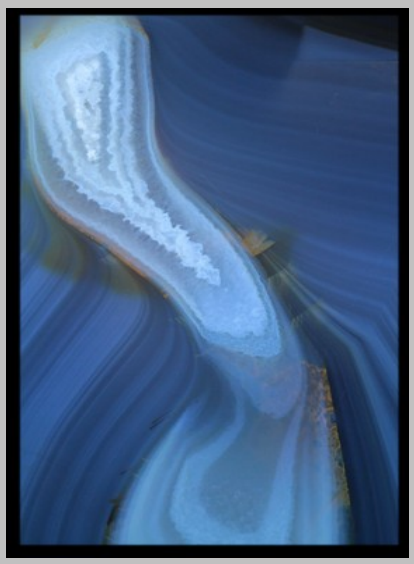
Agate Structures I:

Formation and Classification of Common Agate Structures.

Putting a Name on an Agate

So, now we have some basic classifications of agates – those formed in volcanic host rocks and those formed in sedimentary host rocks. Agates that form in pockets, massive seam agates, and vein agates that are planar in shape. Then there are the fossil and mineral replacement agates that take the shape of the structure replaced. To those basics, we can add whole arrays of identifiers; some descriptive of patterns like fortification and moss or plume. Other identifiers are based on location like 'Lake Superior', 'Death Valley', 'Bloody Basin'; and some are proprietary trademarked names like 'Prudent Man' and 'Royal Aztec Lace'.


Brazilian Agate

Some of the more common terms describing the appearance of agate are wall banded, water-level, onyx, shadow, lace, eye, moss, plume, dendritic, tube, drape, sagenite, pseudomorph, geode, flame, stalactite, floating, brecciated, and ruin. Even stringing several of these classifiers together, as in “Laguna Lace”, or “Lake Superior Sagenite” can't adequately describe the simplest agate but it will put it in the ball park. Coming up is a section describing and attempting to explain some of the structures we see in agate. Realizing that one photo is worth a thousand words, we'll look at numerous of examples of these structures as we go along.

Color and Color Banding

Please recall from a few pages back (if you take these pdfs in series), that I spoke of crystallization and banding as inextricably interconnected, which they are – but also complexly interconnected. Before I can get into the kind of color banding I am referring to here, I must step back and take a broader look at coloration in agate.

There are several different forms of banding in agates that can be considered 'color banding', some of which are apparent in the photograph above:

There may be bands, sometimes alternating, of chalcedony, macro-quartz, and opal which usually produce bands of blue-gray, clear to translucent white, and opaque white respectively. Blues derive chiefly from the dispersion of light in a relatively clear chalcedony – the same phenomenon that makes the sky blue. White coloration is usually the result of a hydrous silica like opal containing microscopic water or gas bubbles that reflect light.

There may be bands of nearly clear chalcedony of varying widths and clarity that disperse light differently and appear as different shades of blue and gray.

There may be bands of macro-quartz or chalcedony with coloration due to impurities inside the quartz crystals as are the cases in amethyst and rose quartz.

All these variations are derived from changes in the conditions and chemistry of the sol/gel as rhythmic banding is occurring. The most likely causes of fluctuations in the chemistry during banding is the banding process itself taking up silica, taking up or releasing water, etc.

Finally, but most notably, agate coloration comes from microscopic impurities trapped in the inter-crystalline structure of chalcedony. That is the type of color banding we'll be considering now.

At the extreme end of that type are **'exclusion bands' made almost entirely of mineral impurities**. As we know, relatively porous chalcedony, as opposed to macro-quartz, allows the incorporation of certain amounts of water and mineral impurities that give it color. Chiefly, these are iron hydroxides and oxides that provide a range of colors from bright yellow through orange, reds, browns, and black. Green color in many agates is the product of minute particles of the mineral chlorite. More rarely, green coloration comes from inclusions of Nickel and Chromium compounds. And green coloration may even derive from a rare iron reaction called “green rust”.

Granular, water level type chalcedony bands that settle under gravity may contain various levels of impurities, that's pretty easy to understand. Wall banding is a little more difficult. In classic nodular agates, the fibrous bands crystallize from the outer wall towards the center. They may grow continuously from the outer margin to the center or to a cavity in the case of a geode. They might be stopped by a color band (one with a high level of impurities), and skipping over it, start another fiber band, sometimes going through many cycles making many short fibrous bands all growing, as nearly as possible, parallel to the walls and towards the center. The color bands, unless distorted, also lay parallel to the walls.

Bear in mind, that although we haven't discussed it yet, chalcedony also crystallizes outward from fixed surfaces in the same fashion it crystallizes inwardly from the walls of cavities - as we see below.

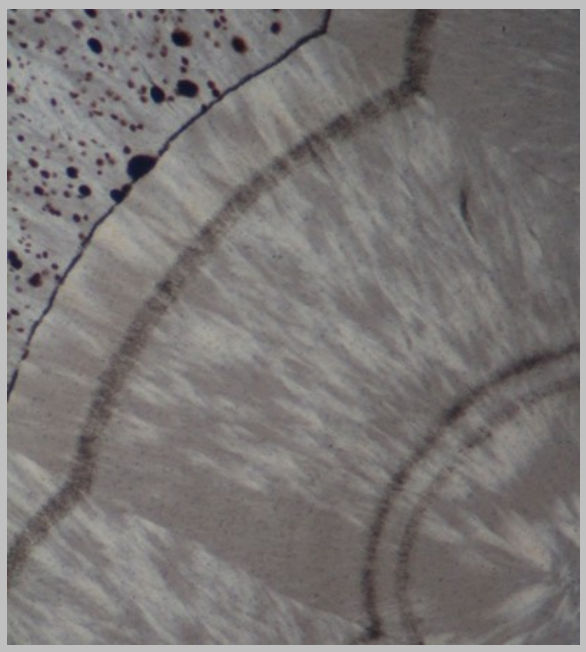
Texas Biscuit Agate

Notice that the banding on this cut face appears to proceed inwards from the outer rim, and outwards from rock intrusions inside, because the chalcedony bands are continuous surfaces. They cover the interior wall and all the protrusions into it. The center is an open drusy cavity but around it are alternating color bands and clear chalcedony bands giving it that 3-D look. The bands are colored by microscopic bits of iron impurities concentrated in the bands.

Even chalcedony can tolerate only certain amounts of impurities and the pressures of the oncoming crystallization front moving from the margins inward pushes and concentrates excess impurities into bands ahead of it.

Depending on conditions in the sol/gel, the crystallization front can continue through the band, absorbing the impurities into the spaces between the fibers, or skip over the band and begin new 'fibers' beyond. If there is enough silica in a band, it will polish; if not, it will be soft and 'undercut' - a bad word in lapidary circles.

I'm back to a thin section to illustrate this point. Note in the micro-photograph that fibers proceeding outward from the lower right pass through several faint mineral exclusion bands but are stopped by a thinner but much more concentrated band at the upper left. The mineral globules are a different phenomenon but also contribute to agate color. The pattern in the fiber "colony" is caused by twisting of the fiber bundles.



Agate Thin-Section

Let me try a simple analogy to explain the banding process. Imagine it this way: A stadium gets really trashed and the cleaning crew lines up around the outside edge of the field with push brooms. They each begin to push a mound of trash before them towards the center of the field, always remaining abreast of each other. After a few yards, the mound of trash each is shoving in front of him may get too big so they step over it and begin pushing again. There is now a ring of trash out in the field parallel to the edge of the field and at right angles to the brush lines (analogous to the fibers).

There is another force at work in our stadium analogy too; let's say there's someone inside the ring of pushers blowing the trash outward towards them. **The same attraction of like molecules that concentrates silica also applies to such impurities as iron oxides and hydroxides in the silica gel.** The photo to the right is a close up of the Condor agate you saw in the "lineup". You can clearly see the concentration of the coloring material, probably iron hydroxide, leaving a halo of clear chalcedony around it.

It is probable that the energy input into the system by the distortion of the banding initiated the concentration and could be called 'chromatography'. When that energy dissipated, the concentration played out. This phenomenon becomes much more apparent in some of the plume agates we'll look at toward the end of this little discussion. It also accounts for the little tufts of mineral matter commonly seen in agates, sometimes called 'champagne bubbles'.

Notice on this macro-photo of a Paint Rock Agate how the iron hydroxide has organized into dotted lines. Remember that these iron concentrations, probably flocculated colloids, are held in and on translucent to clear chalcedony. These are rather large floccules visible even at low magnification. **Size of the floccules and their concentration are key to color banding.** The best banding consists of uniformly distributed microscopic floccules held in the fibers.

Paint Rock Agate

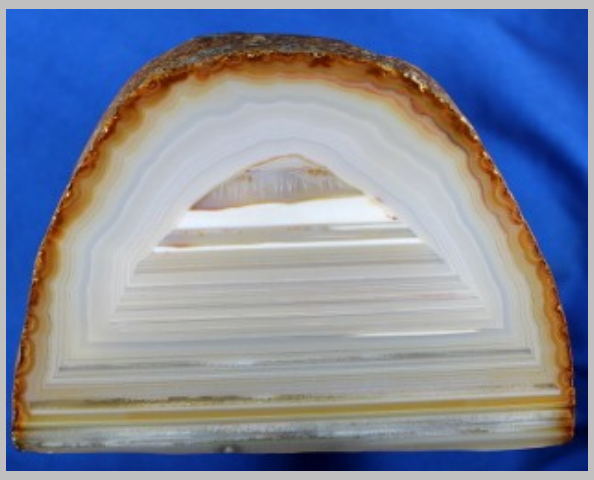
Let's add yet another process to our stadium analogy. Before the sweep-up began, an aluminum can collector picked over the trash and we now have small piles of aluminum cans around the edges. **I am referring to the formation of other minerals, particularly zeolite minerals, in our vug. Zeolites are aluminum silicate minerals, cousins of chalcedony, and they hang out together a lot.**

Besides the alumina and silica content, zeolites can contain a variety of minor constituents and thus they are a large and diverse group of minerals. **We see zeolite minerals forming radial spheres, needle sprays, tree-like and haystack forms.** Very often associated with volcanic rocks, zeolites may inhabit cavities before silica filling or develop along with silica/chalcedony fillings, helping clean the silica solution.

This geode has a rim of zeolite crystals that developed first, with the chalcedony/agate forming around them. It is a moot point as far as I am concerned whether these plumes and moss are included minerals or agatized sagenites.

Banded Nodular Agates

Now that we know a little about banding, we will begin to identify agates on the basis of their banding structure. First, the classic nodular banded agate, the 'true agate'. The photo below is of a mixed wall banded and water level agate nodule from Brazil. Yes, you've seen the center before. This agate illustrates so many important features that I have added a large file photo link for you to examine along with the text and this, little more than thumbnail, photo.



Big Brazilian Agate Photo

Notice that the lower few layers are true **water level bands** without any apparent connection to the wall. Looking closely you can clearly see that some of these water-level bands are composed of spherules that settled in layers. Other layers are too fine grained to see a texture, but are probably composed of smaller spherules or larger colloids.

Only a short way up, however, hemispheres form around the outer edge and **fibrous wall banding** starts. The subsequent bottom bands remain flat because the bottom wall is now flat. **Many "water level", or "onyx banded", agates are like that- just flat sided wall banding.**

No, there are no large hemispheres along the flat, bottom wall bands. I believe the fiber colonies on the lower, flat bands are spreading out radially in a horizontal plane; a phenomenon we will see later on when we look at what I call 'layered agate'.

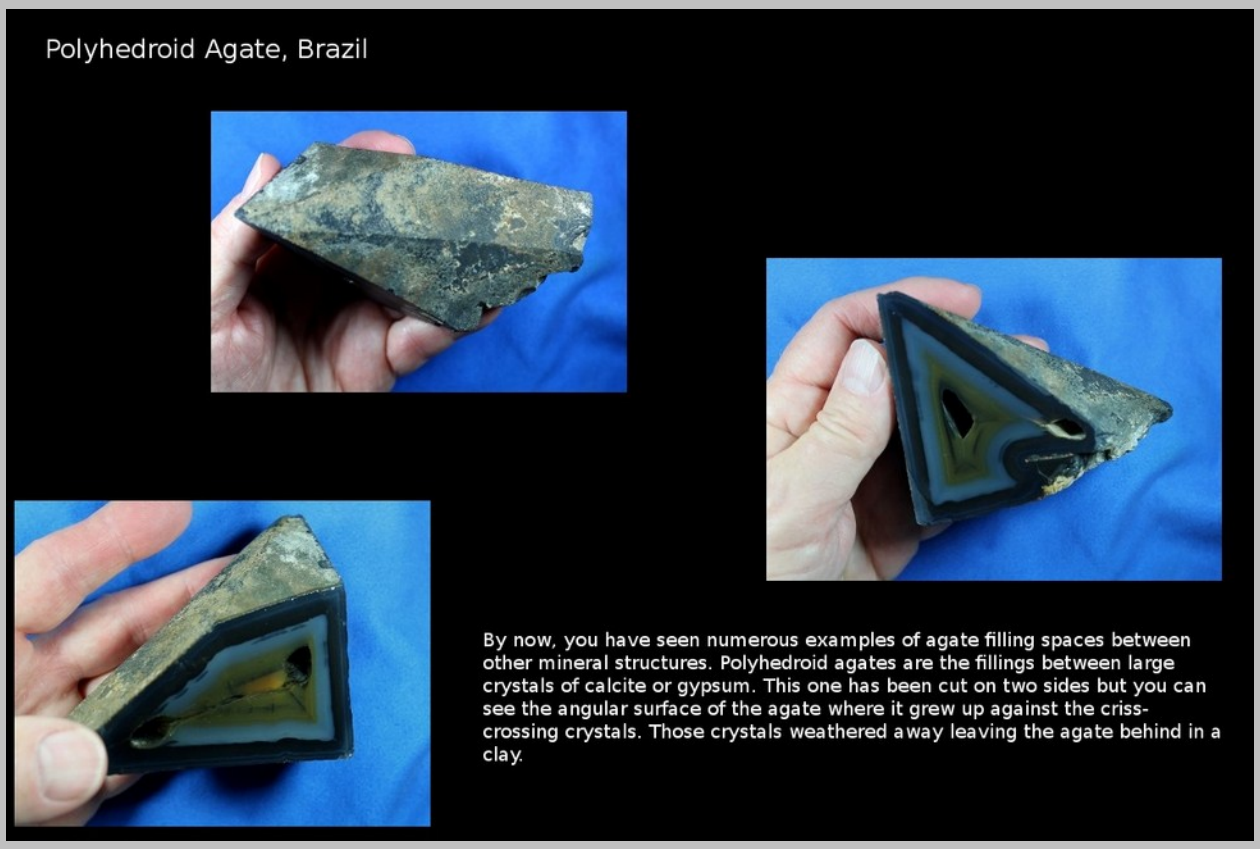
Though the 'water level' flat banding is continuous with the upper wall banding, the layers are sometimes slightly thicker at the bottom. There are also a few scattered true water level bands in between the wall bands. Some continued settlement seems to contribute to making the bottom banding wider than the upper wall banding, however, there is a remarkable thing about that.

Notice the symmetry of the banding; the angles between the flat bottom banding and the upper wall banding form almost perfectly straight lines. That indicates largely uniform, rhythmic or periodic episodes of band formation throughout the sol/gel pocket. There are several theories to account for that but, to my knowledge, none are fully established as the cause.

One problem with some of the theories is that they were developed for volcanic agate, and they can't account for the apparently identical banding process in sedimentary agates that have not experienced high temperatures. Others require far too complex reactions, it seems to me. So, I'm not going to broach any of the formal theories of rhythmic crystallization and merely offer some observations of my own.

It seems that chalcedony crystallization and rhythmic banding occurs at relatively low temperatures (as opposed to volcanic temperatures) and is mediated by the chemistry of the solution/gel – the silica concentration and polymerization level, pressure, Ph, and the content of water and other non-silica impurities. It also seems to me that the agate above was a closed system with largely uniform conditions throughout for the duration of the crystallization except perhaps at the very end. I apply that logic only to cases where it seems to fit observable features; I do believe some agates display evidence of changes to the chemistry and conditions of the solution/gel.

Let's make a small digression here to look at an example of what in some ways is an ordinary nodular agate, but one that doesn't form in an ordinary vug. Instead, these **polyhedroids form in the spaces between large criss-crossing gypsum crystals**, that then dissolve away, leaving the odd shaped 'nodules'. Of course, agate can form in voids of any shape or origin, in almost any kind of host rock.



More Complex Banding

Now let's add a little more complexity to banding - the distortion of banding. **Both the polymerization and crystallization of silica produce water. This water expelled from the solution/gel is still occupying space in the vug, and water is incompressible. If the cavity is well sealed off by the initial gel/chalcedony layers, and the crystallizing gel is still sufficiently plastic, this hydraulic pressure may distort the color banding as it seeks release through some weak spot to the exterior.**

To avoid confusion, I should explain that silica gel and chalcedony never seal off the cavity completely, molecular diffusion in and out can still occur. But diffusion is a slow process, whereas the polymerization and crystallization may be expelling water at a much faster pace than it can diffuse out. These distortions such as we saw in the Condor a few paragraphs above provide some of the most interesting features of many agates and are usually considered a plus for a specimen. Here is a small photo gallery of pressure release structures.

Pressure Release Gallery

Perhaps you noticed that several pressure release structures are associated with crenelated banding and small areas of water level banding. I can't help but speculate that both those anomalies are associated with the release of pressure in the agate chamber. I'll have more to say about that idea later.

Now some more unconventional banding.

The following section is something of a transition and introduction to later discussions of unconventional agates like mosses and plume, and how they too are formed, at least in part, of banded chalcedony.

Descriptions of agate banding tend to concentrate on the classic agate nodules but fibrous chalcedony and color banding are seen in many places besides the classic nodule. We'll look at some unconventional agates in the following photos. The picture on the left is of a slice through an agate stalactite from Uruguay. It clearly has fibrous banding, even though no real color except on the outer rings. **It is something of an inside out agate geode – agate forming around mineral fibers at the center and growing outward, topped off with a ring of amethyst crystals.**

It would have to form inside a vug, only a large one with internal features, and this area of Brazil and Uruguay produce some whoppers. Stalactites (really pseudo-stalactites) that form around other mineral inclusions are very common in agates. Smaller ones are called 'tubes', like this one, below, in an Agua Nueva agate.

Agua Nueva Agate, Mexico

Agua Nueva agates are noted for their tubular banding, but tubes and pseudo-stalactites are very common in many agates and often are the cause of an 'eye' pattern. This tubular eye pattern is, of course, somewhat different from the 'eye' pattern produced by hemispheric banding we looked at earlier.

This little Laker (below) shows **tubes** very well, and structures sometimes called **'drapery'**, especially on the left side, but we can readily see that both are formed by mineral exclusion bands filled in between with clear chalcedony, giving the slab a three-dimensional look.

Just for the pleasure of it, we'll take another look at a Laguna we just looked at for its pressure release structure; now we'll look a little to the sides of that to focus on banding around mineral inclusions.

The vug in which this agate formed contained some long thin mineral crystals that apparently supported the nucleation and growth of banded chalcedony. Remember that the 'bands' are actually continuous layers that cover the walls of the vug and everything that projects into them. The mineral fibers seem to have been completely, or nearly completely replaced with chalcedony. If these banded agate structures had projected into a hollow cavity, they would be known as pseudo-stalactites, but this vug filled completely with agate.

Pseudo-stalactites also form around plumes of various types. Summerville agates seem particularly prone to produce pseudo-stalactites which, when cut or broken, produce a concentric, or eye, pattern.

The above montage of Summerville agate photos show the surface of an agate that formed in a large open seam and is composed almost entirely of pseudo-stalactites formed over plumes, as shown in the cross-section; and another piece ground down flat displaying the concentric rings that could be considered an eye pattern. Unfortunately, this is not a high quality lapidary agate, but interesting just the same.

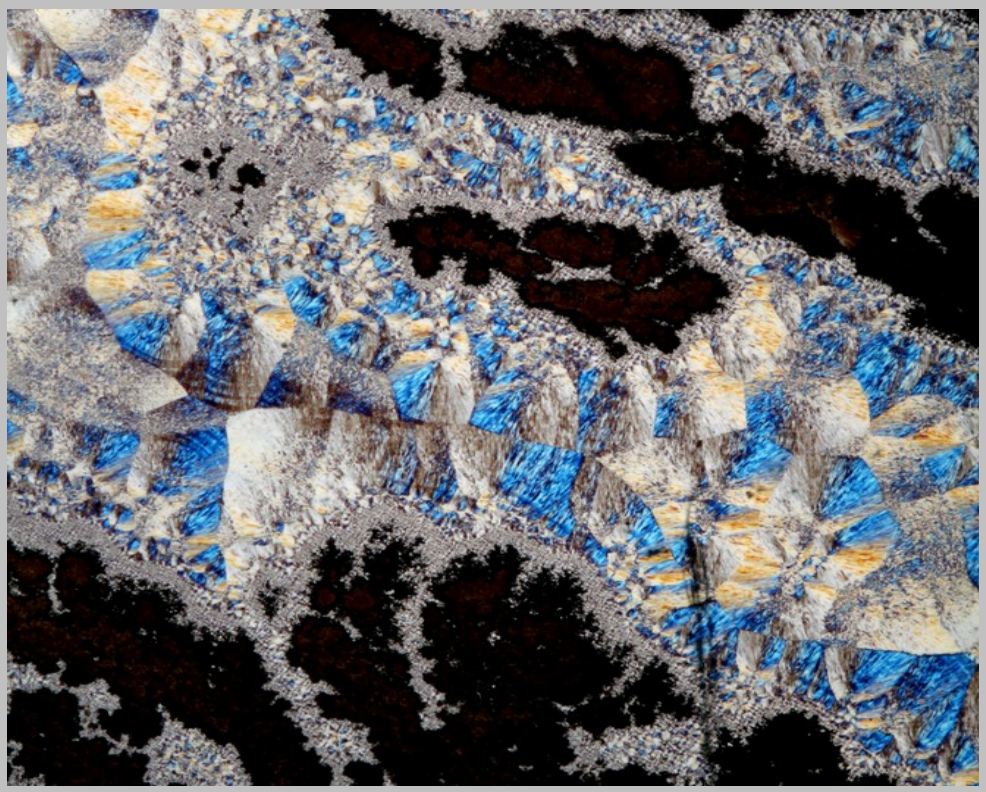
Just as a note, the proper terminology for true cave formations is 'stalactite' for drip stone structures fastened to the cave roof, and 'stalagmite' for those that form on the cave floor. The term 'stalactite' seems to be the only one in use for these agate structures. As they do not form in the same way as cave drip stone, and may be more likely to form at high angles, 'stalactite' is only a term of convenience.

Now we will make quite a bit of a larger leap into unconventional agate banding with a look at plume agate.

Look now at the Nyssa **Plume Agate** to the right, something that might at first seem a totally different phenomenon. See the white color banding and botryoidal surfaces surrounding what seems a very insubstantial plume? Although they look very different, these are all the same phenomenon, fibrous chalcedony banding – or 'agate'. The point is that banding will initiate on outside surfaces as well as on inside surfaces. In fact, any surface that can sustain nucleation can establish fibrous banding.

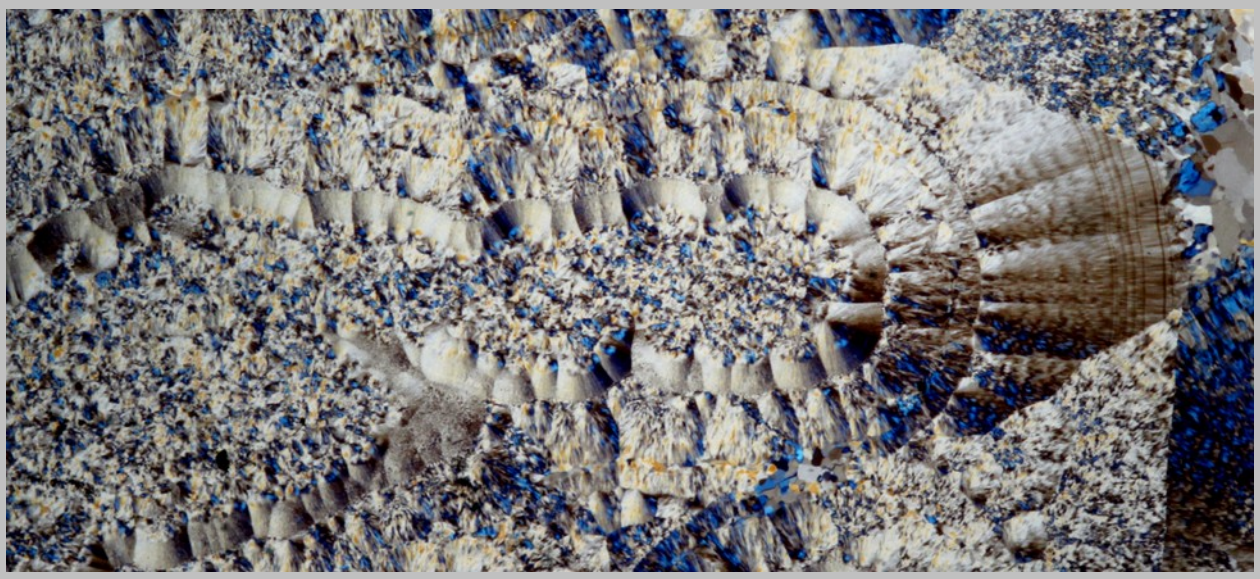
To better understand fibrous banding, let's look at a couple more thin-sections. These are very busy and complex thin-sections of 'unconventional agates' with fibrous chalcedony that we will be looking at in considerable detail later.

The first one, below, is a thin-section cut off the same slab as the above picture and, of course, much enlarged. The white to pale yellow plumes are opaque in the thin-section. I took the photo with a bellows lens and a make-shift polarizer in order to get a larger field that I would get with a petrographic microscope and so can't tell much about the plumes themselves. They appear to have a high metal content, but whatever they are is substantial enough to serve as a continuous nucleation surface for granular chalcedony, which then develops into complex fibrous colonies.



Nyssa Plume Agate Thin-section, Oregon

The thin-section below is of a **sagenite agate** from Mexico. The original, needle like mineral crystals had already been reduced to almost transparent rusty shadows which quite disappeared in the thin-sectioning process. Their relict structures can still be seen however in the traces of granular chalcedony. Notice, proceeding left to right in the center of the photo, a string of granular chalcedony marking the location of the original crystal. That is overgrown by a complex rim of radial fibrous chalcedony.

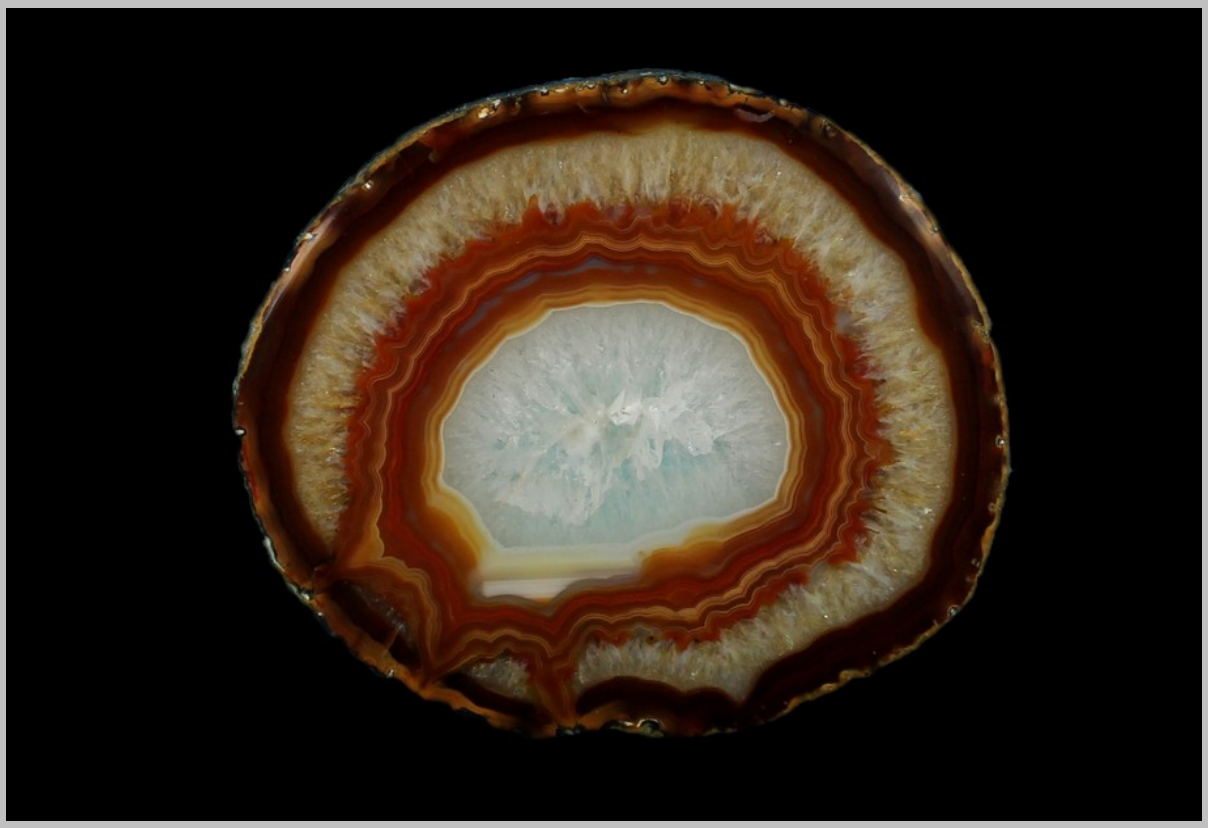


Mexican Sagenite Agate Thin-section

Again, **I am using the term 'agate' as it is used in rockhounding and lapidary arts**. A mineralogist might restrict the term 'agate' to wall banded specimens and describe water level, or onyx banded, stones as 'onyx'. That same mineralogist might also describe moss agate and sagenite as chalcedony with mineral inclusions. His agate definition would also require crystallization from a silica gel and would probably not include 'agatized' fossil and mineral replacements. These might be described as per-mineralized or silicified fossil remains and secondary mineral replacements. However, for hobbyists, it is quite ok to speak of water level agate, moss agate, plume agate, agatized wood and agatized dino bone, etc.

In the end, we can only speculate about whatever complexities form these various agates. To the rockhound, it is enough simply to know that there are agates with fibrous color banding (the true agates) and agates like moss and plume, and sagenite completely or partially unbanded that may consist of one or both types of chalcedony. Some of these may be colored, like carnelian, with no discernible pattern. They are often mixed. Most lapidarists have probably noticed that fibrous banded agates are tougher and take a better polish, if the bands don't undercut.

A History Written in Stone



This agate formed in a lava vug among countless others in one of Brazil's many agate regions and its history is revealed in its rings. Unlike trees however, agate history begins at the outside and progresses toward the center. Like most agates, this one began laying down layers of rather dirty chalcedony around the outside margin. Then an unusual thing happened, conditions changed and allowed the formation of a ring of dingy quartz. Even macro-quartz can tolerate a small amount of impurities. Had its history stopped there it would have been simply an unattractive geode.

But then conditions changed again and the quartz was covered over in dirty brown chalcedony. Whether this represents an onslaught of water and impurities from the outside or these impurities were there all along I can't tell. My 'model' of agate formation requires a sealed chamber with no new material introduced from the outside. If this material was introduced from the outside, how did it get in?

In very close inspection, I notice that the three visible blow-outs distort only the outer chalcedony rim. The inner chalcedony bands seem to follow the previously distorted structure but are not distorted themselves. The back of this slab shows the blow-out of the outer rim better, and it appears that the quartz ring simply filled the gap and was not, itself, blown out. None of these structures seem to offer an entry point to the center of the agate.

Of course, we are seeing only a small part of the nodule with this slice. That being the case, we can only speculate about what happened. But, since this exercise is just for fun, I'm going way out on a limb about what could have happened that would make this agate fit my theoretical model.

Let's say the vug began to 'ripen' with a highly saturated silica sol/gel. An initial film of polymerized silica sol or gel sealed-off the vug. Continuing precipitation of silica and release of water increased the pressure and blew-out the nascent chalcedony rim. Pressure and silica concentration dropped, allowing macro-quartz to form. The macro-quartz forced most of the iron impurities ahead of it, concentrating it in the sol/gel center. It also re-sealed the vug. That allowed pressure and silica concentration to rise and again produce chalcedony, or it's not quite so hard precursor.

The process of growing past the impurities began as some were absorbed into the inter-crystalline structure of the chalcedony and the excess shoved ahead of the crystallization front. The bands began to be cleaner and cleaner towards the center. But, then something totally unexpected, and as far as we will ever know for sure, something unexplained, happened. The dirty brown chalcedony disappeared, some impurities settled in whitish water level bands, and the remaining silica solution crystallized as pure white quartz – the most perfect form of silica for which the natural chemical and physical processes impel it.

So what happened? Perhaps, if I am right that water level banding is related to pressure changes, there was a major blow-out in some other part of the vug. What happened to the all the iron contamination then? Perhaps it was still there, localized in some now lost part of the nodule; who knows?

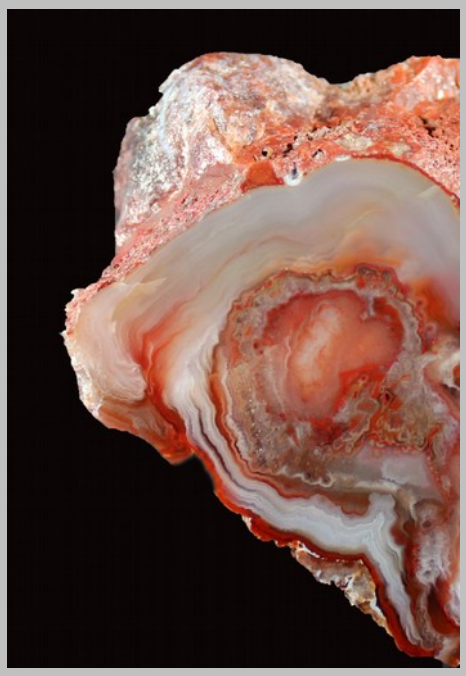
This scenario is rather like the lives of Christians; we struggle to free ourselves from sin and may achieve some success, like the dingy quartz. That is perhaps the most dangerous time for a Christian, when we think we have become good enough. Better to fall back than to remain in that condition. Looking at this agate, we would never know how dirty the first quartz ring is without having the clean quartz center for comparison. God's purity is the standard. Perfect cleansing can come only through the help of God. And God is gracious in giving that miraculous help, throwing our sins into the depths of the sea (Micah 7:19). But only if we are striving for righteousness with all our might.

A Different Banding – Clouds and Feathers?

Wall banding and water level banding we already know something about, but there is another type of agate banding we need to look at, and it is related to the mode of formation; then we'll move along to moss, plume, and dendritic agate. These agates break all the rules of 'true agate banding' and some aren't even recognized as banded agates by most authorities. All I can say is, that if what we see in these agates isn't an aberrant agate banding, I can't imagine what it is. They constitute some of the most popular 'agates' as lapidarists and rockhounds use the term but little is known about them, at least as far as I can find. I am, therefore, again going out on a limb with a few observations of my own – bear that in mind as you read.

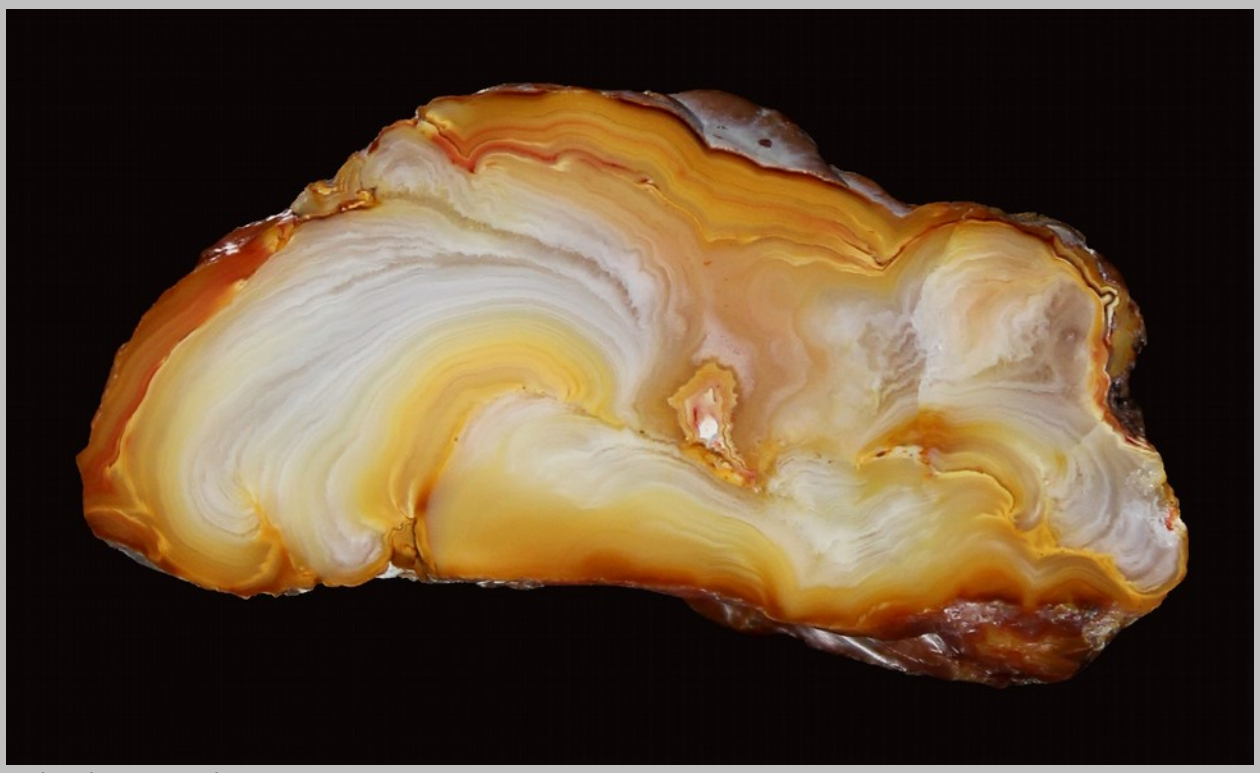
I am grouping several agate types and calling them **'Layered Agates'**, for reasons that will become apparent when we look closely at a few. As I will be using the term, 'layering' and 'banding' are different phenomena. Unlike the wall banded and water level agates we have looked at up until now, that fill enclosed spaces in essentially one layer separated only by banding, these agates grow outwardly in unconfined spaces. Although the silica gel may essentially be one layer, its lateral growth causes it to overlap creating two or more layers with a botryoidal or reniform surface. Those overlapping layers then develop their own banding. Included in this group are the 'cloud agates' (aka 'feather agates' and, in Germany, 'flame agates'), Ocos agates, fire agate, some Mexican Lace agates, among others.

Let's begin with these two cloud agates from the Friesen area of Germany. In the first one, right, the heart or liver looking center of the cut face is a knob of the host rock showing through a thin layer of chalcedony from the back. **The silica gel/chalcedony formed around this knob, growing outward into the characteristic botryoidal surface and viscous flows rolling over edges (reniform structure).**



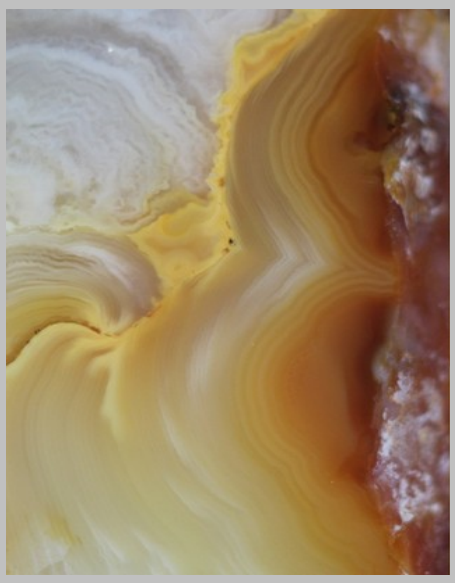
Rhythmic banding developed as the gel crystallized into chalcedony. But this crystallizing silica gel was not subject to the physical and environmental confinement of a wall banded nodular agate. That lack of confinement allowed the banding to become quite eccentric in places, forming 'clouds' or 'feathers' at the roll fronts.

The second cloud agate gives the impression of crashing waves. What you really see are thick overlapping layers of banded chalcedony. They appear to be individual viscous gel flows separated from each other by some type of film or membrane. In this self-imposed confinement these thick layers developed their own individual banding.

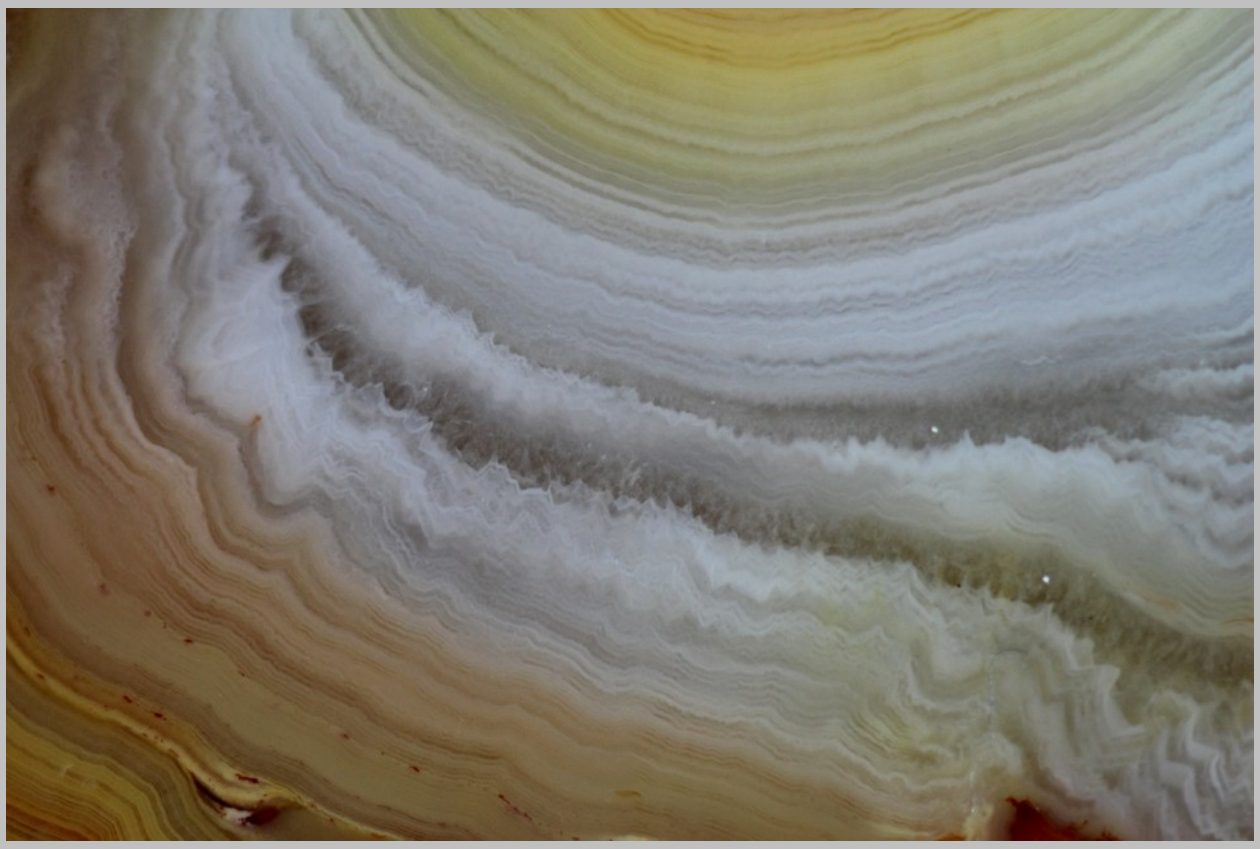


'Cloud' or 'Feather' Agate , Germany

When we look at this close-up of the lower right corner of the cut face, we see the usual initial hemispheres, only this time they formed on the outside of some long-gone surface – not the inside. When we look at the exterior surface of this agate, we see the chalcedony piled up in a 'reniform' structure. There had to be enough containment for a gel to form but it was obviously not closely constricted or these rough surfaces couldn't develop.



The chalcedony banding begins in quite orderly, or ordinary, fashion but soon grades into wild wisps of very fine macro-quartz crystals. The extreme blowup of a wispy 'cloud' in the same agate shows faint quartz crystal tips covered with thin chalcedony bands.



We will find the South American (Uruguay and Brazil) branch of the family even wilder. The little **Ocos (or Occos, or Ochos) geodes** may be the most unusual agates I have run across; and the most puzzling to me. Search as I may, I haven't found any real information on their formation, except a mention from a commercial web site stating that they are found in plowed fields, indicating the host rock has weathered away.

The Ocos geode from Uruguay to the right is a pretty standard specimen. It is dyed black to accentuate the difference between the chalcedony part and the macro-quartz wisps or 'clouds'. It is the pattern of the wisps that makes them fascinating from an origins standpoint, as we will see in the upcoming photos. We see the outward expression of the wisps in the reniform surface.

Ocos Geode Slice, Uruguay

Nodular agates and typical geodes form within a confined area like a gas pocket with the surface of the pocket to grow from. The German Cloud Agates seemed to grow mounding-up on an exterior surface, even though the surface has now eroded away. This natural colored Ocos slice shows the reniforn structure on the outer surface and no sign of a support structure on the inside of the geode except for a short distance on the bottom. It appears that thick chalcedony layers rolled over each other beginning at the bottom center and growing up each side until meeting and mounding up at the top center – forming a ring. Or perhaps I have it upside down and the ring formed by downward growth, or sideways growth. Anyway it grew, forming a ring is baffling.

Reverse side of above slice of Ocos Geode

Of course, in a slice we see the agate in only two dimensions. Perhaps what help there is in understanding these lovely little gems comes from examining their exterior. This photo of a tiny sliced Ocos geode shows several chalcedony 'conchos' on the outer surface. The cross-section of these circular growths show them to be hemispheres very similar to the ones that begin the crystallization of chalcedony in nodular agates.

There are two main differences in these and normal amygdular agates, I believe. In the first place, there are relatively few nucleation points in these agates, represented by the conchos, but those grow over much wider areas. Secondly, while the confining surface in the typical nodular agate is firm, the host rock of the Ocos geodes has already weathered into a soft, yielding material that the crystallizing chalcedony pushed away, forming ridged rings. If the initial chalcedony sealed the amygdule (and these are very almond shaped structures) it would have become pressurized and the internal fluid pressure might be greater than the resistance of the confining rock, forcing the chalcedony growth into spreading the skin rather than thickening it. (Warning! The above is slightly educated guesswork)

Recall 'turtleback' structure in nodular agates. Chalcedony hemispheres develop outwardly and press together forming distorted cones or even regular polygons, but they never merge. The reniform surfaces of Ocos geodes may be simply the unconfined, or poorly confined, equivalent of that structure – a natural structure for chalcedony. Random and widely spaced nucleation points formed hemispherical crystallizations that overran each other as they grew outward from the center.

With a light shinning through, the Ocos looks rather like a jack-o'-lantern. The conchos, where the crystallization began, are relatively thin and pure. As they grew together, the chalcedony rumpled up, trapping some contaminants between the folds and becoming opaque.

A larger Ocos does not show the circular structures very well but has very obvious overlapping layered structure. This overlapping layered chalcedony structure forms the shell of the geode in which the macro-quartz crystals grew.

Rummaging through a box of assorted agates at a friend's, I ran across a rather flat, elongated Brazilian nodule with feather banding and a reniform surface on one side and fibrous wall banding on the other. Farther on down the nodule it becomes reniform on both sides. I don't have a definitive explanation for this unusual combo, but I surmise that the top of the cavity didn't have a solid roof and the reniform surface and feather banding developed. After that, the cavity was effectively pressurized and standard wall banded agate developed. (???)

If you will recall the thunder egg gallery, you might have noticed a thunder egg with almost identical feather structure to the Ocos geodes, and another thunder egg with a large concho inside. I am fairly convinced that confinement and pressure are the factors accounting for these odd patterns.

Chalcedony forms many odd shapes inside vugs and openings of various types where the gel becomes detached from the wall, or was never attached. This Arizona desert rose forms almost a hemisphere, and seems to grow without any outward scaffolding at all except the reniform structure it builds.

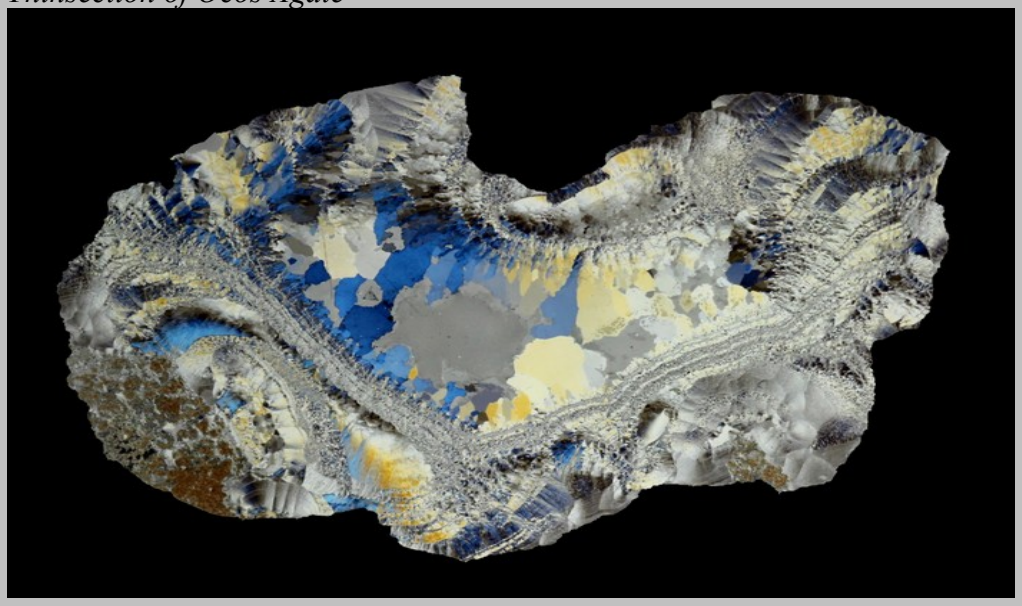
The outside is mostly smooth botryoidal chalcedony while the inside is covered with quartz crystals. Neither outside nor inside appear to have been attached to anything, except that it does have what appears to have been a small attachment point at the bottom, perhaps two points. From the attachment area(s), it appears to have grown outward, concho-like until the edges began turning up. It also has a sort of banding.

These are sometimes found in place in voids in lava but the exact cause of their unique form is unknown – except that it is due to the interplay of chalcedony's crystalline nature and the physical environment at its formation.

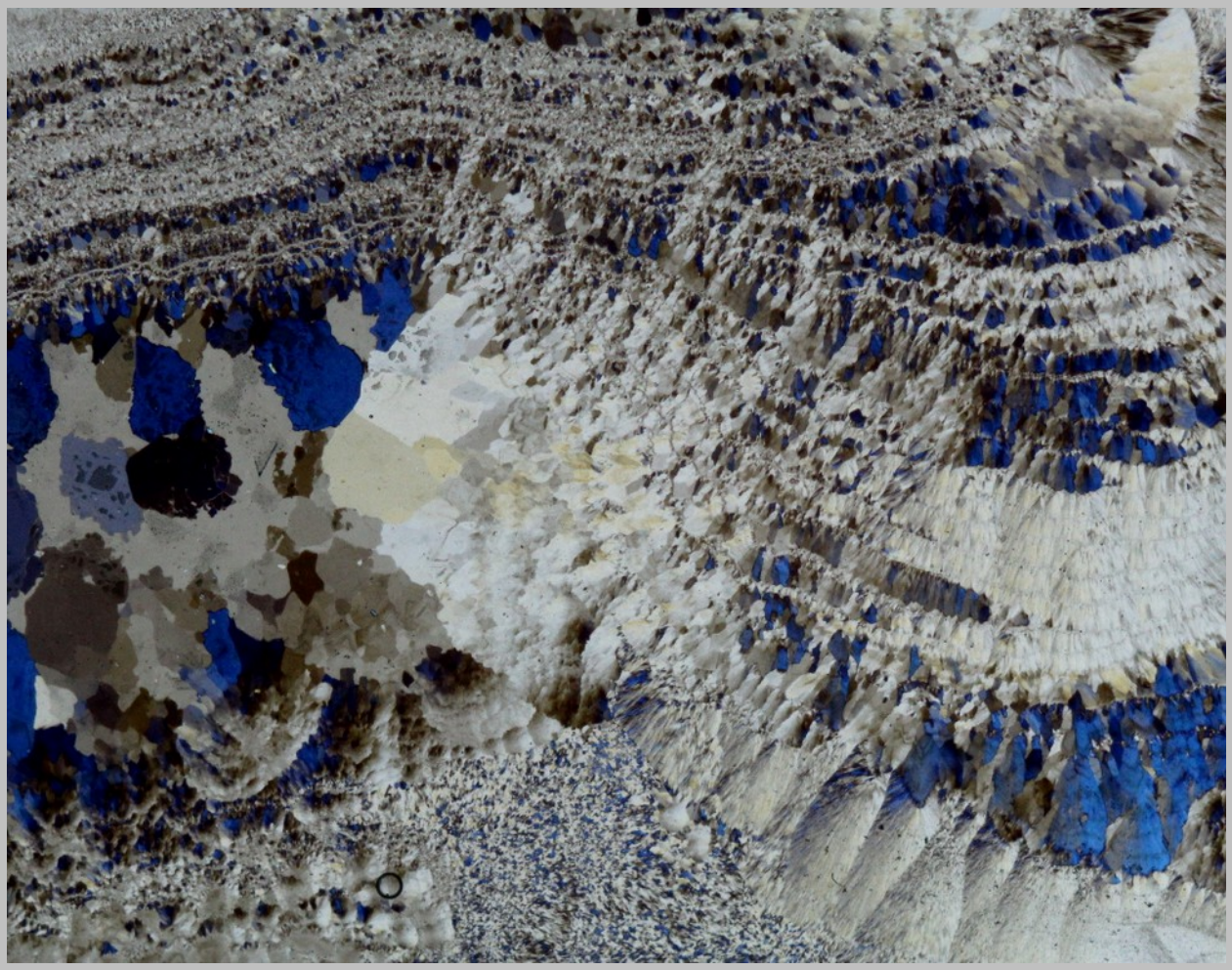
Speculating on the structure of these geodes just begins unraveling their mysteries, however; we still need to investigate the wispy 'clouds' that grace these little agate gems. That is somewhat easier to do, but still leaves a great deal of a gap between what we can observe now and a sure understanding of how that developed. The best thing about this investigation is getting to look at more of these beauties – and in different ways.

This is a thumb sized Ocos Geode half – another pretty ordinary dyed one with a macro-quartz lined cavity and a wild array of plumes, or feathers, or clouds (What do you see?) If you think this agate is wild now, look at it in **thin-section under crossed polarized light:**

Thinsection of Ocos Agate



The shape changed a little in the processing but you can make out the gross structures – the cavity (plain gray), the macro-quartz crystals (blue & pale yellow), the country rock at the left end, and of course, the very fine and complex structure of the 'clouds'. Let's take a little closer look at the structure:



Yea, it is still pretty overwhelming, isn't it! I'm not going down any closer; this tells us what we need to know. The Ocos 'clouds' or 'feathers' are complex alternating and intergrown structures of chalcedony and macro-quartz – including some unusual forms of macro-quartz. The quartz accepts the dye while the macro-quartz presents as white – very similarly to the naturally colored Ocos geodes above. The dye doesn't color the thin-section.

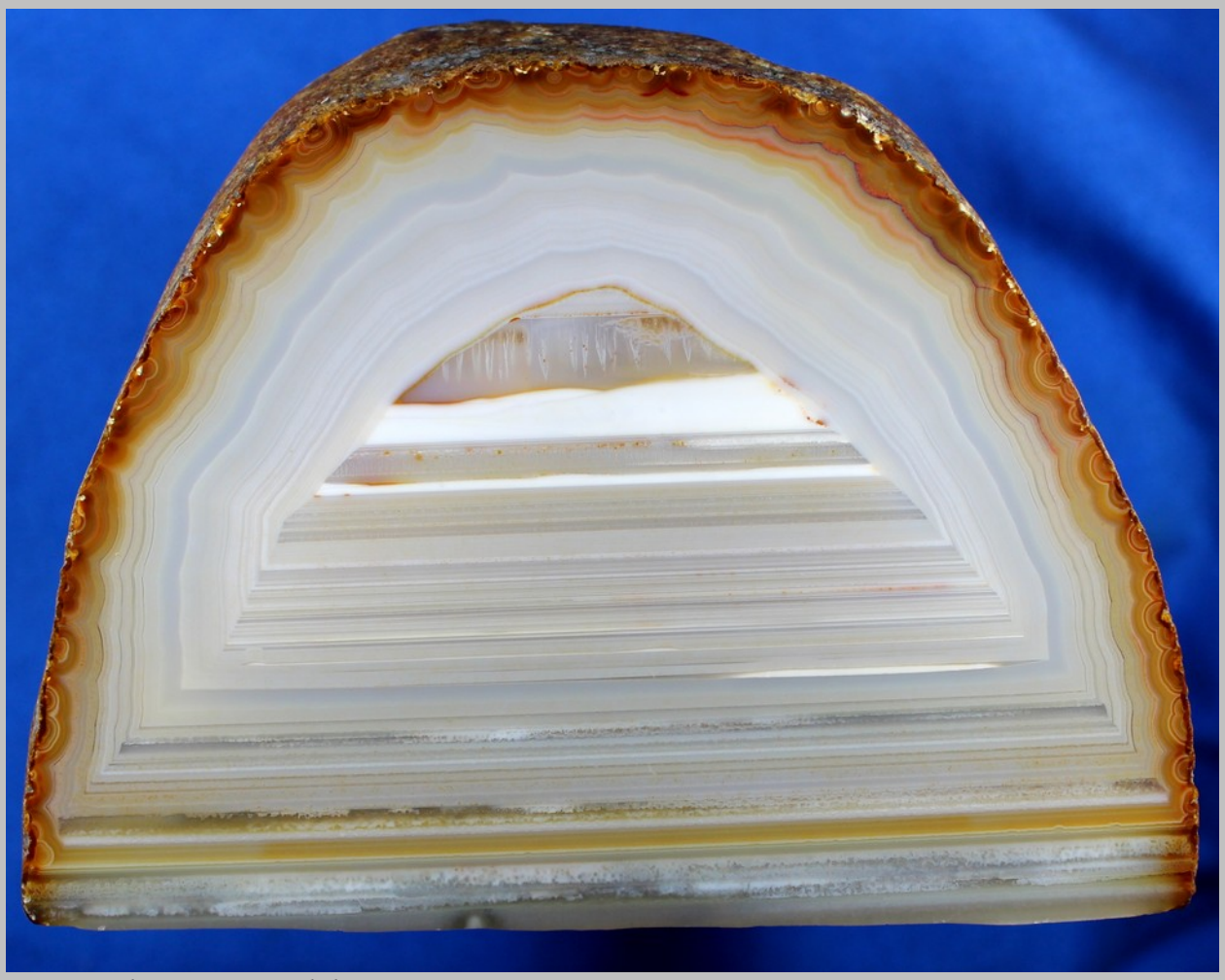
What causes the alternating chalcedony and macro-quartz? I will speculate this far: that the phenomenon is controlled by the usual forces of concentration and confinement pressure. Perhaps there is something new added also - shear stresses as the crystallizing gel 'colonies' roll over each other?

Perhaps someone understands the mysteries of these agates and can explain them to me. In the meantime, it is enough to enjoy them as objects of beauty and curiosity. Life is like that, God has given us infinite ability to enjoy His creation even though we do not fully understand it.

Let's look at one more Ocos Geode slice before we move on the next chapter/pdf:

Ocos Agate, Uruguay

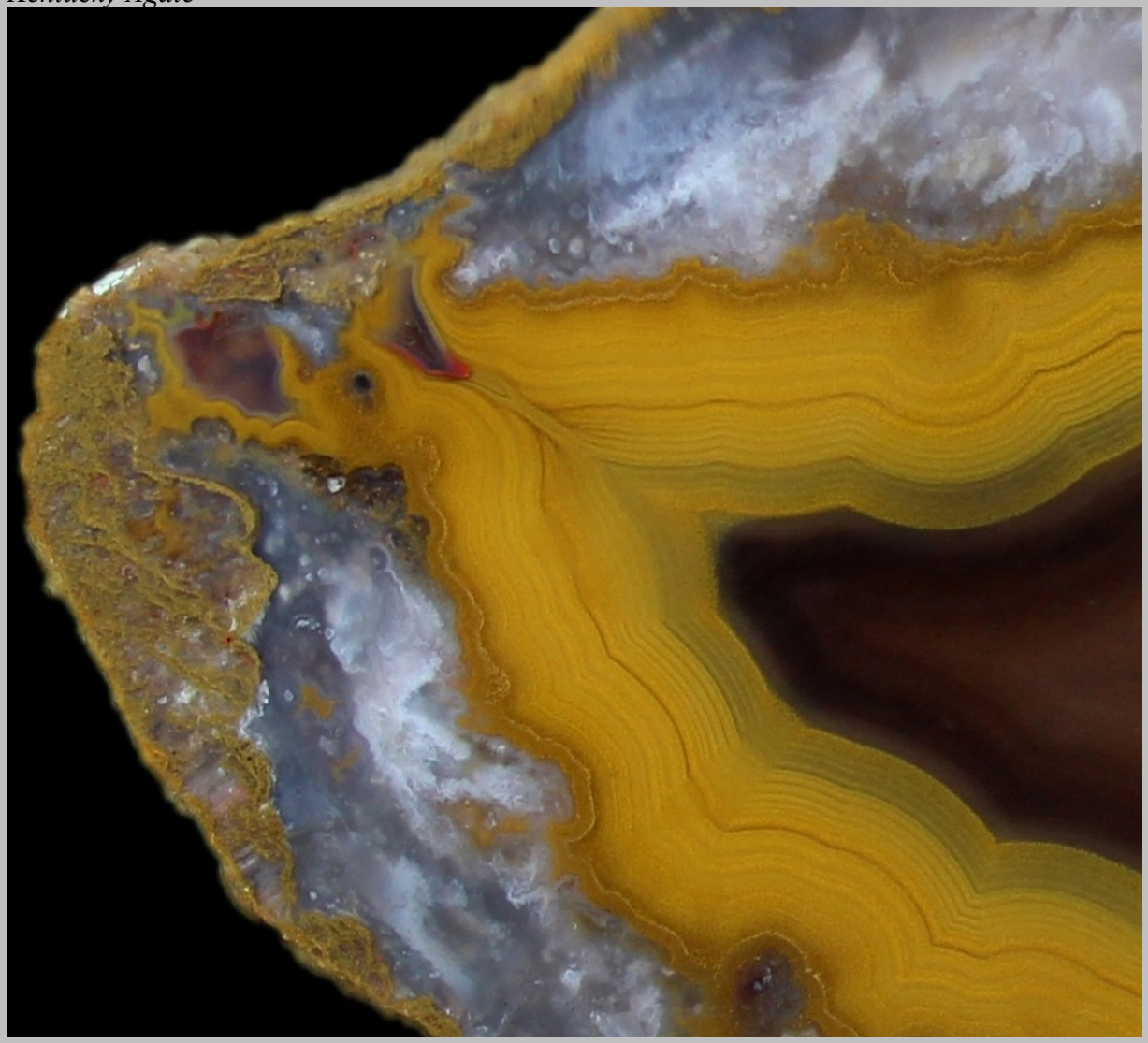
That's all Folks!



Big Brazilian Agate Nodule

Pressure Release Gallery

Kentucky Agate

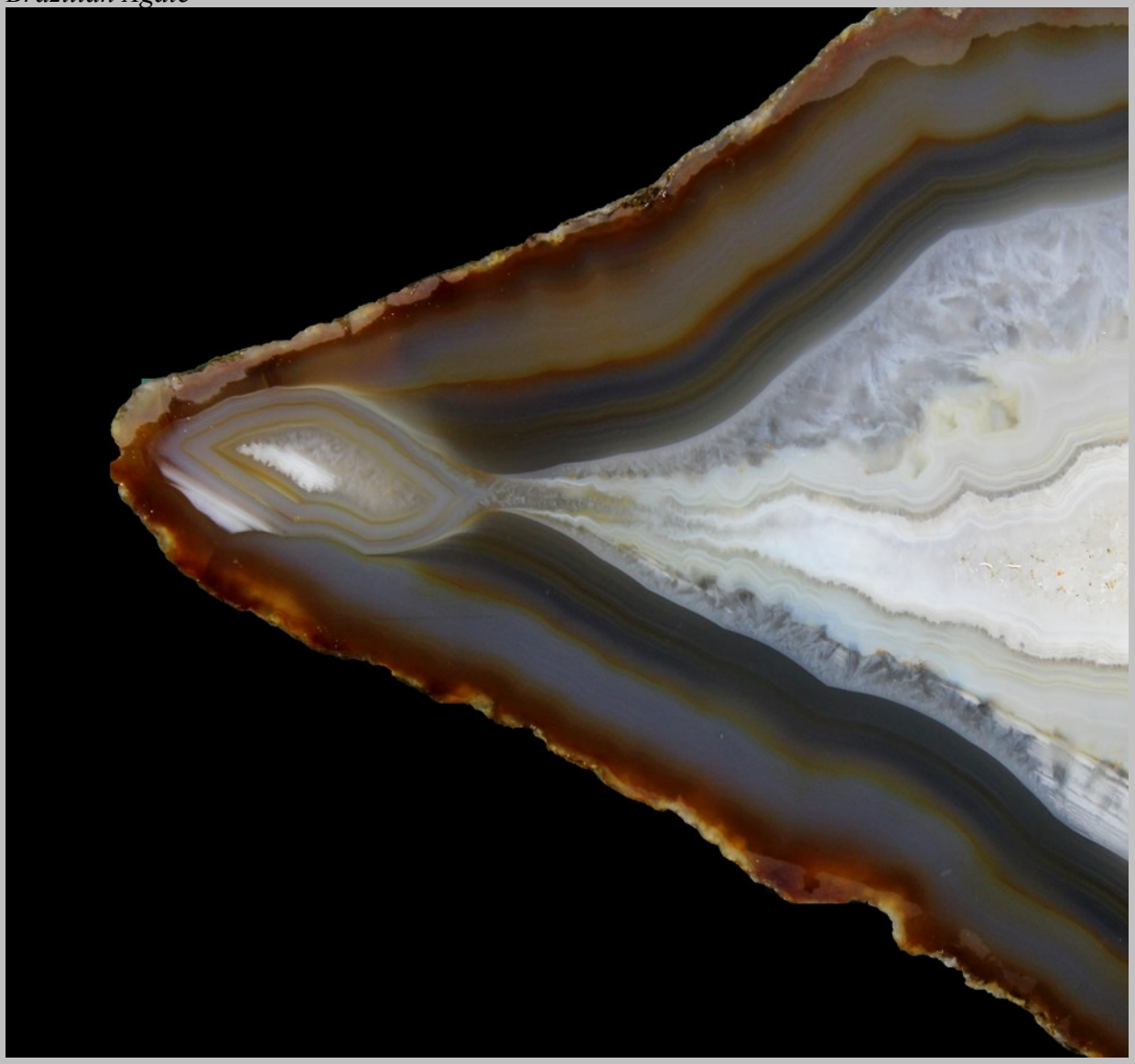


Kentucky Agate with a very pronounced pressure release structure deforming all but the innermost, darker bands. Notice the clear macro-quartz at the mouth of the tubular appearing structure.

Botswana Agate

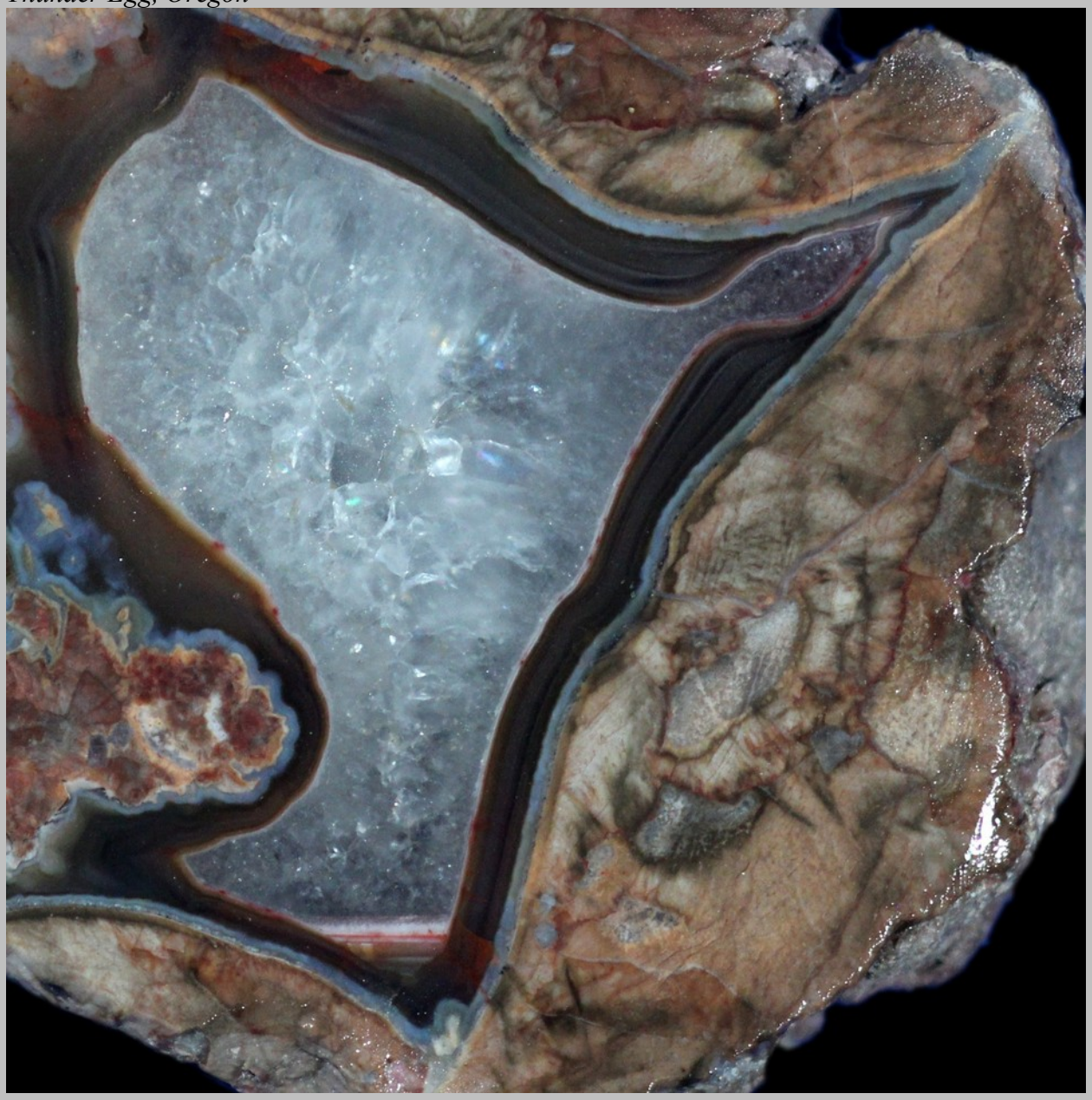
It seems that crystallization of the chalcedony built up hydraulic pressure in the center, eventually forcing the still fluid center out into the banded but immature and yielding chalcedony seeking relief. All the bands are distorted at the outlet. The release of pressure may have precipitated the crystallization of the macro-quartz filling.

Brazilian Agate



This Brazilian Agate has created another little agate at the outlet. Notice the water-level banding and crenelated banding associated with the pressure release.

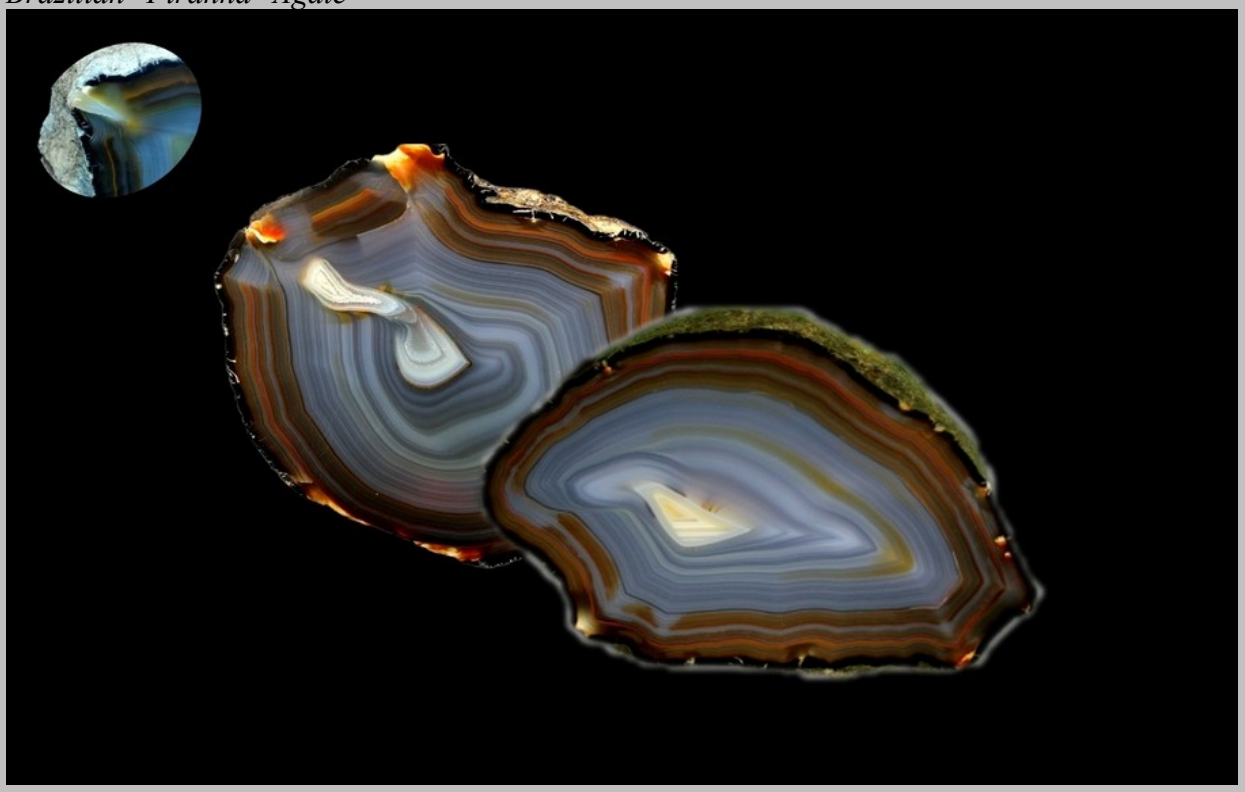
Thunder Egg, Oregon



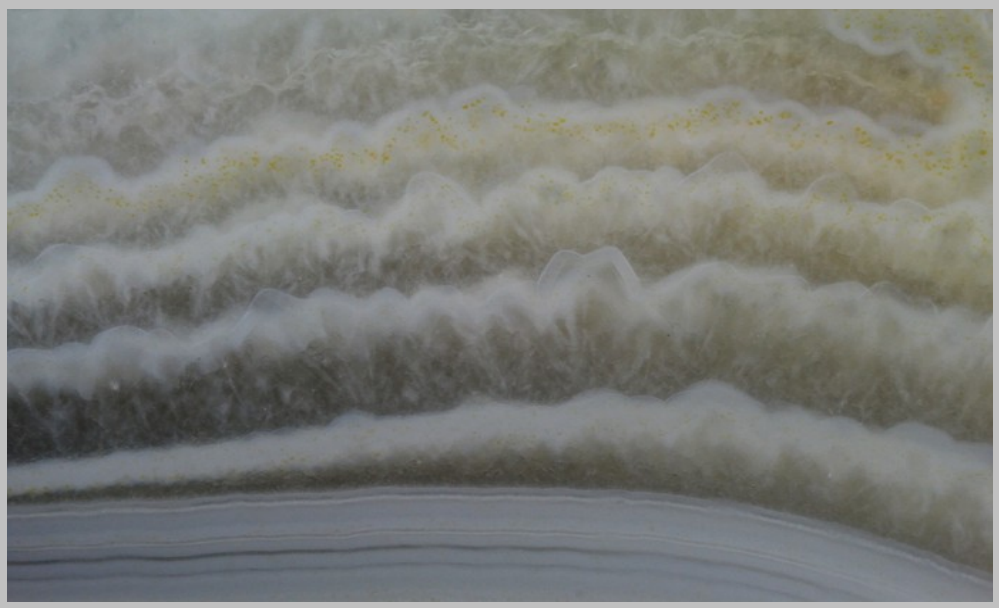
Pressure release structures like this are rare in thunder eggs, at least in my limited experience. It appears that the cavity sealed off, pressure rose and blew-out, taking out some of the still gelatinous bands. Notice the water-level banding that may be associated with the blowout.

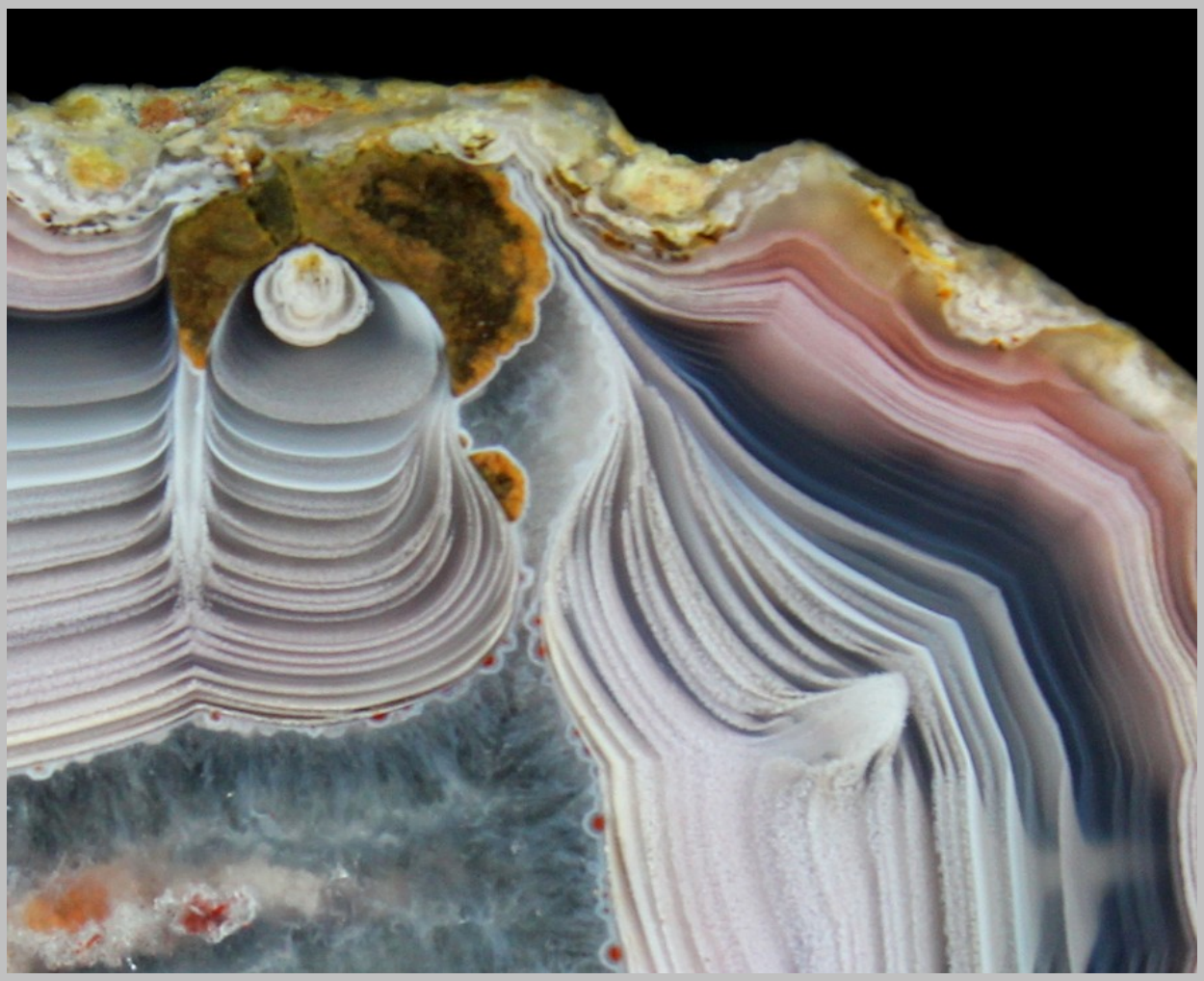
Laguna Agate Pressure Release

Brazilian "Piranha" Agate



This picture shows three sections of one Brazilian agate. It has a small center of water-level agate connected to the outside of the nodule by a tube-like structure lined with crenelated banding. The exit point, shown at the upper left, is on the backside of the second (middle photo) slab. Under magnification (below), the "crenelated banding" proves to be layers of macro-quartz with thin coverings of chalcedony very similar to the "cloud" and "feather banding" we will come to shortly. In this case, I believe these structures reflect a lowering of pressure due to the blowout. The photo at the beginning of this chapter is taken from the second slab, though the color came out a bit differently.





This Laguna agate displays some interesting pressure related structures.

The end of this Gallery

And this pdf!