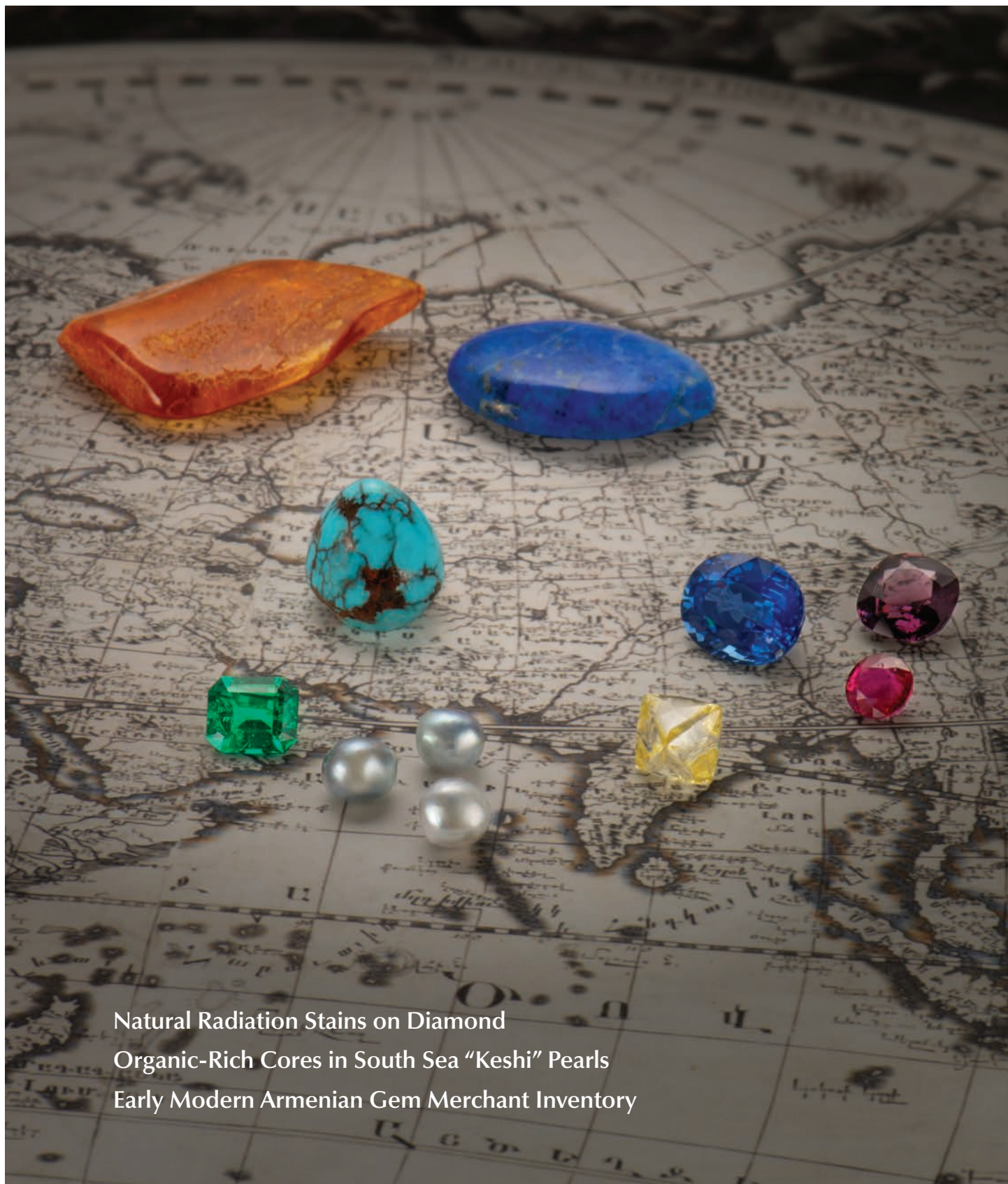


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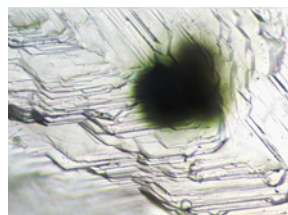
GEMS & GEMOLOGY

VOLUME LXII



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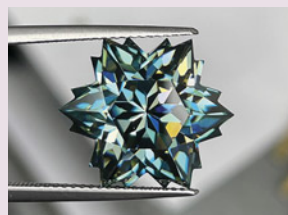
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About the Cover

The cover displays examples of gems traded by a seventeenth-century Armenian merchant, the subject of this issue's third feature article: Lithuanian amber, a lapis lazuli cabochon from Afghanistan, a 21.80 ct Iranian turquoise cabochon, an 11.16 ct blue sapphire from Madagascar, a 4.42 ct purplish pink spinel, a 2.06 ct Burmese ruby, a 2.53 ct Colombian emerald, three powder-blue pearls, and a 6.16 ct South African diamond octahedron. Photo by Michael Creighton; courtesy of GIA Museum. Turquoise gifted in memory of Iranian miners and their families.

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A Purpose Shaped by History, Renewed for the Future



To change the future, we must first understand the past—only then can we imagine new possibilities. *Gems & Gemology*, like GIA itself, was born during the Great Depression, just as gemology was becoming a practical science. In January 1934, GIA founder Robert M. Shipley declared the journal's purpose was "to increase the gem merchant's knowledge and ability...[to] protect more thoroughly his customers' best interests." By the second issue, Shipley expanded that objective "to keep the student abreast with the latest and the most important advances in the science of gemology." The journal would supplement GIA's gemology courses by providing new information that was not available when they were first written. Shipley's

"...G&G will transition to a timelier, online-first publication model."

statements clearly defined *G&G*'s core audience—the trade and students—which continues as our primary audience today.

During the 1940s and 1950s, many of gemology's pioneers contributed to *G&G*, among them Basil Anderson, Robert Webster, and Edward J. Gübelin, as well as Robert Crowningshield, Richard T. Liddicoat, and Shipley himself. In the Summer 1947 issue, Shipley announced the formation of a "special editorial board" composed of eminent gemologists and academics. Their role was to suggest new authors and topics for publication and to ensure the technical accuracy of submitted articles.

Almost half a century after *G&G*'s founding, Liddicoat, now editor-in-chief, sought guidance from GIA's board of governors on the journal's future direction. After their feedback, the Spring 1981 editorial reaffirmed *G&G*'s purpose to keep gemologists and gem enthusiasts well informed about new developments in gemology. Liddicoat recruited a professional with a background in scientific publishing, Alice Keller, who went on to steer the journal for more than two decades as his successor.

This period brought substantive changes to *G&G*'s presentation. The journal format increased to today's dimensions, with full-color—often specially commissioned—photography that showed the beauty of gem materials, reinforcing the gem trade as a major audience. Liddicoat declared *G&G*'s commitment to become the most comprehensive periodical in the field of gemology. As part of that effort, he revived and expanded the editorial board, which had lapsed in the 1960s, formally listing its members on the masthead, and introduced new manuscript guidelines for prospective authors.

Today, we continue to uphold Shipley's and Liddicoat's vision. Even so, we now face a defining question: In an age shaped by artificial intelligence and instant information, can a printed journal still make sense?

Reader engagement metrics show that a wide range of *G&G* content—from laboratory-grown diamonds to geographic origin studies for colored stones—has strong relevance and sustained value. With this in mind, and following Liddicoat's approach from more than four decades ago, we again surveyed academic and trade members of GIA's board, as well as key contributors, posing fundamental questions about *G&G*'s purpose, goals, and audience, and the most effective ways to serve that audience today.

Our governors reaffirmed that *G&G*'s primary mission is to educate and inspire; to showcase GIA's research; to provide timely and relevant information on gems and related topics; and to serve as the most trusted source for gem and jewelry knowledge. They confirmed our target audiences are practicing gemologists, GIA students and alumni, jewelers, researchers, educators, gem collectors and enthusiasts, and the wider public with an interest in gems.

The governors focused on three priorities: accessibility, timeliness, and reach. They encouraged us to provide summaries of technical material in plain language. They emphasized the importance of a quicker publication cycle, a shift to an online-first model, and the exploration of additional delivery formats. Several suggested adopting a more photo-forward approach, which would include technical information while remaining accessible to educated non-specialists.

At the same time, they recognized the printed journal's value. Each issue is a thoughtfully curated package of visual content designed to engage a broad audience interested in gems and jewelry.

Our governors' message was clear: Preserve what *Gems & Gemology* does best and build on it to make the journal even better.

In 2026, *G&G* will transition to a timelier, online-first publication model. We will also begin exploring new formats and types of content, starting with a new regular column, *From the Field*, focused on field gemology.

To further strengthen confidence in our scientific publishing standards, we have revised our author guidelines for feature articles, placing a greater emphasis on data quality, image integrity, and verifiable provenance. Authors must have sufficiently robust and well-documented gemstone sample sets of known origin to validate any conclusions they present. Manuscripts based on poorly documented or limited samples will no longer be considered for publication.

As we evolve, our commitment remains unchanged. We will continue to cover gem science, deliver practical gemological insights for the trade, and uphold the standards of excellence that have defined the journal since its founding. I am grateful to our readers for their steadfast support as *G&G* enters this new era.



Duncan Pay | Editor-in-Chief | dpay@gia.edu

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A CLASSIFICATION SCHEME OF NATURAL RADIATION STAIN MORPHOLOGY AND TEXTURE ON DIAMOND

Taryn Linzmeyer, Roy Bassoo, Sally Eaton-Magaña, Bernd Zechmann, Nathan D. Renfro, and John I. Koivula

Although green surface coloration on diamonds is mentioned in numerous studies, no morphological classification of the subject appears to exist. This study presents a classification of radiation stain morphology and texture to supplement known characteristics of naturally irradiated diamonds. “Radiation stains,” as they are often termed by gemologists, are a common indicator of alpha radiation damage that can impart a green color, which may turn brown with annealing. Studying radiation stain micromorphology and textural characteristics informs us of diamond residence in sedimentary systems, which helps to better characterize green diamonds. In this study, 84 natural diamonds with radiation stains were cataloged using photomicrography. Additionally, four of these were cataloged using atomic force microscopy. These stains were classified by color, opacity, shape, and coincident surface textures. For this study, green and brown radiation stains covered up to 93% and 12% of the diamond surface, respectively. Shapes were regular (circular or oval-shaped) or irregular and formed isolated or nondiscrete color zones. In regions imaged, circular radiation stains ranged in diameter from 22–77 μm , and oval-shaped ones ranged from 25–104 μm at their short axis to 36–158 μm at their long axis as viewed on their surface plane. One diamond exhibited raised surface topography coincident with radiation staining, and two had staining accompanying ruts or cracks. In 24% of the diamonds, the rare occurrence of fine negative surface topography coincident with radiation stains was documented. These features were angular to rounded, and some had acicular to tabular habits. The cause of the textural complexity coincident with radiation stains is currently a subject of debate and in some cases may involve localized diamond dissolution in the near-surface environment.

Diamonds residing in placer deposits frequently display distinct patches of green and/or brown coloration due to radiation damage from nearby radioactive minerals or fluids. These zones of color, termed “radiation stains” by gemologists, form from alpha (α) radiation exposure, which damages the crystal structure, creating vacancies and interstitials (Raal and Robinson, 1980; Koptil and Zinchuk, 2000; Breeding et al., 2018) (figure 1). Radiation damage leads to the formation of the GR1 defect (V^0 , ZPL 741 nm), which primarily absorbs light in the red region of the visible spectrum (Clark et al., 1956). In type I diamonds with green bodycolor, absorption in the blue

portion of the visible spectrum is often caused at least in part by nitrogen-related centers (e.g., Collins, 1982; Green et al., 2022). In radiation stains themselves, the stains can appear as green even in the absence of significant nitrogen content. For example, green radiation stains are observed on type II diamonds, even those with blue bodycolor (e.g., figure 15 in Eaton-Magaña et al., 2018).

Green stains can turn brown due to natural or laboratory annealing, or accidental and uncontrolled heat during polishing. This is due to annihilation of the GR1 defect and the depletion of the corresponding red absorption (e.g., Nasdala et al., 2013; Eaton-Magaña and Moe, 2016; Eaton-Magaña et al., 2023).

Green diamonds primarily colored by the GR1 can occur in kimberlites (e.g., Vance et al., 1973), but they are more prevalent in ancient diamondiferous paleoplacer or sedimentary rocks, which can have abundant radioactive minerals such as zircon,

See end of article for About the Authors and Acknowledgments.

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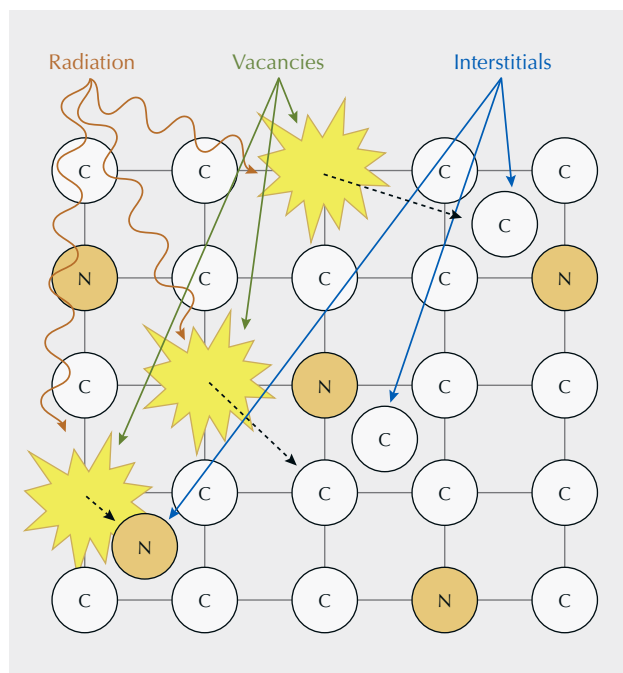


Figure 1. Schematic representation of radiation damage creating vacancies and interstitials (atoms displaced from their positions) within the diamond structure. The circles labeled “C” represent carbon atoms, and the circles labeled “N” represent nitrogen atoms.

monazite, uraninite, and thorinite. They are most commonly found in Brazil, Guyana, Venezuela, Zimbabwe, the Central African Republic, and India (Breeding et al., 2018). One major source of green diamonds, the Roraima Supergroup in South America, is host to ancient diamondiferous sedimentary rocks that are >1.75 billion years old (Santos et al., 2003; Beyer et al., 2015). Prolonged burial provides ample time and opportunity for continuous irradiation (Chaves et al., 2001; Santos et al., 2003; Schulze and Nasdala, 2016).

The type of radiation influences the intensity and depth of green color penetration in the diamond.

In Brief

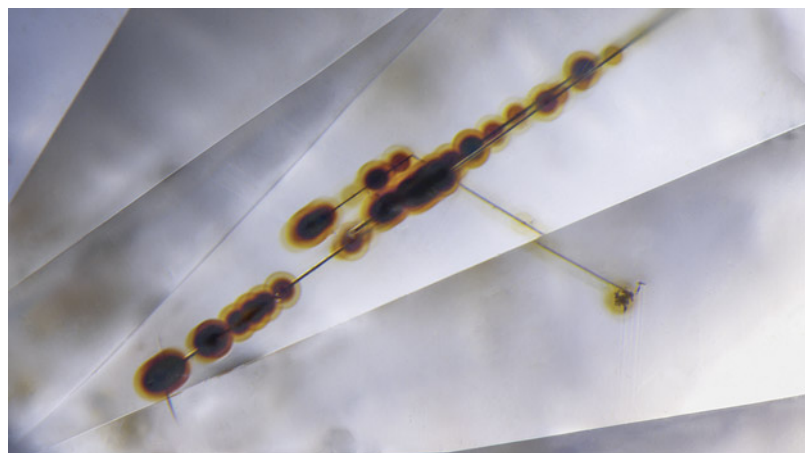
- Radiation stains on diamond can be brown or green and form isolated or nondiscrete shapes.
- Shallow negative surface textures coincident with radiation stains may indicate diamond etching following irradiation in the near-surface environment.
- Radiation stains on diamond can be classified based on color, opacity, shape, and coincident features.

Alpha radiation results in the shallowest penetration, with damage to diamond confined to depths within 25–30 μm (Nasdala et al., 2013; Breeding et al., 2018; Eaton-Magaña et al., 2018). When present, radiation stains are often located on the surface of diamonds and may exhibit strain when viewed in cross-polarized light (Koivula, 2000). They also can occur internally in etch channels (figure 2), or rarely as halos of green color observed around radioactive inclusions (Koivula, 2000).

Naturally green diamonds are of particular interest to the trade due to their value and rarity. Fancy-color diamonds are uncommon, with those having natural green, blue, or pink/red color components accounting for about 0.4% of all diamonds submitted to GIA (Breeding et al., 2018).

During manufacturing, diamond polishers can preserve natural green radiation stains on the girdle or pavilion to allow perceived green color through the table, thereby adding value to an otherwise colorless diamond (Koivula, 2000; Breeding et al., 2018). Documenting the characteristics of natural green diamonds, especially those of known provenance, provides a baseline for future comparison with diamonds irradiated in a laboratory setting. In this study, photomicrography of natural diamonds permits the development of a radiation stain classification scheme based on observations of green and/or brown radiation stain morphology and associated textures for use in the gem trade.

Figure 2. This faceted diamond with etch channels shows a number of radiation stain halos resulting from shallow alpha radiation that extend along its length. The etch channels and radiation stains on the original natural surface were retained after faceting. Photomicrograph by Nathan Renfro; field of view 1.03 mm.



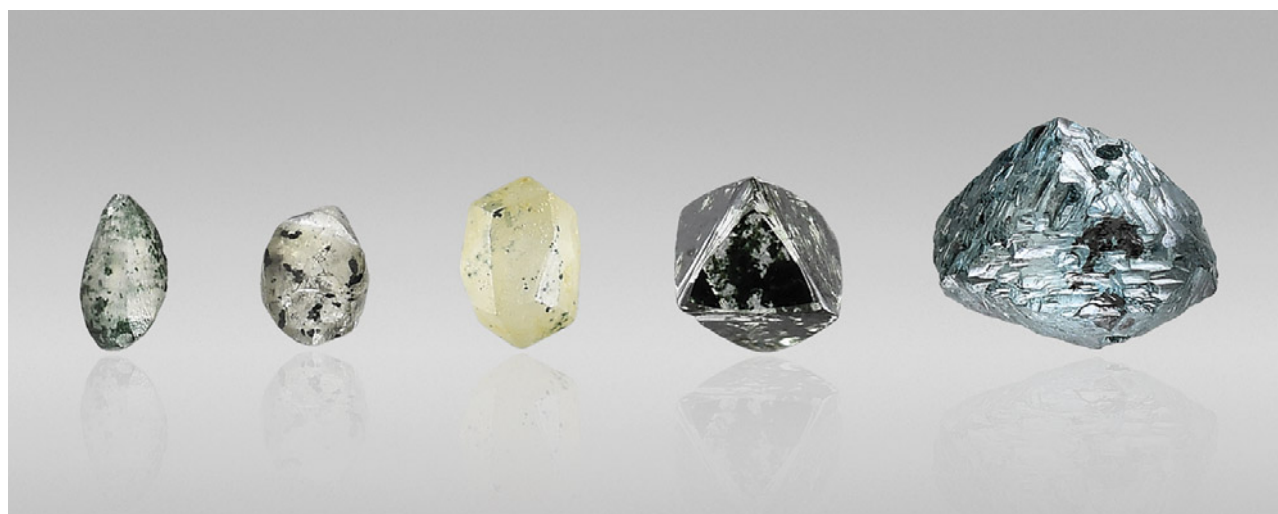


Figure 3. Five rough diamonds from this study of various colors and habits, displaying natural radiation staining. These samples originate from Guyana except for the second from the right, which is reportedly from Venezuela. Carat weights from left to right are 0.01 ct (Guy304), 0.04 ct (Guy572), 0.06 ct (Guy712), 0.11 ct (GV001), and 0.23 ct (Mus17586). Photos by Diego Sanchez.

MATERIALS AND METHODS

Sample Descriptions. A representative sample set of 84 diamonds displaying green and/or brown radiation stains was curated at GIA (figure 3 and table 1). This sample suite consisted of 65 natural rough diamonds collected from the field in Guyana by author RB (see Bassoo et al., 2021), 4 rough diamonds reportedly from Venezuela, 1 rough diamond reportedly from Namibia, and 14 diamonds of unknown provenance. Among the samples of unknown provenance, two were faceted stones submitted to GIA that maintained some natural surfaces and whose color was deemed natural. The samples ranged in size from <0.05 to 1.96 ct (table 1).

The sample set is largely represented by stones from Guyana. However, green diamonds are exceptionally rare globally and Guyana represents one of the few locations where green diamonds are prevalent (Breeding et al., 2018). These are sourced from the Roraima Supergroup, in which diamonds of Guyana, Venezuela, and northern Brazil have resided (Draper, 1951; Santos et al., 2003; Reis et al., 2017). While this dataset serves as a representative example of green diamonds residing in ancient sedimentary rocks of the Roraima Supergroup (Bassoo et al., 2021), expanding the dataset to include more localities where naturally irradiated diamonds are prevalent, such as Zimbabwe or the Central African Republic, will augment this study (e.g., Moore et al., 2009; Smit et al., 2018).

Methods. Radiation stains were imaged in both transmitted and reflected light using a Nikon Eclipse LV100

photomicroscope with 20× (field of view 0.72 mm), 50× (field of view 0.288 mm), and/or 100× (field of view 0.144 mm) objectives. Episcopic or reflected light differential interference contrast (DIC) microscopy was used to increase contrast (Renfro, 2015). A z-stage focus stacking technique was used in which images were stacked together at different focal depths, depending on the flatness of the stone. Step sizes for the 20×, 50×, and 100× objectives were typically 2.5, 0.8, and 0.6 μm, respectively. Stains were cataloged based on notable features, and diameters of rounded stains were measured. Faces of the stones were also imaged to measure the pixel area covered by green and/or brown stains. Four diamonds were imaged at Baylor University in Texas using atomic force microscopy (AFM) with a Bruker Dimension Icon AFM in peak force mode to record and analyze fine surface textures coincident with radiation stains. This technique (box A) precisely measures surface features at a resolution of ~0.1 nm in the Z direction, provided the surface is relatively flat (e.g., Ruiz-Agudo et al., 2009; Fedortchouk, 2019). Depth measurements were compared to a mica specimen, which has a flat and uniform surface with a lateral particle size of less than 5 nm (Ostendorf et al., 2008). The resultant dataset is a micrometer-sized topographic map of a diamond surface. This study defines surface textures coincident with radiation stains as a textural indication of the radiation stains' presence when examining the surface of the rough stone under reflected light, or the presence of features such as cracks and/or ruts in the diamond to which stains are clearly conforming.

TABLE 1. Summary characteristics of radiation stains.

Sample no.	Weight (ct)	Locality	Coincident feature group ^{a,b}	Shape classification ^b	Radiation stain color	Green surface area per face (%)	Brown surface area per face (%)	Comments on coincident features ^b
Guy012	0.04	Guyana	Group 1	Regular isolated	Green	0.1	—	—
Guy022	0.03	Guyana	Group 1	Regular nondiscrete	Green	0.2	—	—
Guy023	0.03	Guyana	Group 1	Regular nondiscrete	Green	21.2	—	—
Guy078	0.03	Guyana	Group 1	Regular isolated and irregular nondiscrete	Green	12.5	—	—
Guy083	0.01	Guyana	Group 1	Regular nondiscrete and irregular nondiscrete	Green	11.0	—	—
Guy149	0.03	Guyana	Group 1	Regular isolated	Green	6.2	—	—
Guy162	0.02	Guyana	Group 1	Regular isolated and regular nondiscrete	Green	14.8	—	—
Guy186	0.01	Guyana	Group 1	Regular isolated	Green	1.8	—	—
Guy196	0.02	Guyana	Group 1	Irregular isolated	Green	5.6	—	—
Guy197	0.04	Guyana	Group 1	Regular nondiscrete and irregular nondiscrete	Green	8.3	—	—
Guy216	0.04	Guyana	Group 1	Regular isolated and regular nondiscrete	Green	2.6	—	—
Guy221	—	Guyana	Group 1	Irregular isolated	Green	3.0	—	—
Guy231	0.12	Guyana	Group 4	Irregular nondiscrete	Green	26.1	—	Acicular to tabular depressions
Guy239	0.05	Guyana	Group 1	Regular isolated	Green	1.3	—	—
Guy241	0.13	Guyana	Group 1	Regular nondiscrete	Green	2.6	—	—
Guy248	0.06	Guyana	Group 4	Regular nondiscrete and irregular nondiscrete	Green	5.1	—	Subhedral to rounded depressions
Guy264	0.04	Guyana	Group 1	Regular isolated and irregular isolated	Green	1.8	—	—
Guy279	0.10	Guyana	Group 1	Irregular isolated	Green	3.6	—	—
Guy285	0.03	Guyana	Group 1	Irregular nondiscrete	Green	20.6	—	—
Guy304	0.01	Guyana	Group 1	Regular nondiscrete and irregular nondiscrete	Green	21.4	—	—
Guy330	0.04	Guyana	Group 2	Irregular isolated	Green	1.0	—	—

^aGroups are defined as no coincident surface texture (group 1); rut, crack, or inclusion (group 2); smooth expanded surface (group 3); and surface roughness, acicular, tabular, and other (group 4).

^bObserved from the region photomicrographed.

TABLE 1 (continued). Summary characteristics of radiation stains.

Sample no.	Weight (ct)	Locality	Coincident feature group ^{a,b}	Shape classification ^b	Radiation stain color	Green surface area per face (%)	Brown surface area per face (%)	Comments on coincident features ^b
Guy386	0.03	Guyana	Group 1	Regular nondiscrete	Green	0.9	—	—
Guy404	0.13	Guyana	Group 1	Regular isolated	Green	1.4	—	—
Guy504	0.02	Guyana	Group 1	Regular isolated	Green	4.0	—	—
Guy517	0.04	Guyana	Group 1	Regular isolated	Green	1.5	—	—
Guy533	—	Guyana	Group 1	Regular isolated	Green	0.8	—	—
Guy536	0.02	Guyana	Group 1	Irregular nondiscrete	Green	3.8	—	—
Guy551	—	Guyana	Group 1	Regular nondiscrete and irregular nondiscrete	Green	5.4	—	—
Guy562	0.02	Guyana	Group 1	Irregular isolated	Green	5.4	—	—
Guy563	—	Guyana	Group 1	Regular isolated	Green	4.1	—	—
Guy571	0.02	Guyana	Group 1	Regular nondiscrete	Green	8.1	—	—
Guy572	0.04	Guyana	Group 4	Irregular nondiscrete	Green	11.0	—	Subhedral to rounded depressions
Guy593	<0.01	Guyana	Group 1	Regular isolated	Green	4.7	—	—
Guy607	0.02	Guyana	Group 4	Irregular nondiscrete	Green	28.1	—	Fine surface roughness
Guy620	0.01	Guyana	Group 1	Irregular isolated	Green	1.9	—	—
Guy632	0.01	Guyana	Group 1	Regular isolated	Green	1.1	—	—
Guy636	0.01	Guyana	Group 1	Regular isolated	Green	13.5	—	—
Guy651	0.03	Guyana	Group 1	Irregular nondiscrete	Green	22.6	—	—
Guy662	—	Guyana	Group 1	Regular isolated and irregular isolated	Green	3.7	—	—
Guy672	0.05	Guyana	Group 1	Regular isolated	Green	0.3	—	—
Guy678	0.02	Guyana	Group 1	Regular isolated	Green	0.3	—	—
Guy709	0.01	Guyana	Group 1	Regular isolated and irregular isolated	Green	0.2	—	—

^aGroups are defined as no coincident surface texture (group 1); rut, crack, or inclusion (group 2); smooth expanded surface (group 3); and surface roughness, acicular, tabular, and other (group 4).

^bObserved from the region photomicrographed.

TABLE 1 (continued). Summary characteristics of radiation stains.

Sample no.	Weight (ct)	Locality	Coincident feature group ^{a,b}	Shape classification ^b	Radiation stain color	Green surface area per face (%)	Brown surface area per face (%)	Comments on coincident features ^b
Guy710	0.01	Guyana	Group 1	Regular nondiscrete and irregular nondiscrete	Green	3.4	—	—
Guy711	—	Guyana	Group 1	Regular isolated	Green	2.0	—	—
Guy712	0.06	Guyana	Group 1	Regular isolated, regular nondiscrete, and irregular nondiscrete	Green	4.4	—	—
Guy713	0.03	Guyana	Group 1	Regular isolated	Green	17.0	—	—
Guy714	0.03	Guyana	Group 1	Regular isolated	Green	0.2	—	—
Guy715	0.01	Guyana	Group 1	Irregular nondiscrete	Green	16.4	—	—
Guy717	0.07	Guyana	Group 1	Regular isolated	Green	0.8	—	—
Mus17586	0.23	Guyana	Group 1	Irregular nondiscrete	Green	8.3	—	—
JK001	0.16	Namibia	Group 3	Regular isolated	Green	0.9	—	—
2845	0.97	Unknown	Group 4	Irregular nondiscrete	Green	—	—	Acicular to tabular depressions
3810	0.06	Unknown	Group 4	Regular nondiscrete and irregular nondiscrete	Green	93.4	—	Fine surface roughness
3825	0.05	Unknown	Group 1	Irregular nondiscrete	Green	11.3	—	—
3842	0.03	Unknown	Group 1	Irregular nondiscrete	Green	25.6	—	—
9018	1.96	Unknown	Group 2	Irregular nondiscrete	Green	—	—	—
GS-7	0.09	Unknown	Group 4	Irregular nondiscrete	Green	31.0	—	Subhedral to rounded depressions
GS-9	0.12	Unknown	Group 4	Regular nondiscrete and irregular nondiscrete	Green	18.0	—	Fine surface roughness
Mus12308	0.10	Unknown	Group 4	Regular isolated and irregular nondiscrete	Green	21.2	—	Fine surface roughness
Mus24646	0.02	Unknown	Group 1	Irregular nondiscrete	Green	31.1	—	—
Mus31608	0.17	Unknown	Group 4	Regular nondiscrete and irregular nondiscrete	Green	1.2	—	Subhedral to rounded depressions
RH001	0.04	Unknown	Group 4	Regular nondiscrete	Green	19.1	—	Subhedral to rounded depressions
RH002	0.05	Unknown	Group 4	Irregular nondiscrete	Green	23.7	—	Subhedral to rounded depressions

^aGroups are defined as no coincident surface texture (group 1); rut, crack, or inclusion (group 2); smooth expanded surface (group 3); and surface roughness, acicular, tabular, and other (group 4).

^bObserved from the region photomicrographed.

TABLE 1 (continued). Summary characteristics of radiation stains.

Sample no.	Weight (ct)	Locality	Coincident feature group ^{a,b}	Shape classification ^b	Radiation stain color	Green surface area per face (%)	Brown surface area per face (%)	Comments on coincident features ^b
SM001	0.03	Unknown	Group 1	Irregular nondiscrete	Green	28.6	—	—
GV001	0.11	Venezuela (Guaniamo area)	Group 4	Irregular nondiscrete	Green	35.1	—	Acicular to tabular depressions
GV002	0.06	Venezuela (Guaniamo area)	Group 4	Regular isolated and irregular nondiscrete	Green	15.1	—	Fine surface roughness
GV003	0.05	Venezuela (Guaniamo area)	Group 4	Irregular isolated	Green	8.3	—	Acicular to tabular depressions
GV004	0.02	Venezuela (Guaniamo area)	Group 4	Regular isolated and irregular isolated	Green	10.5	—	Etched surface
Guy515	0.03	Guyana	Group 4	Irregular nondiscrete	Brown	—	7.9	Surface roughness
Guy529	0.02	Guyana	Group 1	Irregular nondiscrete	Brown	—	12.1	—
Guy553	0.04	Guyana	Group 1	Regular isolated	Brown	—	1.5	—
Guy046	0.02	Guyana	Group 1	Regular nondiscrete	Green and brown	4.3	<0.1	—
Guy099	0.03	Guyana	Group 1	Irregular isolated	Green and brown	1.9	0.2	—
Guy120	0.02	Guyana	Group 1	Regular nondiscrete	Green and brown	0.8	<0.1	—
Guy126	0.03	Guyana	Group 1	Regular nondiscrete	Green and brown	1.0	0.3	—
Guy156	0.05	Guyana	Group 4	Regular isolated and irregular isolated	Green and brown	2.9	<0.1	Fine surface roughness
Guy501	0.01	Guyana	Group 1	Regular isolated	Green and brown	1.0	<0.1	—
Guy503	0.01	Guyana	Group 1	Regular nondiscrete	Green and brown	0.5	0.5	—
Guy516	0.02	Guyana	Group 1	Regular isolated	Green and brown	0.5	0.3	—
Guy622	0.03	Guyana	Group 4	Regular isolated, regular nondiscrete, and irregular nondiscrete	Green and brown	7.2	1.5	Acicular to tabular and subhedral to rounded depressions
Guy631	0.03	Guyana	Group 1	Regular isolated	Green and brown	0.4	3.7	—
Guy708	0.05	Guyana	Group 1	Irregular nondiscrete	Green and brown	7.0	6.4	—
Guy716	0.02	Guyana	Group 1	Regular nondiscrete and irregular nondiscrete	Green and brown	7.9	0.2	—
7682	1.86	Unknown	Group 4	Regular isolated and regular nondiscrete	Green and brown	42.4	<0.1	Subhedral to rounded depressions

^aGroups are defined as no coincident surface texture (group 1); rut, crack, or inclusion (group 2); smooth expanded surface (group 3); and surface roughness, acicular, tabular, and other (group 4).

^bObserved from the region photomicrographed.

Box A: Atomic Force Microscopy

Atomic force microscopy (AFM) is a micro-imaging technique that uses a sharp tip to move across a surface, recording the topography and elevation differences in the Z direction as it scans across the surface in the X and Y directions. The tip is typically made of silicon or silicon nitride and is reusable due to its relative hardness. The tip is attached to an optical lever or cantilever, which is in the optical path of a laser and photodetector. When the cantilever moves across the surface, it bends up and down, and a laser reflects from the back of the cantilever onto a photodetector with each motion of the cantilever (figure A-1). The angular motion of the cantilever causes the recorded position of the laser to change accordingly. In “peak force tapping mode” devices, the cantilever oscillates within 0.1–10 nm of the sample surface and never makes contact. Instead, forces repel the tip when in close proximity to the surface. These configurations significantly reduce tip and sample surface damage. A piezoelectric scanner measures and monitors the X, Y, and Z directions as the cantilever moves according to instrument-appropriate and preselected maximums to prevent any damage from occurring. The position data is recorded across the surface of a material. The signals are turned into a 3D image of the surface (e.g., Eaton and West, 2010; figure A-2). Cross-sectional profiles of topography across different regions of the 3D maps can be drawn (figure A-2) and numerical data for heights and depths recorded.

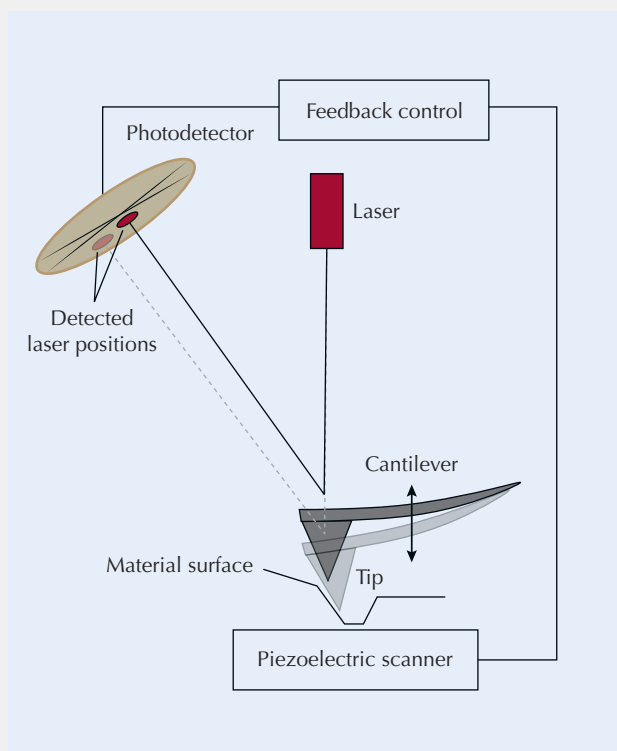


Figure A-1. Schematic demonstrating the basic principle of atomic force microscopy.

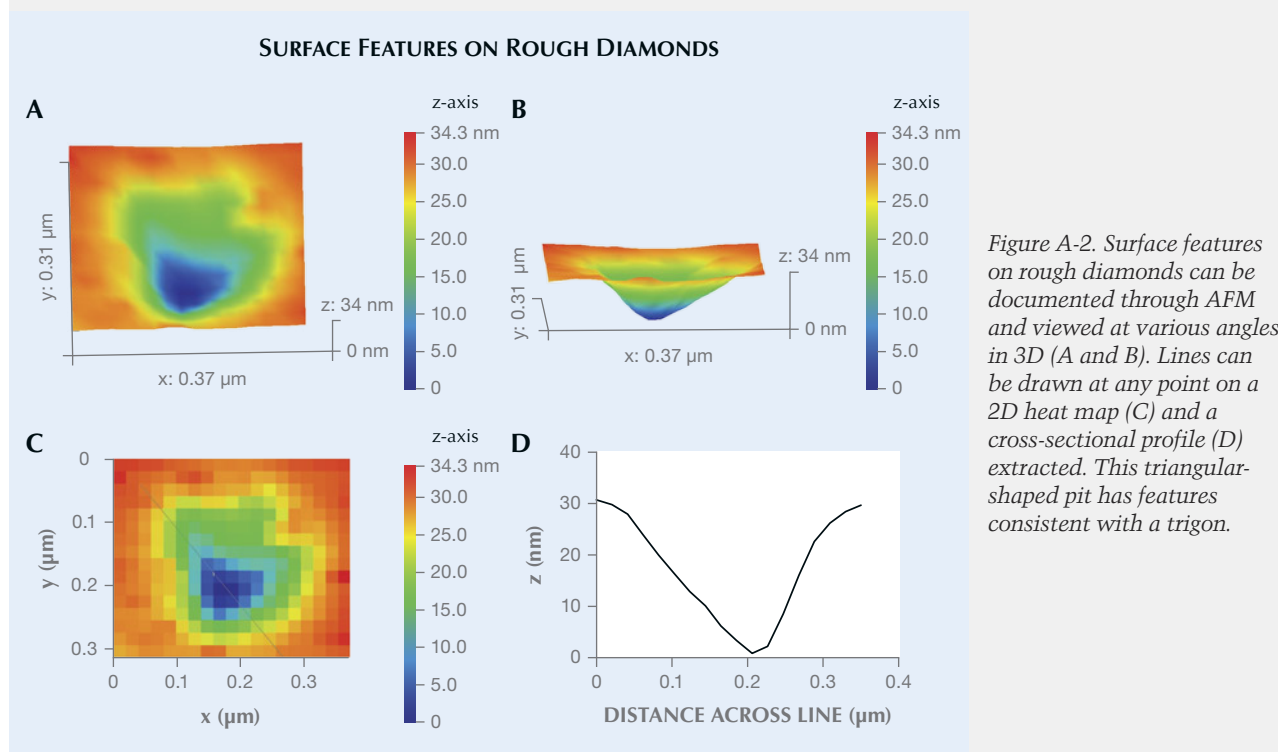


Figure A-2. Surface features on rough diamonds can be documented through AFM and viewed at various angles in 3D (A and B). Lines can be drawn at any point on a 2D heat map (C) and a cross-sectional profile (D) extracted. This triangular-shaped pit has features consistent with a trigon.

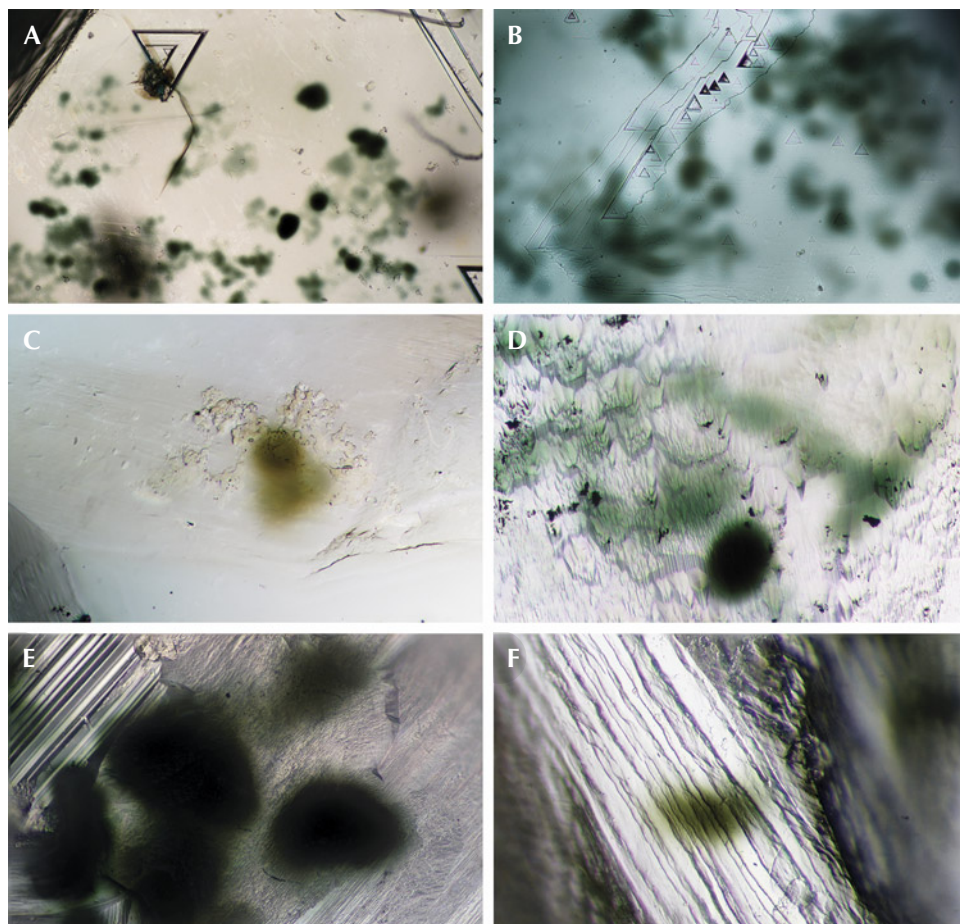


Figure 4. Radiation stains on surfaces of rough diamonds from Guyana, displaying variability in shape, hue, size, and opacity. Photomicrographs by Taryn Linzmeyer; fields of view 1.44 mm (A), 0.72 mm (B), and 0.288 mm (C–F).

RESULTS

Radiation stains in the samples varied in color, morphology, and texture (figure 4), with some inter-stain variability within the same stone. Variations in opacity, color, dominant shape, and coincident surface textures found in natural radiation stains on diamonds were documented as observed through photomicrography. Preliminary AFM measurements of negative surface textures coincident with radiation stains are also presented. These features have rarely been documented (Mendelssohn, 1971; Eaton-Magaña and Moe, 2016; Bassoo, 2022) and to our knowledge have never been documented by AFM in published literature.

Color and Opacity. Most of the diamonds contained only green radiation stains, accounting for 81% of the samples in this study. Solely brown radiation stains were observed on about 3.5% of the diamonds, and brown and green radiation stains occurred together in 15.5% of the samples. Green radiation stains covered

<1–93% of a diamond's total surface area, with most in the range of <1–25%. Brown radiation stains in this study covered <1% to up to 12% of a diamond's surface area. Diamonds from other localities such as Zimbabwe often have brown radiation stains over a larger proportion of their surface area (Smit et al., 2018). Opacity ranges from opaque to translucent.

Shape and Size. About 42% of the diamonds displayed radiation stains that were exclusively circular to oval in shape in the field of view. Circular radiation stains ranged in diameter from 22 to 77 μm , with a median of $34 \pm 5 \mu\text{m}$ (figure 5; see appendix 1 at <https://www.gia.edu/gems-gemology/spring-2026-radiation-stains>). (Uncertainties are reported to one median absolute deviation, or MAD.) Oval radiation stains ranged in long-axis diameter from ~36 to 158 μm with a median of $68 \pm 18 \mu\text{m}$, whereas the short-axis diameter ranged from 25 to 104 μm , with a median of $42 \pm 6 \mu\text{m}$ (figure 5; see appendix 1). Solely irregularly shaped radiation stains occurred in about 33% of the

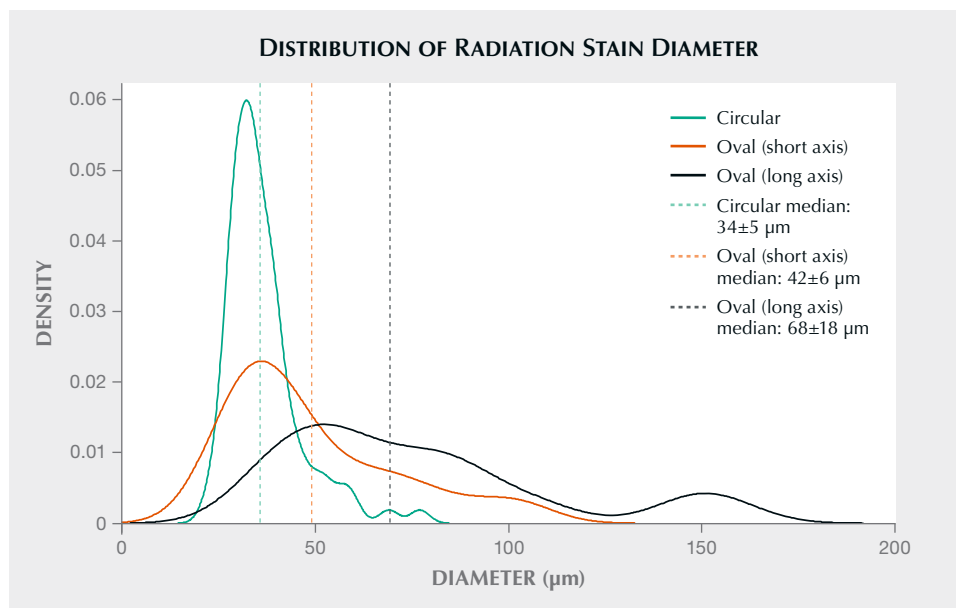


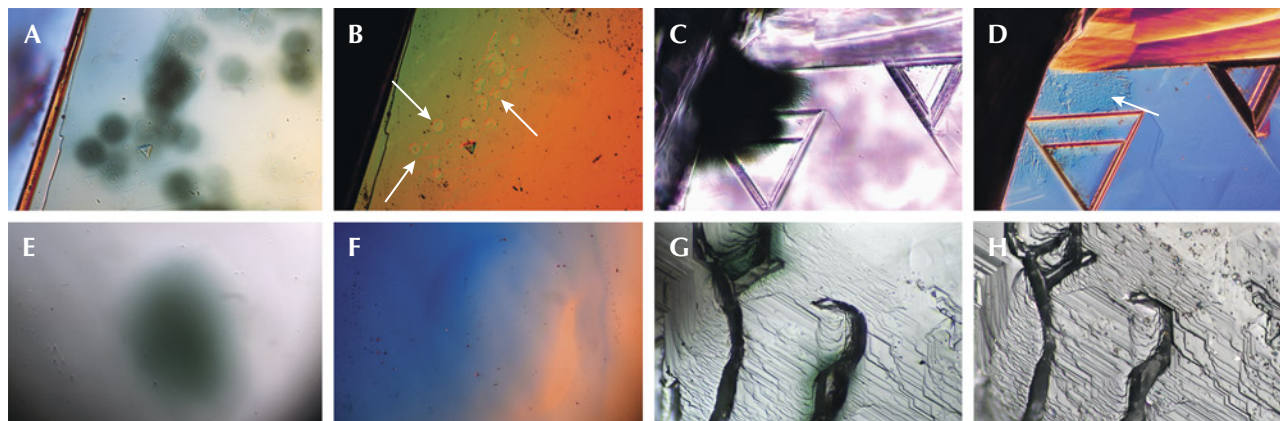
Figure 5. Kernel density estimate (KDE) plot of the diameter of circular radiation stains and the major and minor axes of oval radiation stains. KDE is similar to a histogram, but it is a method of plotting that is independent of arbitrary “bins.”

diamonds, whereas about 24% of the samples displayed both regular and irregular radiation stains. Irregularly shaped radiation stains occurred as large lobate or mesh-worked patches of green color, or they corresponded with agglomerations of individual circular or oval radiation stains connected by translucent or diffuse “halos.”

Underlying Surface Features Coincident with Radiation Stains. Approximately 73% of the diamonds examined in this study showed no obvious surface

textures coincident with the radiation stains imaged. Underlying surface textures coincident with radiation stains included ruts, cracks, expanded rounded surfaces, and fine surface irregularities (figure 6). Diamonds with ruts or cracks corresponding with radiation stains accounted for 2% of the samples. The sole diamond from Namibia had smooth positive relief coincident with the radiation stain (figure 6, E and F). In samples Guy572 and Guy515, surface roughness corresponded with the most opaque regions of the radiation stains and did not extend all the way

Figure 6. Underlying surface textures coincident with radiation stains. Samples RH001 (A and B), GV003 (C and D), JK001 (E and F), and Guy330 (G and H) are shown. A–D display etching coincident with radiation stains. Surface textures in B and D are noted by arrows. E and F show positive relief at the site of a radiation stain on a Namibian diamond. G and H show radiation stains coincident with ruts at the surface of the diamond. These are imaged in transmitted light (A, C, E, and G) along with the corresponding false-color DIC images (B, D, F, and H). Image B's brightness and contrast were adjusted to increase visibility of the topography. Photomicrographs by Taryn Linzmeyer; fields of view 0.144 mm (A and B), 0.451 mm (C and D), and 0.288 mm (E–H).



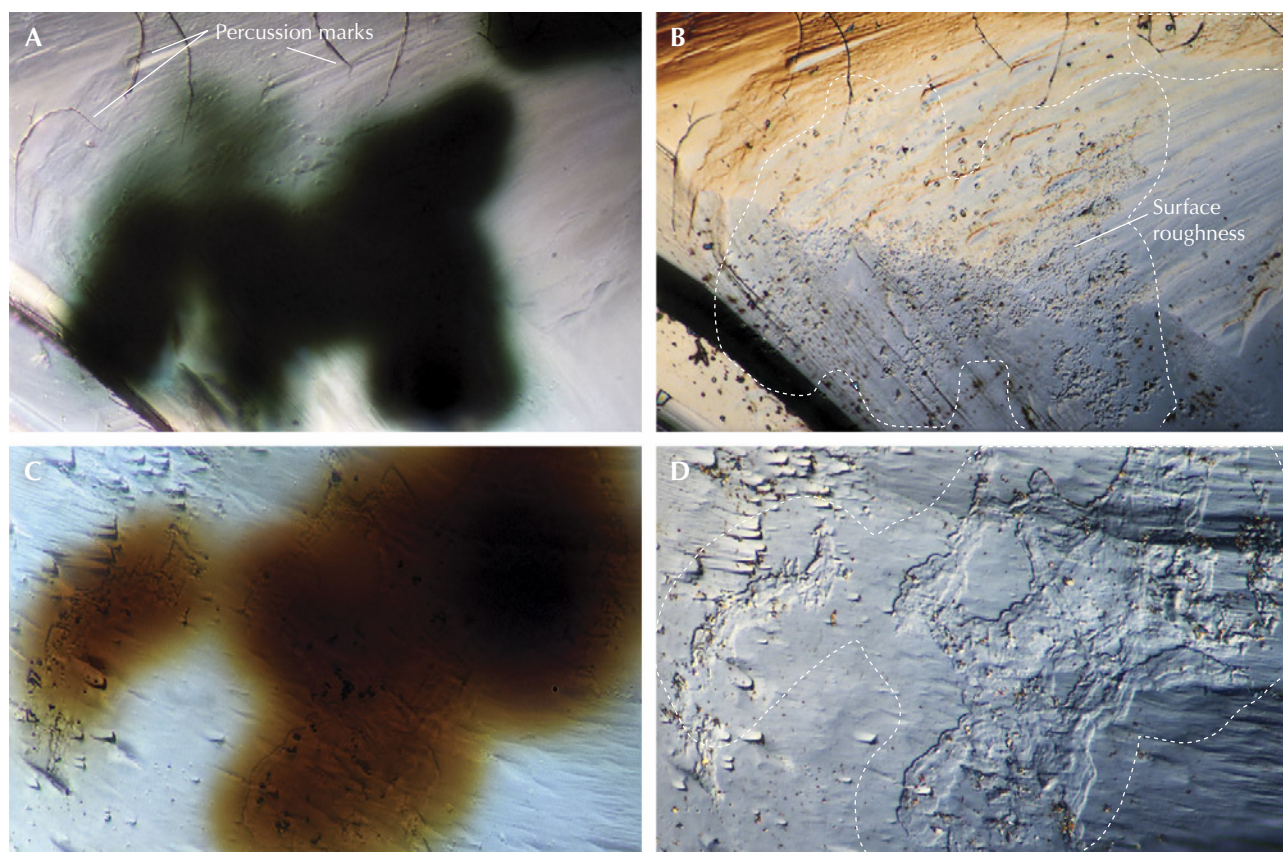


Figure 7. Samples Guy572 (A and B, field of view 0.288 mm) and Guy515 (C and D, field of view 0.144 mm) display surface textures coincident with green (A) and brown (C) radiation staining. The surface roughness in B contains rounded pits. Percussion marks labeled in A are abrasion and transport features typically associated with placer diamonds such as these. Reflected light images were taken using white-balanced DIC settings to increase shadow contrast. Photomicrographs by Taryn Linzmeyer.

to the margins (figure 7). For example, Guy515's surface roughness extended to a maximum distance of $\sim 18\ \mu\text{m}$ from the diffuse margin of the radiation stain edge. In all, 24% of the diamonds had either fine irregular surface roughness coincident with radiation stains or fine acicular (figure 8, opposite page), tabular, or rounded (figure 9) surface textures coincident with radiation stains. Preliminary AFM measurements ver-

ified that these were negative surface features penetrating into the surface of the diamond.

DISCUSSION

Color. The radiation stains in this study were green or brown. Pink radiation stains do occur, but they are extremely rare and to our knowledge have only been reported in two diamonds (Breeding et al., 2022).

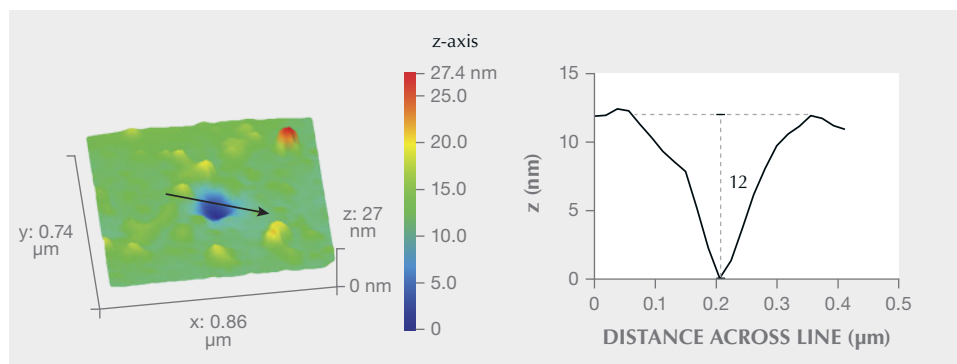


Figure 9. AFM data of etch pits collected on a radiation stain on Guy622. The location and direction in which the cross-sectional profile was drawn is labeled by a black arrow on the left.

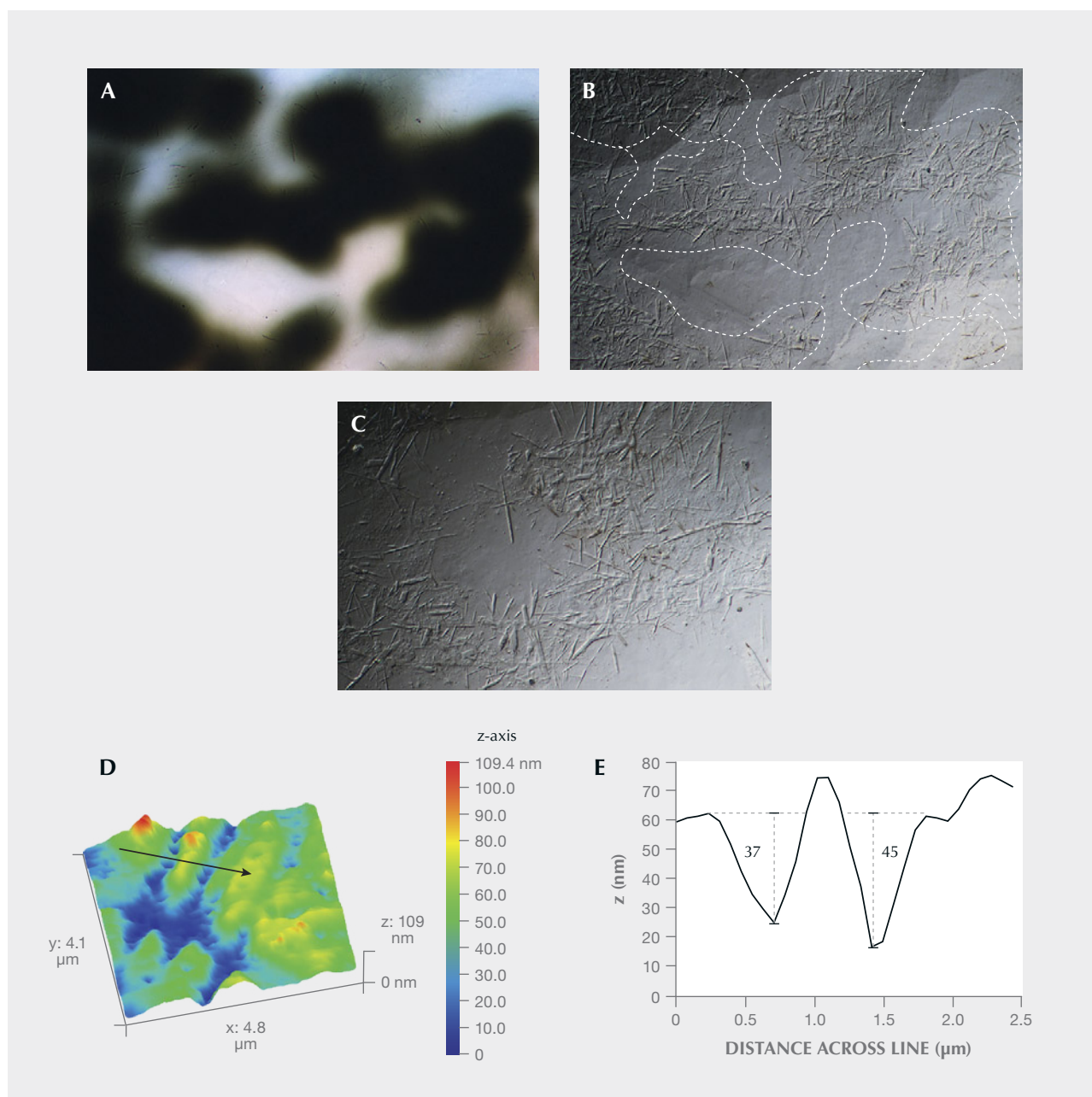


Figure 8. Sample Guy231, photographed in transmitted light (A) and white-balanced DIC (B), displays acicular etching coincident with radiation staining; field of view 0.288 mm. The DIC region using 100 $\times$ magnification is shown in C; field of view 0.144 mm. Photomicrographs by Taryn Linzmeyer. AFM data was also collected on this sample, displaying the depth of some acicular etches coincident with the stain as a 3D diagram (D) and as a cross-sectional profile (E). The location and direction of the cross-sectional profile is labeled by a black arrow in D.

Radiation stains may vary in opacity between stains on the same diamond or even within the same stain. Variations in opacity within the same stain can occur in the form of radiation “halos,” which may appear as translucent rims surrounding more opaque cores. The separation between opaque cores and translucent rims can be diffuse or have sharp boundaries (again, see

figure 2). The exact mechanism causing this variation in opacity is unknown, and the following theories are speculative.

In large areas of opaque radiation staining, this may indicate a radioactive grain in direct contact with the surface of the diamond, with alpha radiation penetrating farther as a halo. Variable opacities and

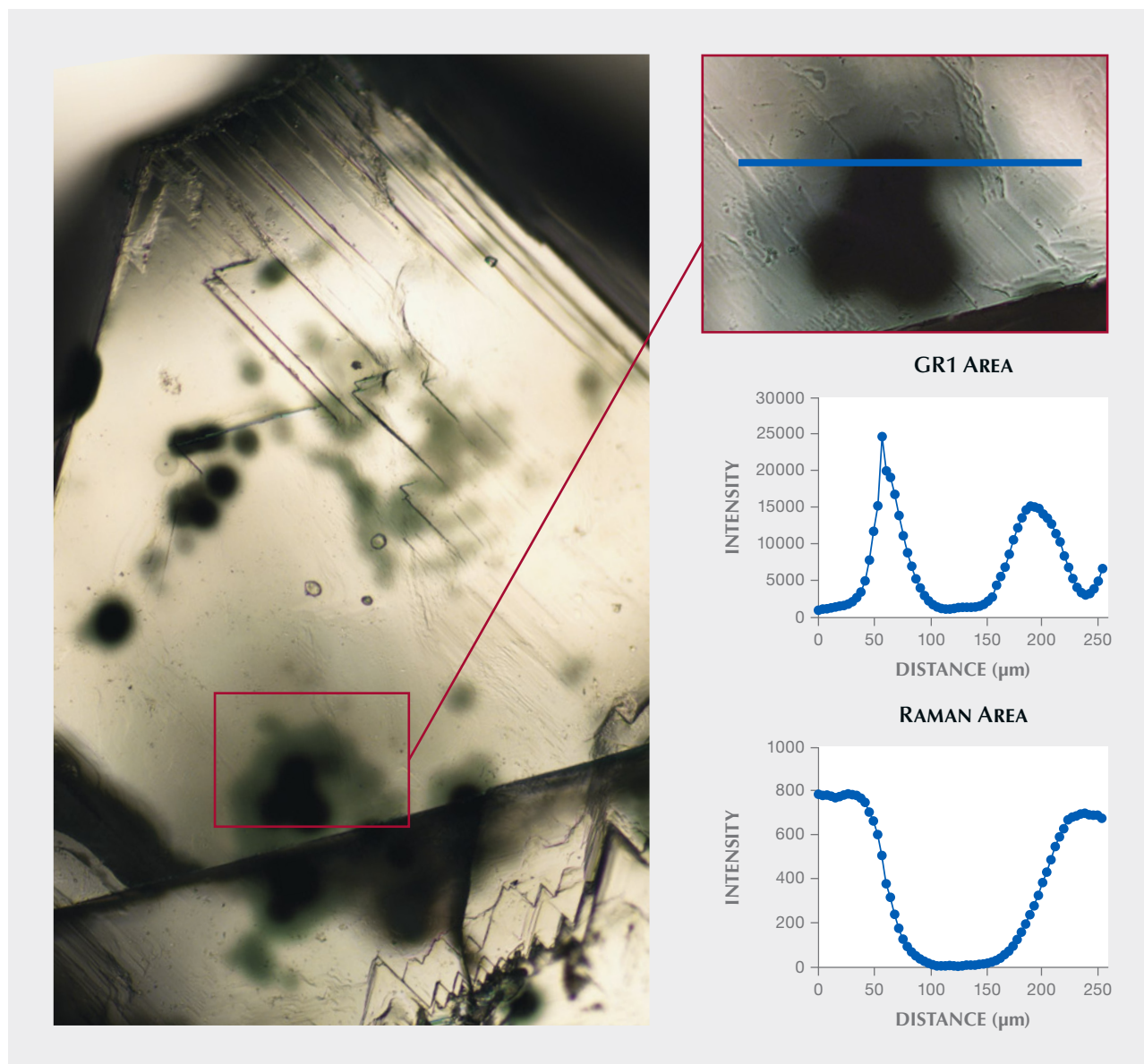


Figure 10. Left: Radiation stains displaying both opaque and translucent staining are shown in Guy651. Photomicrograph by Taryn Linzmeyer; field of view 0.70 mm. Right: Using 633 nm laser excitation, PL spectra were collected at liquid nitrogen temperature along a line transecting “clean” diamond surfaces, translucent radiation staining, and opaque radiation staining (blue line, top right). The pixel size for each spectrum was 3.8 μm. The map was split into a horizontal transect. There are 204 spectra plotted in each of these graphs, with three spectra averaged for each point in the y direction. The intensity of the GR1 is highest in regions of translucent staining and falls off in the opaque regions, despite these regions being intensely irradiated. This is consistent with the intense damage to the diamond structure resulting in a weaker Raman response, as shown in the decrease of the diamond Raman peak at 691 nm.

saturations of green color may be related to variable exposure time and/or concentrations of radioactive minerals (Nasdala et al., 2013; Vasilev et al., 2018). For example, evidence of greater damage to the diamond structure in areas of opaque staining was ob-

served using photoluminescence (PL) mapping of an opaque stain with a translucent halo (figure 10). GR1 peak areas increased in translucent radiation staining compared to a “clean” diamond surface but decreased significantly in the area of opaque staining.

BOX B: RADIATION DAMAGE EXTENDING BELOW THE SURFACE OF A DIAMOND

Damage to the diamond structure due to alpha particle radiation also extends below the surface. Previous studies used the peak area of the diamond Raman band as a proxy for the extent of damage, with decreasing peak areas and a sharpening peak shape into the stone signifying a transition from amorphous carbon to undamaged diamond

(Eaton-Magaña and Moe, 2016). Distortion of the diamond Raman band (1332 cm^{-1}) and other peaks is observed within radiation stains (figure B-1). This supports the premise that alpha radiation may damage the diamond structure to $\sim 25\text{--}30\text{ }\mu\text{m}$ below the surface following irradiation (Eaton-Magaña and Moe, 2016).

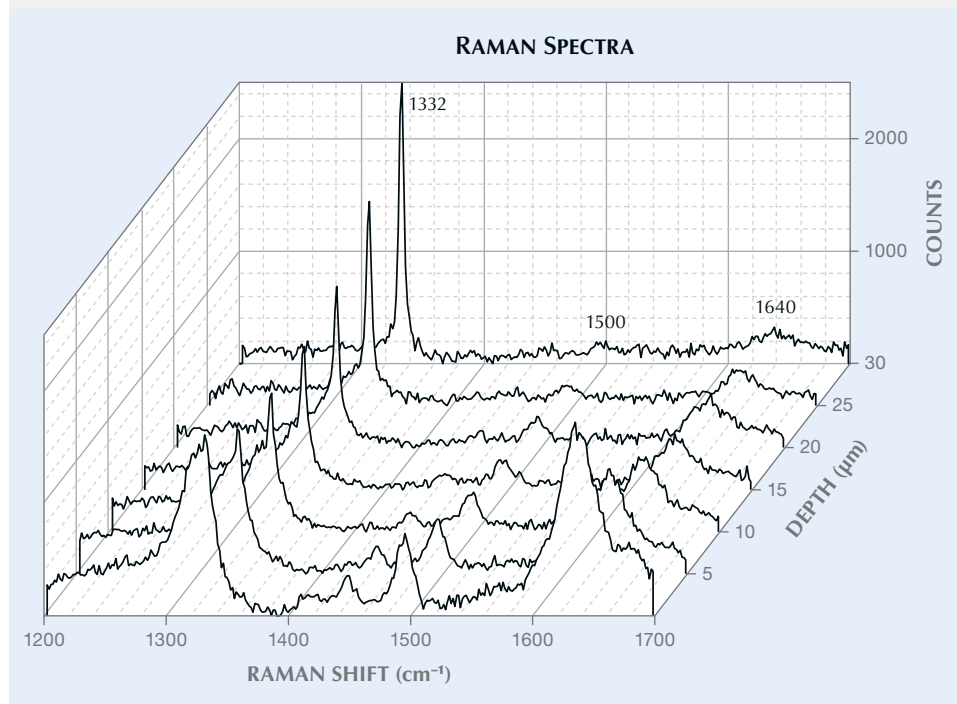


Figure B-1. Raman spectra as a function of depth into a diamond from the surface. This shows how the diamond Raman band at 1332 cm^{-1} (with 514 nm excitation) changes with depth starting at the surface of a heavily irradiated stain. At the surface, the diamond Raman band becomes broader and includes extra peaks consistent with altered carbon states. Adapted from Eaton-Magaña and Moe (2016).

This is due to the extreme damage to the diamond structure, as evidenced by the much lower Raman signal (box B).

Another factor that may affect the opacity of the stain is the separation distance through which the alpha particle travels. For example, a greater separation distance would permit fewer alpha particles to reach a diamond's surface and create the vacancies leading to green color.

In some cases, both green and brown radiation stains are found adjacent to each other on the same diamond (figure 11). The transition from green to brown radiation stains indicates exposure to annealing temperatures of $550\text{--}600^\circ\text{C}$ for short periods or, more likely, at lower annealing temperatures over geologic timescales (Vance et al., 1973; Koivula, 2000; Eaton-Magaña and Moe, 2016; Breeding et al., 2018;

Eaton-Magaña et al., 2023). These stains of different colors sometimes connect, indicating shifting of the diamond relative to the radioactive source and subsequent re-irradiation (e.g., Schulze and Nasdala, 2016).

Shape. Radiation stains on diamond surfaces can occur on all faces, which suggests that diamonds can be irradiated from external point sources from various directions (Schulze and Nasdala, 2016). When alpha particles bombard a diamond surface, they dislodge a collection of carbon atoms that cascade outward and away from the initial point of impact to simultaneously create vacancies and interstitials (Raal and Robinson, 1980; Koptil and Zinchuk, 2000; Breeding et al., 2018). In this study, many instances of circular radiation stains were observed. The diameter of this circle may be related to the maximum

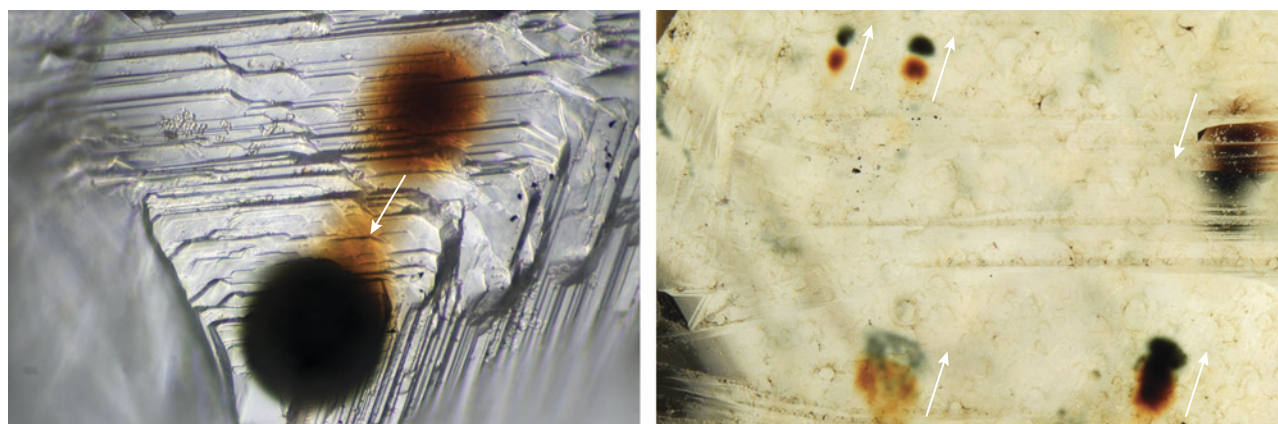


Figure 11. Photomicrographs of radiation stains demonstrating shifting. Left: Green and brown radiation staining on a rough diamond from Guyana (Guy503). The similar size and shape of the round radiation stains, as well as the diffuse staining connecting the two more opaque centers, indicates that this diamond either experienced heating and subsequent cooling before the deposition of the newer green radiation stain or was subjected to different irradiation events over time (e.g., Vance et al., 1973; Raal and Robinson, 1980). The direction that the irradiated region changed over time is indicated by an arrow, from older to newer staining. Photomicrograph by Taryn Linzmeyer; field of view 0.288 mm. Right: Multiple stages of shifting are indicated by the two directions of displacement of the older brown and younger green stains (upward-pointing arrows indicate stains on the top surface of the diamond, and the downward-pointing arrow indicates a view through the diamond to radiation stains located on the bottom surface). Photomicrograph by Sally Eaton-Magaña; field of view 3 mm. Modified from Ardon and Eaton-Magaña (2020).

lateral dispersal of vacancies and interstitials created during alpha particle irradiation. From the surface plane, the circular radiation stains documented in the samples ranged in diameter from 22 to 77 μm .

Oval- and elongate-shaped radiation stains may indicate alpha radiation coinciding with either slight movement of the diamond relative to the radioactive mineral or a radioactive mineral with a non-spherical shape, causing the area of irradiation to present as slightly elongate. These shapes may also arise from multiple circular stains overlapping to create an oval shape. For those diamonds with radiation stains over much of their surface area, this is likely caused by multiple radiation events and/or radiation sources that occurred during erosion and continuous redeposition within the paleoplacer environment (e.g., Koivula, 2000; Chaves et al., 2001; Santos et al., 2003). Interconnected brown and green radiation stains and irregular agglomerations of radiation stains provide evidence of multiple irradiation events over time (figure 11).

The cause of radiation stain shapes is complex and likely influenced by factors such as diamond surface topography, radioactive mineral habit, relative orientation and separation of diamond to the radiation source, and radiation type. Notwithstanding that, radiation stain morphologies are classifiable and certainly warrant further study.

Surface Features Coincident with Radiation Stains.

Rough diamonds display surface textural features that reflect their journey from residence in the mantle, eruption to the earth's surface, and for some, subsequent alluvial transport. Etching can modify diamond surfaces, typically beginning at sites of geometric imperfections such as dislocations (Wilks and Wilks, 1994; Smit and Shirey, 2020). Dissolution features may develop in the mantle and/or kimberlite or lamproite melt, several of which are dependent on diamond morphology. These features are not related to radiation stains, and in most cases they are not coincident. For example, trigons, hexagons, and shield-shaped laminae are found on octahedral faces. However, tetragons are found on cubic faces, while hillocks and terraces are found on dodecahedral faces (Tappert and Tappert, 2011; Harris et al., 2022) (figure 12). Late-stage etching in kimberlite can result in textures such as corrosion sculptures, shallow depressions, and circular micro-disks and micro-pits. Most diamonds in this study had a placer origin and thus had surface textures consistent with late-stage abrasion and transport, such as network patterns or crescent-shaped percussion marks (Tappert and Tappert, 2011; Harris et al., 2022).

Fine negative surface topographies coincident with radiation stains were observed resulting from uncommon irradiation and dissolution conditions.

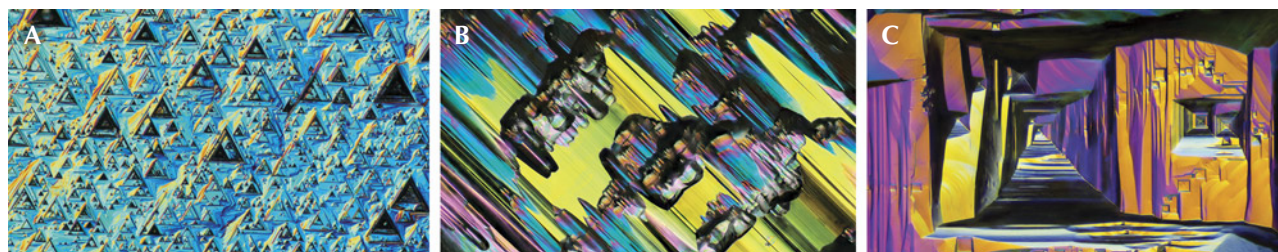


Figure 12. False-color DIC images of typical surface textural features in rough diamond. These include trigons (A), hillocks (B), and tetragons (C). Photomicrographs by Nathan Renfro; fields of view 0.72 mm (A), 1.44 mm (B), and 2.88 mm (C).

In some cases, microscopic raised surface features tended to partially infill obvious rounded pits. The composition of these infill features have not been identified, but some may be surface contamination such as dust particles (Nasdala et al., 2013).

Ruts were also observed, which are formed by diamond dissolution along fractures or cracks, causing them to widen (Tappert and Tappert, 2011; Harris et al., 2022). Subsequently, radioactive minerals can precipitate from percolating fluids (Finch and Murakami, 1999; Hazen et al., 2009; Lauf, 2016) into ruts or cracks when diamonds reside in alluvial environments. This can result in green coloration coincident with these surface dissolution features. Stains can also reflect grain boundaries between adjacent minerals or grains, leaving radiation stains in a mesh-

work pattern (figure 13; Nasdala et al., 2013; Breeding et al., 2018).

The updoming seen in some diamonds (figure 13) likely reflects volumetric surface expansion during irradiation (e.g., Meyer et al., 1965; Vance and Milledge, 1972; Dooley et al., 1993; Bosia et al., 2011; Nasdala et al., 2013). Additionally, in 6% of the samples, we observed fine acicular to tabular depressions from etching (again, see figure 8) that closely mirrored the outline of radiation stains. These features are not observed outside of radiation stains and cross-cut mantle dissolution textures (Bassoo, 2022; Stephan et al., 2022). Dissolution features such as trigons can penetrate significantly deeper into the diamond, in some cases hundreds to thousands of nanometers deep (Fedortchouk et al., 2011; Fedortchouk, 2019).

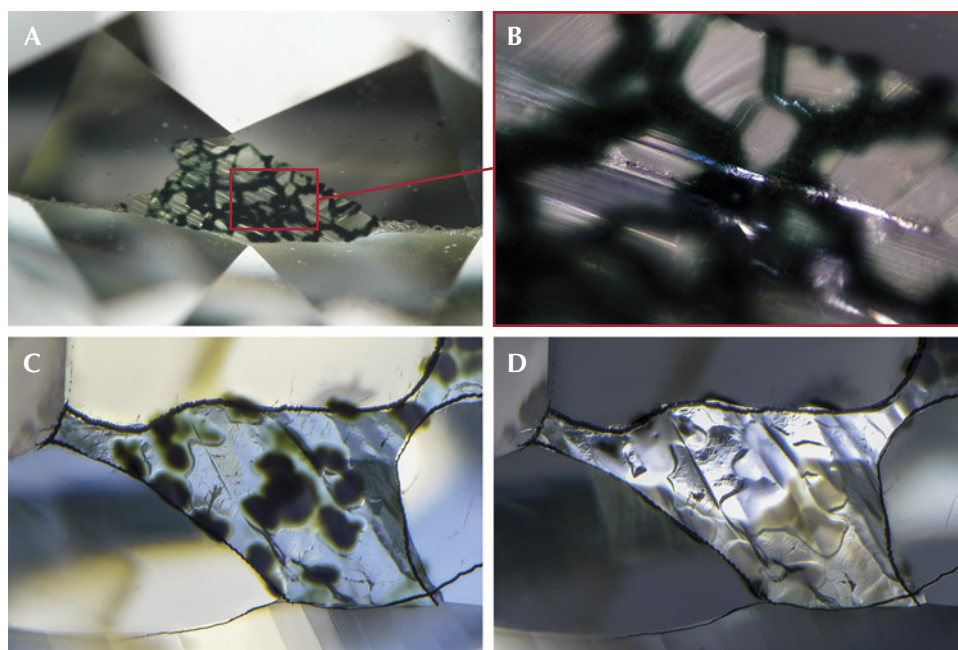


Figure 13. Faceted diamonds with preserved natural surfaces. A and B: Radiation staining coincident with cracks in the surface. This staining is likely deposited by radioactive fluids seeping through the cracks of adjacent mineral grains, resulting in a meshwork pattern. Photomicrographs by Taryn Linzmeyer; fields of view 3.57 mm and 0.72 mm. C and D: Radiation staining coincident with smooth, expanded surfaces. Image D was taken in reflected light to emphasize the surface topography. Photomicrographs by Nathan Renfro; field of view 2.24 mm. From Ardon (2021).

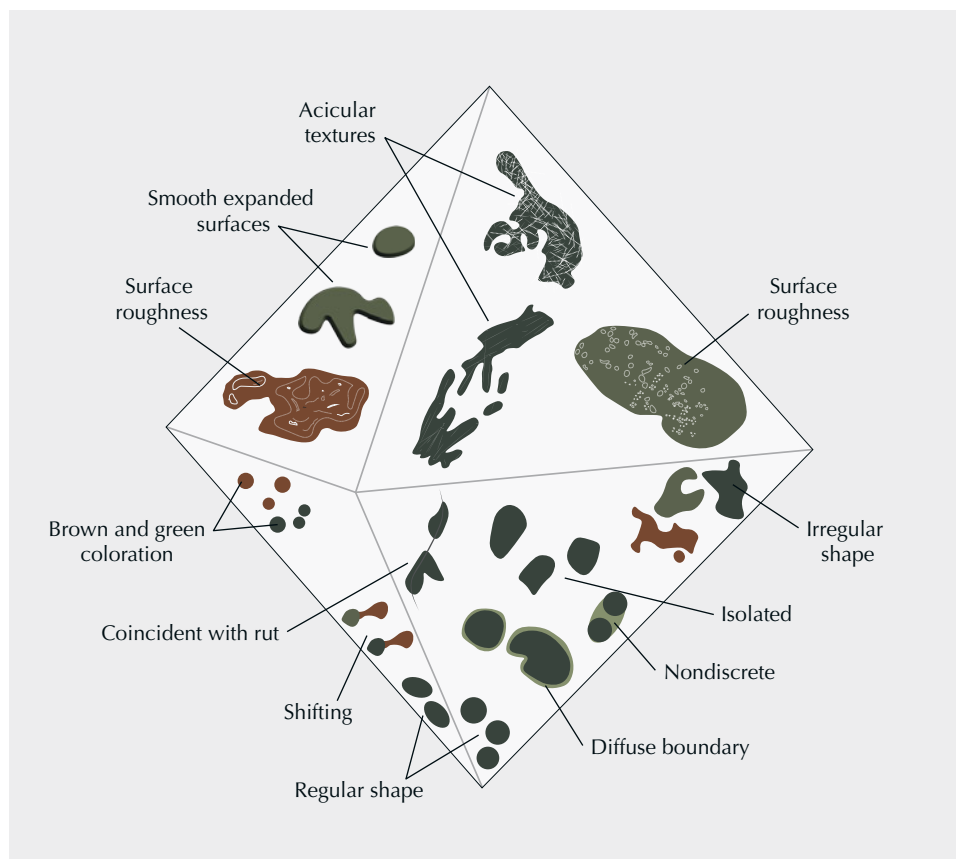


Figure 14. A schematic representation of radiation stain features.

AFM measurements confirmed that both acicular and rounded pits were relatively shallow (figures 8 and 9) and had a smooth topography consistent with diamond dissolution. Previous studies have shown that irradiated diamond surfaces are more prone to etching at the site of irradiation (Mendelssohn, 1971; Mendelssohn et al., 1979). It is likely that highly irradiated sites on a diamond may transition to amorphous carbon such as tetrahedral amorphous carbon (Prawer et al., 1998). Damage to the diamond structure is documented in the broadening and/or weakening of the Raman line in radiation stains (again, see figure 10 and box B; Nasdala et al., 2013; Eaton-Magaña and Moe, 2016; Schulze and Nasdala, 2016) or extra peaks associated with altered carbon states. In the case of acicular-shaped pits, the growth of secondary uranium-bearing minerals with acicular crystal habits may lead to etching. In this scenario, radioactive mineral grains would undergo alteration, leading to the localized formation of smaller secondary crystals with thin acicular habits (e.g., Burns and Hughes, 2003). Subsequently the tetrahedral amorphous carbon would preferentially etch, leaving behind a pit. These etch pits could mirror the morphology of radioactive minerals in physical contact.

Future studies of these enigmatic surface features will contribute to our understanding of diamond dissolution in the near-surface environment.

Radiation stain morphology, color, and coincident surface features across a broad range of diamonds (figure 14) permit the development of a new radiation stain classification scheme (figure 15). The classification may be used to describe individual radiation stains or regions of staining.

Color. This study identifies green and brown as near-exclusive colors of diamond radiation stains. The green color can be very dark green, appearing almost black.

Opacity. The radiation stains varied widely in opacity from opaque to nearly transparent. These may be classified as opaque or translucent. This classification could help to distinguish the degree of structural damage experienced by a diamond population due to irradiation. In most cases, natural radiation stains with an opaque center occur within translucent boundaries. In nondiscrete staining with multiple opaque centers, translucent staining connecting the dominant shapes is implied (see next section).

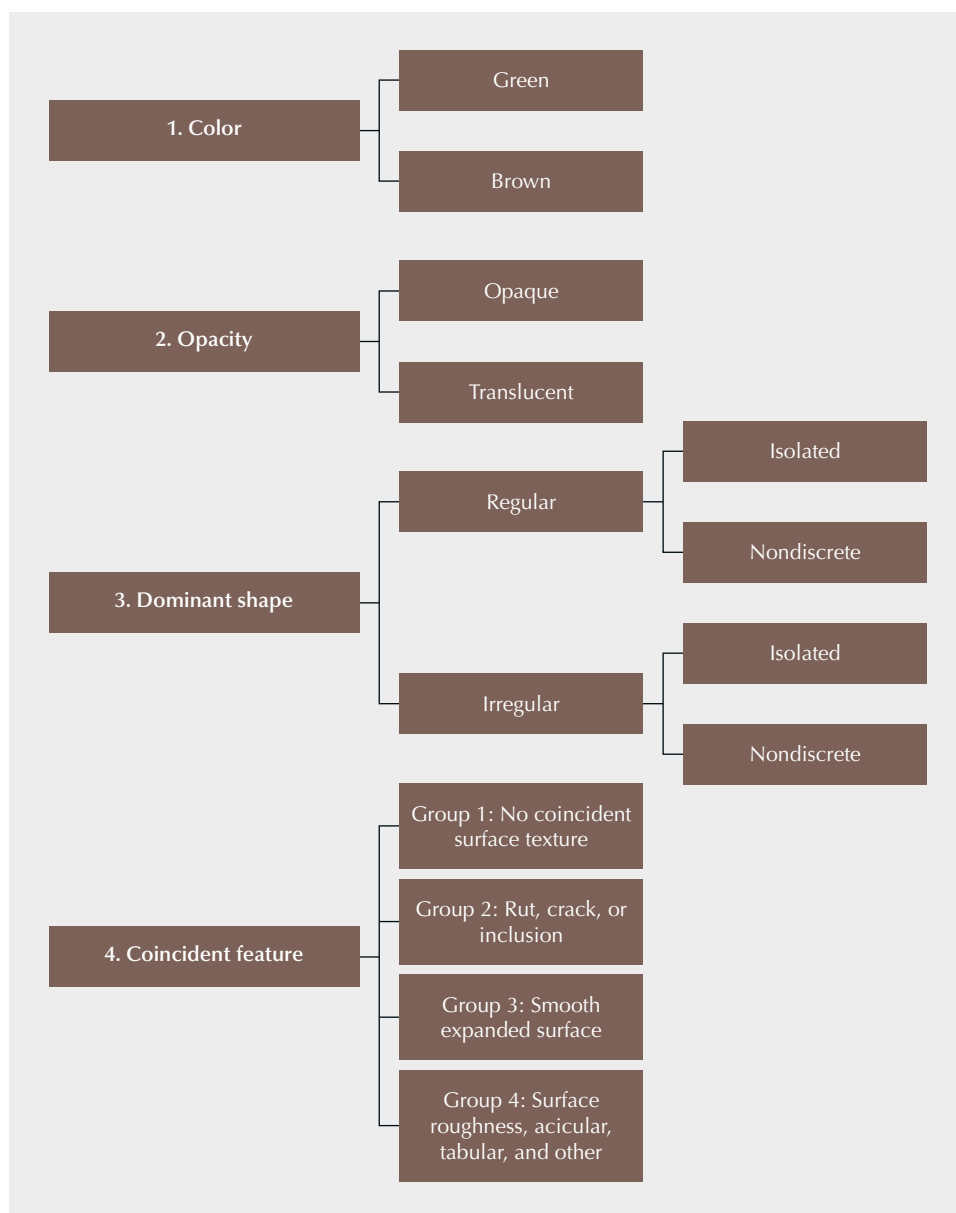


Figure 15. A proposed classification scheme for radiation stains on diamond.

Dominant Shape. The shapes of radiation stains can be classified by their dominant shape as either regular or irregular. This is the most opaque region of the stain. The terms *regular* can be used to encompass stains of both circular and oval shapes and *irregular* to describe all other shapes. To account for stains conjoined with others when their dominant shapes are still visible, regular and irregular radiation stains are subdivided as either “isolated” or “nondiscrete.” Stains that are not obviously isolated may be considered nondiscrete. Examples of nondiscrete stains include those with multiple dark, opaque centers connected to one another by diffuse edges or halos in which a clear boundary is ambiguous (figure 16) or

stains that are likely associated with radioactive fluids such as those with meshwork patterns. If the dominant shapes are rounded and regular, if not isolated, the stains may be defined as regular nondiscrete (e.g., figure 16H). Some dominant shapes are irregular; if not isolated, they may be considered irregular nondiscrete (e.g., figure 16C).

Multiple radiation stain shapes may occur in close proximity within the same diamond. While in some cases it is very likely that nondiscrete stain types are combinations of what were once rounded and regular point sources, we classify the shapes this way in order to provide terminology devoid of interpretation.

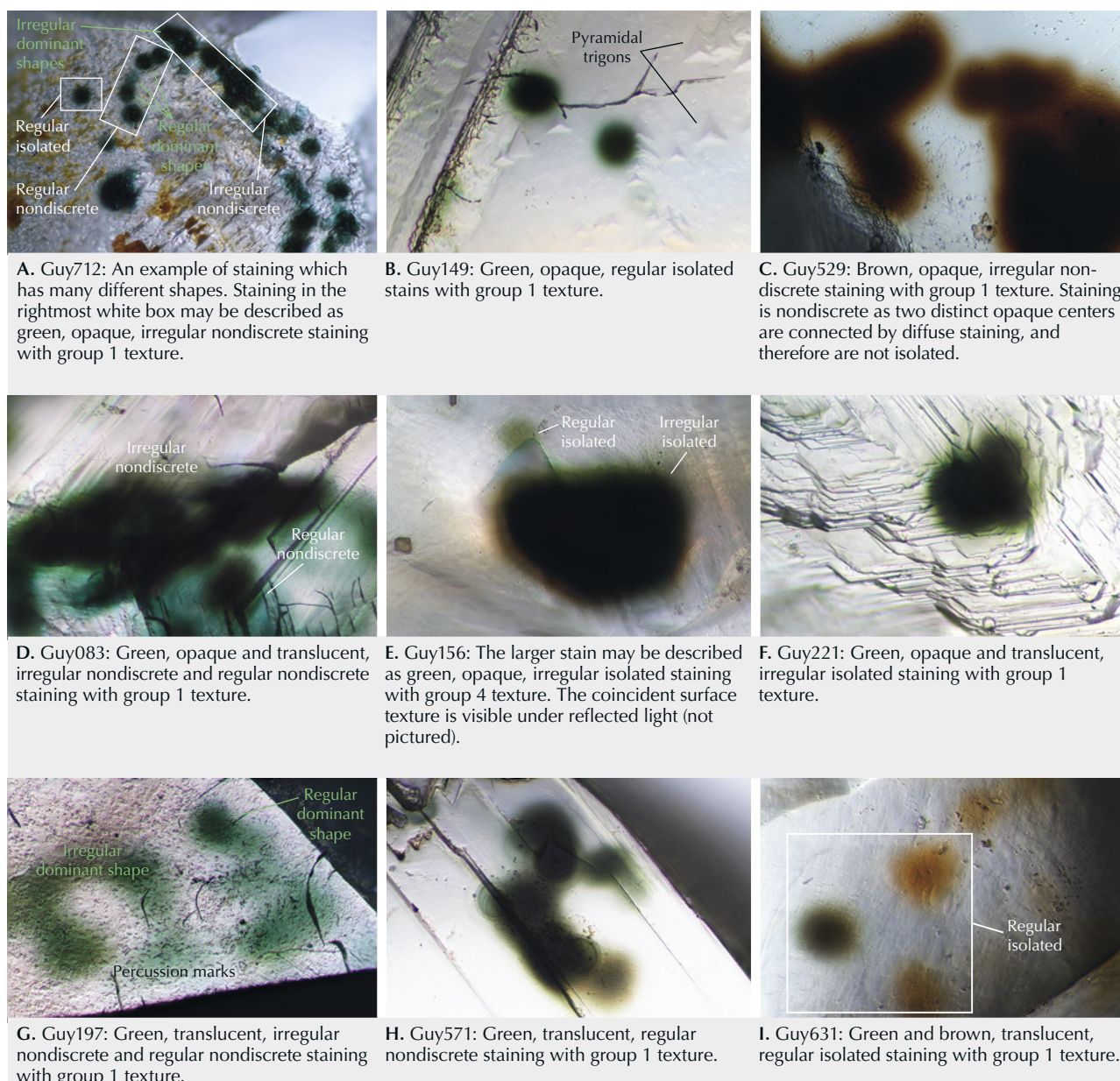


Figure 16. Examples of classified radiation stains. Photomicrographs by Taryn Linzmeyer; fields of view 0.72 mm (A) and 0.288 mm (B–I).

Coincident Texture. Several surface textures located coincident with radiation stains were identified and broadly classified into four groups:

- Group 1: No coincident surface texture
- Group 2: Coincident with a rut, etch channel, crack, or inclusion
- Group 3: Smooth expanded surface
- Group 4: Surface roughness, acicular, tabular, and other

CONCLUSIONS

Radiation stains are opaque or translucent, green to brown, and can encompass nearly the entire surface of a diamond. They are regular to irregular in shape and form single isolated or connected zones of nondiscrete patches of color. Circular and oval radiation stains range in diameter from 22 to 158 μm . In this study, almost 25% of the naturally irradiated diamonds had fine surface irregularity coincident with radiation stains, which we term Group 4 textures.

These features can be circular, irregular, or occasionally exhibit fine-scale geometrical characteristics such as fine acicular or tabular negative surface topographies. These textural features coincident with radiation stains may involve localized diamond dissolution in the near-surface environment and warrant future investigation. This study also found that radiation stains have complex but classifiable color, morphological, and textural characteristics.

This classification scheme is intended to provide a framework to describe radiation stains, which are important to the study of irradiated diamonds. Using comprehensive terminology to describe radiation stain morphology and texture will support future studies. Additionally, systematic recording of radiation stains provides a coherent and consistent language for describing naturally irradiated diamonds.

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DIVERSE RANGE OF ORGANIC-RICH CORES IN SOUTH SEA NON-BEAD CULTURED “KESHI” PEARLS

Nishka Vaz, Abeer Al-Alawi, and Anukul Belanke

Known as South Sea “keshi” in the trade, these non-bead cultured pearls are byproducts of the bead culturing process within the *Pinctada maxima* mollusk, a source of both natural and cultured pearls. The internal features of some of these non-bead cultured pearls can pose a significant challenge in pearl identification due to their similarity to structures observed in natural pearls. A group of 43 pearls showing organic-rich concentric cores, reportedly sourced from an Australian pearl farm, was selected for this study. To determine origin, their structures were analyzed and categorized using several techniques, including real-time X-ray microradiography, computed microtomography, and energy-dispersive X-ray fluorescence chemical analysis. Five of the 43 pearls were partially sanded through their cores to allow for cross-sectional analysis, including visual observations and Raman spectroscopy, to correlate the structure and composition of these cores to their X-ray imagery. The results of this study will assist in separating non-bead cultured pearls formed inside the *Pinctada maxima* mollusk species from natural pearls from the same species.

South Sea cultured pearls, as they are commonly known in the trade, refer to pearls cultivated from the *Pinctada maxima* mollusk. These mollusks are renowned for producing some of the largest and most valuable cultured pearls (Otter et al., 2014; Smaal et al., 2019). Commercial culturing of these bivalves is carried out in the warm, nutrient-rich waters off the coasts of Australia, Myanmar, the Philippines, Indonesia, and in the South China Sea (Southgate and Lucas, 2008). Over the years, significant advances have been made in the methods and technology employed to produce high-quality cultured pearls, building upon the pearl culturing experiments initiated by Mikimoto in 1912 (Strack, 2001). Today, pearl farms produce non-bead cultured (NBC) pearls of large sizes and exceptional quality.

In the past, NBC pearls were mostly considered byproducts (Hänni, 2006); today, they are intentionally grown on pearl farms. Most NBC pearls are believed to grow in the gonad of the bivalves used for cultivating bead cultured pearls. Natural pearls, on

the other hand, are known to form primarily in the mollusk’s mantle. However, although most natural and cultured pearls have distinctly different internal structures, they also have similarities (Hänni, 2012). Hence, pearl testing laboratories must have adequate equipment and expertise to distinguish between natural and cultured pearls.

The internal structures of pearls are analyzed using real-time X-ray microradiography (RTX), and identification is based on recognizing features highlighted in

In Brief

- South Sea “keshi” pearls are byproducts with organic-rich cores featuring characteristics such as light gray nuclei, seed-like features, off-round nuclei, and multiple cores and/or nuclei.
- Cross sections of select samples exhibited similar structures in X-ray imaging with minor differences in appearance or texture of some nacre/organic-rich areas.
- Raman spectra of the cores’ cross sections revealed aragonite as the dominant mineral phase with higher peak intensity in nacreous regions and lower intensity in more organic-rich areas. This correlated to the concentration of aragonite in these areas.

See end of article for About the Authors and Acknowledgments.

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previous research studies. The main structures observed in NBC pearls include voids, linear features, and organic-rich cores with loose ring structures and distinct seed features (Krzemnicki et al., 2010; Sturman et al., 2016; Nilpetploy et al., 2018; Homkrajae et al., 2021b). The radiopaque and radiolucent regions seen with X-rays result from variations in the composition of organic matrix and nacre (Rosc et al., 2016). While nacre itself consists of aragonite platelets cemented by organic phases, the latter material is a more chemically complex substance. The organic-rich matrix present in the internal structures of pearls that causes the darker areas to appear in X-ray imaging is composed of a combination of scleroproteins—which include amino acids such as leucine, alanine, glycerin, and cysteine—that are secreted by the mollusk (Tanaka et al., 1960). In this article, “organic-rich cores”

refer to the dark and light gray concentric structures seen in the X-ray images of these pearls, while “nucleus” refers to their light gray centers. Technological advancements applied in pearl farming, along with environmental changes, have led to a gradual change in the internal structures observed in cultured pearls (Sturman et al., 2020). Therefore, it is important to routinely study the pearls originating from these farms.

MATERIALS AND METHODS

For this study, 43 nacreous NBC pearls from silver-lipped *Pinctada maxima* mollusks from Australia were selected (figure 1). These were acquired from a trusted dealer based in Mumbai who sources pearls directly from a farm in Australia. Only pearls with internal structures consisting of organic-rich cores

Figure 1. The 43 non-bead cultured “keshi” pearls (0.18 to 1.96 ct) from the *Pinctada maxima* mollusk selected for this study. Photo by Gourav Bera.



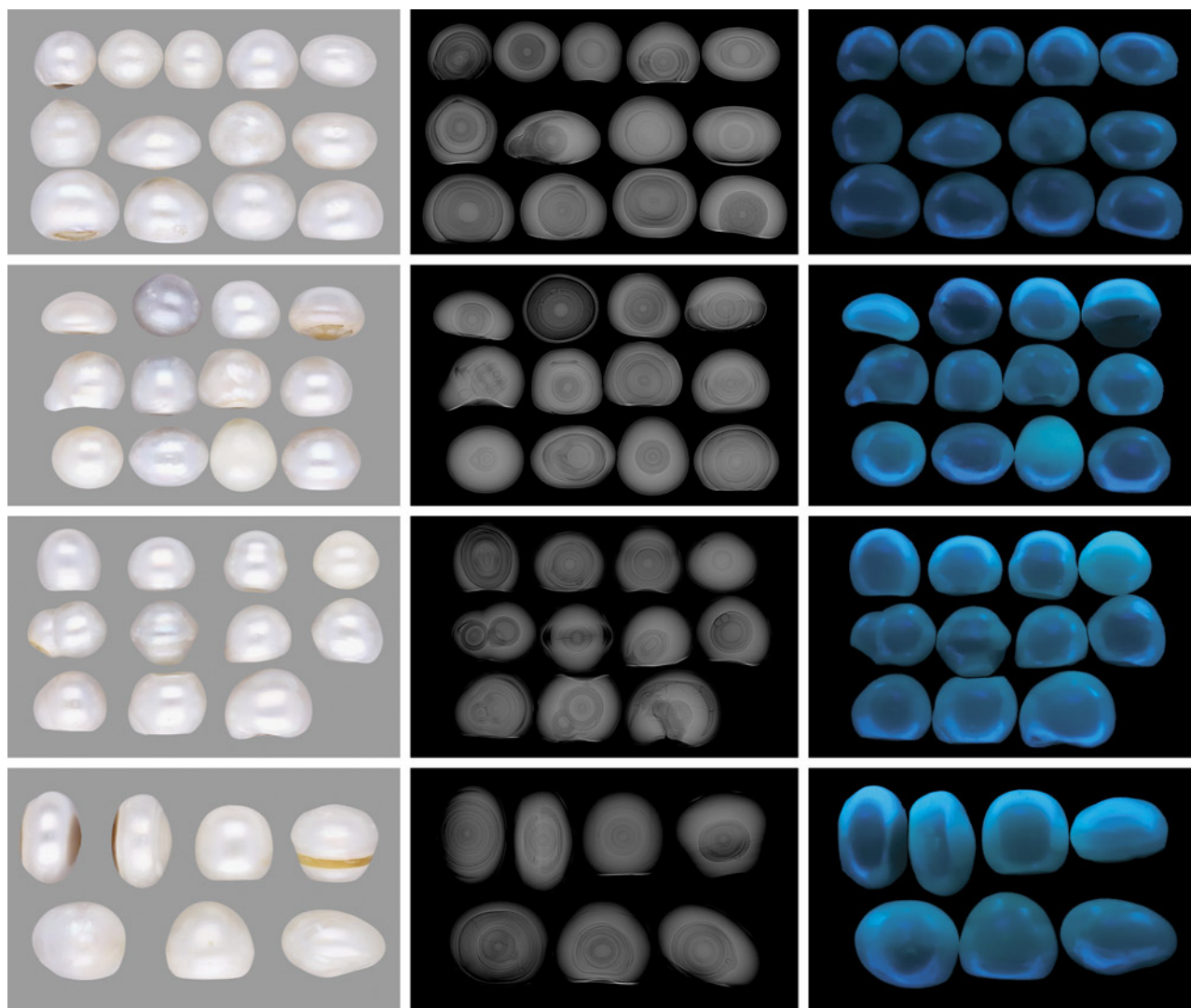


Figure 2. Photographs, RTX images, and long-wave UV reactions, respectively, of the 43 non-bead cultured pearls with organic-rich concentric cores from *Pinctada maxima*, sorted by size. Photos by Gourav Bera.

were selected through a preliminary evaluation by RTX imaging (figure 2). The majority of these pearls were button shaped with flat or concave surfaces on one side forming a base, with a few near-drop and baroque-shaped pearls. They ranged from $3.37 \times 3.15 \times 2.92$ mm to $7.69 \times 7.33 \times 5.23$ mm in size and weighed 0.18 to 1.96 ct. Among the 43 examined pearls, three ranged from light gray to gray, three displayed a silver hue, and the remaining 37 were white in color. Most of the pearls exhibited orient.

The internal structures of these samples were further categorized into four subgroups, with four pearls selected from each group as representative examples based on the radiopacity and pattern of features they showed in RTX and X-ray computed microtomography (μ -CT) imagery. These pearls

were assigned sample identifiers based on their structural classification:

- Group A: Core with a light gray nucleus (pearls A-1 through A-4)
- Group B: Seed-like features (pearls B-1 through B-4)
- Group C: Off-round core and nuclei (pearls C-1 through C-4)
- Group D: Multiple cores and/or nuclei (pearls D-1 through D-4)

To further study their composition, five of the 43 pearls with internal structures representing each group (one each from groups A–C and two from group D) were sanded down to their cores. Raman spectroscopy was also performed on multiple spots

along the cross sections for an overview of the compositions of these areas.

All the samples were examined using a binocular gemological microscope under magnifications of 10× to 135× with fiber-optic illumination. The reactions of all samples were studied under various radiations: X-ray fluorescence using a FocalSpot Verifier FSX-PF100 unit with 100 kV voltage, and 5 mA current X-ray source and a GIA-designed UV unit incorporating a narrowband 365 nm long-wave ultraviolet and 254 nm short-wave ultraviolet LED source.

RTX was performed on all samples using a Pacific X-ray Imaging GenX 90P X-ray inspection system with a 4 μ m microfocus, 90 kV voltage, and a 0.150 mA current X-ray source with an exposure time of 200–400 milliseconds per frame combined with a PerkinElmer 1512 flat panel detector with a maximum of 128 frames average and 74.8 micropixel pitch with 1920 $\times$ 1080 pixel resolution. X-ray computed microtomography was also performed for all 43 pearl samples using a ProCon CT-MINI X-ray system with a 5 μ m microfocus, 130 kV voltage, and 0.30 mA current X-ray source with a Varex 1207 flat panel detector with 74.8 micropixel pitch and 1944 $\times$ 1536 pixel resolution. Raman spectra were obtained using a Renishaw inVia micro-Raman spectrometer system with a 50× magnification Leica objective lens and an

830 nm diode laser. This laser provided a better resolution of mineral peaks than the 514 nm laser often used for Raman spectroscopy of pearls. A laser power of 50 mW was used directly on the samples, and the system was calibrated with a silicon standard. The elastic Rayleigh scattering was blocked using edge filters. The laser was set at 50–100% power with three accumulations and an exposure time of 10 seconds with a grating of 1200 grooves/mm.

Chemical analyses were conducted on all the samples using an energy-dispersive X-ray fluorescence (EDXRF) spectrometer and a Thermo Scientific ARL QUANT'X system calibrated using U.S. Geological Survey (USGS) carbonate microanalytical reference materials MACS-1 and MACS-3 (in pressed powder pellet form), incorporating a 50 W, 4–50 kV voltage, and 0.02–1.98 mA current X-ray source with a SDD500G silicon-lithium drifted detector.

OBSERVATIONS AND DISCUSSION

External Observations. Each pearl sample exhibited a smooth surface with lustrous appearance. Under high magnification, fine, evenly spaced overlapping nacreous terrace structures were visible, some with a spiral pattern typical of pearls from *Pinctada maxima* (figure 3A). Most of the button-shaped pearls had

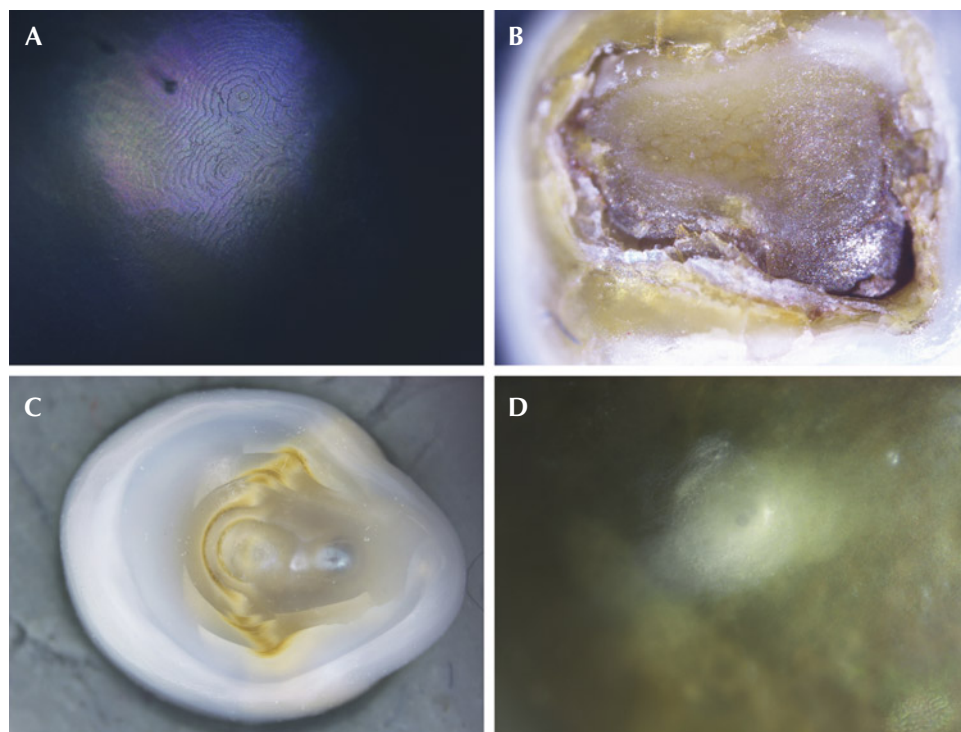


Figure 3. A: A spiral nacreous terrace structure on pearl A-2. B: The base of pearl C-4 with uneven organic-rich layers. C: Concave base on pearl D-4 with cores and nuclei seen through translucent nacre. D: Subsurface white spots on pearl B-1. Photomicrographs by Nishka Vaz; fields of view 0.5 mm (A), 1.3 mm (B), 3.2 mm (C), and 0.85 mm (D).

organic-rich patches evident on the bases. In addition, areas of broken nacre with darker brown and lighter translucent organic-rich layers interspersed with nacre layers were commonly found on the pearls' bases (figure 3B). Button-shaped pearls with concave bases and visible growth arcs with the cores occasionally apparent are also typical features associated with NBC pearls. These could also have a double core with bulging areas due to the accumulation of organic-rich material seen in the growth arcs (figure 3C). Moreover, translucent surface nacre can reveal features such as the white bumps associated with NBC pearls (figure 3D), which may be either subsurface or raised. Although white spots in freshwater cultured pearls are associated with the presence of vaterite (Wehrmeister et al., 2007), the pearls studied did not appear to contain vaterite based upon their Raman spectra.

All the pearls showed an inert reaction when exposed to X-ray fluorescence (XRF), indicating salt-water origin. EDXRF analysis conducted on all pearls revealed manganese levels ranging from below detection limit (29.8 ppmw) to 39.8 ppmw and strontium levels ranging from 1403 to 3301 ppmw. These levels are a good indicator of the marine environment in which the pearls formed and are comparable to those observed in pearls from the *Pinctada maxima* mollusk (Karampelas et al., 2019b).

With exposure to long-wave UV, a near-uniform moderate blue fluorescence reaction was observed on all of the pearls' surfaces. In addition, short-wave UV exposure gave a similar but weaker blue fluorescence reaction.

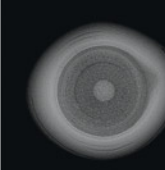
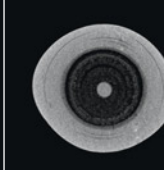
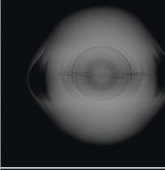
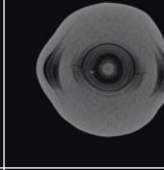
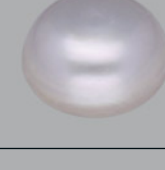
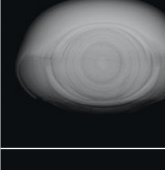
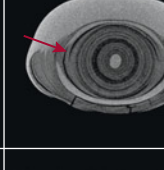
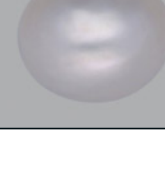
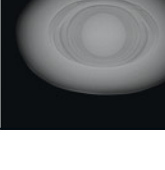
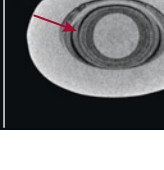
Internal Structures. Because pearls are organic gems formed through biological processes within a mollusk (Vaz et al., 2023), each pearl possesses some unique characteristics. Although it is not always easy to distinguish between natural and cultured pearls (Sturman et al., 2019; Homkrajae et al., 2021a), certain textures and patterns in their internal structures can help indicate whether human influence led to the pearl's formation. Examining these types of structures in pearls of reported NBC origin aids laboratories in providing accurate results for the pearls submitted for testing.

All the selected pearls revealed cores with different forms of organic-rich concentric structures (again, see figure 2). Both natural and cultured pearls from *Pinctada maxima* often have cores with distinct organic-rich concentric structures (Scarratt et al., 2012; Manustrong et al., 2019); hence, it is important

to study the differences in the structures of such cores from natural and cultured pearls. Four types of internal structures were observed in the studied pearls.

Group A: Core with a Light Gray Nucleus. The centers of the large organic-rich concentric cores observed in NBC pearls are often composed of a calcium carbonate (CaCO_3) nucleus that appears light gray in RTX and μ -CT imagery. This nucleus indicates the initiation point of the pearl's growth. Thus, layers formed around the nucleus progressively decrease in age from the point of initiation, with the outermost layers formed most recently. The nucleus may vary in size, as observed in the samples in table 1. A distinct boundary is often visible between the core and the alternating light and dark rings of nacre and organic-rich material, respectively. In some pearls, such as A-1, the dark organic-rich core exhibits very faint patchiness in addition to the concentric pattern, whereas other pearls, such as A-2, may display well-defined fine rings of nacre within the organic-rich

TABLE 1. Group A: Four non-bead cultured pearls from *Pinctada maxima* with light gray nuclei and core structures (red arrow indicates step-down features).

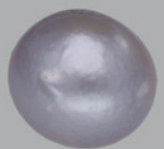
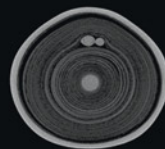
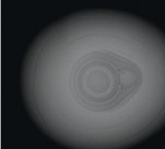
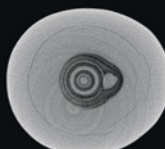
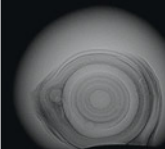
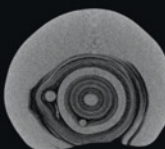
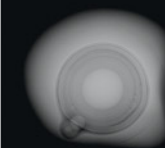
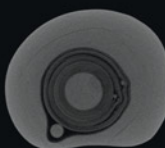
Sample	Macro	RTX	μ -CT
A-1 0.22 ct 3.26 × 3.21 × 3.14 mm			
A-2 0.80 ct 5.25 × 5.24 × 4.98 mm			
A-3 0.56 ct 5.13 × 5.11 × 3.53 mm			
A-4 0.31 ct 4.03 × 3.99 × 2.72 mm			

concentric core. A dark radiolucent ring may also be observed around the circumference of the pearl. When viewed in μ -CT, it appears as a bulge of organic-rich material on either side of the core, such as in pearl A-2.

Another pattern for the more radiolucent alternating layers may also be seen. The thickness and tightness of these rings and their textures are important details to note in such cores. While distinct uniformly thick rings are more frequently seen in cultured pearls, radiolucent crescent-shaped gaps between consecutive layers, known as “loose layers,” may also be present. On some occasions, these loose layers can appear as though a single concentric layer is flowing from one level to the next, producing a “step down” feature as observed in pearls A-3 and A-4 (indicated with arrow), and has been often observed in South Sea NBC pearls (Homkrajae et al., 2021b). Additionally, a faint acicular pattern can also be seen radiating from the nucleus in the central region of the core, such as that in A-3. A common observation in cultured pearls is the presence of a thick layer of nacre growth around the core that lacks growth arcs, such as that in pearl A-4. This lack of growth arcs has been speculatively attributed to the rapid growth of nacre in cultured pearls (Scarratt et al., 2017). The large round nuclei seen in pearl A-4 and the lack of structure within the nuclei are more commonly observed in NBC pearls rather than in natural ones, especially in pearls from the *Pinctada maxima* mollusk. Similarly, the presence of cracks running through the core or radiating within the organic-rich layers, potentially due to the pearl’s desiccation, was evident in pearls A-2 and A-3.

Group B: Seed-Like Features. In addition to the nucleus, similar light gray concretions indicative of the calcium carbonate matrix are also often found within the organic-rich layers. When these concretions occur beyond the point of initiation (nucleus), they are often referred to as “seed” features or “globuli” (light gray features shown in the organic-rich concentric cores in pearls in table 2). The sizes of these seed features vary significantly, with some appearing larger than the nucleus, equivalent to it in size, or much smaller, such as in pearls B-2, B-3, and B-4, respectively. Unlike the nucleus, these seeds are always found after the initiation of the pearl, during its growth. As these features are composed of nacre and potentially form during the deposition of the organic-rich matrix, the concentric layers of the core often deform as they flow around these concretions.

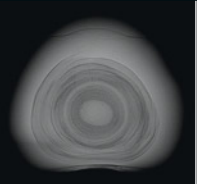
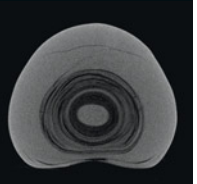
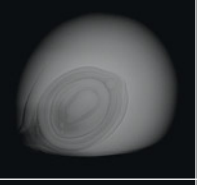
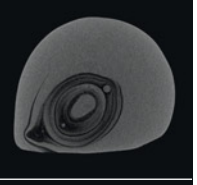
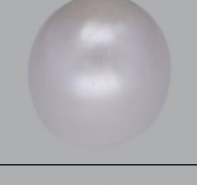
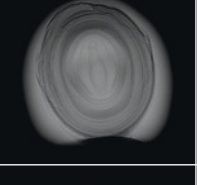
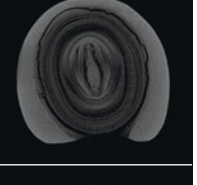
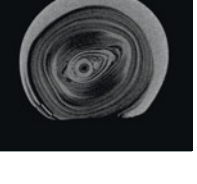
TABLE 2. Group B: Four non-bead cultured pearls from *Pinctada maxima* with seed-like features.

Sample	Macro	RTX	μ -CT
B-1 0.46 ct 4.88 × 4.54 × 4.51 mm			
B-2 0.65 ct 4.85 × 4.44 × 4.37 mm			
B-3 0.30 ct 3.72 × 3.65 × 3.11 mm			
B-4 0.88 ct 5.40 × 5.03 × 4.79 mm			

In cultured pearls, these seeds are often embedded in the layers of the organic-rich concentric core. Although most seed features are round and light gray, it is not uncommon to find seeds with minor growth features such as growth arcs or slightly elongated seeds, as in pearls B-1 and B-2. Often, these seeds or globuli are not easily visible in RTX but are clearly seen in μ -CT images, such as in pearl A-2. Hence, laboratories exercise extreme caution while testing pearls with such cores. The presence of a thick light gray ring within these concentric layers, as seen in pearls B-2 and B-3, is also commonly observed in NBC pearls from *Pinctada maxima*.

Group C: Off-Round Cores and Nuclei. Off-round cores and nuclei (table 3) are considered characteristic features of South Sea NBC pearls (Manustrong et al., 2019). Although natural pearls may occasionally have nuclei that are not perfectly round, the presence of a distinctly oval-, pear-, or lens-shaped calcium carbonate nucleus within a pearl is likely a result of the culturing process. Off-round cores with oval nuclei, such as those seen in pearls C-1 and C-2, are

TABLE 3. Group C: Four non-bead cultured pearls from *Pinctada maxima* with off-round cores and nuclei.

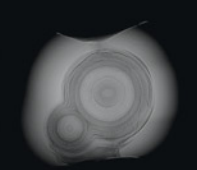
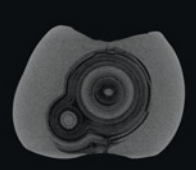
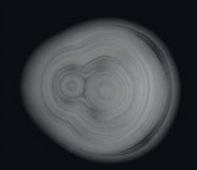
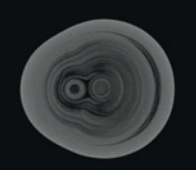
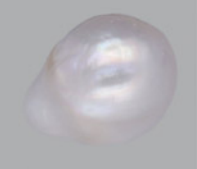
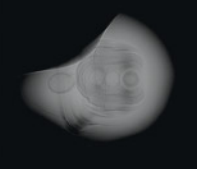
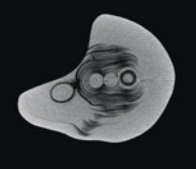
Sample	Macro	RTX	μ-CT
C-1 1.96 ct 6.92 × 6.69 × 5.96 mm			
C-2 0.86 ct 5.15 × 5.08 × 4.39 mm			
C-3 0.73 ct 4.84 × 4.80 × 4.69 mm			
C-4 0.18 ct 3.37 × 3.15 × 2.92 mm			

examples of such structures. Despite their relatively dense, radiopaque nature, these nuclei seem to be enclosed in a radiolucent organic-rich layer. Unlike the light gray nuclei in group A, these off-round nuclei often exhibit minimal faint growth arcs. More extreme versions of these distorted nuclei were observed in pearls C-3 and C-4, where the nuclei have a highly elongated spindle shape with the pointed edges curving in on the elongated nucleus in pearl C-3, and where a complex elliptical nucleus has multiple nuclei or seeds attached to it, as in pearl C-4. Notably, the shape of the core itself appears independent of the central nucleus. This inconsistency in shape from nucleus to core to the shape of the pearl itself is observed more in NBC pearls, which is reflected in the 43 pearls studied. This is obvious in pearl C-1, where the nucleus appears oval in a round organic-rich concentric area that grows into a button-shaped core and pearl. Similarly, the oval nucleus in pearl C-2 is also surrounded by oval organic-rich concentric layers that are further distorted by two seeds present at alternating axial positions. A radiolucent dark gray pocket outside the

core is also an observed feature often associated with bead cultured pearls due to the culturing process (Krzemnicki et al., 2010), which might be seen in NBC pearls as well. A gradual change in the pearl's shape from nucleus to nacre due to the shape of the organic-rich layers of the core can be seen in C-3 and C-4, with the denser light gray rings evident along axial positions and the looser, darker rings visible along the sides.

Group D: Multiple Cores and/or Nuclei. While multiple cores are occasionally observed in natural pearls, they are more prevalent in NBC pearls. For instance, pearl D-1 in table 4 features a large core adjacent to two smaller cores in contact with each other. The larger feature (main core) contains a light gray calcium carbonate nucleus surrounded by loose organic-rich layers and a distinct thick, large light gray ring, a characteristic not typically observed in natural pearls from the same species. The organic-rich layers surrounding this core exhibited multiple step-down features. Conversely, the other two smaller cores are enfolded by a dense organic layer that appears to have an acicular radial texture following the outline of the two cores. The multiple cores may further be enveloped by layers of an organic-rich concentric structure as seen in pearls D-2 and D-3 and may be either of different sizes and shapes, as in pearl D-2, or similar sizes but different textures, as seen in pearl D-3. The structure of these two pearls is also a good example of the differences between various types of organic-rich concentric structures. While the radiopacity of the rings in pearl D-2 is darker and more contrasted compared to the more diffused concentric layers of pearl D-3, they both show loose structures, step-down features, and voids between the cores. A more complex structure can be seen in pearl D-4, where the pearl contains four nuclei, three of which appear as dense light gray calcium carbonate entities, while one appears to have some organic structure around it. Three of the nuclei are in contact with one another and surrounded by a series of organic-rich layers and significant cracks that fuse into the nacre at one end, with one nucleus surrounded by nacre outside these layers. Natural pearls may occasionally show structures with multiple cores and/or nuclei (Homkrajae et al., 2021a); however, their patterns and arrangements are distinctly different from those seen in cultured pearls. Based on GIA's observations of numerous pearls from both known samples and client submissions, such cores are considered type examples for NBC pearls.

TABLE 4. Group D: Four non-bead cultured pearls from *Pinctada maxima* with multiple cores and/or nuclei.

Sample	Macro	RTX	μ-CT
D-1 0.78 ct 6.11 × 4.57 × 4.36 mm			
D-2 1.23 ct 6.18 × 5.65 × 4.70 mm			
D-3 0.91 ct 5.65 × 5.10 × 4.62 mm			
D-4 0.61 ct 5.43 × 4.40 × 3.99 mm			

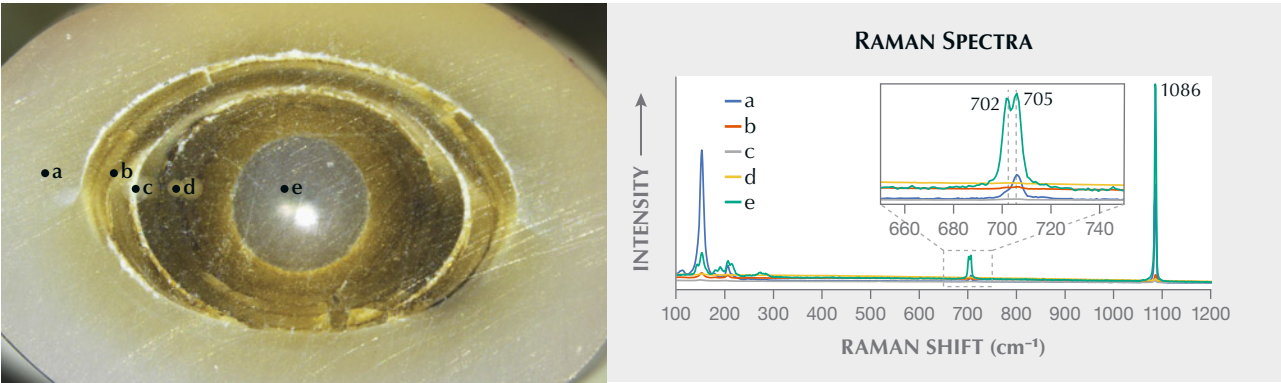
Raman Spectroscopy. Pearl identification in laboratories is carried out by studying internal structures through nondestructive tests such as RTX and μ-CT. However, it is also important to visualize the pearl’s internal structure and understand its composition;

therefore, five pearl samples were sanded down to their cores to further analyze their cross sections.

Raman spectra collected with an 830 nm laser helped identify three distinct phases based on the composition of the material at different points of the core. The nacre and light regions showed distinct peaks at 1086 cm⁻¹, a doublet or broad peak at 701/705 cm⁻¹, and a series of peaks from 100 to 280 cm⁻¹. These peaks indicate the presence of an aragonite mineral phase. In addition to these peaks, a few spots on the surface showed a small peak around 716 cm⁻¹, indicating the presence of magnesium-rich calcite along with aragonite peaks, showing a bimineralic composition in these areas. While the calcite Raman peak in pearls is typically observed at 712 cm⁻¹, this shift has previously been attributed to vibrational modes at longer wavelengths and the presence of higher magnesium content in calcite (Sun et al., 2014; Borromeo et al., 2017; Karampelas et al., 2019a). Very weak or no mineral peaks were observed in the organic-rich areas due to high concentrations of organic matter rather than mineral-rich phases.

The cross section of pearl A-4 showed similarities to its RTX and μ-CT images outlined in table 1. These similarities are evident in the radiopacity of the nuclei and nacre with X-ray imaging, which also appear more solid and white along the cross section. Furthermore, the organic-rich concentric core around the nucleus also displays a pattern similar to that observed with X-rays, with the darker areas appearing more organic-rich and the lighter areas more aragonite-rich, based on the relative intensity of the aragonite peaks as seen in the Raman spectra (figure 4).

Figure 4. Left: Cross section of pearl A-4 with spots marked for Raman spectroscopy. Photo by Nishka Vaz; field of view 2.7 mm. Right: Raman spectra collected with an 830 nm laser from pearl A-4 on indicated spots, showing peaks of varying intensity at 1086 cm⁻¹, 701/705 cm⁻¹, and 100–280 cm⁻¹, indicating the presence of aragonite. Spectra are baseline corrected and offset vertically for clarity.



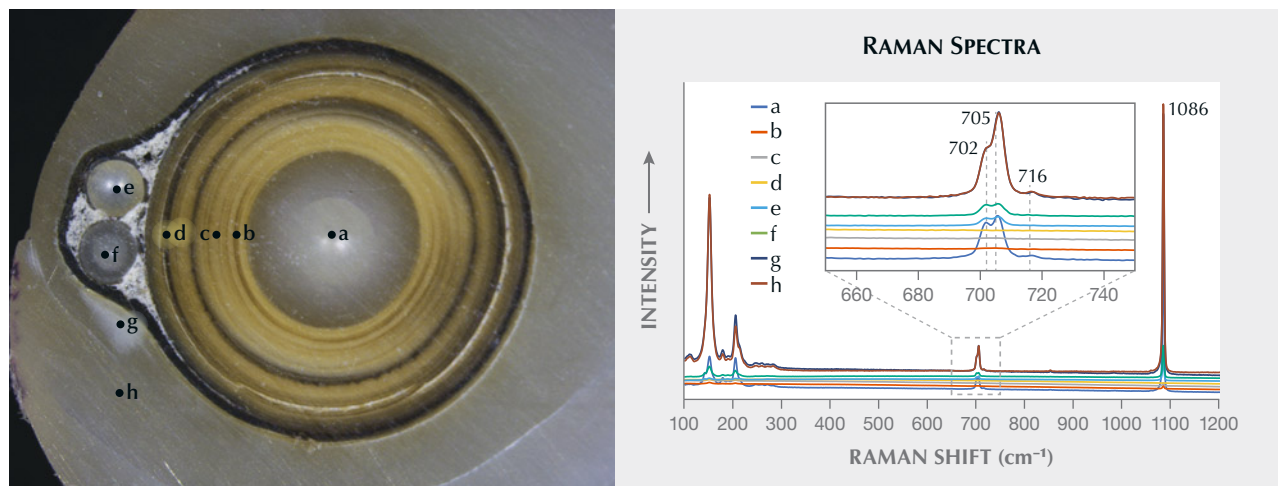


Figure 5. Left: Cross section of pearl B-4 with spots marked for Raman spectroscopy. Photo by Nishka Vaz; field of view 3.19 mm. Right: Raman spectra collected with an 830 nm laser from pearl B-4 on indicated spots, showing peaks of varying intensity at 1086 cm^{-1} , 701/705 cm^{-1} , and 100–280 cm^{-1} , indicating the presence of aragonite. Spots a, g, and h showed an additional weak peak at 716 cm^{-1} , indicating a calcite phase in addition to aragonite, while spot d showed very weak mineral peaks due to higher organic content in those regions. Spectra are baseline corrected and offset vertically for clarity.

Similarly, the cross section of pearl B-4 also resembled its RTX and μ -CT images (again, see table 2), with the large light gray core appearing similar to that seen in pearl A-4. However, unlike the similarities in radiopacity seen in the X-ray images, the organic-rich concentric core appears much lighter in pearl B-4. Additionally, the nucleus and surrounding nacre of the pearl also showed the presence of very weak calcite peaks in Raman spectroscopy in addition to aragonite, indicating a likely bimineralic composition dominated by aragonite with minor calcite (figure 5).

The cross section of pearl C-3, with its spindle-shaped nucleus, revealed an interesting structure. This nucleus appeared to be light colored, with the organic-rich concentric structure surrounding it matching the pattern seen in the X-ray images (again, see table 3). A distinctive difference between the two stages of growth in the organic-rich core was also visible. The initial stage after the formation of the nucleus appears to be followed by a series of mineral-dominant rings around the nucleus, succeeded by a stage of growth of organic-rich dominant concentric layers. This distinction can be observed in the radiopacity of the layers corresponding to their color when sanded into cross sections and in the intensity of the aragonite peaks seen in Raman spectra. A dense layer of nacre deposition appears to have occurred after the core formation, and both the nacre and the core are composed of aragonite based on their Raman spectra (figure 6).

Pearl D-1 was sanded down to reveal its triplet cores. As observed in the μ -CT images, all three of these cores had distinctly different structures (again, see table 4). From the point of initiation to the radiopacity to the texture of the organic-rich layers around them, all three of these cores and the organic-rich layer enveloping the two smaller cores differed in pattern and appearance. This variance likely signifies the individual growth of each nucleus in different pearl sacs within the mollusk, ultimately fusing together to form an aggregate pearl (Mariom et al., 2019). The compositions of these cores also had varying aragonite content, as seen from the intensity of their corresponding peaks in the Raman spectra. The white ring in the larger core, often associated with NBC pearls from *Pinctada maxima*, as well as the pearl nacre were composed of a bimineralic phase with faint calcite peaks in addition to strong aragonite Raman peaks. The void-like areas between the cores observed in both the RTX and μ -CT images appeared to be filled with a resinous organic material that did not exhibit strong mineral peaks due to its organic-rich composition (figure 7).

The complex arrangement of nuclei and cores in pearl D-4 also proved to be an intriguing study. Unlike the multiple cores in pearl D-1, this structure appears to be an aggregate of nuclei comprising of round/oval bodies in spots f, h, and k, as well as small

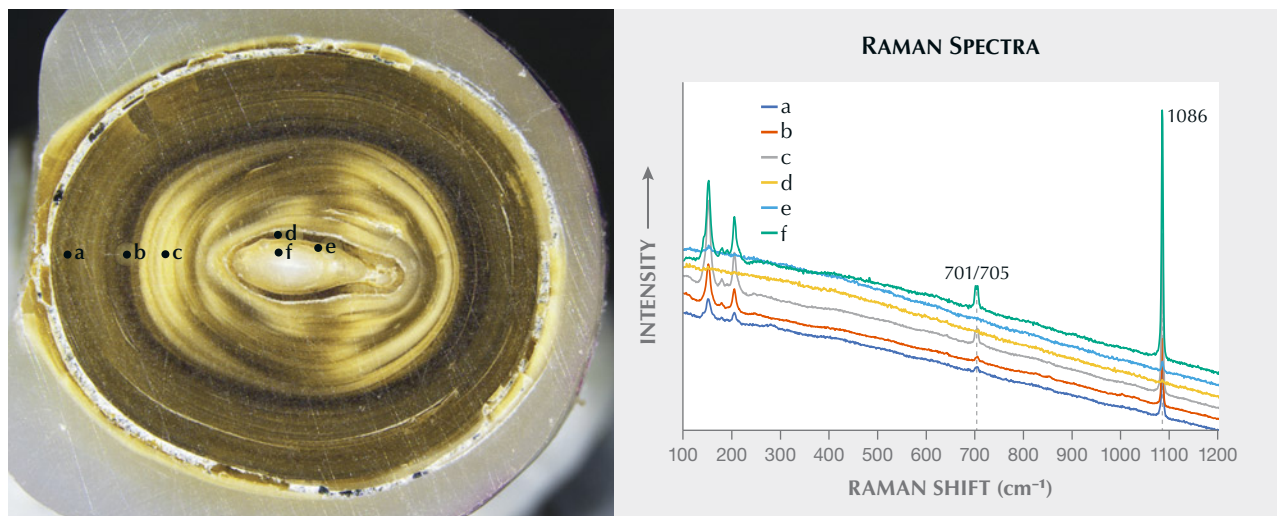
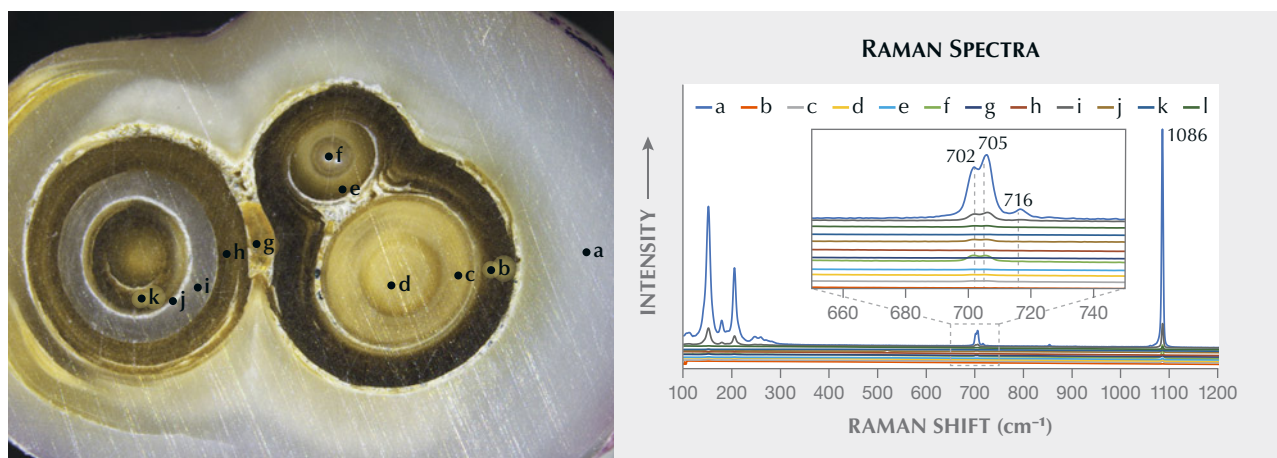


Figure 6. Left: Cross section of pearl C-3 with spots marked for Raman spectroscopy. Photo by Nishka Vaz; field of view 6.8 mm. Right: Raman spectra collected with an 830 nm laser from pearl C-3 on indicated spots, showing peaks of varying intensity at 1086 cm^{-1} , 701/705 cm^{-1} , and 100–280 cm^{-1} , indicating the presence of aragonite. Spots a, c, and f showed weak to moderate aragonite peaks, while spots b, d, and e appeared to be more organic-rich, with very weak to almost absent mineral peaks at spot d. Due to the relatively higher organic content of these spots, the baseline appears to be raised toward the lower Raman shift end. Spectra are baseline corrected and offset vertically for clarity.

round cores, as seen in spots d and j (figure 8). These cores and aggregates are surrounded by organic-rich layers and nacre with a small seed observed at spot n. Although the darker areas of this pearl are more organic-rich based on the Raman spectra, and arago-

nite seems to be the dominant mineral phase in the nacreous regions, the outer nacre and nucleus at spot h seem to have weak calcite peaks, indicating a bimineralic phase dominated by aragonite with minor calcite in these regions.

Figure 7. Left: Cross section of pearl D-1 with spots marked for Raman spectroscopy. Photo by Nishka Vaz; field of view 4.5 mm. Right: Raman spectra collected with an 830 nm laser from pearl D-1 on indicated spots, showing peaks of varying intensity at 1086 cm^{-1} , 701/705 cm^{-1} , and 100–280 cm^{-1} , indicating the presence of aragonite. Spots a and i showed an additional weak peak at 716 cm^{-1} , indicating a calcite phase in addition to aragonite, while spots b, j, and k showed very weak mineral peaks due to higher organic content in those regions. Spectra are baseline corrected and offset vertically for clarity.



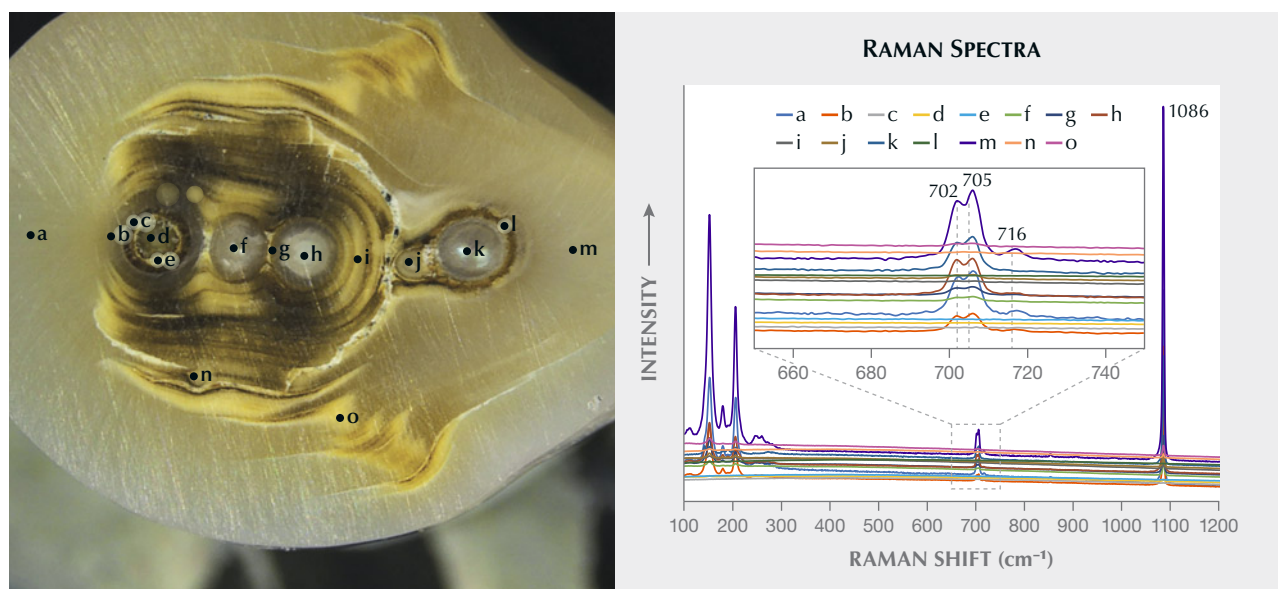


Figure 8. Left: Cross section of pearl D-4 with spots marked for Raman spectroscopy. Photo by Nishka Vaz; field of view 4.5 mm. Right: Raman spectra collected with an 830 nm laser from pearl D-4 on indicated spots, showing peaks of varying intensity at 1086 cm^{-1} , 701/705 cm^{-1} , and 100–280 cm^{-1} , indicating the presence of aragonite. Spots a, b, g, h, and m showed an additional weak peak at 716 cm^{-1} , indicating a calcite phase in addition to aragonite. Spectra are baseline corrected and offset vertically for clarity.

CONCLUSION

NBC pearls from the *Pinctada maxima* mollusk tend to have a distinct appearance compared to those from most natural and cultured pearls from other *Pinctada* species. Their silky luster and often large sizes distinguish them from other pearls. While this mollusk is a source of both natural and cultured pearls, certain features are more often seen in cultured pearls, such as the texture and pattern of terrace structures formed by aragonite platelets in the nacre, concave bases with resinous patches of organic-rich material often exhibiting desiccation fissures, and small white subsurface spots from underlying seeds. These external features are helpful indicators to support other data used to identify a pearl's origin.

The internal structure seen in microradiographs can also provide valuable insights about the identity of a pearl. Certain features such as the texture of the rings in organic-rich concentric cores, the presence of a distinct calcium carbonate nucleus, seeds or globuli within the organic-rich concentric core, multiple cores and/or nuclei features, and off-round nuclei are strong indicators of NBC pearls from *Pinc-*

tada maxima. Additionally, supporting features such as white rings, step-down features, loose structures, desiccation fissures, distinct alternating light and dark rings, and very dark and patchy acicular radial cores are often considered signs that support an NBC origin.

It is noteworthy that the cores in the selected groups chosen for cross-sectional analysis exhibited similar structures in X-ray imaging and in cross section, with minor differences in appearance or texture of some areas of nacre or organic-rich regions. However, all the cores in the pearls studied seemed to contain a combination of organic-rich phases and calcium carbonate mineral phases, with a few pearls showing very weak calcite peaks in addition to strong aragonite peaks in the nacreous regions.

Whether natural or non-bead cultured, each organic-rich concentric core is unique. The factors discussed in this article represent only a few of the numerous features that must be considered while testing pearls. These structures encompass typical features that are representative of cores observed in many of the South Sea NBC pearls in circulation today.

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RECORDS FROM A LUXURIOUS PAST: GEM INVENTORY OF A SEVENTEENTH-CENTURY ARMENIAN MERCHANT

Sona Tajiryan

A rare 1688 probate inventory documents the extensive gem collection of Gregorio di Girach-Mirman (1612–1688), a prominent Armenian merchant active in Venice and Livorno, Italy. Originally written in Armenian and later translated into Italian, this archival record lists more than 100,000 gemstones, including diamonds, sapphires, emeralds, and pearls, as well as more than 1,700 kilograms of rough amber, garnet, lapis lazuli, and turquoise. Housed in the State Archives of Venice, the inventory offers a uniquely detailed window into the early modern luxury trade and highlights the global commercial reach of Armenian merchant families like the Girach-Mirmans. Drawing on this previously unstudied source, along with a broader set of archival documents from across Europe and Armenia, the present article reconstructs the world of seventeenth-century gem dealing and collecting. It argues that Armenian merchants were central figures in the global trade of luxury goods, operating alongside and sometimes in competition with better-known European contemporaries. The provenance and diversity of Gregorio's gem holdings, likely sourced from as far as modern-day Colombia, Sri Lanka, Iran, and Myanmar, attest to the geographic reach of Armenian trading networks and the sophistication of their market knowledge. By placing this inventory in its global and material context, the article contributes to ongoing discussions around early modern economic history, material culture, and global commodity flows across Eurasia and the New World. It demonstrates that gem inventories, often overlooked as solely bureaucratic and estate documents, can illuminate the complexity of merchant strategies, the transcontinental mobility of luxury goods, and the dynamics of status and prestige in the early modern period. Finally, one of the central aims of this article is to illuminate the inner workings of gem dealing in this period, including practices of sourcing and collecting, through a rare body of obscure commercial correspondence. These materials offer an exceptional view into a dimension of the trade that remains largely inaccessible and nearly absent from existing historiography.

Translated from an Armenian document dated July 21, 1688, a seventeenth-century gem merchant's inventory has recently come to light after languishing in a European archive for more than 300 years.¹ The Italian translation of the original probate document, which is unaccounted for, lists the gem collection of Gregorio di Girach-Mirman at the time of his death in 1688. (See appendix 1 at the end of the article for the English translation of the inventory.) Most notable are his emerald holdings: more than

10,000 loose stones totaling 5,021 carats, the largest of which weighed 172 carats, as well as 85 faceted emeralds with undocumented weights. According to the inventory, Gregorio also owned 89 carats² of loose and

See end of article for About the Author and Acknowledgments.

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¹Sebouh Aslanian provided the author with digital images of this booklet, which he photographed in Venice (see figure 2). The booklet is entitled *Mirman* and kept at Procuratori di San Marco, Misti, Busta 180/D, State Archives of Venice. For the purpose of this article, the booklet will be called *Mirman* from here on.

²It should not be assumed that carat weights recorded in the probate document would be equivalent to the current metric carat value, which was not adopted until 1907. Before then, each country had its own definition of a carat (Kunz, 1913; Zhengzhang, 1991). During the early modern period, the carat was far from a standardized unit, varying considerably from Asia to Europe and elsewhere. See Manutchehr-Danai (2019).



Figure 1. Gregorio di Girach-Mirman's inventory documents a wide range of gems traded during the seventeenth century, including emeralds, "balas rubies" (red spinel), sapphires, pearls, and turquoise (such as the examples shown here). Photo by Michael Creighton.

faceted rubies; 17 "balas rubies" (a misnomer for red spinel)³ weighing a total of 26 carats; an 84 carat "oriental topaz"⁴ (a misnomer for yellow sapphire); a blue sapphire weighing 174 carats, as well as another 16 carat sapphire; 94,915 pieces of cut turquoise and 92 pounds⁵ of rough turquoise; 431 pounds of rough garnet; 4,036 pounds of lapis lazuli; 801 pearls; and several bags of rough amber. Beyond the value, variety, quantity, and quality of gems, the significance of this

collection becomes more apparent when considering the historical and economic contexts in which he conducted the global trade of gems and other luxury goods more than 300 years ago (figure 1).

With the expansion of mining, European exploration, and the movement of people across continents, luxury commodities such as gems began circulating more widely in the early seventeenth century. As South Asian gems appeared with greater frequency in European collections and inventories, their stated or inferred provenance was also deemed important because of the perceived rarity of gems from particular regions. Given this, one might expect historians, gemologists, and other scholars to have abundant evidence of gem collecting, but primary source material on the movement of precious gems remains rare. This scarcity can be attributed to widespread smuggling⁶ during the early modern period

In Brief

- A rare and previously unstudied inventory recorded in 1688 in Venice documents more than 100,000 diamonds, colored stones, and pearls and more than 1,700 kilograms of rough traded and collected by Armenian merchant Gregorio di Girach-Mirman.
- A previously unexamined corpus of obscure commercial correspondence highlights the inner workings of early modern gem dealing, offering a window into an understudied dimension of the luxury trade.
- The wide range of gemstones sourced from multiple continents demonstrates the extensive reach of early modern gem-trading networks and their ability to assemble a remarkable portfolio of luxury commodities.
- Inventories are valuable sources for understanding merchant strategies, global commodity flows of gemstones, and the role of luxury goods in building status and prestige in the early modern world.

³Named after the Balaschia region (now Badakhshan) of northern Afghanistan (Schumann, 2009; Manutchehr-Danai, 2019; De Carvalho, 2024).

⁴For more on "oriental topaz," see Shipley et al. (1945) and Manutchehr-Danai (2019).

⁵Weights are approximate as the historical Italian pound (*libbra*) varied from 0.301 to 0.339 kilograms depending on region and trade (Zupko, 1981).

⁶Smuggling, at least in the early modern period, was not considered a crime. In fact, within the circles of private gem merchants, smuggling was encouraged to maximize profit and minimize protection costs. See Gottmann (2016, pp. 51–102).

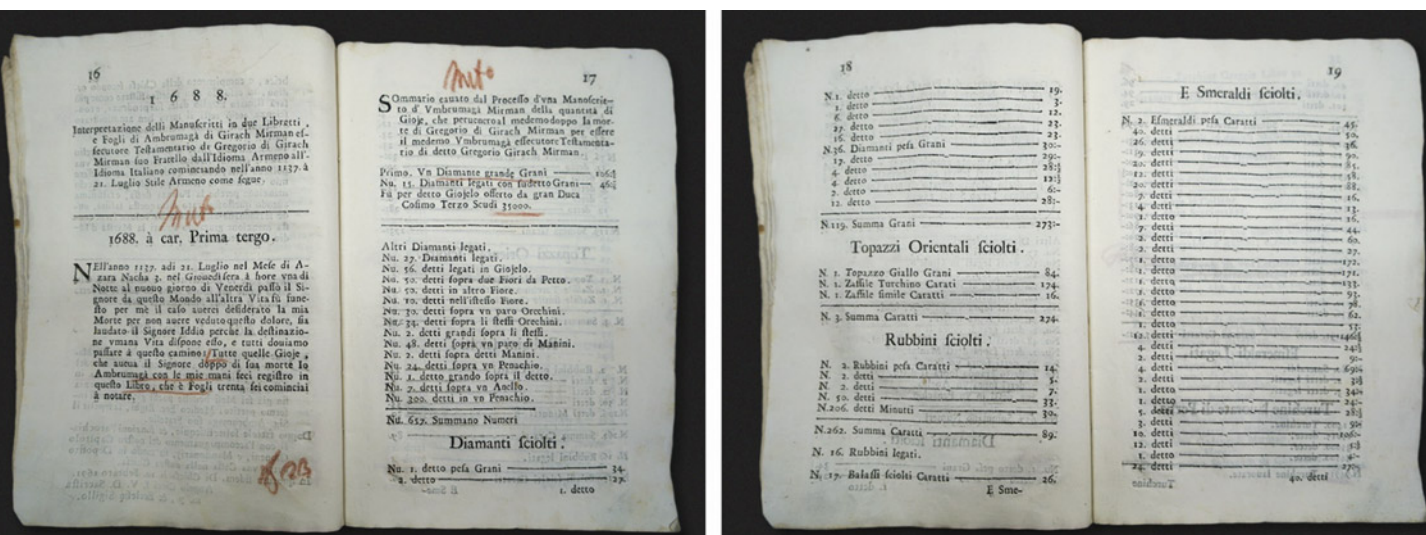


Figure 2. Folios from the printed Mirman booklet listing some of the gems in the inventory. Photos by Sebouh Aslanian; courtesy of Procuratori di San Marco, Misti, Busta 180/D, State Archives of Venice.

(approximately 1500–1800) and the fact that traders often kept their dealings concealed for safety.

This inventory is only one of the many documents included in the undated booklet (figure 2), which was translated and printed in Italian sometime during the eighteenth century and housed at the State Archives of Venice. Consisting of 187 pages, the booklet includes various family-related business and legal documents, Gregorio di Girach-Mirman's will written in 1687, and correspondence between Gregorio and his brothers, Ėmbrumagha and Zaccaria. The booklet was likely produced, according to historian Sebouh Aslanian, "for the benefit of assimilated family members [of the deceased] who had lost touch with their roots and could no longer understand the language used by their ancestors only a generation or two before."⁷

History of Material Culture Through Inventories.

Over the past century, the emergence of material history has highlighted how objects and artifacts can provide unique insights into the everyday lives and practices of people in the past. Studies on the material culture of early modern Europe have relied heavily on the analysis of probate inventories preserved in archives across Europe and elsewhere.⁸ In recent decades, historians and other scholars have used such inventories to trace the details of the economic and social aspects of early modern people.⁹ Their material lives and belongings provide historians with a unique opportunity to move beyond strictly textual sources. In fact, material "things" have been described by global historians as more

mobile than people themselves (Riello, 2022, p. 195) and are therefore deemed extremely useful in studying the circulation of commodities, trade, and travel (figure 3).

Probate inventories in Europe were usually drawn up after a person's death for legal and administrative purposes, either by notaries or in some cases their next of kin (Riello, 2013, p. 130). These documents listed the possessions of the deceased, with descriptions and occasionally the monetary value of the items. Whether drawn up because of death, legal matters, relocation, or any other major life event, these inventories offer a wealth of information about the owners, their social practices, commercial and cultural activities, fashion, style preferences, and, most importantly, the consumption patterns of a particular time and place.

⁷The inventory was translated into Italian from the New Julfan mercantile dialect of Armenian, the primary language used in the correspondence of the trade network. See Aslanian (2022, p. 93).

⁸Scholarly literature on early modern European consumption and material history, as well as probate inventories and their utility for historians and others, is extensive. For a few examples, see Wills (1993), Burke (1993), Findlen (2013), and Riello (2013).

⁹Due to only very recent contributions to research on the history of the Armenian gem trade, documents such as Gregorio's inventory have not been examined from a gemological angle. As comparison, see the inventory from 1707 of gems and jewelry that belonged to the famed Sceriman family of Armenian merchants, kept at the State Archives of Padua (Archivio Sceriman, b.27, jase. M, pp. 15–20) and also published as an appendix in the exhibition catalog *Gli Armeni in Italia* (1990–1991), edited by Boghos Levon Zekian, pp. 245–247. For more on the Sceriman family, see Bonardi (1990, 1996).



Figure 3. This astrolabe was produced in 1699 by Ghukas Vanandetsi, an Oxford-trained Armenian intellectual and philologist who also authored a comprehensive manual for young Armenian merchants. The astrolabe's intricate design and technical sophistication reflect the growing importance of navigation and distance calculations within Armenian mercantile culture during Vanandetsi's lifetime. Courtesy of the National History Museum of Armenia.

European archives are inundated with inventories of household items, books, furniture, works of art, weapons, and other items people considered valuable. Jewelry and art historians have also made extensive use of medieval and early modern inventories of crown jewels from different courts to draw inferences about elite tastes and the evolution of jewelry art.¹⁰ Many inventories contain mixed categories of belongings, including gems and jewelry. One such example is the inventory of gems belonging to the wife of Emmanuel Ximenez (1564–1632), a Portuguese merchant-banker residing in Antwerp. The Ximenez family traded popular commodities of the time from the New World, South Asia, Europe, and West Africa. Precious gems, including pearls, were also part of their portfolio. In 1617, an inventory of the marital property of Emmanuel and his wife, Isabel da Vega, was drawn up upon her death. The inventory included loose and mounted gems and jewelry (mostly hat ornaments) containing diamonds, pearls, and rubies.¹¹ Another example comes from seventeenth-century Dutch silversmith Jan Herck (1593–1660), with an inventory recorded after the death of his wife. Along with paintings, tapestries, and statuettes, they owned more than a thousand diamonds and some 1,500 pearls (Rijks, 2019).

It is extremely rare, however, to find a specialized inventory such as that of Gregorio di Girach-Mirman. Gregorio's gem inventory includes items that

are seldom documented in standard probate records, offering a glimpse into the inner world of gem dealers or collectors from the past in order to understand “the intentions of the owners of the goods described” (Riello, 2013, p. 126). Gem inventories, if found and analyzed at a large scale, are valuable sources for gem and jewelry historians in identifying consumption habits.

In the discussion of luxury commodities, it is important to avoid generalizations. While luxury was “central to the global history of consumption” (Berg, 2004, p. 93), access to buying, selling, wearing, or otherwise dealing with luxury commodities in the early modern period was limited to a very small group—mainly elites and royalty. Another shortcoming of highly curated inventories lies in the context in which they were created. They can reveal preferences, lifestyles, and taste, translating “material things into linguistic statements” (Keating and Markey, 2011, p. 209). However, their potential worth is much greater when considered alongside other archival documents to provide a broader picture. In

¹⁰The literature on European crown jewels is too vast to comprehensively cite. A few key publications include Angelucci (1861), Bapst (1889), Twining (1960), Meen and Tushingham (1969), Prince Michael of Greece (1983), Blair (1998), and Keay (2011).

¹¹See the translation of Ximenez's 1617 inventory at <https://ximenez.unibe.ch/inventory/reading/>. For a discussion of the jewelry, see Siebenhüner et al. (2014).



Figure 4. The Girach-Mirman family tree. Courtesy of the Matenadaran State Repository of Ancient Manuscripts, Manuscript 372.

the case of Gregorio di Girach-Mirman's gem inventory, fortunately, accompanying sources such as legal documents, a book of nobility containing the Girach-Mirman family tree (figure 4), accounting ledgers, and business correspondence complement and contextualize the story of this important early modern gem merchant.

GREGORIO DI GIRACH-MIRMAN'S LIFE AND THE FAMILY NETWORK

According to the inscriptions on his tombstone,¹² Gregorio di Girach-Mirman was born in 1612 and passed away in 1688. He was born in the Armenian quarter of Isfahan, the capital of the Safavid Empire, to one of the most prominent Armenian trading families in New Julfa.¹³

Gregorio spent his adult life in Venice and Livorno and owned multiple properties in prime locations throughout Italy. His four-story apartment in Venice was located near the church of San Basso and a minute's walk from Saint Mark's Basilica. He also owned two houses in Livorno and an estate in Tuscany given to him by the Grand Duke of Tuscany, Cosimo III de' Medici (figure 5).¹⁴ Gregorio started the Italian branch of the Mirman family and had likely settled in Venice by 1664. He served as an envoy of the Safavid Shah Suleiman in Italy, and the title "Agente Generale della Corte di Persia in Italia" appears beneath his name on the family tree (Seth, 1939, pp. 259–261). He also founded the Santa Croce Catholic Armenian Church in Venice (figure 6), which opened its doors in 1688 and remains in use today. His gem dealings likely earned him status in Italy, especially with the ruling Medici family in Florence. Gregorio died in 1688 after being ill for six months and was buried in Santa Croce.

The more than 100,000 gems and nearly 2,000 kilograms of rough Gregorio left behind might seem extraordinary at first. After all, only royalty or the most powerful elites could amass such wealth during this period. Yet Gregorio was one of dozens of Armenian merchants of his era who crisscrossed continents, carrying luxury commodities, particularly gems, as a central part of their caravans and maritime cargo. To understand Gregorio's trade network, it is necessary to first consider the pivotal role Armenian merchants played in the global gem trade of the early modern period.

The Girach-Mirman family was one of the most prominent New Julfan gem trading firms of noble

¹²The translation of his tombstone inscription in Armenian reads as follows: "This is the tomb of Grigor, son of Girach of the Julfa-born Mirman family, who passed away in Christ in the year 1137 [1688], on June 21." The Latin text translates to "Gregarious Girach Mirman, an Armenian of Persia, lived seventy-six years as a dove; he died as a swan in 1688; he shall live as a phoenix for eternity." (See figure 6C.)

¹³For Gregorio's detailed biography and more specifically his fluid religious identity, see Aslanian (2022).

¹⁴For details of properties mentioned in Gregorio's will, see Aslanian (2022).



Figure 5. Silver medallions commissioned by Gregorio di Girach-Mirman for the Grand Duke of Tuscany, Cosimo III de' Medici. The medallions depict Gregorio's portrait in a silk turban and Safavid robe rather than European dress, a notable ode to his Persianate identity. The reverse features the Agnus Dei (Lamb of God), with a beehive and honeypot at the base, likely symbolizing the wealth of the family capital, while bees may represent the family's extensive network of agents. Courtesy of Bargello National Museum, Florence.

ancestry in the late seventeenth and early eighteenth centuries. Based in both Italy and Safavid Iran, the Girach-Mirmans and their agents operated on the global gem trade routes between the three “gunpowder empires”¹⁵ of the early modern world—the Safavids, the Ottomans, and the Mughals—and the

¹⁵The three “gunpowder empires” during this time were the Ottoman, Safavid, and Mughal empires. The term was coined by historians Marshall G.S. Hodgson and William H. McNeill to emphasize the use of cannons and firearms in the expansion of these three empires from roughly the mid-sixteenth to early eighteenth centuries. See Hodgson (1974).

Figure 6. A: An ink-on-paper drawing of Santa Croce degli Armeni (Holy Cross Armenian Church) by Giovanni Pividor, a nineteenth-century Venetian painter and draftsman. This church symbolizes the close relationship between the Republic of Venice and the Armenian merchant community. Courtesy of Museo Correr, Venice. B: The church's interior features biblical scenes, as well as a depiction of the baptism of Armenian king Tiridates III by St. Gregory the Illuminator. C: Within the church, the tombstone of Gregorio di Girach-Mirman bears the family coat of arms. Photos by Sona Tajiryan (B and C).



consumer markets of the Mediterranean, Russia, and northern Europe. The firm's commercial reach extended from the 1650s until the early 1700s. As one historiographer of New Julfa wrote of a Mirman family member, his "arms of commerce stretched to Europe, Astrakhan and Gilan" (Hovhaneant's, 1880, p. 139). Gregorio di Girach-Mirman, as mentioned earlier, was envoy of the Safavid Iranian court to Italy, a fact recorded in the Girach-Mirman family tree (again, see figure 4) and confirmed by an official certificate preserved in the family's book of nobility.¹⁶ Gregorio's brother Ėmbrumagha, the executor of the will containing the gem inventory, was the King of Iran's agent in Asia.

The Girach-Mirman coat of arms, also contained in the book of nobility, portrays a crown atop a double-headed eagle (figure 7). The crown is set with diamonds and rubies, a symbol of their deep involve-

ment in the gem trade. In the middle is a beehive with a swarm of bees overhead, probably symbolizing the family's extensive trade network. Crossing long distances to sell gems and other early modern commodities, these "bees" put the family's capital to work, returning high profits to the "honeypot" of the extended family. One of the most useful sources on the commercial activities of the Girach-Mirman family is the accounting ledger of one such agent, Hovhannes Ter-Davt'ian¹⁷ (figure 8). Ter-Davt'ian started recording his journal in 1682 when he left New Julfa for Surat in India aboard the Armenian vessel *Sleman*, sailing from the Persian Gulf port of Bandar Abbas. Ter-Davt'ian was given an initial capital of 250 tumans¹⁸ in commodities, including red and green English broadcloth and cash worth 2 tumans and 8500 dians (currencies used in the Safavid Empire), given to him by his masters, Gregorio's brothers Zaccaria and Ėmbrumagha. The profits were to be divided by a ratio of three to one: three parts to the Girach-Mirman family, and one part to Ter-Davt'ian.

While traveling to Asia, a region known for its diamonds and colored stones during this time, Ter-Davt'ian carried with him coral and amber from the Mediterranean and northern Europe. These two gems were particularly sought after in the Indian subcontinent. Throughout his journey, Ter-Davt'ian appeared to constantly trade in gems, acquiring new stones and selling those he had brought along. Between 1682 and 1693, he bought amber and about 32 kilograms of coral, intending to sell them in Tibet and other major Asian centers. The amber, likely originating from the Baltic Sea, was sold to the Armenian and other local merchants in Tibet in exchange for musk (Khachikyan and Papazyan, 1984, p. 32). Ter-Davt'ian spent five years in the Tibetan city of Lhasa before returning to India in 1691. Reaching Patna in northeast India in 1692, he bought precious stones, including emeralds, and did business with local merchants, who probably helped him in

Figure 7. The Girach-Mirman family coat of arms features a double-headed eagle surmounted by a gem-studded crown, alongside the Persian Lion and Sun emblem, long recognized as a central symbol of Iran, as well as the beehive symbolizing the wealth of the family capital. Courtesy of the Matenadaran State Repository of Ancient Manuscripts, Manuscript 372.



¹⁶Manuscript 372, folios 5v–6v, Mesrop Mashtots Institute of Ancient Manuscripts in Yerevan, Armenia. The author worked at this museum in the summer of 2017 and was able to acquire the digital copy of this family book that includes the coat of arms of the Girach-Mirmans, as well as their family tree and history. The book was also cited in Aslanian (2022).

¹⁷This ledger was introduced to the scholarly community when Levon Khachikyan wrote a short article about its discovery in Lisbon. See Khachikyan (1966).

¹⁸Iranian currency.

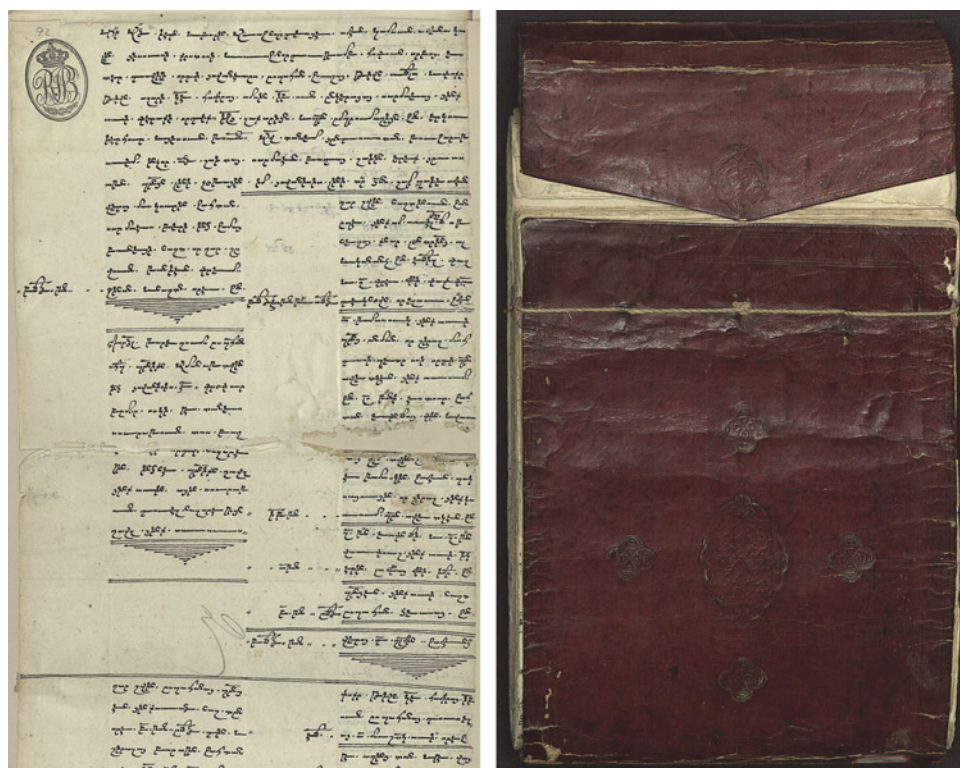


Figure 8. A folio and leather-bound cover from the accounting ledger of Hovhannes Ter-Davt'ian of Julfa, a leading agent for the Girach-Mirman family. The first folio serves as an introduction to the ledger and as the contract between Ter-Davt'ian and Gregorio's brothers, Ėmbrumagha and Zaccaria. The ledger reveals that Ter-Davt'ian continually acquired new gems and sold items from his stock as he traveled. Courtesy of the National Library of Portugal (shelfmark Cod. 7970, Arm).

selling emeralds, even transporting some all the way to Nepal (Khachikyan and Papazyan, 1984, p. 33). During the course of his travels, which ended in Hooghly (or Chinsurah) in West Bengal (where his accounting ledger entries end), Ter-Davt'ian traded amber, coral, lapis lazuli, emerald, spinel, pearl, and other commodities. His accounting ledger offers valuable insight into his multilayered gem dealing practices. Whether Ter-Davt'ian acquired most of his gems in Asia or received some from Gregorio's comenda agents in Europe remains unclear, as little research has been done on this aspect of his trade.

THE NEW JULFAN TRADE NETWORK AND THE GLOBAL TRADE IN GEMS AND OTHER LUXURY GOODS

The role of Armenian merchants in the long-distance trade of gems between the Mediterranean and the Indian Ocean during the seventeenth and eighteenth centuries is a new area of scholarly inquiry, despite the abundance of primary source material across different European archives. While research into the New Julfan Armenian mercantile network and its activities in early modern global commodity trade in general has been on the rise (Raveux, 2007, 2008, 2015), scholarly literature on their engagement in the global gem trade is almost nonexistent. Most studies

have focused on the role of Europe's East India companies, as well as the Sephardic and Ashkenazi Jewish networks, as the main long-distance players in the trade of South Asian and Brazilian diamonds as well as other gems in the Mediterranean markets of Europe.¹⁹

Small-scale enterprises of the early modern period, such as Armenian and Asian family firms and private merchants, conducted their trade against the backdrop of the first large European joint-stock corporations: the English, Dutch, Portuguese, and other East India companies. Unlike these state-chartered, vastly financed, and well-armed corporations, private gem merchants were vulnerable to abuses of power by customs officials, governments, and criminals over the long distances they crossed to conduct business.²⁰ Because of their small scale and the scarcity of archival sources on early modern Asian merchants and family firms—especially compared with the systematically archived correspondence of the East India

¹⁹For a few key works on the involvement of Jewish networks both independently and in the context of early modern East India companies in Europe, see Yogeve (1978), Mentz (2005), Trivellato (2009), and Vanneste (2011).

²⁰For a comparison of small Asian long-distance merchants and the European East India companies, see Aslanian (2015).



Figure 9. In 1604–1605, Shah Abbas I forcibly deported a large Armenian population from Old Julfa, a town on the Ottoman-Safavid border, as part of a broader strategy to strengthen the Safavid economy. Known for their expertise in the silk trade, these Armenian merchants were resettled near Isfahan in a new community they named New Julfa. Courtesy of Wikimedia Commons.

companies—these merchants went largely overlooked by historians until recently.

Most of the Armenian gem merchants lived in New Julfa, a community in Isfahan, the capital of the

Safavid Empire since the early seventeenth century. The New Julfan mercantile network emerged after the forced migration of predominantly Armenian silk merchants from Old Julfa, a town on the banks of the Arax River near the Caspian Sea, in 1604–1605 (figure 9). They were relocated approximately 1,000 kilometers away to Isfahan, the newly established capital of Safavid Iran. These deportations were part of Shah Abbas's larger "scorched-earth" policy during the Ottoman-Safavid wars of the seventeenth century, with the aim of regaining the lands that had been lost to the Ottomans at the end of the sixteenth century during the ongoing wars between two empires.

After resettling in Isfahan, the Armenians founded their own community in 1606 and named it New Julfa. As these merchants became more affluent, they commissioned and built churches in Isfahan and beyond (figure 10). The most prominent

Figure 10. A panoramic view of Isfahan in the early 1700s by Cornelis de Bruijn (1652–1726/7), a Dutch artist and traveler. Courtesy of Wikimedia Commons.

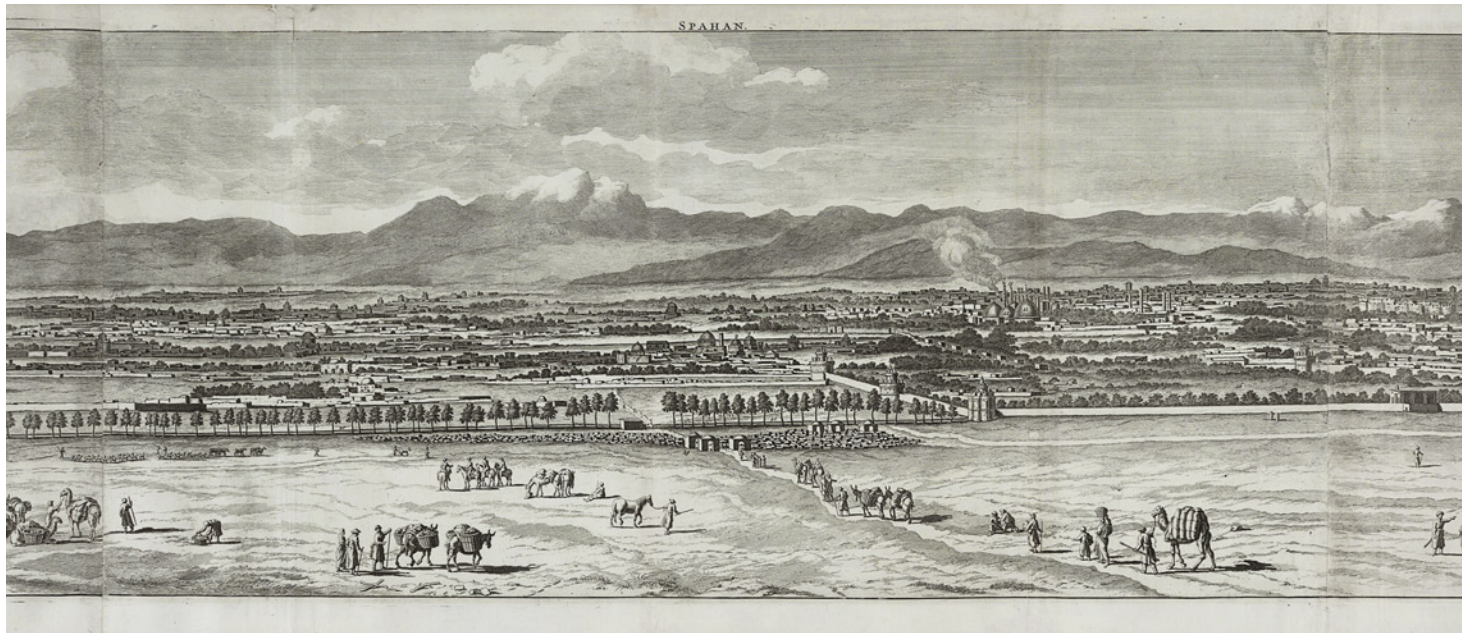




Figure 11. The churches and monasteries of New Julfa were mostly built with support from the merchant community and reflected their affluence. All Savior's Monastery (top) combines a dome similar to Islamic architectural styles with exquisite frescoes and gilded carvings (bottom). Scenes depict Creation, the life of Jesus, the suffering of Armenian martyrs, and floral motifs. Photos by Rasool Abbasi, courtesy of Wikimedia Commons (top), and Nane Khachatryan (bottom).

of these was All Savior's Monastery (figure 11), constructed between 1606 and 1664. Commonly known as Vank Cathedral, it stands today as a powerful symbol of the New Julfans' collective prosperity and their devotion to the Armenian Church. For centuries, it has served as a testament to Armenian faith and community within Iran (Landau and van Lint, 2015). As skilled silk merchants, the Julfans were

deemed instrumental by the Shah for expanding the Iranian raw silk trade into the Mediterranean and beyond. Drawing on their previous involvement in overland and maritime trade, the Armenian mercantile community of New Julfa established an extensive trade network that stretched east to Mughal India and Tibet; west to the Mediterranean and the European cities of Amsterdam, London, and

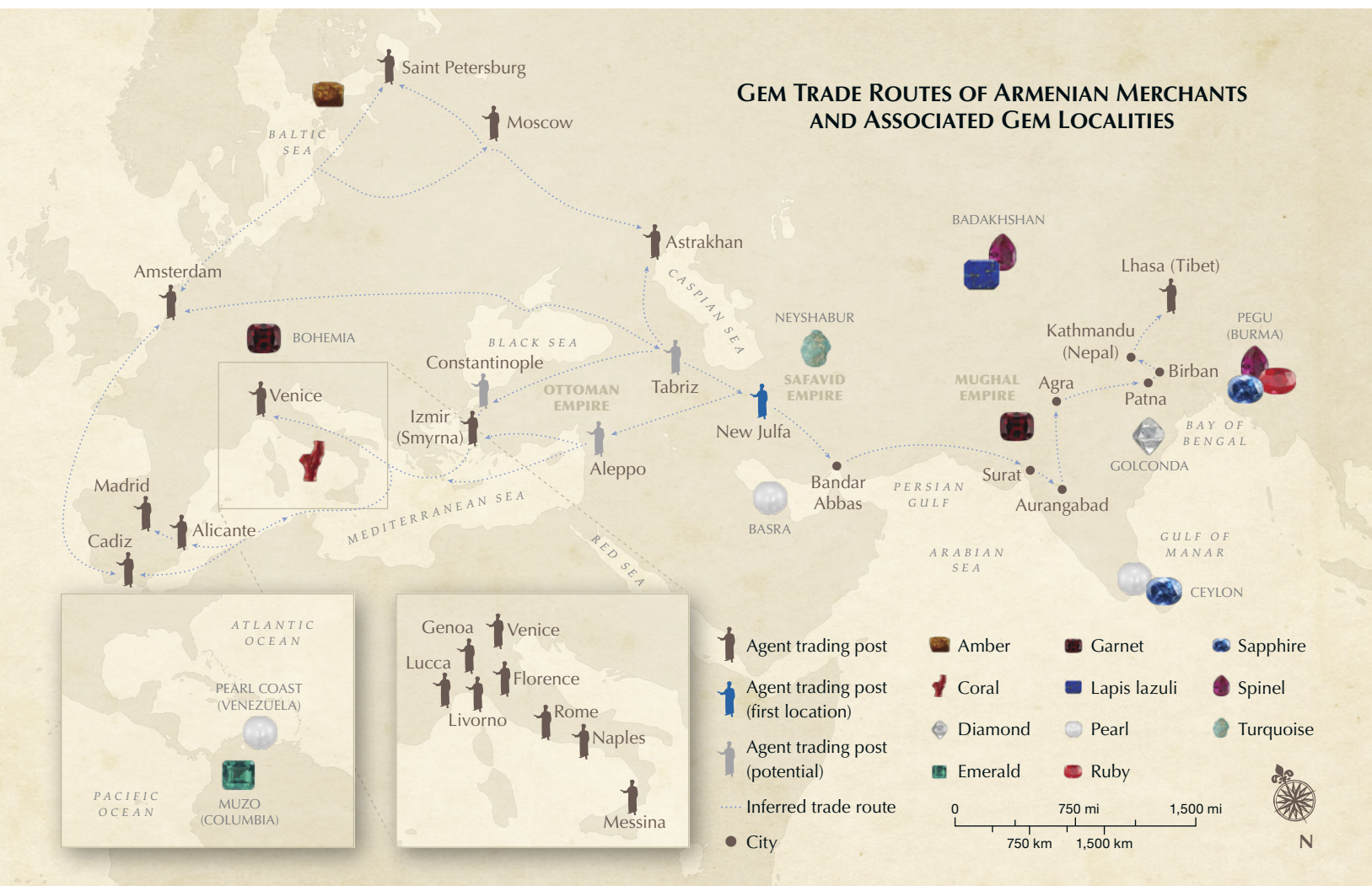


Figure 12. This map illustrates the principal trading posts of the Mirman family's commenda agents across Eurasia, as currently known from available archival evidence, as well as possible sources of the traded gems. This reconstruction remains provisional and will likely expand as further study of the family's commercial history is undertaken.

Cadiz; and north to the Russian Empire (figure 12). This network was maintained for roughly a century and a half.

These merchants and their family firms are vital to understanding the early modern global gem trade. Their business documents, written in a nearly extinct Armenian dialect, provide a unique glimpse into the largely hidden world of long-distance Asian merchants and family-owned trading companies. These global players had a much more important role in the oceanic and caravan worlds of South Asia and Europe than historians previously recognized, largely due to the scarcity of primary source material that could be accessed and interpreted.

Even in very recent scholarship on the economic history of New Julfa, gems are scarcely mentioned as

important commodities for this merchant network (figure 13). Historians have long considered the New Julfans as chiefly silk merchants. Shortly after settling in their new hometown, they won exclusive rights to export Iranian raw silk to Europe in 1619.²¹ However, recent studies demonstrate that Iranian raw silk and South Asian textiles were not their only trading commodities. Some Julfan families were involved exclusively in luxury goods such as gems. The three leading merchant families in New Julfa—the

²¹In a public auction organized by Shah Abbas, New Julfan merchants united to outbid the English East India Company for monopoly export rights on Iranian silk until the second half of the seventeenth century and beyond. See Herzog (1991), Matthee (1999), and Aslanian (2011).



Figure 13. Wealthy Armenian merchants combined European and Islamicate fashions to suit different social and commercial contexts. While frequently wearing silk turbans (left), they were also recognizable in bazaars and port cities by their triangular-shaped hats (right). The left image depicts Melcon di Nazar, a seventeenth-century Armenian merchant, while the portrait on the right shows a mid-eighteenth-century equivalent in Amsterdam. Courtesy of a private collection and Sebouh Aslanian (left) and Merujan Karapetyan (right).

Minasians, the Scerimans, and the Girach-Mirmans—were all significantly involved in the long-distance trade of gems (see Tajiryan, 2020).

Safeguarding the Transcontinental Flow of Gems. How did merchants such as Gregorio conduct their day-to-day business over these long distances, and what tools did they have at their disposal to safeguard their transactions? The two main factors in their success were a robust family organization and the use of “paper instruments”²² such as business, partnership, and legal contracts, as well as letters of recommendation and powers of attorney. As a trade network, the New Julfans operated through family firms. Merchants established these firms and hired traveling commenda agents who put the firm’s capital to work, crossing thousands of miles along caravan and maritime routes of South and Southeast Asia, the Russian Empire, and Europe. These family firms were the cornerstones of the New Julfan community. Thanks to this system, Armenian merchants in New Julfa maintained their mercantile network for more than 150 years, up until the 1750s. Alongside the first joint-stock corporations of the time, as well as the Sephardic and Ashkenazi Jewish mercantile networks, the New Julfans became important players in the global gem trade of the seventeenth and eighteenth centuries, even though only a small number of families were involved.

Gregorio and his brothers Ėmbrumagha and Zacaria established the Girach-Mirman family firm

(called *sark’ar*, Persian for “firm” in the New Julfan dialect) in 1656, when they pooled their funds in New Julfa. Gregorio was the executive manager of the firm, which survived for almost forty years, operating mainly from Italy, Spain, and Asia (Aslanian, 2022, p. 91). Together, the brothers employed at least 22 commenda agents²³ who traveled as widely as Tibet and Nepal, as well as to Alicante in Spain and the Italian cities of Livorno, Venice, Naples, and Florence, which were main nodes in their network. The Girach-Mirman agents and their extended network of correspondents traded in diamonds, colored stones, pearls, and amber, as well as mirrors, Venetian glass, wheat, and other popular commodities. Based on Gregorio’s inventory, it appears the Girach-Mirmans built their wealth primarily through dealing in precious gems, some of which they had brought with them from Iran to Italy in the 1650s.

Commenda Contracts and Agents. Wealthy merchants like Gregorio often employed commenda agents who traveled on their behalf. The growth and success of the New Julfan mercantile network depended on this partnership contract. The commenda was a bilateral contract, typically between a

²²This is Aslanian’s term to describe the different legal documents used by New Julfans to organize and conduct their trade. See the chapter titled “Paper Instruments” in Aslanian (2023).

²³The number of agents is recorded in the *Mirman* booklet on folios 21–22.

merchant who had ready capital or merchandise and an agent with commercial skills and a trusted reputation (Aslanian, 2007). These agents were usually selected by the wealthy partner, or *khwāja*, of a family firm and chosen from a pool of skilled young merchants at the beginning of their careers. It was the combination of commenda agents, the capital provided by wealthy merchants, and—more importantly—the circulation of vital commercial information through timely and systematic correspondence that made the trade in gems possible.

Commenda agents facilitated the circulation of gems and other commodities through their language skills and business knowledge. They carried expensive diamonds, colored stones, and pearls along maritime and caravan trade routes and across European borders. The commenda partnership was at the heart of New Julfan extended households or family firms. At least four commenda agents for the Girach-Mirman family operated in Europe. Herapet di Martin²⁴ played a pivotal role in the firm's gem trading activities in Venice, which was arguably the most significant part of the Girach-Mirman family's diverse portfolio, along with the Venetian mirror glass that was shipped to Alicante and Madrid (Aslanian, 2022, pp. 92–93).

The other three agents in Europe mentioned in the *Mirman* booklet are Paulo di Tadeo, Sanasar, and Amirbēk di Vardan. The latter also served as executor of the will for Gregorio's brother Ėmbrumagha. Vardan's correspondence, comprising about a hundred documents exchanged with Herapet di Martin, is preserved in the Avogaria di Comun archives.²⁵ A larger body of business letters between Martin and Vardan, together with correspondence from several other Girach-Mirman commenda agents, is housed in two dossiers under the Documenti Armeni Mercantili collection at the State Archives of Venice.

One of the dossiers (Busta 2) contains more than 50 letters from Vardan and fellow agents such as Martiros di Sarkis, who was based in Livorno. These letters were dispatched from Florence, Naples, and Livorno to Martin in Venice between 1680 and 1706, reflecting the wide geographic spread of the Girach-Mirman commercial network across Italy's main port cities and trade hubs. The most substantial portion of the correspondence, which documents the family's gem-trading activities, is preserved in Busta 3. This dossier contains copies of hundreds of letters sent to and received by Martin, dating from the 1680s but concentrated mainly in the late 1690s and early 1700s, underscoring the central role of Venice as the

European node in the Girach-Mirman trading system. A much smaller archive of 17 letters belonging to Martin is kept in London at the British Library.²⁶ Even a preliminary look at these documents reveals a wealth of information about large gem shipments to Venice from different Italian cities, as well as from the Ottoman Turkish port of Izmir, a probable transit point for Asian gems from Iran and India.

FROM MINE TO MARKET: GEM PROVENANCE IN GREGORIO'S INVENTORY

The gem inventory of Gregorio di Girach-Mirman, compiled after his death in 1688 and recorded by his younger brother Ėmbrumagha as the executor of Gregorio's will,²⁷ is a testament to the family's deep involvement in the global gem trade. The Girach-Mirman family likely engaged in the trade even before their move to Italy. According to Mesrop Ughurlian, who chronicled the Armenian presence in Livorno, the Girach-Mirman family brought precious stones with them from Iran (Ughurlian, 1891).

The inventory does not specify the geographic origins of the gems, except for the turquoise stones, which are explicitly identified as Persian. Although the provenance of Gregorio's other gems is not recorded or may have been omitted during the translation of the inventory into Italian, it is still possible to infer their likely places of origin based on contemporary gemological knowledge and patterns of global trade, as will be discussed later. Determining the origin of these gems is complicated by several factors: the lack of documented information in historical records, the possibility that relevant details remain unavailable or unrecognized, and the potential confusion arising from the terminology used by early modern gem dealers.

The inventory in discussion and its portfolio of gems listed reflect only the world of a single merchant. Whether Gregorio assembled these gems for personal use or for sale (or both) remains unclear, although colored stones notably outnumber diamonds and pearls. This imbalance may have

²⁴This transcription of the name is based on the spelling used by Herapet di Martin himself in a bill of exchange, written in Venice on March 20, 1702.

²⁵The Avogaria was the office of public prosecutors in the Republic of Venice responsible for safeguarding the rights of the city's noble families.

²⁶Oriental MS 15794, British Library.

²⁷Drafted in January 1687, less than a year before his passing, through a public notary in Venice. See Aslanian (2022, p. 93).

reflected either personal preference or broader market conditions at the time; a single inventory cannot resolve this question. For major gem dealers such as Gregorio, however, the possession of an exceptional collection likely functioned as a marker of social status and prestige, a pattern that remains evident among modern dealers.

Emeralds. The gems most prominently featured in Gregorio's portfolio were emeralds. Historically, the best-known emerald deposits since Ptolemaic and Roman times were in Egypt, mainly in the Gebel Zabara and Wadi Sikait regions (figure 14) of the eastern Egyptian desert between the Nile River and the Red Sea (Cailliaud, 1822; Floyer, 1892; Schneider and Arzruni, 1892; Harrell, 2004; Schmetzer, 2021, p. 338). While Egypt supplied the bulk of the world's emeralds until the late sixteenth century, these stones were small and of lower quality (judging from examples that have been preserved in collections or treasuries).

Gregorio's emeralds were probably from Colombia, the main source of higher-quality emeralds during this time. These began arriving in European markets, particularly Seville, by the beginning of the sixteenth century (Pogue, 1916, 1917).²⁸ Following the Spanish arrival in the Americas in 1492, the Colombian emerald trade soon expanded. Emeralds were shipped west across the Pacific aboard the famous "Manila galleons" (figure 15), departing from



Figure 15. Manila galleons were large Spanish ships that sailed the vital trade route between Manila and Acapulco in the 1700s. They represented a significant step in early globalization, connecting Europe, Asia, and Africa with the Americas across the Pacific Ocean. Courtesy of Wikimedia Commons.

Acapulco to Manila (Schurz, 1939) and then onward to Goa before ultimately reaching Europe. Another well-established route ran from Cartagena to Seville,

²⁸For a useful chronology of Colombian emeralds, their mining, and trading, see Sinkankas (1981).

Figure 14. Left: Egypt's Wadi Sikait mine was the premier emerald source in Greek and Roman times, but much higher-quality Colombian emeralds took over the market by the 1700s. Courtesy of Wikimedia Commons. Right: Egyptian emeralds are featured in this ancient Egyptian necklace from around 100 CE. Beads of emerald alternate with gold, glass, quartz, amethyst, and faience. Photo by Robert Weldon; courtesy of the Royal Ontario Museum, Toronto.

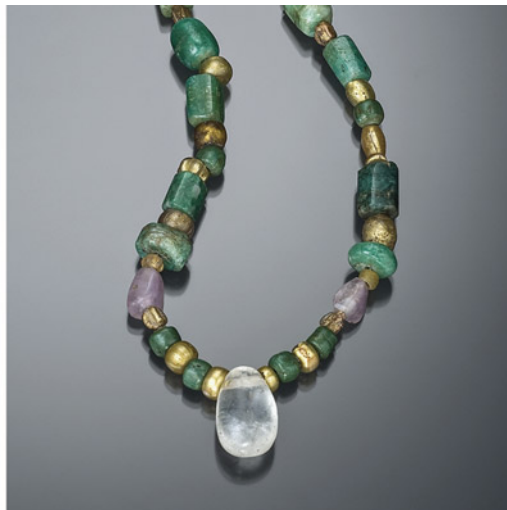
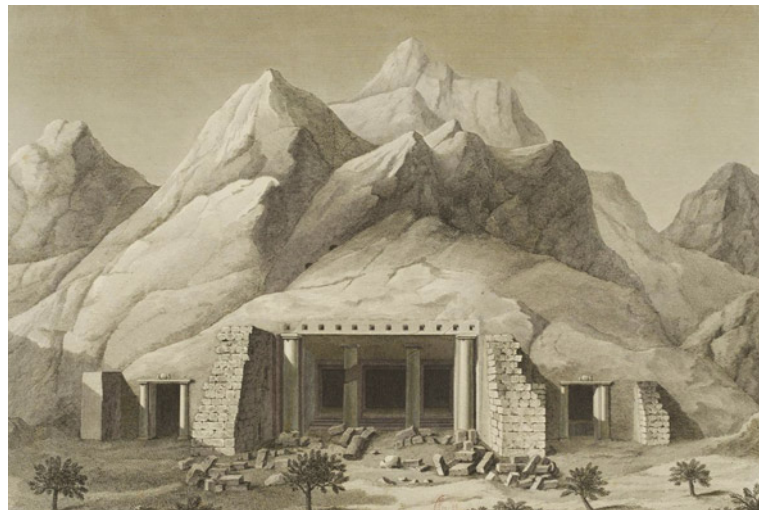




Figure 16. Left: Colombia's Muzo mine has produced high-quality emeralds since the mid-sixteenth century. Photo by Peter Keller. Right: The emerald gold rosary, recovered from the wreckage of the *Nuestra Señora de Atocha*, showcases the craftsmanship of Spanish jewelers and provides a "time capsule" for historians and gemologists studying colonial wealth and trade. Photo by Robert Weldon; courtesy of Ellen Weatherbee.

with stops in Havana or the Azores. It is possible that the Girach-Mirmans bought their Colombian emeralds through both routes.

Because gem shipments were often secretive or involved smuggling, tracking their volume can be exceedingly difficult, if not impossible, for modern historians. Nevertheless, historians and geologists have access to sporadic evidence suggesting that the circulation of Colombian emeralds was extensive. For example, oxygen isotope ratio analysis conducted by one group of mineralogists indicated that in the beginning of the seventeenth century, emeralds from the Muzo mines in Colombia were being transported to both Europe and Asia on a significant scale. In the study, an analysis of four emeralds from the eighteenth-century treasury of the Nizam of Hyderabad in India determined that three of them originated from the "western emerald zone of Colombia," and one from Afghanistan's Panjshir Valley mines (Giuliani et al., 2000). Unfortunately, no reliable historical data supports the study's claim that Panjshir Valley emeralds were used in Indian jewelry as early as the seventeenth century. These emeralds may have been swapped in at a later time—perhaps the twentieth century, when Afghan emeralds were readily available in global markets.²⁹

Some European merchants, such as the Helleman family in Antwerp, whose trading network spanned the Atlantic, bought emeralds directly from the New World. The Hellemans, mainly through their branch

in Seville, had dealt in emeralds since at least 1586 (Anderson, 2019, p. 75). The Hellemans were at the forefront of receiving South American gem shipments flowing into Europe, mostly under the auspices of the Spanish Crown.

One example that demonstrates the scale of the global circulation of gems during this time is the Spanish treasure galleon *Nuestra Señora de Atocha*. This ship, capable of transporting 500 tonnes of cargo, left Havana for Spain in September 1622 but sank during a violent storm only a day after embarking. The *Atocha* was carrying about 32 kilograms of Colombian emeralds and emerald and gold jewelry, along with other commodities, such as gold and 40 tonnes of Bolivian silver. The *Atocha* shipwreck was discovered near Key West, Florida, in the 1970s, and the emeralds salvaged from it are considered some of the most beautiful to emerge from the Muzo mines (figure 16). In addition to seven rough emeralds, several other objects recovered from the *Atocha* wreck were analyzed by GIA researchers, including a rosary and crucifix set with nine emeralds, two emerald-set rings, and a gold brooch set with a step-cut emerald, among other items. They were all confirmed to have Colombian origin (Kane et al., 1989). The discoveries from the *Atocha* offer a dramatic example of the

²⁹For a more recent comprehensive study of emerald geology and localities, see Giuliani (2022).

global trade in gems during the early modern period. Never before had luxury commodities traveled such long distances.

Gregorio's emerald-rich inventory could also reflect simple economics: During the seventeenth and eighteenth centuries, emeralds arguably fetched their highest price in India. Considering that the Girach-Mirman family had extensive business operations there, Gregorio probably sent most of the firm's emeralds to India, where demand and prices were higher (Lane, 2010, pp. 240–244). As early as the mid-1500s, high-quality Colombian emeralds were inundating the markets of Europe and Asia. Ironically, the inferior Egyptian emeralds commanded much higher prices, probably because Colombian emeralds were oversaturating the market.

Juan de Arfe y Villafañe (1535–1603), the Spanish court jeweler of Philip II, wrote a book in the sixteenth century containing detailed price comparisons for diamonds, rubies, spinel, and more importantly for old and new emeralds. His price lists clearly indicate the price difference between “*esmeralda vieja*” (old-mine emeralds from Egypt) and “*esmeralda nueva*” (new emeralds from South America), the latter selling for half the price (Arfe y Villafañe, 1572, pp. 48–49, 51–54). In the first half of the eighteenth century, 150 years later, Armenian gem dealer Aghamal Khwāja Minasian noted that Egyptian emeralds, which he called “old” or *ṣaʿīdī* emeralds (*ṣaʿīd* in this context also refers to Upper Egypt), sold for higher prices than the “new” ones from Colombia.³⁰ Egyptian emeralds, judging from examples preserved at museums around the world, tended to be of lower quality and more opaque than those from Colombia. Even in the early modern period, gems with fewer flaws and inclusions were preferred. While it is possible that some high-quality, so-called “old-mine” Egyptian emeralds were in circulation during this time, evidence suggests that labeling an emerald as “old-mine” was a marketing strategy to command a higher price. This designation often misrepresented the gems' true provenance; in reality, many of them came from the New World.

Whether Gregorio's emeralds were Egyptian, Colombian, or a combination of the two is difficult to determine. Surviving correspondence suggests, however, that Girach-Mirman agents Amirbēk di Vardan and Herapet di Martin bought at least some of the emeralds in the markets of Venice, Naples, Florence, and Livorno, along with pearls, turquoise, and diamonds. In a 1694 letter to Vardan, Martin lamented the shortage of high-quality emeralds in the market:

Let it be known to your highness that in the letter of mercy from June 25th... you had written about Mr. Zak'ar's [Zaccaria's] emerald and ordered the purchase of a small, good [quality] emerald. The issue is that there are no middlemen left from whom I have not placed orders, nor merchants whom I have not consulted; there are simply no good [emeralds]. There are clear ones, but they are pale, lack clarity, and are large.³¹

Throughout the Girach-Mirman agents' correspondence, finding emeralds of desired size and quality seemed to be a constant challenge.

Recent advances in gemological, chemical, and spectroscopic analyses of both loose and set gemstones housed in museum collections have raised the possibility that emeralds from the Swat Valley in present-day Pakistan were in circulation as far back as the early modern period (Gilg et al., 2025).³² If Swat emeralds were indeed mined prior to 1958, the year of their official discovery (Gübelin, 1982), their presence in early modern gem markets would be plausible, given the region's integration into long-distance trade routes and the broader circulation of luxury commodities during that era.

It is also possible that some of the Girach-Mirman agents' emeralds came from the Habachtal region in Austria,³³ given the proximity to Italy and the firm's extensive local network of merchants, middlemen, and gem suppliers there. While there is no documentation of large-scale mining activities in Habachtal in the 1690s, when most of the correspondence between the two Girach-Mirman agents was created, a small number of Austrian emeralds may have reached the European markets.

³⁰See Aghamal Khwāja Minasian's entry on emeralds from the first half of the eighteenth century in his unpublished manuscript, written in Armenian and preserved at the Mesrop Mashtots Institute of Ancient Manuscripts in Yerevan, Armenia, MS 5994, folio 11. See also Lane (2010, pp. 240–244).

³¹Letter from Amirbēk di Vardan (in Naples) to Herapet di Martin (in Venice), written on July 14, 1694. Letter N174, Documenti Armeni Mercantili collection, Busta 3, State Archives of Venice.

³²A recent gemological analysis of the Imperial Crown of the Holy Roman Empire from the early sixteenth century, preserved in the Imperial Treasury in Vienna, suggests that two of the twenty emeralds set in the crown may originate from the Swat Valley in present-day Pakistan. As with any gemological analysis, it is important to note that the identification of a geographic origin does not necessarily imply that a given source was actively exploited at the time the object was created. It is also necessary to consider the possibility that certain gemstones were replaced or reset at a later date, which may account for their attributed origin. Further gemological and historical research is therefore required to arrive at more definitive conclusions.

³³For more on the history of emerald mining in Austria, see Schmetzner (2021, 2022).



Figure 17. Left: Until diamonds were discovered in Brazil around 1725, India's Golconda mines were virtually the only source. Golconda's diamonds were crucial to the British East India Company trade and were coveted by Mughal emperors and European royalty alike. Courtesy of the National Library of France. Right: This European gold and enamel hat ornament from the 1600s, accented with table-cut diamonds likely recovered from the Golconda mines, shows how these gems also adorned more modest pieces. Photo by Harold and Erica Van Pelt; courtesy of a private collection.

Jewelry Pieces and Diamonds. Among the items listed in Gregorio's inventory were numerous jewelry pieces, most notably 85 gold rings set with diamonds, emeralds, rubies, and other gems. Of particular interest is a diamond weighing $106 \frac{3}{4}$ carats,³⁴ described as "Un Diamante grande Grani $106 \frac{3}{4}$." This diamond is followed by 15 others, together weighing $46 \frac{7}{8}$ carats. Embrumagha mentions that the Medici duke offered a fortune for those gems: "35000 Scudis³⁵ were offered by the Grand Duke Cosimo Terzo [Cosimo III]."

Historical and gemological research has enabled scholars to identify the locations of the main gem deposits in the seventeenth and the eighteenth centuries. In the case of Gregorio's inventory, it can be said with certainty that his diamonds originated from the mines in the Golconda region of India (figure 17), with a slight possibility that some came from the island of Borneo. Until the early eighteenth century, these were the only two known diamond deposits (Howard, 1677; Heyne, 1814; Voysey, 1825; Ball, 1880, 1881).

Despite substantial offers, the Girach-Mirman family never sold these large diamonds to Cosimo III. It is believed that the Grand Duke of Tuscany even offered one of his "most remarkable" estates in

exchange for the largest diamond, but the offer was declined. Gregorio presumably claimed that the diamond served as entertainment for his sons, and he would not part with it for that reason (Pera, 1888, p. 210). Rumors in Livorno suggested that the Girach-Mirman family possessed a large diamond, possibly the 106.75 ct stone listed in the inventory, which was stolen during a nighttime burglary in 1716 from the residence of Petros Mirman and led to his killing (Ughurlian, 1891, pp. 203–204). Authorities searched but never found the diamond. According to a later account, this diamond ended up on the crown of the Imperial House of Austria (Pera, 1888, p. 210), though this claim lacks archival documentation and remains unverified.

³⁴The list of gems, written in Italian, uses "grain" instead of "carat" when describing this diamond. The author would argue that *grani* here refers to carats for two reasons. First, *grani* is used in place of carat multiple times in the document, with some gems listed in grains and the rest in carats. But at the end of each entry, the sum is always presented in carats. Second, it is known that the Girach-Mirman family owned an unusually large diamond, for which one family member was later killed. Converted to carats, a gem of $106 \frac{3}{4}$ grains would only equal about 30 carats—an average-sized stone.

³⁵*Scudo* (plural *scudi*) was a currency used on the Italian peninsula until the nineteenth century.



Figure 18. Ferdinando II de' Medici (1610–1670) and his wife, Vittoria della Rovere, were significant patrons of the arts, supporting painters, jewelers, sculptors, and musicians while accumulating vast collections of art, jewels, and decorative objects. Courtesy of Wikimedia Commons.

The Girach-Mirman brothers' standing as gem providers to the Medici court began even earlier. In 1684, Vittoria della Rovere (1622–1694), Grand Duchess of Tuscany and wife of Grand Duke Ferdinando II (figure 18), purchased 20 rough rubies for 285.5 ducats³⁶ from Gregorio. These gems likely decorated the “magnificent gold filigree crown encrusted with over six hundred precious gems: 412 diamonds, 114 rubies, 80 emeralds and surmounted by 5 large baroque pearls, as a gift to the Carmelite nuns” (Modesti, 2020). A close look at the images of the newly resurfaced

crown (figure 19) commissioned by the Grand Duchess for Santa Maria Maddalena de' Pazzi shows more than a hundred rubies.³⁷ No gemological studies or analyses have been conducted on the Carmelite nuns' crown, and it remains nearly impossible to verify the accuracy of the gemstones listed in the document.

³⁶An early European currency.

³⁷For a detailed look at the gems used in creating the crown, see Pacini (2010).



Figure 19. In 1685, Grand Duchess Vittoria della Rovere of Tuscany commissioned Giovanni Comparini and Giuseppe Vanni to create a jeweled crown in honor of Santa Maria Maddalena de' Pazzi. The crown is studied with 655 stones, including 412 diamonds, 80 emeralds, and 114 rubies. Thought to be lost during Napoleonic times, it was rediscovered in 2010. Courtesy of Ecclesiastical Heritage.



Figure 20. Left: The town of Mogok and its rubies were already legendary in the 1600s. These luxury gems—prized for their color, clarity, and mystical properties—became emblems of power and wealth, highly coveted by Indian Mughal emperors and European royalty alike. Photo by Vincent Pardieu. Right: This fine Mogok ruby crystal originates from the same famous mines. With the strong demand for ruby in finished jewelry pieces, it is rare to find high-quality specimens intact. Photo by Robert Weldon; courtesy of Bill and Jeanne Larson.

Rubies. Gregorio left relatively few rubies in his collection—just over a hundred—with some set in jewelry but most kept loose. The finest rubies during this time came from Burma (present-day Myanmar).³⁸ The Burmese mines are among the oldest ruby sources. The mines of the Mogok Stone Tract in north-central Burma (figure 20) have been producing for at least 800 years (d’Amato, 1833; Streeter, 1887; Gordon, 1888; Brown and Judd, 1896). The beauty of Burmese rubies was described by European travelers before Gregorio’s time, including Niccolò de’ Conti, Duarte Barbosa, Ludovico di Varthema, and Jean-Baptiste Tavernier. Evidence suggests rubies were being traded by European gem dealers as early as the seventeenth century,³⁹ though much research remains to be conducted on the ruby and sapphire trade across the centuries.

Spinel. Gregorio’s inventory also includes 17 “balas rubies,” which were actually spinel but frequently misidentified as rubies due to their reddish color (figure 21). These certainly would have come from the famed Badakhshan mines in the Safavid Empire, spanning portions of modern-day Afghanistan, Tajik-

istan, and China (Prinsep and Kalikishen, 1832; Ball, 1894; Pedani, 2002; Content, 2016). Armenian merchants from New Julfa not only differentiated between spinel and rubies (which they called “red sapphires” in Armenian) but also dealt extensively with spinel from Badakhshan in the latter seventeenth century, as shown in a few examples from the business correspondence of Armenian gem dealers like Gregorio. In one of the hundreds of letters written by Minas Minasian, head of the Minasian gem trading family of New Julfa, he noted sending three spinels from Iran or India to his agents in the Ottoman Empire, with the final destination in

³⁸Aghamal Minasian cites the Burmese mines of “Pegu” as the source of rubies. While the present-day city Bago in Myanmar was known as Pegu in the medieval and early modern periods, Armenians used “Pegu” to describe Burma as a whole, and that is probably what Aghamal meant. There is no record of ruby mining in Pegu itself, but rather in locations such as Sagyin, Mogok, and Naniazeik, some 300–650 kilometers away.

³⁹See Jacques de Coudré’s dealings in ruby and other gems in Lane (2010, pp. 129–130). For a brief description of Burmese and Sri Lankan rubies and their sourcing, as well as other gems in the Middle Ages and onward, see Schmetzer and Gilg (2020).



Figure 21. Left: Miners still work the ancient gem deposits in the mountains of Central Asia. Photo by Vincent Pardieu. Right: In the 1700s, spinel from Tajikistan and Afghanistan was the premier red gemstone, often mistaken for ruby. These gems were prized by royalty and valued for their exceptional size, brilliant color, and status as symbols of power and wealth throughout Asia and Europe. Photo by Emily Lane; courtesy of Edward Cleveland, KashmirBlue.

Livorno. In his letter from July 22, 1691, Minasian reported that three Badakhshan spinels had been dispatched, including a larger, high-quality stone weighing 45 carats and valued at 16 tumans, as well as a pair weighing 55 carats with a sale price of 14 tumans.⁴⁰ An expert such as Minasian would be able to distinguish between a ruby and a spinel (called *la'al*),⁴¹ which he described as the “red ‘stone’ of Badakhshan.” According to him, the finest spinel was “clear with water, inclusion-free, flawless” and “had the color of an onion.”⁴² Besides Tajikistan, the island of Ceylon (now Sri Lanka) was another traditional source of red spinel that may have passed through the hands of Armenian merchants (Gorghinian et al., 2013).

Sapphires. It was not until 1801 or 1802 that European mineralogists established ruby and sapphire as the two gem varieties of corundum (e.g., von Kobell, 1864, pp. 526–529). Before that, sapphires of different colors were often labeled as “Oriental” to denote their perceived “superior hardness” (Hughes et al., 2017). Hardness was the characteristic merchants

and lapidaries used to differentiate between gems of similar color, such as garnets and rubies.

Gregorio owned comparatively few sapphires, which seemed to be chosen for their size. His collection included a yellow sapphire, a common color for corundum, as well as blue sapphires. One of the blue sapphires weighed 174 carats, an impressive size by any standard. The origin of these sapphires is difficult to trace. Corundum mines were far more widely distributed across Eurasia than those for other gems

⁴⁰Manuscript 98, Busta 123, Documenti Armeni, Acquisti e Doni, State Archives of Florence.

⁴¹The New Julfan mercantile vocabulary was a combination of more than a dozen Eastern and European languages, including the Persian language of the host empire. Identifying gem names such as ruby, spinel, or garnet can be problematic due to the same word (*la'al*) being used to denote all three red stones. It is very important to look at the context of the source in which the stones are described to accurately translate them. See Melikian-Chirvani (2001, pp. 77–110).

⁴²Aghamal Minasian is probably referring to the purplish red color of red onions, as most spinels come in red, violet, and reddish purple. See Aghamal Khwāja Minasian, MS 5994, folios 11–12, Mesrop Mashtots Institute of Ancient Manuscripts.



Figure 22. Gregorio di Girach-Mirman's gemstone inventory very likely contained ruby and sapphire sourced from Central Asian mines. Possible sources include the ruby mines of Jegdalek, Afghanistan, which still supply the gem market in Kabul today (left), and the sapphire deposits of Afghanistan's Badakhshan Province, which reportedly provided the modern examples shown on the right. Photos by Vincent Pardieu.

(figure 22). The main sources in the seventeenth century were Burma, Afghanistan (first mentioned in the tenth century), Ceylon, and to a lesser extent, the Chanthaburi mines of modern-day Thailand (Hughes et al., 2017). The Sri Lankan corundum mines (figure 23) are among the oldest sapphire sources and may well have produced Gregorio's sapphires (Häuy, 1799; Mahroof, 1999; Dharmaratne, 2003).

Pearls. Pearls were also part of Gregorio's inventory, which describes them as "Oriental." Oriental pearls, according to G.F. Kunz, were found "in the true pearl-oyster, and have a marine or salt-water origin, being found either in the ocean or one of its adjacent tributaries, and belonging to one of the numerous species of the *Margaritiferae*" (Kunz, 1908, p. 351). In

the early modern period, pearls from both the Persian Gulf⁴³ and the Gulf of Mannar were categorized as "Oriental" to denote their very high quality. Most round natural pearls circulating in the Eurasian markets at the time would have come from the *Pinctada radiata* mollusks found in the Persian Gulf (Strack, 2006, p. 135), as well as the Gulf of Mannar fisheries, especially Thoothukudi (formerly Tuticorin) off the southern coast of India. Tuticorin was an abundant source of high-quality natural pearls. Yet compared with the "Basra" pearls from the famous fisheries of the Persian Gulf, Gulf of Mannar pearls have

⁴³For an overview of the history and archaeology of Persian Gulf pearls in the early modern period, see Carter (2012).

Figure 23. The island of Ceylon (now Sri Lanka) has been a significant source of gem sapphires and rubies since the third century BCE. Left: Miners today often rely on time-honored methods and tools, including the *mammoty*—a metal blade attached to a long wooden pole—to scrape away surface sand and overburden to scoop out the river gravels. Photo by Andy Lucas. Right: These gravels are washed and sorted to separate the gems. Photo by Vincent Pardieu.



received little attention in the historical context of the global gem trade (Strack, 2006, p. 138). The pearl fisheries located in the shallow waters between southern India and northern Sri Lanka were consecutively occupied by the Portuguese (1505–1658), Dutch (1658–1796), and British (1796–1948) empires, making them a much more integral part of the global trade than previously discussed.

The European markets also saw an influx of pearls from the Americas after Columbus' third voyage to the New World in 1498 (Bycroft and Dupré, 2019, p. 9). Fisheries located mainly along Venezuela's Costa de Perlas (Pearl Coast) became a major source of pearls for the Spanish and the Portuguese. Once transferred through Spain or Manila and arriving in the European markets, many of these Caribbean pearls (sometimes called "Portuguese") could be distinguished by their baroque shape or granular texture. It is highly plausible that some of the "Oriental" pearls circulating in the European markets, as well as in Gregorio's inventory, were Caribbean. Just as with the case of New World versus Egyptian emeralds, "Oriental" pearls identified as from the Persian Gulf (figure 24) and the Gulf of Mannar, appear to have fetched higher prices. Used arbitrarily by merchants and jewelers of the early modern period, the term *orient* could refer to a pearl's "general luster," its "historic association with the Far East," or simply its overall excellence (Warsh, 2018, p. 115). As with other gems, dealers' price-setting based on locality was highly arbitrary.

Figure 24. Most of the round natural pearls circulating in Eurasian markets during Gregorio di Girach-Mirman's time likely would have come from the Pinctada radiata mollusk, found in the Persian Gulf. These modern examples show the type of pearls prized by merchants centuries ago. Photo by Robert Weldon; courtesy of Ahmad Abdullah Alomaish Alajmi.



Figure 25. At more than 94,000 pieces, polished turquoise was the most plentiful item in Gregorio di Girach-Mirman's inventory. Most of this material likely came from the Iranian deposit of Neyshabur, a valuable source of turquoise for more than 5,000 years. The modern Persian turquoise tablet shown here is intricately engraved with an Arabic prayer. Photo by Robert Weldon; courtesy of Shaikha Haya bint Ali Al-Khalifa and Shaikha Marwa bint Abdulrahman Al-Khalifa.

Turquoise and Lapis Lazuli. The turquoise from Gregorio's gem collection came from Iran, as indicated in the inventory (figure 25). Unlike other popular colored gemstones during the early modern period, turquoise attracted little interest from Europeans. Symbolizing the color of Islam, the "celestial shade of blue," and representing imperial victory and power (Khazeni, 2014, p. 13), turquoise was highly valued within the Islamic world. It circulated extensively throughout the Mughal, Ottoman, and Safavid empires (Houtum-Schindler, 1884; Shirdam et al., 2021). Persian turquoise entered European markets mainly through the Ottoman caravan trade routes and was often used to decorate rings and other jewelry items.

Reliable information on the Eurasian intercontinental trade of turquoise in the early modern period has hitherto been very scarce due to the lack of primary source material. However, hundreds of archival documents left by the Armenian merchants of New Julfa provide ample evidence of substantial turquoise shipments from Safavid Iran to European cities such



Figure 26. Left: The lapis lazuli in Gregorio di Girach-Mirman's inventory undoubtedly came from the mines of Sar-e-Sang in Afghanistan's Badakhshan Province, the source of these modern examples. Photo by Eric Welch. Right: In Kabul today, these artisans fabricate lapis-inlaid bowls, the same type of work Mirman's agents would have encountered along this stretch of early modern trade routes. Photo by Vincent Pardieu.

as Venice and Livorno in the late seventeenth and early eighteenth centuries. For example, on May 25, 1700, Amirbēk di Vardan shipped (probably from Naples) 390 bags holding a dozen stones each to Rome to a Mr. Mkrtum, who was expected to forward them to Herapet di Martin, most likely in Venice or Livorno.⁴⁴

Persian turquoise was heavily represented in Gregorio's inventory: 94,915 cut pieces and 92 pounds of rough. Some, if not all, of the turquoise in Gregorio's possession would have come from Neyshabur, which was considered the most valuable source of high-quality Persian turquoise (Khazeni, 2014, p. 39). Why Gregorio owned such a large quantity of turquoise is unclear, but the predominance of cut and polished stones suggests the Girach-Mirmans sold them to merchants and jewelers in Italy and elsewhere in Europe. The possible scarcity of turquoise and the relatively limited access of European merchants to the Iranian mines could have motivated the Girach-Mirmans to seize a potentially lucrative market opportunity.

Gregorio also collected lapis lazuli (which the Julfan merchants called *lajvard* in Persian). He had 4,036 pounds shipped from the famous Badakhshan province in northern Afghanistan by the Girach-Mirman agents, along with turquoise. Lapis lazuli is arguably the oldest commercially mined and traded gem, historically used as a blue pigment and in carvings (Lo Giudice et al., 2009). Gregorio's lapis lazuli undoubtedly would have come from Sar-e-Sang in the Badakhshan Province (figure 26).

Correspondence between the Girach-Mirman commenda agents trading at multiple locations in Europe and Asia shows that turquoise shipments rep-

resented a considerable part of the family firm's consignments. Because no research has been done on these documents regarding their importance in the gem trade, it is too early to draw conclusions about where the Girach-Mirmans purchased their turquoise. As with the example of the shipment of 390 bags containing a dozen stones each of turquoise within Italy, further research is needed to determine whether the agents bought their turquoise in the major European markets or imported it from Iran through Ottoman trade routes. This point is supported by a letter from Martin to Vardan, written in 1700. Vardan had apparently complained about the high price Martin had set for large turquoise pieces before shipping them to Naples. Martin responded:

You wrote that I had set high prices for the large turquoises. Dear Sir, believe me when I say that those prices are hard to come by here too. Who can get their hands on those [large] turquoises unless they come from our country or via Istanbul, which only happens once a year, and what comes are the small sizes?⁴⁵

Garnet. Garnet sources are probably the most difficult to pinpoint due to the number of mines and alluvial deposits, both in Europe and India. The garnets in Gregorio's inventory were identified as Indian by his brother Ėmbrumagha's inventory, recorded

⁴⁴See Amirbēk di Vardan's letter to Herapet di Martin, written in 1703. Documenti Armeni Mercantili collection, Busta 3, State Archives of Venice.

⁴⁵Letter written in 1700, from Herapet di Martin (in Venice) to Amirbēk di Vardan (in Naples), in response to a letter written on June 19, 1700. Documenti Armeni Mercantili collection, Busta 3, State Archives of Venice.

after the latter's death. Ėmbrumagha's inventory likely lists the same garnets as Gregorio's but includes an additional detail, identifying their origin as Indian. While the Girach-Mirman brothers collected Indian garnets, their agents also traded in Bohemian garnets in Venice, as evidenced by a 1699 document in Italian at the State Archives of Venice.⁴⁶ Bohemian garnets, found in Central Europe, are small but bright red in color. They were mentioned by Georgius Agricola in his 1546 work *De Natura Fossilium* (see also Reuss, 1838; Kunz, 1893; Oehmichen, 1900; Farges, 1998; Kouřimský and Hyršl, 2008; Duraj et al., 2015). In the sixteenth and seventeenth centuries, most Bohemian garnets were cut in Freiburg and Waldkirch, with some larger ones cut in Nuremberg. Large-scale cutting began in Bohemia only around 1750 (Schmetzer and Kaiser, 2024), but Bohemian garnets circulated widely in European markets during the eighteenth and nineteenth centuries. Since it is unclear whether the Bohemian garnets mentioned in the inventory were in rough form or already cut, it is difficult to determine where the Girach-Mirman agents sourced their garnets: directly from Germany, or as rough stones from the Venetian markets.

Amber. Gregorio di Girach-Mirman also owned bags of rough amber, probably collected from the Baltic Sea (Grimaldi, 1996; Causey, 2011). Amber, which forms from fossilized tree resin, has washed up on Baltic shores since antiquity. Along with coral, it was one of the very few gems sought after in South Asian and Southeast Asian markets. The Baltic Sea was not only the largest amber deposit but also the source of the most highly traded amber since as early as the Paleolithic era, with routes extending overland to the Mediterranean and east toward the Adriatic Sea (Zadach, 1861; Runge, 1868). Amber was probably widely available in major European markets, where Gregorio's agents would have purchased it. As men-

tioned earlier, the Girach-Mirmans also transported amber from Iran to Tibet.

CONCLUSION

The trail of archival documents left by the Mirman family and their commenda agents is extensive. Preserved mostly at the State Archives of Venice, these documents number more than a thousand but have yet to be thoroughly studied for insights into the family's involvement in the long-distance gem trade of the early modern period. The remarkable success of Armenian mercantile families resulted in trade and communication networks that connected important gem sources and buyers on several continents, over a span of some 10,000 kilometers. Through family-owned companies such as that of the Girach-Mirmans and prominent dealers such as Gregorio, gem trading practices were shaped that are still relevant today. Gregorio's gem inventory, discussed in detail for the first time in this article, demonstrates the diversity of early modern gem portfolios. More importantly, his gem collection reveals extraordinary mobility and global reach of gem dealers and agents who transported these luxury commodities from the mining centers to major consumer markets. Whether it was the gems bought by Amirbēk di Vardan and Herapet di Martin in Italian cities or by Hovhannes Ter-Davt'ian on his lengthy journeys from Iran to Nepal and Tibet during the 1680s and 1690s, it is clear that the Mirman agents operated over enormous distances. Through these caravan and maritime routes, Gregorio was able to collect an impressive and truly global portfolio of gems.

⁴⁶See a letter written in Venice in Italian in August 1699, which mentioned Bohemian garnets, along with shipments of turquoise and pearls. Documenti Armeni Mercantili collection, Busta 3, State Archives of Venice. See also Revheim (2021) and Schmetzer et al. (2023).

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APPENDIX 1. Translation of Gregorio di Girach-Mirman's gem inventory from Italian.

"On July 21 of the year of 1137 [1688] in the Azar[i]a month of Nakha 3, after an hour at night between Thursday and Friday, the gentleman passed from this world to the other life. This occurrence was so distressing for me that I would have wished for my own death instead of seeing this pain, but praise be to God as this is the fate of human life and we all must pass through this path. All the jewels that the gentleman had, I Ambrumagà,¹ after his death, registered with my own hands in this book, which has thirty-six sheets, I start to note."²

"Summary obtained from the examination of a manuscript by Umbrumagà Mirman of the amount of jewelry that came to him after the death of Gregorio di Girach Mirman, because the said Umbrumagà was the executor of Gregorio Girach Mirman's will."³

1 large diamond, 106:3/4 grains ⁴ [carats] ⁵	<i>Grand Duke Cosimo Terzo offered 35,000 scudis for these jewels</i>
15 set diamonds, 46:7/8 grains [carats]	

Other Mounted Diamonds: 657⁶

27 mounted diamonds	2 large diamonds (on the same earrings)
56 diamonds (mounted in jewels)	48 diamonds (on a pair of hand-bracelets)
50 diamonds (on two flower brooches)	2 diamonds (on the same hand-bracelets)
50 diamonds (in another flower)	24 diamonds (on a plume)
10 diamonds (in the same flower as above)	1 large diamond (on the [plume] above)
30 diamonds (on a pair of earrings)	7 diamonds (on a ring)
34 diamonds (on the same earrings)	300 diamonds (on a plume)

Loose Diamonds: 119 (273:- grains in sum)⁷

1 diamond, 34 grains	36 diamonds, 30:- grains
2 diamonds, 27 grains	17 diamonds, 29:- grains
1 diamond, 19 grains	4 diamonds, 28:1/2 grains
1 diamond, 3 grains	4 diamonds, 12:1/2 grains
6 diamonds, 12 grains	2 diamonds, 6:- grains
27 diamonds, 23 grains	12 diamonds, 28:- grains
16 diamonds, 23 grains	

Loose Oriental Topazes [Sapphires]: 3 (274 carats in sum)

1 yellow topaz [sapphire], 84 grains [carats]	1 sapphire, 16 carats
1 blue sapphire, 174 carats	

¹Note that the names Ambrumagà, Umbrumagà, and Ėmbrumagha are all different spellings of the same person, Gregorio di Girach-Mirman's brother. This variation in spelling may be the result of differences in the Armenian spelling found in the original inventory, upon which the Italian translation is based.

²From Mirman, *Procuratori di San Marco, Misti, Busta 180/D, fol. 16, State Archives of Venice*.

³*Ibid.*, fol. 17. The gem inventory of Ėmbrumagha, as recorded by Amirbēk di Vardan (folios 162–167), is found toward the end of the Mirman printed booklet. Most are the same gems that Gregorio had left behind, including 431 garnets from India in pouches ("Grannatte d'India"). Musk was also added to Ėmbrumagha's inventory.

⁴Colons and slashes (rendered in this document as hyphens) represent decimal markers within the complex numerical system used by New Julfan merchants, likely derived from Persian or Gujarati commercial practices. In this system, ":-" corresponds to 1/64. Accordingly, for every ":-" appearing in the document, 1/64 (or 0.015625) must be added to the whole number in order to calculate the accurate value. See chart in Abrahamyan (1972, p. 62).

⁵The terms grains and carats may have been used interchangeably when the inventory was translated from Armenian to Italian.

⁶Total also includes 16 diamonds mentioned above.

⁷All totals reflect the printed inventory. Note that some calculations are incorrect.

APPENDIX 1 (continued). Translation of Gregorio di Girach-Mirman's gem inventory from Italian.

Loose Rubies: 262 (89 carats in sum)		
2 rubies, 14 carats		206 very small rubies, 30 carats
2 rubies, 5 carats		
2 rubies, 7 carats		16 mounted rubies
50 rubies, 33 carats		17 loose "balas rubies" [spinel], 26 carats
Loose Emeralds: 10,191 (5,021:- carats in sum)		
2 emeralds, 45 carats	1 emerald, 62 carats	109 emeralds, 43:- carats
40 emeralds, 50 carats	1 emerald, 53 carats	55 emeralds, 31:- carats
26 emeralds, 36 carats	12 emeralds, 146:1/2 carats	310 emeralds, 70:- carats
9 emeralds, 90 carats	4 emeralds, 24:1/2 carats	495 emeralds, 50:1/2 carats
20 emeralds, 85 carats	2 emeralds, 9:- carats	175 emeralds, 12:- carats
12 emeralds, 58 carats	4 emeralds, 69:- carats	407 emeralds, 380:- carats
20 emeralds, 88 carats	2 emeralds, 3:1/2 carats	507 emeralds, 313:- carats
7 emeralds, 16 carats	1 emerald, 34:- carats	520 emeralds, 90:- carats
4 emeralds, 13 carats	1 emerald, 24:- carats	420 emeralds, 86:- carats
1 emerald, 16 carats	5 emeralds, 28:1/2 carats	3,100 emeralds, 220:- carats
7 emeralds, 44 carats	3 emeralds, 27:- carats	1,500 emeralds, 108:- carats
2 emeralds, 60 carats	10 emeralds, 106:- carats	650 emeralds, 127:- carats
2 emeralds, 27 carats	12 emeralds, 5:1/2 carats	85 emeralds, 28:- carats
1 emerald, 172 carats	1 emerald, 4:- carats	140 emeralds, 212:- carats
1 emerald, 171 carats	24 emeralds, 27:- carats	200 emeralds, 272:- carats
1 emerald, 133 carats	40 emeralds, 96 carats	1,010 emeralds, 235:- carats
1 emerald, 93 carats	10 emeralds, 94 carats	336 emeralds, 644:- carats
1 emerald, 78 carats	101 emeralds, 29 carats	
Mounted Emeralds		
80 emeralds		3 mounted emeralds
2 mounted emeralds		
Persian Turquoise: 94,915 (polished turquoises)		
1,400 turquoises		35,000 turquoises
15,015 turquoises		34,500 turquoises
[Assorted Rough]		
92 pounds ^a of rough turquoise		1,270 pounds of rough amber (in pouches)
431 pounds of rough garnets (in several pouches)		4,036 pounds of lapis lazuli (in several pouches)
Oriental Pearls		
57 pearls, 81 carats		165 pearls (in necklaces)
29 pearls, 53 carats		550 baroque pearls
Gold rings set with 85 various gems (diamonds, emeralds, rubies, and others)		

^aThe term *libre* (used in the original Italian translation of the inventory) likely refers to *libbra* ("pound"), a local Italian unit of weight with exact values that varied by city and commercial context.

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The Dr. Edward J. Gübelin Most Valuable Article AWARD

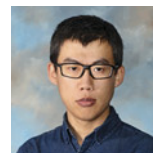
First Place

STRUCTURES BEHIND THE SPECTACLE: A REVIEW OF OPTICAL EFFECTS IN PHENOMENAL GEMSTONES AND THEIR UNDERLYING NANOTEXTURES

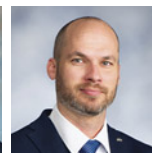
SUMMER 2025

Shiyun Jin, Nathan D. Renfro, Aaron C. Palke, and James E. Shigley

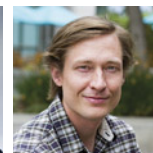
Shiyun Jin is a senior research scientist of colored stones at GIA in Carlsbad, California. Dr. Jin's research focuses on the crystal chemistry, crystallography, and optical effects of gem minerals. **Nathan Renfro** is senior manager of colored stone identification at GIA in Carlsbad. He earned a bachelor's degree in geology from Appalachian State University in North Carolina. **Aaron Palke** is senior manager of research at GIA in Carlsbad. He holds a PhD in geology from Stanford University. **James Shigley** is distinguished research fellow at GIA in Carlsbad and holds a PhD in geology from Stanford University. He is the author of numerous articles on diamonds and colored gemstones.



Shiyun Jin



Nathan D. Renfro



Aaron C. Palke



James E. Shigley

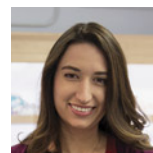
Second Place

A STUDY OF THE WINSTON RED: THE SMITHSONIAN'S NEW FANCY RED DIAMOND

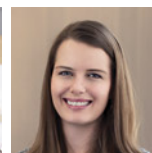
SPRING 2025

Gabriela A. Farfan, Ulrika F.S. D'Haenens-Johansson, Stephanie Persaud, Eloïse Gaillou, Russell C. Feather II, W. Henry Towbin, and Daniel C. Jones

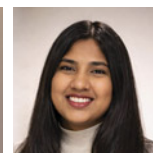
Gabriela Farfan is the Coralyn W. Whitney curator of gems and minerals for the National Gem and Mineral Collection at the Smithsonian Institution, NMNH. She earned a PhD in geochemistry from the MIT-WHOI Joint Program and studies gems and how mineral and biomineral crystal structures change under varying environmental conditions. **Ulrika D'Haenens-Johansson** is senior manager of diamond research at GIA in New York and holds a PhD in physics from the University of Warwick, United Kingdom. Her research focuses on the defect physics of natural, treated, and laboratory-grown diamond materials using optical and EPR spectroscopy. **Stephanie Persaud** is a research associate at GIA in New York, specializing in instrument testing and analytical spectroscopy with a focused expertise in diamond characterization. **Eloïse Gaillou** is director and curator of the Mineralogy Museum of Mines Paris – PSL (Paris School of Mines). She holds a PhD in material sciences and a gemology diploma from the University of Nantes, France. **Russell Feather** has worked at the Smithsonian Institution for more than 40 years, primarily as the collection manager of the National Gem and Mineral Collection. He has authored works on gemstone inclusions and the histories of many of the museum's iconic gemstones. **Henry Towbin** is a former GIA postdoctoral research fellow, holding a PhD in earth and environmental science from Columbia University. He studies how diamonds grow from carbon-rich fluids deep in the earth. **Daniel Jones** is a research scientist at GIA in New Jersey and has a background in advanced spectroscopy and imaging of diamonds and colored stones. He currently works in instrumentation development, designing state-of-the-art instruments for researchers involving multidimensional imaging and spectroscopy of photoluminescence.



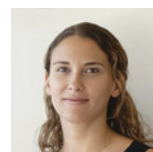
Gabriela A. Farfan



Ulrika F.S.
D'Haenens-
Johansson



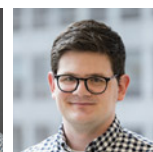
Stephanie Persaud



Eloïse Gaillou



Russell C. Feather II



W. Henry Towbin



Daniel C. Jones

Third Place

THE 3309 CM⁻¹ SERIES IN SAPPHIRE AND RUBY: A FOCUS ON FTIR PEAK POSITION VARIATION

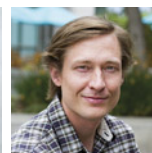
SPRING 2025

Wasura Soonthorntantikul and Aaron C. Palke

Wasura Soonthorntantikul is a senior research scientist at GIA in Bangkok. She received a PhD in analytical chemistry from Chulalongkorn University in Thailand. **Aaron Palke** was profiled in the first-place entry.



Wasura
Soonthorntantikul



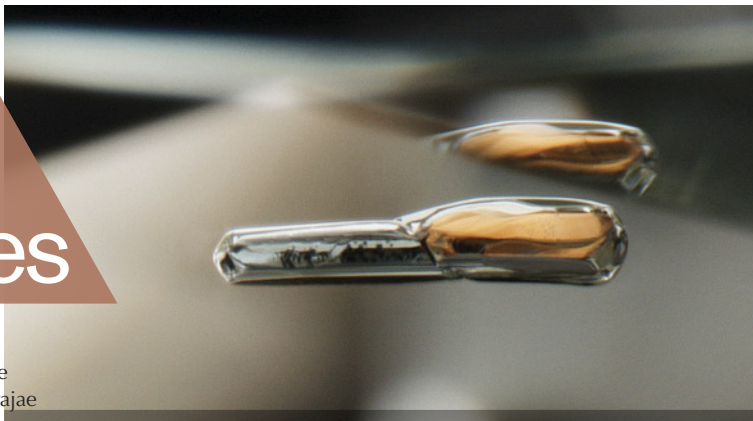
Aaron C. Palke

Many thanks to the members of G&G's Editorial Review Board for voting this year.

Lab Notes

Editors

Thomas M. Moses | Shane F. McClure
Sally Eaton-Magaña | Artitaya Homkrajae

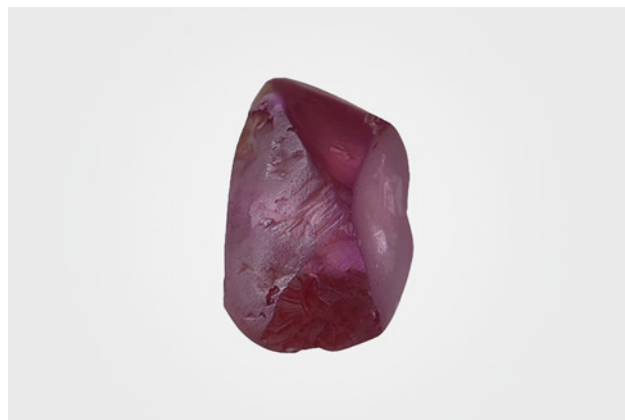


DIAMONDS

Color-Treated Purple Diamond Rough with Interesting Growth Pattern

Recently, GIA's Dubai laboratory received a purple diamond rough submitted for an identification report, weighing 3.93 ct and measuring $10.26 \times 6.82 \times 6.05$ mm (figure 1). Fourier-transform infrared spectroscopy confirmed this diamond as type Ib with single substitutional nitrogen atoms (N_s^0) of approximately 5 ppm, with characteristic peaks at 1130 and 1344 cm^{-1} . The visible/near-infrared absorption spectrum showed features at 637 nm (NV^-) and 741 nm (GR1). The combination of intense bodycolor, diamond type, and NV centers immediately raised suspicion for color treatment, which ultimately proved to be a combination of irradiation and

Figure 1. This 3.93 ct diamond rough was color treated to introduce its vibrant purple color. Photo by Nick “Ka Chun” Chan.



Editors' note: All items were written by staff members of GIA laboratories.

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subsequent annealing. Several noteworthy cases of laboratory-grown polished diamonds color treated to orange to pink hues have been reported by GIA (Summer 2015 Lab Notes, pp. 182–183; Winter 2023 Lab Notes, pp. 489–490), and such post-growth treatment is common in the trade. To the best of the author's knowledge, however, naturally grown rough diamonds color treated to a vibrant purple color description are not commonly submitted for identification reports.

DiamondView images revealed interesting patterns that provided additional details on its growth history. Under deep-ultraviolet (UV) illumination (<230 nm), a dark non-fluorescing area resembling an arrow pointing toward a profile view of an elongated diamond was observed (figure 2). The rest of the diamond fluoresced a bright orange, which was likely associated with nitrogen vacancy ($NV^{0/-}$) defects (K.S. Byrne et al., “Photochromic charge transfer processes in natural pink and brown diamonds,” *Journal of Physics: Condensed Matter*, Vol. 26, No. 3, 2014, article no. 035501). This distinct pattern indicated that several growth sectors were formed during the diamond's natural growth processes.

Impurities are usually heterogeneously distributed among different growth sectors due to their varying incorporation efficiencies and sector growth rates. Experiments have shown nitrogen concentration is typically higher in the {111} growth sector than in {100} (R.C. Burns et al., “Growth-sector dependence of optical features in large synthetic diamonds,” *Journal of Crystal Growth*, Vol. 104, No. 2, 1990, pp. 257–279). Upon irradiation followed by annealing, the pairing of N_s^0 with vacancies to form NV centers becomes significantly more abundant in the {111} sector than in {100}. Photoluminescence spectroscopy further confirmed that {111} was predominated by the negatively charged NV defects (NV^-), while {100} was dominated by the neutral form (NV^0). The 575 nm (NV^0) and 637 nm (NV^-) peak areas in the {111} orange fluorescing areas, normalized to diamond Raman area, were also found to be 7 to nearly 140 times higher than in the {100} dark non-fluorescing region, respectively. The uneven coloration of the treated rough, as seen in visible light, also coincided with the observed differences in the distribution of NV centers between the {111} and {100} sectors (figure 3).

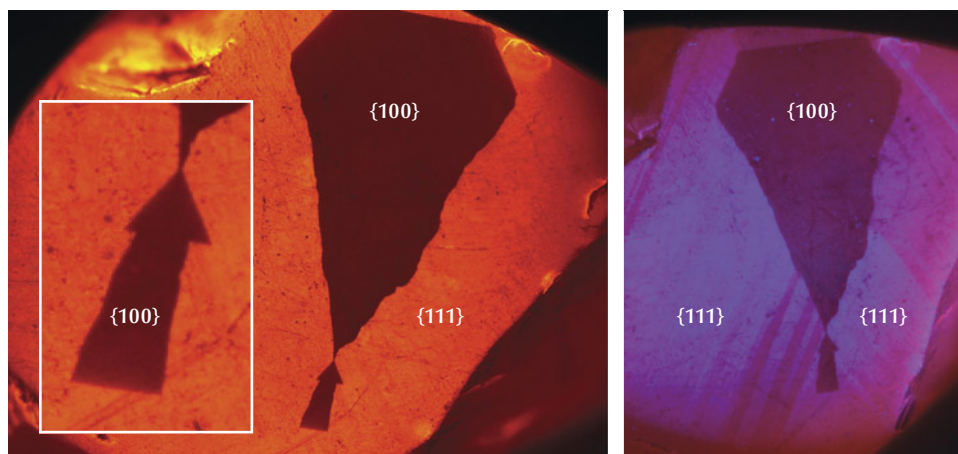


Figure 2. DiamondView images show a dark non-fluorescing region under a standard filter (left; inset shows an enlarged image of the arrow-shaped pattern) and surrounding natural growth patterns using a filter that reduced the NV-related fluorescence relative to other wavelengths (right). Images by Nick “Ka Chun” Chan.

Purple color in diamond is often attributed to transmission windows in the blue and red regions of the visible spectrum. Interestingly, the introduction of NV centers in this stone produced an intense, unmodified purple body-color that lacked a pink component commonly observed in diamonds colored with NV centers. Recent studies have shown synthetic type Ib diamonds grown by high-pressure, high-temperature that have undergone high-dose electron irradiation followed by low-temperature annealing of $\sim 750^{\circ}\text{C}$ can develop an intense purple color within $\{111\}$ sectors by having predominantly NV^{-} centers over NV^0 . The concentration of NV^{-} and the intensity of purple body-color in those experiments reached a maximum at $\sim 850^{\circ}\text{C}$ and gradually reduced at higher temperatures (N.M.

Kazuchits et al., “Color evolution of type Ib synthetic diamonds after high dose electron irradiation followed by low-temperature annealing,” *Diamond and Related Materials*, Vol. 163, 2026, article no. 113334). Based on these observations, it is likely the examined rough underwent a carefully controlled treatment of irradiation followed by annealing at a low temperature.

While arrow facet patterns produced through polishing are often valued, this diamond, however, exhibits pareidolia in the form of an arrow “hidden” from within. It highlights the contrast between distinct growth sectors and is only discernible under deep-UV illumination.

Nick “Ka Chun” Chan

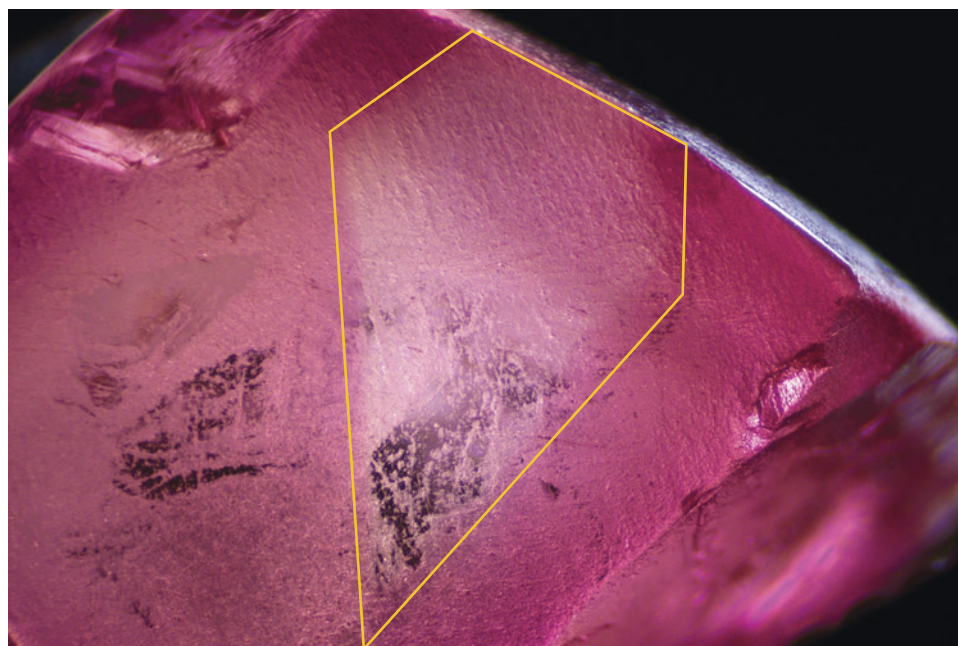


Figure 3. An uneven color distribution is observed under visible light with a distinct boundary resembling a profile view of an elongated diamond (outlined in yellow). Photomicrograph by Nick “Ka Chun” Chan; field of view 7.50 mm.

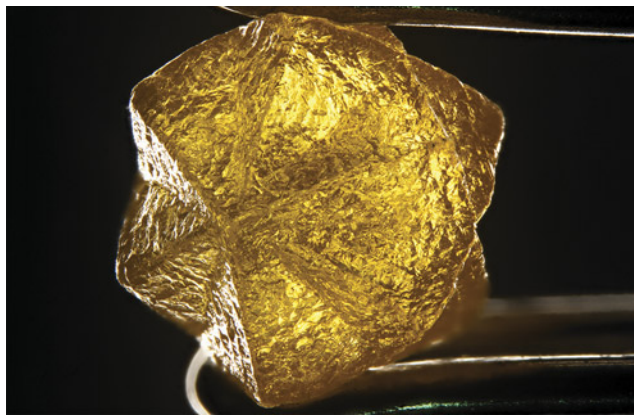


Figure 4. Left: The twinned 0.37 ct diamond displays a vivid orange yellow color. Right: The intersection of cuboid crystals is clearly observed from this view. Photomicrographs by Taryn Linzmeyer; field of view 7.19 mm.

Interpenetrant Twins in Natural Diamond

A 0.37 ct vivid orange yellow rough diamond displaying penetration twinning, on loan from the GIA Museum, was recently examined by the author (figure 4). Growth twinning is a natural process involving the symmetrical intergrowth of two crystals of the same mineral. Diamonds can exhibit growth twinning as either contact twins or penetration twins. Contact growth twinning is commonly observed in octahedral diamonds, forming macles (e.g., A. Abduriyim and M. Kitamura, "External morphology and internal zonal structure of macle diamond," *Fall 2025 G&G*, pp. 250–269). Much more rarely, interpenetrant twinning is observed in cuboid diamonds displaying fibrous growth (e.g., K. Sun et al., "Growth and crystallographic features of interpenetrant twins in natural diamonds," *American Mineralogist*, Vol. 110, No. 8, 2025, pp. 1249–1256; J.W. Harris et al., "Morphology of monocrystalline diamond and its inclusions," *Reviews in Mineralogy and Geochemistry*, Vol. 88, No. 1, 2022, pp. 119–166).

Spectroscopic analysis was performed to further characterize the diamond. Ultraviolet/visible spectroscopy revealed a broad absorption continuum primarily in the violet to blue regions of the visible spectrum. This is seen in diamonds colored by isolated substitutional nitrogen atoms (N_2^0) or C-centers. Fourier-transform infrared spectroscopy detected these C-centers in addition to A-centers (paired nitrogen atoms), revealing this stone to be type IaA+Ib.

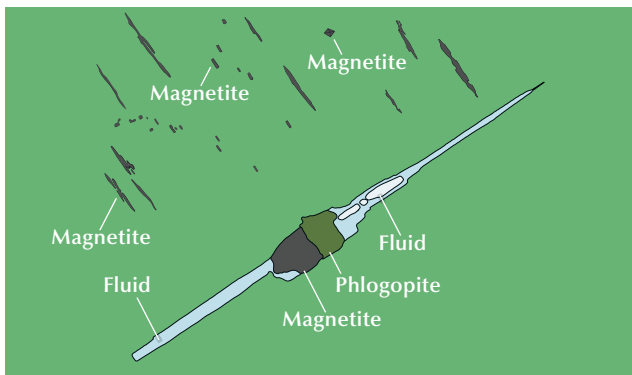
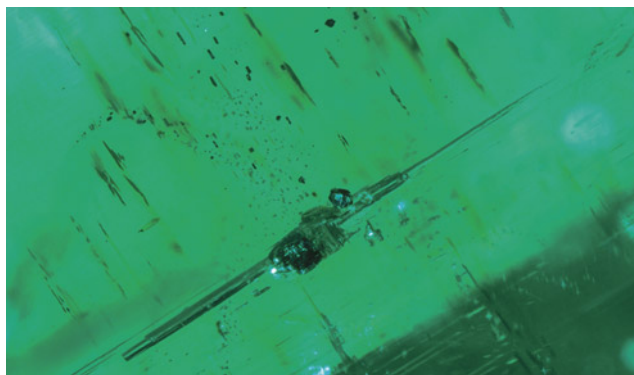
This natural diamond is an example of how "accidents" during crystal growth can result in fascinating mineral specimens.

Taryn Linzmeyer

EMERALD with Abundant Magnetite Inclusions

Gemologists use several key inclusions to aid in origin determination and to distinguish between naturally grown and laboratory-grown emeralds. Among these, two-phase

Figure 5. Rare multiphase inclusion containing fluid (liquid and gas) and solid phases of magnetite and phlogopite, along with magnetite crystals in four distinct forms (irregular, octagonal, blocky, and dendritic), observed in a 3.03 ct Semapongpan; field of view 1.80 mm.



and multiphase inclusions are particularly important. In addition, some characteristic inclusion features are particularly useful for origin determination, such as iridescent two-phase thin films reported in certain Russian emeralds.

Recently, a 3.03 ct natural emerald was submitted to the Bangkok laboratory. Standard gemological testing, characteristic inclusion features, and chemistry supported a Zambian origin. Under the microscope, the stone showed the typical blocky two-phase inclusions expected in Zambian emerald, along with numerous opaque black metallic inclusions of various shapes and rare multiphase inclusions containing liquid, gas, and two solid phases (figure 5). Raman spectroscopy identified the opaque black metallic inclusions as magnetite and the transparent green solid in the multiphase inclusions as phlogopite.

Magnetite inclusions in Zambian emeralds are related to the host rock composition and the metamorphic-metasomatic formation process. Beryllium-rich fluids from pegmatites react with chromium-bearing talc-magnetite schist to form emeralds, which can trap magnetite grains from the surrounding rock (H. Zwaan et al., "Emeralds from the Kafubu area, Zambia," Summer 2005 *G&G*, pp. 116–148). In this stone, magnetite occurred in unusually high abundance and exhibited four distinctive crystal habits. Dendritic or skeletal forms appeared as fine planar networks roughly parallel to the basal pinacoid. Blocky and octagonal crystals formed in more stable growth environments, while irregular crystals indicated more variable growth conditions. The simultaneous presence of all four forms is rarely observed in Zambian emeralds and makes this stone particularly unique.

The abundance of magnetite produced a weak but noticeable attraction to a handheld magnet, an uncommon physical response in emeralds. This observation, together with the inclusion assemblage and chemical data, supports a Zambian origin and highlights how unusual internal features can reflect natural geological variation.

This emerald expands the reference for Zambian material, showing that magnetite can appear not only as small,



Figure 6. The fashioned dyed shell weighing 17.99 ct and measuring 19.58×12.25 mm. Photo by Gourav Bera.

scattered grains but also in multiple distinct habits and in high quantities. The combination of abundant magnetite, four crystal forms, magnetic response, and rare multiphase inclusions makes this specimen particularly noteworthy and a fine example of natural variation in Zambian emeralds.

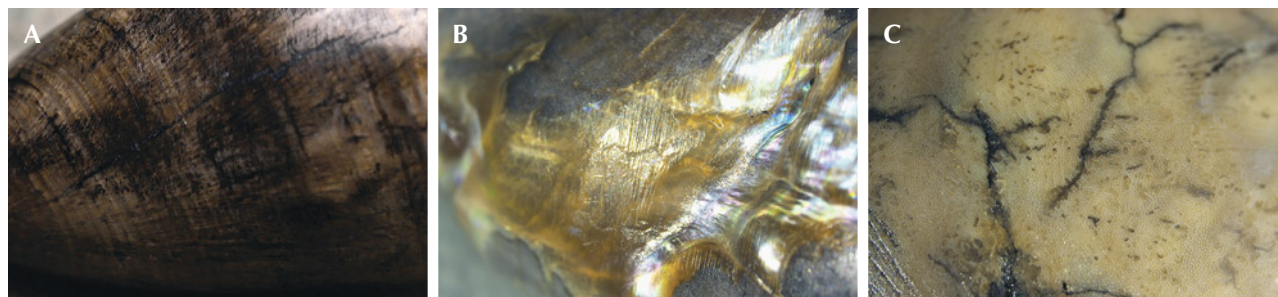
Aprisara Semapongpan

A Fashioned Dyed Shell IMITATION PEARL

Recently, GIA's Mumbai laboratory received a parcel of brown and black non-nacreous pearls for identification. Among these, the largest dark brown drop-shaped specimen, weighing 17.99 ct and measuring 19.58×12.25 mm (figure 6), exhibited visual and structural features inconsistent with the other examined pearls.

Externally, the specimen displayed fine banding across its dark brown non-nacreous surface (figure 7A), with an irregular light brown nacre covering one area. Microscopic examination using fiber-optic illumination revealed working and polishing lines on both the nacreous and non-nacreous portions, with the lines more distinct on the nacreous surface (figure 7B). The non-nacreous area showed a mosaic-like cellular pattern, with black concentrated

Figure 7. A: Fine banding in the dark brown non-nacreous areas. B: Distinct grinding and polishing lines on the light brown nacreous surface; field of view 8.60 mm. C: Mosaic-like cellular structure with a black dye residue in the surface-reaching cracks; field of view 3.80 mm. Photos by Gourav Bera (A) and Anukul Belanke (B and C).



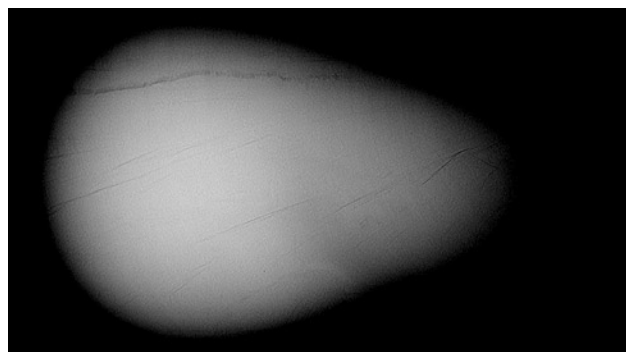


Figure 8. RTX imaging revealing parallel banding. Image by Anukul Belanke.

along the banding and surface fractures attributable to the presence of a dye (figure 7C) (Fall 2021 Lab Notes, pp. 264–266), making it difficult to determine the mollusk species. When exposed to X-ray excitation, the specimen was inert. In addition, chemical analysis using energy-dispersive X-ray fluorescence detected no measurable manganese and a strontium level of 1283 ppm, indicating its saltwater origin.

Under long-wave ultraviolet radiation, the specimen showed a weak greenish yellow reaction on its light brown areas, while darker portions remained inert. Raman spectroscopy using a 514 nm laser on the lighter brown nacreous area produced a doublet at 701 and 704 cm^{-1} and a peak at 1086 cm^{-1} , indicative of aragonite. In contrast, no spectral peaks were detected on the dyed, darker brown non-nacreous area due to high fluorescence interference. Real-time X-ray microradiography (RTX) revealed distinctive internal parallel banding and fine surface-reaching cracks (figure 8), typical of shell material.

Collectively, these observations confirmed that the examined specimen was fashioned out of shell, carefully

shaped and polished to imitate the appearance of a non-nacreous pearl, such as those produced from the Pinnidae family (N. Sturman et al., “Observations on pearls reportedly from the Pinnidae family (pen pearls),” Fall 2014 *G&G*, pp. 202–215). The presence of dye, combined with deliberate shaping and polishing, significantly enhanced its resemblance to a natural pearl. With the increasing market presence of imitations, continued caution and thorough analytical examination are essential for ensuring accuracy in pearl identification.

Anukul Belanke, Roxane Bhot Jain, Nishka Vaz, and Abeer Al-Alawi

Chocolate OPAL

Opal is renowned for its wide range of colors, from deep blue to intense red to completely black. All bodycolors are caused either by the presence of nanoscale mineral inclusions or chemical elements incorporated directly into the amorphous silica structure. Aside from their contributions to visual appeal, these color-causing compounds are also of scientific interest, as their presence can provide more precise constraints on the local conditions and environment of opal formation.

Recently, GIA’s New York laboratory acquired a collection of various rough Ethiopian opals (Wollo and Shewa provinces) for research purposes, displaying a range of bodycolors from colorless to red-orange (so-called “fire opals”). The collection included an exceptional 37.93 ct common specimen with a 4.05 ct small detached fragment, bearing a striking resemblance to a bar of chocolate (figure 9). Both pieces displayed a lustrous appearance on the conchoidal fracture and homogeneous bodycolor throughout the volume, leaning toward red in thinner parts, with slight



Figure 9. A 37.93 ct chocolate common opal (left) and its 4.05 ct detached fragment (bottom) next to a piece of a chocolate bar (right). Photo by Towfiq Ahmed.

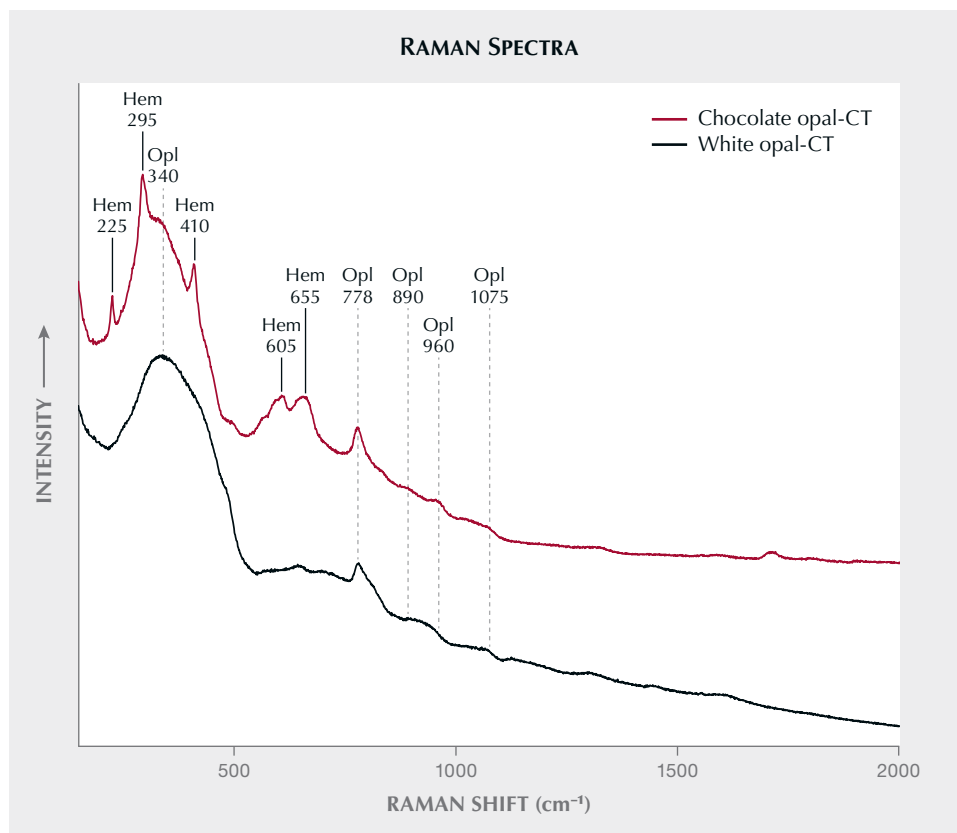


Figure 10. Comparison of the 830 nm Raman spectra of the chocolate common opal and a white common opal from the same Ethiopian deposit. Opl = opal; Hem = Hematite. Spectra are offset vertically for clarity.

variation on the surfaces and localized zones of lighter brown color. Standard gemological testing on the larger piece revealed a specific gravity of 2.00 and a spot refractive index of 1.46, typical for opal.

Raman spectroscopy and laser ablation–inductively coupled plasma–mass spectrometry were performed to better characterize this material. With an 830 nm excitation laser, Raman peaks at 340 and 780 cm^{-1} confirmed the specimen as opal-CT. Faint Raman peaks related to iron oxides were also seen (figure 10). Using a 514 nm laser, the opal signal was almost completely suppressed, enhancing the signal of the iron oxides; these were confirmed as hematite (Fe_2O_3) (figure 11) (C.P. Marshall et al., “Polarized Raman spectra of hematite and assignment of external modes,” *Journal of Raman Spectroscopy*, Vol. 51, No. 9, 2020, pp. 1522–1529).

The chemical composition in the major (silicon, oxygen, and water) and main minor elements (sodium, magnesium, aluminum, and calcium) of this chocolate brown specimen falls within the classical range of values established in the literature for the chemistry of Ethiopian opal (B. Rondeau et al., “Geochemical and petrological characterization of gem opals from Wegel Tena, Wollo,

Ethiopia: Opal formation in an Oligocene soil,” *Geochemistry: Exploration, Environment, Analysis*, Vol. 12, No. 2, 2012, pp. 93–104; B. Chauviré et al., “Pedogenic origin of precious opals from Wegel Tena (Ethiopia): Evidence from trace elements and oxygen isotopes,” *Applied Geochemistry*, Vol. 101, 2019, pp. 127–139). However, certain trace elements such as iron, titanium, manganese, zinc,

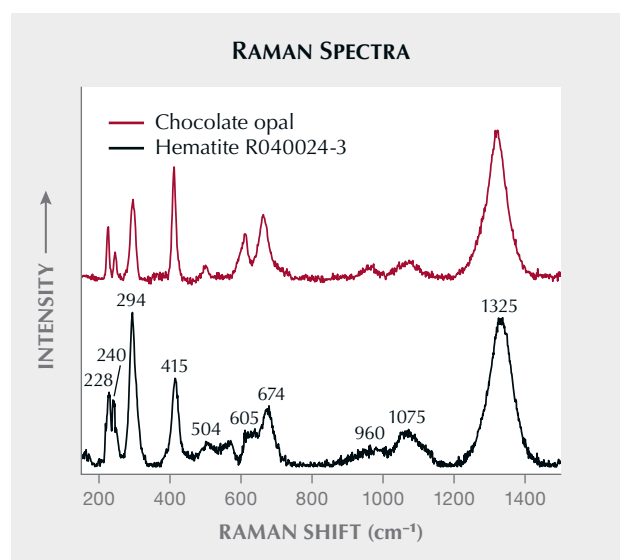


Figure 11. Comparison of the 514 nm Raman spectra of the chocolate opal and hematite reference. Spectra are offset vertically for clarity.

niobium, lead, and thorium are enriched relative to most Ethiopian opals. Furthermore, there is considerable enrichment in the rare earth elements (REEs) in conjunction with a pronounced and unusual positive cerium anomaly.

The strong positive cerium anomaly (463 ± 14 ppm) relative to most Ethiopian opals (< 90 ppm), along with the presence of embedded iron oxides, would indicate that this specimen formed under oxidizing conditions. Ethiopian opals are known to form within volcanic tuffs (compacted ash, also called ignimbrite) of rhyolitic composition that have undergone active soil formation processes (also called pedogenesis). Moreover, the presence of fossils in the surrounding rocks and within the opals themselves indicates that their formation environment was also rich in living organisms (and their organic byproducts); recent research has revealed clues toward an active interaction between opal and these organisms (S. Gouzy et al., "Whitening of fire opal: Transformation of silica in soils," *Chemical Geology*, Vol. 616, 2023, article no. 121237). Among other parallel processes that might occur in this complex setting, microbial mediation (i.e., wherein microorganisms facilitate chemical transformations of an environment) has been specifically identified as a possible origin of strong cerium anomalies (B. Chauviré et al., 2019, and references therein) and control overall REE partitioning during opal formation. Therefore, it can be hypothesized that the peculiar chemistry of this opal could be related to an intense, localized microbial activity in its immediate growth environment.

Correlated to the positive cerium anomaly, the chocolate opal is also enriched in europium compared to

more common Ethiopian samples. However, this europium enrichment is not accompanied by similarly high concentrations of strontium and barium, a suite previously attributed to feldspar-dominated weathering as the source of chemical elements for opal (B. Chauviré et al., 2019). This suggests that, for this specimen, the predominant source of elements was likely the volcanic glass component of the ignimbrite rather than feldspar phenocrysts.

This specimen stands out among all opals from Ethiopia and around the world, not only for its striking dark chocolate color, but also for its unique chemical composition enriched in REEs and other elements commonly believed to only occur in trace concentrations, such as cerium (usually lower than 90 ppm and here 463 ± 14 ppm). Finally, this peculiar chocolate opal highlights, once again, the high sensitivity of opals to their hyperlocal environmental variations, even within the same deposit.

Simon Gouzy, Sarah Arden, and Tyler Smith

PEARLS

Atypical Bead Cultured Pearls Identified in a Natural Pearl Necklace

Recently, GIA's Mumbai laboratory received a five-strand necklace for identification, consisting of light cream and cream pearls (figure 12, left). The pearls varied in shape from near-button to near-oval, with diameters ranging from 3.27 to 4.80 mm, providing an overall well-matched appearance. Real-time X-ray microradiography (RTX)



Figure 12. Left: Necklace consisting of natural pearls and eight atypical bead cultured pearls. Right: The removed atypical bead cultured pearls from the necklace, ranging in weight from 0.51 to 0.68 ct. Photos by Gourav Bera.

revealed that the majority of pearls were natural, showing different-sized cores surrounded by concentric growth arcs, while some displayed minimal structures. However, eight pearls exhibited suspicious internal structures, with some showing unclear demarcations. These were difficult to conclusively identify in their strung condition and were removed for further analysis (figure 12, right).

The eight removed pearls weighed between 0.51 and 0.68 ct, with sizes ranging from $4.45 \times 4.33 \times 3.53$ mm to $5.30 \times 4.22 \times 3.98$ mm. Energy-dispersive X-ray fluorescence revealed no traces of manganese, with strontium levels ranging from 981 to 1270 ppm, indicating a saltwater growth environment. However, when exposed to X-rays, some of the pearls showed a very weak yellowish green fluorescence and a stronger fluorescence in their drill holes. While saltwater pearls are usually inert to X-ray fluorescence, saltwater bead cultured pearls with freshwater shell nuclei tend to fluoresce with a weak to moderate yellowish green reaction (Fall 2023 Lab Notes, pp. 365–366). The weak fluorescence observed in these saltwater pearls, along with stronger fluorescence in the drill holes, indicated the potential presence of a freshwater nucleus within each pearl.

Detailed analysis of the internal structures via RTX and X-ray computed microtomography (μ -CT) confirmed that each of the eight pearls had a nucleus and boundary

structure (figure 13). These nuclei appeared slightly more radiopaque than the surrounding nacre, were asymmetrical in shape, and lacked the growth structure present in the nacre surrounding them. In general, traditional bead cultured pearls are produced with spherical freshwater shell beads, which are easily identifiable through RTX analysis. When these freshwater shell beads are cut into differing shapes, or any other materials are used as nuclei, the resulting pearls are classified as atypical bead cultured (aBC) pearls.

The identification of this type of aBC pearl with an irregularly shaped shell bead presents significant challenges due to its deceptive similarities to the external appearance of natural pearls. Their irregular shape, characterized by asymmetrical and non-traditional nucleation, can mislead both gemologists and consumers alike. This necklace is particularly noteworthy as it marks the first time GIA's Mumbai laboratory has encountered numerous relatively small aBC pearls of this type, drilled and strung alongside natural pearls. As cultivation techniques continue to evolve, the challenges associated with pearl identification will only increase. Therefore, it is essential for gemologists to accurately identify cultured pearls when intermixed with natural pearls of similar appearance.

Nishka Vaz, Karan Rajguru, and Abeer Al-Alawi

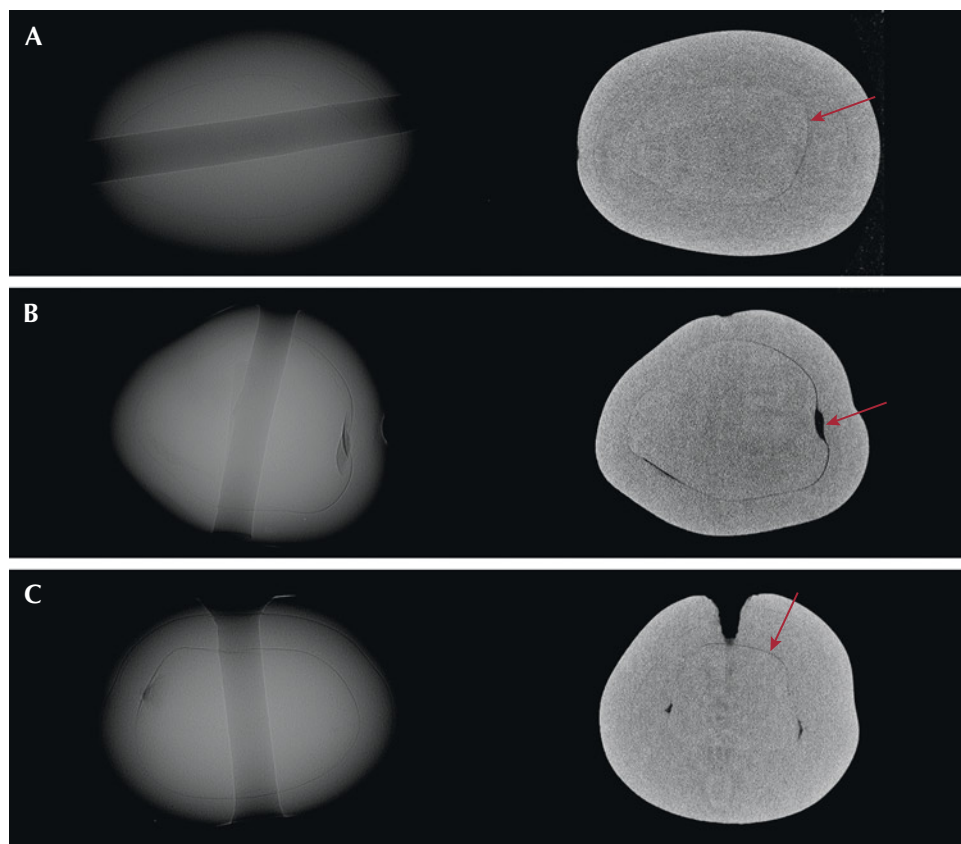


Figure 13. RTX (left) and μ -CT (right) images of three of the eight atypical bead cultured pearls. A: A very faint discontinuous demarcation that appears more like a growth structure in the RTX image but shows different radiopacity and a continuous demarcation in the μ -CT image (red arrow). B: A faint demarcation and small void (red arrow). C: A more definite boundary structure (red arrow) and radiopacity difference.

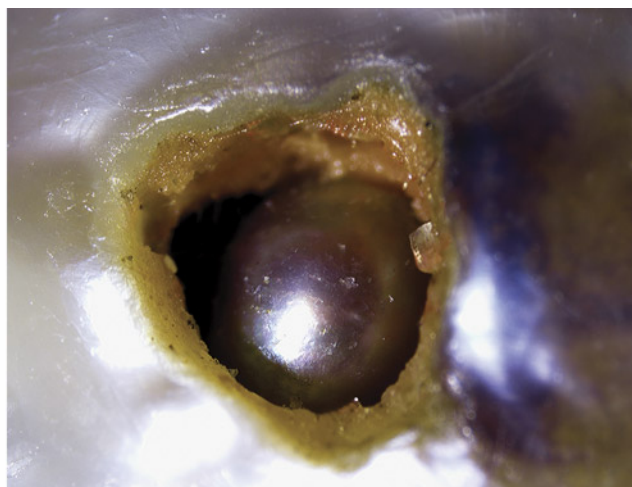


Figure 14. Left: A light gray near-round pearl weighing 13.12 ct and measuring $14.06 \times 13.75 \times 12.76$ mm, plugged with a drilled seed pearl. Right: A closer view of the seed pearl embedded in the pearl's opening. Photos by Gourav Bera (left) and Karan Rajguru (right).

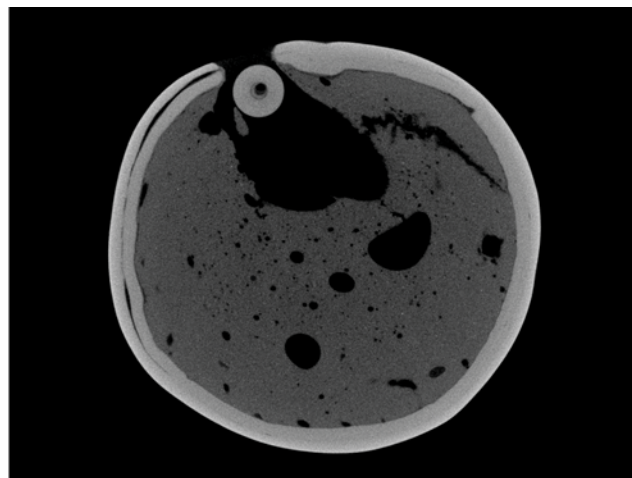
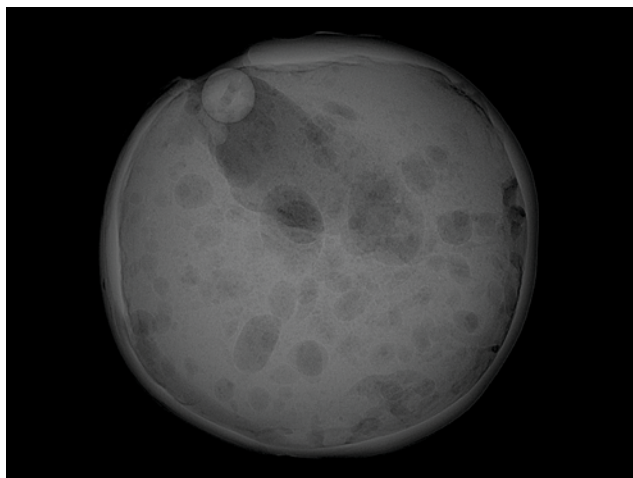
An Unusual Filled Cultured Pearl

Recently, GIA's Mumbai laboratory received a light gray near-round pearl for identification, weighing 13.12 ct and measuring $14.06 \times 13.75 \times 12.76$ mm. Externally, the surface of the pearl displayed an uneven texture with white blotches and had an opening plugged with a small light brownish gray near-round seed pearl (figure 14). Under higher magnification, the surface of both the pearl and the seed pearl revealed typical nacreous structures with overlapping aragonite platelets. The presence of aragonite was further confirmed by Raman spectroscopy using 514 nm laser excitation.

Chemical analysis of the pearl using energy-dispersive X-ray fluorescence revealed no traces of manganese and a strontium level of 1535 ppm. Both the pearl and the seed pearl showed inert reactions when exposed to X-ray fluorescence, confirming their saltwater origins.

Real-time X-ray microradiography (RTX) and X-ray computed microtomography (μ -CT) images both revealed a distinct light gray demarcation of nacre surrounding a large dark gray area of an unidentified radiolucent foreign material within the large pearl (figure 15). The unidentified material contained darker gray blotches of gas bubbles. The seed pearl was seen resting atop the filling material,

Figure 15. RTX (left) and μ -CT (right) imaging reveal a seed pearl at the opening and an unidentified foreign material inside the pearl.



suggesting it was intentionally used to seal the pearl's opening. The drilled seed pearl exhibited a central core surrounded by fine growth arcs similar to those observed in natural pearls.

Two possible scenarios arise regarding the pearl's formation. The first suggests the use of an atypical bead for culturing the pearl, differing from the conventional freshwater shell bead. Numerous experimental attempts have explored alternative materials as bead nuclei, including organic nuclei or, as in this case, an unknown material similar to synthetic substances such as plastic or resin (L. Cartier and M.S. Krzemnicki, "New developments in cultured pearl production: Use of organic and baroque shell nuclei," *Australian Gemmologist*, Vol. 25, No. 1, 2013, pp. 6–13; S.C. Shih and P. Cevallos, "Polystyrene nucleus in a freshwater cultured pearl," *Journal of Gemmology*, Vol. 39, No. 5, 2025, pp. 445–447). The second scenario could be that it was filled after the formation of the pearl. The latter scenario appears more plausible due to the presence of gas bubbles within the void and along the demarcation. This intention to mask the unidentified foreign material with the seed pearl further complicated identification.

Identifying the nature of such a pearl can be challenging, whether it is an atypical bead cultured pearl or a filled non-bead cultured pearl. While the possibility of alternative culturing methods cannot be overlooked, the characteristics observed in the examined pearl suggest that it is not of natural origin but rather a product of a cultured formation. Further analysis is required to understand the composition of the unidentified foreign material and to reach a more conclusive identification of the pearl.

*Karan Rajguru, Abeer Al-Alawi, Roxane Bhot Jain, and
Artitaya Homkrajae*

Transparent STAUROLITE

The Carlsbad laboratory recently received a transparent 1.58 ct dark red-brown freeform step cut measuring approx-

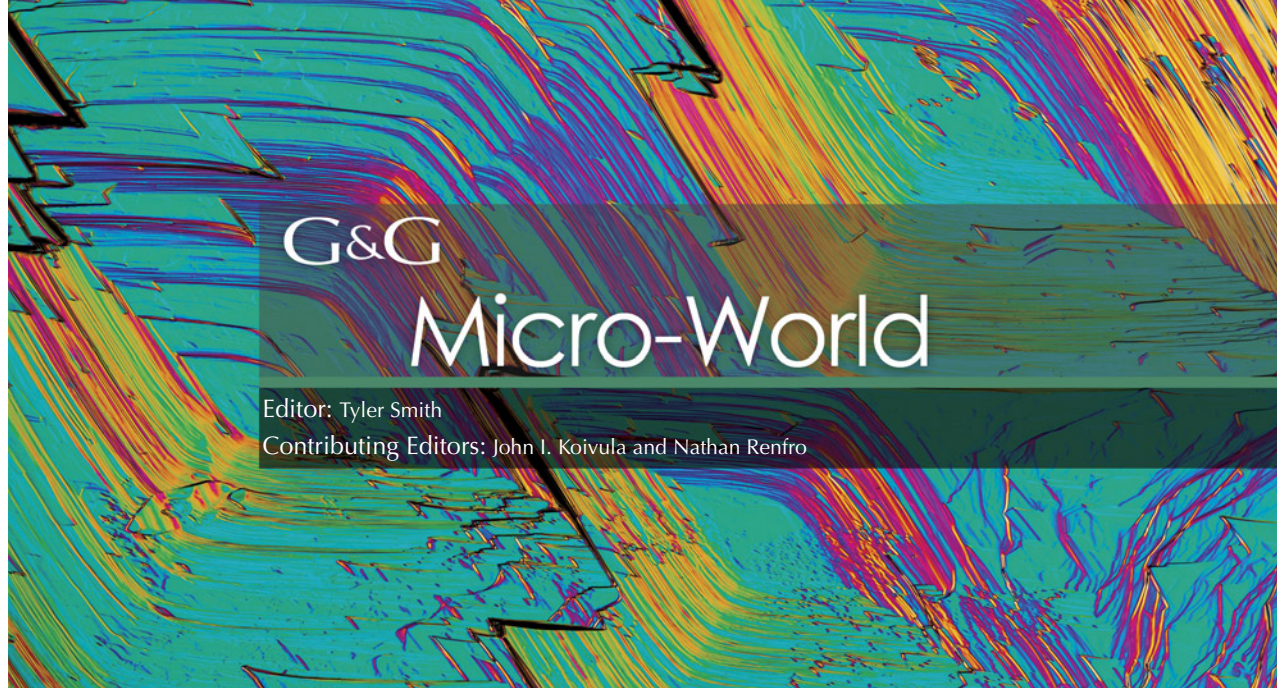


Figure 16. A rare transparent 1.58 ct dark red-brown staurolite. Photo by Santi Jittathai.

imately 6.24 × 8.08 × 3.56 mm (figure 16). Standard gemological testing results included a specific gravity of 3.76 and a refractive index of 1.738–1.748. These properties suggested the stone was a rare transparent staurolite, which was confirmed by Raman spectroscopy. Typically, staurolite forms as opaque brown to black X- or cross-shaped twin crystals. Due to its typical cross-shaped appearance, the material was named using the Greek word for "cross," *stavros* (J.W. Anthony et al., Eds., *Handbook of Mineralogy*, Mineralogical Society of America, Chantilly, VA, <http://www.handbookofmineralogy.org/>).

Transparent staurolite is extremely rare; this is only the second transparent specimen examined by GIA to date. However, examples of transparent staurolite as an inclusion have been documented in ruby (e.g., Spring 2020 *G&G Micro-World*, pp. 144–145; Fall 2020 *G&G Micro-World*, pp. 434–435).

Michaela Damba



G&G

Micro-World

Editor: Tyler Smith

Contributing Editors: John I. Koivula and Nathan Renfro



Figure 1. Goethite sprays in an apatite's surface-reaching fracture. Photomicrograph by Michaela Damba and John Koivula; field of view 1.26 mm.

Goethite Sprays in Apatite

The authors recently examined a 0.89 ct green-blue apatite that contained intriguing brownish yellow mineral inclusions trapped within a large fracture (figure 1). Visual examination revealed these inclusions were sprays of goethite, a hydrous ferric oxide named in 1806 in honor of German scientist and author Johann Wolfgang von Goethe. These sprays formed epigenetically where the preexisting apatite host encountered groundwater enriched with ferric oxide. This groundwater invaded the fractures of the apatite and then precipitated crystalline goethite as it dried out (J.I. Koivula, "Useful visual clue indicating corundum heat treatment," Fall 2013 *G&G*, pp. 160–161).

*Michaela Damba and John I. Koivula
GIA, Carlsbad*

Fireworks in Aquamarine

The author recently examined a large 25.08 ct greenish blue beryl (aquamarine) containing numerous oriented small two-phase (liquid and gas) thin film inclusions. These inclusions were hardly visible in brightfield

About the banner: Growth hillocks on the surface of a heliodor beryl from Volodarsk-Volynskii, Zhytomyr Oblast, Ukraine, using differential interference contrast microscopy. Photomicrograph by Nathan Renfro; field of view 1.44 mm.

GEMS & GEMOLOGY, VOL. 62, No. 1, pp. 78–85.

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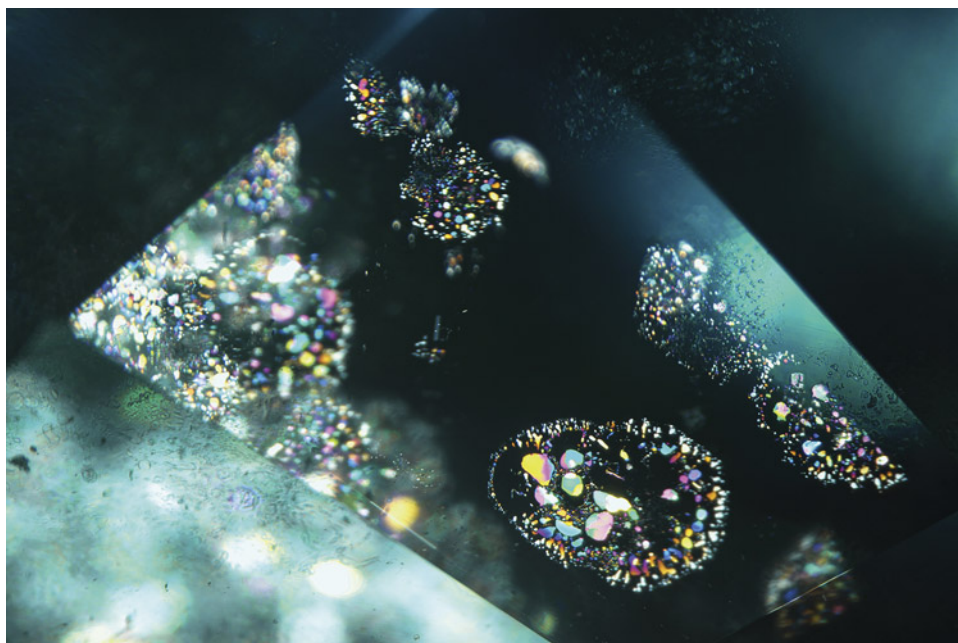


Figure 2. Iridescent thin films in aquamarine viewed with fiber-optic illumination. Photomicrograph by Michaela Damba; field of view 7.19 mm.

illumination but became reflective and iridescent when viewed with fiber-optic illumination (figure 2). The most diagnostic of beryl inclusions (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones, Volume 2*, Opinio Publishers, Basel, Switzerland, 2005, pp. 312–314), the thin films were situated in planes perpendicular to the *c*-axis of the host. The thin films in this aquamarine resembled fireworks in the night sky.

Michaela Damba

“Basketball Player” in Diamond

During routine examination, a natural D-color round brilliant diamond with SI₁ clarity, weighing 0.84 ct and

measuring $5.98 \times 6.02 \times 3.78$ mm, captured the author’s attention for its interesting combination of internal features. A cloud subtly formed the outline of a human figure, complete with arms and legs, while a nearby rounded crystal evoked the shape of a ball (figure 3). Together, the inclusion scene provided a perfect snapshot of a basketball player dribbling a ball down the court. The overall visual impression was not only rare but uniquely expressive, giving the diamond a personality beyond its standard gemological attributes. This captivating internal structure is a prime example of how nature can create art that mirrors human life and movement.

*Tejas Jhaveri
GIA, Mumbai*

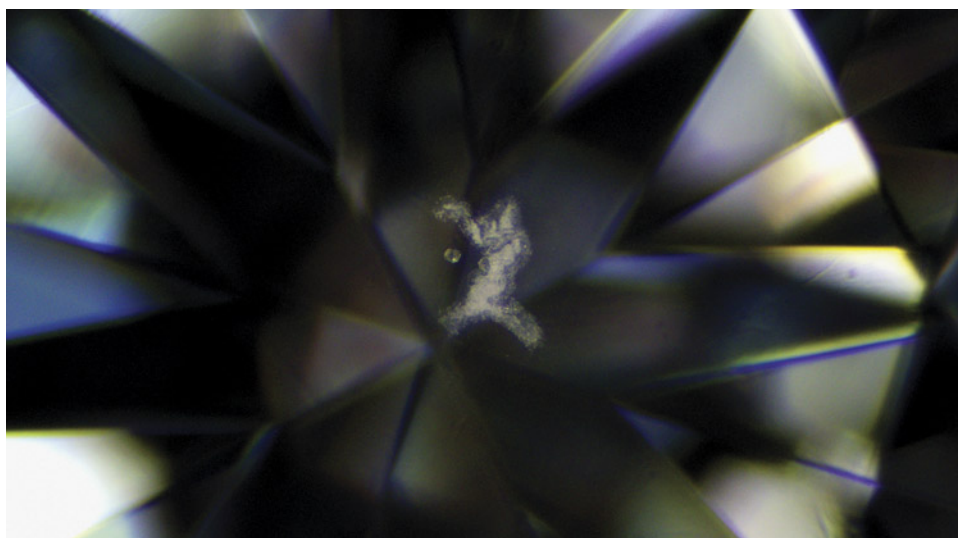


Figure 3. This diamond’s cloud and crystal inclusions resemble a basketball player in action. Photomicrograph by Tejas Jhaveri and Nishant Shah; field of view 3.20 mm.



Figure 4. A collection of needle inclusions in a 2.30 ct pyrope-almandine garnet. Photomicrograph by Isabelle Corvin; field of view 2.5 mm.

“Comet Tail” Needle Cluster in Garnet

While needles are common inclusions in many garnet species, this 2.30 ct pyrope-almandine garnet showcased them in a spectacular fashion (figure 4). The cluster of needles resembled a comet’s tail, with the needles intersecting at approximately 70 degrees in the center of the gemstone. The contrasting color of the needles with the red bodycolor of the garnet helps highlight this striking group of inclusions. Needle inclusions can provide important clues about a garnet’s formation, including pressure and temperature conditions during the growth process (J.A. Axler and J.J. Ague, “Oriented multiphase needles in garnet from ultrahigh-temperature granulites, Connecticut, U.S.A.,” *American Mineralogist*, Vol. 100, No. 10, 2015, pp. 2254–2271).

Isabelle Corvin
Olympia, Washington

“Meteor Shower” in a Pearl

Recently, the authors examined a natural nacreous pearl from the Mytiloidea superfamily of marine mollusks. The gray and violet button-shaped pearl weighed 4.13 ct and

measured $8.70 \times 8.46 \times 7.91$ mm. Under magnification, distinct natural curved striations were observed on the pearl’s surface, resulting from unusual stacking of its nacre layers. Regularly spaced microscopic gaps within these striations allowed incident light to penetrate the inner subsurface layers of the pearl. When gently tilted away from direct light, these small rays appeared as radiant streaks resembling shooting stars (figure 5). This intriguing surface phenomenon was reminiscent of a meteor shower traversing the night sky.

Rajesh Patel and Abeer Al-Alawi
GIA, Mumbai

Play-of-Color on a Pen Pearl

Pearls from *Pinna* species are commonly referred to as “pen pearls,” belonging to the Pinnidae family, and can be found in both nacreous and non-nacreous forms. Recently, the authors encountered a non-nacreous pen pearl with a unique surface phenomenon. This dark brown drop-shaped pearl, weighing 7.85 ct and measuring 11.75×9.97 mm, exhibited prominent surface-reaching cracks. Under high magnification with fiber-optic illumination, its surface dis-

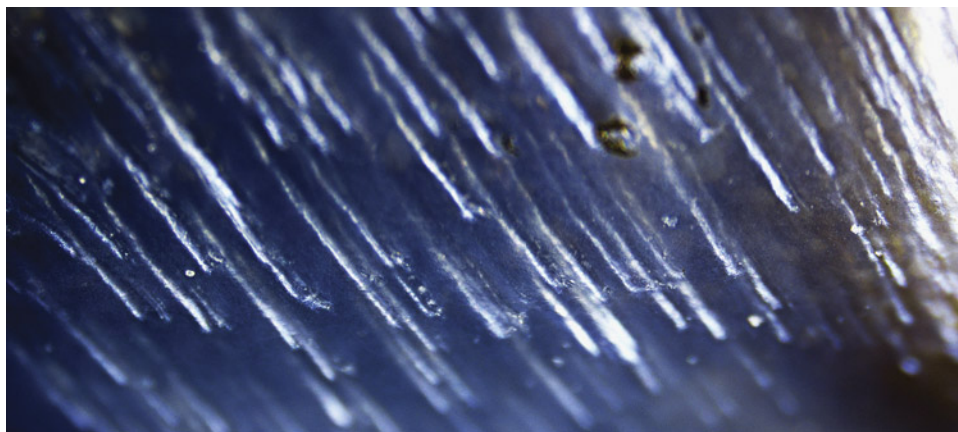


Figure 5. A natural nacreous pearl from the Mytiloidea superfamily displays an effect reminiscent of a meteor shower. Photomicrograph by Rajesh Patel; field of view 4 mm.

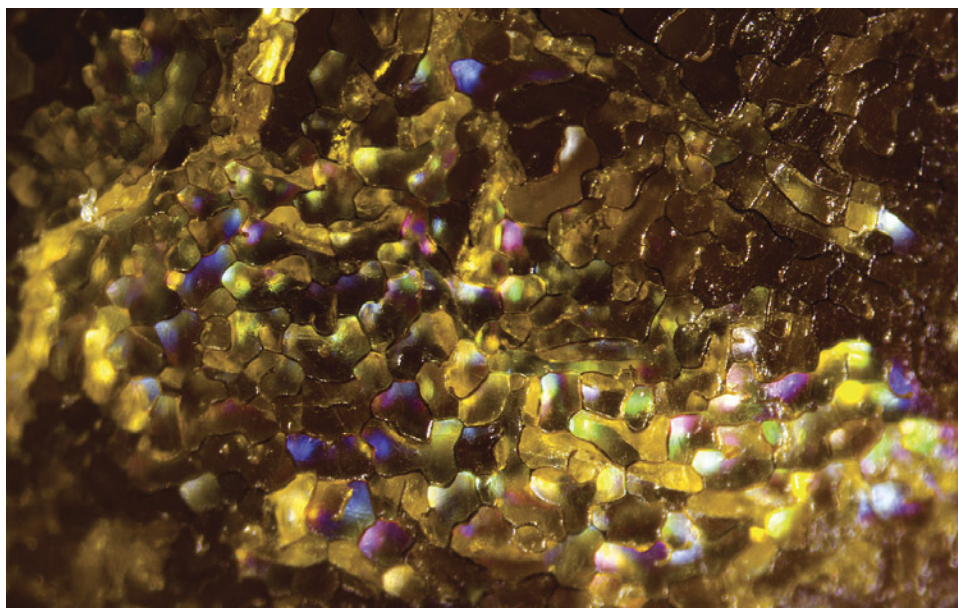


Figure 6. Cellular arrangement of calcitic crystals on the surface of a pen pearl showing play-of-color caused by their interaction with light. Photomicrograph by Gauri Sarvankar; field of view 3.30 mm.

played a pseudo-hexagonal mosaic pattern, with each cell revealing a vertical columnar arrangement of calcitic crystals (N. Sturman et al., "Observations on pearls reportedly from the Pinnidae family (pen pearls)," Fall 2014 *G&G*, pp. 202–215). The semitranslucent nature of these cells allowed light to diffract, producing a vibrant play-of-color featuring shades of pink, blue, yellow, and green (figure 6). Although natural opals also exhibit a similar surface phenomenon, it is rare to see this phenomenon in pearls.

*Gauri Sarvankar and Abeer Al-Alawi
GIA, Mumbai*

"Spiderweb" Structure on a Pearl's Base

The authors recently examined a natural light cream near-button pearl weighing 4.27 ct. Externally, the pearl

exhibited a dark brown non-nacreous base with significant surface-reaching cracks. Notably, the center of the base displayed a cavity formation with a web-like structure (figure 7). When viewed under higher magnification, very thin thread-like filaments containing small yellow globules trapped between them were observed (figure 8), resembling the delicate and intricate features of a spiderweb. However, the identity of the fibrous formation remains unknown as its fragile nature prevented any analytical testing that might cause damage to the pearl.

Spiderwebs are renowned for their fascinating structures, often showcasing complex patterns and fine, silky threads. The web-like formation observed in this pearl possesses qualities that are both enchanting and peculiar.

*Eram Shaikh and Abeer Al-Alawi
GIA, Mumbai*

Figure 7. Spiderweb-like structure on the non-nacreous base of a natural pearl. Photomicrograph by Eram Shaikh; field of view 2.00 mm.

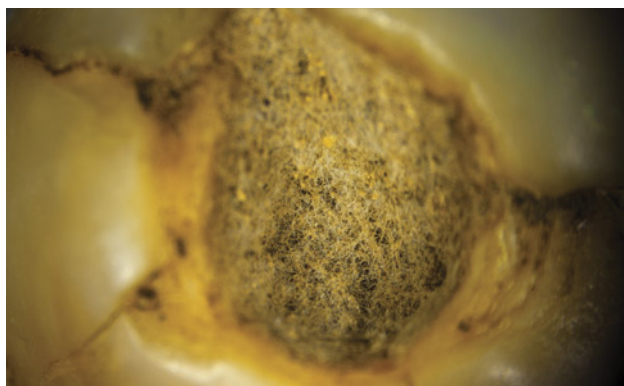


Figure 8. Thread-like filaments of the webbing with yellow globules trapped between them were observed on the non-nacreous area of the pearl. Photomicrograph by Eram Shaikh; field of view 8.00 mm.

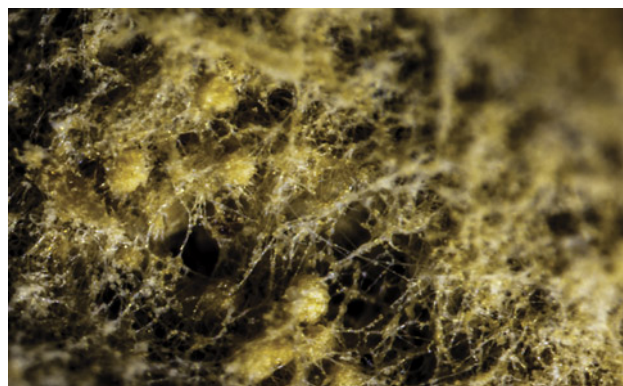




Figure 9. A well-formed aquamarine crystal embedded within colorless quartz. Photomicrograph by Wingtak Lui; field of view 3.2 mm.

Euhedral Aquamarine Crystals in Quartz

A $1.87 \times 1.53 \times 1.17$ cm colorless quartz specimen containing interesting inclusions was recently studied by the authors. Microscopic examination revealed multiple well-formed blue hexagonal prismatic crystals embedded within the quartz (figure 9). These inclusions exhibited moderate pleochroism from greenish blue to light greenish blue, distinct from the non-pleochroic quartz host. Their morphology and optical properties suggested a beryl-group mineral. Spectroscopic analyses (infrared and Raman) confirmed the inclusions as beryl. Ultraviolet/visible absorption features attributed to Fe^{2+} – Fe^{3+} intervalence transition indicated iron as the chromophore responsible for the blue coloration, further identifying the inclusions as aquamarine. This specimen illustrates the diagnostic value of crystal morphology, pleochroism, and spectroscopic analysis in inclusion identification.

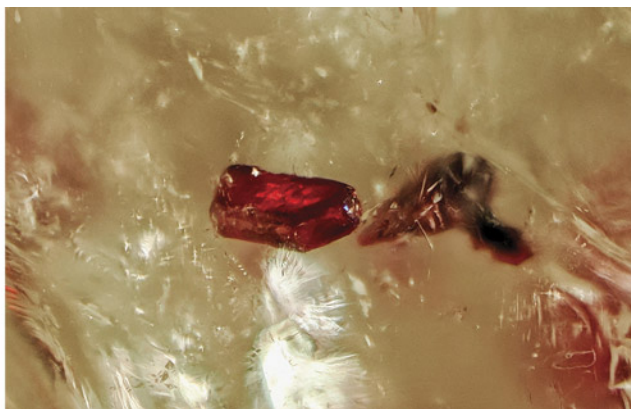
*Rui Rui Xing and Wingtak Lui
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Cinnabar in Quartz

A fascinating quartz specimen with bright red inclusions was recently analyzed. It originated from the Chatian mine, Xiangxi, Hunan Province, China—a locality known for its fine cinnabar and mercury ore deposits.

Visual inspection revealed striking red inclusions scattered throughout the quartz, appearing as high-luster, intensely red crystals, with some exhibiting well-defined habits (figure 10). Their vivid color and brilliant internal reflections were consistent with cinnabar. Microscopic

Figure 10. Bright red to dark red crystals of cinnabar in colorless quartz. Photomicrographs by Wingtak Lui; fields of view 16 mm (left) and 5 mm (right).



examination showed that many inclusions were transparent to translucent with short prismatic or barrel-shaped habits embedded at various depths. To confirm their identity, Raman microspectrometry was performed. The spectrum showed characteristic cinnabar peaks, definitively identifying the inclusions as cinnabar.

Wingtak Lui, Rui Rui Xing, and Yu-Chen Huang

Uniquely Patterned Clouds in Sri Lankan Sapphire

Corundum is found in many disparate locations. Similarly, the morphology of impurity clouds in corundum can vary between localities, from the ultrafine, wide-banded clouds of Kashmir to the layered geometric clouds of Madagascar. Although rarely endemic, they can be used by gemologists to support geographic origin determinations.

The author recently examined a 4.00 ct Sri Lankan blue sapphire from GIA's colored stone reference collection. The stone exhibited groups of intersecting needles, fingerprints, and a twinning plane. Additionally, particle clouds with a unique interlocking triangular pattern were found under fiber-optic illumination (figure 11). This is the first time the author has observed this pattern in a sapphire from Sri Lanka.

Titapa Tanawansombat
GIA, Bangkok

Mystery Bubble in Spinel

Gemology is a forensic science, and often what we don't know can be as interesting as what we do know. Recently, the authors encountered a fascinating spinel. The owner noted that the stone (reportedly from Myanmar, formerly

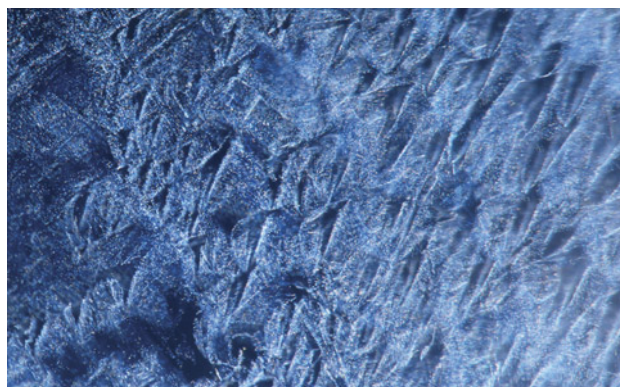


Figure 11. A unique pattern of particles in a Sri Lankan blue sapphire is observed under fiber-optic illumination. Photomicrograph by Titapa Tanawansombat; field of view 1.80 mm.

Burma) contained an inclusion feature with a bubble inside. Closer inspection revealed a negative crystal or cavity that indeed contained a mobile bubble (figure 12). With gentle heating from the warmth of the microscope's light bulb, the authors were able to see the bubble expand and contract (see video at <https://www.gia.edu/gems-gemology/spring-2026-microworld-bubble-in-spinel>).

Both micro-Raman and micro-Fourier-transform infrared spectroscopy were used in attempts to identify the liquid, but the results were inconclusive. The inclusion was inert when exposed to both long-wave (365 nm) and short-wave (254 nm) ultraviolet illumination.

Sulfur-rich fluids have been reported in Burmese spinel (Winter 2017 *G&G Micro-World*, p. 468). However, the sample did not match sulfur-rich fluids, either in appearance (sulfur-rich fluids tend to have a yellowish

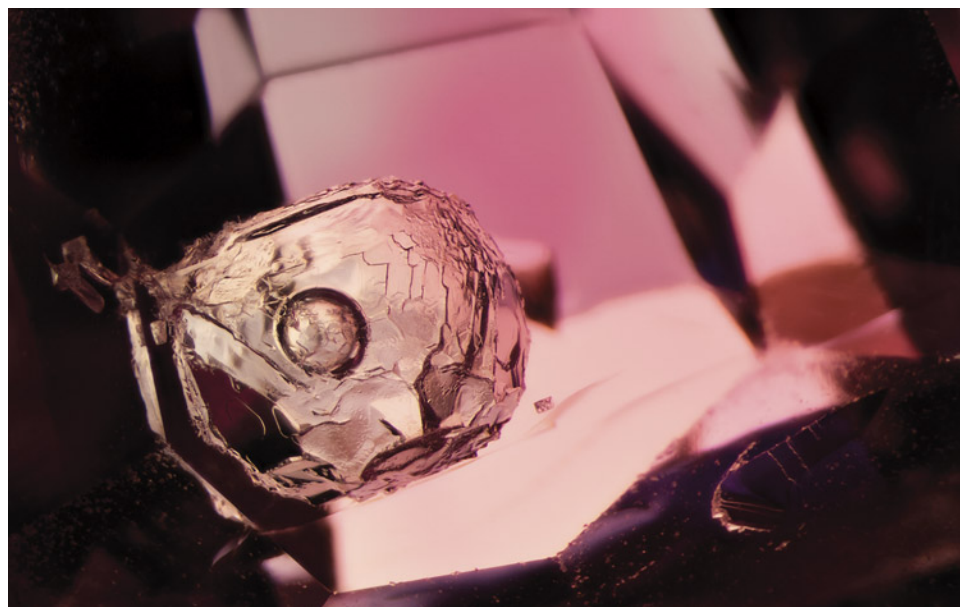


Figure 12. A mobile bubble floating in a cavity in spinel observed under diffused transmitted light. The nature of the substance inside the cavity remains a mystery. Photomicrograph by E. Billie Hughes; field of view ~3.5 mm.

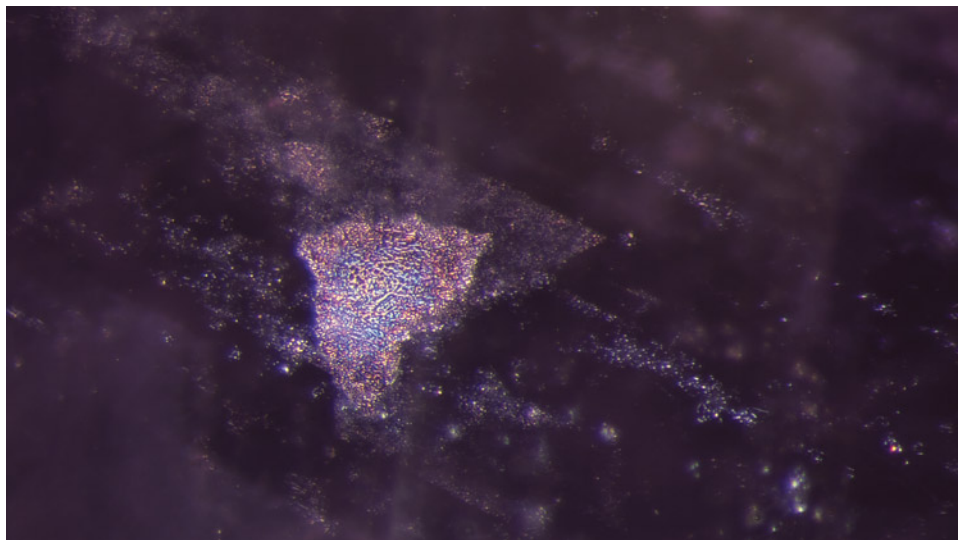


Figure 13. Complex planes with mottled particles in this heated spinel may be the remnants of oriented lamellae. Viewed in diffused fiber-optic lighting. Photomicrograph by E. Billie Hughes; field of view 1.6 mm.

color) or in its Raman spectrum. In many cases, cavities in corundum displaying a similar appearance have been found to contain carbon dioxide. However, in the authors' experience, it is often possible to identify carbon dioxide with Raman spectroscopy, whereas in this case, Raman spectroscopy did not yield a conclusive answer.

Currently, the exact nature of this inclusion remains a mystery.

E. Billie Hughes
Lotus Gemology, Bangkok
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Evidence of Heat Treatment in Spinel

Although most spinels that pass through gemological laboratories are untreated, treated samples are occasionally

received. Oiling is the most common treatment, but heated spinels are observed on rare occasions.

A red spinel was recently examined, with a declared origin of Tanzania. Both the photoluminescence spectrum and microscopic observations provided evidence that the stone had been heated. Given how rarely heated spinel is encountered, the inclusion scenes were worth documenting.

One interesting characteristic was the presence of several flat plates with a mottled surface appearance (figure 13), which may have been heated remnants of the oriented lamellae sometimes seen in Tanzanian spinel. Partially healed fissures with a glassy appearance and irregular melted channels were also observed (figure 14). These features were quite different from the fingerprints often present in unheated spinel.

E. Billie Hughes

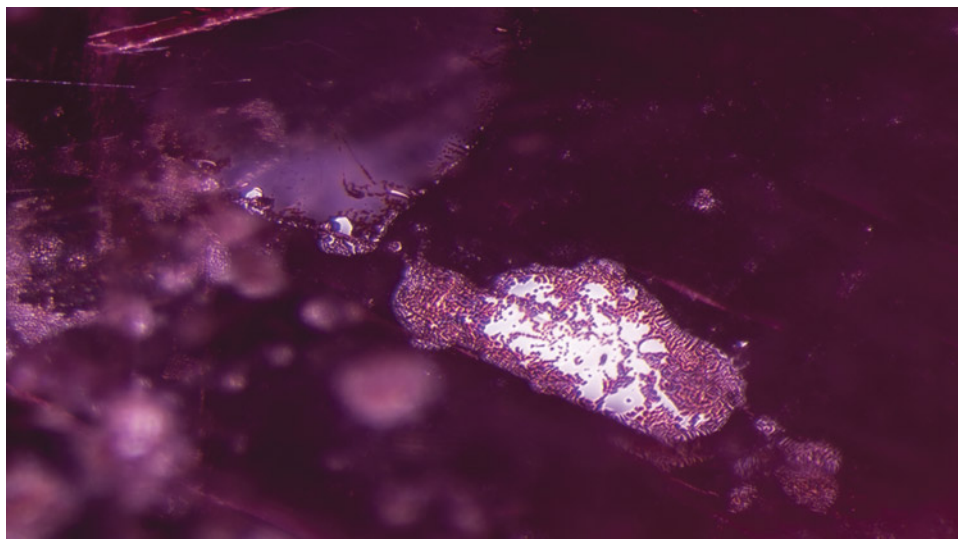


Figure 14. Partially healed fissures with melted channels and glassy areas provide evidence that this spinel underwent heat treatment. Viewed in dark-field and diffused fiber-optic lighting. Photomicrograph by E. Billie Hughes; field of view 1.9 mm.

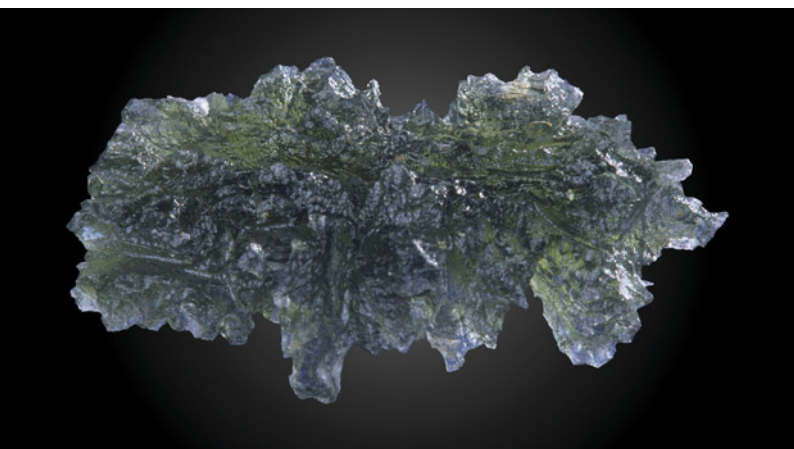


Figure 15. A true collector's item, this 32.06 mm long ornate leaf-shaped olive green moldavite is from the Besednice strewn field in the Czech Republic. Possessing unbroken spires and undamaged surfaces, this pristine condition is rare. Photo by Maha Calderon.

Quarterly Crystal: Spires on Moldavite

A well-formed moldavite tektite from the Czech Republic is the subject of this issue's Quarterly Crystal. As tektite is technically not a crystal but rather a naturally occurring glass, flexibility was required to include this 18.48 ct leafy

moldavite tektite in this issue's column (figure 15). The recently examined specimen came from Norm Lehrman at the Tektite Source in Reno, Nevada.

The transparent to translucent slightly grayish green moldavite measured $32.06 \times 19.83 \times 9.74$ mm and hosted numerous unbroken spires on its heat-sculptured surface (figure 16). The fresh unbroken nature of the spires on this tektite is unusual considering the violent formational process of tektites. This makes well-formed unbroken moldavites rather rare.

This moldavite is from Besednice in the Český Krumlov District in the South Bohemian Region of the Czech Republic. Besednice moldavites are widely considered the finest examples of the material, and the beautiful olive green glass is often faceted into gemstones. However, moldavites with detailed leafy natural ornamentation such as this one are not cut, but instead kept as natural specimens. Moldavites are derived from the meteorite impact at the Nördlinger Ries crater in Germany approximately 15 million years ago. Moldavite tektites were first found in association with the Venus of Willendorf archaeological site in Austria, dating back approximately 29,000 years.

*John I. Koivula and Nathan Renfro
GIA, Carlsbad*

Figure 16. Details of the unbroken spire tips and undamaged surface structure of the leaf-shaped moldavite are highlighted by the internal strain as revealed in polarized light with a first-order red compensator. Photomicrograph by John Koivula; field of view 11.50 mm.





GEM NEWS INTERNATIONAL

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Figure 1. An alligator measuring roughly 29 × 11 × 9 inches fashioned from fine nephrite from the Polar mine in British Columbia. This exceptional hand-carved work was purchased at GJX on opening day. Photo by Jennifer Stone-Sundberg; courtesy of Jade West Corp.

TUCSON 2026

At the AGTA GemFair in Tucson, Arizona (February 2–6), many vendors had very strong sales on opening day, with several reporting challenges to satisfy the demand with on-hand staff. Some AGTA exhibitors expressed concern that the fewer number of show days this year could affect sales, as customers who would normally visit on the weekend might have been deterred by the show ending on Friday. Many Gem & Jewelry Exchange (GJX) vendors indicated that Monday was slow, but attendance picked up on Tuesday after higher-end buyers finished shopping at the AGTA show. High-end and unusual items sold quickly, including

a finely carved nephrite Polar Jade alligator from the Polar mine in British Columbia (figure 1). Numerous AGTA and GJX sellers voiced relief that their sales were high enough to not only break even, but resulted in a strong if not near-record year. The foot traffic appeared somewhat lower at other venues, including the Pueblo Gem & Mineral Show, the 22nd Street Mineral, Fossil, Gem & Jewelry Show, and the JOGS Gem & Jewelry Show, but vendors with premium goods at attractive price points reported brisk sales.

Due to increased challenges for foreign vendors bringing goods into the U.S., some long-time participants did not attend this year. As predicted, empty booths were observed at some of the shows, but an unexpected result was the presence of some new faces at both AGTA and GJX, as vendors who relinquished their booths opened up opportunities for those waitlisted. For example, RG Crystals exhibited at GJX for the first time, selling extraordinary laboratory-grown gems, including synthetic hydrothermal emeralds mimicking both the color and overall appearance of Colombian emerald (figure 2). As with last year, many buyers relied on video calls to coordinate with colleagues, contributing to lower attendance as companies limited the number of staff attending the shows. Buyers and sellers expressed concern over pricing pressures driven by tariffs, reduced global gem availability, and elevated gold and silver

Editors' note: Interested contributors should send information and illustrations to gandgeditorial@gia.edu.

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Figure 2. Laboratory-grown emeralds with color and overall appearance imitating Colombian emerald. Left: A 66.57 ct rectangular step cut measuring 30 × 22 mm. Right: A 1.72 ct trillion and a 2.20 ct rectangular step cut. Photos by Jennifer Stone-Sundberg; courtesy of RG Crystals.

prices. The price instability of precious metals also caused some trepidation. In fact, as the shows were starting, the price of silver precipitously dropped more than 30% from \$114.43 an ounce on January 29 to \$78.53 the very next day, whereas gold dropped about 13% from \$5,354.80 an ounce on January 29 to \$4,652.60 on February 2. In some venues, this resulted in daily price changes for goods. With diminished international trade activity, many vendors focused on clearing older inventory.

As with last year, GIA's Show Service Laboratory had an all-time record year. Lab personnel reported that the majority of show submissions were traditional colored stones: ruby, sapphire, emerald, and Paraíba tourmaline.

According to exhibitors carrying a wide variety of gem materials, fancy-color sapphires were the most popular stones, particularly pinks and purples, as well as teals and greens. Strong U.S. and international demand for Montana sapphire has driven prices for stones over 1 ct to exceptional levels, reportedly due to increased global awareness and an unpredictable supply of rough. Garnets sold very well this year, and sales of unheated "opalescent" or "sleepy" stones continued to be strong. Star ruby and sapphire (figure 3) were some of the hottest items, followed by cat's-eye stones (figure 4), including cat's-eye moonstone, offered at several of the shows at very attractive prices. "Rainbow moonstone" from Madagascar (Spring 2024

Figure 3. Exceptional star sapphires from Nivithigala, Sri Lanka, viewed in sunlight: a 7.45 ct purple color-change star sapphire (left) and a 19.74 ct light grayish blue star sapphire exhibiting an extraordinarily sharp and distinct star (right). Photo by Jennifer Stone-Sundberg; courtesy of Dudley Blauwet Gems.



Figure 4. Stones with strong chatoyancy set in sterling silver rings: an 8 mm tiger's-eye (left) and a 7 × 9 mm cat's-eye moonstone (right). Courtesy of Jennifer Stone-Sundberg.





Figure 5. Gray matrix labradorite from Madagascar with pink flash. Courtesy of Jennifer Stone-Sundberg.

GNI, p. 102) continued to sell quickly among buyers. Ethiopian opal was abundant at shows around town, with a particularly strong presence of rough and loose stones at the 22nd Street show. Prices varied widely, offering some highly affordable options; however, prices may start to rise as supply becomes increasingly limited due to the depletion of easily accessible material in the Wollo region. Labradorite was popular at several shows, including a Madagascar variety with a gray matrix and pink flash available at venues such as the Pueblo and 22nd Street shows (figure 5).



Figure 7. Guatemalan blue jadeite jade bracelet with 6 mm diameter cylindrical beads. Photo by Jennifer Stone-Sundberg; courtesy of Jade West Corp.

This year's trending colors included hot pinks and purples, as illustrated by both the AGTA Spectrum and Cutting Edge Buyer's Choice Awards (figure 6), along with neon blue-green, light green, teal, greenish blue, and lilac. A newer popular material, Guatemalan blue jadeite jade (figure 7), displayed a teal color similar to that of some of the most in-demand unheated Montana sapphire.

Figure 6. AGTA Buyer's Choice Award winners. Cutting Edge Award (left): Ben Kho, 35.25 ct pink-purple octagonal-cut kunzite. Spectrum Award (right): Mimi So, 18K rose gold "Cotton Candy" necklace featuring a 16.71 ct pink pear-shaped kunzite, 4.05 ct vivid pink spinel, and 5.65 ct imperial topaz accented by sapphires, spinels, tourmalines, and diamonds. Photos by Jeff Mason Photography/AGTA; courtesy of Kho International Ltd. (left) and Mimi So (right).

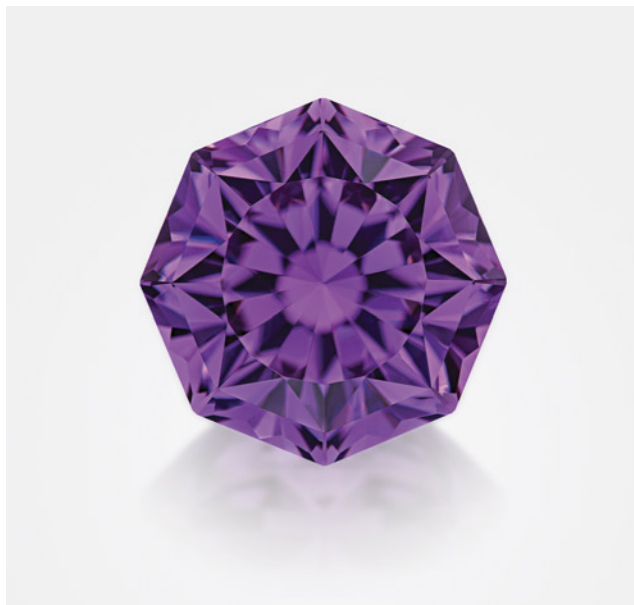




Figure 8. Precision-cut, calibrated gems in a variety of shapes ranging from 1.0×1.5 mm baguettes to 4.0×6.0 mm lozenges, including amethyst, citrine, tourmaline, topaz, garnet, and peridot, arranged to illustrate various color combinations and patterns. Photo by Jennifer Stone-Sundberg; courtesy of Shanu G. Inc.

Several cutting trends stood out, driven by demand for well-cut stones maximizing light return and color over carat weight, whether through precision cutting or more unconventional styles. While the term *precision cutting*

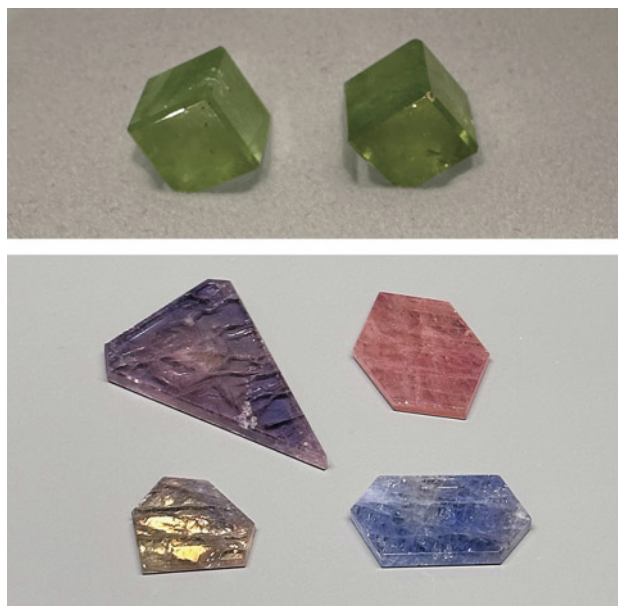


Figure 10. Top: A pair of 7.5 mm tourmaline cubes totaling 12.14 carats. Photo by Lisa Kennedy; courtesy of M.T. Mohr. Bottom: Natural sapphire slabs from Umba Valley in Tanzania ranging from 7.73 ct (yellow) to 26.40 ct (purple). Photo by Jennifer Stone-Sundberg; courtesy of Misfit Diamonds.

was used variably, buyers consistently valued sharp meet points at facet junctions, optimal cutting angles for light return, and mirror-finish flat facets. Precision cutting was illustrated in a wide variety of small gemstones (figure 8), as well as larger stones. Star shapes were popular at AGTA, appearing in pieces such as the moissanite “Snowflake” and faceted star-cut gems (figure 9) in materials including Montana sapphire, neon beryl, red Idaho garnet, and various quartz. Other unconventional cutting styles, including cubes (figure 10, top) and cones, also attracted considerable attention for their bold architectural approach. Polished gem slabs in rectangles, triangles, and other simple shapes were in demand among several designers. Attractive sapphire slabs with distinct inclusions

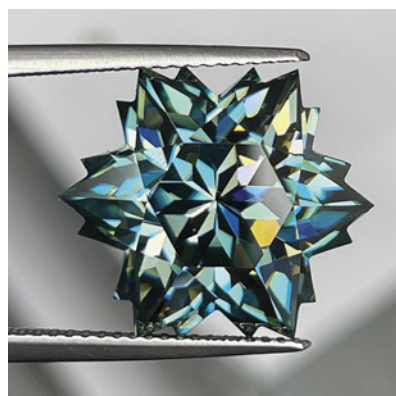


Figure 9. Left: 14.80 ct blue moissanite “Snowflake”; courtesy of Wobito. Right: Star-cut Montana sapphire in lilac and light yellow (4 mm each), Nigerian beryl in neon blue (5 mm), and orange Madeira citrine (5 mm). Photo by Jennifer Stone-Sundberg; courtesy of Columbia Gem House.



Figure 11. Elongated baguette-cut rock quartz from Brazil (left, 80 × 10 mm, 61.41 ct stone; right, two 70 × 9 mm stones totaling 83.07 carats) accented by Bolivian citrine (left, 25.27 ct triangular brilliant; right, two pear brilliants totaling 15.30 carats). Photo by Jennifer Stone-Sundberg; courtesy of Pillar & Stone International.

(figure 10, bottom) and long baguette-cut gems (figure 11) were particularly popular.

In summary, buyers and sellers arrived in Tucson with concerns about availability and pricing, but many found relief as the shows progressed. Although no major new trends or viral products emerged, vendors offered a broad selection of attractively colored gems with an emphasis on cut quality and provenance documentation tracing a stone from the mine to its finished form. Lower foot traffic may be the signal of a lasting shift, as smartphones enable companies to send fewer in-person buyers. Exhibitors also explored creative strategies to navigate tariffs, including arranging U.S.-based storage to reduce repeated border crossings. For some, reduced participation created opportunities, allowing new businesses to secure highly desirable booth spaces across the major shows.

Jennifer Stone-Sundberg and Tao Hsu
GIA, Carlsbad

Lisa Kennedy
GIA, New York

COLORED STONES AND ORGANIC MATERIALS

High-clarity suite of color-change pyrope garnets. At the Pueblo Gem & Mineral Show, a visit with self-described “crystal machinist” Todd Wacks (Tucson Todd’s Gems, Arizona) did not disappoint. Wacks, who apprenticed with master faceter Meg Berry, has been cutting gems professionally for more than a decade. His approach to gem cutting prioritizes beauty and results in distinctive cuts and patterns tailored to each gemstone. Wacks believes that cuts should be shaped to the natural form of the rough rather than forced into a preset, potentially wasteful pattern. Every stone he cuts is unique and optimized for the piece of rough, with a strict adherence to appropriate pavilion and crown angles coupled with extremely flat facets and a mirror polish. Wacks has a special passion for garnets (e.g., E. Hogarth, “Beyond Beauty: A Garnet Necklace Decoded,” Spring 2024 *G&G*, pp. 140–143), with extensive experience cutting thousands of them.

An exceptional graduated suite of 65 matched color-change pyrope garnets from Morogoro, Tanzania, weighing 106.35 carats total, drew significant attention at his booth. These garnets, ranging from 6.5 to 9.5 mm in diameter, change from a bright pinkish purple in daylight to a hot pink in incandescent lighting (figure 12). What distinguished this one-of-a-kind set was the extraordinary clarity achieved for each stone. Wacks noted that producing the perfectly matched suite required nearly 6 kilograms of rough, hundreds of production hours, and the cutting of more than 100 stones. His primary challenge was addressing the clarity issues characteristic of this garnet, which required consistently removing hazier stones rich with rutile needles.

The material, a garnet ranging in color from bright pink to purple, was reportedly discovered in 1987 (C.M. Stockton, “Pastel pyropes,” Summer 1988 *G&G*, pp. 104–106), but initially drew little interest as it was included, mistaken for rhodolite garnet, and its color-change property had not yet been recognized. For Wacks, the story began in 2014, when three dealers approached him with a new “pink” garnet rough that had been stored in a safe for nearly 30 years. After cutting a sample, he was excited by the color and decided to set it into a ring. Wacks noticed a color change from purple to hot pink as he moved the ring from his microscope’s fluorescent lighting to his polishing station’s incandescent lighting. At this point, he was sure he had something worth investigating further. After gathering some standard gemological data including refractive index (1.729) and specific gravity (3.61), along with an unfamiliar spectrum from a spectroscope, Wacks realized that he could not definitively match the garnet to any varieties he knew. This prompted him and several colleagues to submit material to GIA’s laboratory, which confirmed it as a distinct variety: a vanadium- and chromium-bearing pyrope garnet exhibiting color shifts or changes between illumination sources (Spring 2015 GNI, pp. 88–89; Z. Sun

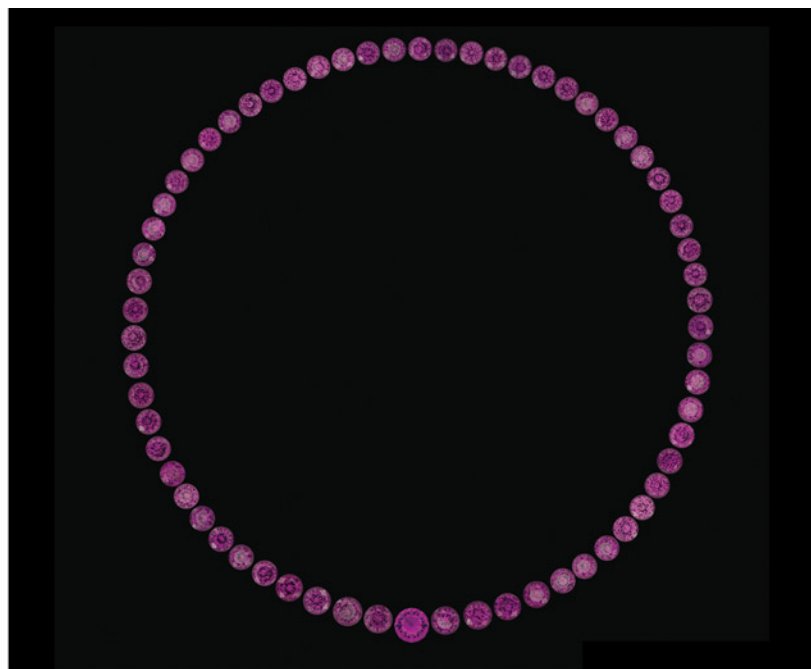
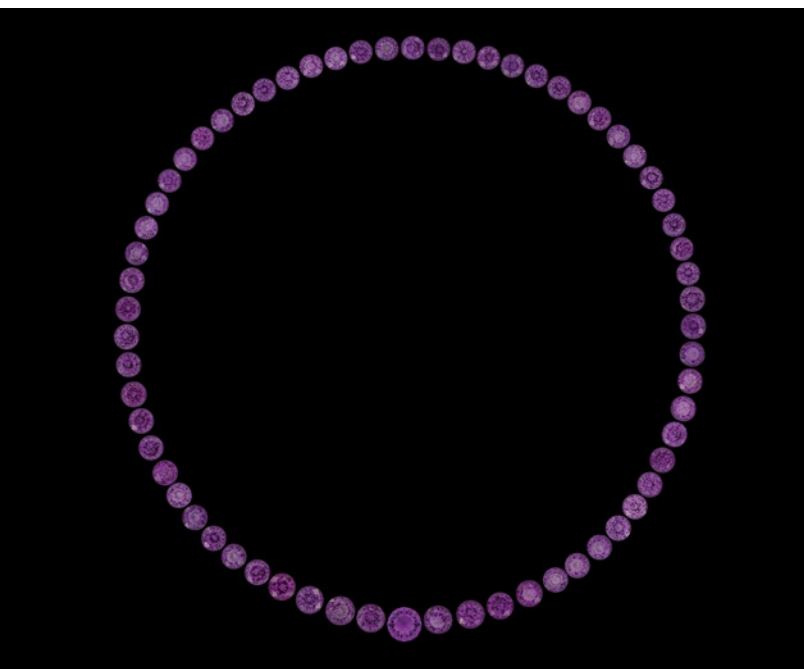


Figure 12. The suite of pyrope garnets showing their color-change effect using daylight-equivalent (left) and incandescent (right) illumination. Photos by Robert Weldon; courtesy of Tucson Todd's Gems.

et al., "Vanadium- and chromium-bearing pink pyrope garnet: Characterization and quantitative colorimetric analysis," Winter 2015 *G&G*, pp. 348–369).

After acquiring a substantial portion of the available rough in 2014, Wacks has since faceted many of these distinctive garnets, producing stones as large as 35 ct. With the source now exhausted and only limited material remaining, this high-quality suite of unique pyrope garnets was noteworthy to see. We look forward to seeing what Wacks produces next, as he has recently been expanding his skill set by training as a gem carver in Idar-Oberstein.

Jennifer Stone-Sundberg

Gold sheen sapphire. At the JOGS Gem & Jewelry and 22nd Street Mineral, Fossil, Gem & Jewelry shows, Genuine Gems & Jewellery (Bangkok) offered "gold sheen" sapphire from eastern Kenya in a striking range of colors and effects. This translucent material is known for exhibiting an attractive golden sheen, a result of oriented platelets and needles of titanium and iron oxides including hematite, ilmenite, and magnetite (T.N. Bui et al., "From exsolution to 'gold sheen': A new variety of corundum," *Journal of Gemmology*, Vol. 34, No. 8, 2015, pp. 678–691). Additionally, some stones displayed distinct asterism, while others had visible bands of color zoning (figure 13).

Figure 13. Gold sheen sapphires displaying asterism (left) and multicolored zoning (right). Photos by Jennifer Stone-Sundberg; courtesy of Genuine Gems & Jewellery.



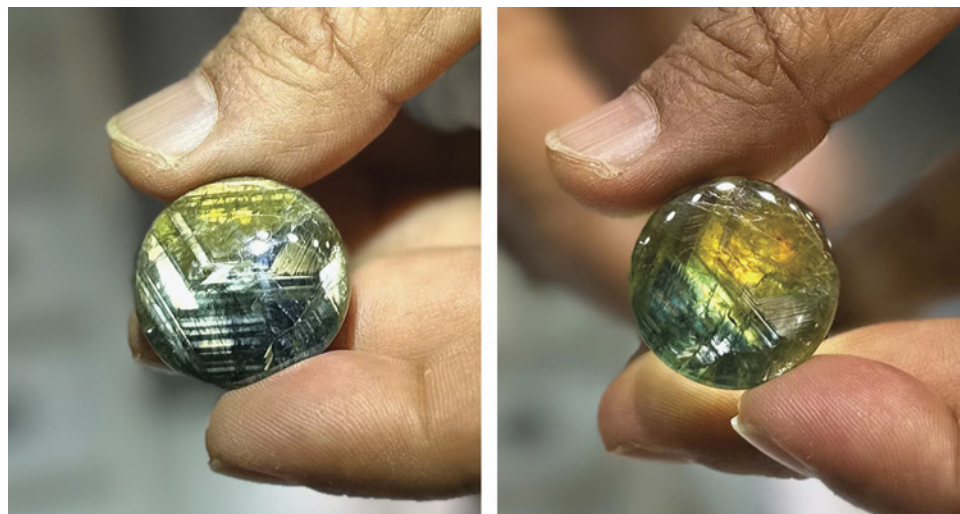


Figure 14. A gold sheen sapphire showing its yellow and blue color banding (left) and translucency with illumination from the back (right). Photos by Jennifer Stone-Sundberg; courtesy of Genuine Gems & Jewellery.

The stones exhibited single or multiple bodycolors, including yellow, blue, green, brown, and gold (figure 14). This material was untreated and cut primarily into cabochons and checkerboard patterns to optimize its optical effects. Stones from less than a carat to hundreds of carats were available.

In 2009, Tanzim Khan Malik, owner of Genuine Gems & Jewellery, was approached by a longtime Kenyan dealer regarding unusual rough stones found on the ground near Kenya's eastern border with Somalia. The report of the material intrigued Malik, who acquired a small parcel for examination. The initial parcel of this corundum was not gem-quality. While the fragile material lacked stability for faceting and exhibited a layered internal structure, it showed a distinct golden shimmer that excited Malik. This led him to fund a systematic exploration with controlled digging to discover the corundum-bearing seam. The location was kept classified to protect the mine and its operation. This work, executed by local miners, ultimately uncovered the seam bearing gem-quality sapphire, and extraction continued until 2014. During that period, Malik, who owned the mine's entire production, amassed approximately 25 tons of rough material.

When the first gem-quality material emerged from the mine, Malik focused on cutting this unique sapphire to optimize its beauty. With its color variety, banded quality, and striking gold sheen, he saw an opportunity to bring a brand-new sapphire variety to market and named the material "gold sheen" sapphire. Owning a fabrication facility, Malik has each stone cut to maximize its optical characteristics and hence its value. As the sole global supplier of this material, he has marketed gold sheen sapphire as a luxury stone. Malik described his customers as mainly high-end designers, investment buyers, and gem collectors, mentioning a variety of high-end jewelry houses that have incorporated the shimmery stone in one-of-a-kind pieces. The material has the strongest sales in the United States,

followed by Japan, Switzerland, the United Kingdom, and Monaco.

When asked about a glittery brown material from Madagascar being marketed in Tucson as gold sheen or golden sheen sapphire, Malik cautioned that the stones from Madagascar lack the color variety, oriented banding, or golden shimmer characteristic of the Kenyan material and are being deceptively sold under his product's name.

Jennifer Stone-Sundberg

Tucson 2026: Pearl market report. The authors visited many pearl vendors at the AGTA, Gem & Jewelry Exchange (GJX), and Pueblo Gem & Mineral shows to gain insight into the past year's global pearl market. Since the surge of global pearl demand and cultured pearl prices in 2023, the market has experienced some correction over the last two years, providing American buyers with more opportunities to source the goods they need. Most vendors reported a stronger show compared to last year, although trends varied slightly across sectors.

At all three shows, large round and near-round freshwater bead cultured pearls, often referred to as "Edison" pearls (C. Zhou et al., "Detection of color treatment and optical brightening in Chinese freshwater "Edison" pearls," Summer 2021 *G&G*, pp. 124–134), dominated the market due to the continuous improvement of color, size range, and quality levels over the past five years (figure 15). Edison pearls typically range in size from 9 mm to more than 15 mm. Despite a noticeable price increase, buyers continue to find great potential in these pearls, as they remain much more affordable than their saltwater counterparts. While multicolor strands were available, uniformly colored strands were most common. Single loose Edison pearls and pairs were also readily accessible. These pearls were carried by not only pearl vendors but also those selling beads and other colored gemstones. In



Figure 15. A strand of freshwater bead cultured pearls measuring 10 to 13 mm, showing all possible colors available in the market. Courtesy of Yen's Jewelry & Accessories Inc.

addition, small near-round and round freshwater bead cultured pearls from China were available from various vendors, predominantly in white but also in other colors (figure 16). Some of these pearls now reach 6 to 7 mm, a

Figure 16. Small round and near-round freshwater bead cultured pearls from China were widely available in Tucson, many of them white, with some reaching sizes of 6 to 7 mm. Photo by Artitaya Homkrajae; courtesy of Yen's Jewelry & Accessories Inc.



size noticeably larger than in previous years and comparable to typical akoya pearls. Based on the authors' observations, the quality of these freshwater bead cultured pearls has continued to improve.

For saltwater cultured pearls, despite relatively low production, Tahitian pearls remained in demand at this year's shows, with color being a significant draw for buyers, particularly the highly desired "peacock" variety for its combination of green bodycolor and significant overtone or orient. Various shades and tones of gray continued to be a classic choice for many. Though uniformly colored strands and pairs were still the mainstream inventory at the shows, multicolored Tahitian strands began to attract more attention (figure 17). Demand for Tahitian pearls in the 6 to 7 mm range remained consistent, but supply was very limited, with only a few dealers carrying these smaller sizes.

The demand for South Sea pearls, both white and golden, held steady. South Sea strands combining variously shaped white and golden pearls, sometimes paired with

Figure 17. Necklace featuring multicolored Tahitian bead cultured pearls measuring approximately 9 to 12 mm, in a combination of various colors and overtones. Photo by Artitaya Homkrajae; courtesy of Eliko Pearl Company.





Figure 18. Many vendors offered necklaces showcasing a variety of white and golden South Sea cultured pearls, attractively arranged with dark Tahitian cultured pearls. Photo by Artitaya Homkrajae; courtesy of Mastoloni.

Tahitians, were a notable trend this year, displayed by many vendors (figure 18). Akoya pearls were also readily available, especially those of higher quality produced in Japan. Smaller untreated akoya pearls in 2 to 5 mm sizes from Vietnam were offered as well, often in white, cream, yellow, and silver.

In addition to these four major types of cultured pearls, vendors carried a very limited supply of cultured *Pteria sterna* pearls from Mexico. Non-bead cultured (NBC) freshwater pearls have become more difficult to source recently, as many Chinese farms have shifted their focus to producing bead cultured pearls. NBC saltwater pearls, often referred to as cultured “keshi” in the trade, were limited in supply, prompting buyers to take a more proactive approach to sourcing.

Figure 19. An assortment of large size and high-quality natural Pinctada pearls at the GJX show. Photo by Artitaya Homkrajae; courtesy of Ocean Flame Ltd.



Natural pearls, both nacreous and non-nacreous, were exhibited by only a small group of vendors, with abalone and American freshwater pearls dominating the nacreous selection. *Pinctada* and *Pteria* natural pearls were spotted around the shows (figure 19), though only in limited quantities. While a variety of non-nacreous pearls were represented, conch, melo, and tridacninae subfamily (clam) pearls comprised the majority of this sector.

Overall, the pearl market has become more multifaceted than ever before with the availability of so many varieties offered at a more reasonable price point than in previous years.

Tao Hsu and Artitaya Homkrajae
GIA, Carlsbad

Akira Hyatt
GIA, New York

JEWELRY DESIGN

Animal motifs with purpose. Animal motifs have always had a place in jewelry, but many of today’s buyers are looking for more than ornament; they want one-of-a-kind pieces with a story and sense of purpose. That shift has created space for designers to rethink traditional themes, a direction reflected in Samira Mazloom’s “Fading Footprints” collection.

A seasoned designer and gemologist from a family of jewelry makers, Mazloom is deeply rooted in the craft. The author took an interest in Mazloom’s work at the Gem & Jewelry Exchange, where she was carefully sourcing very specific gemstone cuts for her latest pieces. When she spoke about her work, it was clear this was more than a collection—it was a calling.

Each piece in “Fading Footprints” embodies an endangered species. Crafted primarily in platinum and 18K gold,

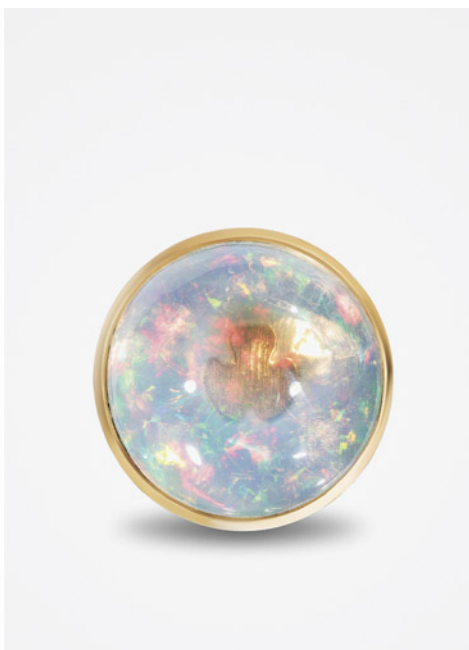
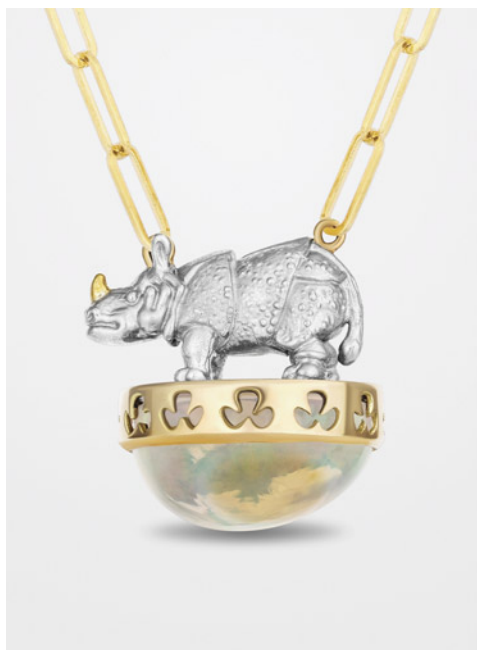


Figure 20. A platinum and 18K yellow gold Asian rhinoceros necklace (left), set with a round Australian opal cabochon showcasing a reproduction of the critically endangered animal's footprint (right), part of the "Fading Footprints" collection. Courtesy of Samira Mazloom.

the designs feature a single high-clarity, high-domed cabochon. The stone acts as a lens, magnifying the representation of the animal's footprint beneath it. Mazloom works closely with her jeweler, Chuang Yu, to bring each piece to life.

Awareness is central to the collection. Mazloom has traveled to conservation sites in Laos, Thailand, Kenya, South Africa, and beyond, drawing inspiration from animals she has encountered firsthand. Each gemstone is chosen intentionally to connect with the story. For her Asian rhi-

noceros piece (figure 20), she selected an Australian opal. The opal's shifting rainbow colors evoke the modern, magical imagery of the unicorn, a mythical creature often compared to Asian rhinos due to their endangered status. Her polar bear design features crisp blue topaz (figure 21), inspired by Arctic ice.

For Mazloom, jewelry is not simply decoration—it is storytelling and quiet activism, embedding remembrance, protection, and meaning in a wearable form.

Lisa Kennedy



Figure 21. A platinum and 18K yellow gold polar bear necklace (left), set with an oval blue topaz cabochon showcasing a reproduction of the endangered animal's footprint (right), part of the "Fading Footprints" collection. Courtesy of Samira Mazloom.



Figure 22. “Nile” earrings featuring a one-of-a-kind pair of Royston River turquoise, chrysocolla druzy, blue spinels, and diamonds in 14K yellow gold. Courtesy of Eleux Jewelry.

Hardstones in fine jewelry. Raised among the striking rock formations of Tucson, Arizona, Aria Thomas, designer, gemologist, and founder of Eleux Jewelry (Denver, Colorado), has transformed a lifelong love of stones into a distinctive fine jewelry brand. She brings hardstones—durable and often translucent or opaque—into the high-end jewelry spotlight by pairing them with diamonds and other precious gems.

The author connected with Thomas at the AGTA GemFair, where she shared insight into her design philosophy. Thomas explained that the stone comes first, and

each design builds outward from there, with complementary hues and textures chosen to enhance the natural character of the centerpiece. Because of their organic forms, every piece is handmade and often prong-set to allow light to fully reveal each gem’s depth and detail. Various agates, opalized wood, and uniquely patterned turquoise (figure 22) are just a few of her favored storytellers, shaping the narrative of her bold fine jewelry designs.

Lisa Kennedy

ANNOUNCEMENTS

Ninth annual Gianmaria Buccellati Foundation Award winner. Catherine “Cathy” Aulick, a GIA Carlsbad graduate, received the ninth annual Gianmaria Buccellati Foundation Award for Excellence in Jewelry Design. Aulick’s winning design, a necklace featuring gold, Ethiopian opal, and peridot (figure 23), was selected out of 12 finalists from five of GIA’s worldwide campuses. The award was presented at the GIA Alumni Collective’s “Night at the Museum” event held during the AGTA GemFair in Tucson.

As part of the honor, Aulick will travel to Italy and meet with a representative from the foundation.

Created in partnership with the Gianmaria Buccellati Foundation in 2018, the award recognizes outstanding talent in design among GIA students worldwide. This is the final year of the award, and planning for GIA’s new design competition is currently underway.



Figure 23. Catherine “Cathy” Aulick’s winning necklace design sketch for the 2025 Gianmaria Buccellati Foundation Award for Excellence in Jewelry Design, featuring gold, Ethiopian opal, and peridot.



Figure 1. Two pieces of rough chrysoprase with several polished stones. The cabochons range from 0.77 to 2.15 ct. Photo by Nuttapol Kitdee; courtesy of John Wibberley, Chrysoprase Australia.

REGULAR FEATURES

COLORED STONES AND ORGANIC MATERIALS

New chrysoprase production from Western Australia.

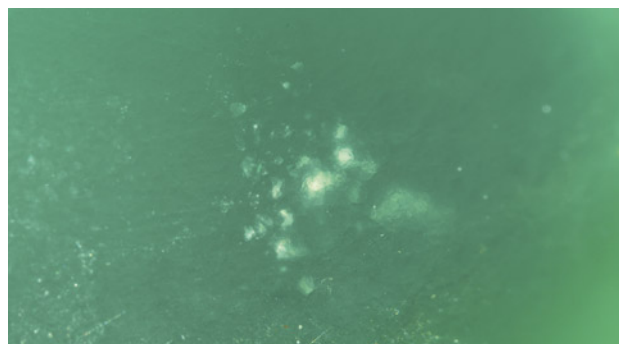
Since mid-2024, new chrysoprase from Western Australia has been available at gem markets in Bangkok. Discovered by small-scale gold miners, the material is reportedly mined in an area with no previously identified gem mineralizations. However, this discovery lies in a region in which many nickel mineralizations have occurred, and the well-known Yerilla chrysoprase deposit is only a few kilometers from the newly discovered claim.

GIA's Bangkok laboratory recently received a suite of rough and cut stones from John Wibberley, who mined the material (figure 1). The cut samples selected for study were variously shaped cabochons weighing 0.77 to 2.15 ct, in colors ranging from yellow-green to blue-green. Standard gemological properties were consistent with chalcedony. The refractive index was 1.53–1.54 (spot reading), and the hydrostatic specific gravity ranged from 2.59 to 2.65. Fluorescence was generally inert. Observation with a polariscope revealed an aggregate (AGG) reaction; the stone remained light through 360° under crossed filters, indicating an aggregate structure consistent with its cryptocrystalline nature.

No reaction was observed when the stones were viewed through a Chelsea filter. Microscopic examination revealed a cryptocrystalline structure with whitish inclusions exhibiting a cottony texture (figure 2), as well as tiny orangy brown/black and fluid inclusions.

Analysis using both a handheld spectroscope and ultraviolet/visible/near-infrared (UV-Vis-NIR) spectroscopy revealed two main broad absorption bands in the violet (~380 nm) and red (~660 nm) regions, along with an additional

Figure 2. Small clumps of whitish cottony inclusions were observed in some of the studied chrysoprase cabochons. Photomicrograph by Suwasan Wongchacree; field of view 4.80 mm.



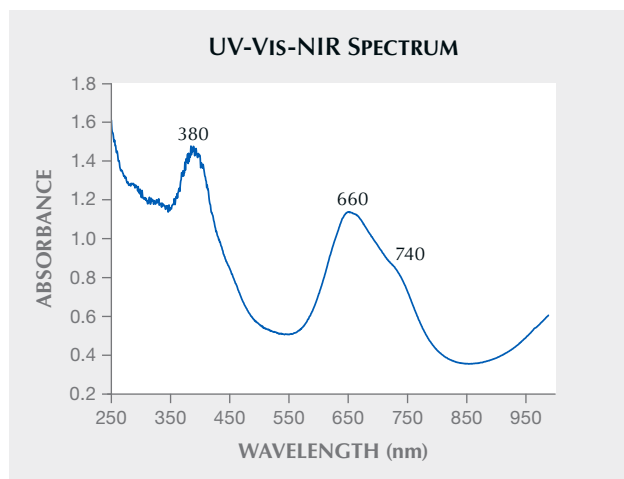


Figure 3. UV-Vis-NIR spectrum of one of the studied chrysoprase samples revealed two main broad absorption bands at approximately 380 nm and 660 nm, characteristic of Ni^{2+} , together with an additional band near 740 nm, also attributed to Ni^{2+} .

feature at approximately 740 nm attributed to Ni^{2+} . These absorptions left a transmission window in the green-blue region, producing the characteristic hue of chrysoprase, caused by Ni^{2+} (figure 3; Y. Jiang and Y. Guo, "Genesis and influencing factors of the colour of chrysoprase," *Scientific Reports*, Vol. 11, 2021, article no. 9939).

Energy-dispersive X-ray fluorescence confirmed the presence of nickel, the chromophore defining this green variety of chalcedony. Silicon was also detected, consistent with chalcedony's composition. Chromium, iron, and copper, which can also contribute color in other chalcedony varieties, were not detected. Fourier-transform infrared spectra displayed patterns typical of chalcedony.

Despite limited volume, this new discovery has gained some attention from connoisseurs, especially in markets with an appetite for fine green translucent gemstones.

Aprisara Semapongpan
GIA, Bangkok

RESPONSIBLE PRACTICES

Your Purchase Feeds: Vaibhav Global Limited's social-impact approach. Before Vaibhav Global Limited (VGL) evolved into a multinational retailer offering affordable fine jewelry and natural and laboratory-grown diamonds, founder Sunil Agrawal made a decision that would redefine the company's purpose: Every purchase would help feed a child in need. This simple idea, now known as Your Purchase Feeds, has since provided nearly 100 million meals and currently supports approximately 50,000 children per day, with a long-term goal to reach one million meals daily by 2040.

Agrawal's professional roots trace back to Jaipur, India, historically one of the world's leading centers for gemstone

cutting and ethical jewelry manufacturing. Early in his career, he spent time in the city's workshops and markets, observing artisans who relied on fluctuating export demand for their livelihoods. This experience highlighted a persistent disparity: The communities producing fine gemstones often remained economically distant from the markets that sold them. Agrawal responded with a reimagining of the traditional supply chain. Instead of relying on multiple intermediaries, he sought to build an end-to-end enterprise encompassing sourcing, cutting, manufacturing, broadcasting, and direct-to-consumer e-commerce.

Today, VGL employs more than 4,000 people worldwide and operates through Shop LC in the United States, The Jewellery Channel (TJC) in the United Kingdom, and Shop LC Germany in Europe. This integrated structure allows the company to maintain shorter supply chains, improve cost transparency, and preserve craftsmanship while offering more accessible pricing for consumers seeking affordable, high-quality jewelry (figure 4) and laboratory-grown diamond pieces. By consolidating operations, VGL not only streamlined production but also created steadier employment for artisans, protecting generational skills that are increasingly at risk of automation or outsourcing. The result is a dual-impact model: for consumers, increased transparency and affordability, and for artisans, stable employment and recognition for their craftsmanship.

The jewelry sector has long valued legacy, the transmission of skills, materials, and traditions from one generation to the next. Agrawal sought to expand this idea beyond the object itself. If jewelry marks life's most meaningful moments, he reasoned, then part of its value should also sustain the communities that bring it to life. Out of this philosophy emerged Your Purchase Feeds. Instead of

Figure 4. Moissanite earrings (left) and pendant (right) in vermeil yellow gold over sterling silver from Shop LC's Clarté Dorma collection, made in Jaipur, India. Courtesy of Shop LC.

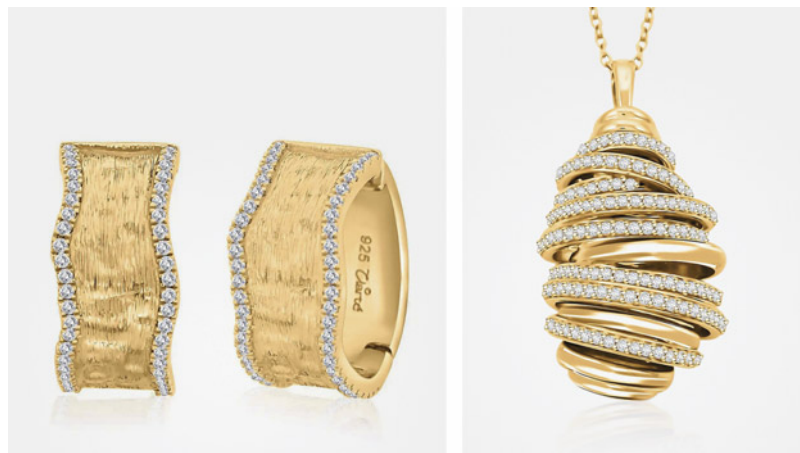




Figure 5. School meal distribution supported by Akshaya Patra in India. Courtesy of Shop LC.

building a proprietary foundation, VGL partnered with established hunger-relief organizations that already had deep community reach and operational infrastructure. Key partnerships include Akshaya Patra in India, which provides large-scale school meals (figure 5); No Kid Hungry and Backpack Friends in the United States, addressing child hunger during weekends and holidays; and Magic Breakfast and The Felix Project in the United Kingdom, ensuring students start their day with nutritious meals. This partnership model allows VGL to measure direct outcomes, such as meals funded per item sold, creating a tangible link between commerce and community.

As global consumers increasingly align their purchasing behavior with ethical and social values, the definition of *value* within the jewelry sector continues to evolve. For some, value remains rooted in rarity and provenance. For others, it is now inseparable from purpose, sustainability, and accessibility. VGL's case illustrates a shift toward integration over separation, positioning responsible practices as central to operations rather than peripheral initiatives. The company's example underscores how vertical integration can simultaneously address efficiency, traceability, and social responsibility while helping consumers find affordable, ethically sourced jewelry with verified quality.

This approach has also earned recognition within the broader business community. In recent years, VGL and its subsidiaries have been honored for sustainability and social impact, including the Austin Chamber of Commerce's Bold Giver Award and the Community Catalyst Award at the 2025 Jewellery World Awards. In 2026, ShopLC was ranked 24th out of 125 top impact companies by Real Leaders.

Your Purchase Feeds reframes the relationship between luxury and responsibility, positioning nourishment—not just ornamentation—as part of jewelry's value chain. For Agrawal and his team, the initiative is more than a corporate responsibility program; it is a guiding principle that merges commerce, compassion, and continuity, a model of what responsible retail and ethical jewelry sourcing can look like in the decades ahead.

Francesca Kennedy
Shop LC, Austin, Texas

SYNTHETICS AND SIMULANTS

CVD synthetic fashioned to imitate a rough natural diamond. This report covers the first instance, to the authors' knowledge, of a synthetic diamond grown by chemical vapor deposition (CVD) being deliberately fashioned into the approximate shape of a rough natural diamond crystal. The authors recently examined a 6.87 ct near-colorless crystal (figure 6). Raman spectroscopy confirmed the stone as diamond, and the near-octahedral shape was similar to the morphology of a natural rough diamond.

Figure 6. A 6.87 ct CVD-grown synthetic diamond, measuring approximately 11 mm across, fashioned in the approximate shape of an octahedron. Photo by Danny Bowler.



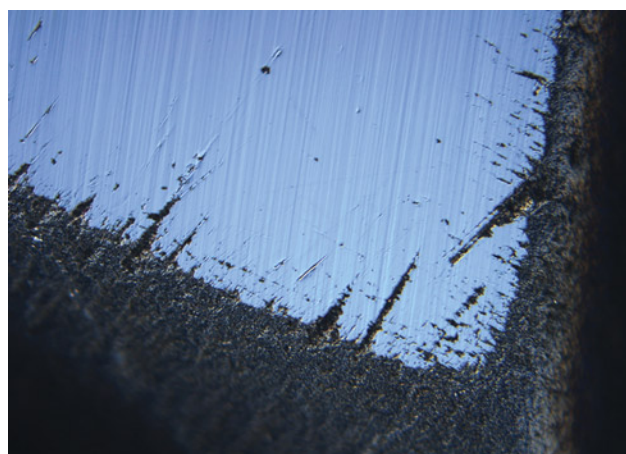


Figure 7. Differential interference contrast image near an apex of the stone showing the roughening of junctions between the faces and evidence of polishing after the roughening occurred. Image by David Fisher; field of view 0.48 mm.

Further examination revealed that it was not a genuine octahedron, with only one set of opposite faces being parallel. Microscopic observation using differential interference contrast showed extremely flat faces with a series of parallel polishing lines as the only significant feature (figure 7), unlike the growth steps and trigons typical of octahedral faces in natural diamond. The junctions between the facets were extremely rough, possibly due to graphitization during heat treatment to improve the color of the stone, with the main faces having been repolished after the heat treatment.

X-ray Laue diffraction was used to confirm the orientation of the faces. In a natural diamond octahedron, all eight faces are parallel to {111} planes. None of the faces of this stone were parallel to {111} planes. Two of the opposite faces were parallel to {100} planes, consistent with the preparation of a stone from a block of CVD-grown synthetic diamond. The favored direction of growth in CVD synthesis is in a (100) direction on a substrate with a planar face in a {100} plane. An octahedral block maximizing the height of the as-grown material could be prepared from this with two {100} faces aligned with the substrate interface and the final growth surface. Producing a stone such as this one from a block of CVD material grown in a (100) direction requires careful processing, and any resultant polished diamond would have a much lower yield than one produced directly from the as-grown block of material. The only motivation for such an action appears to be a deliberate attempt at deceit.

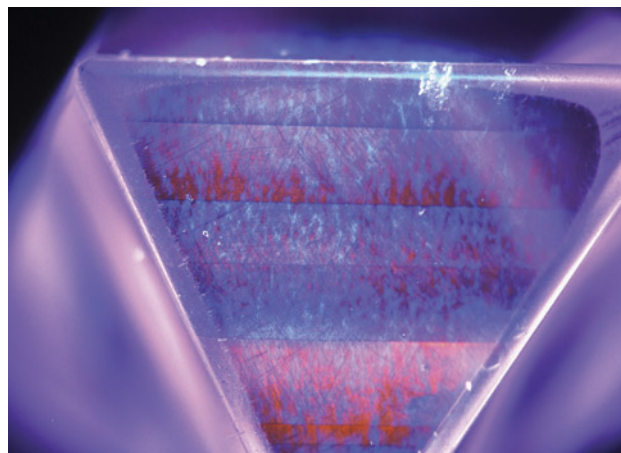
Infrared absorption measurements indicated that this was a type IIa diamond (i.e., one that contains no detectable nitrogen-related absorption). Around 1 to 2% of natural diamonds are type IIa, but they are usually irregular in shape (I. Sunagawa, "A discussion on the origin of irregular

shapes of type II diamonds," *Journal of Gemmology*, Vol. 27, No. 7, 2001, pp. 417–425). Natural octahedral diamonds with a well-formed crystal habit are almost always type Ia, making the type and morphology combination observed for this stone inconsistent with natural diamond. All colorless synthetic diamonds are type IIa or very weak type IIb due to the presence of a small concentration of uncompensated boron.

The stone was definitively identified as a CVD synthetic diamond through DiamondView imaging of the flat faces (figure 8). The background luminescence showed bands of orange emission of varying intensity from nitrogen vacancy centers incorporated during the CVD growth process. The bands were consistent with a stop-start growth process in which periods of reasonably consistent growth are interrupted either by a significant change in growth parameters or possibly the stopping of the process to reposition the stone with respect to the plasma in the chamber. Within the coarse growth bands, it is also possible to see growth striations due to step-flow growth with differential uptake of impurities at the terraces and risers of the steps (P.M. Martineau et al., "Identification of synthetic diamond grown using chemical vapor deposition (CVD)," Spring 2004 *G&G*, pp. 2–25).

Also evident in figure 8 are "plumes" of blue luminescence that thread through the coarse bands roughly perpendicular to them. These are associated with dislocation bundles due to columnar growth and have been widely reported for CVD synthetic diamonds (M.P. Gaukroger et al., "X-ray topography studies of dislocations in single crystal CVD diamond," *Diamond and Related Materials*,

Figure 8. DiamondView image of one of the faces of the stone showing luminescence features consistent with a CVD synthetic diamond. Coarse bands of variable intensity orange emission from nitrogen vacancy centers are visible, along with growth striations and "plumes" of blue emission from dislocations within the bands. Image by Sema Firat; field of view 9.0 mm.



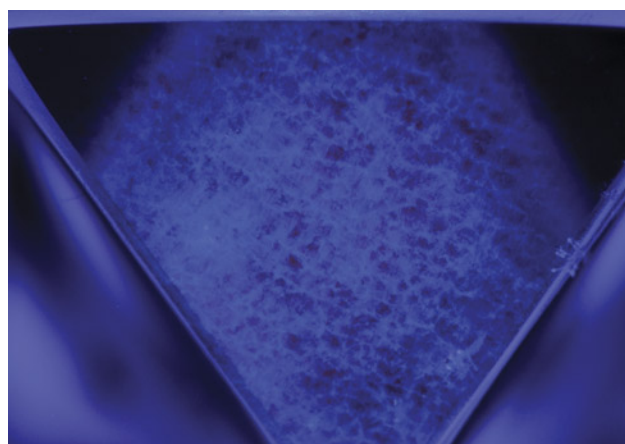


Figure 9. DiamondView image of one of the {100} oriented faces adjacent to the final growth surface of the original CVD synthetic. It shows low-intensity orange background emission and a network of blue dislocation-related luminescence, consistent with columnar growth typical of CVD synthetic diamonds. Image by Sema Firat; field of view 9.0 mm.

Vol. 17, No. 3, 2008, pp. 262–269). The dislocations run approximately parallel to the growth direction and form a network where they intersect the final growth surface. This is evident in figure 9, a view of the face adjacent to and parallel with the final growth surface. This region has very weak orange emission, and the only significant features are the blue dislocation networks.

There is currently no evidence of any widespread switching of synthetic for natural diamonds in the rough diamond pipeline, but overreliance on practices such as assessing the “heft” of a stone would obviously not allow reliable screening for synthetic diamonds. Careful examination of the detailed appearance of this stone allowed it to be identified, and while it could be possible to replicate some of the surface features of a natural diamond (e.g., growth steps and trigons) through etching processes, these features would be extremely difficult to reproduce in detail due to the difference in crystallographic orientations of the polished faces compared with a genuine diamond octahedron. Should synthetic diamonds fashioned in this way become more prevalent, an immediate screening solution for rough diamonds could be implemented through adaptation of existing screening instruments for polished diamonds. Analysis of this stone with a wide range of diamond verification instruments gave the correct referral results, and the main characteristics were consistent with those seen routinely in polished synthetic diamonds.

Nick Davies, Sema Firat, David Fisher,
and Thoufiek Shaik
De Beers Science & Technology
Maidenhead, United Kingdom



Figure 10. George R. Rossman holding an eponymous sample of the tourmaline group mineral rossmanite. Photo by Lance Hayashida; courtesy of the California Institute of Technology.

IN MEMORIAM

George R. Rossman. Emeritus professor of mineralogy George R. Rossman passed away on February 6, 2026, at the age of 81.

In 1971, Rossman obtained his PhD in chemistry from the California Institute of Technology (Caltech). In that same year, Caltech’s Division of Geological and Planetary Sciences hired him as an assistant professor of mineralogy after initially recruiting him as a mineralogy instructor. Over the next 55 years, he made significant contributions to the field and instructed thousands of students in mineralogy and mineral spectroscopy. He is remembered as an engaging and dedicated instructor, and in 2004 was awarded Caltech’s most prestigious teaching honor, the Richard P. Feynman Prize for Excellence in Teaching.

An active researcher, Rossman published more than 400 papers with several still in progress when he passed away. His work was largely driven by a straightforward question: “Why do gems and other minerals possess their distinctive colors?” This led him to become an invaluable contributor to GIA, serving on the board of governors from 1995 to 2007, mentoring GIA researchers, and coauthoring numerous papers with them. He was also a respected member of *Gems & Gemology*’s editorial review board and authored and coauthored many significant articles featured in the journal, including a set of four seminal papers in the 1980s that spoke to his fundamental question regarding color.

Rossman had an infectious curiosity, and his special passion for minerals led to many awards throughout his storied career. Notably among them, he received the inaugural Dana Medal from the Mineralogical Society of America (MSA) in 2001 and the Roebling Medal (MSA’s top honor) in 2021. He also had three tourmaline mineral species named in his honor: rossmanite (figure 10), alumino-oxy-rossmanite, and fluor-rossmanite.

We extend our sincere condolences to Rossman’s family, friends, and colleagues. A more detailed tribute recognizing his contributions to gemology and mineralogy will be published in an upcoming issue of *Gems & Gemology*.



Figure 11. Pete Yantzer with his beloved dog. Courtesy of the Yantzer family.

George Peter Yantzer. *Gems & Gemology* mourns the loss of “Pete” Yantzer (figure 11), who passed away on January 10, 2026, at the age of 77. A gemologist, educator, and visionary leader at both GIA’s and the American Gem Society’s (AGS) diamond grading laboratories, Yantzer will be missed by his many friends in the trade.

Unsure of a career path after serving in the U.S. Air Force, Yantzer was told by a family friend in the jewelry industry that gemology was a fine career choice, so he enrolled at GIA using his GI Bill. After graduation, Yantzer joined the Institute in 1973 to become the New York Gem

Trade Laboratory’s seventh staff gemologist. He always expressed his good fortune to be mentored by some of the true giants of gemology—Richard Liddicoat and Robert Crowningshield. By 1976, he was leading GIA’s newly established Los Angeles lab. There, he steered the rapid expansion of GIA’s diamond grading services during the diamond “investment” boom of the late 1970s.

After a break from the trade, Yantzer became the first executive director of the AGS diamond grading laboratory in 1996. Over the next five years, he worked tirelessly with a team of optical scientists, mathematicians, and industry professionals to develop the AGS Light Performance Cut Grade System. At the heart of this project was Yantzer’s conviction that cut grading was the most important factor in a diamond’s beauty. During his time at AGS, Yantzer mentored the next generation of diamond cut researchers, several of whom continue to advance the practice of cut grading at GIA following the acquisition of the AGS laboratory in 2022.

Yantzer’s decades of leadership and intellectual curiosity elevated the practice of diamond grading and guided the industry toward cutting standards that produced more attractive diamonds for consumers. Because of his lifelong contribution to the practice and science of diamond grading, Yantzer was the 2005 recipient of AGS’s Robert M. Shipley Award, its highest honor.

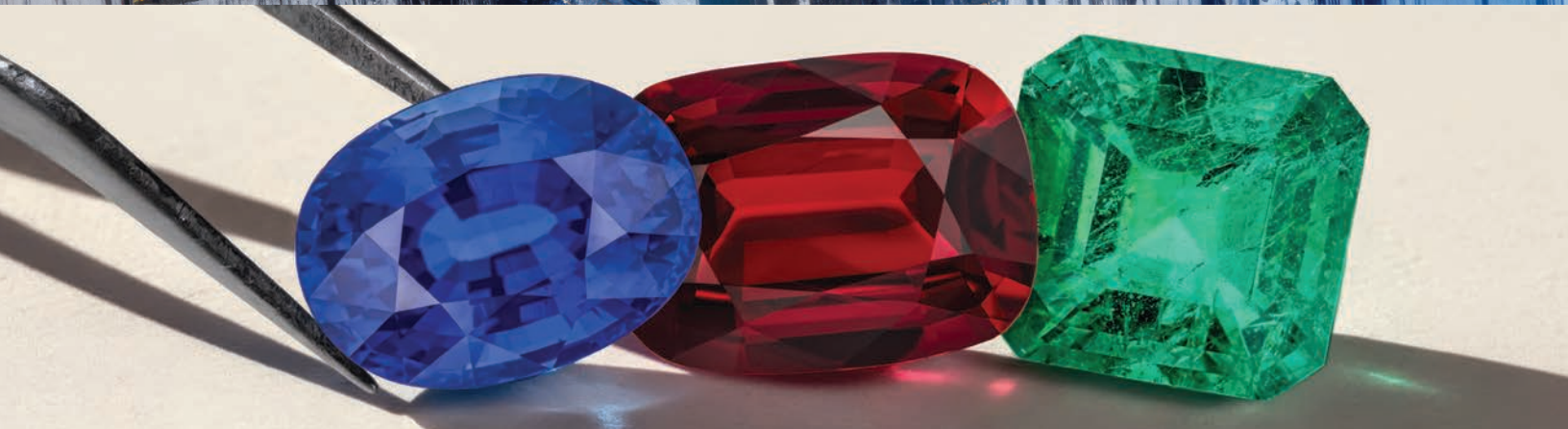
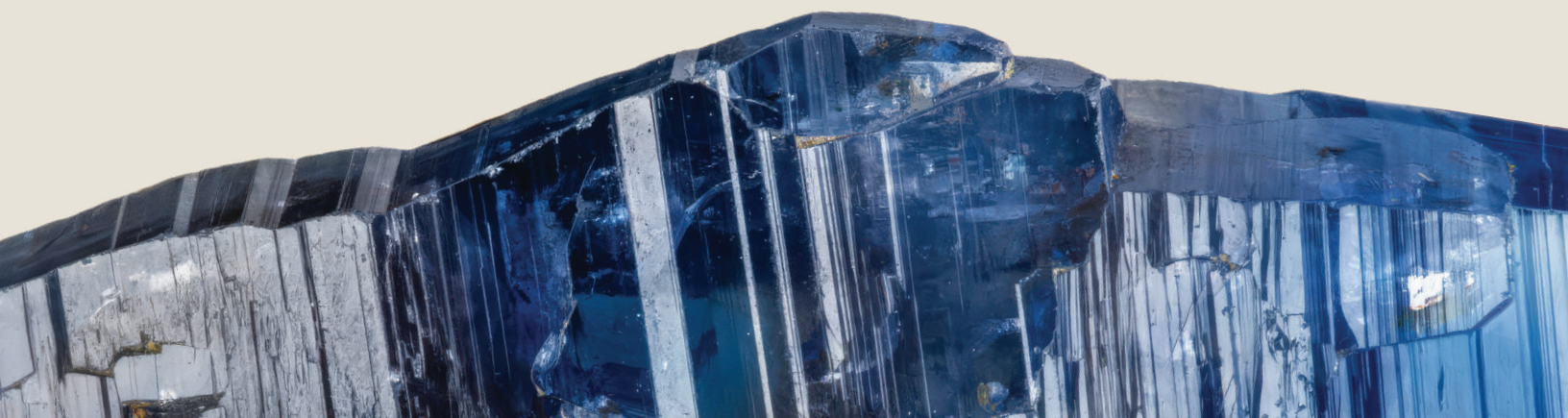
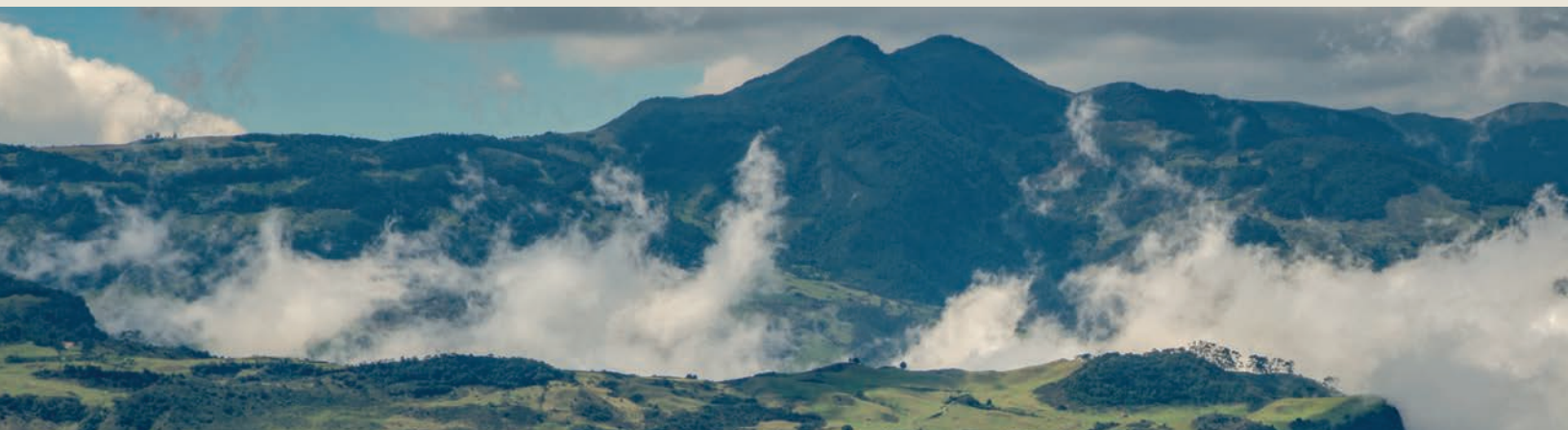
Yantzer is survived by two daughters, seven grandchildren, and brothers, Steve, John, Paul, and Phil. We extend our sincere condolences to his family and friends.

GIA Colored Stone Reports

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***Cartier and Myths* Exhibition at Rome's Capitoline Museums**

Fanny Raponi | GIA, London

C*artier and Myths*, the first temporary exhibition at the Palazzo Nuovo of Rome's Capitoline Museums, was on display for four months beginning in November 2025. The exhibition integrated Cartier jewels with one of the city's most significant classical art collections—the permanent collection of marble sculptures assembled by Cardinal Alessandro Albani—and works on loan from other institutions and private collections. The result traced dialogues between the jewel and classical antiquity, and between the jewel and ancient mythological gods and zoomorphic sym-

bols, from Cartier's earliest neo-archaeological designs to contemporary interpretations. It also unveiled previously unseen photographs from a newly discovered album documenting Louis Cartier's 1923 visits to archaeological sites Pompeii and Herculaneum. In the accompanying catalog composed of interdisciplinary essays, Cartier president and CEO Louis Ferla described the exhibition as "a return home, a reaffirmation of our indissoluble bond with a land that has profoundly shaped our creative vision," recalling the transformative impact Italy once had on Louis Cartier.

Figure 1. A view of the entrance to the Cartier and Myths exhibition at the Capitoline Museums. Photo courtesy of Cartier Italy.





Figure 2. Desk clock, Cartier Paris, 1927, featuring gold, nephrite, Kingfisher feathers (dial), rose-cut diamonds, and red and blue enamel. Courtesy of the Cartier collection.

Exhibition visitors entered the Palazzo via a cinematic staircase designed by production designer and art director Dante Ferretti, featuring projections from his film work, including Pier Paolo Pasolini's *Medea* and Terry Gilliam's *The Adventures of Baron Munchausen*. Beyond the staircase, the atmosphere seemed suspended in time, with ambient music and animated projections of Giovanni Battista Piranesi's clouds on the vaulted ceilings (figure 1). The jewelry cases alternated with ancient works in a perfect counterpoint. Each section concluded with video installations tracing the connections between Cartier and classical antiquity, while olfactory elements by Cartier perfumer Mathilde Laurent added another layer. The immersive multisensory experience invited engagement on multiple levels.

Cartier's relationship with Rome stretches back to the Maison's founding by Louis-François Cartier in 1847. Its inspirations have included French architecture, archaeology, classical antiquity, and myth. Jewelry historian Bianca Cappello, one of the exhibition curators, said the project began with Cartier's desire "to create a dialogue with the works of Rome" in the world's first public museums, established in the eighteenth century.

In shaping the exhibition, Cappello was asked to explore the jewels and narrate their scientific, historical, philological, and aesthetic aspects—an approach that immediately resonated with her. Archaeologist Stéphane Verger, director of the National Roman Museum, helped define the cultural framework and the narrative of myth through jewelry. Capitoline superintendent and archaeologist Claudio Parisi Presicce provided an in-depth study of

the statues, highlighting their distinctive qualities and historical and cultural importance. The project relied on the expertise and resources of Cartier's teams, including the archives in Paris, London, and New York, and the Cartier collection in Geneva, which expanded for the occasion and now comprises more than 3,500 pieces.

"The opportunity to see, handle, and study the jewels was extremely important," Cappello said. "We discovered countless details that are impossible to perceive from an image." These insights influenced the exhibition's narrative and dialogue with Rome's ancient art.

The exhibition could be understood on several levels. The first, Cappello said, was one of "formal beauty": sculptures, vases, jewels, and other ancient works presented simply to be seen and appreciated. A second level explored the cultural terrain of classical antiquity and myth, themes that guided the selection of the pieces. Classicism, she noted, remains a persistent framework for how societies define and transmit ideas of beauty. Its principles have shaped aesthetics from ancient Greece through the Renaissance and Enlightenment and continue to inform Cartier's design vocabulary.

"Think of the golden ratio and Pythagorean geometry as the foundation of our perception of beauty and of the forms of nature," Capello said. One example is a desk clock (figure 2) featuring a dial with the same pattern as the iconic pavement of the Piazza del Campidoglio—Michelangelo's design rooted in the golden ratio and Pythagorean geometry. "We see these proportions in the Egyptian pyramids and in the Pantheon," she continued.



Figure 3. “Temple” brooch, Cartier Paris for Cartier New York, 1927. Half-moon, baguette-cut, and square diamonds set in platinum. The baguette-cut technique, used by Cartier beginning in the early 1910s, became highly fashionable in the 1920s. Courtesy of the Cartier collection.

“In Cartier’s works, innovation is always balanced by these principles of classical proportion.” The “Temple” brooch (figure 3) further exemplifies this with its proportions, rectangular stones, stepped layers, and symmetry.

Myth was another important theme. “Myth survives through the centuries because it has always been able to effectively convey the invisible, feelings and emotions such as love and envy, embodied by deities and their stories,” Cappello said. She noted its influence in the late nineteenth century in early psychoanalytic research and the Symbolist movement in art, and its continued legacy today in symbols such as the panther, the serpent, and Medusa, all active in Cartier’s iconography.

The exhibition was divided into two halves. The first, a “historical-philological” section curated by Cappello, showed the evolution of Cartier’s approach to antiquity and myth: from the pastiche of the nineteenth century (combining and copying multiple historical periods) to the third generation—Louis, Jacques, and Pierre of the twentieth century—in which classical inspiration is no longer only decorative but communicates the complex symbolic meanings of myths. It also became playful and rich with

historical references based on the new science of archaeology. The second half, curated by archaeologist Stéphane Verger, staged a narrative dialogue between classical myths and Cartier jewelry. These myths and symbols continue to be a powerful source of inspiration for contemporary design.

Among Cappello’s favorite pieces is the 1906 “Head of Medusa” pendant (figure 4, left), a high-relief cameo in angel skin coral. The cameo features diamonds, green guilloché enamel reminiscent of Fabergé, and a platinum setting. The head of Medusa is a copy of the one held by the Perseus statue sculpted by Antonio Canova at the Vatican Museums. Medusa fascinates and petrifies through her gaze (figure 4, right); she represents defense and protection but also the dangerous, rebellious, independent woman. According to a legend recounted by Ovid and Pliny the Elder, coral is born from Medusa’s blood falling into the sea and transforming into this precious material.

Another theme in the exhibition was the panther and other large cats—symbols associated with the elite since the mid-fifteenth century and linked to the myth of Jason and the Golden Fleece. Although the Golden Fleece comes from a ram, artists often reinterpreted Jason’s perilous

Figure 4. Left: “Head of Medusa” pendant, Cartier Paris, 1906. This pendant incorporating a Medusa head in a garland-style setting is characteristic of the stylistic transitions that took place under Louis Cartier. The cameo and tear-shaped drop are made from angel skin coral, with round old- and rose-cut diamonds, green and white enamel, and natural pearls, set in platinum and gold. Right: “Medusa,” Gian Lorenzo Bernini, 1644–1648. Marble. Courtesy of the Cartier collection (left) and the Capitoline Museums, Palazzo dei Conservatori, Rome (right).



voyage through the lens of contemporary imperial expansion, substituting large cat pelts for the fleece as symbols of elite status and the allure of distant lands. American heiress and philanthropist Barbara Hutton was among the first to commission Cartier jewelry featuring felines: a 1957 tiger brooch (figure 5) with diamonds ranging from

colorless to varying hues, tones, and saturations of yellow. In the 1980s, Cartier developed its patented “fur setting” (figure 6): a type of pavé created by gemstones surrounded with tiny grains of gold, which are drawn into delicate threads over the stones to more realistically render a feline coat.

Figure 5. “Tiger” clip brooch, Cartier Paris, 1957. Single- and brilliant-cut diamonds ranging from colorless to various hues of yellow, set with marquise-shaped emeralds (eyes) and onyx (stripes) in gold. Courtesy of the Cartier collection.





Figure 6. Tiger necklace and detachable brooch, Cartier Paris, 1986. Intensely colored yellow diamonds, marquise-shaped emeralds (eyes), and onyx (stripes) set in gold, showing Cartier's patented "fur setting" developed in the 1980s. Courtesy of the Cartier collection.

Another significant part of the exhibition was a necklace containing an Egyptian faience piece more than 3,500 years old, depicting a goddess representing the feminine mythos, with “panther skin” pavé—diamonds, onyx, and colored gemstones to resemble a panther’s spotted fur—added by Cartier to cover missing parts (figure 7). “It is rich in symbolism connected to the feminine myth: the Egyptian cult of Sekhmet [Isis], the goddess of healing but also chaos; the panther often depicted with Dionysus and the Maenads,” Cappello said.

Cartier revisited this myth in the 1920s, when women were asserting new forms of independence and influence—the era of designers Coco Chanel, Elsa Schiaparelli, and Jeanne Toussaint, who became the Maison’s creative director in 1933. Toussaint made the panther her signature motif, ensuring its place in Cartier’s visual language for decades to come.

Cappello also pointed to the serpent as one of the exhibition’s central mythological figures. In antiquity, she explained, the serpent was regarded as a *eudaemon*,

Figure 7. Left: “Egyptian necklace,” Cartier Paris, 1927–1928. Egyptian faience featuring diamonds, sapphires, emeralds, carnelian, turquoise, and onyx set in platinum and gold. This statuette of Isis nursing Horus comes from Cartier’s stock of apprêts, containing fragments from disassembled jewelry, watches, and other ancient objects. Right: Isis, second century CE. Marble. Courtesy of the Cartier collection (left) and the Capitoline Museums, Palazzo Nuovo, Rome (right).

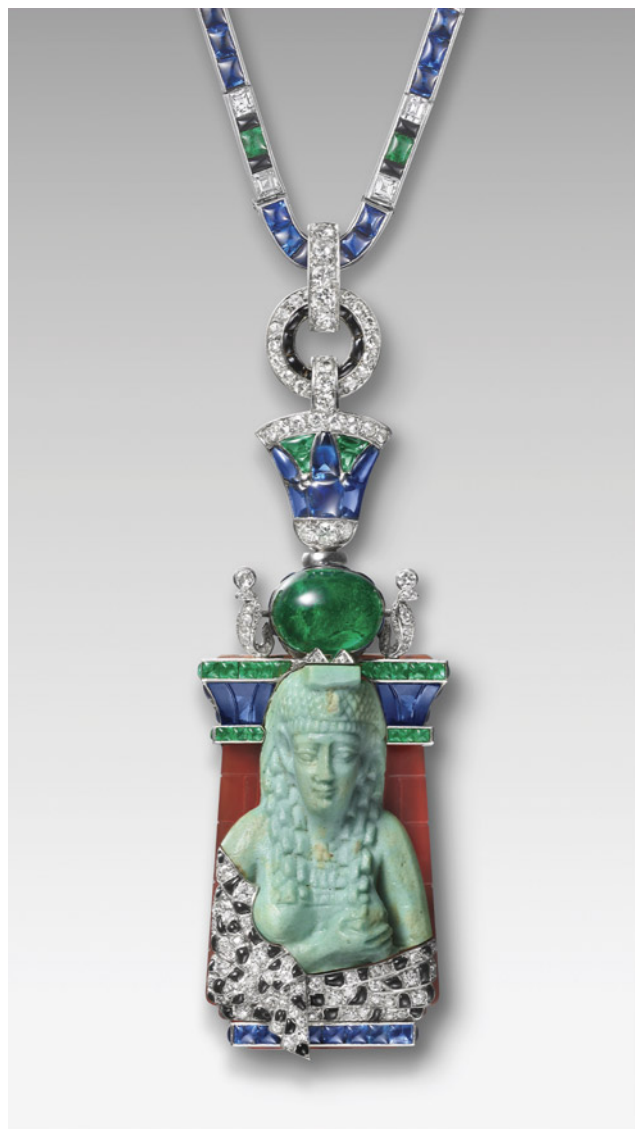




Figure 8. “Snake” necklace, Cartier Paris, 1919. Round old-cut diamonds set in platinum. The open back of the flexible necklace, which clasps where the tail entwines, allows light to pass through the diamonds. Courtesy of the Cartier collection.

“a positive spirit” connecting humans and the divine. Herculaneum’s and Pompeii’s houses contained shrines featuring serpents, meant to lead souls toward good fortune. Jewelry shaped like coiled serpents was worn for good luck. A 1919 Cartier necklace (figure 8) reflects this heritage.

Capello highlighted many more jewels, each special for a particular reason. Some pieces carried strong anthropological significance, such as a brooch/pendant (figure 9) reflecting the significance of the amphora (vase) in Greek myth and culture. Together they took visitors on a journey beginning with ancient cultures—Egypt, Greece, Rome—through cycles of classical revival, influenced by the nineteenth- and twentieth-century cultures, and continuing today.

The intertwining of art, history, mythology, and symbolism in these pieces was undeniable, and all connected to something universally magical. Since time immemorial, humans have adorned themselves to communicate their uniqueness, status, and power; to express an ideal or a dream; to attract or to inspire awe. Through myths and

archetypes, every jewel tells not only the story of the Maison Cartier but also a little of the human story. Cartier embodies these themes in this ongoing connection between the ancient and the innovative.

When asked what she hoped the public took away from the exhibition, Cappello said, “Beauty, because it represents positivity, [is] a feeling each of us radiates from within.” She described the exhibit as exploring a kind of beauty with ancient roots that can be understood through culture or felt through emotion. She pointed out that cultural exchange is nothing new: ancient Greece had contact with India as early as the fourth century BCE, and ancient Rome traded with China and Africa. For her, these historical connections reveal “a shared root of aesthetic languages,” creating fertile ground that revives beauty as a shared identity—one that, through its many interpretations, also allows for a rediscovery of individual expression. “Equality,” she noted, “is beauty with this same root.”

“This is the first time that haute jewelry has been put into direct dialogue with antiquity, from both a visual and



Figure 9. Left: Brooch/pendant, Cartier Paris, 1922. Pear-shaped, round old- and rose-cut diamonds, coral, and onyx set in platinum. The vase can be worn alone as a brooch or on a cord. Right: Black figure Attic amphora (vase), 550–500 CE, showing Hercules fighting the Nemean lion in the presence of Athena. Terra-cotta. Courtesy of the Cartier collection (left) and the Capitoline Museums, Centrale Montemartini, Rome (right).

intellectual perspective,” Cappello said. “This could be just the beginning of many other stories to tell, and an opportunity to see and experience jewelry in a completely different way.”

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