

January 2013 Mineral of the Month: Turquoise

TURQUOISE

This month's mineral is turquoise, the iconic gemstone of the American Southwest, from Arizona's famed Kingman Mine. Our write-up explains the mineralogy of turquoise, its rich history and lore, and why turquoise is the most widely enhanced of all gemstones.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: $\text{CuAl}_6(\text{PO}_4)_4(\text{OH})_8 \cdot 4\text{H}_2\text{O}$ Basic Hydrated Copper Aluminum Phosphate, usually with small amounts of iron and calcium.

Class: Phosphates

Subclass: Hydrated Phosphates

Group: Turquoise

Crystal System: Triclinic

Crystal Habits: Usually as fine-grained masses, nodules, crusts, and veinlets; also reniform, stalactitic, and disseminated; crystals are rare and are very small, transparent, and bright blue.

Color: Pale blue, bright blue, blue-green, greenish-blue, and green; also yellowish-green and bluish-white.

Luster: Waxy to dull

Transparency: Sub-translucent to opaque; transparent only in small crystals.

Streak: White to bluish-white or greenish-white

Refractive Index: 1.610-1.650

Cleavage: None

Fracture: Conchoidal to sub-conchoidal

Hardness: 5.0-6.0

Specific Gravity: 2.6-2.8

Luminescence: None

Distinctive Features and Tests: Best field marks are occurrence in oxidized zones of copper deposits; color; absence of visible crystals, and hardness. Can be confused with variscite [hydrated aluminum phosphate, $\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$]; and chrysocolla [basic hydrated copper aluminum acid silicate, $(\text{Cu},\text{Al})_2\text{H}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$]; the latter is softer.

Dana Classification Number: 42.9.3.1

NAME: The word "turquoise," pronounced TUR-coyz, stems from the French *turkeis*, meaning "Turkish," alluding to Persian turquoise brought to Europe via Turkey and was mistakenly thought to have been mined in Turkey. Alternative names for turquoise include "calaité," "chalchuite," "chalchihuitl," "johnite," "blue chalk," and "torques." In European mineralogical literature, turquoise appears as *turquesa*, *Türkis*, and *turchese*.

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COMPOSITION: Turquoise, one of more than 300 members of the phosphates, arsenates, and vanadates class of minerals, consists of 7.81 percent copper, 19.90 percent aluminum, 15.23 percent phosphorus, 55.08 percent oxygen, and 1.98 percent hydrogen. Turquoise is an idiochromatic mineral; its characteristic blue-green color caused by the essential element copper, a powerful chromophore for the colors blue and green. Pure turquoise has a clean, sky-blue color that is often described as “robin’s-egg” blue. But traces of calcium and iron that substitute for copper and aluminum in the crystal lattice alter this basic blue color to a wide range of blues and greens. As a secondary mineral, turquoise forms by hydrothermal deposition as thin veins, fracture coatings, and nodules in shallow oxidation zones of copper-rich deposits and in conditions of low temperature and low pressure. It is an uncommon mineral that is found mainly in warm, arid climates. Turquoise also occurs to a much lesser extent within basalt fissures and granite pegmatites.

COLLECTING LOCALITIES: The United States, currently the world’s largest source of turquoise, has notable localities in Arizona, New Mexico, Nevada, and Colorado. Turquoise also occurs in Australia, Chile, China, Democratic Republic of Congo, Russia, Iran, and Mexico.

HISTORY, LORE & GEMSTONE/TECHNOLOGICAL USES: Archaeologists have found turquoise bracelets and amulets in Egyptian cultural sites dating to 5000 B.C. Medieval physicians in Europe prescribed powdered turquoise to treat an array of illnesses from insanity and stomach disorders to internal bleeding and hip ailments. Native Americans in the Southwest have systematically mined turquoise since at least 800 A.D. for decorative, ceremonial, and religious purposes, trading it across much of North America. Archaeologists have recovered southwestern turquoise at cultural sites as distant as the southeastern United States, Canada, southern Mexico, and several Caribbean islands. One of the oldest known gem materials, turquoise is traditionally fashioned into cabochons that are worn as pendants, earrings, necklaces, bracelets, rings, belt buckles, and bolo-tie clasps. It is also fashioned into figurines and inlay creations. Turquoise enjoyed great popularity in Victorian-era jewelry. Native Americans of the Southwest profoundly influenced modern turquoise-jewelry styles by setting large pieces of turquoise in silver, epitomized by their “squash-blossom” necklaces, a style that remains popular today. Almost all turquoise currently used in jewelry has been artificially enhanced in some way. Turquoise is the birthstone for December, the official state gemstone of Arizona and New Mexico, and the official state semiprecious gemstone of Nevada. Modern metaphysical practitioners believe that turquoise is a powerful healing stone, a stone of communication that helps overcome the fear of public speaking, and enhances creativity, empathy, intuition, and happiness.

ABOUT OUR SPECIMENS: Our turquoise specimens were collected at the Kingman Mine at Turquoise Mountain in the Cerbat Mountains of the Mineral Park Mining District, an area 10 miles north of Kingman, Arizona. This classic turquoise locality was first mined by Native Americans about 800 A.D. Anglo prospectors reopened this site during the turquoise boom that began in the 1880s. After the initial phase of Anglo mining ceased about 1910, the Kingman Mine remained inactive until miners returned in 1962. The Kingman Mine then gained fame for its large output of distinctive, bright-blue turquoise nuggets laced with streaks of black matrix. The mine closed again the 1970s, then reopened in 2004. It has since produced steadily and is now the leading turquoise source in the United States, yielding about 1,600 pounds of rough

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turquoise per month. The Kingman Mine supplies gem-quality turquoise, virtually all of which is enhanced before cutting and polishing. It also provides turquoise specimens to collector markets and is the source of our specimens, which are completely natural and have not been enhanced or treated in any way.

COMPREHENSIVE WRITE-UP

COMPOSITION

Turquoise's chemical formula $\text{CuAl}_6(\text{PO}_4)_4(\text{OH})_8 \cdot 4\text{H}_2\text{O}$ identifies its elemental components as copper (Cu), aluminum (Al), phosphorus (P), oxygen (O), and hydrogen (H). The molecular weight of turquoise consists of 7.81 percent copper, 19.90 percent aluminum, 15.23 percent phosphorus, 55.08 percent oxygen, and 1.98 percent hydrogen.

The chemical formula of turquoise can appear daunting, but is easy to understand by remembering that all molecules consist of positively charged ions called *cations* and negatively charged ions called *anions*. Turquoise's compound cation, which consists of one copper ion (Cu^{2+}) and six aluminum ions (6Al^{3+}), has a collective electrical charge of +20. Its compound anion consists of two radicals, which are groups of different atoms that act as entities in chemical reactions. Within the turquoise anion are four phosphate radicals $4(\text{PO}_4)^{3-}$ and eight hydroxyl radicals $8(\text{OH})^{1-}$. Together, these anionic radicals have a collective charge of -20. This balances the +20 cationic charge to impart electrical stability to the turquoise molecule.

As a phosphate, turquoise is one of more than 300 members of the phosphates, arsenates, and vanadates class of minerals. The basic building blocks of these minerals are the phosphate radical $(\text{PO}_4)^{3-}$, arsenate radical $(\text{AsO}_4)^{3-}$, and vanadate radical $(\text{VO}_4)^{3-}$. All form tetrahedral structures with four oxygen ions surrounding the ion of a metal or semi-metal (vanadium is a metal; arsenic and phosphorus are semi-metals). In the phosphate radical, the phosphorus ion (P^{5+}) is surrounded by, and bonded covalently to, four oxygen ions (4O^{2-}). Because the resulting collective -3 charge is distributed evenly over the four oxygen ions, the phosphate radical can bond ionically to different metal cations.

In turquoise, four phosphate radicals bond ionically to one copper and six aluminum ions to form the intermediate, octahedral-shaped, copper aluminum phosphate radical $[(\text{CuAl}_6(\text{PO}_4)_4)]^{8+}$. These radicals, which are unstable because of their +8 charge, bond together into chains of octahedra that establish turquoise's triclinic crystal structure. In spaces between these linked octahedra, hydroxyl ions $[(\text{OH})^{1-}]$ bond ionically to alternating metal ions to complete the molecule and provide electrical balance. Triclinic crystals have three axes of different lengths, none of which are perpendicular to the others. This arrangement results in low symmetry and often makes triclinic crystal structures difficult to define. In turquoise, this low triclinic symmetry actually inhibits crystal development—the reason that turquoise crystals are very small and rare. Almost all turquoise consists of tightly bonded microcrystals in massive or compact forms. Because these microcrystals have a random arrangement, turquoise exhibits no cleavage. Turquoise's close atomic packing strengthens its atomic bonding to result in a substantial hardness of Mohs 5.0-6.0. Despite its close atomic packing, turquoise has a low

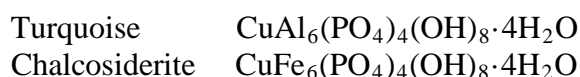
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density (specific gravity 2.6-2.8) that is due to the light atomic weights of its elemental components. The only heavy element present in turquoise is copper (atomic weight 63.55), which comprises only 7.81 percent of the total molecular weight.

Minerals are generally classified as allochromatic or idiochromatic according to the origin of their colors. The colors of allochromatic or “other-colored” minerals are due to the trace presence of accessory elements called chromophores (color-causing agents). The colors of idiochromatic (self-colored) minerals are caused by essential elements or the light-absorbing properties of the crystal lattice. Turquoise is idiochromatic because its blue-green color is due to the essential element copper, which is a powerful chromophore for the colors blue and green. Pure turquoise has a clean, sky-blue color often described as “robin’s-egg” blue. But traces of calcium and iron, substituting for copper and aluminum within the crystal lattice, alter this basic blue color. Calcium decreases the amount of copper present, thus lessening the chromophoric effect and shifting the color to pale blue or bluish-white that is known as “chalk.” The substitution of divalent iron for copper and trivalent iron for aluminum imparts shades of yellow, green, and brown. These traces of iron and calcium explain why turquoise colors have such a broad range from blue, greenish-blue, and bluish-white through bluish-green, green, and yellowish-green.

As a secondary mineral, turquoise forms in shallow oxidation zones of copper-rich deposits. In turquoise formation, copper is derived from the oxidation of copper-sulfide minerals, aluminum from alteration of aluminum-bearing surface rocks, and phosphate radicals from groundwater-dissolved apatite-CaF [calcium fluorophosphate, $\text{Ca}_5(\text{PO}_4)_3\text{F}$]. Turquoise forms only in conditions of low temperatures and pressures, and mainly in warm, arid climates. Hydrothermal turquoise deposition forms thin veins, fracture coatings, and nodules in association with quartz [silicon dioxide, SiO_2], limonite (a mixture of hydrous iron oxides), and kaolinite [basic aluminum silicate, $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$], all of which may be emplaced within the turquoise itself as “matrix.” Turquoise also forms to a much lesser extent within basalt fissures and granite pegmatites.

The Dana mineral-classification number 42.9.3.1 first identifies turquoise as a hydrated phosphate containing hydroxyl or halogen ions (42). The subclassification (9) defines it by the general formula $\text{ABC}(\text{PO}_4)_n\text{Zq}\cdot\text{xH}_2\text{O}$, in which “A,” “B,” and “C” can be any combination of copper, calcium, zinc, iron, or aluminum; “Z” is a hydroxyl or halogen ion; and “n,” “q,” and “x” are variables. Turquoise is assigned to the turquoise group (3) as the first (1) of six chemically and structurally related members. Turquoise is by far the most abundant member of this group. One of the turquoise-group members, chalcosiderite, forms a complete solid-solution series with turquoise by cationic substitution:



These formulas show the complete substitution of trivalent iron Fe^{3+} for trivalent aluminum Al^{3+} and vice versa. This substitution creates a continuous range of intermediate members, all with graded, predictable color variations from the “sky-blue” of pure turquoise to the yellowish-green of chalcosiderite.

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COLLECTING LOCALITIES

Although turquoise is uncommon, its occurrences are widespread. Few, however, provide gem-quality material. Most turquoise comes from the American Southwest. Arizona localities include the Kingman Mine and the Ithaca Peak and Tiffany properties in the Cerbat district of Mohave County; the Gleeson, Turquoise Mountain, and Courtland mines in the Dragoon Mountains, and the Lavender Pit at Bisbee in the Warren District, both in Cochise County; various mines in the Miami-Inspiration area and the Sleeping Beauty Mine at Miami, both in the Globe-Miami district in Gila County; the Morenci Mine at Morenci in the Copper Mountain district and the Safford district mines at Safford, both in Graham County; and the New Cornelia Mine at Ajo in the Ajo district, and the Silver Bell Mine in the Silver Bell district, both in Pima County. Colorado sources include the King Turquoise Mine in Conejos County; the Turquoise Chief Mine near Leadville in Lake County; the Elkhorn, Florence, and Roanoke claims at Cripple Creek in Teller County; and the Villa Grove Turquoise Mine at Villa Grove in Saguache County. Nevada sources include the Crescent Peak, Morgan, and Aztec claims in the Crescent district of Clark County; the Persian Blue mine in the Candelaria district and the Royal Blue Mine in the Royston district, both in Esmeralda County; the Copper King and Main Mike mines in the Maggie Creek district of Eureka County; the Blue Gem and Turquoise King mines in the Battle Mountain district, the Little Chief, Blue Gem, and Blue Nugget mines in the Bullion district, and the Cortez Mine in the Cortez district, all in Lander County; the Turquoise Bonanza, Pilot, Blue Gem Wonder, and Montezuma mines in the Pilot district of Mineral County; and the Royal Blue and Bunker Hill claims in the Tonopah district, and the Copper Blue and Monarch Star mines in the Belmont district, both in Nye County. Sources in New Mexico include the Burro Chief, Tyrone, and Azure mines in the Tyrone district, the American Turquoise and Aztec mines in the Eureka district, and the Chino Mine in the Hanover-Fierro district, all in Grant County; and the Castilian and Tiffany mines in the Cerrillos district in Santa Fe County.

Australian specimens come from the Greta South turquoise field at Greta Field, Victoria; the Greenbushes tin placer at Greenbushes, Western Australia; and the Iron Monarch Open Cut at Iron Knob on the Eyre Peninsula, South Australia. In Chile, turquoise is collected at the Escondida Norte mine in Al Loa Province and the Santa Catalina Mine in Antofagasta Province, both in the Antofagasta Region. Other sources are the Wuhu turquoise deposit in Ma'an Shan Prefecture, Anhui Province, China; Wadi Maghara, Sinai Peninsula, Egypt; Katonto Hill in the Kolwezi district, Katanga Copper Crescent, Katanga, Democratic Republic of Congo; and the Temir Mountain quarry at Zauarolovo, Chelyobinsk Oblast', Southern Urals, Urals Region, Russia. Iranian sources include the Bavanat turquoise deposit at Shiraz, Fars Province; the Damghan turquoise mine at Damghan, Semnan Province; the Ali-abd copper deposit in Yazd Province; the Agh-Darrah Mine at Takab in West Azarbaijan Province; and the Nishâpûr copper deposit in Razavi Khorasan Province. Mexican specimens come from the Reina Turquesa and Preciosa mines near Ensenada in Baja California Norte and the Socovón de la Turquesa Mine at Concepción del Oro, Zacatecas.

JEWELRY & DECORATIVE USES

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Turquoise is among the oldest known gem materials, and for good reason. It has an attractive blue color, takes a fine polish, and is sufficiently hard and durable enough to endure prolonged wear as jewelry. It is also available from easily mined, near-surface deposits, yet is rare enough to maintain its value. Because it is opaque, turquoise is traditionally fashioned into cabochons for pendants, earrings, necklaces, bracelets, rings, belt buckles, and bolo-tie clasps. It is also cut into figurines and used in inlay creations. Turquoise is loosely grouped into several general classes. In “matrix turquoise,” blue or green gem material is mixed with bits and veins of such matrix materials as quartz, kaolinite, or limonite. With lace-like, matrix patterns, the stone is known as “spiderweb turquoise.” “Egyptian turquoise” has a distinct green or yellowish-green hue. “American turquoise” occurs in any shade of green or blue, and always with matrix. “Persian turquoise,” sometimes considered to be the world’s finest, is unusually dense, only slightly porous, takes an excellent polish, and has uniform, intense, medium-blue colors. The presence or absence of matrix is a matter of personal preference. Traditionally, the highest grades of turquoise were free of matrix material. But many gemstone connoisseurs now insist that matrix material adds to the visual complexity and “shows off” the color of the turquoise. Turquoise enjoyed great popularity in Victorian-era jewelry. The Native American cultures of the American Southwest profoundly influenced turquoise-jewelry styles (see “History & Lore”). Their large pieces of turquoise set in silver, epitomized by the “squash-blossom” necklace, remain popular today. Almost all turquoise used in jewelry today has been altered or enhanced in some way (see “Treating Turquoise”).

HISTORY & LORE

Archaeologists have found turquoise bracelets and amulets in early Egyptian cultural sites in dating to 5000 B.C. The first great turquoise source was the Wadi Maghara region of the Sinai Peninsula, which the ancient Egyptians mined extensively. The Egyptians used turquoise for decorative, jewelry, religious, and ceremonial purposes, and employed powdered turquoise as a paint pigment and eye-shadow material. Both the ancient Egyptians and the Sumerians inlaid turquoise in gold to create very sophisticated jewelry. The Sinai Peninsula turquoise deposits were worked by slaves and mined out by 3000 B.C., when attention shifted to the turquoise sources of Persia (present-day Iran). Persian turquoise became a major trade commodity that caravans transported throughout much of Asia. During his visit to China, the Venetian traveler and author Marco Polo (1254-1324) noted the trade importance of Persian turquoise and how the Chinese used it extensively in carvings and valued it nearly as highly as jade.

Medieval physicians in Europe prescribed powdered turquoise to treat a broad array of illnesses ranging from insanity and stomach disorders to internal bleeding and disorders of the hips. Throughout much of medieval Europe, the collars and harnesses of dogs, horses, and other animals were often decorated with bits of turquoise to protect both the animals and their masters from injury. The word “turquoise” entered the English language in the 14th century as an Anglicization of the French *turkeis*, which referred to country of Turkey. Because Persian turquoise that arrived in France had passed through Turkey, it was erroneously assumed to have been mined there.

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In the Southwest, Native Americans had systematically mined turquoise since about 800 A.D. Turquoise from Cerrillos in New Mexico and Morenci and Kingman in Arizona had many decorative, ceremonial, and religious uses and was an important commodity in trade systems that extended across much of North America. Archaeologists have recovered turquoise from New Mexico and Arizona from cultural sites as distant as the southeastern United States, Canada, southern Mexico, and several Caribbean islands.

The rebirth of turquoise as a fashionable modern gemstone began in the American Southwest in the 1880s, after southwestern tribes had been confined to reservations and railroads arrived in the territories of Arizona and New Mexico. With few other economic opportunities, Navajo and Pueblo peoples turned to turquoise for income. Obtaining turquoise from their historic mines, they cut and polished the stones, then mounted them in silver obtained by melting down silver dollars. They then offered their turquoise jewelry to train passengers at every railroad station between Santa Fe, New Mexico, and Kingman, Arizona. Demand skyrocketed and the 1890s and early 1900s marked the zenith of turquoise mining in the Southwest with a dozen mines in operation. This time period also saw the beginning of another trend—enhancing the color of turquoise. Navahos and Pueblos realized that their Anglo customers paid the highest prices for bright-blue turquoise. The supply of such stones, however, was limited. But what *was* available in large quantities was “chalk” turquoise—poorly colored material, much of which had actually been mined and discarded centuries earlier. After the Native Americans learned that this poor-quality, porous turquoise readily absorbed the blue aniline dyes that were sold at reservation trading posts, they sold huge quantities of dyed-turquoise jewelry to unsuspecting buyers. By 1910, the trend of future turquoise marketing was firmly established. Turquoise would be set in silver; “southwestern” and “Indian” designs would predominate; color enhancement would become increasingly common, and turquoise would be recognized as the iconic gemstone of the American Southwest.

Turquoise is the birthstone for December, the official state gemstone of Arizona and New Mexico, and the official state semiprecious gemstone of Nevada. Turquoise has appeared on the United States’ two-cent stamps of 2004 and 2005, and the Italian 60-cent stamp of 2009. Modern metaphysical practitioners believe that turquoise is a powerful healing stone, a stone of communication that helps to overcome the fear of public speaking, and an aid that promotes creativity, empathy, intuition, and happiness.

TREATING TURQUOISE

Color-enhancement of gemstones, which has been practiced since antiquity, remains common today. For several reasons, this practice is most prevalent with turquoise. First, as a porous stone, turquoise can easily absorb liquids, such as chemical dyes and resins. Another reason is that consumers have grown accustomed to the idea that all turquoise must have a bright, intense blue or green color, despite the fact that many pale turquoise stones can also be quite attractive. Finally, because turquoise occurs in shallow, easily mined deposits, most of the top-grade material was mined out long ago, thus creating a commercial need to enhance the lower grades that are still available.

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Oils, waxes, and dyes have been used to enhance the color of turquoise since ancient times. But in the 1880s in the American Southwest, Native Americans raised dye-enhancement to new levels and set the precedent for today's turquoise treatments. In the 1950s, turquoise enhancement grew into a mini-industry when western automobile tourism developed and demand for turquoise soared. With limited amounts of quality turquoise available, entrepreneurs began improving upon many old treatment processes and also created new techniques that enhanced not only color, but also structural stability as well.

How successful has this been? Of the large quantities of turquoise on the market today, experts believe that 99 percent has been treated in some way. Following are some of the terms now in use regarding turquoise and its treatments.

Natural turquoise refers to stones that have been altered only by cutting, shaping, and polishing. Very little natural turquoise is available on today's markets. And natural turquoise is not necessarily the "best" turquoise for jewelry use. Because it is porous, it can over time change color as it absorbs materials like as skin oils, sweat, and cosmetics.

Dyed turquoise is usually pale "chalk" material that has been immersed in chemical dyes. Its color, which is sometimes unnaturally bright, may or may not be stable. Dyed turquoise was common until about 1950, when it was largely replaced by more advanced treatment methods. Little dyed turquoise is seen on the market today.

Reconstituted turquoise is turquoise dust and chips, usually a mix of cutting waste from quality turquoise or ground-up pieces of "chalk" material, that has been combined with epoxy resins and blue dyes, then heated and compressed into solid blocks that resemble turquoise. Reconstituted turquoise represents the bottom rung in today's turquoise-treatment ladder, for the finished "gems" have nothing to do with authentic, cut-and-polished turquoise gemstones.

Stabilized turquoise is turquoise that has been treated to harden and impart structural stability to stones before they are cut and polished into gems. Epoxy resins are infused with heat and pressure into the porous stones. Stabilization strengthens the stones so that they can more readily withstand cutting-and-polishing operations; it also hardens soft stones to enable them to better endure frequent wear in jewelry. Although no dyes or other coloring agents are employed, stabilization itself may slightly darken the color of some stones. Nevertheless, stabilized turquoise generally retains the color it had when it was mined.

Color-enhanced/stabilized turquoise is turquoise that has been stabilized *and* color-altered. It usually consists of turquoise that is too soft and pale to have much value. Using heat and pressure, it is infused with epoxy resin that has been mixed with blue dye to both strengthen the stone and create a marketable blue color. The resulting blue color is much more stable than in stones that have simply been dyed. But color-enhanced/stabilized turquoise often appears "too blue" and can have a plastic-like luster.

Structurally enhanced turquoise represents state-of-the-art in turquoise treatment and is usually applied to high-quality turquoise. Structural enhancement employs neither chemical dyes nor organic resins. Details of these processes are carefully guarded, proprietary secrets, but

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some may involve impregnating quality stones with vaporized silica (quartz). This substantially increases the stone's strength and hardness, while only minimally altering the color.

Turquoise treatments have greatly increased the supply of beautiful turquoise gems that are available on the world's jewelry markets, but the practice remains controversial. The main concern is the frequent lack of treatment disclosure on the part of many sellers. Unfortunately, countless millions of dollars of turquoise gems have been sold in recent decades at the higher prices of "natural turquoise" when, in fact, they have been treated. When it comes to buying turquoise gems, the consumer must assume that they have been treated. Any seller's claim of "natural turquoise" should be questioned simply because the overwhelming odds are that the stones have been treated—even though seller might not be aware of this.

TECHNOLOGICAL USES

Powdered turquoise has been used in the past as a minor pigment. Apart from serving as the model for its own laboratory synthesis, turquoise has no technological uses.

ABOUT OUR SPECIMENS

Our turquoise specimens were collected at the Kingman Mine at Turquoise Mountain in the Cerbat Mountains of the Mineral Park Mining District, an area 10 miles north of Kingman, Arizona. Kingman, population 28,000, is located in the northwest corner of the state 90 highway miles southeast of Las Vegas, Nevada, and 185 miles northwest of Phoenix. Kingman, elevation 3,341 feet, lies in high desert country where low, rolling hills are covered by creosote bush and mesquite and thin growths of scrub oak and conifers appear at higher elevations.

Prospectors discovered copper-molybdenum-silver mineralization north of Kingman in the 1880s and developed a number of small silver mines. In the 1960s, Duval Corporation developed the Mineral Park Mine, a major, open-pit copper mine. This mine produced and milled 12,000 tons of ore per day until the early 1990s, when it was acquired by the Cyprus Mining Corporation and converted into a solvent-extraction operation. Another owner, Australia-based Equatorial Mining, increased solvent-extraction production before selling out in 2003 to Mercator Minerals, a Canadian company. Mercator completely rebuilt the mill, modernized the open pit, and reopened the mine in 2011 as a conventional mining-milling operation with a capacity of 50,000 tons of ore per day. The mine has sufficient ore reserves for 23 years of operation and is projected to yield one billion pounds of copper, 250,000 pounds of molybdenum and 14 million troy ounces of silver.

The Mineral Park Mine exploits a massive copper-porphyry deposit. "Porphyry" refers to igneous rock containing conspicuous crystals (phenocrysts) in a fine-grained groundmass. In its mining context, the term "copper porphyry" refers to porphyry-type rock that has been secondarily enriched by copper mineralization. These "two-phase" deposits consist of an original, shallow, oxidized deposit, remnants of which may still exist, and a lower, larger, enriched porphyry deposit of copper-sulfide minerals. The formation of copper-porphyry

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deposits begins when magma intrudes country rock. In Arizona, numerous intrusions were emplaced between 150 million and 50 million years ago. During or shortly after emplacement, copper-rich, hydrothermal solutions circulated upward through the fractured country rock and above the intrusions where, with decreased pressures and temperatures, they precipitated copper-sulfide minerals. After erosion eventually exposed this mineralization, the action of groundwater and atmospheric oxygen oxidized the sulfide minerals. Later, groundwater dissolved much of the copper in both the sulfide and oxidized deposits. It then percolated downward into the underlying porphyritic intrusions to precipitate disseminated copper-sulfide minerals, mainly chalcopyrite [copper iron sulfide, CuFeS_2] and chalcocite [copper sulfide, Cu_2S]. This type of secondary mineralization is known as “supergene enrichment” (literally “post-formation mineralization”); the mineralized porphyry rock is referred to as a “copper-porphyry” deposit.

Arizona’s copper-porphyry deposits generally have a deep, massive, copper-enriched, porphyry intrusion underlying the remnants of shallow, oxidized copper minerals. These shallow, oxidized zones often consist of such collectible minerals as azurite, malachite, chrysocolla [basic hydrous copper aluminum silicate, $(\text{Cu},\text{Al})_2\text{H}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$], turquoise, brochantite [basic copper sulfate, $\text{Cu}_4(\text{SO}_4)(\text{OH})_6$], wulfenite [lead molybdate, PbMoO_4], and native copper [Cu].

The Kingman turquoise mine, the source of our specimens, is adjacent to the Mineral Park open-pit copper mine. The Kingman Mine exploits the turquoise-rich remnants of an oxidized zone that lies atop the huge Mineral Park copper-porphyry deposit. This classic turquoise locality was first mined by Native Americans as early as 800 A.D. Anglo settlers and prospectors reopened this historic mine during the turquoise boom of the 1880s. A succession of companies that included Aztec Turquoise, Los Angeles Gem, Arizona Turquoise, Southwest Turquoise, and Mineral Park Turquoise then operated the mine until 1910.

The Kingman Mine saw little subsequent activity until it was reopened in 1962, when it again gained fame for its bright-blue turquoise nuggets laced with streaks of black matrix. When mining exhausted the main vein in the 1970s, operations were suspended. But the mine reopened yet again in 2004 and has since produced steadily. It is currently the leading source of turquoise in the United States, producing an average of 1,600 pounds of quality rough turquoise each month, virtually all of which is stabilized before cutting and polishing. Only the material marketed as specimens is not treated.

As you examine your specimen, note that it consists of turquoise within a host or matrix rock. The turquoise color is a very clean, “robin’s-egg” blue with little if any green coloration. This is the color for which Kingman turquoise is famous. While your specimen would polish beautifully, it is not considered top-gem grade because of its lack of color uniformity, as seen in the areas of lighter coloration within the basic blue color. Now notice how the turquoise occurs as veins and coatings within fissures in the host rock, which is typical for turquoise formation. The host rock is weathered granite that is composed of plainly visible crystals of translucent, gray quartz and opaque, cream-colored feldspar crystals, along with much smaller, jet-black crystals of hornblende (a group of chemically complex, rock-forming, basic silicates) and biotite (a series of chemically complex, rock-forming, basic silicates that are members of the mica group). In places, these granitic components appear as small crystals within the turquoise itself. Such matrix inclusions are common in most American turquoise. Your turquoise specimen has

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not been treated in any way. It is a fine example of natural turquoise, the iconic gemstone of the American Southwest.

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