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OLIVIER SEGURA

DISCOVER GEMS

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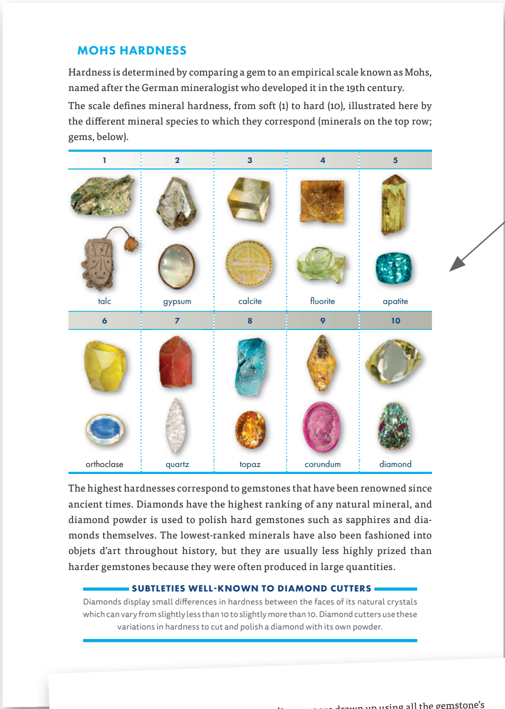


MOHS HARDNESS

Hardness is determined by comparing a gem to an empirical scale known as Mohs, named after the German mineralogist who developed it in the 19th century.

The scale defines mineral hardness, from soft (1) to hard (10), illustrated here by the different mineral species to which they correspond (minerals on the top row; gems, below).

1	2	3	4	5
talc	gypsum	calcite	fluorite	apatite

6	7	8	9	10
orthoclase	quartz	topaz	corundum	diamond

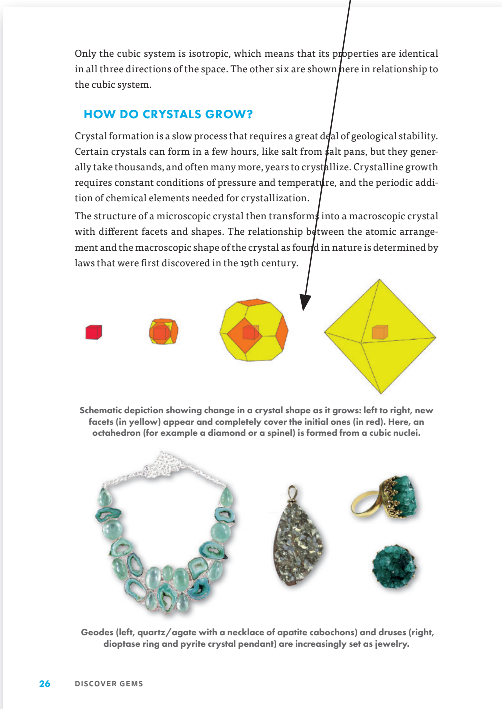
The highest hardnesses correspond to gemstones that have been renowned since ancient times. Diamonds have the highest ranking of any natural mineral, and diamond powder is used to polish hard gemstones such as sapphires and diamonds themselves. The lowest-ranked minerals have also been fashioned into objets d'art throughout history, but they are usually less highly prized than harder gemstones because they were often produced in large quantities.

SUBTLETIES WELL-KNOWN TO DIAMOND CUTTERS

Diamonds display small differences in hardness between the faces of its natural crystals which can vary from slightly less than 10 to slightly more than 10. Diamond cutters use these variations in hardness to cut and polish a diamond with its own powder.

Classification grids

More than 1,000 photos and illustrations



Only the cubic system is isotropic, which means that its properties are identical in all three directions of the space. The other six are shown here in relationship to the cubic system.

HOW DO CRYSTALS GROW?

Crystal formation is a slow process that requires a great deal of geological stability. Certain crystals can form in a few hours, like salt from salt pans, but they generally take thousands, and often many more, years to crystallize. Crystalline growth requires constant conditions of pressure and temperature, and the periodic addition of chemical elements needed for crystallization.

The structure of a microscopic crystal then transforms into a macroscopic crystal with different facets and shapes. The relationship between the atomic arrangement and the macroscopic shape of the crystal as found in nature is determined by laws that were first discovered in the 19th century.

Schematic depiction showing change in a crystal shape as it grows: left to right, new facets (in yellow) appear and completely cover the initial ones (in red). Here, an octahedron (for example a diamond or a spinel) is formed from a cubic nuclei.

Geodes (left, quartz/agate with a necklace of apatite cabochons) and druses (right, dioptase ring and pyrite crystal pendant) are increasingly set as jewelry.

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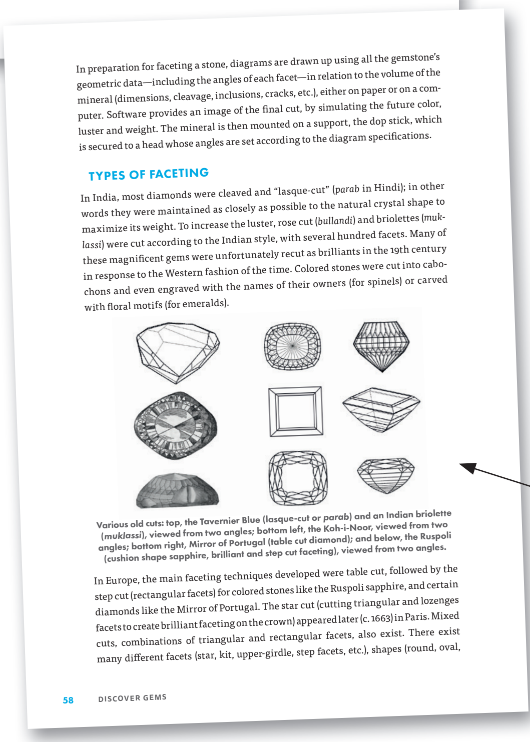

In preparation for faceting a stone, diagrams are drawn up using all the gemstone's geometric data—including the angles of each facet—in relation to the volume of the mineral (dimensions, cleavage, inclusions, cracks, etc.), either on paper or on a computer. Software provides an image of the final cut, by simulating the future color, luster and weight. The mineral is then mounted on a support, the dop stick, which is secured to a head whose angles are set according to the diagram specifications.

TYPES OF FACETING

In India, most diamonds were cleaved and "lasque-cut" (*parab* in Hindi); in other words they were maintained as closely as possible to the natural crystal shape to maximize its weight. To increase the luster, rose cut (*bullandi*) and briolettes (*muklassi*) were cut according to the Indian style, with several hundred facets. Many of these magnificent gems were unfortunately recut as brilliants in the 19th century in response to the Western fashion of the time. Colored stones were cut into cabochons and even engraved with the names of their owners (for spinels) or carved with floral motifs (for emeralds).

Various old cuts: top, the Tavernier Blue (lasque-cut or *parab*) and an Indian briolette (*muklassi*), viewed from two angles; bottom left, the Koh-i-Noor, viewed from two angles; bottom right, Mirror of Portugal (table cut diamond); and below, the Ruspoli (cushion shape sapphire, brilliant and step cut faceting), viewed from two angles.

In Europe, the main faceting techniques developed were table cut, followed by the step cut (rectangular facets) for colored stones like the Ruspoli sapphire, and certain diamonds like the Mirror of Portugal. The star cut (cutting triangular and lozenges facets to create brilliant faceting on the crown) appeared later (c. 1663) in Paris. Mixed cuts, combinations of triangular and rectangular facets, also exist. There exist many different facets (star, kit, upper-girdle, step facets, etc.), shapes (round, oval,

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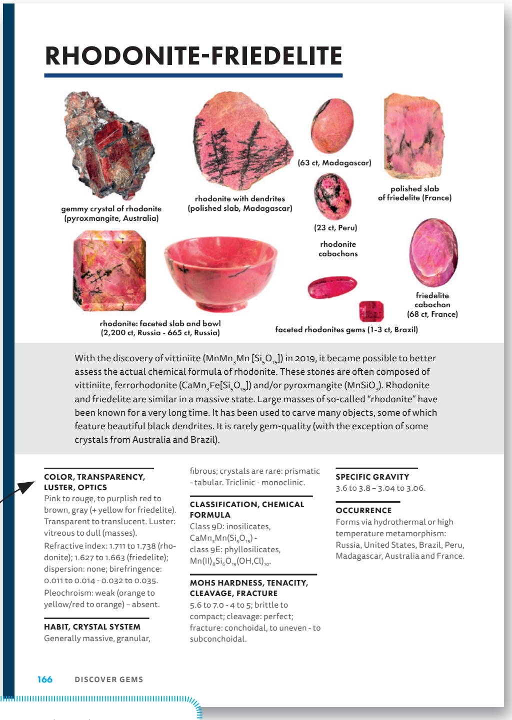
From stone to jewel: information about jewelry techniques

IDENTIFYING GEMS: 100 ENTRIES

Explanations providing further information



RHODONITE-FRIEDELITE

gemmy crystal of rhodonite (pyroxmangite, Australia)

rhodonite with dendrites (polished slab, Madagascar)

(63 ct, Madagascar)

(23 ct, Peru)

rhodonite cabochons

polished slab of friedelite (France)

rhodonite: faceted slab and bowl (2,200 ct, Russia - 665 ct, Russia)

faceted rhodonites gems (1-3 ct, Brazil)

friedelite cabochon (68 ct, France)

With the discovery of vittiniite ($MnMn_3Mn[Si_5O_{15}]$) in 2019, it became possible to better assess the actual chemical formula of rhodonite. These stones are often composed of vittiniite, ferrorhodonite ($CaMn_3Fe[Si_5O_{15}]$) and/or pyroxmangite ($MnSiO_3$). Rhodonite and friedelite are similar in a massive state. Large masses of so-called "rhodonite" have been known for a very long time. It has been used to carve many objects, some of which feature beautiful black dendrites. It is rarely gem-quality (with the exception of some crystals from Australia and Brazil).

COLOR, TRANSPARENCY, LUSTER, OPTICS
Pink to rouge, to purplish red to brown, gray (+ yellow for friedelite). Transparent to translucent. Luster: vitreous to dull (masses).
Refractive index: 1.711 to 1.738 (rhodonite); 1.627 to 1.663 (friedelite); dispersion: none; birefringence: 0.011 to 0.014 - 0.032 to 0.035.
Pleochroism: weak (orange to yellow/red to orange) – absent.

HABIT, CRYSTAL SYSTEM
Generally massive, granular, fibrous; crystals are rare: prismatic - tabular. Triclinic - monoclinic.

CLASSIFICATION, CHEMICAL FORMULA
Class 9D: inosilicates, $CaMn_3Mn(Si_5O_{15})$ - class 9E: phyllosilicates, $Mn(II)_8Si_6O_{15}(OH,Cl)_{10}$.

MOHS HARDNESS, TENACITY, CLEAVAGE, FRACTURE
5.6 to 7.0 - 4 to 5; brittle to compact; cleavage: perfect; fracture: conchoidal, to uneven - to subconchoidal.

SPECIFIC GRAVITY
3.6 to 3.8 – 3.04 to 3.06.

OCCURRENCE
Forms via hydrothermal or high temperature metamorphism: Russia, United States, Brazil, Peru, Madagascar, Australia and France.

HEMATITE

itabirite, tiger iron, red ocher

hematite crystals (Italy)

tumbled and faceted (76 and 82 ct, Brazil)

intaglio (21 ct, Italy)

tiger iron (59 ct, Australia)

cave painting with hematite pigment (Altamira, Spain)

banded jasper and itabirite (Australia)

sigillated ochre (France, 18th c.)

Hematite is the ferric analog of corundum (see rubies and sapphires, pp. 167, 169 and 170). Mineral collectors prefer the glossy black crystalline variety. Banded hematite is called itabirite. Tiger iron is an iridescent chalcedony with hematite, hence its classification by some as jasper, even when there is more hematite in its composition. Finally, the brownish-red color of the earthy form, red ocher, was one of the first pigments used in prehistoric times for cave paintings.

COLOR, TRANSPARENCY, LUSTER, OPTICS
Glossy black, metallic gray or vermilion red. Opaque. Luster: metallic (black) to earthy (red). Surface can be iridescent.
Refractive index: 2.690-3.220; dispersion: very strong; birefringence: 0.280.
Pleochroism: dichroic (red brown /reddish yellow but difficult to observe).

HABIT, CRYSTAL SYSTEM
Massive, granular, oolitic, earthy, stalactitic, mamillary, fibrous. Hexagonal, often tabular, dendritic or rosette crystals. Trigonal.

CLASSIFICATION, CHEMICAL FORMULA
Class 4: oxides (etc.), Fe_2O_3.

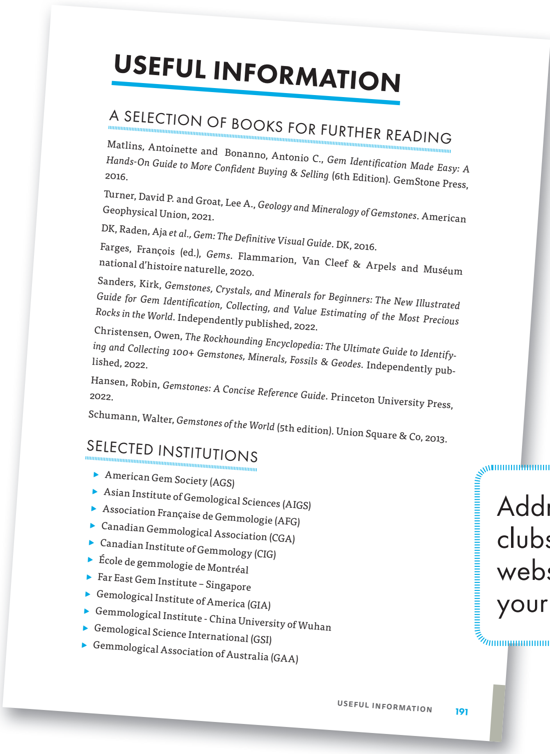
MOHS HARDNESS, TENACITY, CLEAVAGE, FRACTURE
5 to 6; brittle; cleavage: none; fracture uneven to conchoidal.

SPECIFIC GRAVITY
5.26.

OCCURRENCE
In hydrothermal metallic deposits (Germany, United Kingdom, Mexico, United States (Michigan) and in metamorphized sediments (Banded Iron Formations, BIF), as in Australia and Brazil (itabirite).

Key criteria for identification

USEFUL INFORMATION



USEFUL INFORMATION

A SELECTION OF BOOKS FOR FURTHER READING

Matlins, Antoinette and Bonanno, Antonio C., *Gem Identification Made Easy: A Hands-On Guide to More Confident Buying & Selling* (6th Edition). GemStone Press, 2016.

Turner, David P. and Groat, Lee A., *Geology and Mineralogy of Gemstones*. American Geophysical Union, 2021.

DK, Raden, Aja *et al.*, *Gem: The Definitive Visual Guide*. DK, 2016.

Farges, François (ed.), *Gems*. Flammarion, Van Cleef & Arpels and Muséum national d'histoire naturelle, 2020.

Sanders, Kirk, *Gemstones, Crystals, and Minerals for Beginners: The New Illustrated Guide for Gem Identification, Collecting, and Value Estimating of the Most Precious Rocks in the World*. Independently published, 2022.

Christensen, Owen, *The Rockhounding Encyclopedia: The Ultimate Guide to Identifying and Collecting 100+ Gemstones, Minerals, Fossils & Geodes*. Independently published, 2022.

Hansen, Robin, *Gemstones: A Concise Reference Guide*. Princeton University Press, 2022.

Schumann, Walter, *Gemstones of the World* (5th edition). Union Square & Co, 2013.

SELECTED INSTITUTIONS

- American Gem Society (AGS)
- Asian Institute of Gemological Sciences (AIGS)
- Association Française de Gemmologie (AFG)
- Canadian Gemmological Association (CGA)
- Canadian Institute of Gemmology (CIG)
- École de gemmologie de Montréal
- Far East Gem Institute – Singapore
- Gemological Institute of America (GIA)
- Gemmological Institute - China University of Wuhan
- Gemmological Science International (GSI)
- Gemmological Association of Australia (GAA)

Addresses of institutions, clubs, museums and websites to pursue your interest

FOREWORD

Gems: the word alone stirs up dreams of sparkling stones. They conjure fantasies of color and light, transmuting and elevating matter to the realm of wonder. The brilliance of gemstones also recalls the geological depth of time. Wearing a gem on your neck, your arm or your finger is a testimony to a vast, billion-year-old history—that of the Earth itself. It is a time capsule contained in a few centimeters of pure color. It carries a telluric memory, and sometimes that of the encounter of an asteroid with the Earth's crust, creating a small cosmos we wear as adornments. But time does more than merely create these marvelous stones. It has also altered how we view gemstones themselves. Our appreciation of them has evolved over the centuries, as have, at times, their names.

Two specialists, Professor François Farges and Olivier Segura, Scientific Director of L'ÉCOLE, School of Jewelry Arts, take us on a journey into this fascinating labyrinth. Definitions and nomenclature are merely the prelude, offering names for these enchanting stones. The authors offer us an in-depth look into the history of the Earth, from the nature of the different gems to their properties and formation. They present geology and gemology combined—or, science in support of a world of dreams.

This richly illustrated book is based on the collections of the French Muséum national d'histoire naturelle, along with those of other museums in France and abroad, stones in private collections, and the reference collection at L'ÉCOLE, School of Jewelry Arts. Gemology has been one of the three pillars of L'ÉCOLE since the beginning. The mission of L'ÉCOLE, School of Jewelry Arts, founded in 2012 with the support of Van Cleef & Arpels, is to share the culture of jewelry with the widest possible public, drawing on three principal themes: the history of jewelry, craftsmanship and the world of gems. This book supports this goal.

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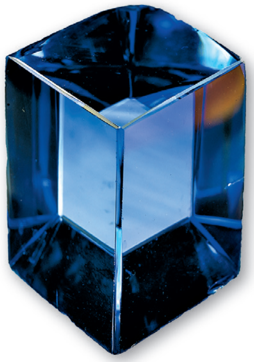
Nicolas Bos
President & CEO of Van Cleef & Arpels

Bruno David
President of the French Muséum national d'histoire naturelle

DISCOVER GEMS

WHAT IS A PRECIOUS STONE?

In everyday language, the term “precious stone” describes naturally occurring, often mineral substances used for ornamental purposes, usually jewelry. This definition is neither scientific nor legal, yet it prevails in most dictionaries. In our imaginations, precious stones sparkle, glimmer and feature incredible colors; they are also rare, an exceptional characteristic that further fuels their desirability. We associate them with pirate loot and mysterious treasures hidden in the buried chests of lost caves, or on the other end of the spectrum, with magnificent jewels displayed proudly by famous men and women, from royals to actresses.



The “Grand Sapphire” of King Louis XIV of France, part of the French Crown Jewels: crystal or faceted gem? The question was hotly debated throughout the 18th century. A scientific study of its angles concluded that the polish was man-made, as this polyhedron defies all the laws of crystallography.

A SHIFTING DEFINITION

There has been no legal definition for the term “precious stone” in many countries since the early 21st century. From the 1950s to c. 2000, this name was used to designate what were considered to be the rarest of minerals: diamonds, rubies, sapphires and emeralds. However, this classification was broader in the 19th century; dictionaries at the time defined precious stones as “any mineral that could be used in an art form, particularly for jewelry.”

These minerals are highly prized: they are fascinating for their optical properties and unusual colors that are rarely—perhaps never—encountered in the living world: luster, diaphaneity, chatoyancy, iridescence, asterism. Some of these materials retain their natural form in the objets d'art that incorporate them; these are the crystals, pearls, masses, sections, pebbles, nodules and various crystalline aggregates that we so admire. Petrified fossils can even be found as "precious materials"; these include fossilized dinosaur bones in agate, and shells fossilized into opal and even emerald. Finally, meteorites are considered to be "precious stones" in the broadest sense of the term. Those that are iron-rich display spectacular geometric figures after they have been polished and acid-treated; others contain crystals of olivine (peridot variety)—sometimes older than the Earth itself—that can be faceted.

The diverse materials that form gemstones: top, mineral (transparent rock crystal on marble matrix, Italy), rock (iridescence in a labradorite, Finland); bottom, biomineral (mabe pearl in an oyster shell, French Polynesia), fossil (opalized gastropod, Australia) and meteorite (pallasite peridot, Canada).

If a mineral is not kept "rough," i.e., in a natural state, it may be simply cut and polished to reveal its magnificent internal structure and provide information on its geological history. This is true for agates and malachite, which are often sliced and polished. Despite these operations, these minerals remain naturalistic specimens, as they are not worked on or treated further: their integrity and geological significance are, for the most part, retained.

The majority of "precious stones" are hard minerals that have a good physicochemical stability. There are exceptions, however, due to the complexity of the natural world as well as to cultural traditions: amber, for example, is considered to be a mineral in certain mineralogical classifications, while scientists consider it to be a fossilized plant resin. For others, it is not a fossil, because the original molecules are somewhat preserved, but is rather an aggregate of polymerized macromolecules, therefore some kind of organic material.

The diverse uses of gemstones: left to right and top to bottom, agalmatolite statue of the Buddhist goddess Guānyīn (观音, China, 18th century); lapis lazuli seal carved with Islamic inscriptions (India, 18th century); Egyptian emerald on a gold earring (France, 2nd-3rd centuries); micro-mosaic (portrait of a Vestal virgin, Italy, 19th century) with a detail of her eye illustrating the minuscule tesserae of limestone and jasper, and a gem collection of diamonds cut into diverse shapes.

GEMS

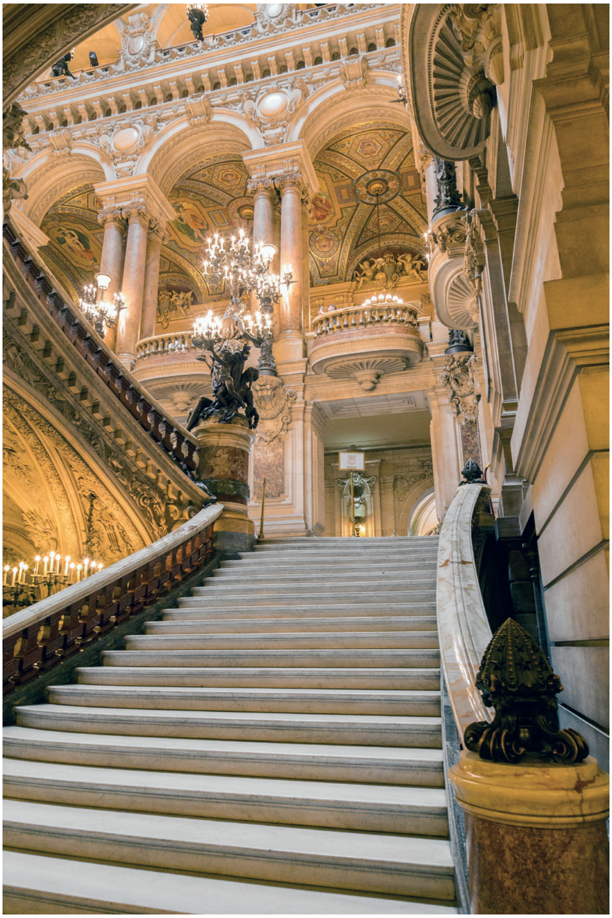
Gems, like gemstone, is a word that, according to dictionaries like Oxford Languages, refers to “precious or semi-precious stones, especially when cut and polished or engraved.”

However, like all definitions, exceptions are not uncommon: some gems, for instance, can be organic (like amber) or a biomineral (like pearls or mother-of-pearl). Not all gems will necessarily be set in a jewel: cameos, intaglios can be kept isolated, i.e., unset. Furthermore, the distinction between precious and semi-precious stones is no longer accepted by many experts recognized worldwide. “Gem” is therefore a more general and, at the same time, correct wording.

For gemologists, gemstones include all natural materials that are “beautiful,” “rare” and “durable.” Even if exceptions occur, as is usual with definitions.

Gems are often set into pieces of jewelry or used to objets d’art such as vases, tables, dressers, portraits, mirrors, boxes and other ornamental cases. Other craft objects are considered to be instruments of power and hold a powerful symbolic charge: crowns, scepters, command batons, as well as reliquaries, ciboria and other devotional objects.

Example of a gemstone created from a "gem-quality salt crystal": the obelisk (right) was carved from a gem-quality, rock salt crystal mined in Poland in the 19th century that is similar to the mineral on the left.



The staircase in the Opéra Garnier in Paris was built with more than 60 minerals and rocks, which were mostly sourced in France and used in different ways.

A mounted gem-set may also refer to a gemstone, usually ornamental, that has been carved, often in the shape of a chalice or a shell, and then set in a metal frame, on a gold or vermeil base, for example.

Gemstones also adorn palaces and prestigious buildings. The staircase in the Paris opera house, designed by Charles Garnier, consists of 60 different varieties that were fashioned into balusters (fluorite), steps (various marbles), sculptures (serpentine) and other architectural ornaments (jasper, etc.).

THE DIVERSITY OF NOMENCLATURES

The nomenclature of gemstones has varied over time, while mineralogical subtleties that once went unnoticed have been identified by researchers. A mineral known by a certain name at a given time may therefore later be renamed or reclassified in another way. This phenomenon has increased considerably since the 2000s, with the appearance of many new varieties of minerals and rocks not recognized by specialists, but sold as gems with new, but unofficial names. These include “unakite” (a granite containing epidote), “mookaite” (an Australian jasper), “ancestralite” (hematite) or “merlinite” (gabbro or dendritic agate, depending on the seller) just to cite a few. Hundreds of others have appeared recently, paralleling the rise in movements promoting practices that have not been validated scientifically, like lithotherapy.

Historic gems with older and confusing nomenclatures: left, a “water sapphire” (blue cordierite, Brazil); above, a “Brazilian ruby” (pink topaz, Brazil); right, an “oriental amethyst” (violet corundum, Sri Lanka) and below, an “oriental topaz” (orange-yellow corundum, Sri Lanka).

There was a great deal of confusion until the 18th century, when nearly every red to pink gemstone was called a ruby; a qualifier was sometimes added to this name, as for example the "balas ruby" (actually a spinel) or the "Brazilian ruby" (a pink topaz). For green gemstones, a variety of supposed emeralds were created, such as "oriental emerald" or "prime d'émeraude" (as in old French texts) that are not emerald. As for blue gems, they were inevitably associated with sapphire: indigolite, for example, a blue variety of elbaite, a mineral in the tourmaline family, was called "Brazilian sapphire." Other examples that led to confusion include "oriental amethyst" (corundum), "water sapphire" (cordierite) and "new rock turquoise" or "bone turquoise" (heated fossilized ivory, also known as odontolite).

The CIBJO (Confédération Internationale de Bijouterie, Joaillerie, Orfèvrerie des Diamants, Perles et Pierres, or World Jewellery Confederation in English) bans the use of many terms that have no scientific basis, either new or old, such as "celestial opal" and "Bohemian topaz," with the aim of standardizing the names. In theory, museums must apply the nomenclature rules established by the International Mineralogical Association (IMA) or CIBJO despite cultural and local vernacular that often add some additional complexity. With changes in names due to more advanced knowledge, various definitions have become more specific, but confusion persists in the gem trade, which does not facilitate the work of gemologists, historians and journalists, and which sometimes mystify gem enthusiasts.

THE NATURE OF GEMS

Precious stones are most often geological in origin and are minerals, for the most part, and sometimes rocks. But there are also organo-mineral gemstones, including pearls, and organic ones like amber, and even extraterrestrial gems, such as peridots from meteorites. Let's take a look at these various categories of gemstones.

MINERALS: GROUP, SPECIES AND VARIETY

Minerals are homogenous natural solids of geological origin, characterized by a specific combination of atoms forming a singular structure. In quartz, for example, which consists of silicon dioxide SiO_2, the silicon (Si) and oxygen (O) atoms alternate according to a pattern that repeats in three dimensions. The composition and structure of the different mineral species are defined according to chemistry and crystallography standards.

A single mineral species may include varieties that differ in small ways; rubellite and indigolite are therefore different colored variations of the same mineral, elbaite. Furthermore, species belong to different groups (or families) according to the classifications. Elbaite and a dozen or so other species, like schorl and liddicoatite, form the tourmaline group. Thus, the word "tourmaline" has not designated a species since the 19th century, but rather refers to a group of minerals that are known as the "tourmaline group."

Most minerals are crystallized: they show crystals. In other words, the atoms that form them are arranged in a regular way in a three-dimensional space as specified above. The atomic structure has a "long-range order" larger than a nanometric scale, and up to several meters in exceptional cases. If, during geological growth, these crystals have space to grow, they will form polyhedrons ranging from minuscule/sub-millimetric to meters in size, isolated or in aggregates displaying complex geometric forms.

Among the thousands of mineral species that contribute to geodiversity, more than one hundred (not including their varieties) are nowadays polished, faceted, carved, etc.

Further confusing this issue is the fact that the nomenclatures used differs depending on the specialties. For chemists, the various oxides of silicon (quartz, chalcedony, jasper, opal) are included under the name "silica," a family name that does not exist in mineralogy, strictly speaking, but is still often used for the sake of convenience. Gemologists sometimes use nomenclatures that are not officially recognized by some mineralogists, notably the names of varieties (like ruby and aquamarine), which are rarely accepted in mineralogy literature. Obsolete, confusing or purely poetical names have been used by historians and writers for centuries, like "chrysolite" (peridot), "agalmatolite" (a rock composed of pyrophyllite and related minerals) or even "jade" (that can be either tremolite, jadeite or some other peculiar rocks containing jadeite, etc.).

ROCKS

A rock is an aggregate of minerals that are submillimetric or centimetric in size. There are different types of rocks (the term "species" is never used). Marble, for example, is mostly composed of compacted microcrystals of a mineral: calcite. Marble and calcite share the same chemical formula (calcium carbonate, $CaCO_3$), but have different properties—marble is easier to sculpt into specific shapes than calcite. The latter has perfect cleavages and therefore shears easily, a characteristic that makes it a difficult material for sculptors to work with.

Tremolite, from mineral to rock: single crystal (left); easily detachable and flexible fibrous crystals of white asbestos (top); and compact (tenacious) pebble of microcrystalline tremolite, known as tremolitite or nephrite (bottom).

As with minerals, the nomenclature for rocks is complex and sometimes less well known to gem specialists. Imperial jade is often called "jadeite," but pure jadeite, a monocrystalline mineral species, is rarer and more fragile: its millimetric crystals exist mostly in California. Instead of jade or jadeite, rock specialists are usually referring to jadeitite, which is a compact rock consisting of microcrystals of jadeite as well as other minor species. Another example: diamonds and carbonado. The latter is a rock composed essentially of highly compacted microscopic crystals of diamonds, hence its use for polishing gemstones, including monocrystalline diamonds.