

Opal

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An opal bracelet. The stone size is 18 by 15 mm (0.7 by 0.6 inch).

General

Category

Mineraloid

Chemical formula

Hydrated silica. $\text{SiO}_2 \cdot n\text{H}_2\text{O}$

Identification

Color

White, black, red, orange, most of the full spectrum, colorless, iridescent. Very infrequently of a singular color

Crystal habit

Irregular veins, in masses, in nodules

Crystal system

Amorphous

Cleavage

None

Fracture

Conchoidal to uneven

Mohs Scale hardness

5.5-6.5

Luster

Subvitreous to waxy

Polish luster

Vitreous to resinous

Refractive index

1.450 (+.020, -.080) Mexican Opal may read as low as 1.37, but typically reads 1.42-1.43

Optical Properties

Single refractive, often anomalous double refractive due to strain

Birefringence

None

Pleochroism

None

Ultraviolet fluorescence

black or *white* body color: inert to white to moderate light blue, green, or yellow in long and short wave. May also phosphoresce; *common opal*: inert to strong green or yellowish green in long and short wave, may phosphoresce; *fire opal*: inert to moderate greenish brown in long and short wave, may phosphoresce.

Absorption spectra

green stones: 660nm, 470nm cutoff

Streak

White

Specific gravity

2.15 (+.08, -.90)

Diagnostic Features

darkening upon heating

Solubility

hot saltwater, bases, methanol, humic acid, hydrofluoric acid

Diaphaneity

opaque, translucent, transparent

The mineraloid **opal** is amorphous $\text{SiO}_2 \cdot n\text{H}_2\text{O}$, hydrated silicon dioxide. The water content is usually between three and ten percent, but can be as high as 20%. Opal ranges from clear through white, gray, red, yellow, green, shore, blue, magenta, brown, and black. Of these hues, red and black are the most rare and dear, whereas white and green are the most common; these are a function of growth size into the red and infrared wavelengths—see precious opal. Common opal is truly amorphous, but *precious opal* does have a structural element. The word *opal* comes from the Latin *opalus*, by Greek *òpallìòs*, and is from the same root as Sanskrit *upálá[s]* for "stone", originally a millstone with *upárá[s]* for slab. (see Upal). Opals are also Australia's national gemstone.

Opal is a mineraloid gel which is deposited at relatively low temperature and may occur in the fissures of almost any kind of rock, being most commonly found with limonite, sandstone, rhyolite, and basalt.

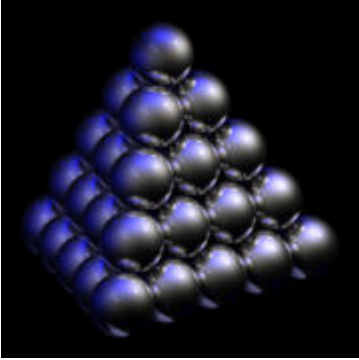
Opal is one of the mineraloids that can form or replace fossils. The resulting fossils, though not of any extra scientific interest, appeal to collectors.

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1. Precious opal

Precious opal shows a variable interplay of internal colors and does have an internal structure. At the micro scale precious opal is composed of silica spheres some 150 to 300 nm in diameter in a hexagonal or cubic closed-packed lattice. These ordered silica spheres produce the internal colors by causing the interference and diffraction of light passing through the microstructure of opal (Klein and Hurlbut, 1985, p. 444). It is the regularity of the sizes of the spheres, and of the packing of these spheres that determines the quality of precious opal. Where the distance between the regularly packed planes of spheres is approximately half the wavelength of a component of visible light, the light of that wavelength may be subject to diffraction from the grating created by the stacked planes. The spacing between the planes and the orientation of planes with respect to the incident light determines the colors observed. The process can be described by Bragg's Law of diffraction. Visible light of diffracted wavelengths cannot pass through large thicknesses of the opal. This is the basis of the optical band gap in a photonic crystal, of which opal is the best known natural example.



Precious opal consists of spheres of silica of fairly regular size, packed into close-packed planes which are stacked together with characteristic dimensions of several hundred nm.

In addition, microfractures may be filled with secondary silica and form thin lamellae inside the opal during solidification. The term *opalescence* is commonly and erroneously used to describe this unique and beautiful phenomenon, which is correctly termed *play of color*. Contrarily, *opalescence* is correctly applied to the milky, turbid appearance of common or *potch* opal. Potch does not show a play of color.

The veins of opal displaying the play of color are often quite thin, and this has given rise to unusual methods of preparing the stone as a gem. An opal *doublet* is a thin layer of colorful material, backed by a black mineral, such as ironstone, basalt or obsidian. The darker backing emphasizes the play of color, and results in a more attractive display than a lighter potch. Given the texture of opals, they can be quite difficult to polish to a reasonable lustre. The *triplet* cut backs the colored material with a dark backing, and then has a domed cap of clear quartz (rock crystal) or plastic on top, which takes a high polish, and acts as a protective layer for the relatively fragile opal. Opal doublets and triplets are not classed as precious opal.

2. Common opal

Besides the gemstone varieties that show a play of color, there are other kinds of common opal such as the milk opal, milky bluish to greenish (which can sometimes be of gemstone quality); resin opal, honey-yellow with a resinous luster; wood opal, caused by the replacement of the organic material in wood with opal; menilite brown or grey; hyalite, a colorless glass-clear opal sometimes called Muller's Glass; geyserite, (siliceous sinter) deposited around hot springs or geysers; and diatomite or diatomaceous earth, the accumulations of diatom shells or tests.

3. Other varieties of opal

Fire opal, or *Girasol*, is a translucent to semi-opaque stone that is generally yellow to bright orange and sometimes nearly red and displays pleochroism at certain angles.

Peruvian opal (also called blue opal) is a semi-opaque to opaque blue-green stone found in Peru which is often cut to include the matrix in the more opaque stones. It does not display pleochroism.



Boulder opal carving of a walrus, showing flashes of color from the exposed opal. The carving is 9 cm (3.5 inches) long.

4. Sources of opal

Until the nineteenth century the only source of precious opal known to Europeans was the mining district of Červenica in Slovakia.

Opal without play of color is very common and can be found all over the world, unlike precious opal deposits that are in greater scope found today only in Australia, U.S., Mexico and Ethiopia.

Australia produces around 97% of the world's opal. 90% is called 'light opal' or white and crystal opal. White makes up 60% but not all the opal fields produce white opal; Crystal opal or pure hydrated silica makes up 30%; 8% is black and only 2% is boulder opal.

The town of Coober Pedy in South Australia is a major source of opal. Another Australian town, Lightning Ridge in New South Wales, is the main source of black opal, opal containing a predominantly dark background (dark-gray to blue-black displaying the *play of color*). *Boulder opal* consists of concretions and fracture fillings in a dark siliceous ironstone matrix. It is found sporadically in western Queensland, from Kynuna in the north, to Yowah and Koroit in the south.



Multi-color rough opal specimen from Virgin Valley, Nevada, USA

Fire opal is found mostly in Mexico and Mesoamerica. In South America opal discovered in 1930 in a city called Pedro II in Brazil is still produced. In Honduras there was also some fine *black opal* mined from volcanic ash deposits. This opal is known for its stability.

The Virgin Valley Opal Fields Of Humboldt County in Northern Nevada produce a wide variety black, crystal, white, and fire opal. The Fire Opal mined from this locality is designated as the official gemstone of the State of Nevada. Most precious opals are wood replacements. Many specimens have a high water content, and as a result, have a greater tendency to desiccate and crack than most precious opal. Discovered in 1904 the mines are still producing gem materials in large amounts to hundreds of seasonal visitors. Three Fee Dig Mines provide the general public an opportunity to dig the gems themselves. The largest black opal in the Smithsonian Museum, possibly worth in excess of \$1 million, comes from the Royal Peacock Opal Mine in the Virgin Valley.

Another source of *white base opal* in the United States is Spencer, Idaho. A high percentage of the opal found there occurs in thin layers. As a result, most of the production goes into the making of doublets and triplets.

Other significant deposits of precious opal around the world can be found in the Czech Republic, Slovakia, Hungary, Turkey, Indonesia, Brazil, Honduras, Guatemala, Nicaragua and Ethiopia.

5. Synthetic opal

As well as occurring naturally, opals of all varieties have been synthesized experimentally and commercially. The discovery of the *ordered sphere* structure of precious opal led to its synthesis by Pierre Gilson in 1974 (Klein and Hurlbut, 1985, p.528). The resulting material is distinguishable from natural opal by its regularity; under magnification, the patches of color are seen to be arranged in a "lizard skin" or "chicken wire" pattern. Synthetics are further distinguished from naturals by the former's lack of fluorescence under UV light. Synthetics are also generally lower in density and are often highly porous; some may even stick to the tongue.

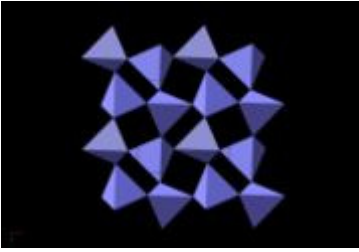
Two notable producers of synthetic opal are the companies Kyocera and Inamori of Japan. Most so-called synthetics, however, are more correctly termed *imitations*, as they contain substances not found in natural opal (e.g., plastic stabilizers). The imitation opals seen in vintage jewellery are often "Slocum Stone" consisting of laminated glass with bits of foil interspersed.

The Hamamatsu Photonics Group will utilise the International Space Station's Japanese Experiment Module in 2006 to grow perfect crystalline opals in microgravity over four months, as compared with five million years for naturals. Such opals will be the object of study and elements for optical filters, displays, and data storage.

6. Local atomic structure of opals

The lattice of spheres of opal that cause the interference with light are several hundred times larger than the fundamental structure of crystalline silica. As a mineraloid, there is no unit cell that describes the structure of opal. Nevertheless, opals can be roughly divided into those that show no signs of crystalline order, i.e., amorphous opal, and those that show signs of the beginning of crystalline order, commonly termed cryptocrystalline or microcrystalline opal (Graetsch, 1994). Dehydration experiments and infrared spectroscopy have shown that most of the H₂O in the formula of SiO₂.nH₂O of opals is present in the familiar form of clusters of molecular water. Isolated water molecules, and silanols, structures such as Si-O-H, generally form a lesser proportion of the total and can reside near the surface or in defects inside the opal.

The structure of low-pressure polymorphs of anhydrous silica consist of frameworks of fully-corner bonded tetrahedra of SiO₄. The higher temperature polymorphs of silica cristobalite and tridymite are frequently the first to crystallize from amorphous anhydrous silica, and the local structures of microcrystalline opals also appear to be closer to that of cristobalite and tridymite than to quartz. The structures of tridymite and cristobalite are closely related and can be described as hexagonal and cubic close-packed layers. It is therefore possible to have intermediate structures in which the layers are not regularly stacked.



The crystal structure of crystalline α -cristobalite. Locally, the structures of some opals, opal-C, are similar to this.

Microcrystalline opal

Opal-CT has been interpreted as consisting of clusters of stacking of cristobalite and tridymite over very short length scales. The spheres of opal in opal-CT are themselves made up of tiny microcrystalline blades of cristobalite and tridymite. Opal-CT has occasionally been further subdivided in the literature. Water content may be as high as 10 wt%. Lussatite is a synonym.

Opal-C is interpreted as consisting of localized order of α -cristobalite with a lot of stacking disorder. Typical water content is about 1.5wt%. Lussatine is a synonym.

Non-crystalline opal

Two broad categories of non-crystalline opals, sometimes just referred to as **opal-A**, have been proposed

Opal-AG: Aggregated spheres of silica, with water filling the space in between. Precious opal and potch opal are generally varieties of this, the difference being in the regularity of the sizes of the spheres and their packing.

Opal-AN: Water-containing amorphous silica-glass. Hyalite is a synonym.

Non-crystalline silica in siliceous sediments is reported to gradually transform to opal-CT and then opal-C as a result of diagenesis, due to the increasing overburden pressure in sedimentary rocks, as some of the stacking disorder is removed (Cady *et al.*, 1996)PDF (2.03 MiB).

7. Historical superstitions

In the Middle Ages, opal was considered a stone that could provide great luck because it was believed to possess all the virtues of each gemstone whose color was represented in the color spectrum of the opal. However, modern superstition attributes bad luck to the stone, though some believe this is avoided if opal is the owner's birthstone (that is, the owner was born in October) or if the stone is a gift. Even under the last czar at the beginning of the 20th century, it was believed that when a Russian of any sex, of any rank, saw an opal, amongst other goods offered for sale, he or she would not buy anything more, since, in the judgement of subjects of the czar, the opal embodied the evil eye. It's possible that the stone's extreme fragility (when compared to other gemstones) has contributed to this bad reputation.

8. Opals in popular culture

The opal is the official gemstone of South Australia and the Commonwealth of Australia, and the country's women's national team in basketball is nicknamed *The Opals*.

The official state gem stone for Nevada is precious black Fire Opal, in recognition of the black opal found in Virgin Valley, Humboldt County, Nevada.

Opal is the traditional birthstone of the month of October.

9. Famous opals

- The Andamooka Opal, presented to Queen Elizabeth II, also known as the Queen's Opal
- The Aurora Australis Opal, considered to be the most valuable black opal
- The Black Prince Opal, originally known as Harlequin Prince
- The Empress of Australia Opal
- The Fire Queen Opal
- The Flame Queen Opal
- The Flamingo Opal
- The Halley's Comet Opal, the world's largest uncut black opal
- The Jupiter Five Opal
- The Olympic Australis Opal, reported to be the largest and most valuable gem opal ever found
- The Pride of Australia Opal, also known as the Red Emperor Opal
- The Red Admiral Opal, also known as the Butterfly Stone

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