Agate Genesis 2

Forged in the Fiery Furnaces of Mt...ummm...not always.

The first modern scientific interest in agates developed in Europe in areas of volcanic geology – the same areas that produce many beautiful agates even today. It is understandable then, that early study and theorizing on the genesis of agate assumed a direct relationship between volcanic activity and agate. As time went by and the wide ranging occurrences of agate became better known, however, it became apparent that it was the chemical and mineralogical properties of silica that bred all the multiple varieties of agates.

As we are considering several different materials as 'agate', we have to consider several broad categories of geologic origin, parent rocks and sources of silica. **Agates, under the broad definition, can form virtually anywhere and in many kinds of host rock; all that is needed is a place to form and a source of silica.** Some major sources of agate are secondary deposits like the gravel beds along the Yangtze River coming out of the Himalayas, the gravel beds of the mid-continent USA left by retreating glaciers from the last ice age, and the gravel deposits of Germany and the Netherlands coming out of central Europe, but we are going to consider primary origins only.

The two main super-groups, as agates are generally categorized, are agates formed in volcanic rocks, and agates formed in sedimentary rocks. That differentiation is perhaps less momentous than it might seem for there are actually greater similarities between some volcanic agates and some sedimentary agates than between some different agates of volcanic origin. So, though it needs to be made, the distinction between volcanic and sedimentary origins recedes into the background as we consider their other attributes.

I may sound contradictory here, so let me explain my use of some terminology. Agates are in something of a class by themselves as far as I'm concerned, and not subject to the common classification of rocks as Igneous, Metamorphic, and Sedimentary. When I describe an agate as of “volcanic origin” I simply mean that it formed by its own unique processes in rocks of volcanic origin - host rocks. The same with agates of sedimentary origins – they formed by basically the same processes in host rocks of sedimentary origin. **The process of agate formation occurs at more or less ambient surface temperatures due to the chemistry of silica.** Certainly volcanic activity does have its effect on some agates, but agate is not, as once thought, an effluent of molten rock.

If I had to put a scientific label on agate, the best fit I can think of is an 'authigenic rock' (though I've never heard that term used for agate) – meaning a rock that formed in place from its own unique processes somewhat distinct from the geologic processes goings on around it.

There is a third super-group coming under our loose, let's say 'hobbyist's', definition of agate - replacement agate, or “agatized”...you name it...wood, bone, rock, mud, dino dung. This grouping differs from true agate in it's crystalline structure which is predominantly non-banded, non-fibrous crypo-crystalline chalcedony and/or chert. The mode of replacement “agatization” is essentially the same whether operating in volcanic or sedimentary rocks, on mineral matter or on organic matter. Generally, these are quite distinct from true agates, but some confusing overlap frequently occurs. We will take a look at replacement agates separately later on.

In order to illustrate the similarity of agate formed in volcanic and sedimentary rock, here is a montage of photos featuring agates from both groups. See if you can identify them: Brazil Nodule (volcanic), Tampa Bay Coral (sedimentary limerock), Polish Thunder Egg (volcanic), Las Choyas Geode (volcanic), Keokuk Geode (sedimentary shale), South Africa Blue Lace Agate (sedimentary dolomite).

Not a fair test you say? Perhaps not, but I was trying to make the point that similar banded chalcedony occurs in many places and forms under many different conditions. The answers? quiz answers

We will look at each of these super-groups in turn, beginning with the volcanics, as they are further divided into the next level of classification - the mode of formation. After mode of formation we will look at common agate structures and terminology. Then, at the end of this pdf series, relax with some pictures and observations on agates, and some more brain teasers for agate aficionados.

Now, time for a disclaimer. These are very complex, not entirely well understood, and sometimes contentious subjects and I make no claim to having produced here a complete or authoritative explanation. It's my intention to pull together the best information available, steer clear as much as possible from contentious details, and present it in a simplified form for as wide an audience as possible.

Agates of Volcanic Related Origin

The primary source of agates are rocks associated with volcanic activity including lavas, older rocks covered with lavas and ash falls, and sedimentary rocks containing large amounts of volcanic ash. The relatively recent volcanic area of the Big Bend in Texas and adjoining state of Chihuahua in Mexico offers good examples of all those scenarios.

Volcanology is a subject that can, and does, occupy a lifetime of study so I will keep this discussion to a minimum of complexity (as befits one who last studied the subject 40+ years ago). Volcanoes are the surface eruptions of vast intrusions of molten rock into the upper crust of the earth. The physical and chemical, or mineralogic, character of the molten rock (magma) feeding a volcano can change over time and can separate into distinct layers of different densities that may erupt independently if a fissure develops into one layer. Thus are born from a single volcano, or magma chamber, different types of volcanic rocks.

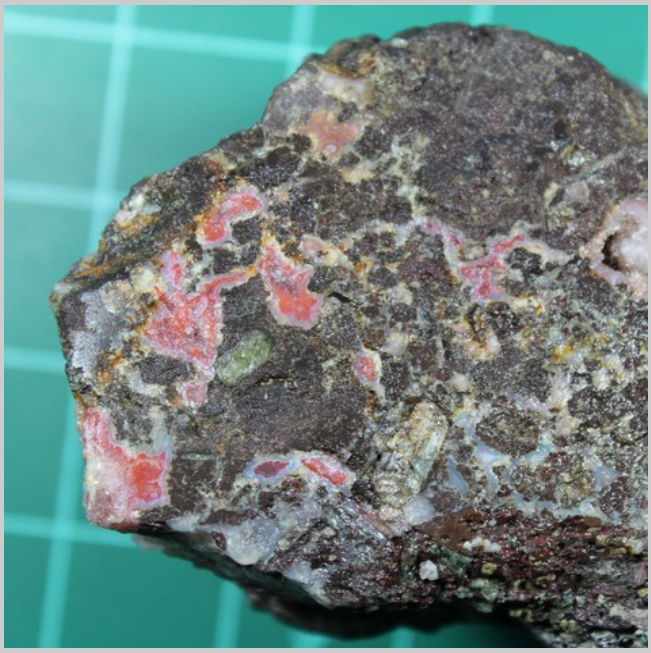
The type of rock produced has a great influence on the type of agate later produced. I'll boil down the complex subject of extrusive igneous rocks to two very generalized types – basaltic lavas and rhyolitic lavas. Basaltic lavas are the darker, denser of the two, and tend to produce more uniform flows and nice round to oblong bubbles. Rhyolites are usually lighter in color, less dense, less viscous, less uniform and less predictable. Perhaps I'd better add in an intermediate type, andesite lava, because it also is a big producer of agates. All three types commonly occur in the Big Bend area, and in much of the rest of the world.

Volcanoes in the Big Bend area produced basaltic lavas that have yielded fine amygdaloidal, or nodular, agates of banded, plume and moss types. Amygdaloidal (ah-mig'-dah-loid-al) refers to the gas bubble voids called amygdules or vesicles, found in certain types of lavic rocks. Molten rock underground contains gases, including water vapor dissolved under extreme pressure. Like a carbonated drink when you pop the top, when the lava erupts onto the surface the gases boil out.

Often the slow moving basaltic lava flows crust over before the gas bubbles all escape. Over time, the gases do escape by diffusion through the rock, or the gases condense into liquids, often accompanied by formation of crystals. But by then, the hardened lava retains the bubbly structure. Larger amygdules are sometimes referred to as 'vugs', and the content of a vug, if an agate, is known as an **agate nodule.**

The chunk of basaltic lava, below right, from the Woodward Ranch in Big Bend country contains small amygdules and chalcedony nodules. These 'bubbles' are slightly distorted by flow of the lava.

Amygdule actually means 'almond shaped', and these gas bubbles are often in that shape. Why some amygdules are filled and some are not – I don't know for sure but I assume is has to do with permeability – or the access of silic acid to the bubble.



This second chunk of Woodward Ranch lava (L) is a jumbled mix of materials including rhyolite and perlite (a glassy lava), though mostly an andesite porphyry.

It contains numerous small, odd shaped agates that seemed to form in pockets created by tumbling movement of a partially hardened, crystallizing lava. 'Nodule' doesn't quite seem to fit because of the odd shapes.

This unidentified chunk of basaltic lava I found rummaging in an old box of rocks is crammed with tiny amygdular agates, one with eye patterns. I suspect it to be from the Great Lakes region.

Rhyolitic lavas also produce agates, but not usually of the smooth nodular type either, as they don't typically produce the nice rounded gas pockets. They yield agates formed in odd shaped pockets of somewhat debatable origin. In common practice, they are often identified as 'Thunder Eggs' after an Indian legend. The scientifically correct plural term seems to be 'lithophysae' however. I've never heard that word pronounced either, nor could I find a pronunciation guide but I guess it would be pronounced something like this: lith-ahph'-ah-say. I'll stick with Thunder Egg. I haven't included a picture of rhyolitic lava here because you've already seen it around the edges of thunder eggs, and will see a lot more soon, some of which vary greatly in appearance.

Thunder eggs come in a wide variety of sizes, shapes, and contents. A rhyolitic lava flow typically produces irregular voids that may result from gas pressure fracturing, or cooling, or crystallization, or chemical reaction with water, or some combination of all the above. Those variations in origin help determine the nature of the agates and are somewhat characteristic of particular thunder egg beds.

Besides the generally odd shape, thunder eggs can be distinguished from other lava borne agates by the material surrounding the agate pocket. As the pocket fills with silica solution, excess silica solution impregnates the immediately surrounding porous material creating the 'egg' shape and making it more resistant to weathering than the rest of the host rock. So, even an irregularly shaped agate may reside in a roundish nodule. The character of this shell around the agate is also very distinctive of the different locations and names of thunder eggs. Some may have a high enough silica content to display a quasi-botryoidal structure.

Then too, volcanic deposits can include material blasted out by the eruption traveling only a few feet to a few thousand feet. That material may be molten lava or pulverized volcanic rock from previous eruptions. These deposits tend to be rugged with angular voids between blocks of ejected material. Silica fills these cavities too, and produces agates sometimes called thunder eggs but, to my knowledge, have no authentic type name – just 'agate', as in Laguna Agate, Condor Agate, etc. The andesite agates in the photo above are related to this group, on a smaller scale.

Let's return to agates we've seen before, now concentrating on the outside to get a better understanding of their formation. This photo isn't clickable, but you've already seen these agates' better sides. Top row, left is the Crater Agate, an odd shaped nodule. Next, a flattened Texas nodule. Then comes a thunder egg in white rhyolite. A Condor nodule finishes that row.

The second row begins with an Agate Creek nodule that formed in adjoining bubbles (amygdules). Past that is a chunk of massive moss agate from Hungary. Then a Botswana nodule, and lastly, a small water worn German agate nodule. All these agates formed in volcanic areas, but they represent at least three different modes of formation – nodular, thunder egg, and massive seam or vein. Notice the cratered appearance of some of the nodules due to forming in bubbly lava – but not all have that look.

Below, is a link to a photo gallery of thunder eggs, nodules, geodes, and others that we might call 'pocket agates' because they form in small, isolated pockets rather than massive agates forming in seams or veins, which we will look at later. The term “pocket agates” is really a term of convenience for this grouping because these types really can't be cleanly separated. A geode, distinguished by being roundish and hollow, can be a thunder egg or a nodule. The Las Choyas geode is a nodule while the Zacatecas geode is a thunder egg. Some agates are a bit of both. Also, many Lagunas have cavities but are rarely called geodes.

The highly prized Laguna and Condor agates can be found as rounded nodules, or filling irregularly shaped pockets that are not amygdules but random spaces in volcanic detritus. They would not be called thunder eggs, however, because they lack the encasing material.

The Crater Agate is hollow but I would not call it a geode because of the elongated shape. I wouldn't call it a Thunder Egg either because of the shape and lack of a rocky shell. It is a solitary occurrence like nodules, not part of a vein. It forms in basaltic lava I believe, and like nodules, it has only a chalcedony shell. I suppose 'nodule' would work, but, like the other labels, doesn't seem quite right. So, I would identify it only as a 'Crater Agate'. Many agates are hard to categorize that way.

The chief distinctions I would draw, realizing the difficulties with it, in differentiating pocket agates from seam and vein agates are their smaller size and well defined boundaries, and closed banding. It is often the case that seam and vein agates have very readily identifiable characteristics, which we will be looking at.

Please take note though, that this is simply my own classification scheme. The distinction between vein and pocket is debatable. Many agates that I have included here as 'pocket agates' would be called 'vein' or 'seam agates' by others, especially if someone had seen the source. Hopefully you will see the distinctions I make and the reasons for them a little farther on.

Pocket Agate Gallery

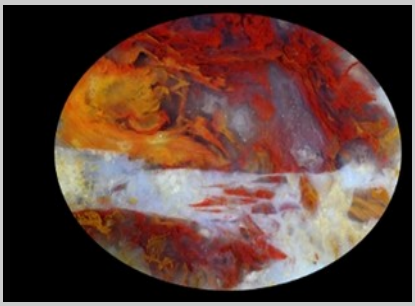
Notice the differences in the volcanic rocks forming the crusts of the thunder eggs – some, like the Zacatecas, have a coarse porphyritic (showing mineral crystals) texture while some, like the Pridays, have an aphanitic (very fine grained, amorphous) texture. Some show fine layering, indicating they are an altered ash deposit. Some have a very well defined, highly silicated nodular form, others less so. Some, like the Skull Springs, have a pronounced radiating structure from crystallization in the lava matrix that became highly silicified. Notice the Baker Ranch with the three banded agates. It displays concentric cracking that is common in thunder eggs and thought to be caused by hydro-thermal pressure acting on concentric silicated bands.

All those types of lava rock are the subjects of a great deal of study in the geologic sciences that go far beyond what the average rockhound or lapidarist needs to know. But it is nice to know that differences in volcanic histories help determine the characters of the agates.

Agate Seams and Veins

The earth movement, heat, and super hot mineral bearing water emanating from volcanoes also affect older volcanic and sedimentary rocks in the area, forming agate bearing seams and veins, some with massive amalgams of silicated 'country rock' (the original host rock), agate and calcite. Some of these amalgams in the Big Bend area weigh thousands of pounds and include some really fine agates and jaspers. Among the agates from this source are San Carlos area plume and moss agates, and lace agates marketed under a variety of names, chiefly Mexican Lace and Crazy Lace.

Massive San Carlos agate



Close-up of San Carlos agate

The above photo is of a large chunk I sliced off a massive agate from the San Carlos area in Chihuahua State. It is part of an amalgam of chalcedony, quartz veins, and calcite pockets and veins formed in volcanically altered host rocks containing limestone.

The geological complexity of the area has created a wealth of great agates. I have seen both 'seam' and 'vein' used to describe these agate deposits. In the technical literature of geology and mining engineering real distinctions are often made between the two, although the differences, especially in common usage are not always clear – nor need they be. Widespread, planar deposits of rock or minerals, especially of sedimentary minerals like coal, are properly called seams – never veins. Veins, properly speaking, are mineral fillings of fractures in rock. They are also planar, wide and thin, but usually smaller and more localized. Usually, veins are at some angle to the horizontal. Often, the term 'seam' is used for larger and/or more horizontally oriented veins, and for most any commercially developed mineral body, however.

I am going to make a rather arbitrary, and probably unnecessary, distinction between the two simply to facilitate a better description of agate as it appears to the retail customer, not necessarily as it occurs in the mine. I would consider the term 'vein agate' for an agate with an elongated or planar form with identifiable edges.

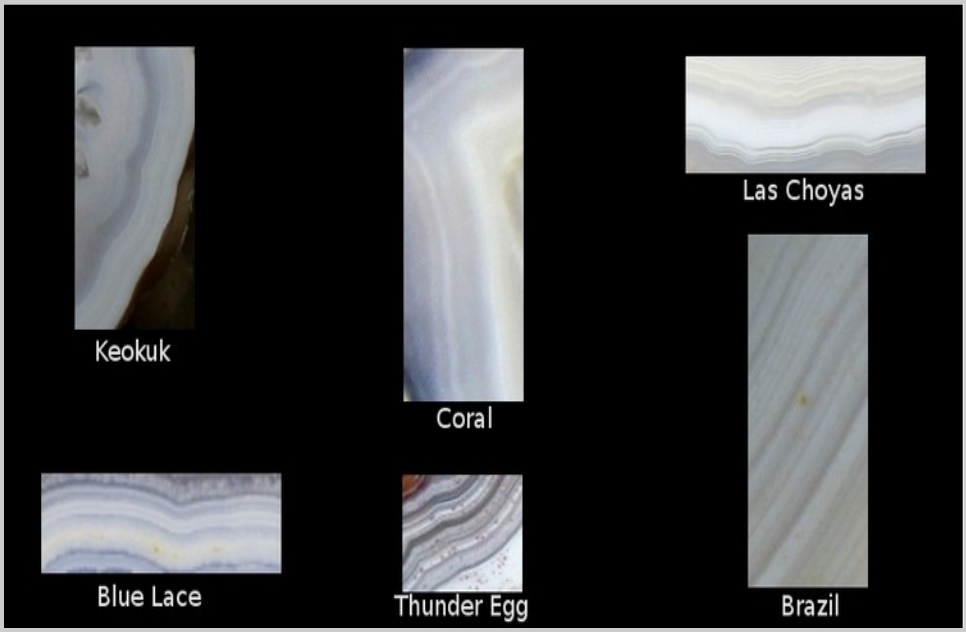
Many vein agates, especially the plumes, show bilateral symmetry – let's say a sandwich-like form. More massive, asymmetrical patterned agates that could come from larger veins, lenses and pods, I am lumping into 'seams'. There would be many exceptions to those rules, of course, but perhaps this would be of some 'rule of thumb' use.

My armchair opinion is that many of the San Carlos plume agates and Mexican Lace agates coming from massive altered sedimentary rocks could be said to derive from seams. Many other agates, like the plume agates dug from narrow fracture fillings in the volcanic rocks of the northwest US seem to me most properly called 'vein agates'. In the casual use of rockhounds and lapidarists, either term should be acceptable simply to distinguish them from agates that form in isolated pockets.

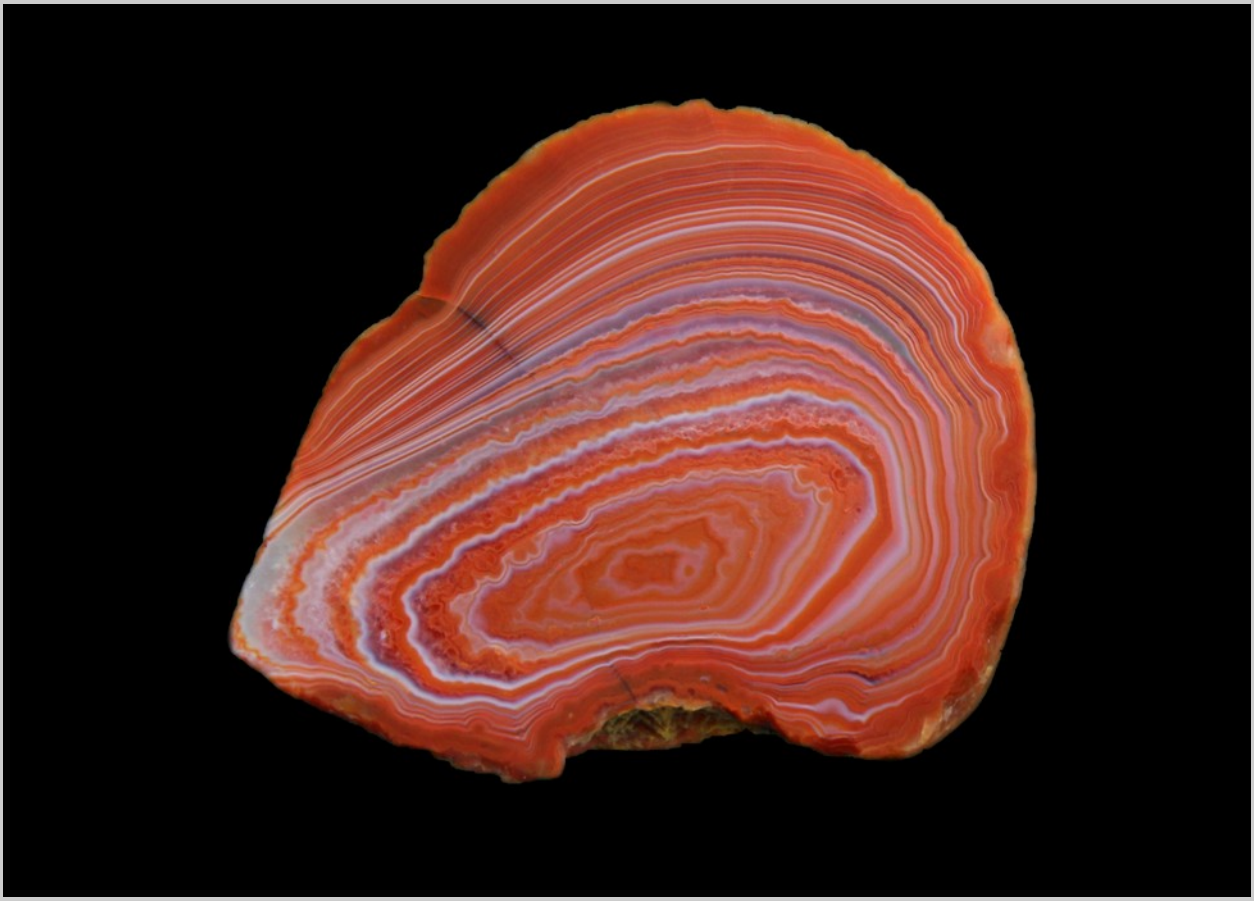
Many of the most popular agates come from narrow veins in volcanic rock. They may feature banding, or they may contain moss or plumes. Many bear at least this one similarity to banded nodular agates: in the common agate vein, chalcedony grows from the sides toward the center. Remarkably, orientation of the vein – vertical or horizontal - doesn't seem to make much difference to plume formation. That gives us a hint of their complexity. Banding builds up in layers of more or less uniform thickness but often in wild patterns. These are usually cut into long strips perpendicular to the plane of the vein. The appearance of an elongated, bi-laterally symmetrical pattern is the key to my identification of a 'vein' as opposed to a seam or pocket agate.

Here are a few examples of massive seam, and vein agates:

Vein and Seam Agate Gallery



Pocket Agate Gallery

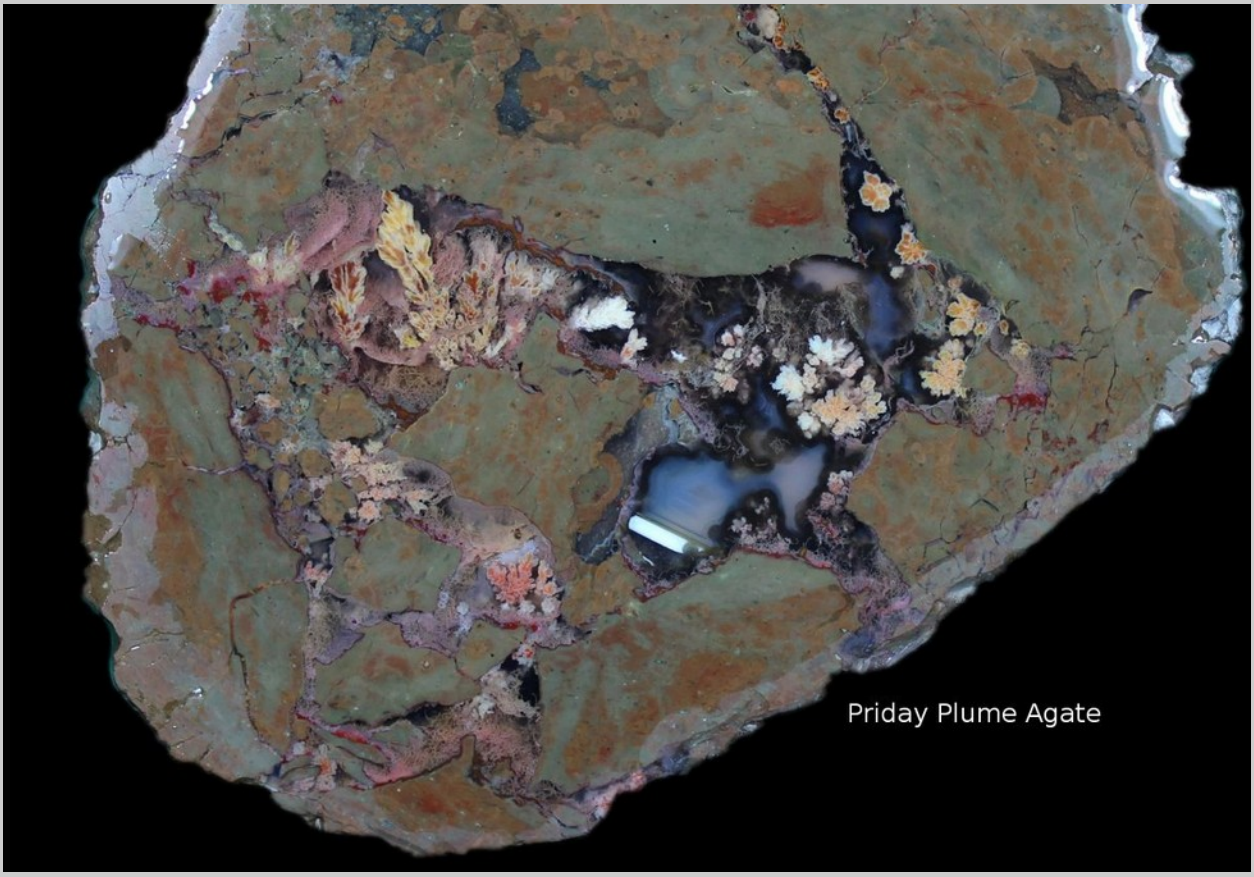


Lake Superior Agate

This colorful 'Laker', though missing a corner, has the classic amygdular nodule look, including the little nob or 'button' at the bottom. What is unusual about it however, are the wild gyrations of the inner bands. We'll see these again later on and I'll make a stab at explaining what causes them.

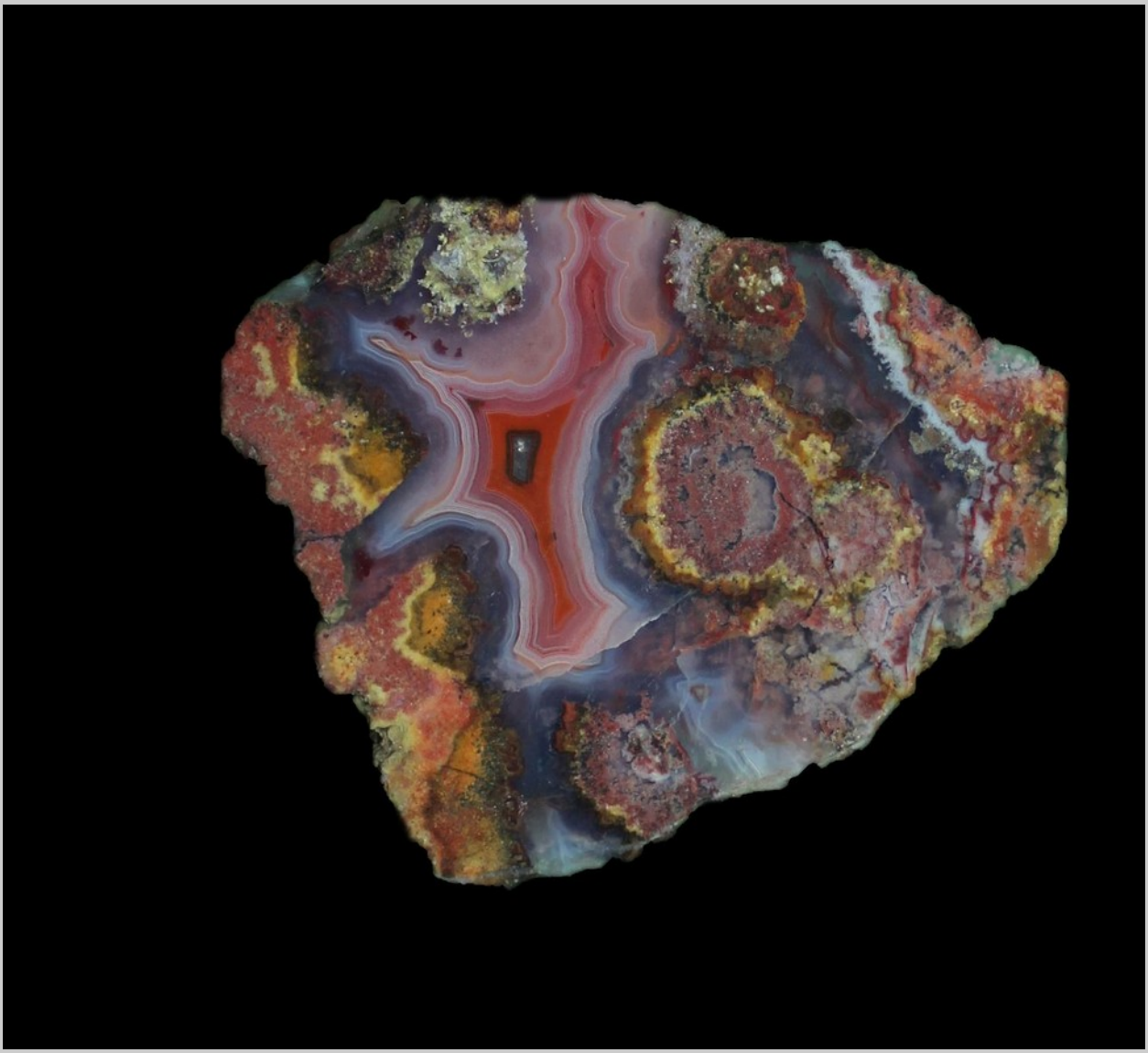
Thunder Egg, Poland

This is not the classic five pointed shape for a thunder egg agate, so what gives it away as a thunder egg? Why the hard, silicified rock shell encasing it, of course.



Priday Ranch Plume Agate

This also is far from a classic thunder egg shape with the agate seeming to form in random cracks and crannies. But, the agate is encased in a five inch ball of hard, silicated rock. Associations also count for what we call agates and this came from perhaps the most famous thunder egg site of all. If you have seen the macro-photo gallery on the website, you have been treated to a close look at this agate already.



Laguna Agate, Mexico

What should we call this beautiful fortification agate that seemed to form in an irregular, happenstance void in jumbled rhyolite? I'll leave it at simply “Laguna Agate” and, admittedly, that's only a guess for this little agate nub end acquired from a dealer friend who acquired it from another dealer's estate.

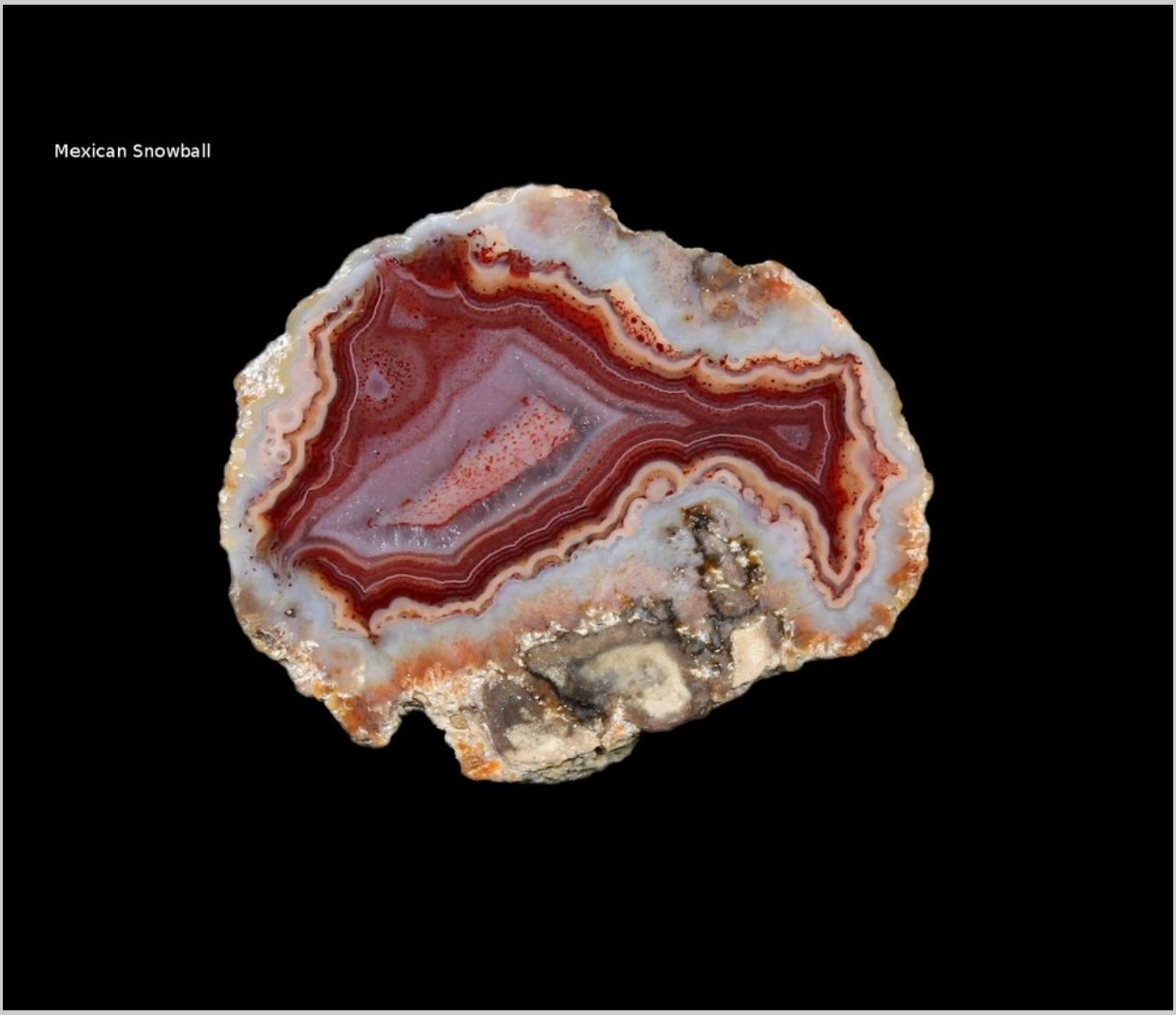
Zacatecas Thunder Egg Geode

This is a classic 5 pointed thunder egg in a course rhyolite shell. That it is hollow makes it a geode. The wispy 'feather' or 'cloud' banding is fairly common but not well understood. It will be discussed in a later section. Macro-quartz crystals line the interior.

Thunder Egg versus Nodule

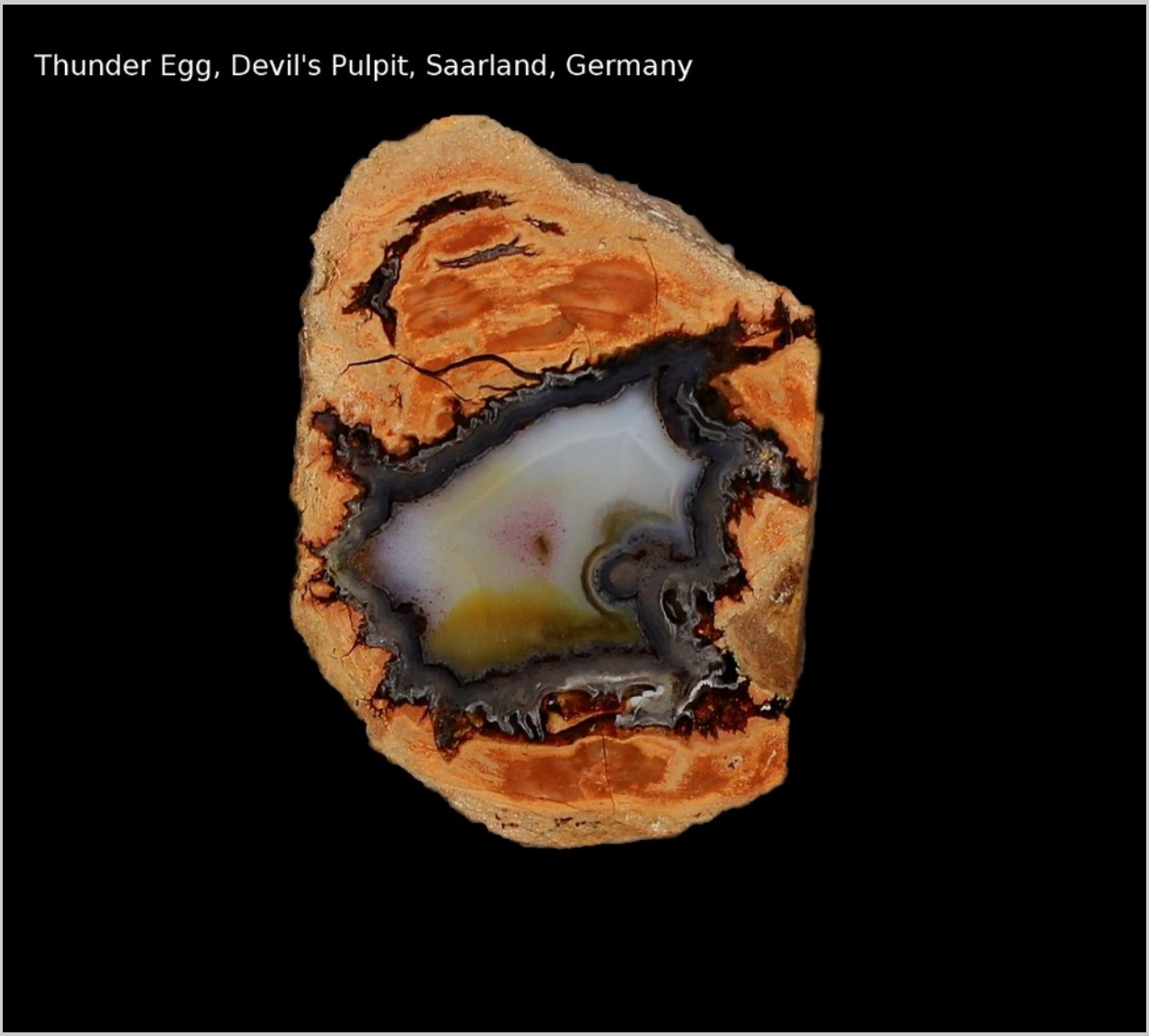
The Zacatecas Geode is clearly a thunder egg. The Las Choyas is more of a question – not whether it should be called a geode since it is not hollow (though that is problematic too), but whether it is a nodule or a thunder egg, or something else entirely. These were long known as 'Mexican Coconuts' because of the roundness, unusual for a nodule. But the complete wall banding and pock marked but fairly smooth outer surface favor formation in a gas bubble. This one has a rim of weathered zeolite crystals, more common in nodules than in thunder eggs.

Still, they don't form in basaltic lavas but are associated more with rhyolites; or rather with a clay associated with rhyolites, perhaps an altered perlite (a glassy volcanic rock). It may be that they formed in secondary gas pockets as did the thunder eggs, rather than from gas bubbles formed in the molten lava. Either way though, if I had to put a label on them, it would have to be 'nodule': calling them simply 'geodes' solves that dilemma.



Mexican Snowball Agate

These small agates from northern Mexico are now getting rather rare. They have a more or less white skin, hence “snowball” and don't seem to fit in neatly with either thunder eggs or nodules; like the “coconuts” in that respect.

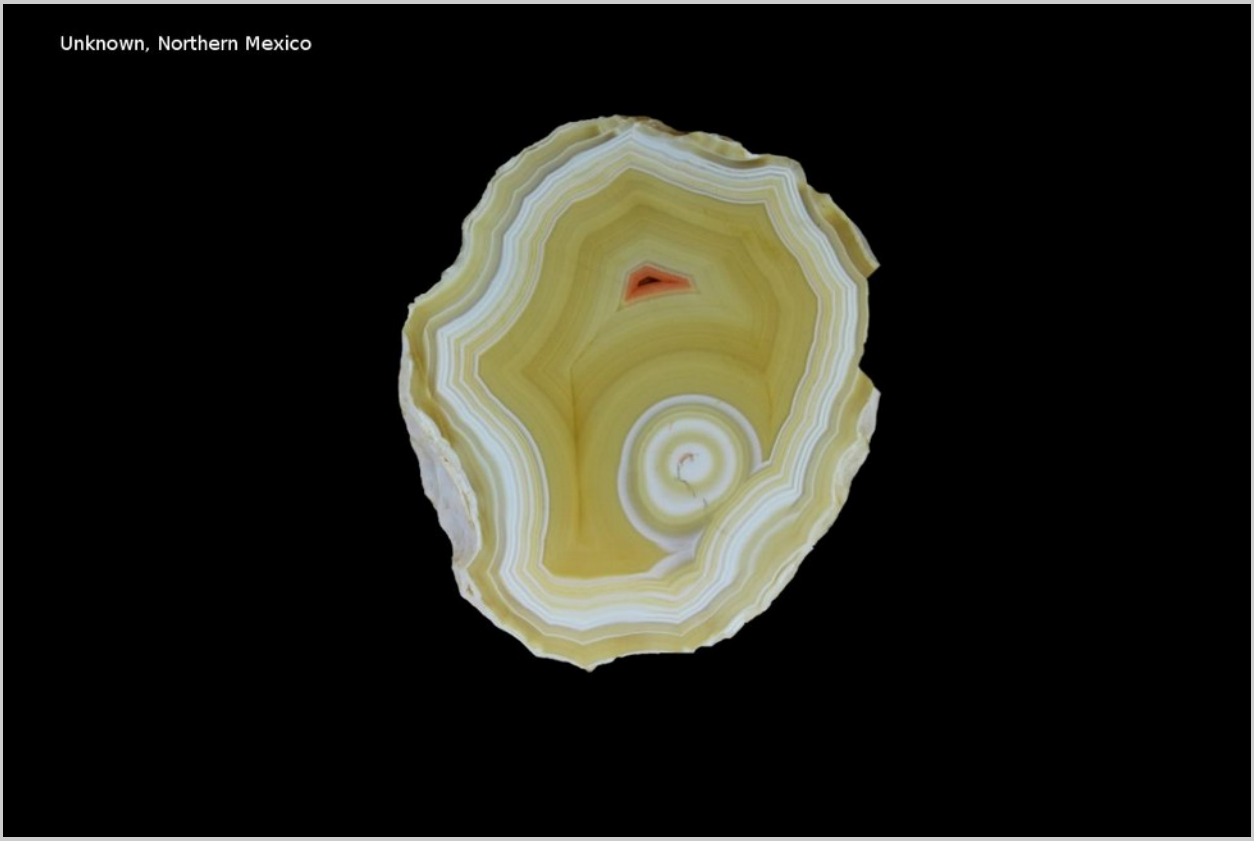


Thunder Egg, Germany

This thunder egg is just as weird looking 'in person' as it is in the picture. Perhaps the location name “Devil's Pulpit” contributes to the creepiness. It is in a very fine rhyolitic shell.

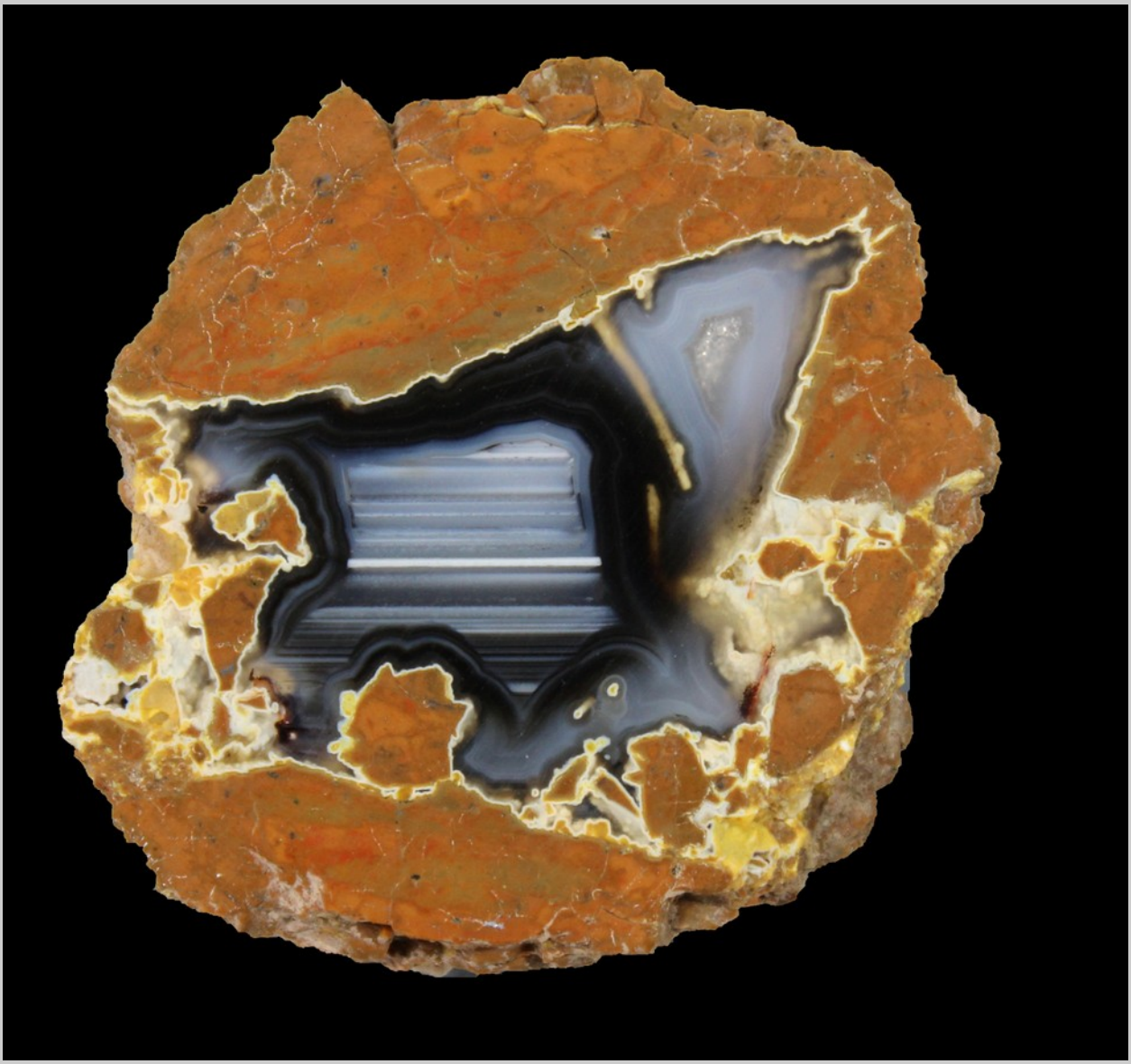
Smokey/Citrine Agate, Northern Mexico

This is a slab off an unusual, rough pocket agate with Laguna-like banding and a center of quartz crystals colored somewhere between smokey and citrine. A geode? Hollow enough (barely) to qualify, I suppose; but not round (earth-like) enough.



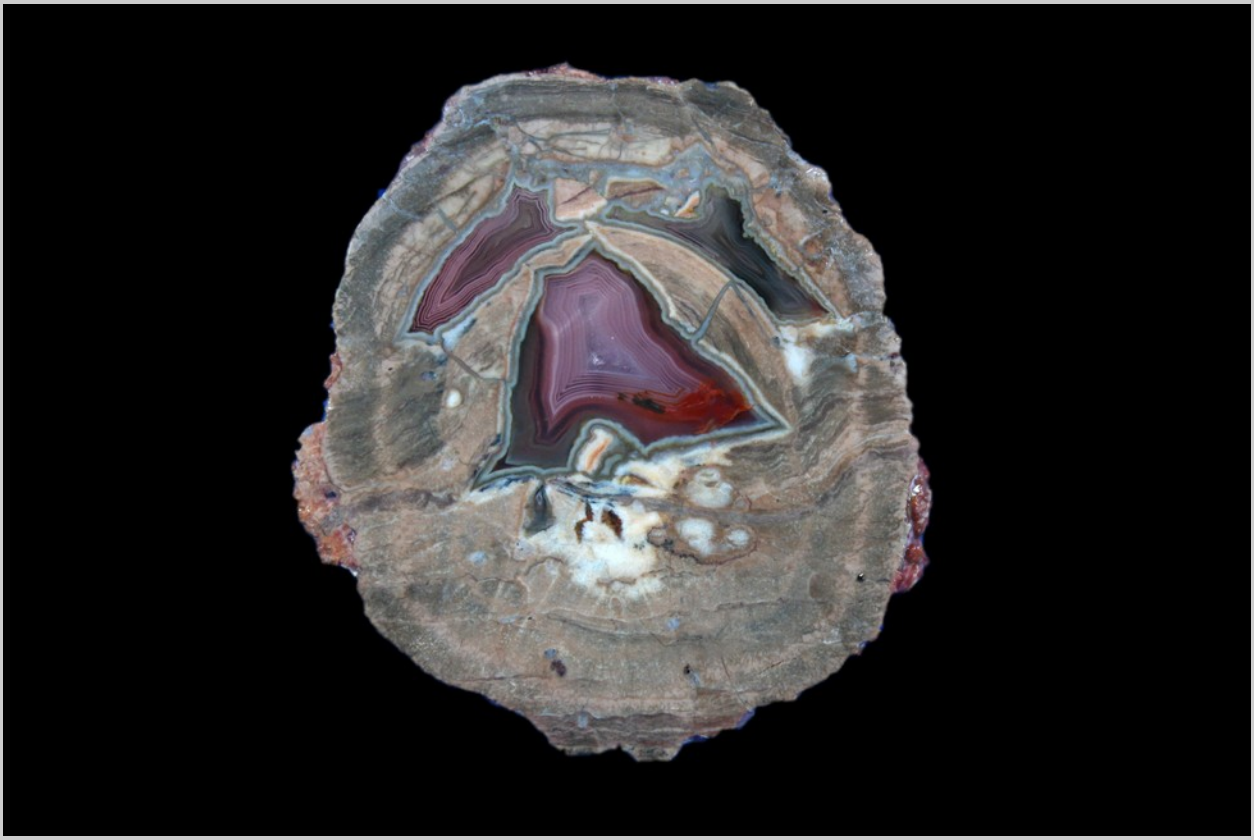
Unknown Agate Nodule

This is a small fortification agate nodule of unknown origin, although I'm reasonably sure it is from northern Mexico. It has a white, glassy but pockmarked skin which is indicative of a few of the many agate beds of northern Mexico. It is oddly opaque for an agate.



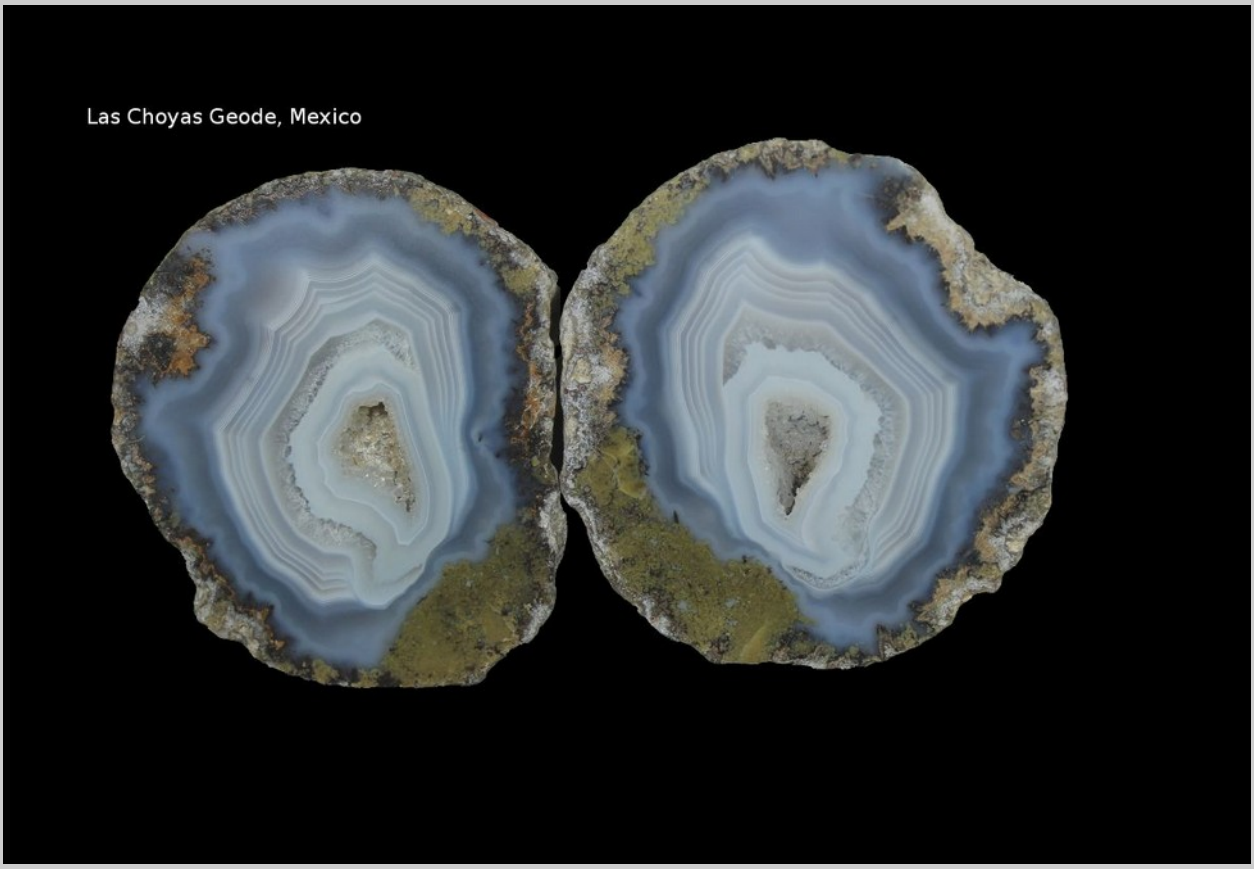
Priday Blue Bed Thunder Egg

This thunder egg contains wall banded and water level agate much as a nodule; indeed if the exterior were missing it would be hard to tell this was not a nodule. I am using the old, established name “Priday” as an identification term; the site, I believe, is now the Richardson's Rock Ranch near Madras, Oregon.



Baker Ranch Thunder Egg, New Mexico

This little egg contains three banded agate pockets interconnected with chalcedony stringers. The outer two pockets occupy cavities in radial cracks, a fairly common phenomenon is some thunder egg beds. The white area below the central agate may represent the original center of the cavity. Fine layering in the shell may represent ash deposits.



Las Choyas Geode, Mexico

This is a nice, smallish, Las Choyas Geode cut and polished. These are better known, at least to old timers, as “Mexican Coconuts”.

Skull Springs Thunder Egg, Oregon

Note the complexity of this elongated thunder egg, both in the highly silicated radiating shell and in the agate core from one end to the other. Notice also, as best you can see it, the very glassy exterior.

Thunder Egg Geode

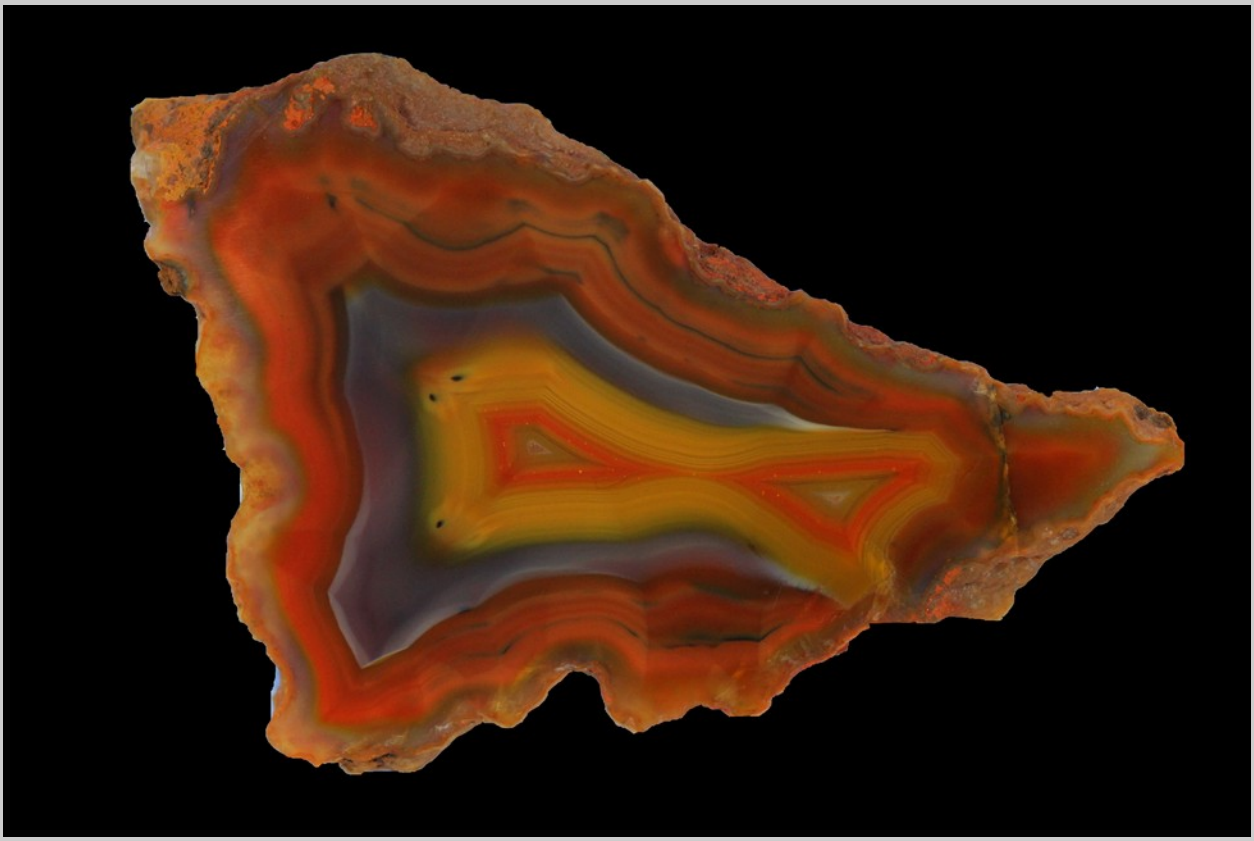
Although roundish and hollow, this is obviously a thunder egg, not a nodule. Some thunder eggs display the edges of the chalcedony fillings on the outside of the 'egg', as this one does. The rope-like exterior is characteristic of certain beds... (one of the great things about being an old rockhound is that you've collected lots of rocks; the drawback is that you may have forgotten what they are. I can't recall at the moment which thunder egg this one is).

Brazilian Agate Slab

A fairly large, about 6.5 inches across, and complex Brazilian agate; but one that can be identified as a nodular agate, one that formed in an amygdule in basaltic lava. Brazilian agate nodules know few bounds in size or shape.

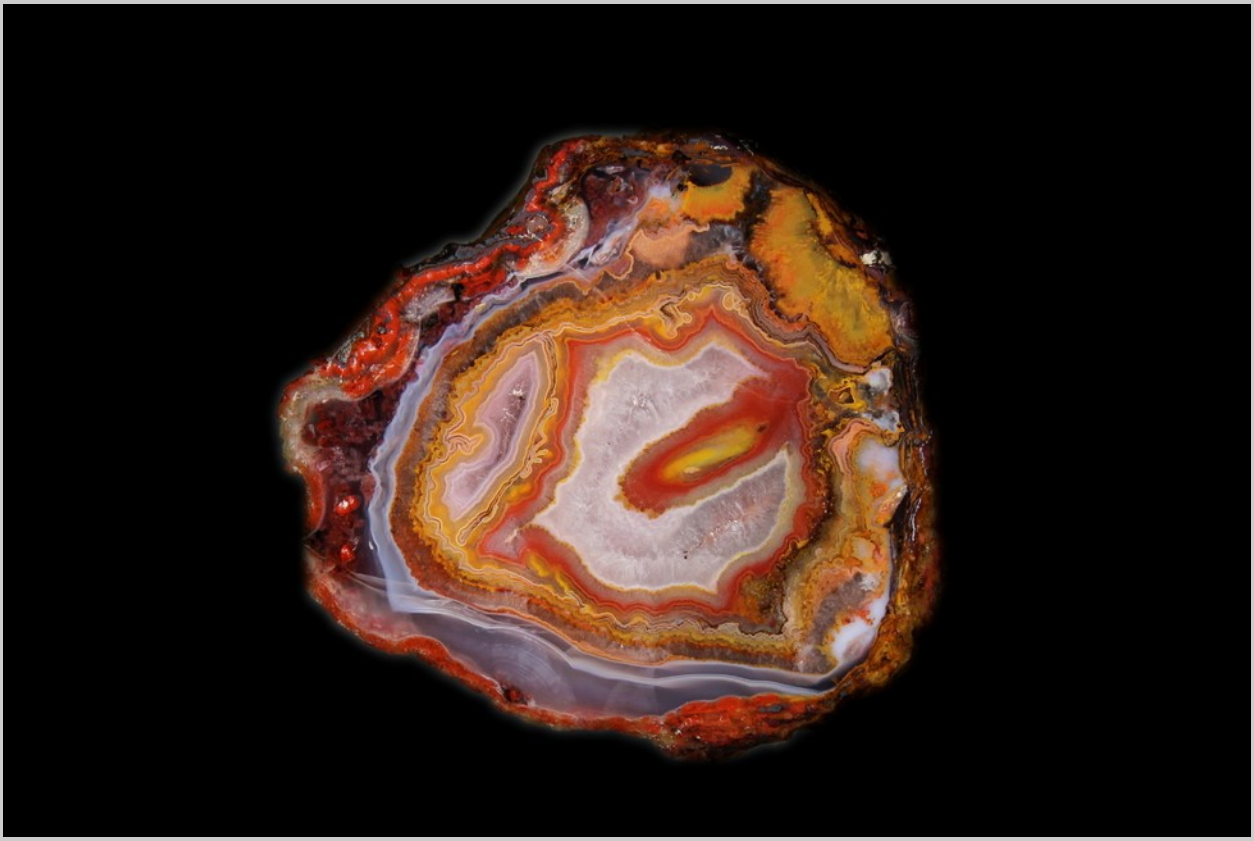
Janos Agate/Thunder Egg, Mexico

These thunder eggs typically come in this unusual shape in rhyolite pods. Some are more colorful than this one, but they are not known for bright colors. Again, the silicated shell marks it as a thunder egg rather than the form of the agate.



Condor Agate Slab

The angular shape of this Condor agate slab could indicate it as a slice off a vein agate, but I consider the closed pattern and pressure release structure (seen better on the back side) proof of its origin as an agate that formed in a pocket.



Ansi, Morocco Agate Nodule

Here we have a very colorful and lively agate nodule from Ansi, Morocco with complex banding and a poorly defined sagenite spray at the top right.

Botswana Agate Nodule

I'm closing out this gallery of 'pocket agates' with this photo of a classic amygdular nodule with near perfect wall banding. Another plus of this agate is that, at about 3.5 inches, it is larger than the average Botswana.

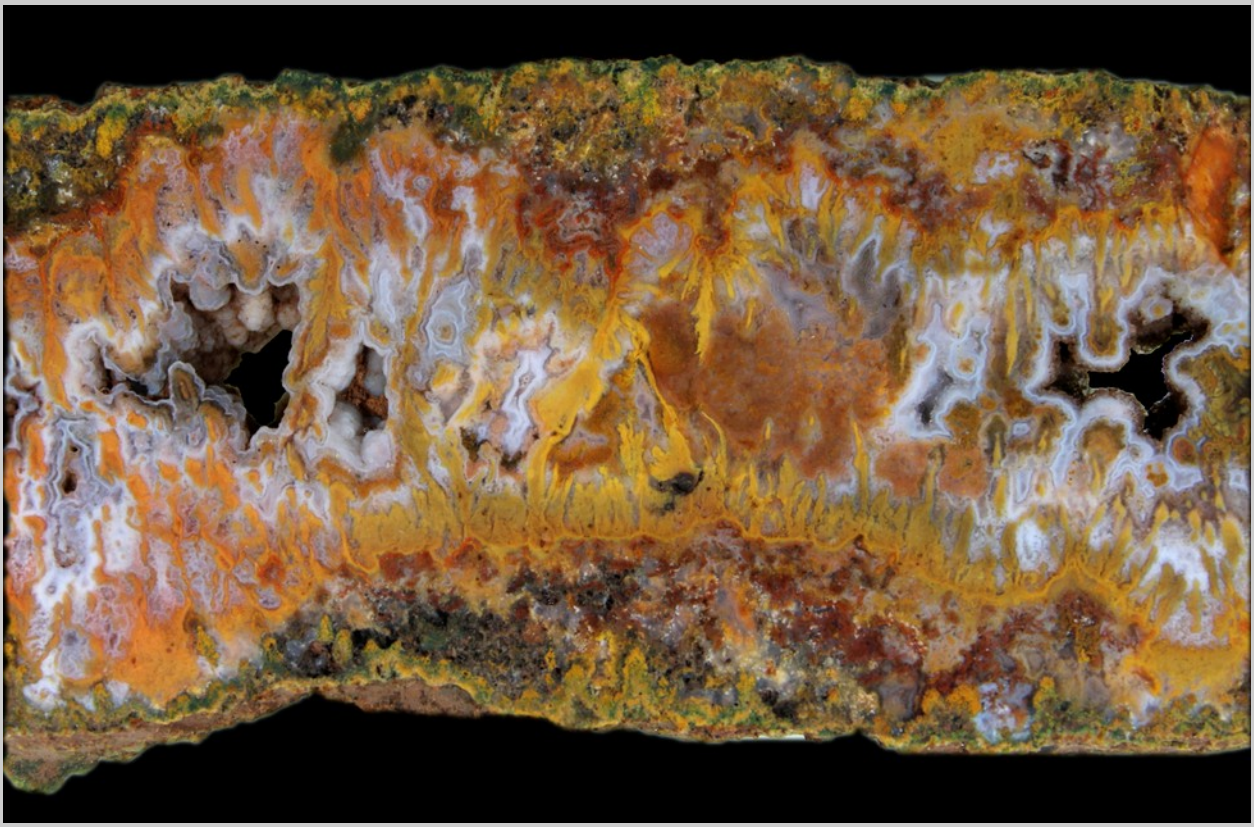
Vein and Seam Agate Gallery

Royal Aztec Lace Agate, Mexico

This agate displays the bi-lateral symmetry that, to my mind, characterizes the ideal vein agate. Royal Aztec Lace is one of the finest vein agates, and my photography was never able to do it justice. The bi-lateral development of plumes and banding will be discussed later.

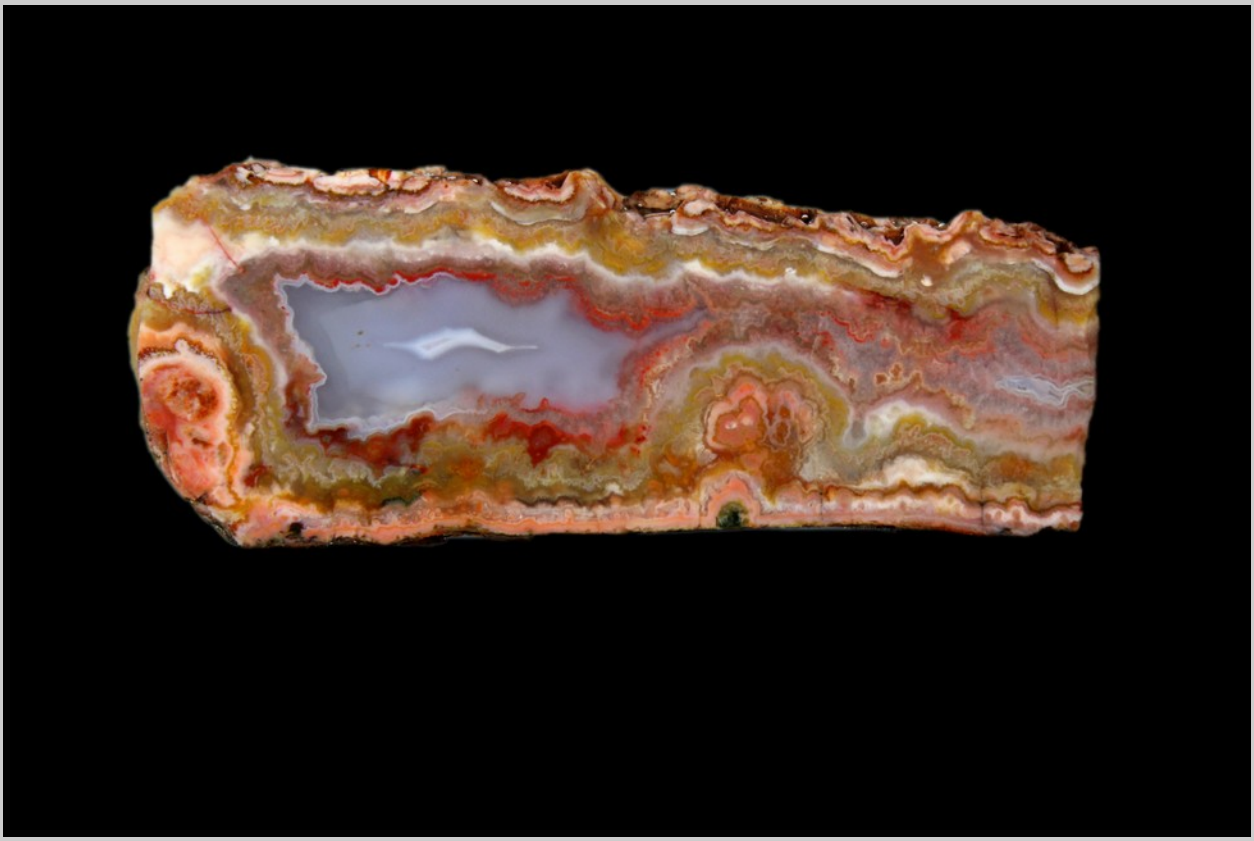
Prudent Man Agate, Seam 2, Idaho

This large slab contains portions of both sides of the vein. The yellow material in the center cavity appears to be silica sinter, a soft somewhat amorphous material common around hot springs that is a secondary deposit. It gives us a reminder that these agates form in volcanically active areas. The banding in the sinter is not, I think, equivalent to the banding in the plume agate but represents cyclic depositions.



Plume Agate, Cape Split, Nova Scotia

This vein agate with fiery plumes might well be counted with the flame agates we will look at in a later section, most of which are vein agates. It contains both top and bottom and displays the bilateral symmetry of a vein agate very well.



Berber Agate, Morocco

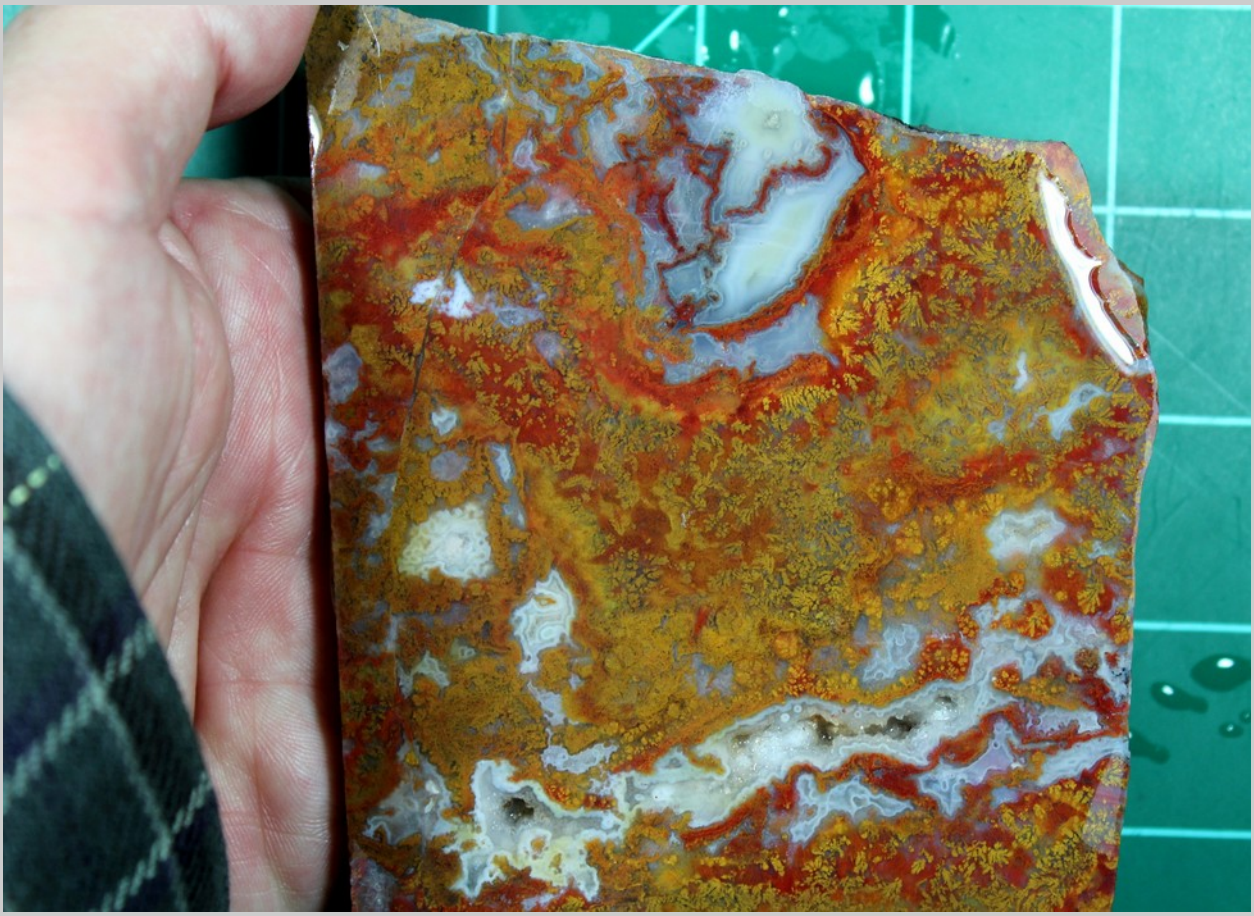
An interesting small vein agate, hardly over a inch thick. Morocco has been a producer of agates from ancient days but new discoveries have produced some really fine agates.

Crazy Lace Agate, Mexico

These agates are blasted out of large seams of altered rock in the northern Mexico volcanic region. The kind and quality of the agate varies greatly in these seams (or veins, if you prefer). They contain agates showing both bilateral symmetry and closed fortifcation banding, but since they are part of larger agate structures I don't include them either with veins or pocket agates.

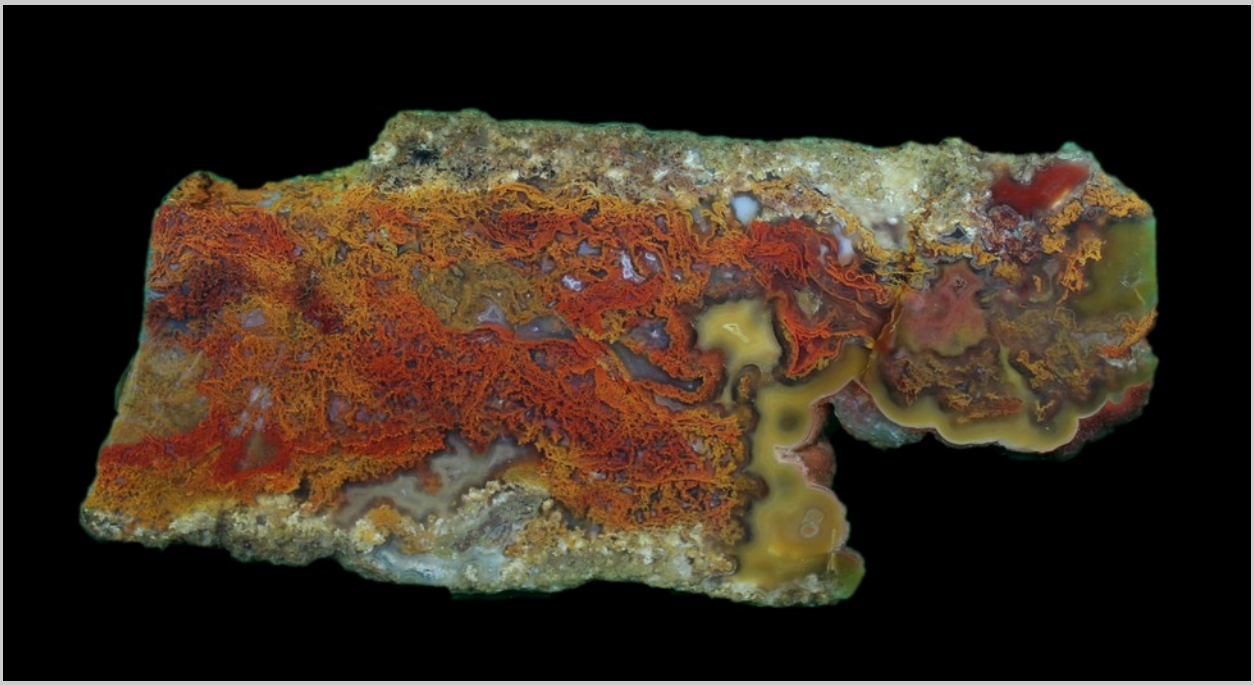
Brenda Agate, Arizona

The Brenda agate beds are prolific producers of what are generally described as vein agates, though not of the ideal bilaterally symmetrical structure. This one has a sagenitic appearance reminiscent of ice crystals around a drusy quartz cavity. And a disrupted outer layer that has settled into the interior.



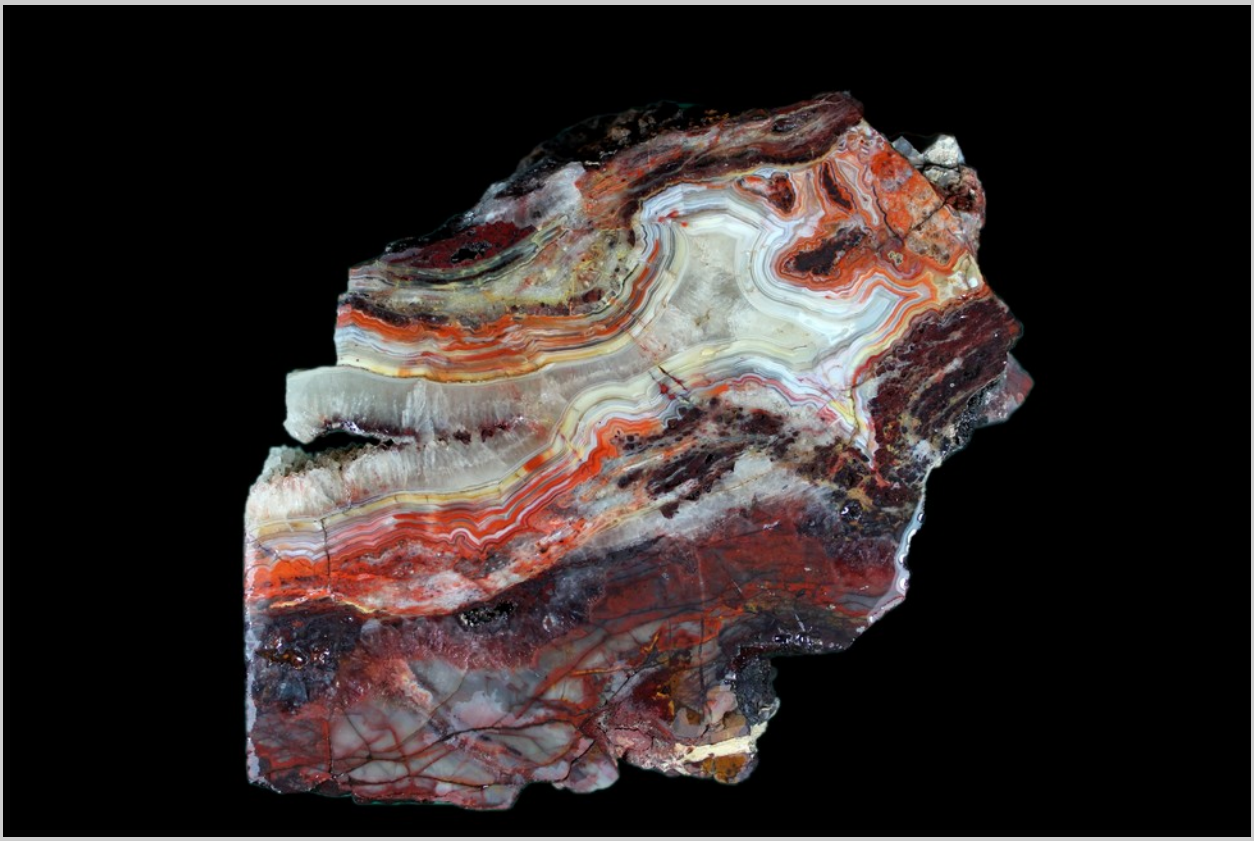
Bloody Basin Plume Agate, Arizona

This fine plume agate I know only from slabs but it appears to be found in larger veins or pods without obvious bi-lateral symmetry. Seam would probably be an appropriate term also. The Macrophoto Gallery has close-up photos of this beauty.



Maury Mountain Moss Agate, Oregon

The Maury Mountain moss agates are possibly the most popular and well known American moss agates. They appear to be found mostly in thin veins. This one is about two inches thick. Like most moss agates, it does not have noticeable symmetry but it does have identifiable upper and lower (or side) edges.

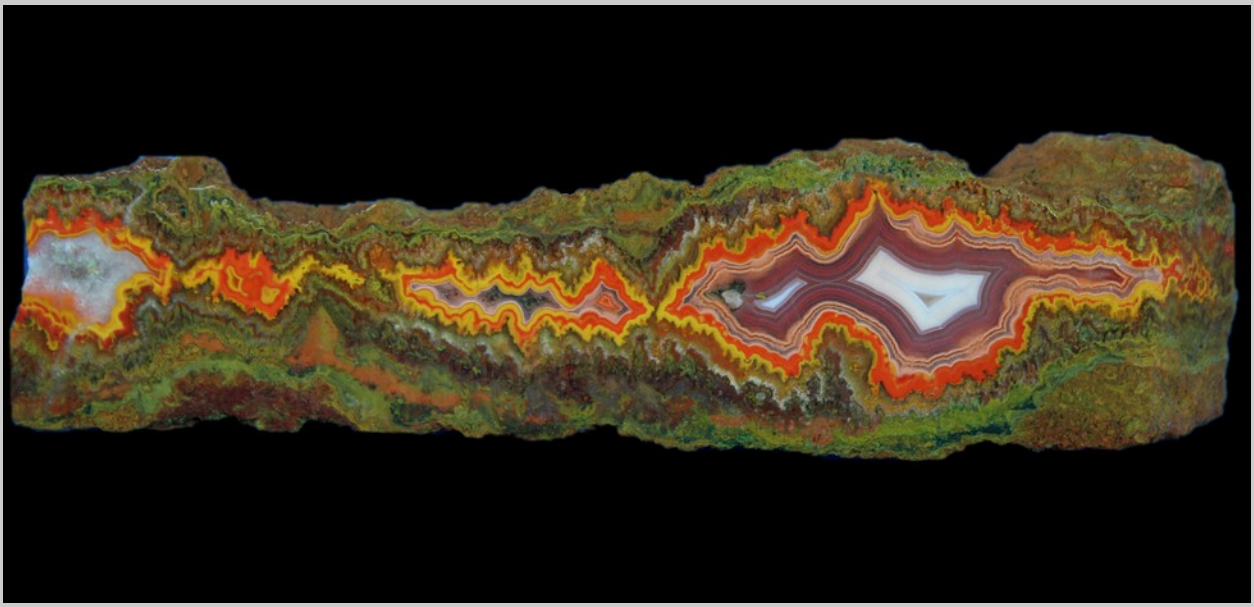


Crazy Lace Agate Seam, Mexico

This agate appears to be a self contained wall banded agate surrounding a macro-quartz lined cavity. That I do not consider it either a pocket agate or a vein takes a little explaining. Like the Crazy Lace above, this piece comes from the massive altered rocks of northern Mexico's volcanic region. The rock surrounding the agate is itself a hydrothermal vein material, perhaps something that could be loosely called an iron skarn type rock. Because of its forming in these massive complexes of constantly changing character I would call it a seam agate.

Crater of Diamonds Vein Agate

This is a 'plate', we might say, of vein agate from the volcanic region of Arkansas' Crater of Diamonds. It shows top and bottom edges (or more likely side edges) and a planar shape with a natural break on the front and a cut on the side. Unfortunately, like most of that material it is an unattractive 'bacon rind' agate.



Kerrouchen Agate, Morocco

I'll close out the Vein and Seam Agate Gallery with a gorgeous vein agate from this newly discovered agate region of Morocco. You may have seen this agate already on the website, but if you are like me, you are not tired of it.