Mineral of the Month Club October 2016

QUARTZ var. AGATE (NODULE)

Distinctive multicoloration and banding make this month's mineral—the agate subvariety of microcrystalline quartz (chalcedony)—one of the world's most recognizable gemstones. Our agate-nodule specimens were collected, cut, and polished in Soledade, Brazil, the world's leading source of gem-quality agate.

OVERVIEW

PHYSICAL PROPERTIES:
Chemistry: SiO_2 Silicon Dioxide, often containing small amounts of iron and manganese.
Class: Silicates
Subclass: Tectosilicates (Framework Silicates)
Group: Quartz
Subgroup: Microcrystalline Quartz (Chalcedony)
Crystal System: Hexagonal
Crystal Habits: The agate subvariety of microcrystalline quartz occurs in massive form as nodules, veinlets, and geode linings.
Color: Red, pink, orange, yellow, green, blue, bluish-gray, gray, white, brown, and black; agate bands, layers, and inclusions are usually multicolored.
Luster: Vitreous and waxy to dull
Transparency: Translucent
Streak: White
Refractive Index: 1.544-1.553
Cleavage: None
Fracture and Tenacity: Conchoidal to subconchoidal and irregular; brittle to tough.
Hardness: Quartz has a Mohs hardness of 7.0; agate is slightly softer at Mohs 6.5-7.0.
Specific Gravity: 2.62-2.65
Luminescence: Agate often fluoresces yellow or bluish-white; fluorescence color and intensity vary among individual layers.
Distinctive Features and Tests: Agate is difficult to confuse with other minerals or mineral varieties. Best field marks are translucency; microcrystalline structure; multicolored banding, layers, or inclusions; wide range of colors; hardness; relatively low specific gravity; and occurrence in volcanic environments.
Dana Classification Number: 75.1.3.1

NAME: The word "agate," pronounced AAH-get (rhymes with "tag it"), stems from *Achatēs*, the ancient Greek name for the Dirillo River on Italy's island of Sicily, a former source of the stone. Agate's many different names are based mainly on its visual appearance ("lace agate," "iris agate," etc.) or source ("Botswana agate," "Fairburn agate," etc.) In European mineralogical literature, agate appears as *agaat*, *Achat*, and *agata.*

COMPOSITION & STRUCTURE: Quartz occurs in two basic forms: macrocrystalline and microcrystalline. Microcrystalline quartz or chalcedony is made up of interlocked, microscopic silica grains or fibrous silica crystals and includes the jasper, chert, flint, and agate subvarieties. Quartz consists of 53.26 percent oxygen (O) and 46.74 percent silicon (Si). Silicon and oxygen, the most abundant elements in the Earth's crust, together comprise three-quarters of the total crustal weight. Quartz is a member of the silicates, the largest of all mineral classes; silicate minerals account for 92 percent of the crustal weight. In the silica tetrahedron $(SiO_4)^{4-}$, the fundamental building block of all silicates, four equally spaced oxygen ions $4O^{2-}$ positioned at the four corners of a tetrahedron (a four-faced polyhedron) surround and are bonded to a single silicon ion Si^{4+}. Quartz is present in virtually all igneous, metamorphic, and sedimentary rocks. Quartz is an allochromatic (other-colored) mineral with colors caused by traces of nonessential, color-producing elements called chromophores. Pure quartz is colorless, but various impurities create a wide range of colors. The microcrystalline variety of quartz is formed from silica that weathered free from silicate minerals and was transported as microscopic particles by groundwater. In the low temperatures and low pressures of shallow mineralogical environments, these silica-rich solutions crystallized into chalcedony composed of interlocking, microscopic grains and crystals. Agate is believed to have formed from silica-rich solutions that, prior to solidification, transformed into thick, colloidal suspensions called "silica gels." Agate occurs as nodules, veinlets, and geode linings in volcanic rocks.

COLLECTING LOCALITIES: Notable sources of the agate subvariety of microcrystalline quartz are located in Brazil, Uruguay, Scotland, Poland, Germany, Japan, China, India, Australia, Angola, Nigeria, Egypt, Tanzania, Mexico, Cuba, Canada, and the United States (Oregon, South Dakota, Nebraska, Colorado, Montana, California, Florida, Rhode Island, Tennessee, and New Jersey).

HISTORY, LORE & GEMSTONE/TECHNOLOGICAL USES: With its translucency, attractive banding patterns, multicoloration, durability, and excellent hardness (Mohs 6.5-7.0), agate is the world's most popular gemstone. It is easy to work with and can be carved in great detail; with its microscopic grain, it can also be polished to a high luster. Because of its relative abundance, the gem and decorative forms of agate are quite affordable. Each agate gem, slab, or specimen is unique; no two pieces of agate have identical colors and patterns, even when cut from the same rough. Agate is often color-enhanced. More than half the agate sold today, especially the lower-priced display pieces and slabs, has been color-enhanced by immersion in solutions containing organic dyes or the chemical salts of iron, nickel, manganese, chromium, cobalt, and copper. Natural agate tends to have earthy, subdued colors. Agate slabs, gems, or decorative items that exhibit vivid, "electric" hues of reds, pinks, yellows, blues, or greens have almost certainly been color-enhanced. Because of their abundance, hardness, and tendency to fracture conchoidally, agate and the other subvarieties of microcrystalline quartz have been flaked into projectile points since Paleolithic times. According to modern metaphysical practitioners, agate enhances one's ability to discern truth, accept circumstances, recall the past, and focus mental energies. Agate is an alternate birthstone for September, the astrological birthstone for Gemini, and the suggested gift gem for the 12th wedding anniversary. Nine states claim agate as their official gemstone, mineral, or rock.

ABOUT OUR SPECIMENS: Our agate-nodule specimens were collected near the city of Soledade (pronounced so-la-DAH-gee) in the Brazilian state of Rio Grande do Sul. As Brazil's southernmost state, Rio Grande do Sul borders the nations of Uruguay and Argentina. German settlers arriving in the Soledade region in the 1820s found numerous agate nodules in the local soils and in outcrops of volcanic rock, and soon began shipping large quantities of these nodules to the gem-cutting center of Idar-Oberstein, Germany. In the early 1900s, Soledade established its own gem-cutting industry. Today, gemstone mining and processing has become so important to the local economy that Soledade's nickname is *Cidade do Pedras Preciosas* or "City of Precious Stones." Soledade, now the world's largest source of rough and worked agate, is located near the center of a massive formation of volcanic rock that covers most of Rio Grande do Sul and adjacent areas of Uruguay and Argentina. When this lava solidified some 135 million years ago, gas bubbles formed cavities that later filled with silica-rich solutions. These solutions transformed into thick silica gels that subsequently solidified into agate nodules. While small quantities of agate nodules are still found on the surface, most commercial collectors now use pneumatic drills and homemade black powder to drive underground drifts through weathered formations of rhyolite and basalt to extract in situ agate nodules. These nodules are trucked to Soledade and sold to dozens of local gemstone cutting-and-polishing factories that export an estimated 3,000 tons of agate slabs, specimens, gems, and decorative items each year.

COMPREHENSIVE WRITE-UP

COMPOSITION & STRUCTURE

This month our featured mineral is the agate subvariety of microcrystalline quartz or chalcedony. Quartz occurs in two basic forms: macrocrystalline and microcrystalline. Macrocrystalline quartz forms large, transparent-to-translucent, individual crystals or crystal groups and includes the amethyst, rock-crystal, milky-quartz, and smoky-quartz subvarieties. Microcrystalline quartz or chalcedony occurs in massive form as silica grains or fibrous crystals and includes the jasper, chert, flint, and agate subvarieties. Unlike other forms of chalcedony, agate exhibits translucency and multicolored patterns of bands, layers, or inclusions.

As indicated by the chemical formula SiO_2, quartz contains two elements, the semimetal silicon (Si) and oxygen (O). Its molecular weight is comprised of 53.26 percent oxygen and 46.74 percent silicon. All molecules, including those of quartz, are made up of cations (positively charged ions) and anions (negatively charged ions). The cation in the quartz molecule is the silicon ion Si^{4+} with its +4 charge. The quartz anion consists of two oxygen ions $2O^{2-}$ with a collective -4 charge. The balance of the +4 cationic charge and the -4 anionic charge provides the quartz molecule with electrical stability.

Quartz is a member of the silicates, the largest of all mineral classes. Silicon and oxygen, the most abundant elements in the Earth's crust, together make up three-quarters of the total crustal weight. Quartz and the many other silicate minerals together account for 92 percent of the total crustal weight. Quartz occurs in virtually all igneous, metamorphic, and sedimentary rocks. The silica tetrahedron $(SiO_4)^{4-}$, the fundamental building block of all silicate minerals, consists of four equally spaced oxygen ions $4O^{2-}$ positioned at the four corners of a tetrahedron (a four-faced polyhedron) that surround and covalently bond to a single silicon ion Si^{4+}. In the quartz-crystal lattice, all four oxygen ions in each silica tetrahedron also bond covalently to the silicon ions of adjacent tetrahedra. In the quartz lattice, each silicon ion is thus surrounded by four oxygen ions, and each oxygen ion by two silicon ions. This arrangement satisfies the -4 charge of each individual tetrahedron to create an infinite, three-dimensional structure in which molecular units are described by the formula SiO_2. In silicate minerals, silica anions bond with metallic or semimetallic cations in repeating chains to form seven structural configurations: 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 silicate or tectosilicate.

Because the covalent bonding within the quartz lattice exerts omnidirectional strength, quartz crystals have no centers of symmetry or cleavage planes. The absence of cleavage and the high bonding strength derived from close atomic packing explain quartz's substantial hardness of Mohs 7.0 (6.5-7.0 for agate). Despite this close atomic packing, the relatively light atomic weights of silicon (28.09) and oxygen (16.00) give quartz a low specific gravity of 2.65 (2.62-2.65 for agate). Because of its microcrystalline nature and tendency to often incorporate nonessential elements and minerals, chalcedony lacks the compositional and structural homogeneity of macrocrystalline quartz. With its homogenous crystal structure and greater purity, macrocrystalline quartz is transparent to translucent, while chalcedony is always translucent or opaque.

Unlike macrocrystalline quartz, which grows by adding silica molecules to its surface, chalcedony forms from silica that has weathered free from silicate minerals and transported by groundwater as microscopic particles (see "All About Agate"). In the low temperatures and pressures of shallow mineralogical environments, these silica-rich solutions crystallized into chalcedony composed of interlocking, microscopic grains and crystals. Agate formed from silica-rich solutions prior to solidification transformed into thick, colloidal suspensions called silica gels. Agate usually occurs as nodules, veinlets, and geode linings in silica-rich, volcanic rocks. Such chalcedonic subvarieties as flint, chert, and jasper occur in sedimentary formations, while less-abundant agate occurs almost exclusively in silica-rich, volcanic rocks.

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

Quartz is an allochromatic (other-colored) mineral with colors caused by traces of nonessential, color-producing elements called chromophores. Pure quartz is colorless, but various impurities create a wide range of colors.

COLLECTING LOCALITIES

Our agate-nodule specimens were collected near Soledade in Rio Grande do Sul, Brazil. Other regional agate sources include the volcanic formations and river gravels near Iguaçú Falls at Foz do Iguaçú, Paraná, Brazil; and the Quarai River gravels at Artigas, Artigas Department, Uruguay.

In Europe, agate is collected at Scurdle Ness at Lunan Bay at Blue Hole and at Todd's Hole near Montrose, both in Angus, Scotland; the Regulice area near Kraków, Malopolskie, Poland; and the Ruchlitz and Kohren-Salls areas of Saxony and the Nahe River quarries at Idar-Oberstein in Rheinland-Phalz, both in Germany. Other sources include Chinkobe, Hiyama Province, Hokkaido, Japan; the Yangtze River gravels at Nanjing, Jiangzu Province, China; and Rajpipla near Gujarat, Maharashtra, India. Australian agate comes from Agate Creek near Georgetown, Queensland; and from Boggabri, Pottinger County, New South Wales. African agate is found at M'banza Congo, Zaire Province, Angola; the Llorin area of Nigeria; the Nile River gravels and Red Sea beaches in Egypt; and the Mtwara region of southeastern Tanzania. Additional sources include Isla de Santa Catalina, Baja California Sur, Mexico; and Bayate, Guantánamo Province, Cuba. In Canada, agate is found at Troitsa Peak and Eagle Creek in the Whitesall Range in the Omenica Mining Division and on the Vancouver Island beaches, both in British Columbia; the north shore of Lake Superior in Ontario; and the basalt cliffs along the Bay of Fundy, Nova Scotia.

In the United States, agate is collected at Grants Pass, Lake Owyhee, Biggs Junction, the Rogue River, and the Madras thunder-egg beds in Jefferson County, Oregon; the Fairburn agate beds near Fairburn, Pennington County, South Dakota; Ashland in Saunders County and Bayard in Morrill County, Nebraska; the Twin Mountains geode field, Rio Grande County, Colorado; and the Bighorn River and Pryor Mountains in Big Horn County and the Yellowstone River gravels in Treasure, Rosebud, Custer, and Prairie counties, all in Montana. California sources include East Park Reservoir at Stonyford, Colusa County; the Black River Quarry at Renton, King County; the Hauser geode beds at Wiley Well, Riverside County; and Pisgah Crater at Ludlow in San Bernadino County. Other sources are Ballast Point in Tampa Bay, Hillsborough County, Florida; Diamond Hill at Cumberland, Providence County, Rhode Island; and the Silvertooth agate fields at Horse Mountain, Bedford County, Tennessee. In New Jersey, agate occurs at the Francisco Brothers' Quarry, Little Falls Township, Passaic County; the Chimney Rock quarries, Bridgewater Township, Somerset County; and McDowell's Quarry, Upper Montclair, Essex County.

JEWELRY & DECORATIVE USES

Translucency and attractive, multicolored banding make agate the world's most popular gemstone. With excellent hardness (Mohs 6.5-7.0) and durability, agate gems can easily stand up to daily wear in jewelry. Easily workable, agate can be carved in great detail; its microscopic grain enables it to be polished to a high luster. Because agate is relatively abundant, its gem and decorative forms are quite affordable. Each agate gem, slab, or specimen is unique; no two pieces of agate have identical colors or patterns, even when cut from the same rough.

Agate is fashioned into a broad array of gems and decorative items. Because of its translucency, agate is not faceted, but is instead cut into cabochons with flat or slightly convex surfaces that are oriented to display banding-pattern cross sections. Cabochons are mounted in silver and usually worn in belt buckles, bolo ties, and pendants. Agate is cut parallel to its banding patterns only when fashioning cameos, in which selective grinding exposes two or more differently colored, adjacent bands. Agate prices vary widely. Most cabochons made of lower-grade or medium-grade agate are inexpensive. Top-quality agate with distinctive colors and well-defined banding is more costly; the highest quality agate is sometimes even sold by the carat. In recent decades, agate has acquired a "western" image and is often combined with turquoise, red coral, and shell in "Indian"-style jewelry. Agate is also cut and tumbled into beads for wear in bracelets and necklaces.

Agate nodules are usually cut in halves or sections and polished for use as display pieces, bookends, and paperweights. Most agate, however, is cut into thin slabs of varying sizes and polished to display its translucency, colors, and patterns, or used as panels for Tiffany-style lamp shades and stained-glass creations. Small, inexpensive agate slabs are high-volume items in rock shops and souvenir shops; large slabs measuring a foot or two in diameter with unusually bright, natural colors and distinctive patterns sell for thousands of dollars in upscale galleries.

Because most natural agate tends to have earthy, subdued colors, it is often artificially color-enhanced. More than half the agate sold today, especially low- and medium-priced display pieces and slabs, has been color-enhanced by immersion in solutions containing organic dyes or the chemical salts of iron, nickel, manganese, chromium, cobalt, and copper. Because agate's degree of porosity varies among its individual bands, selective or repetitive dying can produce slabs with a rainbow of intense colors. Agate slabs that exhibit vivid, "electric" hues of reds, pinks, yellows, blues, or greens have almost certainly been color-enhanced.

HISTORY & LORE

Paleolithic cultural sites have yielded crudely polished agate amulets more than 20,000 years old and agate projectile points more than 100,000 years old. The ancient Egyptians fashioned agate into engraved amulets, cylinder seals, and intaglios, while Hindus believed that agate protected children from fear. The Greek philosopher and naturalist Theophrastus (circa 372-287 B.C.) named agate *achatēs*, after the Achatēs River (now the Dirillo River) on Italy's island of Sicily, a former source of the stone. Medieval Europeans believed that agate ensured good crops, cured insomnia, calmed electrical storms, and brought general good fortune; physicians of that era prescribed wearing agate amulets or ingesting finely powdered agate to treat skin diseases, enhance fertility, protect bone marrow from diseases, alleviate the effects of allergies, and keep the blood healthy.

Around 1450 A.D., the word *achates* passed into German as "*achat*," which was anglicized to "agate" a century later. By 1500 A.D., the agate gems and decorative items produced by the stonecutters of Idar-Oberstein in Rheinland-Phalz, Germany, had become popular trading commodities throughout Europe. Working with a plentiful supply of deeply colored, brownish-red agate from the Nahe River Valley river gravels, German stonecutters developed advanced cutting-and-polishing methods using sandstone wheels powered by waterwheels in the Nahe River. When global trade expanded dramatically in the late 1500s, Idar-Oberstein became the world's leading stonecutting center. By 1700, dozens of Idar-Oberstein stonecutting factories were exporting large quantities of agate beads, cabochons, cameos, pendants, vases, goblets, and bowls.

By 1800, Idar-Oberstein had fallen on hard times with depletion of the Nahe River agate deposits. But the city rebounded in the 1820s when it began receiving shipments of high-quality agate from Germans immigrants in Rio Grande do Sul, Brazil. Because the Brazilian agate lacked the deep, reddish colors of the Nahe River material, Idar-Oberstein stonecutters developed mass-chemical-dying methods to impart colors of unprecedented variety and brilliance. By 1860, more than 100 small factories and shops in Idar-Oberstein were dying, cutting, and polishing Brazilian agate. After 1900, Idar-Oberstein's fortunes again faded as widespread electrification decentralized the stonecutting industry. Today Idar-Oberstein has regained its status as an important stonecutting center, processing agate and other gemstones from around the world. However, the volume of its finished agate is now much smaller than that of Soledade, Brazil (see "About Our Specimens").

Modern metaphysical practitioners believe that agate enhances one's ability to discern truth, accept circumstances, recall the past, and focus mental energies. Agate is an alternate birthstone for September, the astrological birthstone for Gemini, and the suggested gift gemstone for the 12^{th} wedding anniversary. Nine states claim agate as their official gemstone, mineral, or rock. By state and agate type, these are: Arizona, fire agate; Kentucky, yellow-and-blue, fortification agate; Louisiana and Tennessee, agate; Minnesota, Lake Superior agate; Montana, moss agate; Nebraska, blue agate; Oregon, agate-filled thunder eggs (geodes); and South Dakota, Fairburn agate.

Agate has been featured on Algeria's 1.20-dinar postage stamp of 1983, Armenia's 250-dram stamp of 1998, Australia's 7-cent stamp of 1973, Bulgaria's 1-lev stamp of 1995, Czechoslovakia's 80-halura stamp of 1968, the French Southern and Antarctic Territories' 0.15-franc stamp of 2005, the German Democratic Republic's (formerly East Germany) 70-pfennige stamp of 1974 and 25-pfennige stamp of 1978, Kenya's 1.50-shilling stamp of 1977, Malawi's 5-

tambala stamp of 1980, New Zealand's 2-cent stamp of 1982, Switzerland's 10-centime stamp of 1959, Uruguay's 5-peso stamp of 1972, and the United States' 10-cent stamp of 1974.

TECHNOLOGICAL USES

Because of abundance, durability, hardness, and a tendency to fracture conchoidally, the flint, chert, and jasper varieties of chalcedony, and to a lesser extent the agate variety, have been flaked into projectile points and tools since Paleolithic times.

ALL ABOUT AGATE

In the mid-1800s, scientists proposed two general theories to explain the origin of agate and its banding patterns. One postulated that silica-rich solutions filled cavities in volcanic rocks where they sequentially precipitated microcrystalline silica in repetitive, multicolored bands and layers. The other suggested that cavities contained thick silica gels that separated into multicolored bands or layers that, with further cooling, solidified more-or-less simultaneously into agate. The "gel" theory has prevailed, but the inability to fully explain the original source of the silica, the exact method and duration of band formation, and the causes of banding distortions has made agate genesis the subject of an ongoing scientific debate.

Researchers now agree that agate genesis begins in hollow cavities within a suitable host rock, usually high-silica, extrusive (volcanic) igneous rocks such as rhyolite, andesite, and certain types of basalt. These cavities form when frothy lavas flood onto the surface to cool quickly and trap gas bubbles; the cavities are initially devoid of any mineralization.

Agate begins to form when impure, aqueous silica solutions circulate through the host rock, fill the cavities, and coagulate into thick gels. These gels react with the cavity walls, forming thin coatings of greenish-brown celadonite [basic potassium iron magnesium silicate, $KFe^{3+}(Mg,Fe^{2+})Si_4O_{10}(OH)_2$], aragonite [calcium carbonate, $CaCO_3$], and the zeolite-mineral stilbite-(Ca) [hydrous sodium calcium aluminum silicate, $NaCa_4(Al_9Si_{27}O_{72})\cdot 28H_2O$]. These coatings, consisting mostly of celadonite, form the exterior walls of agate nodules and, during weathering or mining, help to separate the nodules from the host rock. The silica gels next precipitate a layer of grayish-white chalcedony on the celadonite layer, sealing the cavity and creating a partially closed system. Although pressure within the host rock can force new solutions into the cavities, the silica gels that are already trapped cannot escape. Based on to differences in chemical composition, density, and temperature, the trapped silica gels then separate into bands of various colors. Finally, with decreasing temperatures, the banded gels solidify into agate. Cavities that are completely filled with silica gel form solid agate nodules; partially filled cavities form hollow agate nodules with center voids lined with drusy coatings of macrocrystalline quartz that is usually colorless or purple (amethyst).

The thickness, color, and color intensity of agate bands are determined by temperature, pressure, chemistry, the presence or absence of impurities, pH level, and saturation level of the silica gels at the time of solidification. Because these factors are usually interrelated, the resulting combinations of colors and patterns are limitless, thus making every agate unique. While the silica gels are still in a plastic state prior to solidification, the bands often become deformed. Solid impurities can act as “seeds” to facilitate the growth of secondary, circular banding patterns, such as those seen in “eye agate.” Other conditions can create thin bands with alternating micro- and macrocrystalline characteristics that diffract light to create the iridescent effect of “iris agate.” Internal pressure can also deform the bands. When internal cavity pressure exceeds that of the surrounding host rock, the silica gels attempt to relieve the pressure by moving toward the weakest points of the cavity wall. This “pushes” the gel bands outward at different points to create “fortification” agate with bands in the distinctive shapes of the outlines of medieval fortresses.

Agate colors are most often shades of red or blue, with reds ranging from pale pinks and oranges to brick-reds and brownish-reds, and blues ranging from bluish-grays to nearly black. These colors are caused by ferrous (Fe^{2+}) and ferric (Fe^{3+}) iron chromophores. Traces of manganese and nickel oxides produce such rarer agate colors as yellows and greens. White bands consist of nearly pure silica that is devoid of any chromophores.

The limitless range of agate patterns and colors is reflected in agate’s hundreds of variety, trade, and scientific names that are based on color, patterns, sources, and light-reflectance properties, along with inclusions and patterns that resemble familiar images. Some major agate types with their descriptive names and identifying characteristics include:

Blue-lace agate: lacy, light-blue bands;
Botswana agate: parallel pink-and-white bands, from Botswana;
Crazy-lace agate: sharply twisting-and-turning, multicolored bands;
Condor agate: brightly colored fortification agate, from Argentina;
Eye (orbicular) agate: numerous concentric, banded rings;
Fortification agate: band patterns resembling the outlines of medieval fortresses;
Fairburn agate: colorful fortification agate, from Fairburn, South Dakota;
Iris (rainbow) agate: multicolored iridescence;
Laguna agate: red-and-white banding, from Ojo Laguna, Chihuahua, Mexico;
Layer agate: parallel banding;
Onyx agate: straight, black-and-white, parallel bands of consistent thickness;
Star agate: star-like inclusions or banding;
Feather agate: bands of delicate, feather-like tufts.

Although the following types of agate lack distinctive banding, they exhibit unusual visual effects caused by manganese and iron inclusions or staining:

Plume agate: dark, feather-like inclusions of manganese and iron oxides;

Moss agate: moss-like inclusions of dark-green, hornblende-group minerals;
Scenic agate: “landscape”-like inclusions of manganese and iron oxides;
Fire agate: ferric and ferrous inclusions with a reddish iridescence;
Dendritic agate: tree-like or fern-like inclusions of black manganese oxides;
Cloud agate: cloud-like inclusions.

ABOUT OUR SPECIMENS

Our agate-nodule specimens were collected near Soledade (pronounced so-la-DAH-gee) in the Brazilian state of Rio Grande do Sul. Rio Grande do Sul is Brazil’s southernmost state and borders the state of Santa Catarina to the north, Argentina to the west, Uruguay to the south, and the Atlantic Ocean to the east. The state capital is Porto Alegre, a port city of 1.2 million residents on Lake Dos Patos, an inlet of the Atlantic Ocean. In the south of Rio Grande do Sul, grasslands support large ranches; in the north, subtropical pine forests cover broad plateaus of rolling hills. Soledade, elevation 2,000 feet, is located in the north-central part of the state, 150 miles northwest of Porto Alegre and 600 miles southwest of the coastal metropolis of Rio de Janeiro. Brazilian farmers and ranchers initially settled the Soledade region in the early 1800s. Soledade was organized as a municipality in 1875 and now has 30,000 residents and a mixed economy based on cattle ranching, farming, timber cutting, stone quarrying, and gemstone mining and processing.

German settlers arriving in the 1820s found large quantities of agate nodules in local soils and weathered lava outcrops. Aware that the German gem-cutting center of Idar-Oberstein had an urgent need for agate (see “History & Lore”), they collected the nodules and shipped them to Germany. Since then, gemstone mining and processing has become such an important part of the local economy that Soledade’s nickname is *Cidade do Pedras Preciosas* or “City of Precious Stones.”

Geologically, Soledade is located within a massive volcanic formation that covers most of Rio Grande do Sul and adjacent areas of Uruguay and Argentina. These formations of basalt and rhyolite were emplaced some 135 million years ago when huge flows of lava extruded onto the surface. Covering 463,000 square miles (an area twice the size of Texas) and a thickness of up to 3,000 feet, these rhyolite and basalt formations are second in size only to those of India’s Deccan Traps.

The first farmers in the Soledade region found agate nodules in their fields in such profusion that they sometimes interfered with plowing. Much of this agate was collected and shipped to Idar-Oberstein in the 1830s and 1840s. When the surface nodules were depleted, collectors began digging them from shallow pits. By the early 1900s, many agate collectors had turned to open-cut mining in which they drilled and blasted the weathered outcrops of rhyolite and basalt. Today, while agate nodules are still collected from the surface in a few areas, most miners use pneumatic drills and homemade black powder to drive short underground drifts through weathered outcrops of rhyolite and basalt to locate and extract in situ concentrations of nodules.

The agate nodules are recovered at widely scattered mines, trucked to Soledade, and sold to stonecutting factories. Soledade, now the world's largest source of agate, has more than 30 such factories, several employing as many as 50 workers. The Soledade factories ship an estimated 3,000 tons of rough and cut-and-polished agate to markets in North America, Europe, and Asia each year. Many factories maintain their own showrooms with huge inventories of rough and cut agate. The popular gem-and-mineral tours that bring groups of international visitors to Brazil's gemstone regions always include visits to Soledade. Most tours spend two full days in Soledade to allow visitors to explore the stonecutting factories and agate showrooms, and to shop for rough agate specimens and agate gemstones, slabs, and decorative items.

Your agate-nodule specimen from Soledade, Brazil, has been cut in half and polished to a high luster. The light-brownish crust on the exterior consists primarily of celadonite (see "All About Agate"). The "ropy" or "worm-like" texture of the nodule's exterior is a cast of the original cavity wall. Your nodule consists of translucent agate in black, white, and gray colors; it also exhibits various plume, feather, and fortification patterns. The color and patterns in your specimen represent the composition and banding of the silica gels that existed at the time of solidification. The gray and black colors are caused by varying concentrations of ferrous (Fe^{2+}) and ferric (Fe^{3+}) iron chromophores. The center cavity of your specimen is filled with a drusy coating of colorless, macrocrystalline quartz or rock crystal. Using a loupe, notice that each tiny quartz crystal consists of a terminated, hexagonal prism, which is the classic habit of macrocrystalline quartz. Notice also the tiny black, equant crystals or thin, flat, needle-like prisms that rest atop the drusy quartz. These are crystals of goethite [basic iron oxide, FeO(OH)]. The iron within the goethite is derived from the iron-rich, volcanic host rock in which your agate nodule formed.

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