THE ORIGIN OF AGATE

Of all the forms of chalcedony, or microcrystalline quartz, agate is the most beautiful and interesting because of its translucency, wide range of colors, and, most importantly, its distinctive, banding patterns.

The original theories of agate origin fell into two categories. One postulated that silica-rich solutions filled cavities in rocks to precipitate microcrystalline silica in repetitive, superposed bands and layers. According to the other theory, thickening lava containing masses of nearly pure silica eventually formed a gel. As the lava cooled, impurities within the gelatinous masses separated into bands that later crystallized into agate. The cavity theory has generally prevailed, but has been weakened by the inability to satisfactorily explain the original source of the silica, the exact method of band formation, and the causes of banding distortions.

Accordingly, agate genesis is the subject of continuing scientific debate. Current theory proposes states that the process begins with hollow cavities within a suitable host rock, usually a silica-rich, extrusive (volcanic) igneous rock. Cavities form when lava quickly solidifies into solid crusts that trap gas bubbles within the still-molten, underlying lava.

Agate then begins to form when impure, aqueous silica solutions seep through the host rock to fill cavities and coagulate into thick gels. Within the cavities, the silica solutions first react with the cavity walls, forming thin coatings of green-brown celadonite [basic potassium iron magnesium silicate, $KFe^{3+}(Mg,Fe^{2+})Si_4O_{10}(OH)_2$]. Celadonite makes up the exterior of all agate nodules and helps to separate the nodules from the host rock during weathering or mining.

Next, the silica solutions precipitate a thin layer of grayish-white chalcedony on the celadonite. Together, these two thin layers seal the cavity to create a closed or partially closed system. Although outside pressure in the host rock can sometimes force new solutions into the cavities, the trapped silica gels, because of their plastic consistency, cannot exit the cavities.

With increasing pressure, the trapped silica gel separates into bands according to differences in chemical composition, density, and temperature. Band formation progresses from the outside toward the center.

Slowly decreasing temperatures then cause the masses of trapped, banded silica gel to solidify into solid, microcrystalline quartz. Cavities that have been completely filled with silica gel form solid agate nodules with no hollow center. Partially filled cavities produce agate nodules with hollow centers (geodes) and interior walls that are covered with macrocrystalline quartz as either drusy coatings or large crystals.

Band formation in agate is a complex process in which band thickness and color are determined by combinations of temperature, pressure, chemistry, the presence of impurities, pH (acidity), and the saturation levels of the silica solutions. Because these factors are often interrelated, the resulting limitless variety of agate patterns and colors makes every agate unique.

While the silica gel is still in a plastic state, bands may become deformed. Solid impurities can act as “seeds” that facilitate the growth of surrounding, independent, banding-pattern systems that are known as “eye agate.” Certain conditions can even result in thin bands with alternating micro- and macrocrystalline characteristics that diffract light to create the iridescent effect in “iris agate.”

Pressure can also distort banding patterns. When internal cavity pressure exceeds that of the surrounding host rock, the silica gel attempts to equalize the pressure by moving toward the weakest point(s) of the cavity wall, an outward movement that distorts the bands. The tiny, hollow channels that often form in these outward-pointing band distortions are called “escape tubes.” Repetitive pressure distortions create “fortification agate” in which the banding patterns replicate the distinctive outline of medieval fortresses.

Most agate is colored some general shade of red or blue, with “reds” ranging from pale pink and orange to brick-red, and “blues” including everything from a spectrum of blues to gray and nearly black. Most of these colors are caused by ferrous (Fe^{2+}) and ferric (Fe^{3+}) iron chromophores (coloring agents). Traces of manganese and nickel oxides produce the rarer agate colors of green and yellow. Agate’s common white bands consist of nearly pure silica.

Mineralogists are continuing to study the origin of the silica solutions, the physical and chemical factors that govern banding formation, the nature of the triggering mechanisms that convert banded silica gel into solid agate, the precise purpose of “escape tubes,” and whether agate formation occurs contemporaneously with host-rock formation or, as most researchers now believe, over longer periods of time. Whatever the final conclusions may be, there is no question about the intricate and distinctive beauty of agate banding.

Steve Voynick

Steve has worked with the Mineral of the Month Club since 2002. As a former hardrock miner, he has mined Colorado molybdenum, Alaska gold, Arizona copper, and Wyoming uranium. Eight of his ten books deal with topics of minerals, mineral collecting, mining, and gemstones. He has written more than 1,000 articles and is a contributing editor and science columnist with *Rock & Gem* magazine. His work has also appeared in *The Mineralogical Record* and *Lapidary Journal*. He is a former member of the board of directors of the National Mining Hall of Fame & Museum