

June 2008 Mineral of the Month: Zircon

This month's mineral is one of the first ever used as a gemstone and is the primary ore of zirconium. Our write-up details the unusual carbonatite deposit in the Australian outback where they were collected, and explains the differences between zircon, zirconium, and cubic zirconia.

PHYSICAL PROPERTIES

Chemistry: ZrSiO_4 Zirconium Silicate, always containing some hafnium and often small amounts of uranium and thorium.

Class: Silicates

Subclass: Nesosilicates

Group: Zircon

Crystal System: Tetragonal

Crystal Habits: Usually as stubby, prismatic crystals with square cross sections and pyramidal terminations, less common with octagonal cross sections and ditetragonal terminations; double terminations common; less frequently as elongated prisms; also as disseminated grains, fibrous aggregates, and irregular masses.

Color: Most often yellowish-brown or reddish-brown; also gray, brown, blue, yellow, orange, green, black, smoky, and colorless.

Luster: Adamantine to vitreous

Transparency: Transparent to translucent, occasionally opaque.

Streak: White

Cleavage: Indistinct in two directions parallel to prism faces.

Fracture: Uneven, brittle

Hardness: 7.5

Specific Gravity: 4.6-4.7

Refractive Index: 1.777-1.987

Luminescence: Fluoresces yellow, golden-yellow, and yellow-brown under ultraviolet light; also thermoluminescent.

Distinctive Features and Tests: Best field marks are hardness, high specific gravity, fluorescence, and tetragonal crystal form.

Dana Classification Number: 51.5.2.1



Figure 1. Ideal zircon crystal.

NAME

Zircon, correctly pronounced ZERR-kahn, derives from the ancient Persian word *zargun*, meaning "gold-colored," in reference to one of its varietal colors. Because of its broad distribution and long use as a gemstone, zircon has many alternative names, including "acorite," "azorite," "calyptolite," "circone," "lyncurion," "meta-zircon," "oesterdite," "ostranite," "ribeirite," "turmali," and "zirconite." European mineralogists refer to zircon as "zircone," "zirkonit," and "zirconita." Among zircon's gemstone varieties, blue is called "starlite"; reddish-brown and orange stones are variously called "jargoon," "jacinth," and "hyacinth"; and colorless stones are known as "matura (matara, matarua) diamond." Mildly radioactive, uranium-rich "cyrtolite" is a green variety; "hafnian zircon" refers to a hafnium-rich variety.

COMPOSITION

We have gone from A (adamite) to Z (zircon) in just two months! Zircon was another of the minerals we never thought we would find in the quantity and quality that we need, at a price we could afford. So we were very happy to make this connection and obtain this lot, even though they are smaller than we normally send. We are also happy to learn more about the related elements zirconium and hafnium.

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The chemical formula ZrSiO_4 identifies zircon's elemental constituents as zirconium (Zr), silicon (Si), and oxygen (O). Zircon's molecular weight is made up of 49.77 percent zirconium, 15.32 percent silicon, and 34.91 percent oxygen. All molecules consist of a cation (a positively charged ion) and an anion (a negatively charged ion). Zircon's cation is a single zirconium ion (Zr^{4+}) that carries a +4 charge. Its anion is a negatively charged radical (a group of ions that acts as an entity in chemical reactions), namely the silicate radical (SiO_4)⁴⁻ with a collective -4 charge. The balance of cationic and anionic charges provides the zircon molecule with electrical stability.

Zircon is a member of the silicates, the most numerous and abundant of all mineral classes. In the silicates class, silicon and oxygen combine with one or more metals. The basic silicate structural unit is the silica tetrahedron (SiO_4)⁴⁻, in which a silicon ion is surrounded by four equally spaced oxygen ions at the four corners of a tetrahedron (a four-faced polyhedron). In silicate minerals, silica anions and metal cations bond together like polymers (repeating chains) in seven distinct structures: double tetrahedral silicates (sorosilicates); framework silicates (tectosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); sheet silicates (phyllosilicates); and independent tetrahedral silicates (nesosilicates).

Zircon is a nesosilicate or independent tetrahedral silicate. In the rigid nesosilicate crystal lattice, silica tetrahedra do not bond to other tetrahedra. They bond only to other metal ions, both covalently and ionically. Because of their structure, close atomic packing, and strong covalent bonding, nesosilicates tend to be hard and dense, and form short, blocky, somewhat square crystals. The zircon lattice is a repeating, three-dimensional structure with nearly equal bonding strength in all directions. Because strong covalent bonding predominates, zircon exhibits only indistinct cleavage in two directions. Its 7.5 hardness surpasses that of quartz [silicon dioxide, SiO_2] at Mohs 7.0 and approaches that of topaz [basic aluminum fluorosilicate, $\text{Al}_2\text{SiO}_4(\text{F},\text{OH})_2$] at Mohs 8.0. In the zircon lattice, eight oxygen ions surround and shield each zirconium ion. Most other tetravalent metals (metal ions with a +4 charge) are stable only when surrounded by *fewer* than eight oxygen ions. Zirconium, hafnium, and thorium are the only metallic elements that are stable in this eight-oxygen arrangement. This unusual arrangement creates zircon's tetragonal lattice symmetry, in which all three axes are mutually perpendicular and two are of equal length.

As an allochromatic mineral, pure zircon is colorless. But small amounts of nonessential elements such as hafnium, thorium, uranium, iron, titanium, manganese, chromium, and aluminum alter zircon's light-absorption characteristics to create a wide range of colors. Zircon is often reddish-brown or yellowish-brown, but uranium imparts green hues, manganese and chromium pink-to-red hues, titanium a range of blue colors, and iron yellow, brown, and black colors. Most zircon fluoresces under short-wave ultraviolet light in dull-to-bright shades of yellow, gold-yellow, or yellow-brown. Many zircon specimens are also thermoluminescent and fluoresce yellow when heated.

Zircon's colors and other properties are sometimes altered by metamictization, a process in which internal radiation slowly degrades the crystal lattice. Zircon metamictization occurs when radioactive thorium and uranium ions substitute for zirconium ions and emit alpha-particle radiation that degrades the lattice, alters colors, and reduces hardness, density, and refractive index. Metamictization can reduce zircon's hardness from Mohs 7.5 to Mohs 6.5. Extreme metamictization can actually degrade zircon into an amorphous form with no recognizable crystal structure. The effects of metamictization on zircon vary widely and greatly impact its suitability as a gemstone (see "Jewelry & Decorative Uses").

Zircon has extraordinary abilities to refract and disperse light. Refraction, the ability to bend light, is measured by the index of refraction, which is the ratio between the speed of light in air and in the crystal. The index of refraction of most gemstones is between 1.4 and 1.9. Higher numerical values indicate greater degrees of refraction that correspond directly to brightness and brilliance in gems. Diamond

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[carbon, C], which is known for its brilliance, has an unusually high index of refraction of 2.417-2.419. But the 1.777-1.987 index of refraction of zircon is not far behind. Zircon also has very high dispersion, which refers to its ability to separate white light into its spectral colors. Dispersion, which in gems creates the beautiful play of color called "fire," is expressed numerically as the difference between a crystal's red and violet refractive indices. Most minerals have dispersion indices between 0.010 and 0.030. Zircon's unusually high dispersion index of 0.038 approaches that of diamond at 0.044.

As an accessory, rock-forming mineral, zircon is present in most igneous and metamorphic rocks in small amounts as tiny, disseminated crystals. Zircon also occurs with diamond (our March 2003 mineral) in kimberlite pipes, with orthoclase [potassium aluminum silicate, KAlSi_3O_8] and biotite (our July 2004 mineral, a dark-mica series of basic potassium iron magnesium aluminum silicates) in feldspar-rich intrusive rocks, and with albite [sodium aluminum silicate, $\text{NaAlSi}_3\text{O}_8$], and augite [calcium sodium magnesium iron aluminum titanium oxysilicate, $(\text{Ca},\text{Na})(\text{Mg},\text{Fe},\text{Al},\text{Ti})(\text{SiAl})_2\text{O}_6$] in carbonatites (carbonate-rich igneous rocks). Zircon crystals are usually very small and often microscopic; they achieve their greatest size in carbonatites and pegmatites. Because of zirconium's strong chemical affinity for uranium and thorium, zircon is often associated with minerals of these two radioactive elements. When zircon weathers free of its original host rock, its hardness, durability, chemical inertness, and high density enable it to concentrate in extensive placer deposits that are sometimes commercial sources of zircon gemstones and zirconium (and hafnium).

The Dana mineral classification number 51.5.2.1 identifies zircon as a nesosilicate with insular (isolated) silica groups (51). The subclassification (5) specifies that its silica cations are arranged in coordinations (the number of oxygen ions bonded to a zircon ion) of greater than six (zircon has an eight-oxygen coordination). Zircon is then assigned to the zircon group (2), as the first (1) of five members. The other zircon-group members are hafnon [hafnium silicate, HfSiO_4], thorite [thorium silicate, ThSiO_4], thorogummite [basic thorium silicate, $\text{Th}(\text{SiO}_4)_{1-x}(\text{OH})_{4x}$], and coffinite [basic uranium silicate, $\text{U}(\text{SiO}_4)_{1-x}(\text{OH})_{4x}$]. Zircon is closely related to hafnon, with which it forms a complete solid-solution series. Zircon becomes hafnon when hafnium replaces 45 percent of the zirconium.

COLLECTING LOCALITIES

Although zircon is widely distributed, sources of fine, large specimens are uncommon. Our specimens are from the Mud Tank carbonatite deposit in the Harts Ranges of Australia's Northern Territory. Specimens are also collected in Western Australia at the Greenbushes pegmatite mine at Alexander River in Esperance Shire and the Smoke Pipe lamprolite and Argyle Mine diamond fields at Wyndam-East Kimberley Shire; and in New South Wales at the Eaglehawk Creek placer at Bingara in Murchison County.

In Europe, zircon is collected in Italy at the Graveglia Valley placers at Ne in Genova Province, Liguria, and at the Locatelli Quarry at Mount Comoscio near Baveno in Verbano-Cusio-Ossola Province, Piemonte; in France at the Brugerolle, Rousseille, and Ricoules mines near Vielle-Brioude in Haute Loire, Auvergne; and in Spain at the Nueva Vizcaya Mine at Burquillos de Cerro near Badajoz, Extremadura.

Asian specimens occur in Sri Lanka at the Ratnapura gem fields in Sabaragamura Province; in Japan at the Fuka Mine at Bicchu-cho in the Chugoku Region of Honshu Island; in China at the Koktokay pegmatite mine at Koktokay, Fuyun County, Ili Kazakh Prefecture, Xinxiang Autonomous Region; in Russia at the Nikolaevskiy Mine at Dalnegorsk, Primorskiy Kray, Far-Eastern Region, and the Burpala Alkaline Massif in the Mama River Basin, Transbaikalia, Eastern-Siberian region; in Myanmar in the greater Mogoke Stone Tract in the Shan State; in Pakistan at Gilgit in the Gilgit District of the Northern Areas; and in Cambodia in the Palin district gem fields, Batdambang Province, and at Andraug Pich in Rattanakire Province.

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South American zircon specimens come from Brazil, mainly from the Ipê Mine at Governador Valadares, the Córrego Frio Mine at Davino do Laranjérios, and the Aldeia do Eme Mine at Cuaraque, all in the Doce Valley of Minas Gerais; and the Serra de Mangabiero, Paramirim, Macarani, and Boqueirãozinho pegmatites at Parelisas in Rio Grande do Norte. African specimens come from the Klein Sptizkopje pegmatites at Swakomund in Namibia's Erongo District, and the Sakavalana Mine at Ambotavita in Madagascar's Fianarantsoa Province.

Canadian sources are located in British Columbia at Ruby Creek in the Atlin Mining Division and the Tulameen and Similkameen river placers in the Similkameen Mining Division; in Ontario at the Dungannon Township quarries in the Bancroft district, Hastings County; and in Québec at the Francón Quarry in the St. Michael district near Montréal, and the Poudrette Quarry at Mont-St. Hilaire in Rouville County.

United States localities include Helen Hunt Falls, the Eureka Tunnel, and St. Peters Dome in the St. Peters Dome district of El Paso County, Colorado; the Idaho City placers in the Boise Basin district of Boise County, Idaho; the Tip Top and Tin Mountain mines at Fourmile in the Custer district, Custer County, South Dakota; the Crystal King Zircon Mine in the Wichita Mountains of Comanche County, Oklahoma; and the Harding pegmatite in the Harding district near Taos, New Mexico. Moving eastward, zircon specimens are also found in Arkansas at the Union Carbide Mine at Wilson Springs, Garland County; in Missouri at the Sheahan Quarry at Graniteville, Iron County; in Wisconsin at the Zircon Quarry and Stettin pegmatite in the Stettin Pluton area of Marathon County; in Connecticut at the Andrews and Hale quarries at Portland, Middlesex County; in New Hampshire at the Iron Mountain mines at Bartlett in Carroll County; in New Jersey at the Trotter Mine at Franklin in Sussex County; and in North Carolina at the J. C. Mills Mine at Brindletown in Burke County.

JEWELRY & DECORATIVE USES

Zircon's image as a gemstone is somewhat contradictory. Its hardness, pleasing colors, and excellent refraction and dispersion provide obvious gem value. But zircon is also somewhat brittle, lacks a single distinctive color, and, as the densest major gemstone, is smaller than other gems of equal carat weight. And zircon's traditional use as an inexpensive diamond substitute, together with its more recent confusion with synthetic cubic zirconia, has further compromised its reputation. Because of its great brilliance and fire, colorless and pale-hued zircon gems have long been sold, often surreptitiously, as diamonds. Gem-quality zircon is mined as water-rounded crystals in Thailand, Cambodia, and Sri Lanka from shallow placer deposits, along with such other gemstones as sapphire and ruby [corundum, aluminum oxide, Al_2O_3] and spinel [magnesium aluminum oxide, MgAl_2O_4].

Gem cutters have traditionally classified rough zircon according to gem suitability as "high zircon" and "low zircon." High zircon, which is usually reddish-brown or yellowish-brown, comes mainly from Thailand and Cambodia. High levels of hardness, density, index of refraction, and transparency make it the most valuable. Although low zircon, which comes primarily from Sri Lanka, has a broader color range, its other gemstone qualities are lacking. The differences between high and low zircon are due to different degrees of metamictization. High zircon, which contains only traces of radioactive thorium and uranium, exhibits only minimal, if any, crystal degradation. In low zircon, degradation is much more advanced (see "Composition").

Zircon was probably the first gemstone ever to be heat-treated to enhance color and transparency. Heating restructures the zircon crystal lattice and oxidizes chromophores to enhance or eliminate color, while increasing hardness and indices of refraction and dispersion. High zircon is often heat-treated to produce very attractive blue, golden-yellow, and colorless stones, while low zircon responds poorly to

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heat-treating. Colorless zircon gems are traditionally faceted in diamond-emulating, round, brilliant cuts, while colored zircon is faceted into oval or emerald cuts. Zircon gems less than two carats are quite affordable, but prices increase rapidly with carat size. The price of quality, three-carat zircon gems ranges from \$250 to as much as \$1,500.

Because fine zircon specimens of any appreciable size are uncommon, mineral collectors value them for their rarity, color range, and crystal form both as individual crystals and as composite specimens in matrix.

ZIRCON, ZIRCONIUM, and CUBIC ZIRCONIA

Zirconium, the metallic element in zircon, is a transition metal in the periodic table. It has an atomic number of 40 and an atomic weight of 91.22. Ranking 18th in crustal abundance, zirconium is about as common as vanadium. Elemental zirconium exists in a crystalline state as a soft, white, ductile metal, and in an amorphous state as a bluish-black powder. Elemental zirconium burns in air at 500 °C (932 °F.). Because of its high chemical reactivity, zirconium is not found free in nature. It occurs chiefly as a silicate in zircon; much smaller amounts exist as an oxide in baddeleyite [zirconium dioxide, ZrO₂].

German chemist Martin Heinrich Klaproth (1743-1817) predicted the existence of zirconium in 1789. He later named the new element “zirconia” (now the commercial term for industrial zirconium oxide) after its primary mineral, zircon. The element was renamed “zirconium” in 1808. Swedish chemist Jöns Jakob Berzelius (1779-1848) first isolated impure zirconium in 1824. But because of zirconium’s strong chemical affinity for hafnium, researchers did not isolate pure zirconium until 1914. And it was not until 1945 that American metallurgist William J. Kroll (1889-1973) adapted his Kroll Process for purifying titanium to produce commercial quantities of pure zirconium. In the Kroll Process, which is still used today, zircon is first reduced to an impure metal with heat and carbon, then converted to zirconium chloride and reduced again with molten magnesium to pure zirconium metal.

Following World War II, the commercial availability of pure zirconium led to the development of special steel and exotic alloys. With their excellent corrosion resistance and low neutron-absorption properties, zirconium alloys are the standard cladding material for enriched-uranium fuel rods in nuclear power-generation plants. Zirconium alloys are also widely used in heat exchangers, pump housings and impellers, valves, and conduits that must withstand acids and other corrosive liquids. Because of its ability to combine quickly with oxygen and other gases, pure zirconium is used to remove traces of gases in the manufacture of vacuum tubes for computer monitors and televisions.

The most important manufactured zirconium compound is white zirconium oxide or “zirconia,” which serves as an opacifier and pigment in ceramic glazes and porcelain. A form of yttrium-stabilized zirconia called “YSZ” is a component of everything from composite golf clubs, automotive engine sensors, and fiber-optic connectors to refractory coatings for jet engines. YSZ is also the feedstock for cubic zirconia (CZ), a popular diamond simulant. CZ must not be confused with zircon. Zirconium oxide (zirconia) crystallizes in the monoclinic system. In 1970, researchers learned that zirconia converts to a cubic phase when molten, but reverts back to the monoclinic phase upon cooling. But the addition of traces of yttrium stabilizes the cooling zirconia in cubic form—hence the name “cubic zirconia.” Because of its great hardness, diamond-like optical properties, and even greater brilliance, CZ is a superb diamond simulant. Some 1.2 billion carats (about 250 tons) of glittering, inexpensive CZ in every imaginable color are now produced each year for simulated-diamond use.

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HISTORY & LORE

Zircon has been known for thousands of years, but was confused with other gemstone minerals until 1789, when German chemist Martin Heinrich Klaproth (1743-1817), after studying specimens collected in Ceylon (now Sri Lanka), determined that zircon's metal cation consisted of a previously unknown metal. Zircon received its current name in 1794. Zircon was initially thought to contain a single metal component, zirconium, but in 1923, Hungarian radiochemist George Charles de Hevesy (1885-1966) discovered hafnium, a metal chemically and physically very similar to zirconium, but much rarer. Mineralogists then found that hafnium was present in varying quantities in all zircon, and in 1974 determined that zircon and hafnion [hafnium silicate, HfSiO_4] are actually end members of a complete solid-solution series.

Zircon was among the first minerals ever used as a gemstone. Archaeologists have recovered crudely carved and polished zircon gems at 7,000-year-old cultural sites in the Middle East. Some biblical scholars believe that zircon, or "jacinth," was one of the twelve gems in the breastplate worn by Jewish high priest descendants of Aaron.

In ancient times, the Kalpa Tree or "wishing tree" of Hindu mythology was thought to glow with leaves of golden zircon. Later, medieval physicians administered potions of powdered zircon to treat a variety of ailments, while mystics believed that zircon gave its wearers wisdom, honor, and riches, protected them from lightning, and warned of imminent danger by losing its luster. According to modern metaphysical practitioners, zircon is a stone of purity and innocence that balances emotions and enhances self-esteem and unity. Blue zircon is a birthstone for December. Zircon crystals and a faceted zircon gem appeared on the four-baht stamp of Thailand in 1972.

TECHNOLOGICAL USES

Zircon, the primary ore of zirconium, is obtained as a coproduct or by-product of mining the titanium ores ilmenite [iron titanium oxide, FeTiO_3] and rutile [titanium oxide, TiO_2] and the tin ore cassiterite [tin dioxide, SnO_2]. These minerals, which occur as "heavy sands" in extensive, beach-type placer deposits, are mined by dredging and recovered and concentrated by gravitational-separation methods. Zircon, which contains zirconium and hafnium in proportions of about 50:1, is also the only commercial source of hafnium. In a few localities, thorium-rich zircon has occasionally served as an ore of thorium.

Most zircon is used in opacification and pigmentation compounds for decorative ceramics, and in the manufacture of refractory ceramics, foundry molds, and firebrick. The remainder is converted to zirconia, a feedstock for the production of other zirconium compounds and zirconium metal. Nearly 1.4 million metric tons of zircon concentrate are mined worldwide each year. Australia is the leading source, followed by South Africa, China, and the United States. Annual production in the United States, mostly from Florida and Georgia, now amounts to 150,000 metric tons of concentrate containing 65 percent zircon. Zircon concentrate costs about \$900 per metric ton.

Zircon is vital to the uranium-lead method of radiometrically dating rocks. Because zircon usually contains traces of uranium, is widely distributed, and durable enough to survive weathering, erosion, transport, and even high-grade metamorphism, it is an extraordinary geophysical tool for dating early rocks. Because uranium eventually decays into the stable form of lead at a known rate, geophysicists can measure the isotope ratios of uranium and lead in zircon to accurately date the host rock, even when it is extremely old. Uranium-lead dating of zircon crystals from a formation in Western Australia has identified the host gneiss as the oldest known rock on Earth with an age of 4.404 *billion* years. Zircon itself is believed to be the Earth's oldest mineral.

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ABOUT OUR SPECIMENS

As previously noted, our zircon specimens were collected at the Mud Tank carbonatite deposit in the Harts Ranges of Australia's Northern Territory. The Mud Tank deposit is within a two-hour drive of Alice Springs near the geographic center of the Australian continent. Alice Springs, a remote city of 26,000, is central Australia's economic, cultural, and transportation hub. The elevation of Alice Springs is 1,700 feet; its climate is arid, with only about 11 inches of precipitation annually. In January (the Australian summer), the average daily high temperature is nearly 100° F. But the average daily July high temperature, a pleasant 68° F., makes Alice Springs a popular, winter-vacation



Figure 2. Desert rain on Mud Tank zircon field.

area and the jumping-off point for treks into the vast, surrounding outback, which equals in area that of the entire state of Texas. One popular destination is the Mud Tank zircon field, the source of our specimens, which is 85 miles north-northeast of Alice Springs. "Mud Tank," the name of a windmill-powered well or "bore" and an adjacent reservoir or "tank," is on the Plenty Highway four miles east of the Gemtree Caravan Park, a commercial campground that is popular among zircon hunters. From Mud Tank, a four-mile-long, marked track leads to the zircon field.

The Mud Tank zircon field is located at the west end of the Harts Ranges, a 70-mile-long series of low mountains. The most prominent peak is 3,100-foot-high Mt. Riddock. The Harts Ranges is one of central Australia's numerous ancient, highly eroded mountain systems that were uplifted more than a billion years ago by tectonic stresses. The Mud Tank zircon field is the eluvial remnant of a pegmatitic carbonatite. Carbonatite refers to igneous (intrusive or extrusive) rock that consists of at least 20 percent carbonate minerals, usually calcite [calcium carbonate, CaCO_3] and dolomite [calcium magnesium carbonate, $\text{CaMg}(\text{CO}_3)_2$]. Carbonatites are uncommon, with only 330 known to exist in the world. The mineral composition of carbonatites varies, but usually includes natrolite [hydrous sodium aluminum silicate, $\text{Na}_2(\text{Al}_2\text{Si}_3\text{O}_{10} \cdot 2\text{H}_2\text{O})$], zircon, fluorapatite [calcium fluorophosphate, $\text{Ca}_5(\text{PO}_4)_3\text{F}$], magnetite [iron oxide, $\text{Fe}^{2+}\text{Fe}_{23+}\text{O}_4$], barite [barium sulfate, BaSO_4], fluorite [calcium fluoride, CaF_2], and muscovite [basic potassium aluminum silicate, $\text{KAl}_2\text{AlSi}_3\text{O}_{10}(\text{OH})_2$], the latter a common member of the mica group.

The Mud Tank deposit originated some 730 million years ago in Precambrian time when carbonate-rich magma intruded existing alkaline-igneous rocks in several phases to emplace pegmatitic carbonatite sills and dikes. Pegmatites are bodies of coarse-grained igneous rock that form when residual magma cools very slowly. Rather than quickly "freezing" into fine-grained igneous rock, this residual magma crystallizes on a fractional or mineral-by-mineral basis. Residual magma, the last of a magmatic body to solidify, is often enriched with rare or accessory elements. At Mud Tank, the residual carbonatite magma was enriched with zirconium. After later surface erosion had exposed sections of this deposit, chemical oxidation and surface weathering caused the exposed carbonatite to deteriorate into unconsolidated gravel. But unlike *alluvial* deposits, which form when water transports, sorts, and deposits weathered rock

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material, the Mud Tank carbonatite minerals have remained in place as an *eluvial* deposit.

The prospectors who discovered the Mud Tank carbonatite deposit in the late 1950s were interested in vermiculite (a mica-like group of complex, basic hydrated magnesium iron aluminum oxysilicates). When mining began in 1962, vermiculite was trucked to the railhead at Alice Springs, then shipped to Adelaide, South Australia. Miners noted the abundance of zircon, some of gem quality, in gravels adjacent to the vermiculite mine. By the 1970s, the Mud Tank zircon fields had become such a popular gemstone-collecting area that the government of the Northern Territory decreed it a Designated Fossicking Area. In

Australia, “fossicking” refers to rockhounding as a noncommercial, recreational activity. Fossicking in the Northern Territory requires a Fossicker’s Permit, which is issued free of charge by state-government or other authorized agencies. Fossicking regulations are similar to those on public lands in the United States. Excavating must be performed with hand tools and cannot exceed one meter in depth. Recoveries are limited to “reasonable” quantities and may be traded, but not sold for profit. Commercial recovery requires a special permit. The zircon field is open to all fossickers, except for certain diggings that are reserved by commercial tour operators holding special permits.

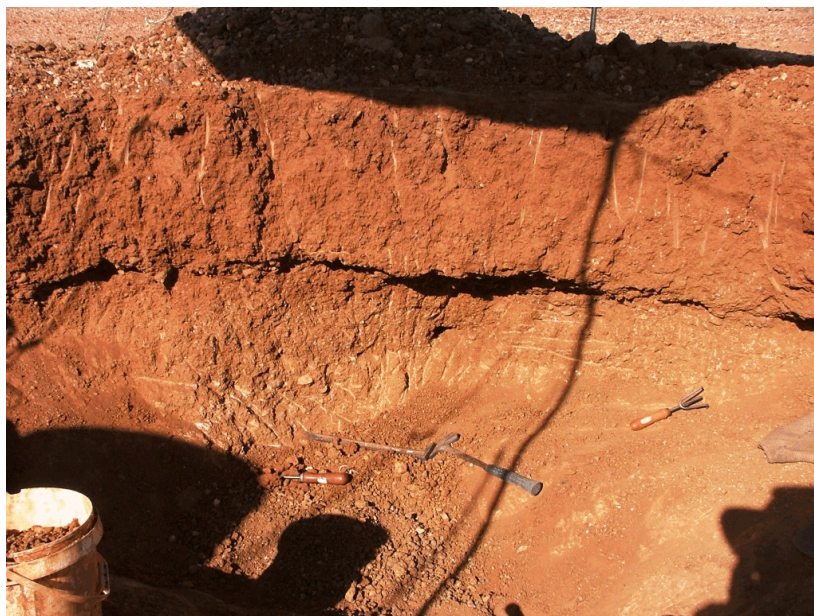


Figure 3. Zircon excavation hole under rigged shade.



Figure 4. Zircons found in excavation hole!

The one-half-square-mile Mud Tank zircon field is adjacent to the open-pit vermiculite mine and extends across two low hills: Zircon Hill and Specimen Hill. Fossickers dig and screen the gravel, then wash the retained material to identify zircon crystals. At Zircon Hill, zircon colors range from orange, reddish-brown, and pale brown to yellow to purplish. Some specimens are colorless or multicolored. Most crystals are double-terminated, many are fragmented, and about 20 percent are gem quality. At Specimen Hill, the zircon crystals are larger, with better developed faces, but the interiors are often cracked and few are of gem quality. Mud Tank zircon, which fluoresces yellow under short-wave ultraviolet light, is classified as “high

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zircon” and has very little radioactive thorium to degrade the crystal lattice. Most Mud Tank zircon crystals range in length from a half-inch to three inches. Fossickers occasionally find exceptional specimens, such as the 10-inch, yellow-brown crystal that attracted much attention in a display case at the 2007 Tucson Gem & Mineral Show. The show theme for 2007 was “Gems and Minerals of Australia,” and two cases were devoted to our featured mineral this month. It was seeing the remarkable zircon crystals in these two cases, photos of which are found on page 10, that made us want to spotlight this marvelous mineral and send one to all of you. From the Australian outback straight to your front door!



Figure 5. Mud-settling tubs at edge of excavation hole.

Your individual zircon-crystal specimen enables you to study certain of its physical properties. The specimen's substantial “heft” in the hand reflects its high specific gravity of 4.6-4.7—nearly twice that of quartz. The color, best observed by rotating the specimen in bright light, is a golden-brown with reddish highlights, typical of high zircon that has undergone little, if any, metamictization. In noting the shape of the specimen, remember that zircon crystallizes in the tetragonal system, mostly as stubby, doubly



Figure 6. Sorting zircon from gravel at Mud Tank. Site photos courtesy of Dehne McLaughlin.

terminated, four-sided prisms with square cross sections and four-sided, pyramidal terminations, as depicted in the ideal crystal drawing in Figure 1. This crystal habit reflects zircon's tetragonal lattice symmetry, in which all three axes are mutually perpendicular and two are of equal length. The smooth, well-developed faces are either prism sides or terminations. Faces that intersect at approximately right angles are prism faces. The remaining faces that intersect at greater than right angles are termination faces—making it easy to visualize the idealized zircon crystal. But modifications are common. Prism sides may be so short that the crystals appear to consist only of two terminations, or their edges can be

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Figures 8, 9 Zircon crystals and faceted zircon gemstones on display at the 2007 TGMS.

runcated to produce an octagonal rather than square cross section. Similar modifications in the terminations can create “stepped” pyramids or eight-sided (ditetragonal) pyramids. Keep these possible modifications in mind when studying the specimen. But regardless of whether the crystal shape of your specimen is simple or modified, it is interesting to relate it to the ideal zircon crystal shape.

Those of us with ultraviolet lamps will detect a yellow color under shortwave UV light, and perhaps orange under longwave. The activators in zircon have not been the subject of much study. Uranium, which as we learned is present with thorium in most zircon, often fluoresces and may be the cause of the yellow color, while hafnium, present in all zircon, may also be an activator. Some zircons from other localities fluoresce red and sometimes green, perhaps due to containing minute amounts of the rare earth elements samarium, terbium, and dysprosium. After reading this write-up, we hope you’ll agree with us that zircon is one of the most intriguing of all minerals!



Figure 10. Close-up of zircon crystal from display above.

References: *Dana’s New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Co.; *2004 Fleischer’s Glossary of Mineral Species*, Joseph Mandarino and Malcolm Back, The Mineralogical Record Company; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Co.; *Manual of Mineralogy*, Cornelius Hurlbut and Cornelia Klein, Twenty-first Edition, John Wiley & Sons; *Gems and Jewelry*, Joel E. Arem, Geoscience Press, 1992; *Gemstones of the World*, Walter Schumann, Sterling Publishing Co., 1977; “Zircon, Zirconia . . . Zirconium,” Steve Voynick, *Rock & Gem*, March 2003; “Zircon: Helen Hunt Falls, El Paso County, Colorado,” Robert B. Cook, *Rocks & Minerals*, July-August 2007; “Zirconium and Hafnium,” Joseph Gambogi, *2006 Minerals Yearbook*, United States Geological Survey; *A Guide to Fossicking in the Northern Territory*, Northern Territory Department of Energy and Mines, 2005; “The Mud Tank Carbonatite Complex, Central Australia,” K. L. Currie, J. Knutson, and P. A. Temby, *Contributions to Mineralogy and Petrology*, Volume 103, Issue 9, 1992; “What’s New in Minerals: Seventeenth Annual Rochester Academy of Science Mineralogical Symposium,” George Robinson and Vandall King, *The Mineralogical Record*, September-October 1990; “Australia—Special Issue,” *The Mineralogical Record*, November-December 1988.