Many different forms of engraved chalcedony and its varieties were found thereafter. The most intriguing use of chalcedony was in the Urartian civilization in Eastern Anatolia, dating to the Late Bronze to Early Iron Age. The number and variety of

Figure 3. A selection of Roman chromian chalcedony intaglios examined by the author in 2007. Staatliche Museen zu Berlin, Antikensammlung, clockwise from lower left : Dressel 32.237, 227; 32.237, 178; 32.237, 222; 32.237, 179; 32.237, 279. Photo by Lisbet Thoresen.

beads produced were a strong indication of a bustling bead industry. The use of such personal ornaments did not suggest any social rank difference since all burial sites were discovered with thousands of beads on bodies (Sevin and Kavakli, 1996).

The Bronze to Iron Age witnessed many shifts in powers and different civilizations throughout Anatolia. One of the significant civilizations was the Lydian Empire in Western Anatolia. While the Sardis River was producing bountiful gold, the majority of the engraved gems within gold jewelry were chalcedony in agate, carnelian, sardonyx, and blue varieties (Cahill, 2010).

Early in the Classical age, a port in modern Istanbul called Chalcedon became the major trading hub for blue chalcedony, as the name suggests. Interestingly, this particular chalcedony, favored in both the Hellenistic and ancient Roman times, was not mined in this region but further southeast in northwest Anatolia, in the modern-day province of Eskişehir. The supply and quality of the material are so remarkable that it can be seen in almost any Hellenistic and ancient Roman engraving collection today. Furthermore, the mine is still operational and its output is regularly exported (figures 2a, b).

Eskişehir Province is rich with chalcedony. Another remarkable variety, chromian chalcedony, is found reasonably close to the ancient blue chalcedony mines and is thought to have been used by the Ancient Romans between the 1st and 3rd centuries AD (figure 3; Lüle, 2012; Platz-Horster, 2010). The comparison between modern and ancient material reveals significant macro and micro features shared in common (figure 4). The study is still being conducted by this author.

Gem cutters in the Classical Age utilized chalcedony in every way possible. Almost all jewelry contained engraved gems, and most of them were chalcedony. There were also small ornamental objects and figurines carved from chalcedony, so the supply clearly was plentiful. Considering how blue and chromian chalcedony from only one region were widespread, it is highly plausible that other Anatolian sources were explored and used as well.

Modern Localities and Varieties of Anatolian Chalcedony

Many varieties of chalcedony are widely used in the modern gem trade, albeit not as one of the more celebrated gemstones. While most of them are fashioned as beads and cabochons, more aesthetically pleasing ones find their way to lapidary artists' workshops or rarely appear in high-end jewelry. Similarly, agates are always a popular collector's choice. Anatolia is still a

Figure 4. Modern chromian chalcedony pieces from Eskişehir Province. Photo by Orasa Weldon.

good supplier of blue chalcedony and various agates to the world market. Relatively new discoveries of green, pink, and purple chalcedonies are in regular production. The most significant agate occurrences in Anatolia are located in the middle region. A small town in Ankara Province called Çubuk produces agates with an outstanding variety of patterns within andesite vugs. The specimens are highly collectible, and they are also used in jewelry in free form designs. Another exciting, yet less known source is in Tokat Province. This newly publicized deposit produces agate and jasper with striking color combinations of reds, yellows, and blues in various patterns.

Conclusion

Chalcedony as a gemstone might not be as exciting as ruby or sapphire to today's jewelry buyer, but evidence indicates that it was revered as an ornamental and gem material throughout human history. From the Bronze Age to modern times, chalcedony has been celebrated for a very long time. Perhaps its common occurrence in any geography makes it less important today, but undoubtedly it is a collector's item when an exceptional piece is found.

Anatolia, with its rich geology and cultural heritage, is a great source to understand the importance of chalcedony in the past. As there is no shortage in modern production of chalcedony varieties, there seems to be a good potential for new findings in the future thanks to Anatolian geology.

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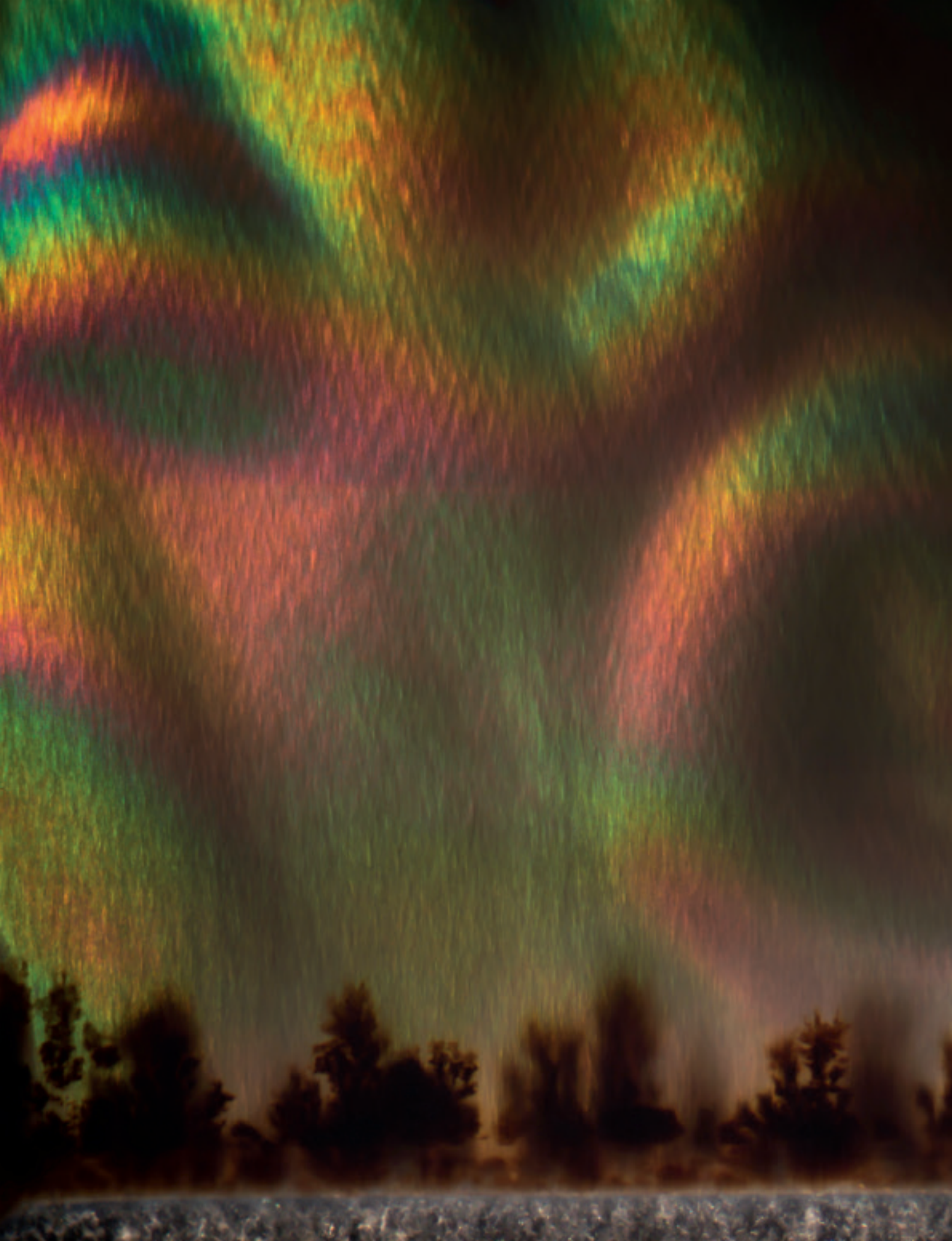


The Microworld of Agate and Chalcedony

Nathan Renfro

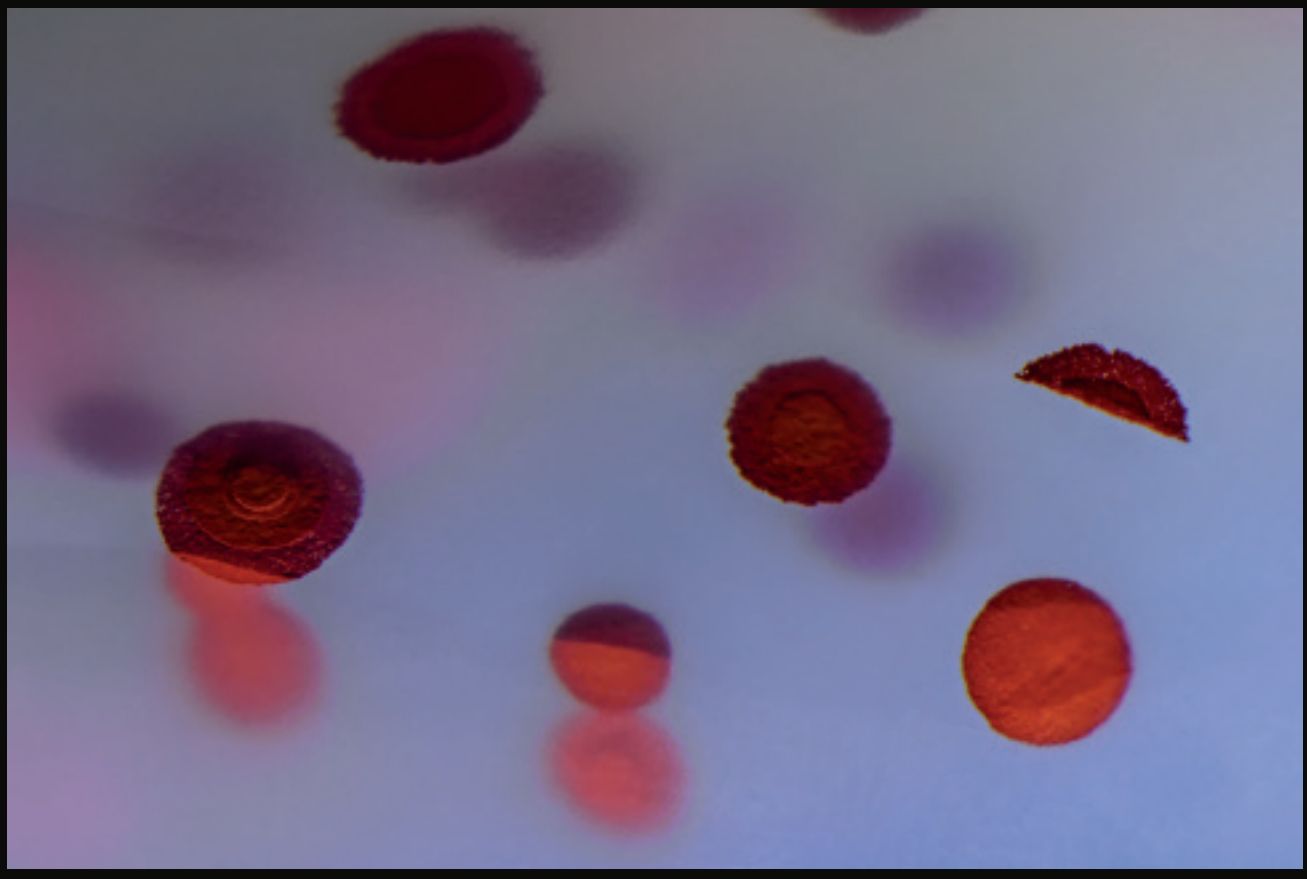
AS A GEMOLOGIST, my original attitude toward chalcedony and agates was one of only minor interest and occasional curiosity. While an interesting pattern or color of chalcedony would sometimes briefly catch my attention, it wasn't until I began to explore them under the microscope that I was able to fully appreciate how spectacular this material is. It quickly became one of my very favorite gem materials.

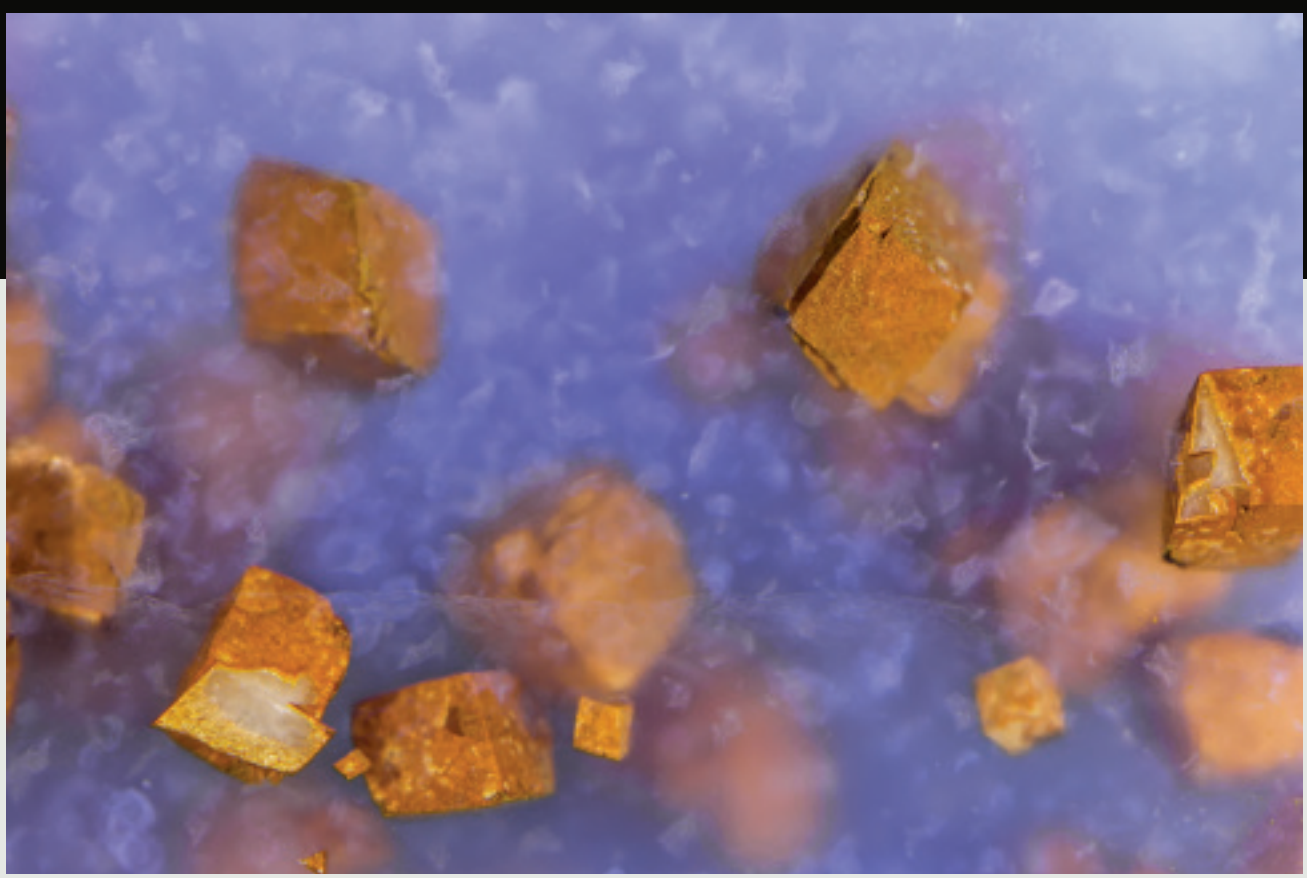
It is the very nature of chalcedony growth that lends itself to form patterns and capture inclusions unlike any other gem material. As a sedimentary gem, the banding and patterns produced during its genesis are truly spectacular and preserve clues about the gem's history and its formation environment. Because of the wide variety of environments in which chalcedony can form, there is really no limit to the types of inclusions you might encounter in such a gem material. Solid mineral inclusions are often well preserved, as well as interesting structures that develop as metal oxide contaminants and are dispersed and deposited throughout, creating interesting and unique patterns. Because of its durable nature and sedimentary growth, chalcedony is also unique in that it is home to a wide range of wonderful fossils preserving remnants of ancient life.

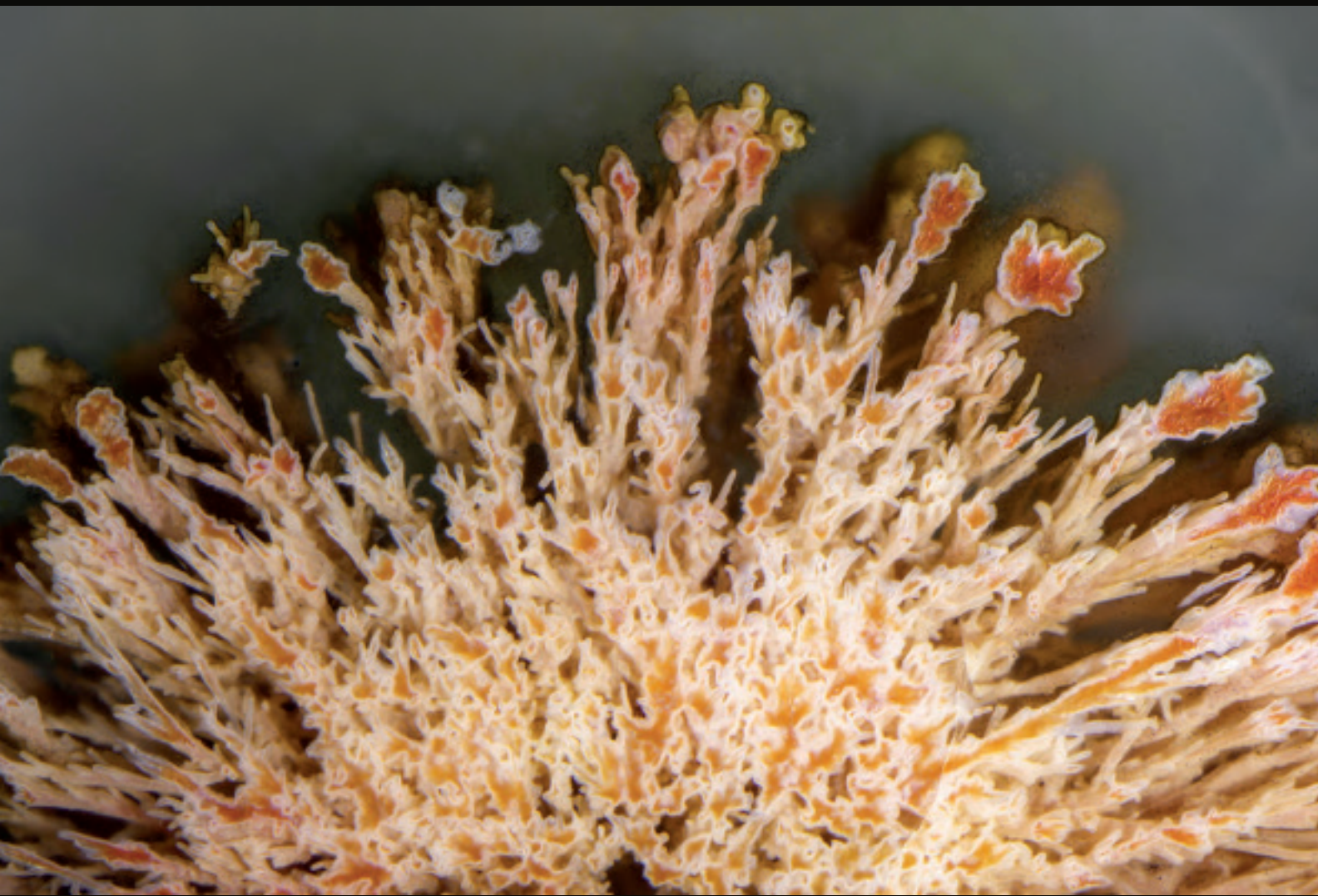
While the following selection of images can in no way be fully representative of the types of microscopic features you might encounter in an agate or chalcedony gem, I hope they will at least make you pause a bit longer and look a little closer the next time such a gem catches your interest.

Above. This agate from Minas Gerais, Brazil, contains an escape tube coated with manganese oxide dendrites that extend into the interior of the stone. Field of view 16.94 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.

Facing page. This iris agate with quartz and manganese oxide plumes resembles a frozen lake with a tree line under the aurora borealis. This is a spectacular example of "pareidolia," or perception of an image in a visual pattern. Field of view 5.28 mm. Photomicrograph by Nathan Renfro.



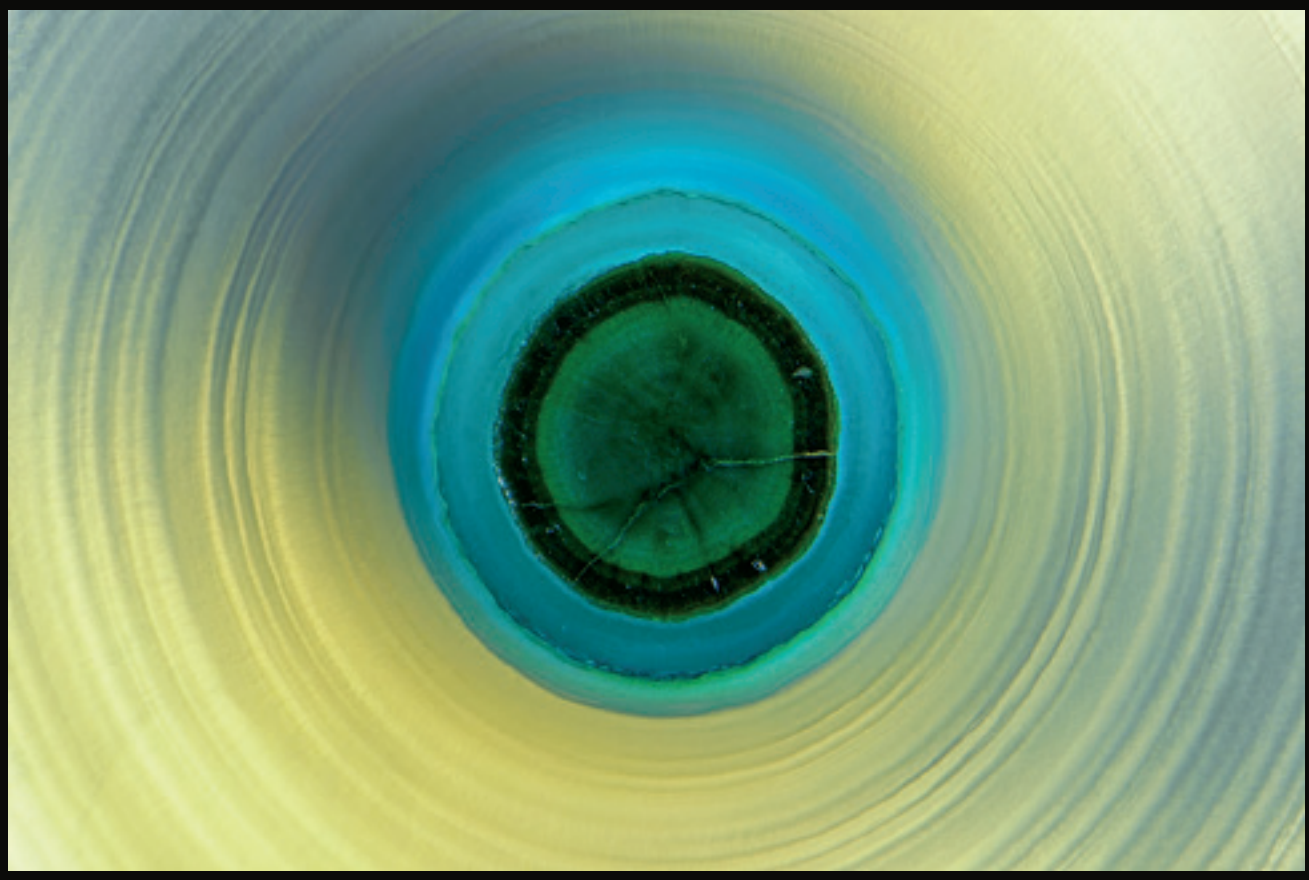


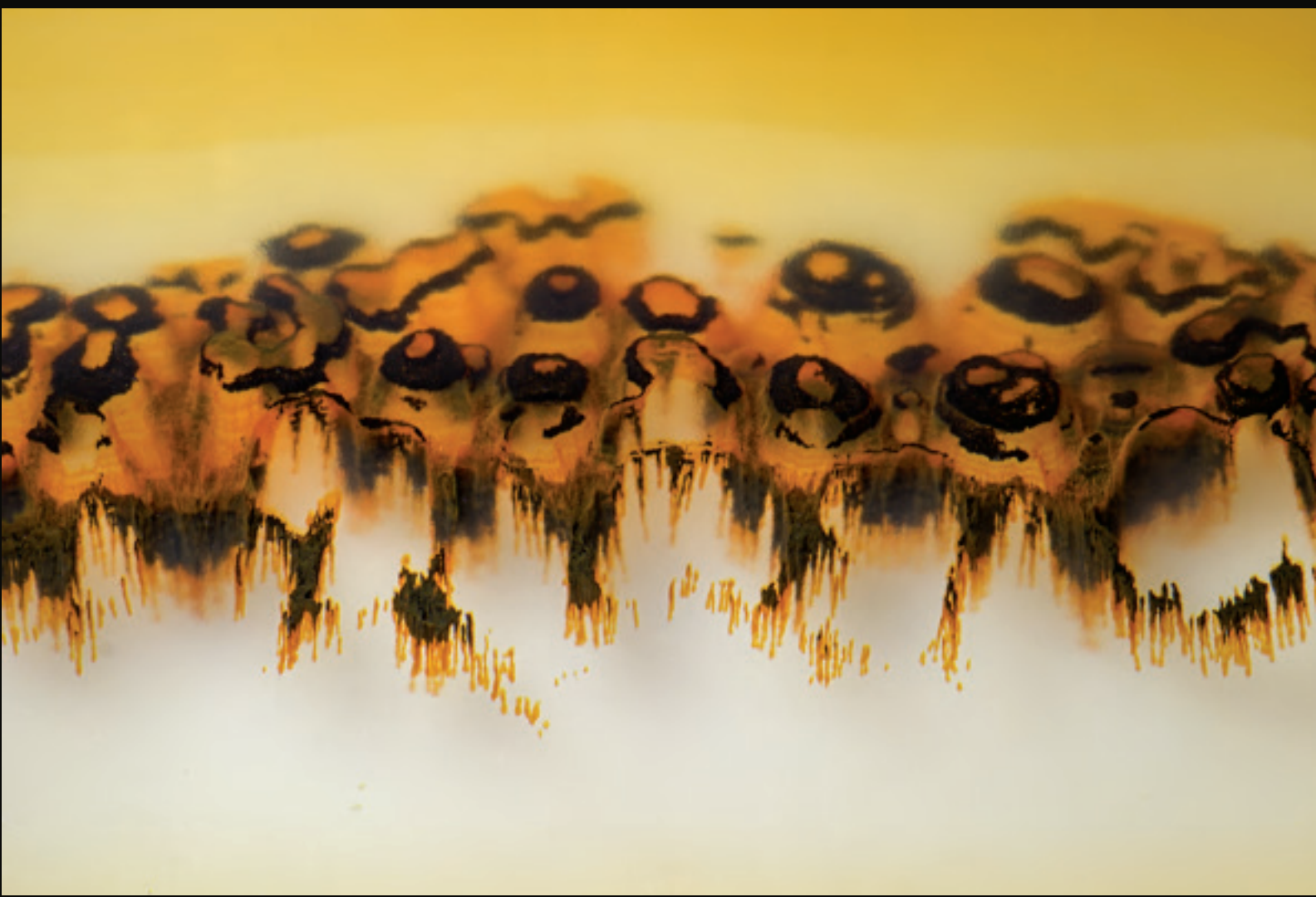


Facing page, top. Concretions of red hematite are prevalent in this “red spot” agate from Minas Gerais, Brazil. Field of view 6.86 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.

Facing page, bottom. A purple chalcedony from Turkey contains several carbonate crystals with a yellow limonite coating. Field of view 8.48 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion collection.

Above. This “Priday Plume” agate from Oregon contains plumes of iron colored compounds such as limonite or clay. Field of view 16.94 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.

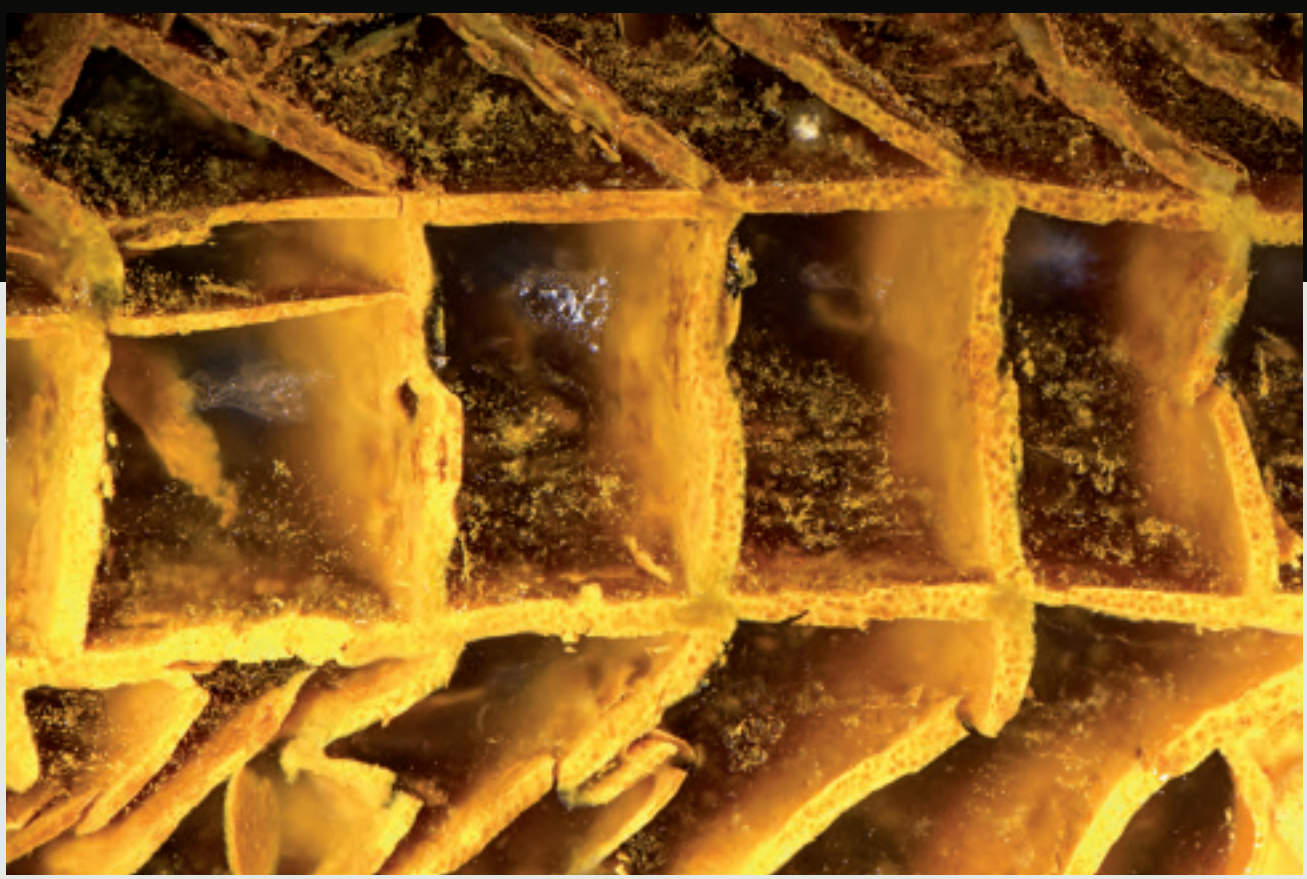




Facing page, top. A core of green malachite is surrounded by a greenish blue rind of chrysocolla in this chalcedony from the Ball Park bench at the Ray copper pit in Arizona. Field of view 6.00 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.

Facing page, bottom. This Mexican gem silica is colored by chrysocolla and has a ghostlike cluster of quartz crystals. Field of view 4.79 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.

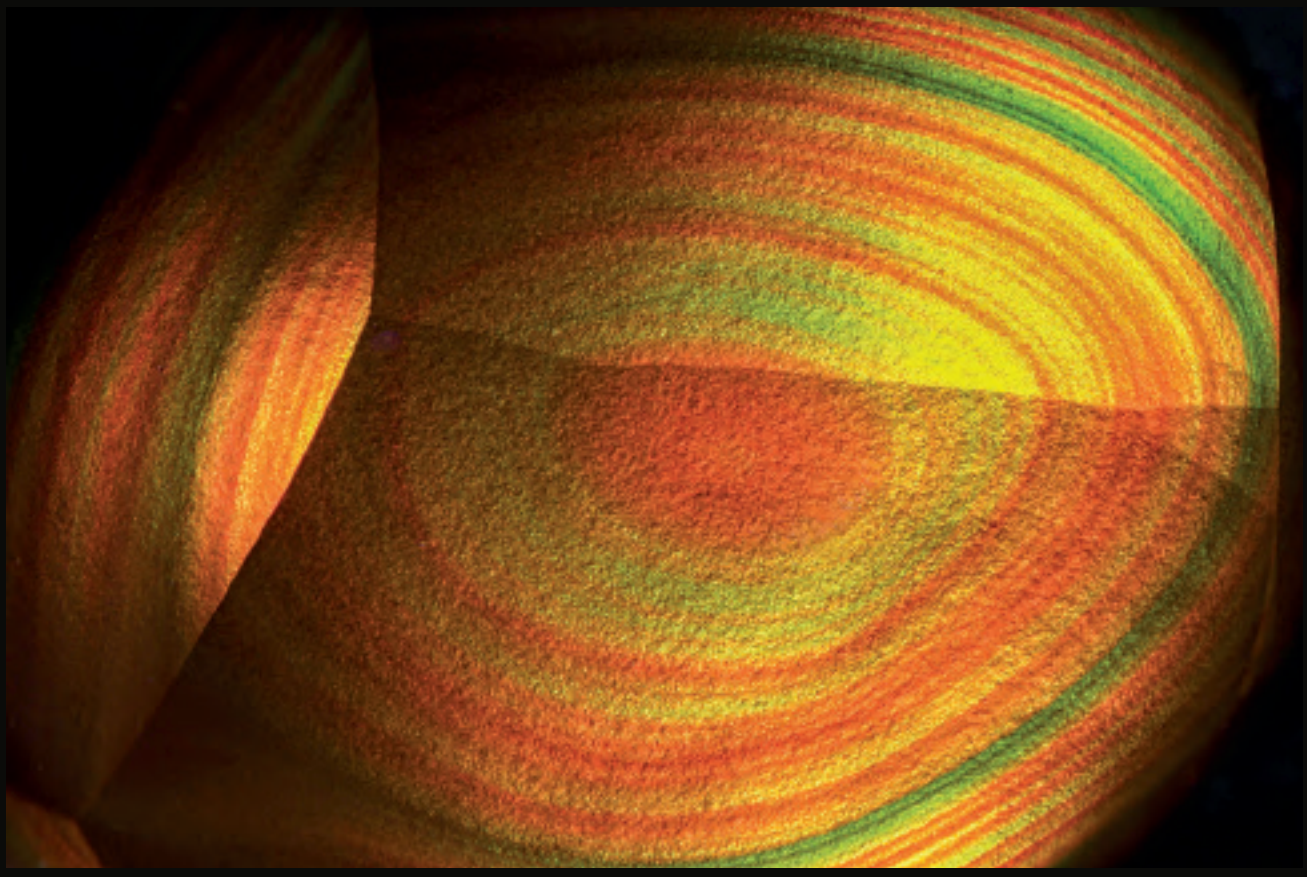
Above. Numerous metal oxide drip-like structures are present in this chalcedony from Minas Gerais, Brazil. Field of view 9.60 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.

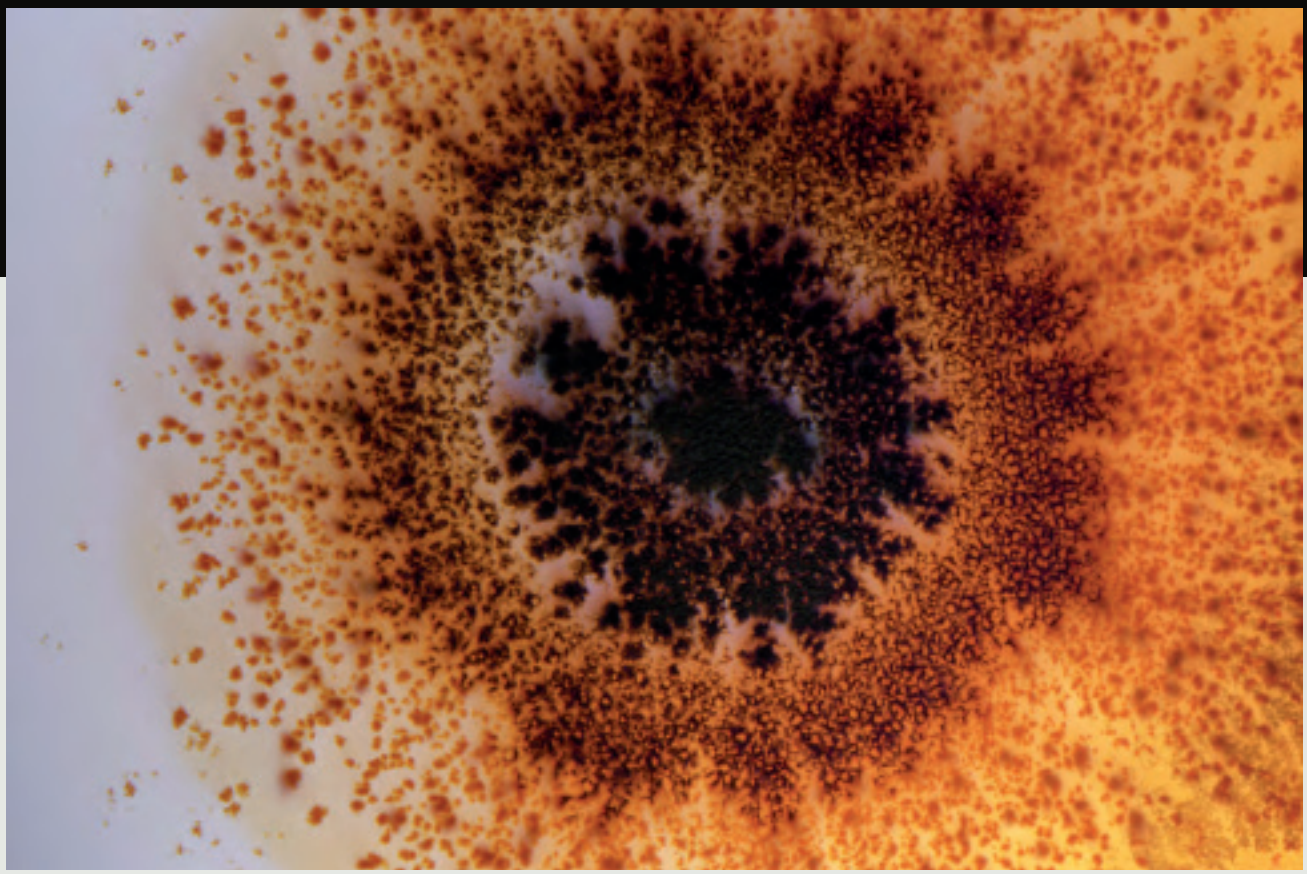


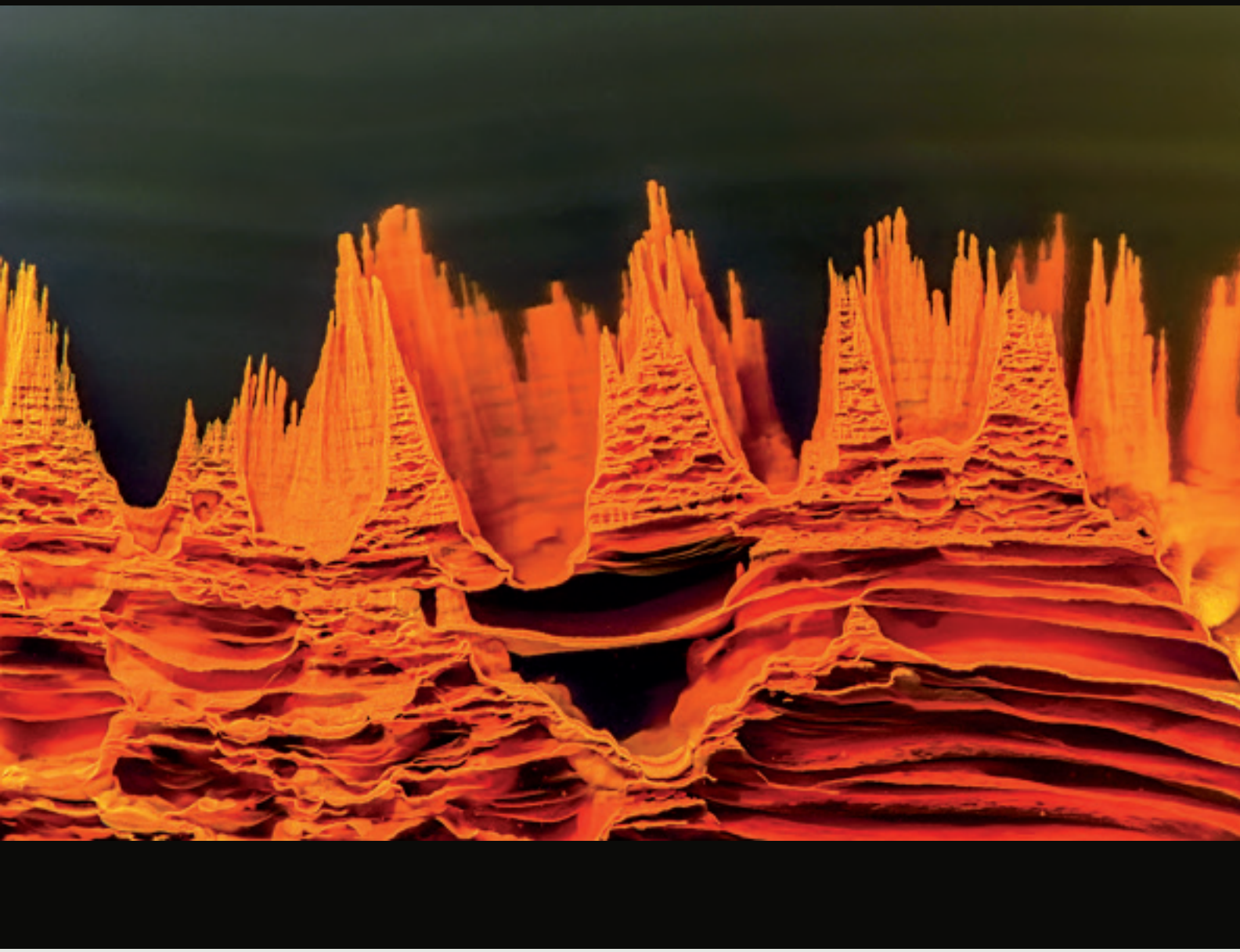
Facing page, top. This sagenitic chalcedony from Oregon contains numerous needles coated with white concretions of chalcedony and yellow limonitic residue. Field of view 8.06 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.

Facing page, bottom. This fossil chalcedony reed from Bend, Oregon, shows a partially collapsed hypha structure. Field of view 14.40 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.

Above. This “owl hole” agate from Nipomo, California, contains numerous goethite fibers that resemble wheat. Field of view 10.28 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.







Facing page, top. The botryoidal structure in this fire agate from Aguascalientes, Mexico resembles the eye of a dragon. Field of view 8.81 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.

Facing page, bottom. Metal oxides have created a remarkable sun-like pattern in this Brazilian agate. Field of view 9.29 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.

Above. The spires in this landscape agate from Brazil are composed of layers of goethite and limonite. Field of view 9.39 mm. Photomicrograph by Nathan Renfro, stone courtesy of the John Koivula Inclusion Collection.

A Historical Look at Gemstone Carving

Si and Ann Frazier

IT WAS ONE of our most memorable experiences in the gem and mineral world. We were attending an after-hours reception at the Deutsche Edelstein Museum in Idar-Oberstein in 1993, the famous gem cutting center in Germany. The night was lovely, the crowd lively, and the museum stunning as always. The occasion was unique: a special reception for Harold Van Pelt, an American gem artist whose work was on exhibit in the museum. This was only the second time in the museum's history that a foreigner had been so honored. All around us were prominent members of the Idar gem Industry, master cutters who had built successful careers finding rough stones and transforming them into objects of beauty and value.

To understand the response to the Van Pelt exhibit, one needs to consider the setting. When we started writing about the history of the Idar gem cutting industry, we quickly learned that secrecy is a way of life there. Knowledge about gem cutting is held very tightly in Idar, passed on from father to son. Formal education and an apprenticeship are required just to begin the long journey to a Meisterbrief (master's certificate). Many of the people at the recption knew firsthand what goes into becoming a master gem cutter.

Even so, the Van Pelt pieces on display were a source of wonder. The Germans were amazed that he was a hobbyist, not a professional, and had not been trained professionally in gem cutting or carving. Most of them knew that we and the Van Pelts were from California and assumed we were practically neighbors, even though the San Francisco Bay Area and Los Angeles are 400 miles apart. "How does he do these carvings?" they asked us. "How much does he charge for one?" Even as friends of the Van Pelts, we had no idea where Harold had learned such skillful gem cutting and artistic creativity. We only knew that it was an artistic pursuit, and that he never sold any of his carvings.

No gem carver could receive any higher accolades than Harold did that evening. It was a wonderful night to be an American. So where does his skill and artistry come from? We still do not know, but there are a few factors that we can state with some degree of confidence. First, artistic sense – what might be called an artist's eye. As highly accomplished professional photographers, Harold and Erica have it in spades. That means a keenly developed sense of form, structure, design, color, and all those things you're supposed to know in the arts.

There is also the inspiration of ancient art. Making images in two or three dimensions in a wide range of media appears to be one of mankind's earliest activities. Primitive objects created in soft soapstone or serpentinite appeared early in archaeological records. Pivotal to man's progress was learning to shape harder stones such as obsidian, flint, agate, jasper, and quartzite by flaking or knapping, then polishing them with loose abrasives. Museums are filled with wonderful examples of tools and decorative objects from these stages of human development.

The Mesopotamian, Chinese, Indian, Egyptian, Mayan and other early civilizations produced fabulous art objects in hard stones. "Hard stones" is a somewhat ambiguous term that refers to stones that are about 6 or higher on the Mohs' scale of hardness, which ranges from 1 (talc) to 10 (diamond). Quartz is 7. The number is important because hard stone poses significantly greater problems for artists than softer media. However, hard stone artists have found ways to overcome some of

This essay originally appeared in *Gemstone Carvings: Masterworks by Harold Van Pelt* (2010).

the technical difficulties in exchange for its aesthetic rewards. The use of hard stone for carving continues to this day.

We know from history thar rock crystal quartz and agate were particularly important in ancient cultures such as ancient Greece. The Greek scientist and philosopher Theophrastus (ca. 371–286 BC) wrote the earliest surviving on gems and minerals in western literature. In *Peri Lithon* (On Stones), he lists rock crystal and several translucent (chalcedonic) quartzes among the stones used for engraving seals. It is difficult today to fully appreciate the role of seals in ancient times. A unique seal allowed an individual with the means to sign a document and mark his ownership on objects. Because seals were symbols of the owner's status and taste, their craftsmanshiop had to be superb. Collecting seals became a passion in some circles. It is said that four men were needed to carry Catherine the Great's collection of these small, exquisite ancient gems. Each of the engraved stnes seen in collections and museums today is to the modern eye a masterful work of art. There are also magnificent illustrated catalogs and artistic tomes published on the subject. The classic three-volume opus by Adolf Furtwängler, *Die antiken Gemmen* (1900), weighs about 30 pounds!

We know from archaeological evidence that artistic containers carved from quartz, agate, and other hard stones dates back to ancient times. Pliny the Elder (23–AD 79), writing at the beginning of Christianity, has much to say about displays of wealth in hard stone creations, especially rock crystal. Quartz crystals with size, form, and clarity suitable for carving are not easy to obtain. It requires luck and stamina, even in those few places where they occasionally occur. Sources today include the Alps, the polar Urals, and Brazil, but lapidary-quality rock crystal has never been a cheap commodity that can be worked by modern mass-production methods. It is the perfect medium for an artist, one equal to the technical challenges of producing a one of a kind work of art.

The lapidary's art constitutes a vital part of our cultural heritage, and Harold and Erica Van Pelt are outstanding practictioners of this form.

Agate lentoid sealstone depicting a griffin (27 mm dia). Late Minoan II, ca. 1450–1400 BC. Metropolitan Museum of Art, New York, 14.104.1. Purchase, by exchange, 1914.

Banded agate scaraboid with a Persian King Spearing a Fallen Greek (17 × 12 × 7 mm), shown with the impression of the engraving. Achaemenid Persian, ca. 450 BC. J. Paul Getty Museum at the Getty Villa, Malibu, California, 2019.13.9.

Banded agate perfume bottle, or *amphoriskos* (6.0 cm h., 4.8 cm dia). Roman, late 1st century BC to early 1st century AD. Vessels like this were treasured luxury objects that were symbols of wealth and refined taste. Metropolitan Museum of Art, New York, 2001.253. Purchase, Mr. and Mrs. Sid R. Bass Gift, in honor of Annette de la Renta, and Rogers Fund, 2001.

Figure 1. Agate chair (97.8 cm; 38 1/2 in. h.), modeled after a Louis XIV-style chair and carved from a single boulder of Brazilian agate. **Overset image:** Close-up detail of one of the chair arms.

Harold Van Pelt
A Passion Carved in Stone

Lisbet Thoresen

Photographs by Harold and Erica Van Pelt

AS A LAPIDARY ARTIST who has produced a vast repertoire of carvings in hard stones dating back more than 50 years, Harold Van Pelt labored quietly for most of them in the shadow of his own reputation as a professional photographer, together with wife Erica, renowned for their photographs of gems and minerals. Their pictures have graced innumerable books and journals, notably *Gems & Crystals from the American Museum of Natural History* and 35 years of covers and interior pages for GIA's award-winning professional journal, *Gems & Gemology*. They have photographed many storied gems, treasures and collections including the Hope diamond and other significant objects in the Smithsonian Institution, Harry Winston's jewelry, and the Michael Scott gem collection.

For many years, Van's lapidary art was known only to a small group of appreciative enthusiasts, notable among them John Sinkankas, who published articles

Figure 2. Van poses next to the entrance of his retrospective exhibition held at the Bowers Museum of Cultural Art, in Santa Ana, California, 2010.

Figure 3 (top). Agate spoons (16.5 cm l.; 6 1/2 in. l.) inspired by period silver, but Van elects to soften the austere design of the originals' straight handles with a graceful curve.

Figure 4 (bottom). Erica was the model for Van's carving of a human foot from rutilated quartz (20.32 × 14.61 cm; 8 × 5 3/4 in.).

that detailed Van's working process and showcased selected carvings in *Lapidary Journal* (1982) and *Gems & Gemology* (1982). As a master carver in his own right, Sinkankas expressed the deepest admiration for Van's skill. Having carved from rock crystal a solid faceted egg of his own, he was awed when Van carved a 5 × 3 in. egg that was hollow. It had 416 facets and a wall thickness measuring slightly less than 1/8". Sinkankas's esteem was such that a photograph of Van's hollow egg adorns the cover of Sinkankas' 1984 edition of his landmark book *Gem Cutting: A Lapidary's Manual*. For his part, Van reciprocated the master's collegial regard, saying that he never learned carving through apprenticeship to anyone, but he read and re-read every word of Sinkankas's book. He owns a well-worn copy, which he consulted throughout his career as a lapidary artist. Flipping through the pages of the book, he says, "Every technical procedure you need to know is right here."

In 2010, the Bowers Museum of Cultural Art in Santa Ana, California, and the Houston Museum of Natural Science mounted the first ever retrospective exhibition of Van's carvings, with the Bowers publishing a sumptuously illustrated catalogue raisonné (Van Pelt, 2010). It featured photographs by the Van Pelts, an essay on "Lapidary History" by Si and Ann Frazier as well as the 1982 *G&G* article on Harold Van Pelt by John Sinkankas.

The Artist at Work

Van produced many large faceted and fluted objects—bracelets, spoons, candlestick holders, vessels, vases, jewel boxes, and decorative objects (figure 3). He also made a wide variety of free-form carvings such as shells and boxes, as well as figural pieces for which Erica was the model (figures 4–6).

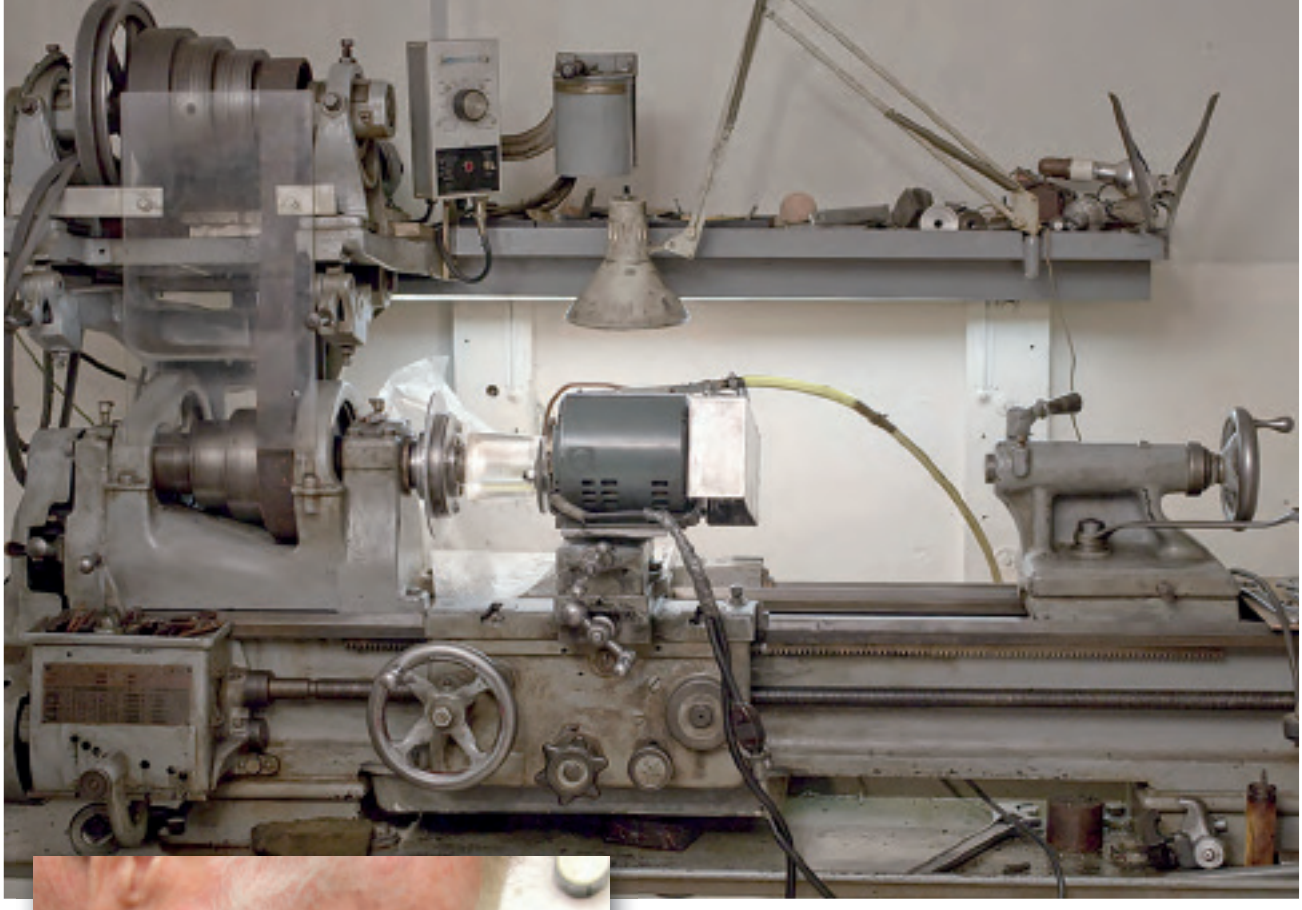
The Masterworks exhibition catalogue (Van Pelt, 2010) and Sinkankas articles presented detailed, illustrated "how-to" discussions on the machinery and the methods Van employed to produce turned and faceted objects. Van is also quick to point out that he always kept an eye open for new books that might provide some useful advice or insight. In addition to Sinkankas's book, the revelations Van found in the reprinted edition of *The Principles and Practices of Ornamental Turning*, by John Jacob Holtzapffel, were especially influential. Reprinted by Dover in 1973, the book derives from three volumes produced by the multi-generational family of German artisans who immigrated to England, where they set up a successful business in lathe turning ivory. The book is the definitive reference on the subject, and Van adapted the techniques of this 19th century gentleman's pastime to his own contemporary work in hard stone. He credits Holtzapffel with the skill he developed to produce delicate fluting and to fit together separately turned pieces.

Adaptation of tools and techniques reveals itself in every aspect of Van's work, from the practical step-by-step process of making a finished piece to the more subjective aesthetic sensibility that went into it. For many projects, Van has resorted to modifying a piece of equipment or building his own to accomplish a desired objective for which off-the-shelf equipment was insufficient to the task. He modified a lathe built in 1925 to work hard stone (figures 7a, b), its motor slowed down to a range of 5 to 10 RPM to minimize the risk of breakage and to enable the efficient removal of large masses of material. He makes his own profiles for objects produced on the lathe, many inspired by European period silverwork. For precision sawing, he built a rotating index head mounted on a table that glides along on friction-free ball-bearing slides (figure 8). It enabled him to present the the object to the saw blade, allowing for unencumbered mobility in any direction. The critical consideration in using this piece of equipment was taking care to avoid material getting bound up on a thin blade that could easily begin to wobble. He constantly measured and re-measured, and he carefully controlled the stream of lubricant to carry off the minute chips as the blade bit through the stone.

Asked if it wasn't terribly time-consuming and laborious building his complicated jigs and mounts and accessory components, Van shrugged off the question, "Living in Los Angeles, there is nothing you can imagine building that you cannot find the parts you need to build it. It's not necessarily fast, but you can build just about anything." He never produced anything by commission, nor ever sold a single piece, so

Figure 5. Anatomical studies are a favorite theme. Shown here, a skeleton hand (20.32 cm h.; 8 in. h.) carved from bone-colored chalcedony, which was carefully chosen to match the color of natural bone. Each bone in the hand was carved separately and then assembled. The plinth is carved from rutilated quartz and finished with 18k gold fittings and trim made in Germany.

Figure 6 (facing page). Another anatomical study using Erica's hand as the model. This life-sized carving was made using a brown-colored Brazilian agate.



Figures 7a, b. Van's lathe, which he built inside his studio, was an adaption of commercial machining equipment, but with the motor slowed down for lapidary projects. **Overset image:** Van turns a rock crystal jar on the lathe. He uses a feeler gauge and stops to monitor depth as he grinds out the core.

Van never felt burdened by the pressure of a deadline. Asked how long it might take to complete any one project, he could only hazard an approximate guess, because he never worked day-in and day-out until a project was done.

The most time-consuming aspects in Van's projects occurred before actual carving began and at the end, during its last phase – polishing. He has had ideas for a project he wanted to do, sketched them out, and then spent years finding just the right material for his concept. Since he liked to carve medium and large-sized objects, the first consideration was ensuring that all the pieces that would be incorporated into one object could be cut from a single piece of stone. For a finished assembled object, especially one carved from agate, he said it is almost impossible to obtain uniform texture and color throughout if individual parts were cut from different nodules. Many of his turned pieces such as vases and candlestick holders were carved from several pieces fit together mechanically with dowel and socket joints. The continuity of the color and pattern of the material imparted the impression that the joined sections were a single piece. For objects that were manifestly made to function as separate opposing

Figure 8. Van carefully aligns a block of agate on his radial arm saw for cutting into smaller pieces.

parts, such as a lidded container, it was still important to ensure the continuity of the color and pattern in the carved material, which is evident in the execution of a faceted agate container with a lid (figure 9). However, for this project he introduced a difficulty factor to the design: instead of making a round cylinder, which could be turned on a lathe and hollow out in fairly straightforward and efficient process, Van made the shape oval. It was far more difficult as well as fabulously time-consuming to produce an oval shape.

Perhaps the most noteworthy aspect of Van's working process was the time he spent polishing. He moved from lathe to lap wheel to working by hand using a Foredom flexible shaft. He had a small mandrel; rotating the object at 800 RPM, he addressed the object with a diamond-impregnated cloth fit onto a rubber wheel. He uses three grits sucessively – 220 grit, 150 micron, and 6 micron – to efface saw cuts, then eliminate chips beneath the saw cuts, and then pre-polish. In Van's process, the final polish was done twice. He used felt wheels and an aqueous slurry of aluminum oxide or cerium oxide or a combination of the two. Polishing is a long, slow process, with tool rotation slowed significantly. Van estimated that polishing took twice the time that grinding required. After proceeding through the polishing phase in stepwise fashion, he inspected the surface for defects that can only be seen in the polish. Noting the problem areas, he would step-repeat the process – returning to the grinding phase, and then revisit the polishing steps all over again.

When a family friend, a third-generation gem carver, was visiting from Idar-Oberstein, Van showed him his shop where he was working on finish polishing a piece. The German carver was incredulous at the second long laborious round of grinding and polishing. Of course, a carver with a commercial business could never afford to take the time to replicate Van's technique, as much as he admired it for both the patience and the results Van achieved.

Figure 9. Faceted oval container with lid (15.24 cm h.; 6 in. h.). Cut from Brazilian agate, accented with gold fittings and mounted on a base of obsidian. This carving is a tour de force of lapidary skill, because hollowing an oval-shaped vessel is far more technically challenging than coring a round cylinder.

Figure 10 (facing page). This footed cup (ca. 15.24 cm h.; 6 in. h.), was lathe-turned from translucent honey-colored agate, with the natural rind preserved on the rim.

Figure 11. Van incorporates the dark rind of an agate nodule into the free-form design of a lidded box (22.9 cm w.; 9 in. w.).

Giving Expression to the Material

Van often looked for unusual, sometimes eccentric qualities when choosing a material for carving. He elicited interesting effects from pieces with parts that other carvers might regard as defects. For example, he produced a footed agate cup that incorporated the nodule's natural black rind to form the cup's rim, which contrasts the body's delicate honey-colored translucency (figure 10). Similar material was employed to great effect in the carving of a lidded box whose organic undulating form is reminiscent of a worn gnarled tree root (figure 11). A moss agate bowl and matching stand playfully suggests a soft, dense green mossy mass which in reality is quite the opposite – hard, highly polished, and ethereally translucent (figure 12).

Figure 12. The free-form design of this moss agate bowl with footed pedestal (27.9 cm w.; 11 in. w.) is dictated by the stone's natural pattern.

A similar piece of moss agate inspired a scallop shell that made its public debut at the Tucson Gem Show, in 1996 (figure 13). Like many other pieces Van produced, elements featuring gold fittings, hinges, rims, and trim were made by a goldsmith in Kassel, where Erica, who is German-born, has close ties. The shell was hand carried to Idar-Oberstein to be fitted with a mechanical hinge that would make it open and close slowly as it rotated atop a sand dune on the floor of the vitrine. It was a delightful, whimsical concept for a music box.

Figures 13a, b (right and facing page). Moss agate carving of a bivalve shell (15.24 cm h.; 6 in. h.) made into a music box that opens and closes while it rotates. Upon opening it reveals a "surprise" of jewelled brooch with freshwater baroque pearls, diamonds and a central tourmaline.

Figure 14. Harold Van Pelt with Dr. George Rossman and the "Izok Skull," 2011.

Lapidary Shock

Van frequently put things to the side, sometimes for months, thinking a long time about each phase in the process. He ruminated over what adjustments needed to be made at every juncture, especially when the bulk of material had been removed and he began measuring critical angles or thinning the walls of a vessel or delicate carving. He carefully considered cracks and vugs and defects he could not see but knew to anticipate. Despite taking such precautions, he had a catastrophic mishap on a longterm project when it was nearly completed. He had spent more than a decade working off and on to carve a smoky quartz skull. Intrigued by the archaeological rock crystal skulls he saw in museum collections, he took them as inspiration to make one of his own. As he had done on so many other projects, he set himself a high difficulty threshhold for making his skull. Unlike the museum pieces, all of which were solid and small, he raised the bar on the technical challenge, making his skull life-size and hollow. After the long, laborious process of carefully removing material from the interior and far along in the painstaking process of thinning the inside walls, well in sight of the project's end, that awful springing pop sound stopped him cold – the skull had shattered. He didn't tell Erica what had happened for two days.

After waiting a few months, Erica encouraged him to make another one, and so Van started looking for

Figure 15. The Van Pelt rock crystal skull.

the right material. Longtime friend Bill Larson found it in a 250-pound rock crystal quartz included with swirling masses of inclusions resembling silvery gray swathes of hair. Dr. George Rossman, Professor of Mineralogy at the California Institute of Technology, in Pasadena, California, identified the silvery inclusion as izoklakeite, an exceedingly rare mineral discovered at Lake Izok, Canada, and first described in 1986.[1]

Van cut it down into a more manageable 52-pound block and set to work on a new skull. This time he worked at a quicker pace, taking the hard-learned lessons of the previous effort—measuring ever more carefully and learning to listen to the piece under the pressure of the tools. He completed the second skull at relatively brisk pace, applying the final polish in just under two years (figures 14, 15).

1 Rossman, Ma and Kampf, 2011.

Figure 16. Agate drinking horn, or rhyton, carved in the form of an African or Persian gazelle, with a gold end cap (6.5 × 15.6 cm, 5.9 cm dia.; 2 1/2 × 6 1/8 in., 2 1/3 in. dia.). Hellenistic, probably 300–100 BC. Shaanxi, China, History Museum.

Ancient Musing

In the previous article in this volume, Si and Ann Frazier described Van's interest in the history of lapidary carving, which provided inspiration for many of his projects. Works produced in hard stone dating back to the cultures of Classical Antiquity were especially fascinating to him. When Erica was travelling in China in the 1990s, she saw an ancient drinking vessel, or rhyton, on exhibit at the Shaanxi History Museum, in the ancient city of Xi'an. It was carved from agate with dark brown and white bands, its horn shape terminating in the head of a gazelle or ibex (figure 16).[2] She snapped photographs of it and brought them back for Van's consideration.

Van loved the elegant simplicity of the carving, but he was also intrigued by its story. The vessel had been discovered in 1970 as part of a Tang dynasty burial hoard in a 8th century tomb near Xi'an, at Hejiacun (Parlasca, 1975 and 1985; Louis 2007; Lapatin 2015). It was found together with other exotic luxury objects. Scholars have debated when in antiquity and by whom this very unusual hard stone rhyton was carved. While virtually every ancient culture produced hard stone carvings of animals in intaglios and cameos (figures 17 and 18), there is only one other rhyton carved in hard stone closely comparable to the Hejiacun rhyton for its size and zoomorphic subject.[3] Such vessels are well known in other media including ceramic, ivory, and precious metals (figure 19), and their cultural range extends thousands of years, from Bronze Age Anatolia to the world of the Greeks (at home and abroad) and dominions of Imperial Roman to the empires of the Parthians (2nd to 4th century) and later Sasanians (3rd to 7th century, modern Iran). One might wonder if the last royal owner of the rhyton had any inkling of how far this treasured heirloom had traveled – thousands of miles, very possibly as far away as Egypt, and through the hands of generations of owners, possibly spanning ten centuries – before reaching its last owner in Xi'an, China, in the 8th century.

Van selected a block of agate from Brazil that would be complementary in appearance to the Hejiacun rhyton. He emulated the ancient gazelle's features in careful detail. However, unlike the ancient original, which was not hollowed through to the spout, Van hollowed his rhyton to the tip of the gazelle's mouth.

2 The museum describes the rhyton as an ox head-shaped cup, which it certainly is not.

3 The only carving closely analogous to the Hejiacun gazelle is a rhyton terminating in a calf's head, which was found in the Egyptian Desert, now in the Egyptian Museum, Cairo. Given its findspot, it was almost certainly manufactured locally in Hellenistic Egypt, ca. 2nd century BC.

Figure 17 (top). Carnelian amulet carved in the form of a recumbent cow looking backwards (1.7 cm; 3/4 in.). Egypt, New Kingdom, 18th Dynasty, 1540-1296 BC. Cleveland Museum of Art, 1914.568. Gift of the John Huntington Art and Polytechnic Trust.

Figure 18 (top). Sardonyx cameo engraved with a tethered goat (alpine ibex?) lying down (3.1 × 3.9 × 1.0 cm; 1 1/4 × 1 1/2 × 1/8 in.). Roman Imperial, 1st-2nd century AD. British Museum, 1824,0301.49. © The Trustees of the British Museum/CC BY-NC-SA 4.0. Bequeathed by Richard Payne Knight.

It is virtually certain that the original rhyton will have been carved from a grayish green to pale gray banded agate nodule and then heat-treated using a sugar or honey solution to produce strongly contrasting white and brown bands. Heat-treating microcrystalline quartzes is a lapidary tradition dating to the 3rd millennium BC, if not earlier, in the Indus Valley Civilization (in modern Pakistan). Both the raw materials and treatment methods were transmitted across the ancient world ftom an early date, and they persisted (figures 18, 20).[4] In many parts of the world,

Figure 19. Silver rhyton terminating in the forepart of a ram (19.99 x 11.99 x 12.29 cm; 7 7/8 x 4 3/4 x 4 7/8 in.). Achaemenid Persian, ca. 5th century BC. Metropolitan Museum of Art, New York, 1989.281.30a, b. Gift of Norbert Schimmel Trust, 1989.

Figure 20. Oblate ellipsoid stamp seal engraved with a standing canine (1.23 × 1.5 × 0.9 cm; 1/2 × 5/8 × 1 1/32 in.). Sasanian, 4th century AD. This agate sealstone was manifestly treated, probably using a combination of honey and heating. It was carved to the desired shape and drilled, then treated, following by engraving and finish polishing. The carving through the treated outer surface reveals the stone's original pale body color. Michael C. Carlos Museum, Emory University, Atlanta, 2012.032.050, Gift of the Estate of Michael J. Shubin. Photo by Lisbet Thoresen.

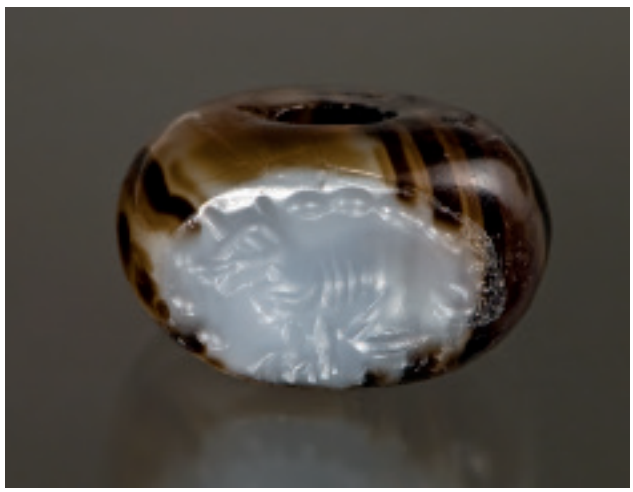


Figure 21 (top). Agate before sugar treatment: slab (lower left) and rough cut piece (back right). Uncut agate rough after treatment (front right). The carved object (left) was sugar treated, then returned to the lapidary's studio to be finish polished.

Figure 22 (middle). Van's rhyton was cut from a Brazilian agate with low contrast, pale-colored bands. Shown here, it has been hollowed through to the spout, gold cap to the side. The first polish left the surface sufficiently porous to take the sugar treatment. Experiments treating agate scraps from the same block involved soaking the piece in a sugar solution for many weeks, then burning off the sugar with sulfuric acid, which produced the attractive high contrast, brown and white bands.

Figure 23 (bottom). The sugar treatment had to penetrate deeply enough to allow finishing polishing of the rhyton, shown here, with the custom designed muzzle cap in 18k gold, produced by a jeweler in Kassel, Germany.

Figure 24 (facing page). The gazelle cradled in its mount, which Van carved from rock crystal quartz. The finished rhyton measures 16.5 cm h. (6 1/2 in. h.).

the technique for sugar-treating agate has changed little since antiquity (figure 21). Van's gazelle was carved from a pale gray and white banded agate (figure 22). He brought the carving to completion, with a first-stage polish applied. Then, for the requisite sugat treatment that would produce the strong contrasting light and dark-colored bands, Van's rhyton was hand carried to Idar-Oberstein and entrusted to a fifth-generation lapidary to apply the weeks-long treatment. The gold cap for the gazelle's muzzle/spout was custom-made in Kassel (figure 23). Upon being returned to Van's studio, the long, laborious process of applying the final polish to the gazelle began. Van made a stand for it from rock crystal quartz. The rhyton gazelle was completed in 2009 and was among the last of Van's major projects (figure 24).

4 Recipes for staining agates appear in Near Eastern texts (see for example: Oppenheim 1966; Collon, 1987, p. 175, British Museum inv. no. BM 89502, Layard excavation no. 1853b, 160; Moorey, 1994, p. 100; Sax et al., 1996), with still other techniques mentioned by other ancient sources including the first century AD Roman naturalist, Pliny the Elder, in his opus *Natural History* (Book 37.194–195), and a 3rd century recipe book known as the *Stockholm Papyrus* (*Papyrus Graecus Holmiensis)*.

Figure 25. One of the lion armrest protomes during the production process, pictured with some of the bits Van used in a Foredom flex shaft to carve the details.

Ars longa, vita brevis

The longest project Van worked on was more than 30 years in the making. The piece was modeled after an ersatz Louis XIV arm chair that he and Erica had purchased from a friend who was a well-known antique dealer in Los Angeles. The overall design of the chair is recti-linear, with cushioned seat and back (figure 1). All the wooden parts of the chair – arms, arm supports, seat back finials, legs and cross stretcher – were cut from a single large block of fracture-free Brazilian agate. The block Van chose closely approximated the dark brown walnut of the real chair. The legs, stretchers, and arm supports were carved in a twisted rope pattern, with the arm rests terminating in carved lion head protomes (figures 1, 25, 26). Van worked on it and set it aside several times, sometimes for intervals spanning years. He recalls having gotten stuck at a certain point, trying to work out how this life-size chair would have to be constructed so that it would be structurally stable and stand under its full weight without any external armature. In the end, he engineered it so that it stands under its own weight like a normal chair. An artist friend painted faux agate cushions for the seat and back. The life-sized finished chair measures 97.8 cm/38 ½ in. high (figure 27).

Figure 26. Close-up view of one of the lion armrests.

Figure 27 (facing page). Van's interpretation of a Louis XIV chair in agate, completed and assembled.

In Retrospect

Sometimes the effects Van achieved in his carvings were purely accidental, but he never deviated from bringing careful planning and patience to every project. Pure discipline and the accumulated experience of more than five decades has produced a body of work numbering more than 90 major pieces. Along the way, it was only when an object was finished and being lit for photography that Van and Erica could stand back and see it with fresh eyes – no more worrying that something might go awry and the carving might suddenly break into pieces. Then, it was on to the next project. This iterative process of creating masterworks in hard stone was a passion they kept almost entirely to themselves for decades. After the publication of a catalogue raisonné in 2010 and the major restrospective exhibition sponsored jointly by the Bowers Museum and Houston Museum of Natural Science, the Van Pelts were delighted, at long last, to share with a wider audience Van's personal interpretion of the wonders of gems and the pleasure of carving them. They are gratified to leave a legacy to others who share their passion.

Acknowledgments

The author wishes to thank Harold and Erica Van Pelt for providing access to their archive of photographs and the opportunity to interview them on multiple occasions. Thanks also to Jay Van Pelt, whose invaluable help included organizing and editing the photographs for publication and reading the manuscript; and thanks to Stuart Overlin, who read the manuscript.

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Challenges of Photographing Agates

Robert Weldon

AGATE PHOTOGRAPHY is fairly straightforward when the agate is a polished slice, or when the photographer is capturing the flat polished surface of an agate nodule.s.

In a typical three-point lighting system (consisting of two side lights and a back light), flat agates can be photographed perpendicular to the camera, with the side lighting on either side placed in such a way that their reflections are not seen in the agate's surface. Backlighting can serve to illuminate a partially transparent agate, and to cast a soft shadow in front of the material. With opaque stones, the backlighting only serves to cast a shadow and to illuminate the surface of the material. Very thin, partially transparent iris agates need only be illuminated with direct (not diffused) backlighting in a darkened room, to best capture the colors in the iris effect.

Flat surfaces are easier to capture in sharp focus because they represent the exact plane of focus of the camera's lens. This yields sharp focus from end to end of the agate, even with relatively shallow depth of field (typically f 2.8–f 8.0). Agate carvings or three-dimensional agate objects require a sharper depth of field (typically f 16–f 25) in order to achieve an acceptable focus from one end of a carving to another. In digital photography, three-dimensional objects are often photographed at various focal points, and then stacked seamlessly together in post-photography processing.

While flat objects present the least challenge (from the standpoint of focus and reflections), agates are sometimes cabochon cut or fashioned spherically, and thus reflect light on all sides, including the curved edges. The bright spots from the lights seen in the images can be extremely distracting. One way to minimize unwanted reflections is to immerse these agates in water, and then photograph them immersed.

Because of the inherent beauty in these gems—appreciated since ancient times—the photographer's task is rendered joyful and productive! The following gallery of images celebrates agates of all sizes and shapes and from a myriad of sources around the world. All were photographed using techniques mentioned above.

Above. Left: Mojave Blue chalcedony, pseudomorphic replacement after melanophlogite (26.94 mm). Mojave Desert, California. Photo by Robert Weldon, courtesy Si and Ann Frazier. Right: Lily carved from agate by master gem carver Gerd Dreher, in 2006, sepal in 18K gold, enamel and gold stamens with diamonds (174 g). Photo by Robert Weldon, courtesy Dreher Family.

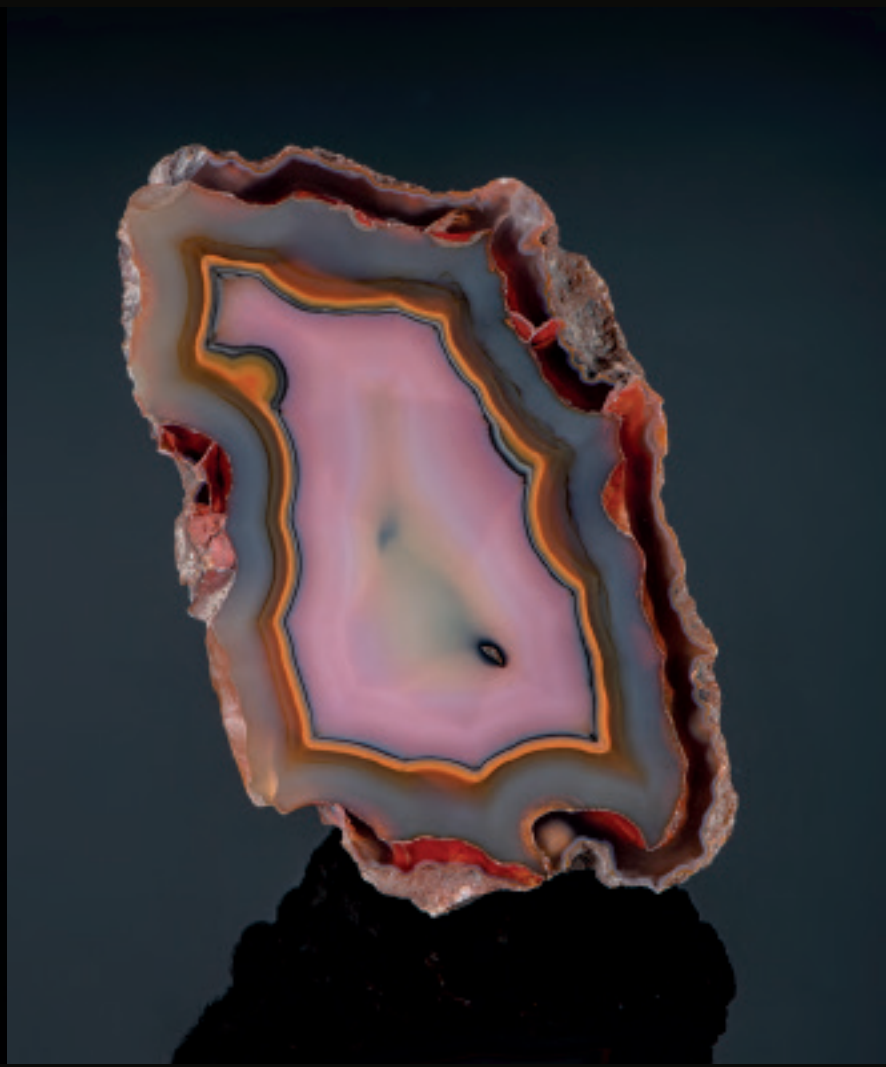
Facing page. Laguna agate (70.85 mm, 129.59 g), from Ojo Laguna, Chihuahua, Mexico. Courtesy of Kristalle.

Facing page. Top: “Hand holding flower” (220 ct), a free-form carving in carnelian from Oregon, USA, by award-winning gem artist Meg Berry. Photo by Orasa Weldon.

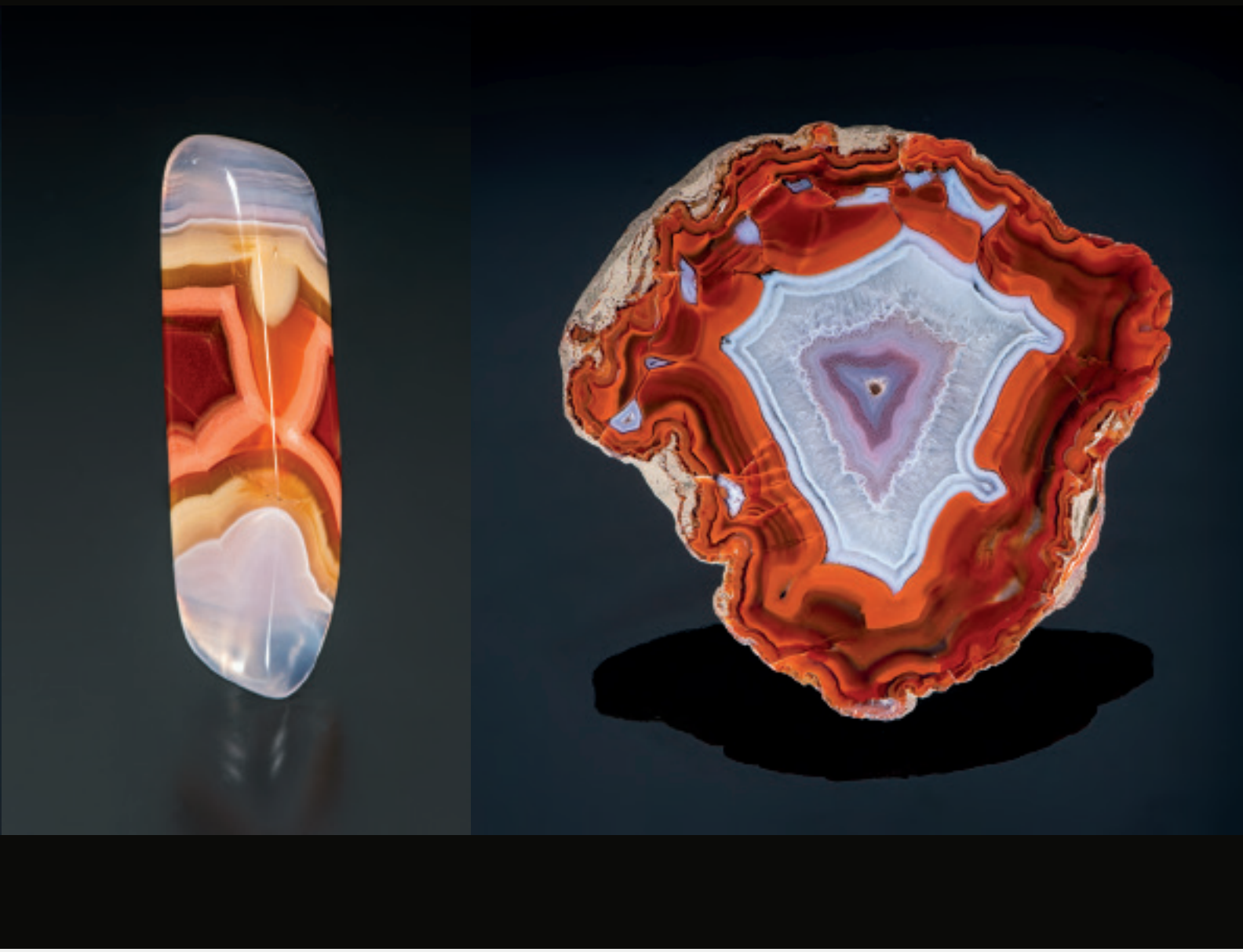
Bottom: A polished agate slice (40 x 21 x 1 cm, 1925.2 g), from Brazil, horizontal aspect. A predominantly ivory and white body color surrounds scalloped bands of brown and translucent golden hues, which frame the center cavity, outer edges trimmed in black. Photo by Orasa Weldon, courtesy of GIA Collection.

Above. Laguna Agate (49.20 mm). Photo by Robert Weldon, courtesy Si and Ann Frazier.

Crazy Lace Agate cut as a pear-shaped cabochon (49.78 mm, 61.22 ct), from Chihuahua, Mexico. Photo by Robert Weldon/GIA, courtesy of Kristalle.



Condor Agate (92.12 mm, 1204.3 ct), from near San Rafael, Argentina. Photo by Robert Weldon/GIA, courtesy of Kristalle.



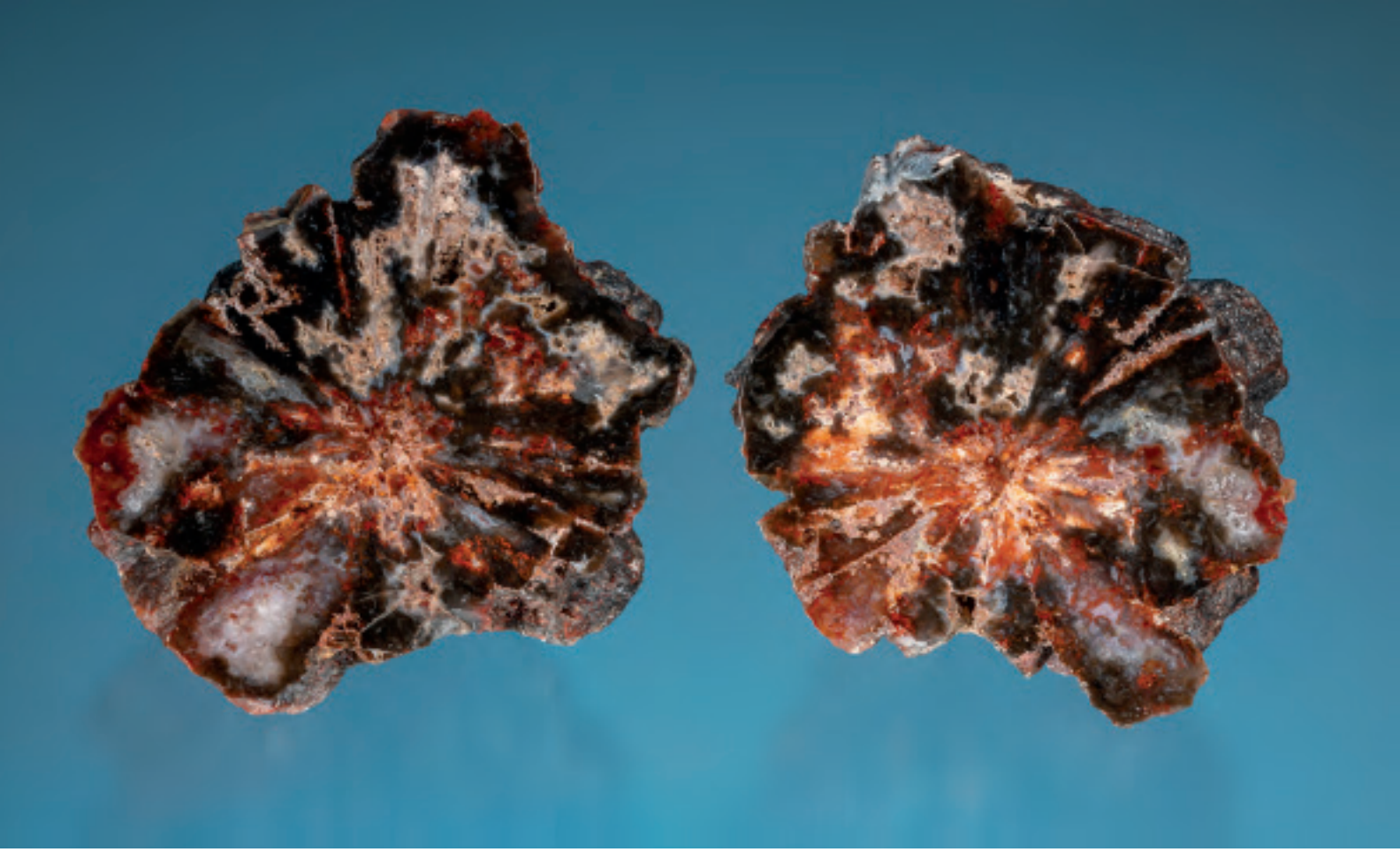
Moctezuma Agate (43.9 mm, 35.52 ct), from Mexico. Photo by Robert Weldon/GIA, courtesy of Kristalle.

Apache Agate slice (180 mm), from Ejido el Apache, Chihuahua, Mexico. Photo by Robert Weldon/GIA, courtesy of Kristalle.

“Cookie Monsters” agate nodule, split in half to reveal cavities lined with drusy quartz, which resemble anthropomorphic facial smiles. Measures approximately 60 mm as a closed nodule. Photo by Robert Weldon/GIA, courtesy of Mike Bowers.

Agate exhibiting Uruguay structure (105 mm top to bottom). Rio Grande do Sul, Brazil. Photo by Robert Weldon, courtesy of Si and Ann Frazier.

Agate (5.8.9 cm), from the 4th of July Butte, Arlington, Arizona. Photographed under ultraviolet fluorescent lighting. Photo by Robert Weldon, courtesy Si and Ann Frazier.



Facing page. Top: Quartz pseudomorph after aragonite, from Valle de Las Plumas, Paso de Indio, Chubut Province, Argentina. Photo by Robert Weldon, courtesy Si and Ann Frazier.

Bottom left: Moss agate (4 x 3 x 2 cm, 55.2 ct), from India. The mossy green inclusions and red splotches in this rectangular flat tablet resemble an abstract expressionist painting. Photo by Orasa Weldon, GIA Collection.

Bottom right: Landscape agate (10.71 ct), from Argentina. Photo by Orasa Weldon, courtesy of GIA Collection, gift of Herb Walters.

Above. Quartz lace agate bowl (7 x 7 x 4.4 cm), from Mexico. Expertly carved by renowned San Diego artist George Ashley. Photo by Orasa Weldon, courtesy GIA Collection.

Gem Virtuosos: The Drehers and Their Extraordinary Carvings

Robert Weldon, Cathleen Jonathan, and Rose Tozer

Abstract

The German towns of Idar and Oberstein (now Idar-Oberstein) have a rich history of gem cutting and carving, notably in agate. The profession continues to be passed on from one generation to the next, as it has been for over five centuries. One of these families, the Drehers, has worked with gem materials for 13 generations. Gerd Dreher apprenticed gem carving with his father starting in 1955, while Gerd's son, Patrick, began his apprenticeship in 1988. While they carve individually, occasionally they work together as a team. The family creates fine carvings from agates and from single crystals of high-quality rough gem minerals. These unique pieces are extraordinarily detailed and utilize natural color zoning to achieve a remarkably lifelike effect.

VIEWED FROM ANY DIRECTION, the gem carvings by the father-and-son team of Gerd and Patrick Dreher are remarkably lifelike. Agate toads appear bumpy, glistening, and slippery. Brimming with personality, their eyes appear to follow the viewer around the room. A carved tiger lily emerges from banded agate (figure 1) as a velvety, dappled flower, its petals enticingly curling inward. And on the backs of these petals, details of the flower's physiognomy are scrupulously maintained. Much like the gem materials from which they are carved, these works are one-of-a-kind creati ons.

Decades of experience between the two imparts virtuosity to their work, as well as a sense of humor often depicted in the subjects. Today, Gerd is globally acknowledged as a master of the craft, while Patrick has emerged from the younger generation, adding new carving techniques to the family repertoire. This enhances the formidable range of skills that have been passed down through the Dreher family for 13 generations.

Following in the path of their ancestors, the Drehers' ability to render the anatomy of flora and fauna in astonishing detail demands an intimate knowledge of their subject matter, not to mention a deep understanding of the characteristics and attributes of the gem materials they carve. The Drehers study rough gem material, sometimes for years. From these observations they conceive a three-dimensional outcome and then set to work bringing the stone to life (figure 2). A growing collection of diamond-sintered tools, and a thorough understanding of how to use them, underpins their closely guarded lapidary techniques.

Facing page, Figure 1. This Gerd Dreher lily carving (2005) is from a single piece of Brazilian agate and measures 11.0 cm in length. His skills are on exhibit through his use of the material and his technique, such as the curled petals that demonstrate a wealth of detail even on their undersides. The leaf, stamen, and enameled pistil accents are crafted from 18K gold and set with diamonds. Patrick Dreher's citrine mouse (2015), 6.0 cm in length, shows attention to the animal's stance and demeanor as well as fine detail in the carving of the fur. Photo by Robert Weldon/GIA, courtesy of the William F. Larson family.

* This article was published in the Winter 2017 issue of *Gems & Gemology*, © GIA, and appears here by permission.

Figure 2. Natural bands of color in a single piece of jasper were used to accentuate Gerd Dreher's 1993 carving of an orangy red toad sitting on a green leaf (left). The small cross section to the right shows how he used the gem's natural color banding to create the effect. The finished piece measures 10.20 cm in length. Photo by Robert Weldon/GIA, courtesy of Leslie Hindman Auction House.

Figure 4. This agate with an amethyst-lined cavity exhibits banding that is typical of the Hunsrück deposit near Idar-Oberstein. The slice measures 27.94 cm in length. Photo by Robert Weldon/GIA, courtesy of Friedrich August Becker Edelsteine.

Idar-Oberstein's Gem Industry

An understanding of the environment that gave rise to the Dreher dynasty—as well as hundreds of other celebrated practitioners of the lapidary arts—is essential to appreciating their story. Idar and Oberstein (figure 3), two picturesque German towns separated by the Nahe River in the state of Rhineland-Palatinate, were united in 1933 to form Idar-Oberstein.

This area in southwestern Germany, nestled in the Hunsrück mountain range, became famous for its agate and quartz deposits, as well as its residents' expertise in gem-related professions such as mining and cutting

Figure 3. Left: The town of Oberstein as it looked in the late 1700s. The picturesque Schloss Oberstein (the castle at the top of the hill) and Felsenkirche (the church built into the wall of the mountain) have changed little since this engraving was made. Colorized by Robert Weldon, from Collini (1776), courtesy of the Richard T. Liddicoat Library and Information Center. **Right:** Oberstein, as photographed in late 2015, bears a remarkable similarity to the sketch from nearly 250 years ago. Photo by Robert Weldon/GIA.

and more recently goldsmithing. Idar lore suggests that agate nodules and quartzes, such as chalcedony, jasper, carnelian, and petrified wood, were discovered by farmers as they plowed their fields centuries ago (figure 4). Agate mining and cutting flourished there for at least five hundred years. Some believe the Romans who conquered the region used Idar's agates more than two thousand years ago. A cameo found at Hidera, a Roman settlement in the mountains above present-day Idar, suggests this ancient glyptic use of its agates (Rapp, 2002). Other scholars dispute the Roman connection, but there is agreement that the deposits were mined during the Middle Ages. Cutters worked with gem materials from the area, and by the fourteenth century the region's agate cutting industry was established (Ball, 1931). Traditionally, the gem cutting trade has been centered in Idar, with jewelry manufacturing and related professions evolving in neighboring Oberstein and other hamlets (Frazier, 1978).

In the early days of the agate cutting industry in Idar, water from nearby rivers—the Nahe, the Idarbach, and others—provided energy used to turn massive sandstone wheels for cutting (Frazier, 1978). Large wheels, up to three meters in diameter, were used to shape the agate's exterior. Cutters from the area developed a technique in which they lay stomach-down on a wooden bench. This position, with their feet pressed against the floor, or against a block of wood nailed to the floor, gave them the necessary leverage to push the gem material against the rotating wheel and cut it (figure 5). The first record of a water mill used to grind stone was in 1454 (Gerdt, 2017). A Grinder's Guild document dating back to 1609 bears witness to the profession, including strong advice to its members: "No stranger must acquire the trade of a grinder, but the craft must be handed down from father to son" (Hadley, 1984).

It was long, difficult work that demanded physical strength. Smaller wheels were used to refine the interior—to hollow out preform bowls, for example. Accounts passed down through the Dreher family note that agate cutters rose at 4:00 a.m. and went to the water mills in Vollmersbach to await their turn at the wheel. Much of the work had to be done around farming obligations since cutting alone could not support the tradesmen. Throughout the small artisan

Figure 5. Top: This engraving from a 1776 book by Colosimo Collini, who explored the agate mining regions of southern Germany, shows a water mill cross-section in Oberstein along the Nahe River. The river current rotates the water wheel, which turns a geared axis. The gears turn the large sandstone wheels used to grind and form agate. **Bottom:** Another engraving illustrates in detail the arduous cutting process practiced by the German agate cutters, who used their bodies and the wheel to work the object. Courtesy of the Richard T. Liddicoat Library and Information Center.

Figure 6. Gerd Dreher shapes the preform of the jasper toad seen in figure 2. Gerd and Patrick Dreher both use a fixed-spindle technique while holding the gem material in their hands, a carving technique that has been used in Idar-Oberstein for centuries. Courtesy of the Dreher family.

workshops of Idar, family secrets learned at the cutting wheel were passed down through generations. Gem carving techniques and individual styles evolved with specific creative refinements and specialties that in many cases could be attributed to different carvers or their families (Dreher, 1979).

Gem cutters later developed foot-powered devices to cut the agates, which was followed by the advent of electric-powered engines to turn the spindles. These refinements allowed cutters to sit upright rather than lying on their stomachs. One technique did not change: While in many other parts of the world the gem material is held stationary and the craftsman moves a flexible tool around it to form the desired shape, Idar's cutters have always held the gem rough, as steadily as they can, in two hands. This practice continues today. The gem is moved around a fixed spindle, progressively grinding down the material. A wide variety of diamond tools are mounted on these spindles, depending on the effect that is needed, and the speed can range from 3,000 to 11,000 revolutions per minute (rpm). According to Patrick Dreher, both the spindles and the diamond tools are manufactured in Idar-Oberstein to each cutter's specifications. Gradually, the process reveals the carver's vision (figure 6).

A dramatic change in the supply of agate and quartz occurred in the early nineteenth century. The Hunsrück deposit was nearing depletion following centuries of exploitation. The resulting decline in centuries-old mining traditions could have spelled the end of Idar's cutting trade. Fortunately, between the 1820s and 1850s, German explorers and farmers homesteading in southern Brazil found new and vastly richer sources for agate and quartz along the border with Uruguay. The agate and quartz were discovered the same way they had been in Idar centuries before: by plowing the fields. Starting in 1825, shipments of the rough gem material made their way to Idar. The quantity and quality of the Brazilian agate surpassed anything that had been known from the Hunsrück deposit. According to a Scientific American report from the time, up to 300 tons of agate were shipped each year to Idar and Oberstein, where some 6,000 people were employed in the trade ("Where agates come from," 1882). Other Brazilian gems such as quartz, tourmaline, topaz, and beryl were eventually imported, greatly expanding the town's offerings. The variety and availability of gem materials brought new opportunities and challenges for the cutting center.

Germany exported much of its new material to French artists in the mid-1800s, during the waning days of Romanticism. Paris was a magnet for artists of all disciplines, including fine art stonecutters and gem engravers. The new Brazilian agate spurred a revival of gem engraving and carving, enabling cutters to create cameos, intaglios, and seals using its multicolored layers for relief (Lindemann, 2017).

Young craftsmen from Idar began flocking to Paris, learning refined engraving and cameo carving techniques from Parisian masters. The start of the Franco-Prussian War in 1870, however, hastened the Germans' return to their native land. These artists, who now had abundant raw imported material at home, were soon able to surpass the skills they had learned in France. With the sudden influx of skilled

carvers, Idar's renaissance as a gem center was well on its way. Many artists formed engravers' guilds upon their return, with more than 230 members in Idar and Oberstein (Pauly, 2012). The guilds helped train apprentices and enabled members to hone their cutting and carving skills. They also established a stable pricing structure for products. These developments cemented Idar-Oberstein's modern role as a center for agate cutting and engraving. The new skills acquired in Paris also prepared the cutters for the development of three-dimensional carving.

The Dreher Dynasty

Accounts suggest that one of the most admired cutters and engravers in nearby Vollmersbach during the late 1800s was Wilhelm Dreher (1840–1900). His meticulous work was widely commissioned both in Germany and internationally. An agate bowl of Wilhelm's, weighing 43 kilograms, was sent to French emperor Napoleon III (Dreher, 1979). Other items were sent to British royalty. One of Wilhelm's sons, possibly Karl (1861–1943), produced a lapis lazuli bowl for Emperor Nicholas II of Russia in the early 1900s. While the whereabouts of the bowl are unknown today, its sale was documented in the Dreher family history (Dreher, 1979). Karl Dreher's work, and that of other German artists at the time, marked the beginning of Idar's three-dimensional gem-carving tradition.

The Dreher lineage has been traced back to 1620, but the family believes their ancestors began working with gems from the region much earlier. Some details were recorded in birth, marriage, and death certificates. Dreher activities were also gleaned from property ownership records, particularly with regard to lapidary mills the family bought, owned, or sold over time.

Unfortunately, many Idar and Oberstein records before 1620 were destroyed during the Thirty Years' War (1618–1648), a religious conflict in central Europe. This period witnessed considerable devastation of churches and the loss of parish records. Destruction of records was repeated in both World Wars, leading to ambiguities about the provenance of some important unsigned works of art, where the craftsmen cannot be verified with certainty. This was true for the Drehers and many other notable agate cutting families in Idar.

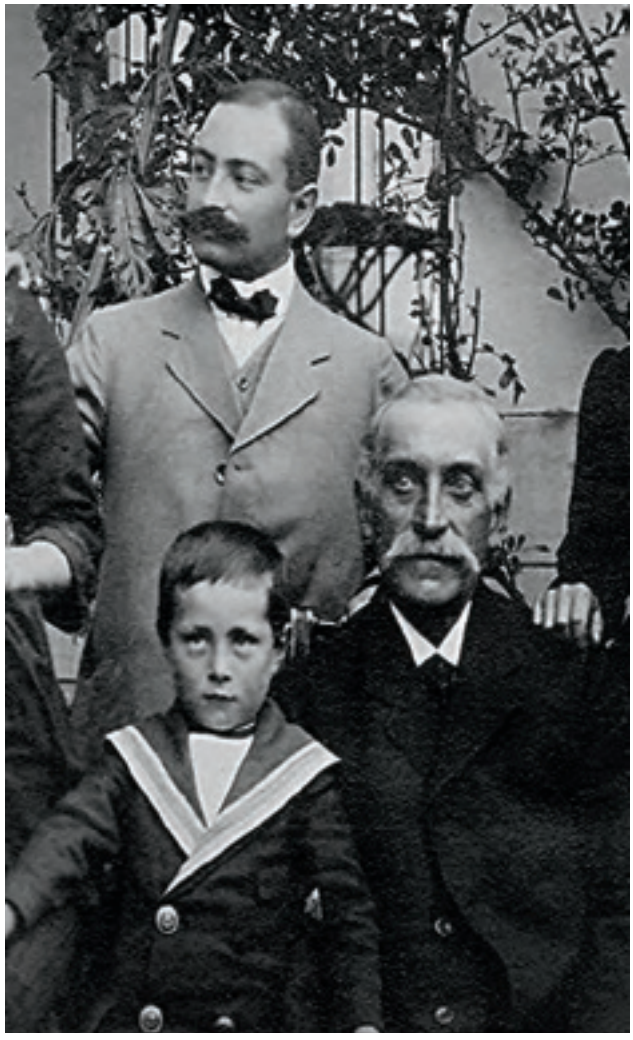


Figure 7. Three generations of Drehers (clockwise from top): Hermann Dreher (1886–1960), Karl Dreher (1861–1943), and a young Paul Dreher (1910–1968). Courtesy of the Dreher family.

Wilhelm's son Karl was the first in the modern line of Drehers (figure 7) who developed skills as gemstone carvers, instead of simply cutters. As a young man he trained under a master carver who had returned from Paris, learning how to carve cameos, monograms, and other ornaments. These skills greatly expanded the Drehers' repertoire as they began to add engraving and carving to their skills. With the increased exposure to international carving styles and art movements, the family's worldview began to expand as well.

Figure 8. Fabergé representatives provided plaster models, such as the toad on the left, as a sample for German carvers in the Idar region to reproduce in agate. The Drehers have kept this plaster model for generations. Photo by Patrick Dreher, courtesy of the Dreher family. **Right:** Gerd Dreher's multicolored jasper toad (1985), measuring 6.5 cm in height, was carved from the family's Fabergé plaster keepsake. Photo by Robert Weldon/GIA, courtesy of the William F. Larson family.

Meanwhile, Karl Wild, a contemporary of Karl Dreher who was related to the Dreher family, saw opportunities outside of Idar and traveled to Russia, acquiring the nickname "Russ-Karl." There he not only sold finished carvings and objects of art by Karl Dreher and others from Idar but also took orders and brought back raw materials (such as Russian lapis lazuli) to be carved. The lapis lazuli bowl mentioned earlier is one such piece.

The Drehers during the Era of Fabergé

The Dreher family, like many others in Idar, relied primarily on a series of brokers to sell their work. One notable gem dealer was Moritz Stern, who brought specific orders to Idar from abroad. These orders were placed with the town's best carvers. Among those who recognized Idar's lapidary talent, and who would soon use Stern's services, was Carl Fabergé, who developed an appreciation for hardstone cutting while traveling through Florence, Dresden, and Idar in the late 1880s (von Habsburg, 1988). Fabergé was also influenced by Japanese *netsuke*[1] carvings, amassing a collection of some 500 pieces. These were popular items from sixteenth-century Japanese clothing.

As a result of these influences, lapidary orders coming into Idar at the turn of the twentieth century included specific requests from Fabergé in St. Petersburg. Fabergé developed small plaster models of animals, which were supplied to the gem cutters and replicated in stone (Adams, 1988). These works were either assembled pieces or objects made from a single piece of stone. After the finished pieces were returned to Fabergé, his workmasters would apply embellishments such as gold legs and feet (Wild, 1981). Patrick Dreher credits these Fabergé orders with changing the family's focus from the simple cutting of agates toward carving in more artistic forms. Karl Dreher's son, Hermann (1886–1960), is one of the artists who provided carvings purchased by Fabergé. The Drehers say these works were faithfully carved from plaster models provided by Fabergé craftsmen (figure 8, left; Ovchinnikov, 2017). Although these models were considered worthless after the hardstone work was done (figure 8, right), and most were lost to time and history, the family managed to keep one such model.

This period marks the earliest shift to three-dimensional gem carvings. The Dreher family maintains only two such early carvings in its possession:

[1] *Netsuke* refers to a toggle or button adorned with a miniature carving, often depicting animals, made from ivory, wood, lacquer, bone, or metal.

the rock crystal bowl seen in figure 9, and the figure of a gem carver with a bowl in figure 10.

Even with family members brokering some of the business, the hardstone carvings went unsigned and were subsumed under the Fabergé name. The venerable Russian firm relied to some extent on outside vendors for a variety of goods they could not manufacture themselves. The items supplied had to be of the highest caliber and craftsmanship, reflecting expertise simply not found in Russia at the time.

German lapidary craft is acknowledged in the Fabergé literature. References indicate that the first carved hardstone animals likely came from Idar. In Fabergé, Dr. Géza von Habsburg writes: "Fabergé took up the search for hardstone carving outside of Russia... [H]is journey led him to Idar-Oberstein, a little town specialized in the cutting and engraving of Brazilian agate." Von Habsburg singles out the German carver Alfred Heine, working for the Wolff Company, who "produced stone animals for Fabergé." He goes on to say that "Fabergé's numerous commissions brought about a new flowering for the old stone cutting center" (von Habsburg, 1988). This is also acknowledged by Russian experts. "It is a well-known fact that the Idar-Oberstein masters made large quantities of carvings for Fabergé," said Galina Gabriel, a member of the International Association of Art Critics and the Russian Union of Artists who spoke at the 2015 International Fabergé Conference in St. Petersburg.

After 1908, Fabergé acquired the Woerffel factory in St. Petersburg to handle the firm's lapidary needs. Orders for the carved animals, commissioned through Fabergé and originally carved in Idar, consequently slowed in Germany. After World War I (1914–1918), such carvings came to an abrupt halt. Widespread social unrest in Russia culminated in the 1917 Russian Revolution and the execution of Emperor Nicholas II and his family in July 1918. Fabergé lost all of its wealthy Russian patrons. The firm was nationalized, closing its doors in November 1918 (Snowman, 1962; Faber,

Figure 9. This rock crystal quartz bowl by Hermann Dreher, ca. 1910, is one of the oldest items in the family's possession. Photo by Robert Weldon/GIA, courtesy of the Dreher family.

Figure 10. Paul Dreher's figure of a gem carver holding a bowl (1935) is another of the earlier pieces in the Dreher collection. Photo by Robert Weldon/GIA, courtesy of the Dreher family.

Figure 11. Paul Dreher (1910–1968) working in his studio. Courtesy of the Dreher family.

2008). The destruction of records in both Germany and Russia left a gap in the full understanding of Idar carvers' links to Fabergé. Nonetheless, the seeds had been sown for the growth of some of the world's greatest three-dimensional gem carvers.

Figure 12. Viewed from any angle, this Paul Dreher doe (1957) is remarkably lifelike. These realistic pieces marked a new design direction in animal carvings for the Dreher family. Photo by Robert Weldon/GIA, courtesy of the Dreher family.

Master Carvers: From Father to Son

Having learned the trade from his father, Hermann, Paul Dreher (1910–1968; figure 11) was third in a line of carving masters. The absence of influence from Fabergé or any other major buyer provided Paul with greater creative latitude, allowing him to render animal sculptures with rich variations. A delicate, lifelike deer and a large, sinuous puma are two Paul Dreher carvings owned by the family (figures 12 and 13). In homage to his innovations, the firm today bears the name Paul Dreher Edelsteine und Gravuren (Paul Dreher Precious Stones and Engraving).

Aside from his large, single-stone carvings, Paul Dreher also experimented with combinations of several carved gem materials in composite sculptures. These animal figures became very popular and were of such exceptional quality that they were sometimes misidentified as Fabergé pieces. According to Gerd Dreher (2012), "We were rather surprised to see two original carvings made by my father in the second edition (1962) of the book The Art of Carl Fabergé by A. Kenneth Snowman." The mistake is somewhat understandable: Unsigned pieces by the Drehers, and others in Idar-Oberstein, continued to be sold through brokers or dealers. The style once inspired by Fabergé had endured for decades, long after the legendary company had ceased to exist.

Why did the pieces go unsigned? The brokers had the luxury of travel and fluency in languages used in international commerce. They often presented the pieces as a shared Idar-Oberstein quality brand. Based in Idar-Oberstein and abroad, these brokers sold the carvings internationally or in some cases passed them along as examples of their own work (P. Dreher, pers. comm., 2017). This was considered normal business practice. There were positive and negative effects of this business model. On one hand, carving families in Idar-Oberstein did not have to concern themselves with marketing and sales. They could concentrate on producing the work and take the time to develop new skills. The obvious drawbacks, however, were that the carvers did not receive recognition, build a reputation,

Figure 13. This puma by Paul Dreher (1965) shows exquisite overall form and beauty in its smoothness, but without the nuanced details that diamond-sintered tools would later allow. It measures 32.5 cm in length. Photo by Robert Weldon/GIA, courtesy of the Dreher family and the Deutsches Edelsteinmuseum.

or understand their own market. This business arrangement lasted well into the career of Gerd Dreher. The unfortunate result was that the Dreher name was not widely recognized outside of Idar-Oberstein.

Gerd Dreher, born in 1939, was trained by his father starting at the age of 16, in the time-honored local tradition of passing these skills from father to son (see "Idar-Oberstein's Gem Industry" section above). Between the 1960s and 1980s, Gerd followed a path similar to that of his father, carving various gem materials, often in ways that could be composited to create animal figures such as the one in figure 14.

After Gerd Dreher took over the family business, he realized the need to change how his carvings were brought to market. He finally began to sign Dreher animal carvings in the 1970s, and collectors quickly seized upon the crisp logo they saw etched along the

Figure 14. "Love Birds" (1979) was created during Gerd Dreher's early years, when he carved various stones and composited them to form a whole sculpture. The birds are carved from aventurine quartz, black agate, and yellow jasper with obsidian tail feathers. They are perched on a base of preserved petrified wood. The piece measures 25.40 cm tall. Photo by Robert Weldon/GIA, courtesy of Leslie Hindman Auction House.

Box A: The Drehers and the Gem Carving Process

Idar-Oberstein's artists exert far more control over the shape, symmetry, details, and final polish of finished work than they did fifty years ago, thanks largely to modern diamond-sintered tools. The speed of cutting (the revolutions per minute of the spindle) has also increased. However, the Drehers prefer to use today's tools to increase the quality and fine detail of the work, rather than to improve turnaround time. The family has maintained their proprietary secrets, but they continue to use the traditional technique of holding the gem material against a spindle to grind away gem material. The following images and short descriptions provide a step-by-step progression resulting in a final carved object of art.

- An agate nodule (figure A-1) is carefully chosen and sliced using a diamond saw into an angular, blocked shape, from which the subject size and dimensions are determined. The Drehers sometimes sketch the animal onto the flat surfaces of the agate using a pencil or marker. This helps them to visualize the finished carving and determine how the material's color zoning will define the animal's characteristics and personality. Gerd and Patrick Dreher use color zoning in a single block of agate to determine how the animal will be posed. Both the agate and dozens of photos of the subject—in this case, a mouse—are studied to ensure anatomical correctness.
- In the second photo, Gerd Dreher has defined the three-dimensional object (a mouse), including the outlines of its tail and ears. All of the aspects of the creature's demeanor, stance, and position have been carved into the agate (figure A-2). The Drehers use 4–6 cm diamond-sintered tools at this stage, spinning at 8,000–9,000 revolutions per minute (rpm), with continuous water drip for cooling and cleaning. Patrick Dreher explains, "This step is one of the most difficult states, because you have to cut away a lot of material; but you can't cut too much because you cannot get it back if there is a mistake." This stage is also critical for observation: The artist must frequently pull away from the grinding to assess the material, sketch new drawings, study color separations, and correct any mistakes. In agates, the

Figure A-1. The first step in carving is to saw the agate nodule, revealing the interior banding and zones of color. Photo by Robert Weldon/GIA, courtesy of the Dreher family.

Figure A-2. Once the concept for a mouse subject is conceived, large sections of the agate are removed in the initial carving stage. Photo by Robert Weldon/GIA, courtesy of the Dreher family.

color borders are sometimes hard to see, which may require a redesigned mouse if color patterns are off.

- At this stage, the mouse has much finer characteristics, with translucent ears and more pronounced facial characteristics and tail (figure A-3). The Drehers generally use smaller diamond-sintered tools at this stage, varying from 5 mm to 2 cm. Different steps in carving require an assortment of tools and shapes as the carver exerts variable speeds (between 8,000 and 14,000 rpm) with a continuous water drip. The carver determines the thickness and fineness of the piece by varying the applied pressure. At this stage, the object, which must now have the animal's correct proportions, begins to appear lifelike.
- Gerd Dreher finishes this mouse (figure A-4) by carving extremely detailed strands of fur, defining the translucency and delicacy of the ears, adding small dimples denoting the mouse's whiskers, and fashioning the characteristics of the rock the mouse is standing on (consider that the mouse and rock on which he stands are all one piece). At least three degrees of polishing occur: pre-polish, fine polish, and high polish. Additionally, some sandblasting takes place on the rock portion for a different degree of texture. These polishing details are performed with small brushes and diamond powder (grits not disclosed). The powder is mixed with oils to create slurry, which can easily be cleaned with water. Dreher leaves small divots in the carving in which to place the animal's eyes, which are carved from black agate and prepared separately, then glued into place (figure A-4). Other accents may be added at this time as well, such as a gold tail or gold-feathered crests. Paraffin is never used to finish off the carvings, ensuring they will last for generations with proper care and handling. Both carvers serve as each other's quality control, Patrick Dreher adds. "It is always great to have a new pair of eyes look at something. But this I know is true: If my father says it is finished, it is finished!"

Figure A-3. Smaller tools are used for additional definition and detail. Photo by Robert Weldon/GIA, courtesy of the Dreher family.

Figure A-4. The final step is to carve minute details including fur, dimples, and muscles, and to polish the finished product. Photo by Robert Weldon/GIA, courtesy of the Dreher family.

Figure 15. "Red Baron" (Gerd Dreher, 2015) is a mostly rubellite tourmaline toad that gradually transitions to green tourmaline toward the base. The toad measures 7.10 cm in height and weighs 280 g (1,400 ct). Photo by Robert Weldon/ GIA, courtesy of the William F. Larson family.

edges of the artwork. Dreher carvings began to emerge from relative obscurity.

He observed that his artwork would benefit from carving single pieces of gem material—demonstrating what can be done with a single gem—albeit with accents, or an occasional quartz base to help a carving stand upright. Accents include gold fins for fish, feathered crests for birds, and tails for various animals. These accents are carved in wax and then cast in gold. Eyes are also added features, and they are sufficiently unique as to require particular attention. They are made from small translucent to opaque sections of agate, or black agates cut as cabochons. The translucent areas are lined internally with gold leaf. This results in the shimmering appearance seen in an amphibian's eye (figure 15) or the brilliant, dark stare of a mouse. Both appear startlingly similar to real eyes.

By 1980, much finer diamond-sintered tools became available. "It allowed us to carve mammals, reptiles, and amphibious creatures with much finer detail than before," Patrick Dreher recalls. These tools could also cut faster. But as Gerd Dreher cautioned his son, who was an apprentice by then, "The tools are not meant for us to produce faster. We will only use them to produce better." Elaborate carving techniques they continue to master show refined, individual detail in fur, where even single strands can be identified (see box A). Varying degrees of carving depth create selected areas of translucency or opacity, which often evoke comparisons with actual animals. Ears on a mouse or rabbit are strikingly thin and translucent, yet they still exhibit the detailed dimples and folds seen in a live animal. Advancements in the quality of the tools, merged with a deep understanding of the subject's

Figure 16. Gerd Dreher's evocative, softly undulating carved agate (2004) emulates coral. With delicately carved translucent agate fins, the fish appears to swim through the coral. The piece measures 25 cm high and weighs 1,960.8 g (9,804 ct). Photo by Robert Weldon/GIA, courtesy of the William F. Larson family.

appearance, imbue the creatures with stunning personalities (figures 16 and 17). Art critic Galina Gabriel considers the present generation of Drehers consummate masters, and Gerd specifically the "world's most prestigious gemstone carver" (Gabriel, 2015; Gabriel, 2017).

The Dreher Philosophy

Neatly categorized shoeboxes line the walls of the tiny Dreher studio, packed with photographs and sketches of fauna in various poses. Some are copied from books or magazines for reference. The photographs also feature animals that are live-captured by the Drehers to act as models for the carvers. It is the Drehers' impressive collection of images and sketches that gives the family a depth of understanding about their subjects that few other carvers enjoy. Patrick Dreher recalls that on one occasion he was looking for a "preening" mouse. He could not photograph the desired pose in a captured mouse until a tiny bit of strawberry jam was strategically smeared on a small patch of the mouse's fur. It had the intended effect: The mouse soon went to work cleaning himself. The photographs, which are taken from multiple angles, help the Drehers interpret and incorporate three dimensions into the finished object. These live animals fulfill their role as models, resulting in carvings such as the startled mouse (figure 18). After that, they are carefully released back into the wild, unaware that their likenesses are sought by collectors around the world.

Figure 17. This Gerd Dreher chameleon (2000), measuring 12.4 cm tall and weighing 2,390 ct, was carved from a single crystal of gem-quality Brazilian green beryl. Photo by Robert Weldon/GIA, courtesy of Silverhorn Jewelers.

Figure 18. A startled mouse (1997) assesses his options from inside an upturned mushroom. Carved by Gerd Dreher from smoky quartz, it measures 12.4 cm wide. Photo by Robert Weldon/GIA, courtesy of Leslie Hindman Auction House.

The Drehers carve a variety of rough gem material ranging from 5 to 9 on the Mohs hardness scale, though their stated preference is always agate. They appreciate agate's toughness but also its wide-ranging color variations, which guarantee distinctive works of art. Carving into the layers of color zoning in agate provides the "canvas" and opportunity for three-dimensionality. Dreher carvings also appear regularly in rock crystal quartz, ruby-in-zoisite, beryl, topaz, rhodonite, obsidian, and tourmaline, among other gem materials. Here, too, the Drehers use color zoning in single crystals to their advantage, or to reveal a story in the carving.

Collectors generally supply the raw material in crystal form or as rough chunks. It is always valuable and often extremely rare. One notable example is a toad (figure 19) carved from a single piece of Brazilian tourmaline crystal provided by California gem mineral collector William Larson.

"This piece came to us in colors of black, red, green, and black again," Patrick Dreher recalls. "As we began to remove the black material, we saw a thin layer of blue we hadn't seen before. This increased the value and became the head of the toad. The pink and red colors that emerged became the body of the toad, and the green color became the feet. This 'Queen of the Toads' is the most valuable piece we have ever carved."

Figure 19. This parti-colored tourmaline (2013) revealed its rich colors as it was being cut. Gerd Dreher did not know at the outset that the toad's head would be blue. It measures 10.8 cm tall and weighs 1,226 g (6,130 ct). Photo by Robert Weldon/GIA, courtesy of the William F. Larson family.

Figure 20. Gerd Dreher's "Three Young Birds" (2006), a carving in Ukrainian heliodor, incorporates part of the natural beryl face in the base. The accents are 18K gold. The piece measures 11.5 cm tall and weighs 922 g (4,610 ct). Photo by Robert Weldon/GIA, courtesy of Silverhorn Jewelers.

Patrick, born in 1970, apprenticed with his father, in keeping with the family's tradition. "My father is the best teacher I could possibly get," he says. Both work together at their home-based studio. "It's not like a traditional job where you go home after work. I'm home already. And my boss is also my father!" Patrick explains that he was exposed to the craft as a toddler, with ample opportunities to absorb his father's carving methods. Actual hands-on work began by the age of 18. In 1997, Gerd and Patrick traveled to Rio Grande do Sul, Brazil's southernmost state, and brought back 3.5 tons of handpicked agate rough, which they continue to work with to this day.

The 1980s and '90s also provided incredible new gemstone finds, such as large beryl crystals from Ukraine that were available after the fall of the Soviet Union. Gem materials were also emerging from Brazil and from newer sources such as Afghanistan, East Africa, and Madagascar. This gemstone windfall dovetailed nicely into the family's growth, with two decades of some of the finest, largest, single-crystal gem materials that had been found in the twentieth century. A young bird's nest lavishly carved from an enormous hexagonal Ukrainian green heliodor (figure 20) exemplifies the era. Sensitive to the beauty of the geometric etched pits on the crystal, Gerd Dreher left one face of the beryl intact with the gem's natural surface. Similarly, a mouse carved from African ruby and zoisite (figure 21) illustrates the massive

Figure 21. Gerd Dreher's ruby-in-zoisite mouse (1993), carved from a single piece of rough, has sapphire cabochon eyes and an 18K gold tail. It measures 6.8 cm tall and weighs 246 g (1,230 ct). Photo by Robert Weldon/GIA, courtesy of Silverhorn Jewelers.

Box B: Dreher Carving Quality Factors

Figure B-1. Gerd Dreher's "Tree Frog" (2002) was carved from chrysoprase and meticulously worked so that the frog's feet would curve to grasp the gold accents. The base of the carving is rock crystal quartz; the stem of the pond reed is 18K gold. The combined artwork weighs 1,032 g. Photo by Robert Weldon/GIA, courtesy of the Deutsches Edelsteinmuseum.

Quality of the Rough: The rough gem material must be extraordinary and rare, such as larger agates with unusual color banding and strength of color. This allows for the development of a themed finished carving. In transparent gems, the material is often crystalline and devoid of any obvious inclusions, resulting in clean, luminous carvings.

Quality of the Carving: The carving must maintain lifelike proportions throughout, and symmetry from all viewing angles should be comparable to an actual animal's appearance (figure B-1).

Details: Dreher carvings are studies in minute detail. How are these details rendered? Does the fur of a bear overlap? Are the ears of a mouse fine and translucent?

Use of Material: The Drehers sometimes spend years looking at a rough gemstone before starting to carve it. Considerable thought, planning, and execution go into the use of the gem's color zoning to convey lifelike features, or to distinguish an animal from its environment.

Uniqueness: Dreher carvings are always original works of art. Though some poses might be similar, no two carvings are identical; there is always variation because they are carved in different materials and at different times.

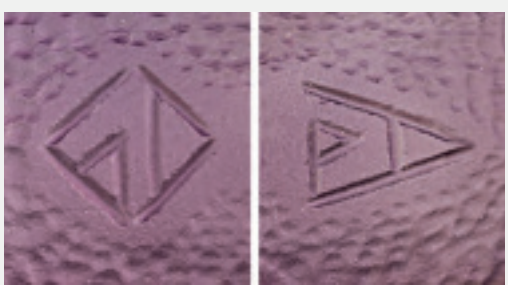
Signatures: Contemporary work is signed by Patrick or Gerd Dreher. In figure B-2, "GD" is Gerd Dreher and "PD" is Patrick Dreher.

Composite Works: Some Gerd Dreher carvings are composites of various gem materials. This generally dates a piece before the 1980s, expressing the material, the know-how, the demand, and the tools that were available at the time.

Single-Gem Carvings: Large single-crystal carvings reflect the company's change in artistic direction and philosophy in the 1980s. Single-gem carvings reveal not only the rarity of the gem material but also the Drehers' ability to render a complete three-dimensional carving from it.

Accents: Gold accents, such as tails and feathers, carved eyes and quartz bases, are used in both composite and single-gem carvings (figure B-1).

Figure B-2. Unlike their Idar-Oberstein predecessors, the Drehers started signing their contemporary work in 1975. The signature on the left is that of Gerd Dreher, while Patrick Dreher's initials are seen on the right. Photos by Robert Weldon/GIA.



ornamental materials beginning to emerge from Africa at the time.

Patrick says that he and his father consistently carve 12–20 new works every year, each of which may take 300–400 hours to complete. Father and son work both independently and collaboratively on pieces and continue to find new collectors to supply them with exceptional gem material.

Patrick's own mastery of the craft was realized in a dramatic fashion when, after decades of apprenticeship, he detailed a plan to carve a rounded but completely smooth and glassy hippopotamus out of citrine quartz. "It cannot and should not be done—you'll be wasting material," his father chided. Nevertheless, Patrick was steadfast in his resolve, and his father ultimately agreed the piece was masterful (figure 22).

Patrick has since carved a number of important pieces, including a starfish from a strawberry quartz specimen that in its rough state had concealed a secret. It was not until he began the removal of unwanted or damaged sections that the strawberry quartz revealed pale amethyst and colorless rock crystal quartz in the layers beneath. The color variations in the amethyst became a coral reef on an ocean floor of rock crystal (figure 23).

Figure 22. This hippopotamus in citrine (2015) shows Patrick Dreher's mastery in rendering the animal, which exhibits a highly polished, glistening surface. It measures 12.0 cm long and weighs 526 g (2,630 ct). Photo by Robert Weldon/GIA, courtesy of the William F. Larson family.

Inside their home studio, the Drehers take turns at the spindle. A collection of diamond-sintered tools, in

Figure 23. Patrick Dreher's strawberry quartz starfish (2014), carved from a crystal similar to the one shown on the right, revealed layers of amethyst and rock crystal as he carved into the stone. The "strawberry" portion of the single piece became the shiny starfish, resting upon an amethyst coral. The rock crystal quartz section was carved as the ocean floor. The starfish measures 13.6 cm tall and weighs 1,279.50 g (6,397.50 ct). Photo by Robert Weldon/GIA, courtesy of the William F. Larson family.

Figure 24. Gerd and Patrick Dreher in their studio. Courtesy of the Dreher family.

different sizes and numbering in the hundreds, await their turn at the workstation. These tools, and the skilled use of them, bring out extremely fine detail. With a few exceptions, it is this detail that defines the present era. In his day, Paul Dreher carved unique large items like the puma and deer, in which the personality came to life in the carvings' well-defined but smooth, soft surfaces, reflecting a mastery that was limited only by his tools. Today's carvings have generally lost that smoothness in favor of extraordinary detail, attention to realism, and quality (see box B).

Conclusions

For centuries, the German towns of Idar and Oberstein have been known for agate cutting. Joined as one town before World War II, the region developed into a cutting and carving center for colored gemstones. Two of its principal carvers, Gerd and Patrick Dreher, can trace their family's association with agate back thirteen generations, with the last five involved in three-dimensional gem carving. Father and son (figure 24) are considered by many to be the world's greatest living gem carvers, and their work continues to be acquired by collectors around the world.

About the authors

Mr. Weldon (rweldon@gia.edu) is director, Ms. Jonathan (cjonathan@gia.edu) is a research librarian, and Ms. Tozer (rtozer@gia.edu) is senior librarian at the Richard T. Liddicoat Gemological Library and Information Center in Carlsbad, California.

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museum. Thanks also to Dieter Hahn, chairman of the Foundation of the Deutsches Edelsteinmuseum, for his insights into the history of the Idar-Oberstein region. GIA has assembled a large collection of photos of Dreher carvings over nearly a decade, starting when gem dealer Michael Ridding of Silverhorn Jewelers (Santa Barbara, California) brought the Dreher carvings to our attention in 2009, and we thank him. We are grateful to Leslie Hindman Auctioneers (Denver) for allowing us to photograph a major collection of Dreher carvings prior to their sale. Gem and mineral dealer Bill Larson and his sons, Carl and William, all of Pala International (Fallbrook, California), introduced us to the Dreher family. We thank them for accommodating our ongoing requests to photograph their growing collection of Dreher carvings.

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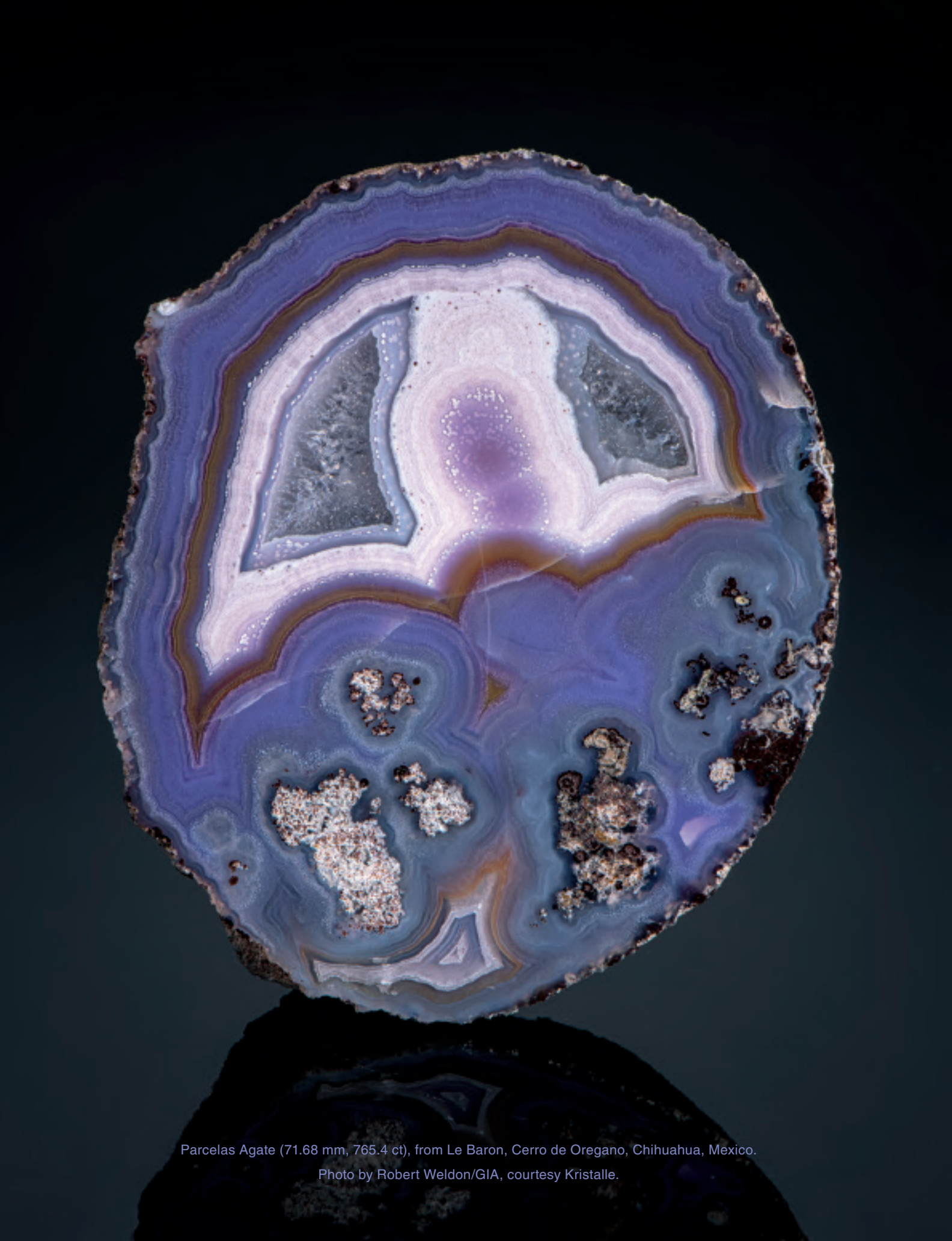

Parcelas Agate (71.68 mm, 765.4 ct), from Le Baron, Cerro de Oregano, Chihuahua, Mexico.
Photo by Robert Weldon/GIA, courtesy Kristalle.

Agate Bibliography

Ann Frazier

WHEN I WAS ASKED to put together this bibliography, I thought no problem. I have cataloged well over a thousand books and articles on agate alone, and I have really only scraped the surface of what could be included. But what to select? Geology, formation of agate, locality, physical properties, nomenclature? Ultimately, I decided to include a little bit of everything. I admit to not having read all of the books and articles listed but have noted, a la John Sinkankas, if the publication is "not seen." Unfortunately, many of the references given are written in foreign tongues. Agate speaks many languages and has no apparent preference for English. If I missed your favorite or left something out, please let me know. All bibliographies are works-in-progress, especially when you have a topic as truly fascinating as agate.

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Agate Rooster (108 mm h., 198 g) by master gem carver Gerd Dreher, 2004.
Carving in banded agate (heated) from Brazil, with 18K gold feet and beak. Signed by the artist. Photo by Robert Weldon/GIA.

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