September 2012 Mineral of the Month: Petrified Wood

PETRIFIED WOOD (QUARTZ var. CHALCEDONY)

This month we are featuring quartz from Madagascar in the beautiful and unusual form of petrified wood. Our specimens are actually 225-million-year-old fossils, and our write-up explains the formation, history, and lore of petrified wood.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: SiO_2 Silicon Dioxide, containing small amounts of iron and manganese.
Class: Silicates
Subclass: Tectosilicates
Group: Quartz
Subgroup: Microcrystalline Quartz (Chalcedony)
Crystal System: Hexagonal
Crystal Habits: Massive and compact with no visible crystal structure; petrified wood consists of microcrystalline quartz (chalcedony) that has replaced wood.
Color: White, gray, tan, brown, and black to red, pink, brownish-red, yellow, green, and blue; many specimens are varicolored.
Luster: Waxy and vitreous to dull
Transparency: Translucent to opaque
Streak: White
Refractive Index: 1.55
Cleavage: None
Fracture: Conchoidal to subconchoidal and irregular, brittle to tough.
Hardness: Mohs 6.0-7.0
Specific Gravity: 2.62-2.66
Luminescence: Impurities occasionally produce weak green and white fluorescence.
Distinctive Features and Tests: Best field marks are hardness, massive or compact structure, relatively low specific gravity, varied colors, occurrence in sedimentary environments, and recognizable ring, bark, and other tree-trunk features.
Dana Classification Number: 75.1.3.1

NAME: The name "quartz," pronounced "kworts," is derived from the German *Quarz*, which is derived from the Slavic *kwardy*, meaning "hard." "Chalcedony," pronounced "cal-SED-do-nie," stems from Chalcedon, an ancient Greek city on the Strait of Bosphorus in Asia Minor. In the term "petrified wood," also known as "silicified wood" or "agatized wood," the word "petrified" comes from the Greek *petros*, meaning "stone." In European mineralogical literature, petrified wood appears as *bois pétrifié*, *versteinetes Holz*, and *legno agatizatto*.

COMPOSITION: Most petrified wood, including our specimens, consists of chalcedony, the microcrystalline variety of quartz [silicon dioxide, SiO_2]. Quartz or silica consists of 46.74 percent silicon and 53.26 percent oxygen. Quartz is a member of the silicates, the largest of all mineral classes, in which silicon and oxygen are combined with one or more metals. The basic building block of the silicates is the silica radical $(SiO_4)^{4-}$, in which a silicon ion is surrounded by four equally spaced oxygen ions positioned at the four corners of a tetrahedron (a four-faced polyhedron). Microcrystalline quartz or chalcedony consists of microscopic silica grains or fibrous silica crystals and forms in the low temperatures and pressures of shallow environments from the solidification of colloidal silica suspensions in restricted growth spaces. In petrified wood, chalcedony has replaced the original wood structures. Quartz is an allochromatic mineral, meaning that its color is caused not by its essential elemental components or the nature of its crystal structure, but by traces of accessory, color-producing elements called chromophores. Iron and manganese oxides are the primary chromophores in petrified wood.

COLLECTING LOCALITIES: Petrified wood is found in Madagascar, Libya, Namibia, the Czech Republic, Greece, Italy, Belgium, France, Romania, Germany, Austria, Russia, Bolivia, Indonesia, Mongolia, Cambodia, China, Japan, and Australia. The American West has many sources, notably in Arizona, California, Colorado, South Dakota, North Dakota, Washington, Nebraska, Texas, Wyoming, Oklahoma, Oregon, New Mexico, and Nevada. Other localities are in Ohio, Louisiana, and Mississippi.

HISTORY, LORE, & GEMSTONE/TECHNOLOGICAL USES: Since the stone ages, petrified wood has served as a source of chalcedony for the manufacture of tools and weapons. In medieval times, amulets of petrified wood, because of their age and resemblance to tree wood, were thought to impart longevity to those who wore them. Because trees have circulatory systems, as well as bark and leaves that seemed to correspond to human skin and hair, medieval physicians prescribed tonics of powdered petrified wood to protect health, increase longevity, and alleviate ailments of the circulation system, skin, and hair. Because of its abundance, attractive colors, workability, fine polishing characteristics, and fascinating preservation of wood structures and shapes, petrified wood has long been a popular gemstone and decorative stone. Petrified wood is fashioned into beads for necklaces and bracelets, cabochons, ring stones, cameos, tie tacks and cuff links. As a decorative stone, petrified wood is made into spheres, snuffboxes, bowls, paperweights, figurines, bookends, polished slabs, countertops, tabletops, and clock faces. Since the late 1800s, petrified wood has been a popular souvenir of the American West. Because of its connection to trees, petrified wood has a prominent place in modern metaphysical lore. With branches reaching high toward the heavens and roots set firmly in the Earth, trees are thought to be particularly wise and balanced. Petrified wood is considered a source of ancient and stable energy that connects with nature, imparts longevity, and provides the power, wisdom, and patience needed to maintain spirituality in the everyday, physical world.

ABOUT OUR SPECIMENS: Our petrified-wood specimens were collected near Morondava in the Menabe Region on Madagascar's southwest coast. The Republic of Madagascar, which occupies an island in the Indian Ocean 400 miles off Africa's east coast, is nearly the size of the state of Texas. During the Triassic Period some 225 million years ago, the Morondava area was covered with dense forests of giant coniferous trees of the gymnosperm genus *Aruacaria*. Sediments from the surrounding highlands quickly buried many *Aruacaria* forests in an anaerobic (oxygen-free or oxygen-deficient) environment that inhibited normal, aerobic decay and thus preserved many tree features. Groundwater rich in silica then circulated through these buried tree trunks, dissolving and carrying away cellulose and other organic matter and replacing it with chalcedony. Relatively recent erosion has exposed these petrified trees on the semiarid, desert grasslands east of present-day Morondava. While some fragments of petrified tree trunks appear on the surface, most of the petrified wood is buried in the iron-rich, reddish soil and is recovered by manually digging shallow trenches. Our petrified-wood specimens were collected by Madagascar Minerals, a company that mines, processes, and markets Madagascar gemstones, ornamental stones, and mineral specimens.

COMPREHENSIVE WRITE-UP

COMPOSITION

The term "petrified wood" is something of a misnomer because it incorrectly implies that the wood has turned to stone. Technically, petrified wood is a pseudomorph, a word derived from the Greek *pseudēs*, "to lie," and *morphē*, or "form," and literally meaning "false form." In its mineralogical context, pseudomorphs are minerals that have replaced an original mineral (or material) while retaining the shape of that mineral or material. Our specimens of pseudomorphic, silicified wood can therefore be described as "silica-after-wood."

Most petrified wood, including our specimens, consists of chalcedony, the microcrystalline variety of quartz [silicon dioxide, SiO_2]. Quartz occurs in two basic forms: macrocrystalline quartz (hereinafter referred to as "quartz"), which consists of visible, well-developed crystals; and microcrystalline quartz or chalcedony, the compact or massive form of silica. Familiar forms of quartz include amethyst, rock crystal, and milky, smoky, and rose varieties, which form visible, transparent-to-translucent crystals. Chalcedony, however, consists of microscopic silica grains or fibers, occurs in many colors, and includes such types as jasper, agate, chert, and flint.

Quartz or silica, SiO_2, consists of two elemental components: the semimetal silicon (Si) and oxygen (O). Quartz's molecular weight is made up of 46.74 percent silicon and 53.26 percent oxygen. The cation, or positively charged ion, in the quartz molecule is the silicon ion Si^{4+} with its +4 charge. The anion, or negatively charged ion, consists of two oxygen ions $2O^{2-}$ with their collective -4 charge. The balance of these cationic and anionic charges provides the quartz molecule with electrical stability.

Quartz is a member of the silicates, the largest mineral class, in which silicon and oxygen are combined with one or more metals. (Quartz, which consists of a semimetal combined with oxygen, is the sole exception.) The silicate minerals make up 93 percent of the total weight of the Earth's crust. Quartz is the most abundant silicate mineral and is found in virtually all igneous, metamorphic, and sedimentary rocks. The basic building block of the silicates is the silica radical $(SiO_4)^{4-}$, in which a silicon ion is surrounded by four equally spaced oxygen ions positioned at the four corners of a tetrahedron (a four-faced polyhedron). In the silicates, silica anions join together with metallic or semimetallic cations in repeating chains to form seven types of structures: independent tetrahedral silicates (nesosilicates); double tetrahedral silicates (sorosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); sheet silicates (phyllosilicates); and framework silicates (tectosilicates). Quartz is a framework or tectosilicate.

In the quartz crystal lattice, the oxygen ions of each silica tetrahedron are bound covalently to silicon ions of adjacent tetrahedra. In this arrangement, four oxygen ions surround each silicon ion and two silicon ions surround each oxygen ion. Because this satisfies the -4 charge of each individual $(SiO_4)^{4-}$ tetrahedron, no other ions are needed for electrical stability. This arrangement also creates the infinite, three-dimensional structure of quartz in which each balanced molecular unit is described by the formula SiO_2. The bonding within the quartz lattice is exclusively covalent. Because covalent bonding is strong and omnidirectional, quartz crystals have neither a center of symmetry nor cleavage planes. Quartz's substantial hardness of Mohs 7.0 (6.0-7.0 for chalcedony) is explained by its lack of cleavage and the high bonding strength derived from close atomic packing. The relatively light atomic weights of its essential elements silicon (28.09) and oxygen (16.00) give quartz a low specific gravity of 2.65 (2.62-2.66 for chalcedony).

The Dana mineral classification number 75.1.3.1 first identifies quartz as a tectosilicate or framework silicate (75). The subclassification (1) defines it by the chemical formula SiO_2 and also by a four-oxygen coordination in which each silicon ion is bound to four oxygen ions. Quartz is then assigned to the quartz group (3) as the first (1) and only member.

Quartz and chalcedony develop differently. Quartz forms at high or low temperatures and pressures in environments where sufficient space allows for orderly crystal development. Quartz crystals grow as silica is added on a molecule-by-molecule basis in successive layers. Chalcedony forms from the solidification of colloidal-silica suspensions in the low temperatures and pressures of shallow environments where space is restricted. Chalcedony development begins with silica that has weathered free from silicate minerals and is carried in groundwater as microscopic particles in colloidal suspension. These particles settle out of suspension as a water-based, amorphous silica gel that eventually loses its water and forms solid masses of chalcedony composed of interlocking, microscopic crystals. In the case of petrified wood, chalcedony replaces the features of the original wood.

As an allochromatic mineral, quartz's colors are caused not by its essential elemental components or the nature of its crystal structure, but by traces of accessory, color-producing elements called chromophores. Pure quartz is colorless, but various impurities create a wide range of colors. Quartz is transparent to translucent, while chalcedony is translucent to opaque. Quartz has a low porosity, while chalcedony is quite porous. Because of this difference in porosity, quartz and chalcedony are colored in different ways. Quartz is colored by chromophores within the crystal lattice that impart color as crystals develop. Most newly formed chalcedony is white or gray. But because of its porosity, it is easily permeated by groundwater solutions containing such chromophores as iron, manganese, copper, and nickel. These solutions deposit chromophoric minerals in the spaces between the microcrystals to create a wide range of colors and color patterns. Iron and manganese oxides are the primary chromophores in chalcedony. Iron creates brown, yellow, and deep-red colors, while manganese creates yellowish-black, pinkish, and orange colors. Cobalt, chromium, and copper minerals create blues and greens, while nickel also imparts green colors. Because of chromophoric mixing, the range of colors and color patterns in petrified wood and other types of chalcedony are limitless.

COLLECTING LOCALITIES

Chalcedonic petrified wood is relatively common, widely distributed, and sometimes occurs in large concentrations. Our petrified-wood specimens were collected near Morondava in the Menabe Region of Madagascar. Localities on the nearby African continent include Wadi Bu Shubariyim near Murzuq, Murzuq District, Libya; and the Khorixas Petrified Forest, Khorixas District, Kunene Region, Namibia.

In Europe, petrified wood occurs at Kralovice in Plzeň-North, Plzeň Region, Bohemia, Czech Republic; Lésvos Island, Lésvos Prefecture, Aegean Islands, Greece; Igna Creek, Vicenza Province, Veneto, Italy; Herkegcöves Hill at Rátka in the Zempién Mountains of Borsod-Abaúd-Zempién County, Hungary; Goudberg near Hoegaarden, Flemish Brabant Province, Belgium; Saint-Pierre-du-Cantel near Cantel, Auvergne, France; and Gurasada, Hunedorara County, Romania. German sources include the Rankach Valley in the Black Forest, Baden-Württemberg; Tanzfleck, Upper Palatinate, Bavaria; Steigersberg near Aizey, Rhineland-Palatinate; the Hargarten Quarry near Merzig, Saarland; Hilsberdorf near Chemitz, Saxony; and the Preetz gravel works in Kiel, Schleswig-Holstein. Austrian localities include Lanz-Stelzing near Kötschach-Mauthen in the Gailtaler Mountains, Carinthia; Klosternauberg near Wienerwald, Lower Austria; and Weising near Vöklabruck, Upper Austria. Among Russia's sources are the Tsil'ma River Basin, Komi Republic, Northern Region; and the Chelyabinsk coal region near Kopeisk, Chelyabinsk Oblast', Urals Region.

Other worldwide localities include Corocoro, Pacajes Province, La Paz Department, Bolivia; the Araguaina river gravels in Tocantins, Brazil; Kali Maya, Banten Province, Java, Indonesia; Ulegei, Dornogovi Aimag, Mongolia; Don Ton, Kompong Sralau District, Preăh Hihĕar Province, Cambodia; the Zhailangzi Quarry at Lushi, Huaying County, Guang'an Prefecture, Sichuan Province, China; and Nichi-Shioko in Ibaraki Prefecture, Kanto Region, Honshu Island, Japan. Australian specimens come from Cadell's Pot Hole, Gough County, New South Wales; Springsure in the Central Highlands Region, Queensland; the Lune River gravels in the Huon District, Tasmania; and the Wannon River gravels at Hamilton, Victoria.

The most prolific petrified-wood region in the United States is Arizona, where occurrences include Monument Valley on the Navajo Reservation and Petrified Forest National Monument near Holbrook, both in Navajo and Apache counties; the San Francisco Volcanic Field and the Cameron areas in Coconino County; the Colorado River benches in Mojave County; Adobe Canyon near Sonoita in the Santa Rita Mountains, Santa Cruz County; the Petrified Wood Formation near Dome, Yuma County; and Sycamore Canyon in the Verde Valley, Yavapai County. Among California's sources are Gem Hill at Rosamond, Kern County; the Calistoga Petrified Forest in the Myacmas Mountains, Napa County; and the Willard Creek agate beds near Susanville in Lassen County. In Colorado, petrified wood occurs in and near Florissant Fossil Beds National Monument in Teller County; Agate Creek in South Park, Park County; the Payton-Elbert area in Elbert County; Lamar in Prowers County; the Coal Creek district in Rio Blanco County; and the Calhan area in El Paso County. South Dakota localities include Petrified Park near Lemmon in Perkins County; Corral Draw near Scenic in Pennington County, and the Little White River near Mission in Todd County. Gingko Petrified Forest State Park is located near Vantage, Kittitas County, Washington. Petrified wood also occurs in many counties in

Nebraska, Texas, North Dakota, Wyoming, Oklahoma, Oregon, Ohio, New Mexico, Nevada, Louisiana, and Mississippi.

JEWELRY & DECORATIVE USES

With its abundance, bright colors, workability, fine polishing characteristics, and the fascinating preservation of visible wood structures and shapes, petrified wood is a popular gemstone and decorative material. Petrified wood is fashioned into beads for necklaces and bracelets, cabochons, ring stones, cameos, tie tacks and cuff links. Petrified-wood gems are mounted in silver and are usually quite affordable. Much petrified wood is tumble-polished in irregular shapes and sold from "grab buckets" in tourist, souvenir, and rock shops. Unlike jasper and agate, petrified wood is not color-enhanced. Petrified wood is also made into spheres, bowls, paperweights, figurines, bookends, polished slabs, countertops, tabletops, and clock faces. Since the late 1800s, petrified wood has been recognized as a classic souvenir of the American West.

Collectors seek petrified-wood specimens in both rough and polished forms. Rough specimens retain their natural appearance and the texture of the original tree bark, while polishing brings out colors and features like growth rings and sometimes even cellular patterns. Many collectors have amassed specialized collections of petrified wood that focus on localities, specific colors, paleospecies of the original trees, and such botanical features as rings and bark.

HISTORY & LORE

Since the stone ages, petrified wood has been a source of chalcedony to make tools and weapons. Noting the visual similarity of petrified wood to living trees, many ancient cultures developed imaginative theories to explain its origin. To some, it was wood that had been frozen so solidly as to never melt; others surmised that it came from underground forests that grew in great caverns. Still others believed it was the remains of ancient trees that had "lived well" and had been turned to stone to preserve them until they could return to life. In medieval times, amulets of petrified wood, because of their link with ancient trees, were thought to impart longevity. And since trees, like humans, had circulatory systems, as well as bark and leaves that seemed to correspond to human skin and hair, medieval physicians prescribed tonics of powdered petrified wood to protect health, assure longevity, and alleviate ailments of the circulatory system, skin, and hair. Some alchemists, believing that petrified wood was a "bridge" between living and mineral objects, sought ways to return life to petrified wood, hoping that the principles they discovered could be applied to the "rebirth" of deceased humans.

By the 1600s, European miners realized that timbers used in underground mines where water was highly mineralized water sometimes "turned" to stone in just 10 to 20 years. Nevertheless, the exact origin of petrified wood remained a mystery until scientists understood both quartz and the phenomenon of mineral pseudomorphism. Initially, chalcedony was not considered a form of quartz. In 1780, Swedish chemist Torbern Olaf Bergmann (1735-1784) first noted the chemical similarity between quartz and chalcedony, yet believed they were different minerals. In 1824, Swedish chemist Jöns Jacob Berzelius (1779-1848) proved that quartz and chalcedony were both silicon dioxide and that most petrified wood consisted of chalcedony. Then in the 1840s, mineralogists discovered the phenomenon of pseudomorphism—the ability of one mineral to replace another while assuming the external shape of the original mineral. Only then did scientists realize that petrified wood was wood that had been replaced by silica.

In the United States, petrified wood received little public attention until the mid-1800s, when spectacular surface occurrences were discovered near present-day Holbrook, Arizona. In 1879, U.S. Army General William Tecumseh Sherman (1820-1891) ordered his soldiers to gather large specimens of "stone trees." They collected two petrified trunks, each 11 feet long and 3 feet in diameter, and shipped them to the Smithsonian Institution in Washington D.C., where they were displayed for many decades. Several years later, when passenger rail service reached northern Arizona, the so-called "Petrified Forest" became a major tourist destination. One of its top attractions was the "Stone Tree House," a multiroom dwelling that had been built entirely from petrified wood by Ancestral Puebloans around 1100 A.D. Arizona's Petrified Forest became a national monument in 1906, then a national park in 1962. The park has long been known for its "Curse of the Petrified Forest." Although unauthorized collection of petrified wood is illegal, park rangers estimate that tourists take home 12-14 tons of "souvenirs" each year. But after pilfering petrified-wood specimens, many individuals have suffered a decline in their personal welfare and fortunes. Hundreds of stolen specimens are now anonymously returned to the National Park Service each year by those hoping to remove the "curse."

Petrified wood is the official state fossil of Arizona, North Dakota, Louisiana, and Mississippi, and the official state gem of Washington. Petrified wood was featured on the 85-franc stamp of Afars & Issas in 1974, the 2000-sucre stamp of Ecuador in 1997, the 70-cent stamp of Kenya in 1997, and the 10-cent stamp of the United States in 1974.

Petrified wood occupies a prominent place in modern metaphysical lore, largely because of its connection to living trees. With branches reaching high toward the heavens and roots set firmly in the Earth, trees are thought to be the wisest and most balanced of all living things. Petrified wood is considered a source of ancient, stabilizing energy that connects with nature, imparts longevity, and provides the power, wisdom, and patience needed to maintain spirituality in the everyday, physical world.

THE PROCESSES OF FOSSILIZATION

Petrified wood is a material that varies in the eye of the beholder. To some it is an unusual form of quartz, to others it is a gemstone or decorative stone. Still others see petrified wood, first and foremost, as the most beautiful of all fossils. Fossils are defined as the remains or traces of prehistoric plants and animals that have been buried in sedimentary rock or trapped in organic matter and preserved through various natural processes. Fossils are records of life forms over a huge span of geological time, ranging from 3.5-billion-year-old traces of microscopic cyanobacteria (blue-green algae) to 10,000-year-old remains of Pleistocene ice-age life forms. Petrified wood has been preserved through a replacement/petrifaction process that is only one of several fossilization processes. Exactly how organisms become fossilized depends on their particular biochemistry and the chemistry of their environment. Along with replacement/petrifaction, other important fossilization processes include the distillation of volatile materials, recrystallization, organic trapping, and molding and casting.

Replacement/petrifaction, the process that created our 225-million-year-old petrified-wood specimens, is a common method of fossilization and is described in "Composition" and "About our Specimens." Very basically, this process occurs when mineral-rich solutions fill organic cells and crystallize (petrifaction) or crystallize in the space left by the removal of organic material (replacement). Petrified wood and fossilized bones are common examples of this fossilization process. Although most petrified organic materials consist of silica, other replacement minerals include pyrite [iron disulfide, FeS_2], calcite [calcium carbonate, $CaCO_3$], gypsum [hydrous calcium sulfate, $CaSO_4·2H_2O$], and carnotite [hydrous potassium vanadium uranate, $K(UO_2)_2(VO_4)_2·3H_2O$]. The mineraloid opal [hydrous silicon dioxide, $SiO_2·nH_2O$] is the fossilizing agent in "opalized wood," a type of petrified wood.

Carbonization is a fossilization process that occurs through the physical and chemical alteration of organic plant and insect material. The volatile hydrocarbon compounds in organic matter are distilled and driven off by the heat and pressure of burial, leaving behind only a chemically stable, carbon film in the shape of the original organism. Stems and leaves are commonly preserved in this manner, often in such detail that structures of the original cells remain visible. Carbonization can produce visually striking fossils, with jet-black, carbonized plant or insect parts contrasting sharply against light-colored, rock matrices. The coalification process, in which massive plant remains are carbonized into coal, sometimes preserves entire tree trunks by reducing them to elemental carbon while retaining their original shapes.

Recrystallization, another method of fossilization, occurs through the chemical alteration of shell material and sometimes of bone. Many shells consist of aragonite [calcium carbonate, $CaCO_3$, orthorhombic], a polymorphic form of calcium carbonate that breaks down over millions of years. Aragonite sometimes converts to more chemically stable calcite [calcium carbonate, $CaCO_3$, trigonal]. Although this recrystallization destroys the microscopic details of the shell, it retains the overall shape. In most preserved shells older than 200 million years, the original aragonite has converted entirely to calcite.

Organic trapping is an unusual fossilization process in which organisms become trapped and preserved in tree sap, natural asphalt, or peat (decaying organic matter). Amber is fossilized tree sap that has been chemically altered through polymerization, a process that desiccates any trapped organic matter such as insects, pollen, and leaves, thus preserving them for millions of years in exquisite detail. Another fossilization medium is natural asphalt or tar, an oil residue that seeps to the surface from lower deposits. Animals that become trapped in surface tar pits, such as those at Rancho La Brea in Los Angeles, fossilize because the encapsulating asphalt creates an anaerobic, desiccating environment. Another fossilization medium is peat, a low-grade form of coal, in which high levels of acidity prevent the normal decay of organic matter.

Molds and casts also preserve the shapes or traces of various life forms. Acidic solutions can sometimes dissolve an animal's shell or skeletal features, leaving behind the space that the shell or bone occupied. This space can function as a mold and fill with sediments that later lithify (turn to rock) into casts in the shape of the original remains. Tracks and trails are often preserved in this manner. When animals walk through soft sediments, their feet and tails can leave impressions that later harden and lithify into molds. In turn, these molds can fill with sediments that lithify into casts of the original impression, as is the case with most known dinosaur tracks.

TECHNOLOGICAL USES

Anthropologists believe that the greatest technological advancement of prehistory was learning to create durable, sharp knives, scrapers, axes, and projectile points from stone. Chalcedony, including petrified wood, with its abundance, durability, hardness, and conchoidal fracture, was a near-perfect stone-working medium. For thousands of years, from Paleolithic through the Neolithic periods of the stone ages, chalcedony was a vital mineral resource and a major trading commodity.

Petrified wood has been synthesized in laboratories. Small cubes of pine are first immersed in acid baths to carbonize the wood, then soaked in silica solutions, and finally heated to 1400° C. (2552° F.) in an inert atmosphere of argon (elemental gas, Ar). This produces a solid, silicon-carbide, ceramic material that replicates the overall shape and cellular structure of the original wood.

ABOUT OUR SPECIMENS

Our petrified-wood specimens were collected near Morondava in the Menabe Region of the Republic of Madagascar. (On older maps, Morondava appears as part of Toliara Province. In 2009, national redistricting replaced Madagascar's original six provinces with 22 newly designated regions.) Madagascar occupies an island in the Indian Ocean 400 miles off Africa's east coast. It is 800 miles long in a north-south direction and roughly 250 miles wide. Covering 226,656 square miles, Madagascar is nearly the size of the state of Texas. It is the largest island nation and fourth largest island in the world. With a tropical climate tempered by the Indian Ocean and widely varying elevations, Madagascar's ecological zones range from tropical rain forests and savannah woodlands to grasslands and semiarid deserts.

Most of Madagascar's population of 20 million is made up of African and Arab ethnic groups. British and French colonists established coffee and vanilla plantations in Madagascar in the mid-1800s. France made Madagascar a protectorate in 1885 and a colony in 1896 before finally granting it independence in 1960. Since then, Madagascar has been plagued by corruption and ethnic conflict and its governments have endured several rebellions. Madagascar is one of the world's poorest nations. More than 80 percent of the national workforce is employed in agriculture. Although the island is rich in minerals, mining is currently limited to ilmenite [iron titanium oxide, $FeTiO_3$], rutile [titanium oxide, TiO_2], chromite [iron chromium oxide, $FeCr_2O_4$], and a variety of gemstones and decorative stones, including petrified wood.

Our petrified-wood specimens were collected near Morondava, a seaport town of 70,000 residents on Madagascar's southwestern coast 220 air miles southwest of the national capital of

Antananarivo. Fishing and farming of corn, cotton, cassava, and sugar support the local economy, while ecotourism is steadily growing in importance. Morondava is known for its "Avenue of the Baobabs," a road lined with 800-year-old baobab trees. As the original forests were cut, only these rows of baobab trees were spared for religious reasons. With massive, cylindrical trunks and oddly flat, leafy crowns, the 100-foot-high baobabs are among the most distinctive and primitive-looking of all extant trees.

The origins of both Madagascar and our petrified-wood specimens are linked to tectonics, the movement and interaction of crustal plates. Madagascar was once part of Gondwanaland, an ancient supercontinent that began breaking up 160 million years ago with the formation of two large rifts or separations in the Earth's crust. After the Mozambique Channel Rift separated Madagascar from Africa on the west, the spreading Mid-Indian Ridge then distanced it from the Indian subcontinent to the northeast. Geologists consider Madagascar to be part of the African Plate.

During the Triassic Period some 220 million years ago, the site of Morondava was covered with dense forests of giant coniferous trees of the gymnosperm genus *Aruacaria*. The Madagascar sub-plate then separated into rifts, with crustal subsidence forming deep basins. Sediments from the surrounding highlands quickly filled the Morondava Basin, burying the *Aruacaria* forests in an anaerobic (oxygen-free or oxygen–deficient) environment that preserved tree features by inhibiting normal, aerobic decay. Meanwhile, groundwater rich in silica circulated through the buried tree trunks, dissolving and removing cellulose and other organic matter, and replacing it with chalcedony. Relatively recent erosion has exposed this buried forest of petrified trees on the semiarid, desert grasslands east of present-day Morondava. Although fragments of petrified tree trunks are found on the surface, most of the petrified wood is buried in iron-rich, reddish soil and is recovered by the manual digging of shallow trenches.

Petrified wood from Morondava received international attention in 2009 when former Madagascar president Marc Ravalomananan (1949-) brought a special gift to the United Nations at its headquarters in New York City—a beautifully preserved and polished, two-foot-long, 18-inch-diameter section of a petrified log. Ravalomananan personally presented this spectacular display piece to United Nations Secretary-General Kofi Annan (1938-), who wryly commented, "This is one thing the Chinese haven't copied yet."

Our petrified-wood specimens were collected by Madagascar Minerals, a subsidiary of the American-owned Norcross-Madagascar Minerals Group, a vertically integrated company that mines, processes, and markets Madagascar gemstones, ornamental stones, and mineral specimens. With 22 years of experience in Madagascar, the company leases numerous mine and quarry properties and explores for new deposits. Some of its mine production is sold as cutting rough and specimens; most, however, is processed into faceted gems, cabochons, beads, spheres, figurines, tiles, free-form carvings, and other objects at the company facility in Antananarivo, then marketed internationally.

Your petrified wood specimen is a cross section of a solid, petrified log. One side of the specimen is polished, which brings out color and patterns; the other is a rough-cut surface. Notice how the exceedingly fine and compact grain of the chalcedony has maximized preservation of details and taken a very fine polish. These specimens exhibit structures and patterns of the external bark, along with the cambrium or "inner bark" layer and the xylem or "wood" that comprises the bulk of the tree trunk. In most specimens, individual, annual growth rings or groups of rings can be identified. In some specimens, the darker pith that formed the original, central core of the tree trunk can also be identified. The basic color of Morondava petrified wood is brown, ranging from light tans to deep, mahogany-browns. Within this generally brown matrix are many other colors, including red, orange, yellow, blue, and off-white. Some small sections will actually appear colorless and transparent. Iron and manganese oxides are the primary chromophores in our specimens. Iron creates the brown, yellow, and deep-red colors, while manganese creates yellowish-black, pinkish, and orange colors. Your specimen is gem quality and could be cut and polished into cabochons and beads and various decorative objects. Your petrified-wood specimen is a 225-million-year old souvenir of Madagascar—now one of the world's leading gemstone sources.

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Company; *2008 Fleischer's Glossary of Mineralogical Species*, J. A. Mandarino and Malcolm E. Back; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Company; *Gems and Jewelry*, Joel Arem, Geoscience Press, 1991; *Gemstones of the World*, Walter Schumann, Sterling Publishing Company, 1997; *The Complete Guide to Rocks & Minerals*, John Farndon, Hermes House, 2007; *The Mystical Lore of Precious Stones*, George Frederick Kunz, Newcastle Publishing Co. (reprint), 1986; "The Mineral Industry of Madagascar," Thomas R. Yager, *2011 Minerals Yearbook*, United States Geological Survey; *Madagascar: A Mineral and Gemstone Paradise*, Federico Pezzotta, Lapis International, 2001; "Gemstones," Donald W. Olson, *2009 Minerals Yearbook*, United States Geological Survey; "Madagascar Gems: Gemstones in the Jungle Bring Both Riches and Chaos," Burkhard Bilger, *The New Yorker*, October 2, 2006; *The World of Fossilized Wood, Cones, Ferns, and Cycads*, F. Daniels, Western Colorado Publishing Company, 1998; *Ancient Forests: A Closer Look at Petrified Wood*, F. Daniels and R. Dayvault, Western Colorado Publishing Company, 2006.

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