



The Sisk Gemology
REFERENCE

by
JERRY SISK

About the Author
JERRY SISK

Cofounder of Jewelry Television®
Graduate Gemologist (GG)
(1953 – 2013)



*Whose vision,
boundless energy, and
hunger for knowledge
brought us treasure
beyond compare*

Jerry Sisk's pursuit of gemstones began during an oceanside walk in his native New York, where, as a young boy, he discovered the first piece of his gem collection, a brightly colored, water-worn pebble. Many pounds of pebbles later, the teenaged collector applied his growing passion to an apprenticeship at a local jewelry store. Jerry's appreciation for fine colored gemstones and jewelry further developed during his college years as he continued working in retail jewelry sales while attending the University of Tennessee in Knoxville.

In the 1980s, Jerry, now a bench jeweler, connected with Bob Hall, CPA, and later, Bill Kouns, goldsmith. Together, in 1993, the trio founded America's Collectibles Network (ACN) in a small television studio in Greeneville, Tennessee, which successfully evolved into the company known today as Jewelry Television® (JTV).

Jerry was a Graduate Gemologist (GIA) and an active member of the International Colored Gemstone Association (ICA). He was adored by coworkers, customers, and vendors alike, and the publication of this book series has been anticipated with great excitement. In April 2012, *JCK Magazine* named Jerry one of the top five most influential people in the gemstone industry. Over the course of his life, Jerry traveled to more than forty countries and was fluent in a half-dozen languages. His legacy lives on in his writings and in the hearts of all of those he touched during his lifetime.

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Tridacna gigas (giant clam) pearl (11 mm) displaying flame structure due to cross-hatching of fiber bundles in the pearl (Mark Mauthner photo, courtesy of Bonhams)

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Citrine crystals



Optical Phenomena

The term optical phenomena is used to describe the variety of ways in which light interacts with structural features or inclusions in gemstones. Gemstones that exhibit an optical phenomenon are typically fashioned in a way that best displays their special property. For example, a gemstone exhibiting asterism (a star) will be fashioned as a cabochon so the star can be easily seen. Optical phenomena described in this book include adularescence, asterism, aventurescence, chatoyancy, color-change, iridescence, play-of-color, labradorescence, tenebrescence, thermochromism, and thermoluminescence.

ADULARESCEnce: Adularescence is an optical phenomenon typically associated with moonstone, a member of the feldspar family. It manifests as a soft shimmer moving within the gemstone as it is rotated.



Rainbow moonstone gem

Adularescence occurs when light hits alternating layers of albite and orthoclase, two slightly differing forms of feldspar within the gemstone. These layers interfere with the passage of light, scattering its rays. The phenomenon is best seen when stones are fashioned as cabochons with the base parallel to the plane of the layers. The shimmer ranges in color from soft blue to milky white.

ASTERISM: Asterism is a four- or six-rayed star pattern of reflected light produced by the presence of fibrous inclusions or growth tubes in a gemstone best demonstrated when fashioned as cabochons.



Star sapphire

AVENTURESCEnce: Aventurescence is a glittery display associated most commonly with aventurine quartz and aventurine feldspar. The phenomenon is caused by small leaf-like or plate-like inclusions interspersed throughout the host material. Light striking the surface of these inclusions is reflected back to the viewer, creating an eye-catching sparkle.



Oregon sunstone

CHATOYANCY: Chatoyancy is the gemological term for an optical phenomenon known as a cat's-eye. The effect is caused by fine needle-like or fibrous inclusions within the host material. The full effect is best demonstrated when the material is fashioned as cabochons.



Cat's-eye sillimanite

COLOR-CHANGE: Color-change is an optical characteristic of a small number of gemstones. A color-change gemstone's appearance varies when viewed in different lighting environments due to shifting wavelengths. *Photochromism* (or *photochromism*) is the technical term for color-change. The best-known color-change gemstone is alexandrite. When viewed in sunlight, this phenomenal variety of chrysoberyl appears greenish. Observed under incandescent light, the gemstone appears reddish. Other color-change gemstones include sapphire, garnet, spinel, diaspore, and tourmaline.



Color-change garnet in daylight (left) and incandescent light (right)

IRIDESCENCE: Iridescence is an interference phenomenon that creates a prismatic, rainbow-like play of color on the surface or within gemstones. Fire agate and ammolite are examples of two gemstones exhibiting this optical effect.



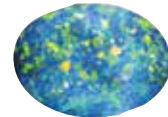
Abalone pendant

LABRADOESCENCE: Labradorescence, an optical characteristic usually seen in labradorite, is due to an interference effect within the host caused by layers of material of varying refractive indices. The play-of-color is a metallic schiller or iridescence.



Labradorite ring

PLAY-OF-COLOR is a phenomenon seen in precious opal. It is an effect created by a combination of diffraction and interference and is the result of the microstructure of opal. Opals are comprised of many layers of small, stacked spheres of silica. The spheres themselves act like diffraction gratings splitting the light into its spectral colors. The layers of spheres create interference allowing certain colors to dominate depending on the angle in which the opal is viewed and producing colors which seemingly "move" within the gem. The size, spacing, and degree of ordered arrangement of the silica spheres determine which colors are visible.



Play-of-color in Lightning Ridge black opal

TENEBRESCENCE: Tenebrescence is often described as reversible color-change (photochromism), a temporary condition occurring when minerals are exposed to radiant energy. The effect is due to a specific wavelength of light interacting with structural defects within the host. The change takes place over a few seconds or several minutes. In some cases, the mineral changes intensity of color, darkening and bleaching (fading) to its previous state. In others, it changes colors entirely.



Tenebrescent scapolite gem, daylight



After exposure to shortwave UV light

Examples of tenebrescent minerals include spodumene and sodalite. In the case of spodumene, a lavender-to-pink variety known as kunzite turns green when exposed to X-rays but reverts to its original color when returned to visible light. Hackmanite, a pink variety of sodalite, can either change color or darken and lighten when exposed to ultraviolet or visible light, respectively.

This property, although rare in minerals, is exploited in the field of optics, as in sunglasses and self-adjusting, light-sensitive glass for automobile windows and mirrors.

THERMOCHROMISM: The roots of this term mean heat and color. The property refers to a change in color associated with a change in temperature. Some gemstones, such as zircon, exhibit thermochromism. When heated, the host changes from brownish to red or yellow.

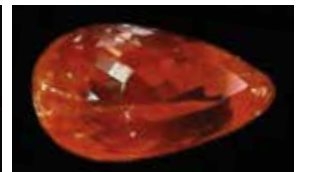


Thermochromic zircon (left) before heating, (right) after heating

THERMOLUMINESCENCE: Thermoluminescence is a form of luminescence occurring when a mineral is heated to a temperature below which the mineral becomes incandescent. The glow is caused by high-energy electrons trapped within the host material. The process of heating frees the electrons and facilitates the release of excess energy in the form of visible light. Calcite, spodumene, petalite, and even some diamonds may exhibit this phenomenon.



Green spodumene



The same green spodumene glowing after exposure to the heat of a fiber optic lamp

(Photos courtesy of Gagan Choudhary, Gem Testing Laboratory, Jaipur, India)



Intense play-of-color stands out against the natural earth tones of this boulder matrix opal, 2.5 x 1.8 cm.

Optical Properties

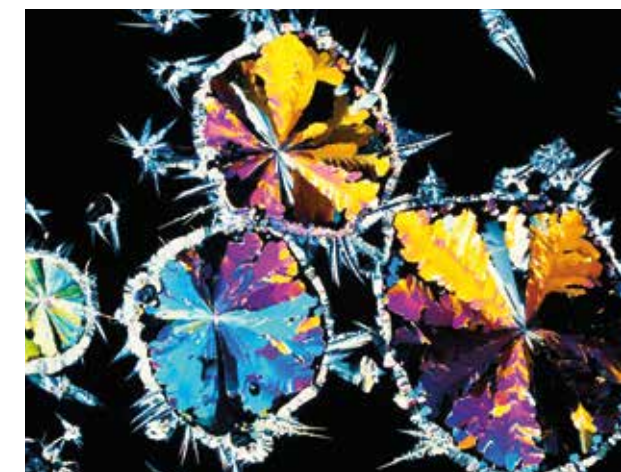
The optical properties of a gemstone are characteristics related to the way that light interacts with it. Although color, luster, dispersion, transparency, and phenomena are also optical properties, the optical properties section of the property box is reserved for characteristics that usually require the use of a gemological tool to be observed, for example, polariscope reaction, optic character, refractive index, birefringence, fluorescence, and Chelsea Colour Filter™ (CCF) reaction. Pleochroism is not included in the property boxes. When observable, pleochroism is instead represented as an icon with either two colors (for dichroic gems) or three colors (for trichroic gems) and an associated caption describing the intensity range.

POLARISCOPE REACTION

When a wave of light enters a gemstone, the light can behave in several ways: it may continue traveling through the gemstone as a single wave (in singly refractive materials, SR) or it may be split into two different waves traveling at different speeds (in doubly refractive materials, DR). The way the light behaves when entering a gemstone depends on the structure of the gemstone. Gemstones are either isotropic (singly refractive), anisotropic (doubly refractive), or aggregates (AGG). Isotropic materials may also exhibit anomalous double refraction (ADR).

Determining whether a gemstone is isotropic, anisotropic, or an aggregate is useful in identifying translucent to transparent gemstones and can be measured using a tool called a polariscope.

A polariscope consists of two polarizing filters and a light source. The polarizing filters are positioned at right angles to each other. This is called the dark position because in this position the light is obstructed. In order to determine the optical nature of a gemstone, the gem is placed between the “crossed polars” (dark position) and rotated 360°.

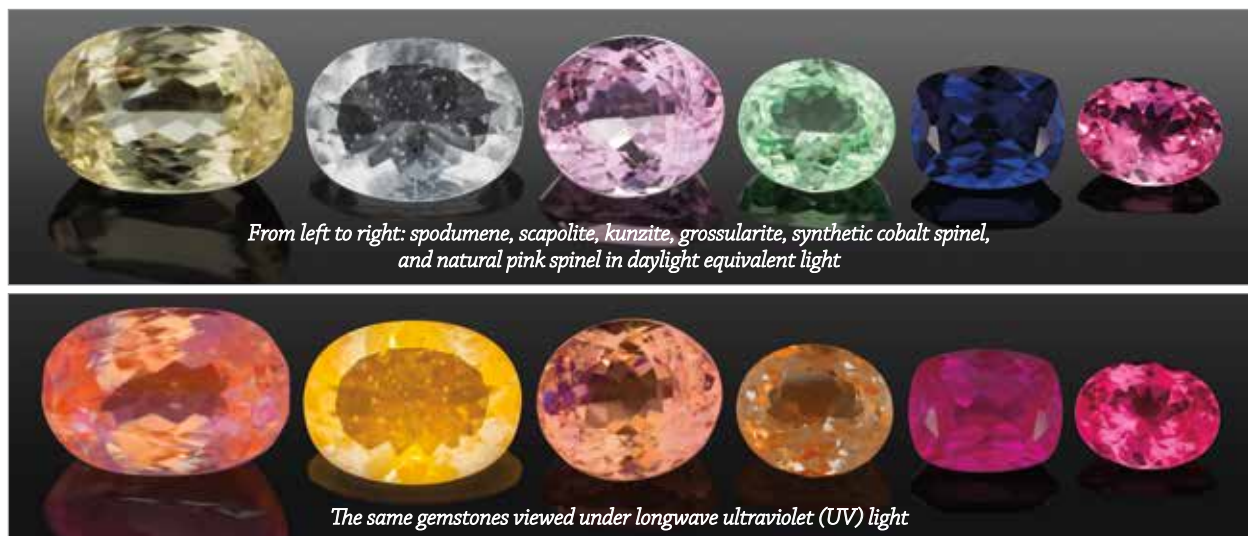


A variety of materials appear as different colors under polarized light, like these crystals of colorless citric acid.

Isotropic gemstones (singly refractive, SR) may be amorphous (lacking a crystal structure, like glass) or may be minerals belonging to the cubic (isometric) crystal system. The length of the crystallographic axes in cubic minerals, like garnet, is the same in all directions; therefore, light interacts with the crystal in the same way throughout. When an isotropic gemstone is placed on a backlit polariscope, the gem will remain dark as it is incrementally



Portable polariscope



FLUORESCENCE

Luminescence describes the emission of visible light by a material exposed to radiant energy. Fluorescence is a form of luminescence caused by absorption of radiant energy that is immediately re-emitted as visible light.

The effect occurs only while the source of radiant energy is present. Ultraviolet light (longwave and shortwave) and X-rays are the two more common forms of radiant energy used by gemologists.

Fluorescence is used as a diagnostic tool in

identifying gemstones and minerals. Its presence or absence provides an additional clue that reduces the range of possibilities. Fluorescence may also be used to separate natural gemstones from their synthetic counterparts.

Phosphorescence is a rare form of luminescence occurring when minerals are exposed to wavelengths of energy within the electromagnetic spectrum. The energy is absorbed by electrons within the host material and later released as visible light. The effect



Synthetic cobalt spinel before and after viewing underneath a Chelsea Colour Filter



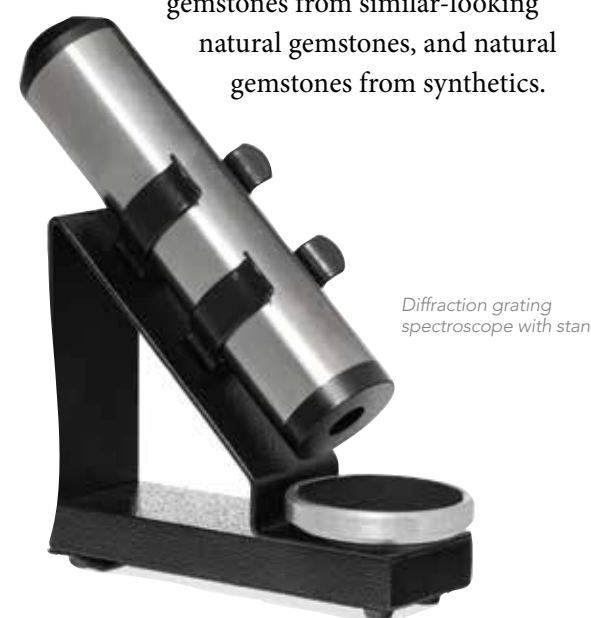
manifests as an afterglow. Phosphorescence is described as fluorescence persisting after the energy source is removed.

Because phosphorescence is limited, its presence or absence is used as a diagnostic tool. The duration of the effect is measured usually in seconds but may extend to minutes.

CHELSEA COLOUR FILTER (CCF) REACTION

The Chelsea filter, also called Chelsea Colour Filter™ (CCF), is a gemological tool used to identify chromium in certain colored stones. It is sometimes called an emerald filter because it was used to separate emerald gemstones from green imposters. It is generally used to confirm the result of other tests and observations.

The Chelsea filter is designed to transmit only red and green light but can be used on all materials, transparent to opaque. Applications include separating dyed materials from their natural counterparts, natural gemstones from similar-looking natural gemstones, and natural gemstones from synthetics.



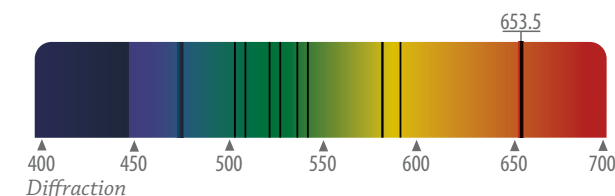
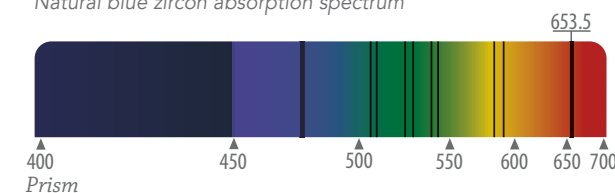
Diffraction grating spectroscope with stand

ABSORPTION SPECTRA

Using a spectroscope to observe the absorption spectrum of a material is a diagnostic test used to identify some minerals and gemstones. Although it sounds technical, the principle behind it is basic.

Human eyes are optimized to perceive visible, or white, light, a form of radiant energy. Visible light is a small segment of the much-larger electromagnetic spectrum and comprises the colors of the rainbow: red, orange, yellow, green, blue, indigo, and violet. Each hue has a corresponding wavelength and increasing level of energy.

Natural blue zircon absorption spectrum



When the eye perceives color, it is interpreting the residual or escaping wavelengths of visible light. If an object appears transparent and colorless, most, if not all, of the visible light spectrum reaches the eyes. If the reverse occurs, the result is black. Between these two extremes are the colors of the rainbow.

When color occurs, wavelengths and their corresponding energy are trapped and absorbed by molecules, atoms, or electrons within the host material. The eye interprets the resulting blend.

abalone



As part of the animal kingdom, abalone belongs to the phylum Mollusca and the class Gastropoda. Abalone is further identified as belonging to the family Haliotidae and the genus *Haliotis*.

In simple terms, abalone is a large, univalve, marine mollusk with a flattened, ear-shaped shell. Its shell, which it carries on its back like a snail, provides protection from predators.

Abalone has been highly prized for thousands of years as a food source for Pacific Rim cultures. The Maori people of New Zealand call abalone *pāua*. In today's world, it has been elevated to the status of gourmet shellfish, cherished for its tender, mild, sweet meat.



Abalone fish

However, abalone is considerably more than a great dinner entrée. It has made two contributions in addition to its culinary legacy: its richly colored mother-of-pearl shell and its incredibly rare and beautiful pearls.

The shells, which vary in color and pattern from species to species, have been used for both ornamental and decorative purposes. Pearls from this mollusk are prized by collectors for their vivid, iridescent colors. Abalone pearls, like those of marine pearl-bearing oysters, are nacreous. Due to the shape of abalone shell, pearls are nearly always baroque. Fine, rounder pearls are almost nonexistent and command exceptional prices. Colors especially prized are deep purplish red or blue and green.

The name *abalone*, generically applied to all species, is said to have originated in California. It is derived from the Spanish word *abulón*. The Spanish also referred to this marine mollusk as *oreja de mar* (sea ear), an apt description of its shape. More than one hundred species of abalone have been identified worldwide.

Abalone Shell CaCO_3 + organic materials

Observational Properties

Color	gray to white, with various iridescent colors
Luster	greasy, pearly, dull, vitreous
Transparency	translucent to opaque
Clarity	N/A
Dispersion	not observable
Phenomena	iridescence

Optical Properties

Polariscope Reaction	AGG
Optic Character	N/A
Refractive Index	1.530 – 1.685 (birefringence blink)
Birefringence	0.155
Fluorescence	SW: variable LW: variable
CCF Reaction	none

Physical Properties

Fracture	uneven, splintery
Cleavage	none
Specific Gravity	2.70 – 2.89
Hardness	2.5 – 4.5
Toughness	fair
Streak	white

Abalone shell, 17.0 x 12.0 x 4.5 cm



*Ammolite replaced the shell of this 71 million year old ammonite *Placenticeras costatum* (a marine mollusk) fossil from the Bearpaw Formation, Alberta, Canada (specimen courtesy Korite International), 32.0 x 26.5 cm.*

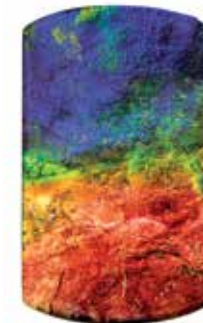
ammolite

Ammolite is a gemstone material derived from the fossilized shell of an extinct, squid-like creature (cephalopod) called an ammonite.

The distinctive and attractive iridescence of ammolite is produced when the shell is replaced with minerals during fossilization. The

primary component of the mineralized layer is aragonite. When light interacts with these layers of aragonite, interference occurs, resulting in a beautiful array of rainbow colors. Because the outer layer of minerals is generally thin with a Mohs hardness of 4, most ammolite is made into doublets or triplets for use in jewelry manufacture.

Ammolite was discovered in Alberta, Canada, which remains the primary source of this material.



Ammolite triplet



(Top) ammolite triplet, (bottom) iridescent fossilized ammonite

Ammolite CaCO_3 + other minerals

Observational Properties

Color	variety of iridescent colors
Luster	vitreous, resinous
Transparency	opaque
Clarity	N/A
Dispersion	not observable
Phenomena	iridescence

Optical Properties

Polariscope	
Reaction	aggregate (AGG)
Optic Character	N/A
Refractive Index	1.520 - 1.680 (birefringence blink)
Birefringence	0.150 - 0.155
Fluorescence	SW: inert or yellow LW: inert or yellow
CCF Reaction	none

Physical Properties

Fracture	uneven, granular
Cleavage	none
Specific Gravity	2.70 - 2.80
Hardness	4.0
Toughness	poor
Streak	white



Aquamarine crystals with albite and muscovite, Pakistan, largest crystal measures 3.0 x 2.3 cm



aquamarine



Etched aquamarine crystals in matrix, Afghanistan

Aquamarine is a blue to green-blue gemstone variety of beryl. Aquamarine is very familiar to the general public. It is popularly recognized as the birthstone for March and the gemstone representative of the nineteenth wedding anniversary.

The name, aquamarine, is derived from two Latin words, *aqua marinus* (water of the sea), an allusion to its color.

Aquamarine is a beryllium-aluminum silicate and owes its color to the presence of trace amounts of iron. The color is rarely intense.

Aquamarine is commonly treated to alter and improve color. Natural unheated aquamarine is typically greenish-blue, however, heating removes the yellow component and intensifies the blue. Irradiation has also been used but to a considerably lesser extent. It produces some rich-colored blues, but the enhancement is

neither stable nor permanent.

Irradiated stones, when exposed to direct sunlight, do not retain their color.

Aquamarine crystals can grow to exceptional size but rarely exhibit intense blues.

Although heating often improves the color, most material is still somewhat pale after treatment.

Gemstones are commonly cut to larger sizes to improve the visual appeal. Color is further intensified by fashioning deeper pavilions and higher crowns.

Aquamarine is one of two March birthstones.



Brazilian Santa Maria aquamarine ring



Untreated Madagascar aquamarine



Bi-color Brazilian aquamarine



Cluster of prismatic aquamarine crystals with schorl

EMERALD



These stones were not considered “true” emeralds when they first arrived on the market, due to the absence of chromium. Even so, color is the primary factor regardless of which trace element is present. Therefore, green chromium- or vanadium-bearing beryl of sufficient tone and saturation is considered emerald.

The normal color range of emerald is quite narrow. Only gemstones exhibiting bluish-green to green coloration, sometimes with a hint of slightly yellowish green, meet the requirements. Transparent gemstones of slightly bluish green with tones of medium to medium dark and saturation of strong to vivid are highly prized. Small variations in the tone or saturation can have dramatic effects on the value. Although rough may range from transparent to opaque, only a small percentage of the material recovered is transparent. Inclusions are common and often visible to the unaided eye.

Although normally thought of as negative, inclusions do have a positive side. They are instrumental in helping gemologists separate

Emerald $\text{Be}_3\text{Al}_2(\text{Si}_6\text{O}_{18})$	
Observational Properties	
Color	light to dark green, bluish green, slightly yellowish green
Luster	vitreous, resinous
Transparency	transparent to translucent
Clarity	Type III
Dispersion	not observable
Phenomena	chatoyancy, trapiche, asterism (rare)
Optical Properties	
Polariscope Reaction	doubly refractive (DR)
Optic Character	uniaxial (-)
Refractive Index	1.560 – 1.602
Birefringence	0.005 – 0.009
Fluorescence	SW: inert to strong red, orangy red, or pink LW: inert to strong red, orangy red, or pink
CCF Reaction	may appear green, red or pink
Physical Properties	
Fracture	conchoidal, uneven
Cleavage	poor
Specific Gravity	2.63 – 2.92
Hardness	7.5 – 8.0
Toughness	poor, good
Streak	none

SMARAGDUS

The ancient Roman name applied to emerald is *smaragdus*. The Greek equivalent is *smaragdos*. Because gemology did not exist as a science until many centuries later, gemstones were classified on the basis of color. Many green gemstones and gemstone materials were described using the same term. Other possibilities include green chalcedony, malachite, green fluorite, green turquoise, and jade.

natural emerald from flux or hydrothermal synthetics. Inclusions can also help gemologists identify the source of some material.

Various types of inclusions may be found in emerald, ranging from solid to liquid and gas phases. Combinations of these, known as two- and three-phase inclusions, are common in many emeralds. Growth tubes or needle-like inclusions may also be present. Solid inclusions may take the form of actinolite, albite, calcite, hematite, mica, pyrite, or other associated minerals that vary by source. Surface-reaching fractures are common and often subject to fracture filling.

Fracture filling, also referred to as fissure filling, is common in emerald. It may take the form of natural oils, resins, or various synthetic polymers. These substances, which have a refractive index close to that of emerald, replace the air within the fissures and cavities and allow light to pass through the host without appreciably altering its speed or direction. As a result, the fissures become substantially less noticeable to the eye and seem to disappear.

A traditional treatment method, practiced by Colombian emerald dealers, is using colorless cedar-wood oil to fill any surface-reaching fractures. Dyed oils, although considerably less common, have also been used on extremely low-grade material. In addition to oiling, a variety of synthetic resins and hardening polymers are becoming more widely available to the gemstone industry. These fillers offer an alternative to traditional oiling and create a more stable product. Treatments for emerald are limited to clarity enhancement; there is no commonly used color treatment process for emerald.

Although treatments do improve the aesthetic appeal of emerald, they are not permanent and should always be disclosed. Care must be taken when cleaning emerald due to issues of durability and stability. Emerald should never be placed in an ultrasonic cleaner or subjected to the direct heat of a jeweler’s torch.

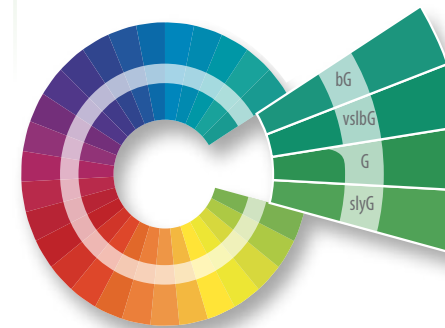
Emerald may exhibit unusual optical effects referred to as phenomena. Although rare, some material



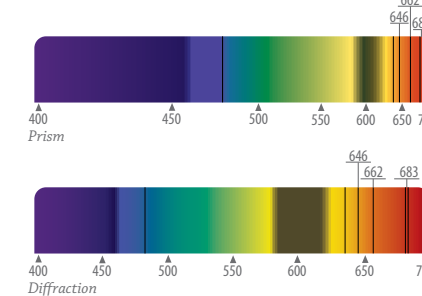
The Colombian trapiche exhibits a wheel spoke pattern created by albite or carbonaceous materials trapped within unusual growth sectors.



Moderate to strong pleochroism



EMERALD SPECTRUM



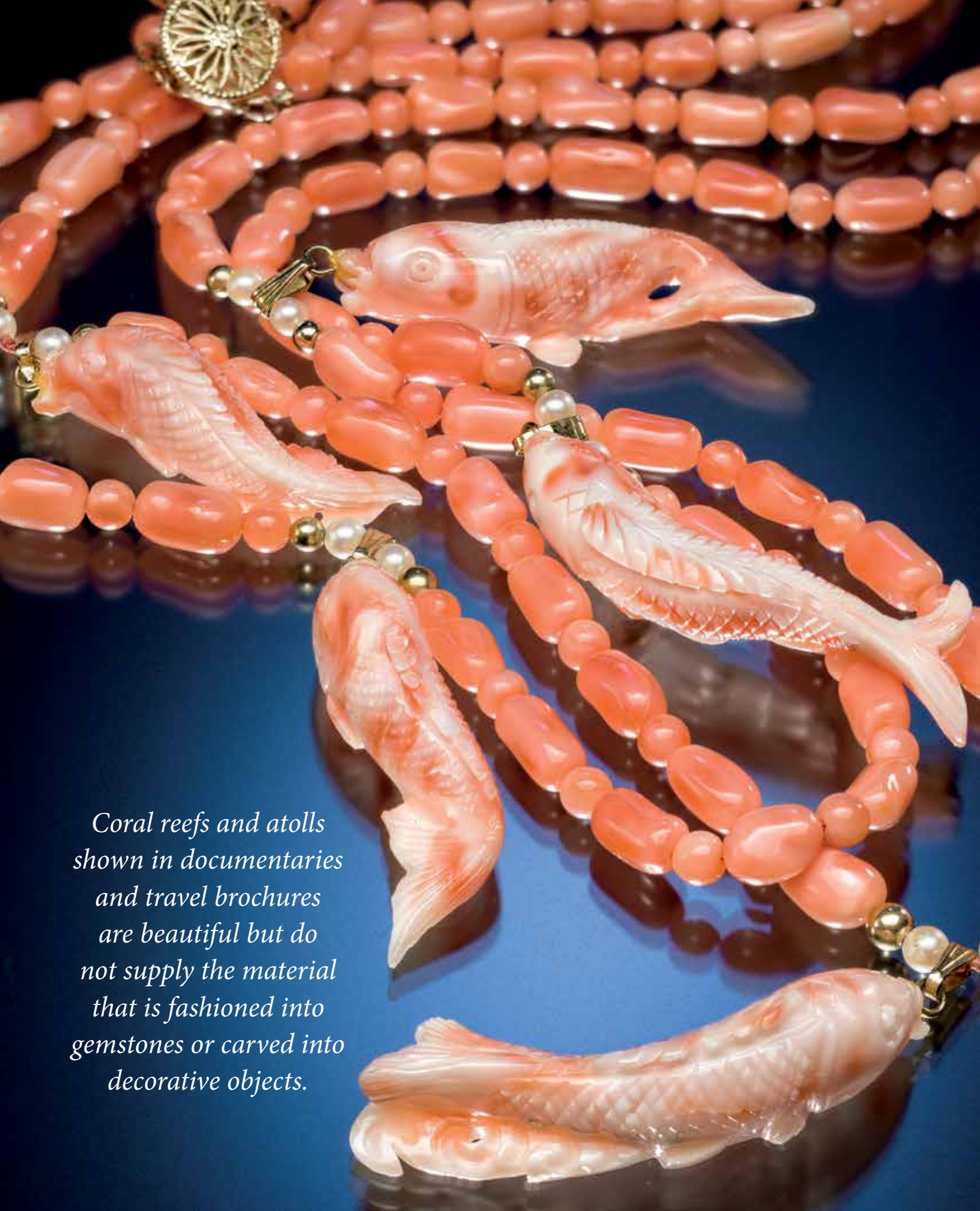
from Colombia has displayed chatoyancy (cat’s-eye). The effect is caused by the presence of parallel tubes or fibrous inclusions. Emeralds exhibiting asterism have also been reported but are rare.

An unusual type of emerald, trapiche exhibits a wheel spoke pattern created by albite or carbonaceous materials trapped within unusual growth sectors. In the finest specimens, six symmetrical, well-defined triangular prisms create the impression of a sliced pie. In some cases, the rays do not run all the way to the center but instead radiate from a hexagonal bull’s-eye. Trapiche emerald, as well as other phenomenal varieties, are fashioned as cabochons to maximize the effect.

Although trapiche emeralds have been found in Brazil and Madagascar, Colombia remains the predominant source.

Pleochroism in emerald can range from moderate to strong but varies by source and intensity of hue. The dichroic colors are commonly slightly yellowish green to green and blue green.

Most emerald is inert under ultraviolet light, but some



Coral reefs and atolls shown in documentaries and travel brochures are beautiful but do not supply the material that is fashioned into gemstones or carved into decorative objects.



Coral cameo

coral

Coral is a well-known organic gemstone prized throughout history. It is the product of the coral polyp, a primitive saltwater animal that looks somewhat like a plant. Its body shape is tube-like and contains eight small tentacles at the top. Its main source of food is plankton carried by currents.

There are hundreds of species of coral worldwide, but only a small number are used in jewelry manufacture. Coral reefs and atolls shown in documentaries and travel brochures are beautiful but do not supply the material that is fashioned into gemstones or carved into decorative objects. *Corallium rubrum* and *Corallium japonicum* fulfill that role. These two red coral species are the source of nearly all coral seen in the jewelry trade. To a lesser extent, black coral (or proteinaceous coral), has also

been used in jewelry. In addition to being black, blue, or golden in color, black corals are comprised of a tough, organic protein called conchiolin, rather than calcium carbonate, which makes up red coral. Dredging is the most common method of harvesting coral.

Corallium rubrum, formerly known as *corallium nobile*, is a variety of angel-skin coral. It is an attractive pink-to-red organic gemstone material produced by coral polyps. The polyps secrete calcium carbonate that forms branch-like structures resembling underwater trees.

Calcareous Coral CaCO_3



Observational Properties

Color	red, reddish orange, pink, blue, or white
Luster	vitreous to waxy
Transparency	transparent to opaque
Clarity	N/A
Dispersion	not observable
Phenomena	none

Optical Properties

Polariscope Reaction	AGG
Optic Character	N/A
Refractive Index	1.486 - 1.658, (birefringence blink)
Birefringence	0.160 - 0.172
Fluorescence	SW: inert to weak bluish white LW: inert to weak bluish white
CCF Reaction	none

Physical Properties

Fracture	uneven to splintery
Cleavage	none
Specific Gravity	2.60 - 2.70
Hardness	3.5 - 4.0
Toughness	fair
Streak	white



Dyed coral necklace



Coral, gold, and diamond earrings



Blue coral bracelet



Indonesian petrified coral



Dyed sponge coral pendant

SAPPHIRE

The term *white sapphire*, commonly used in the jewelry trade, refers to a colorless variety that many sources reference as *leuco-sapphire*. The term *fancy* is used to describe all colors of sapphire other than blue.

One gray area is the dividing line between pink sapphire and ruby. There is no consensus among experts and no clearly defined line of demarcation.



Sapphire ring

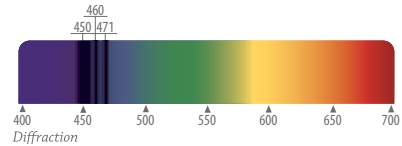
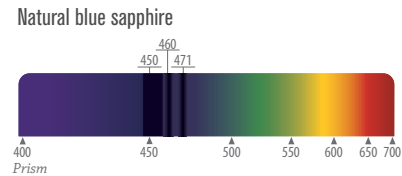
Sapphire is the birthstone of September.



Prior to the twentieth century, all reddish corundum was ruby regardless of the intensity of color. Older texts referred to lesser-saturated material as pink ruby. Some gemologists define ruby as red corundum, which has sufficient chromium to show the chromium line in the spectrum, while pink corundum does not.

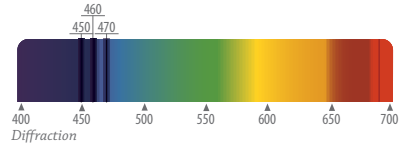
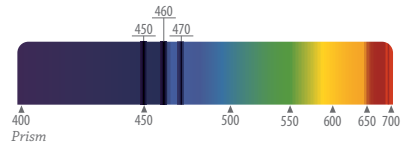
A notable variety of sapphire, called padparadscha, is highly prized for its rich pinkish orange (or orange pink) color.

SAPPHIRE SPECTRA

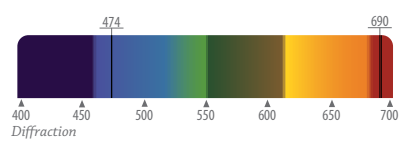
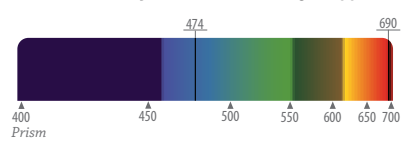


Natural blue sapphires show strong absorption bands at 450 nm, 460 nm, and 471 nm due to the presence of iron.

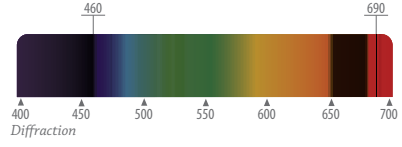
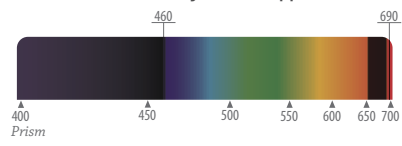
Natural color-change sapphire



Flame-fusion synthetic color-change sapphire



Yellow flame-fusion synthetic sapphire



The most valuable variety of sapphire is a rich, velvety cornflower blue that was historically associated with stones from the Indian portion of Kashmir. It was mined in a river valley in the northwestern Himalayas. Kashmir sapphires set the bar for future comparisons. Due to politics, remote location, and extremes of climate, the mines have not been worked in many decades.

Sapphire may exhibit various phenomena. The two more common are asterism (stars) and color-change. Most stars contain six rays, but in some cases, most notably black sapphire, there may be twelve rays due to the orientation of various inclusions.

Although the presence of trace elements may affect color, other mechanisms, such as radiation-induced color centers, may also be responsible. Black star sapphire, which is both common and inexpensive, derives its color and asterism from inclusions of hematite and ilmenite.



Weak to strong pleochroism. Colors will vary depending on the body color of the gem.

Nearly all sapphire undergoes some form of treatment to enhance its appearance. The most-common method is heating at various ranges of temperature under reducing or oxidizing atmosphere. Depending on the temperature and atmosphere, color can be improved, removed, or altered. Fracture filling is also a common practice.

Newer treatments, such as surface diffusion and bulk/lattice diffusion, have been applied in recent years. Both processes make use of powdered chemicals and heat to create color. In the first case, the color is only “skin deep,” making recutting impossible. In bulk/lattice-diffused gems, the color penetrates to a much-greater depth and does allow for repolishing and, in some cases, recutting if the stone is chipped or cracked. The element responsible for the resultant color in bulk/lattice diffusion is beryllium.

Other affordable alternatives to natural treated sapphire are the many types of synthetic sapphire. Early synthetic sapphires were produced by the Verneuil method, a flame-fusion process in which powdered chemicals are dropped through a flame to crystallize on a rotating cylinder. Soon after,



11.54 ct Montana Sapphire. This is the largest gem-quality sapphire from this source known in the industry (courtesy of the Somewhere in the Rainbow Collection).

the Czochralski, or pulling method, was developed. With the material melted in a crucible rather than dropped from above, a seed crystal is used to pull the molten material out, resulting in both faster crystallization and a more pure crystal. Sapphires may also

be created using flux and hydrothermal processes, but these are more costly and time consuming than the other methods.

Pleochroism may range from weak to strong and varies by color. Fluorescence may range from nonexistent to quite strong, depending on the color and combination of impurities present. Most blue stones are inert under longwave and shortwave ultraviolet light, although some have been reported to exhibit a weak, greenish fluorescence. Black and green stones are also inert. Other fancy colors exhibit variable strength and color of fluorescence.

Notable sapphire sources include Australia, Cambodia, China, India (Kashmir), Laos, Madagascar, Myanmar (formerly Burma), Nigeria, Sri Lanka, Tanzania, Thailand, the United States, Vietnam, and Zimbabwe.



Madagascan pink sapphire



Synthetic Linde star sapphire



Madagascan purple sapphire



Yellow orange sapphire



Unheated Sri Lankan sapphire



THE MYRIAD COLORS OF CORUNDUM

These are the result of trace amounts of transitional elements or combinations of trace elements. The more common replacements are chromium, iron, titanium, and vanadium.

PINK TO RED



PADPARADSCHA



or



+



ORANGE



+



YELLOW



+



GREEN



or



+



BLUE



+



PURPLE



CORNFLOWER BLUE

Cornflower blue is a descriptive phrase commonly associated with fine-quality sapphire from Kashmir. The color was so exceptional that it set the standards for all future color comparisons.



Cornflower blue
Sri Lankan sapphire

In technical terms, cornflower blue can be described as having medium tone and strong to vivid saturation. The color ranges from violet blue to blue, with a velvety luster. The name is derived from the color of the cornflower plant (*Centaurea cyanus*), also known as bluebottle or bachelor's button.

PADPARADSCHA SAPPHIRE

Padparadscha is a highly prized variety of sapphire that derives its name from a Sinhalese word meaning lotus flower. It alludes to the bloom of the plant, which is more pink than orange. In modern trade usage, there is no clearly defined boundary between the orange and pink components, but the color is often described as pinkish orange or orangish pink.

Not all padparadscha sapphires owe their color to natural agents. Some are the direct result of bulk/lattice diffusion. This treatment is capable of creating exceptional colors, but the enhancement is only "skin deep." While such stones duplicate the delicate balance of their natural counterparts, they cannot be recut or repolished if damaged. Other spellings includes padparasha and padparadsha.



Padparadscha sapphire



Displaying fine emeralds and blue sapphires at the Tucson gem show

YOGO SAPPHIRE

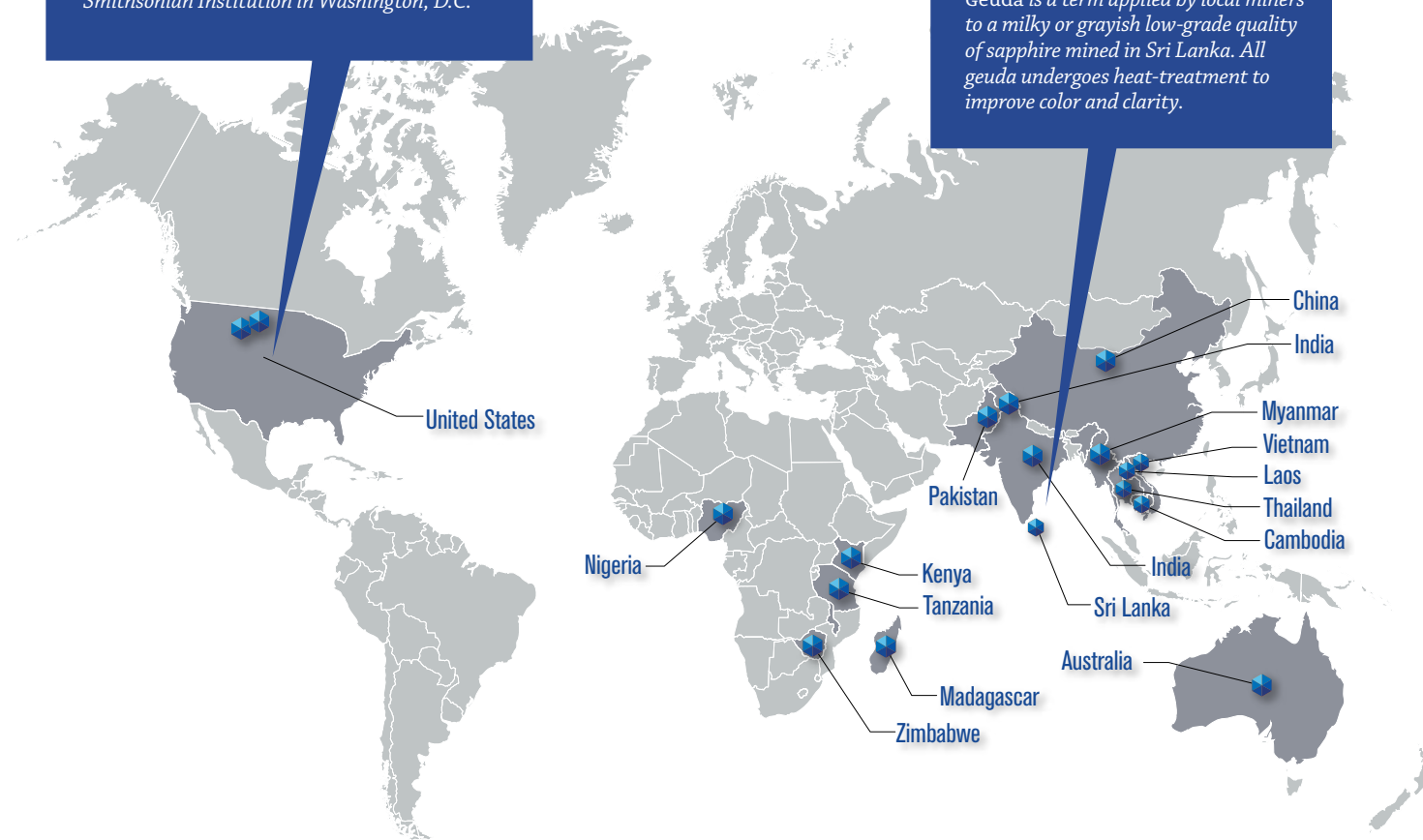
Yogo sapphire is the name applied to corundum mined in Yogo Gulch, Montana. Yogo sapphires are generally unheated, unusual for any variety of corundum. Sizes are commonly small. Colors are often pale blue to violet. The largest cut Yogo sapphire on record (10.2 carats) resides in the Smithsonian Institution in Washington, D.C.



Sapphire mining near Ilakaka, Madagascar

GEUDA SAPPHIRE

Geuda is a term applied by local miners to a milky or grayish low-grade quality of sapphire mined in Sri Lanka. All geuda undergoes heat-treatment to improve color and clarity.



The pyralspite garnet series



Almandine garnet crystals, North Tyrol, Austria, 12.0 x 11.0 x 6.5 cm

The Pyralspite Garnet Series

mineral species	chemical formula	gem varieties
pyrope	$Mg_3Al_2(SiO_4)_3$	pyrope, anthill garnet (chrome pyrope)
pyrope + almandite		rhodolite (when pink or purple)
almandite	$Fe_3Al_2(SiO_4)_3$	almandite
spessartite	$Mn_3Al_2(SiO_4)_3$	spessartite
spessartite + pyrope		color-change garnet
pyrope + almandite + spessartite		Malaia garnet, umbalite

Pyralspite is one of two mineral series within the garnet group; ugrandite is the other.

The pyralspite series consists of three garnet species: pyrope, almandite, and spessartite. The name combines letters from each member of the series (**pyrope+almandite+spessartite**).

The general formula for garnets in the pyralspite series can be written as $X_3Al_2(SiO_4)_3$, where X represents

a divalent metal ion. The three primary divalent ions are ferrous iron (Fe^{2+}), magnesium (Mg^{2+}), and manganese (Mn^{2+}), or some combination of the three.

PYROPE

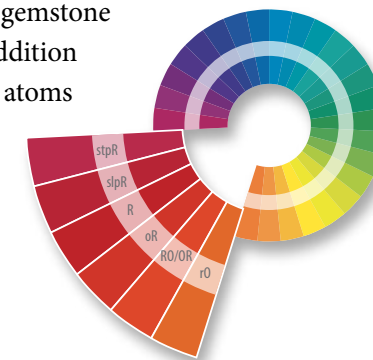
Pyrope is a magnesium-aluminum silicate, but it is never pure. Atoms of magnesium are frequently replaced by iron, creating a mix of pyrope and almandite. This mix, when it approaches a 2:1 ratio, produces an attractive and popular mineral that gemstone aficionados know as rhodolite. In addition to iron, other elements may replace atoms of magnesium.

Since there are numerous possible substitutions, structural irregularities are common. This condition leads to anomalous double refraction, a frequent occurrence with many varieties of garnet. Refractive indices for pyrope vary from source to source. Some texts list refractive-index values at 1.76 or higher.

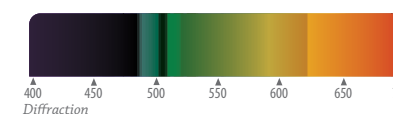
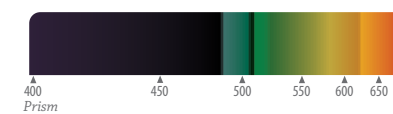
Pyrope is predominantly red but may contain a purple,



Pyrope in eclogite



PYROPE SPECTRUM



Pyrope $Mg_3Al_2(SiO_4)_3$

Observational Properties

Color	purplish red to reddish orange, rarely colorless to pink, may be brownish to black
Luster	vitreous
Transparency	semitranslucent to transparent
Clarity	Type II
Dispersion	moderate, 0.022
Phenomena	color-change

Optical Properties

Polariscope	
Reaction	singly refractive (SR), ADR
Optic Character	N/A
Refractive Index	1.714 - 1.756
Birefringence	none
Fluorescence	SW: inert LW: inert
CCF Reaction	none

Physical Properties

Fracture	conchoidal, brittle
Cleavage	none
Specific Gravity	3.58 - 3.87
Hardness	7.0 - 7.5
Toughness	fair to good
Streak	none



Assortment of Lightning Ridge black opal, center opal is 54.64 ct (3.9 x 2.4 cm)

PRECIOUS OPAL

BLACK OPAL

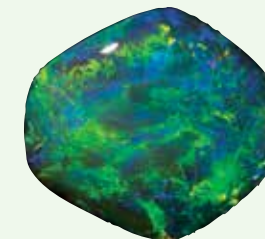
While Shakespeare wrote that opal is the “queen of gems,” black opal is often called the “king of opals.” Discovered in 1902, *black opal* is the rarest and most-valuable variety of opal. The term is used to describe any material that exhibits play-of-color against a dark body tone (N1–N4 on the rock-color chart), although the actual body color may be dark green or blue, blackish brown, or pure black. Black opal can range from translucent to opaque and, if it is transparent to translucent without haziness, it is more properly called black crystal opal.

Most black opal comes from Australia, primarily Lightning Ridge and, to a much-lesser extent, Mintabie. Black opal may also be found in Java, and an attractive yet typically unstable black opal is found in Virgin Valley, Nevada, in the United States. Another source of black opal was recently discovered in the Wollo province of Ethiopia.

The pattern of the play-of-color in a black opal is especially important to its value. The harlequin pattern with red play-of-color is the most valuable, with flagstone, ribbon, and Chinese writing patterns being prized as well.



Black opal rough



Polished black opals



Coober Pedy, Australia

BOULDER OPAL

Boulder opal is mined in Queensland, Australia. It is a form of opal that consists of ironstone or sandstone matrix interlaced with precious opal. When fashioned, the matrix is included in the design of the finished piece or left as backing for the top layer of opal, referred to as a natural doublet. Boulder opal is typically quite stable and is an excellent choice for collectors who favor one-of-a-kind stones. Boulder opal may also be called Queensland opal.



Queensland boulder opal, (left) face up, (right) side view

The Sweet Home Mine Alma, Colorado



The "Millennium Jewel" rhodochrosite specimen was discovered on January 2, 2000. Specimen measures 8 cm tall. (Kevin Dixon photo)



The Sweet Home Mine entrance located on the southern slope of Mount Bross, near the town of Alma, Park County, Colorado



Sweet Home Mine owner, Bryan Lees, holding a plate of rhodochrosite crystals



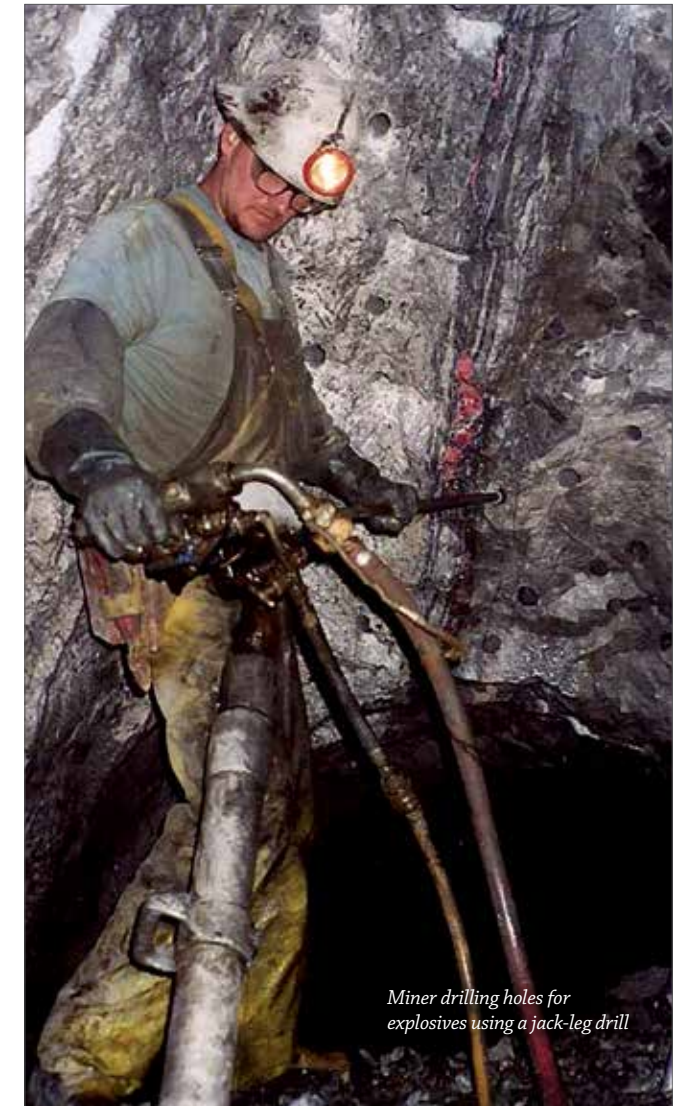
Faceted Sweet Home Mine rhodochrosite gemstone

The source of the world's finest rhodochrosite is the Sweet Home Mine, located on the southern slope of Mount Bross, near the town of Alma, Park County, Colorado. The mine was originally opened in the 1870s to extract silver. What sets Sweet Home rhodochrosite apart is its vibrant, cherry-red color and outstanding transparency. From 1991 through 2004, the Collector's Edge Minerals, Inc. of Golden, Colorado, operated the Sweet Home Mine to produce collector-quality rhodochrosite specimens and gem-quality cutting rough. Hundreds of world-class mineral specimens and thousands of carats of gem-bearing material were recovered. Exceptional rhodochrosite crystal-bearing pockets were very rare. It would often take close to 2 years of mining to find a single, high-quality, crystal-bearing pocket. Collector's Edge owner, Bryan Lees, and the Sweet Home mining crew employed classic hard-rock drilling and blasting techniques and cutting-edge specimen extraction methods utilizing hydraulic rock-splitters and diamond-edged chain saws to recover specimens, a painstaking ordeal due to the fragile nature of the crystals. The mine closed in October of 2004, a



Polished rhomb of Sweet Home rhodochrosite

fact that further enhanced the appeal of Sweet Home mine specimens and gems to collectors worldwide.



Miner drilling holes for explosives using a jack-leg drill



The famous "Sno-Cone" specimen collected from the Good Luck pocket



Sodalite horse carving,
15.0 x 4.7 x 11.4 cm



sodalite

Predominantly a decorative material, sodalite is fashioned as cabochons and beads for use in jewelry.

The name alludes to the element sodium, a major constituent in its chemical formula. Sodalite is both a mineral species and a group. Other members of the sodalite group include lazurite, tugtupite, and haüyne (also known as haüynite).

Sodalite is known for its rich blue to violetish blue color but may also be greenish, yellowish, or even white to gray. A variety of white to pinkish or violet sodalite, known as hackmanite, is attractive and unusual. It is highly prized by mineral collectors for its fluorescence, phosphorescence, and tenebrescence. Some of the better specimens exhibiting these properties come from Greenland.

Although well-formed crystals are common, most sodalite is too dark or lacks sufficient transparency to be faceted. Common habits include dodecahedra and octahedra. Gemstones, which are difficult to find, rarely approach half a carat.

Massive material, which normally exhibits whitish veins of calcite running throughout, is commonly carved into figurines or fashioned into decorative objects. Some rough contains orange to reddish veins that create an attractive contrast to the rich, blue color of sodalite.

Significant sources include Brazil, Canada, Central Asia, Greenland, India, Italy, Myanmar (formerly Burma), Russia, and the United States.



HACKMANITE

Light pink to pale violet, hackmanite is a variety of sodalite named for Victor A. Hackman, a Finnish geologist. It exhibits a rare property called tenebrescence. When exposed to sunlight, its color fades quickly to white. If stored in darkness for a few days, the color returns; exposure to shortwave ultraviolet light will restore the color immediately. The process of color loss and recovery is repeatable, making hackmanite a prized mineral for collectors. Most hackmanite is fluorescent and some is phosphorescent.



Sodalite crystals, Afghanistan (courtesy of the Arkenstone, Joe Budd photo)



Sodalite pendant



Faceted sodalite

Sodalite $\text{Na}_8(\text{Al}_6\text{Si}_6\text{O}_{24})\text{Cl}_2$

Observational Properties

Color	blue, colorless, white, yellow, green, gray, or pink
Luster	vitreous, greasy
Transparency	translucent to opaque
Clarity	N/A
Dispersion	moderate; 0.018
Phenomena	tenebrescence (var. hackmanite)

Optical Properties

Polariscope	
Reaction	singly refractive (SR)
Optic Character	N/A
Refractive Index	1.479 - 1.487
Birefringence	none
Fluorescence	SW: inert to strong orange LW: inert to strong orange
CCF Reaction	may appear brownish

Physical Properties

Fracture	conchoidal, uneven
Cleavage	poor
Specific Gravity	2.25 - 2.33
Hardness	5.5 - 6.0
Toughness	poor
Streak	white

TANZANITE



Tanzanite crystal exhibiting trichroism, 2.3 x 4.5 x 1.4 cm

Tanzanite is an attractive and extremely popular purple to blue gemstone variety of zoisite, brought to light in the mid- to late 1960s. The question of who first found this rare and magnificent gemstone is still debated. It was not until the next decade that tanzanite made its debut in the United States. It was embraced by Henry Platt, then president of Tiffany & Co., and given the current name in honor of Tanzania, its country of origin.

Although an effort was made to market tanzanite, irregular production was its downfall.

It took nearly two more decades for tanzanite to recover. It was not until the early 1990s that supplies became consistent enough to make tanzanite an



economically viable product worthy of marketing dollars. By 2002, tanzanite had become so popular that it was added to the list of birthstones as an alternative gemstone for December.

Even though less durable than many traditional gemstones, tanzanite has been mounted in nearly every form of jewelry imaginable. It is, however, best suited for pendants, pins, and earrings because gemstones are somewhat brittle and sensitive to thermal shock. Care should always be taken when wearing, cleaning, or repairing tanzanite jewelry. Tanzanite should never be placed in ultrasonic cleaners or subjected to steam cleaning.



Cat's-eye tanzanite



The hues of tanzanite are limited to various shades of purple, violet, and blue, often with a grayish tone if not well saturated. The stones prized most highly in the trade are those exhibiting an intense, rich blue with a slight purplish component. Gems of this color are typically cut from the shorter crystallographic axis and do not produce as high of a yield from rough. Tanzanite exhibiting intense blues commands higher per-carat prices than its purple counterparts, but demand is also strong for purple shades, which do not experience as much price variation.

Typically, faceted tanzanite is transparent and clean. Lightly to moderately included rough is generally fashioned into beads and cabochons. Gemstone-quality tanzanite is rarely brilliant cut because this style of fashioning tends to lighten the stone slightly and decreases the yield from rough. Most native cut stones have shallow crowns and deeper pavilions with a slight bulge to increase the intensity of color and improve weight retention.

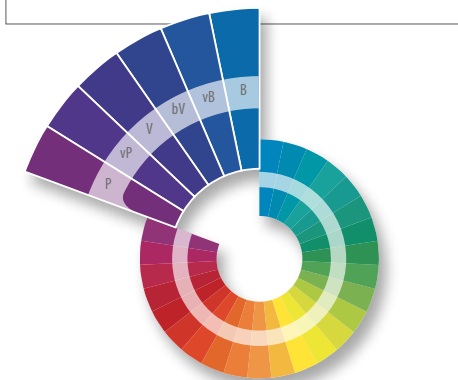
Tanzanite is an alternative birthstone for December.



Tanzanite, like many other minerals, is routinely heat-treated, sometimes naturally by the earth, but the vast majority of the time through human intervention. Most recovered rough is grayish to orangy brown and unimpressive. Without the application of heat, the world would never know the full majesty and beauty of this mineral.

Tanzanite is subjected to three separate applications of heat, each at a different range of temperature. During each treatment, a certain percentage of the material changes color, and once colored it is removed. Any unaffected material is then subjected to a second and third heat treatment if necessary. The process rarely attains 100-percent conversion from brown to the desired range of colors.

Tanzanite $\text{Ca}_2\text{Al}_3(\text{SiO}_4)_3(\text{OH})$	
Observational Properties	
Color	blue, violet blue to violet, bluish purple, purple
Luster	vitreous
Transparency	transparent to translucent
Clarity	Type I
Dispersion	moderate; 0.019 – 0.030
Phenomena	chatoyancy (rare)
Optical Properties	
Polariscope Reaction	doubly refractive (DR)
Optic Character	biaxial (+)
Refractive Index	1.686 – 1.700
Birefringence	0.008 – 0.013
Fluorescence	SW: inert LW: inert
CCF Reaction	may appear reddish brown
Physical Properties	
Fracture	conchoidal, uneven
Cleavage	perfect
Specific Gravity	3.10 – 3.45
Hardness	6.5
Toughness	poor to fair
Streak	white



Strong pleochroism in heated tanzanite; some sources state that gems become dichroic after heating.



Strong pleochroism in unheated tanzanite

Gemstone Properties

NAME	Refractive Index (R.I.)	Birefringence	SR/DR/AGG	Optic Character	Specific Gravity (S.G.)	Hardness
fire opal	1.370 - 1.470	None	SR	N/A	1.25 - 2.30	5.5 - 6.5
fluorite	1.432 - 1.435	None	SR	N/A	3.00 - 3.25	4.0
glass	1.460 - 1.800	None	SR	N/A	2.25 - 4.55	4.5 - 6.5
goldstone (glass)	1.460 - 1.800	None	SR	N/A	2.25 - 4.55	4.5 - 6.5
goshenite	1.560 - 1.602	0.005 - 0.009	DR	Uniaxial (-)	2.63 - 2.92	7.5 - 8.0
grossularite	1.730 - 1.760	None	SR	N/A	3.57 - 3.73	7.0 - 7.5
hackmanite	1.479 - 1.487	None	SR	N/A	2.25 - 2.33	5.5 - 6.0
hauyne	1.494 - 1.509	None	SR	N/A	2.40 - 2.50	5.0 - 6.0
hawk's-eye	1.540 - 1.553	0.009	AGG	N/A	2.60 - 2.71	6.5 - 7.0
heliodor (golden beryl)	1.560 - 1.602	0.005 - 0.009	DR	Uniaxial (-)	2.63 - 2.92	7.5 - 8.0
hematite	2.94 - 3.22 (OTL)	0.28	N/A	N/A	4.95 - 5.28	5.0 - 6.0
hessonite	1.730 - 1.758	None	SR	N/A	3.57 - 3.73	6.5 - 7.5
hiddenite	1.648 - 1.682	0.014 - 0.018	DR	Biaxial (+)	3.03 - 3.23	6.5 - 7.0
hydrogrossular	1.670 - 1.730	None	SR	N/A	3.13 - 3.55	6.5 - 7.0
iolite	1.527 - 1.578	0.008 - 0.018	DR	Biaxial (+/-)	2.54 - 2.66	7.0 - 7.5
jadeite jade	1.654 - 1.693	0.013 - 0.020	AGG	N/A	3.25 - 3.38	6.5 - 7.0
jasper	1.532 - 1.539	0.004	AGG	N/A	2.56 - 2.68	6.5 - 7.0
kunzite	1.648 - 1.683	0.014 - 0.019	DR	Biaxial (+)	3.03 - 3.24	6.5 - 7.0
labradorite	1.555 - 1.570	0.008 - 0.011	DR	Biaxial (+)	2.67 - 2.74	6.0 - 6.5
lapis lazuli	1.500 - 1.522	None	AGG	N/A	2.50 - 3.00	5.5 - 6.0
lazurite	1.500 - 1.522	None	SR	N/A	2.38 - 2.45	5.0 - 5.5
liddicoatite	1.621 - 1.627	0.016	DR	Uniaxial (-)	3.02 - 3.05	7.5
lizardite	1.538 - 1.568	0.005 - 0.012	DR	Uniaxial (-) to slightly Biaxial (-)	2.55 - 2.60	2.5
malachite	1.655 - 1.909 (OTL)	2.54	DR	Biaxial (-)	3.25 - 4.10	3.5 - 4.0
Malaia garnet	1.742 - 1.780	None	SR	N/A	3.78 - 3.85	7.0 - 7.5
melanite	1.860 - 1.894 (OTL)	None	SR	N/A	3.72 - 4.10	6.5 - 7.5
microcline	1.520 - 1.532	0.008	AGG	N/A	2.55 - 2.58	6.0 - 6.5
moissanite (synthetic)	2.650 - 2.690 (OTL)	0.043	DR	Uniaxial (+)	3.21 - 3.22	9.25
moldavite	1.480 - 1.540	None	SR	N/A	2.30 - 2.40	5.5
moonstone (orthoclase)	1.518 - 1.534	0.006 - 0.008	DR	Biaxial (-)	2.56 - 2.60	6.0 - 6.5
morganite	1.560 - 1.602	0.005 - 0.009	DR	Uniaxial (-)	2.63 - 2.92	7.5 - 8.0
nephrite jade	1.600 - 1.640	0.027	AGG	N/A	2.90 - 3.08	6.0 - 6.5
obsidian	1.450 - 1.550	None	SR	N/A	2.33 - 2.52	5.0 - 5.5
oligoclase	1.539 - 1.550	0.155	DR	Biaxial (-)	2.62 - 2.66	6.0 - 6.5
opal	1.370 - 1.470	None	SR	N/A	1.25 - 2.30	5.5 - 6.5
orthoclase	1.518 - 1.534	0.006 - 0.008	DR	Biaxial (-)	2.56 - 2.60	6.0 - 6.5
Paraíba tourmaline (elbaite)	1.615 - 1.665	0.018 - 0.020	DR	Uniaxial (-)	2.90 - 3.10	7.0 - 7.5
pearl	1.530 - 1.685	0.155	AGG	N/A	2.72 - 2.78	2.5 - 4.0

Gemstone Properties

NAME	Refractive Index (R.I.)	Birefringence	SR/DR/AGG	Optic Character	Specific Gravity (S.G.)	Hardness
peridot	1.634 - 1.772	0.033 - 0.042	DR	Biaxial (+)	3.27 - 3.33	6.5 - 7.0
pietersite	1.540 - 1.553	0.009	AGG	N/A	2.60 - 2.71	6.5 - 7.0
pyrope	1.714 - 1.756	None	SR	N/A	3.58 - 3.87	7.0 - 7.5
quartz	1.544 - 1.553	0.009	DR	Uniaxial (+)	2.64 - 2.69	7.0
rainbow moonstone (labradorite)	1.555 - 1.570	0.008 - 0.011	DR	Biaxial (+)	2.67 - 2.74	6.0 - 6.5
red beryl (bixbite)	1.560 - 1.602	0.005 - 0.009	DR	Uniaxial (-)	2.63 - 2.92	7.5 - 8.0
rhodochrosite	1.594 - 1.817 (OTL)	0.22	DR	Uniaxial (-)	3.40 - 3.70	3.0 - 4.0
rhodolite	1.750 - 1.780	None	SR	N/A	3.74 - 3.84	7.0 - 7.5
rhodonite	1.711 - 1.757	0.010 - 0.014	DR	Biaxial (+)	3.30 - 3.76	5.5 - 6.5
ruby	1.758 - 1.778	0.008	DR	Uniaxial (-)	3.98 - 4.05	9.0
sapphire	1.758 - 1.778	0.008	DR	Uniaxial (-)	3.98 - 4.05	9.0
scapolite	1.536 - 1.579	0.004 - 0.037	DR	Uniaxial (-)	2.56 - 2.77	5.0 - 6.0
schorl	1.635 - 1.672	0.027 - 0.032	N/A	Uniaxial (-)	3.18 - 3.22	7.0
serpentine	1.555 - 1.574	0.005 - 0.006	DR	Biaxial (-)	2.50 - 2.60	2.5 - 4.0
shell	1.530 - 1.685	0.155	AGG	N/A	2.79 - 2.89	3.0 - 4.0
sodalite	1.479 - 1.487	None	SR	N/A	2.25 - 2.33	5.5 - 6.0
spessartite	1.790 - 1.840 (OTL)	None	SR	N/A	4.12 - 4.20	7.0 - 7.5
spinel	1.710 - 1.740	None	SR	N/A	3.52 - 3.70	8.0
spinel (black)	1.740 - 1.800	None	SR	N/A	3.58 - 4.10	8.0
sunstone (labradorite)	1.555 - 1.570	0.008 - 0.011	DR	Biaxial (+)	2.67 - 2.74	6.0 - 6.5
sunstone (orthoclase)	1.518 - 1.534	0.006 - 0.008	DR	Biaxial (-)	2.56 - 2.60	6.0 - 6.5
sunstone (oligoclase)	1.539 - 1.550	0.155	DR	Biaxial (-)	2.62 - 2.66	6.0 - 6.5
tanzanite	1.686 - 1.700	0.008 - 0.013	DR	Biaxial (+)	3.10 - 3.45	6.5
tiger's-eye	1.540 - 1.553	0.009	AGG	N/A	2.60 - 2.71	6.5 - 7.0
topaz	1.606 - 1.644	0.008 - 0.010	DR	Biaxial (+)	3.49 - 3.57	8.0
topazolite	1.860 - 1.894 (OTL)	None	SR	N/A	3.72 - 4.10	6.5 - 7.5
tortoise shell	1.540 - 1.560	None	SR	N/A	1.26 - 1.35	3.0
tourmaline (elbaite)	1.615 - 1.665	0.018 - 0.020	DR	Uniaxial (-)	2.90 - 3.10	7.0 - 7.5
tsavorite	1.730 - 1.760	None	SR	N/A	3.57 - 3.73	7.0 - 7.5
turquoise	1.610 - 1.650 (treated material may be lower)	0.400	DR	Biaxial (+)	2.38 - 2.88	5.0 - 6.0
uvarovite	1.798 - 1.865 (OTL)	None	SR	N/A	3.70 - 3.81	6.5 - 7.0
williamsite	1.555 - 1.574	0.005 - 0.006	DR	Biaxial (-)	2.50 - 2.60	2.5 - 4.0
Zandrite® (glass)	1.460 - 1.800	None	SR	N/A	2.25 - 4.55	4.5 - 6.5
zircon (high)	1.925 - 1.984 (OTL)	0.047 - 0.059	DR	Uniaxial (+)	4.60 - 4.73	7.5
zircon (low)	1.810 - 1.815 (OTL)	None - 0.047	SR	N/A	3.90 - 4.10	6.0 - 6.5
zoisite	1.685 - 1.725	0.006 - 0.018	DR	Biaxial (+)	3.10 - 3.45	6.5
Zultanite® (diaspore)	1.702 - 1.750	0.046 - 0.050	DR	Biaxial (+)	3.30 - 3.45	6.5 - 7.0

Stalactitic iridescent goethite,
11.0 x 7.8 x 3.8 cm

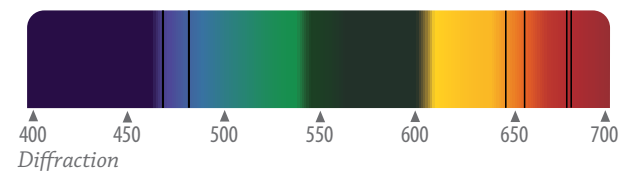
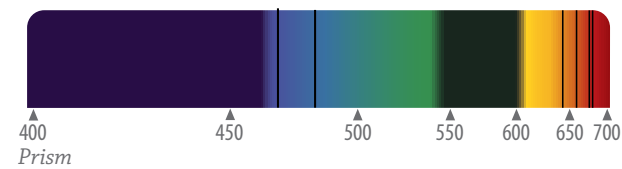


The absorption spectra of the colored gemstones featured in Volume 1 are compiled here for ease of use. The spectra of gemstones vary greatly and these illustrations are presented as a guide only. Gemstones excluded from this section may have absorption spectra; however, only spectra considered diagnostic are provided. No single test is independently capable of confirming the identity of a gemstone. A combination of tests using a variety of gemological tools should be used before making a conclusion. Determining synthetic origin and gemstone treatments requires training, expertise and, at times, the use of advanced analytical equipment. An experienced gemologist or gemological laboratory should be consulted in these cases. The information provided in this book is not intended for these purposes.

Gemstone Spectra organized by color

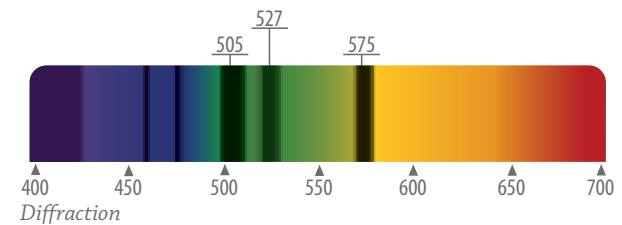
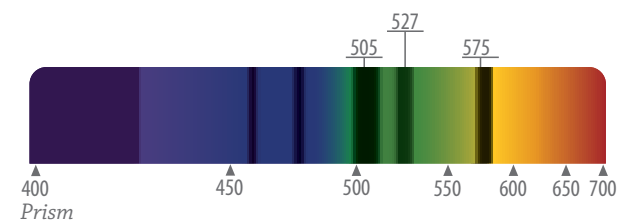
Red and Pink Gemstones

NATURAL ALEXANDRITE (viewed down purple/red direction)

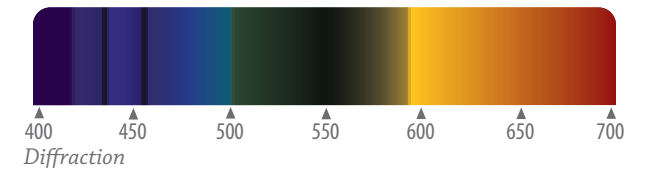
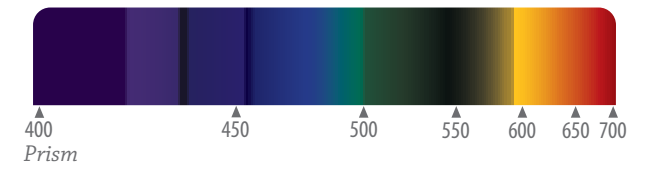


Variations of typical chromium
absorption bands in alexandrite spectra

ALMANDITE GARNET



RED BERYL (BIXBITE)



MALAKIA GARNET

