The World of Jasper

By: Donald Kasper, May 2012, Rev 2

I have completed a book about rockhounding in the Southwestern U.S. titled A Southwestern Field Guide to the Agates, Jaspers, and Opals. At this point, it weighs in at about 466 pages. That is 466 pages of two-column, single-spaced, 10-point type. It's a lot of writing. Half is about the geology and geochemistry of these silicas, and the other half is a classification or Lexicon of terminology for all these silicas as they occur not only in the Southwest, but worldwide. Several hundred charts and several hundred photos are included.

I would like to share some of the observations I have made going though all the literature, collecting, and studying them over the past decade. First and foremost is that there are two great divides people don't see when reading the rockhounding literature. The first great divide is that when we read almost any textbook or article on rocks and minerals for our beloved agates, jaspers, and opals, we are reading the scientific state of 1950 to 1960. This is when most of the ideas in circulation today were written. There was no knowledge of plate tectonics at that time. There were the first electron microscopes starting to be used. This was the dawn of using x-ray spectroscopy to study rocks and minerals and identify them precisely at the atomic level.

So, we have several ideas about the formation of these silicas, and as I have gone through the latest scientific literature, I find that most appear to be wrong. The one that may be right is that some geodes probably do form in gas pockets, but not in volcanic ash. Everything else has pretty much proven up as incorrect. Let me rant about some. First is that jasper is a form of quartz. It is cryptocrystalline. This is untrue. Jasper is a rock of variable composition made up of a combination of silica (quartz) grains, opal in various forms, clay, and iron. There is absolutely nothing crystalline about jasper. It does not form quartz crystals. It is not unstable as an amorphous quartz, waiting to convert to quartz through a process called devitrification. There is no devitrification. It is a myth. Banded Iron Formation jasper occurs throughout the world. It is banded hematite, jasper, and agate. It is 3.5 billion years old. None of it has converted to crystalline quartz. None of it has a crystal structure.

The basic idea about jasper is that it is all sedimentary. In 1950 it was. By 1980, deep sea drilling programs probed the world's oceans and found it around deep sea vents. Those oceanic plates move with plate tectonics, and where they slam into continental plates, get pushed into the crust up to two miles, then pushed up where we can see them today. They form the jaspers in the mountains of Norway. They form the jaspers of the Coast Range Mountains of California. They are all metamorphic. The high pressure but low heat recrystallized the jasper to make new minerals. Chlorite, epidote, stilpnomelane, and some remnant sulfides from the deep sea vents they formed around originally are all to be found. In fact, the reason why jasper has been hard for geologists to pin down as a definition is due to the failure to distinguish between these metamorphic jaspers and continentally formed jaspers.

The continental jaspers, like the agates are supposed to have formed around playa lakes. Few ask these geologists to explain why none is found there today. Lavic Siding has it you say? Really?

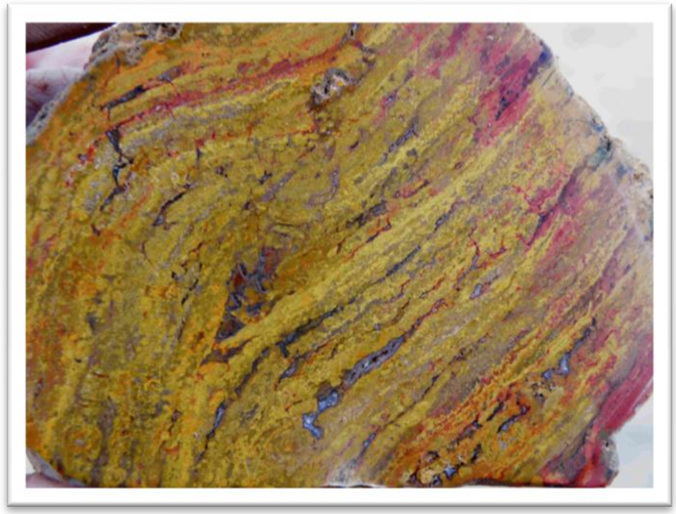
Bloodstone. A mixture of red and green jasper. From Kramer, CA.

Notice how the Lavic jasper field is 20 feet above the Lavic Lake playa? That is a critical 20 feet. It turns out that in hypersaline, alkaline deposits like playas, silica forms zeolite minerals, not agate, and not jasper. That piedmont just above the playas has volcanic ash and gently sloping terrain that allows the accumulation of water. In the soil several feet down, is an impermeable zone of caliche that forms in desert regions. Water accumulates there. Ash and water are our friends in the hunt for the agates, jaspers, and opals. Like NASA would say—follow the water. For us, it will lead to the rocks we are hunting for. It takes seasonally saturated soil to form continental jasper, but it also forms along faults that trap water, and previously active (now extinct) hydrothermal springs. Jasper in continental conditions also forms as an iron constituent of soil.

I suppose at this point I need to define what jasper is. We can use a standard definition: Jasper is any silicified rock that is opaque. This definition is pretty much in line with geologic literature that also calls chert a jasper, hydrothermal silica a jasper, silicified mud a jasper, jasper to them is a garbage can and just covers everything. To me, this is why after 150 years of study, so little advancement has been made in the study of the jaspers. You cannot include everything on earth with silica and get very far because every geologist is probably seeing something different, so there is no consistent literature to learn from.

Let me start with my definition: To be a jasper it must be dominated by iron chemistry with silica. Being opaque is not sufficient. With iron chemistry, the compounds that occur will make it red, yellow, green, purple, and black. I don't like using color to identify rocks, but from a field identification standpoint, these colors are invariably related to iron, and iron's companion, manganese. The iron and manganese come from the volcanic rock that must overlay the deposit to form the jasper. Basalt has up to 25% iron content and so does jasper.

So what about all those opaque tan, cream, white, grey, light brown silica rocks? Those are silicified sediments. In virtually all cases, you can see the erratic layering that defines them as sediments laid down in deltas, rivers, and most commonly, lake deposits. Ever notice the very pale blue agate in these rocks? It is so pale (they call it low chroma) blue, while some think it is a grey. This is a type of fossil soil called gley. Gley is a Russian term that roughly means blue-grey clay. It forms in bogs and waterlogged soils. When we see Mojave Desert palm root for example, we are looking at this silicified bog, and so to distinguish it from jasper, I call it silicified sediment.



Yellow jasper. Banded by forming in a hydrothermal system on the Hector fault. From Hector, CA.

A silicified sediment. Notice the low-chroma blue agate in it that points out its origin so clearly? From Boron, CA.

One critical mineral for formation of the agates, jaspers, and opals is bentonite clay. This mineral has many fascinating attributes. First, it has substantial opal in its composition. This opal is in a special form that forms a colloidal silica gel. A colloid is a tiny, micron-sized sphere of silica. Uncounted millions in a gel do some wonderful things. First they keep impurities that get into it in suspension. Ever notice the red iron spots in agates? That is colloidal iron. It is the ability of bentonite to keep iron colloidal that gives the uniform color to jasper. Without it, our iron cakes into plates, lumps, and layers. Notice the Owyhee jaspers? They are ironstones, muds, and silica. They are not jasper.

Colloidal chemistry gone wild. A green jasper with oolitic spots of opal. From Castle Butte, CA.

The most fascinating thing of all about bentonite is that, when wetted, it expands by 15 times. Notice the plumes in your agates? The cloud structures? The blooms? Yes, in the 50's everything was a mineral and these are all supposed to be iron pseudomorphs. There is, unfortunately, no literature that exists to prove it. These structures all match the behavior of bentonite clay, which is a much more likely candidate. Ever see a form of iron or pyrite that was white? No you say? Neither have I. But I do find that most of these inclusions are white, and so is bentonite.

What I have found is that upon identifying all the conditions of forming bentonite colloidal gels, I can match those conditions to field conditions where I find agates. Where colloidal gels cannot form, I do not find the agates. Let me give an example. If a bentonite silica gel has over 3% salt added, it will flocculate into small flakes that will settle to the bottom and cake. The gel collapses. Okay, do we hunt for agates in salt playas? I think you get the point; there are no such site. The agates must form on the piedmont slopes where the salt is flushed out.

In my Lexicon, this is termed a bentonite-agate from the intrusion of bentonite into this agate nodule. From Fort Irwin, CA. The popular rockhound literature does not recognize the existence of bentonite in agates, probably because the writers do not collect for themselves.

Silica gels have strange behavior. When they sit at rest, they form gels and act like solids. When they are agitated, they act like liquids. If left alone, the silica will realign atomically and expel water. This process is chemistry is called syneresis. The hardening gel captures the iron and other impurities, expelling water that still has some pure silica. The gel shrinks as it contracts, and breaks. The clear silica gel that was pushed out is still there, and moves into the cracks. A jasper-agate is formed and it looks like a breccia. If much more water is present, a jasper-agate-opal is formed. The reaction is creating silica banding structures that will hold water. As the water is taken up, silica will become supersaturated. A supersaturated solution is the chemical condition where a solution is holding more chemical than it takes to form a crystal structure or solid. This is the required condition for crystallization to occur. What is left? Silica. The water is being consumed, and the silica becomes concentrated. It becomes supersaturated. Bang. Crystal quartz forms at the very end. Our jasper and agate has a druzy quartz center. This represents the death of the agate forming system.

Crystal quartz is not the only end state of these amorphous rocks at all. It is what happens at the end of the hardening process of a colloidal silica gel that is supersaturated with silica and has diminishing water. Notice how all the vugs in jaspers, agates, and jasper-agates are always druzy quartz? That occurs at low (surface) temperatures in supersaturated solutions where crystallization occurs quickly. Crystal quartz is the end of the line. The gel is kaput.

Until next winter. Next winter, more rains come. The ground becomes saturated. Silica dissolves out of the volcanic ash and percolates downward, collecting at the caliche zone. It sticks to agate and jasper that has already formed. Nodules and sheets are forming. The process is repeated seasonally.

So, does it take millions of years for agates and jaspers to form? Probably not. From what I have learned in looking at the literature, something more on the order of hundreds to a few thousand years is more likely, with an upper estimate of 30,000 years. There simply are not enough structures found in the agates and jaspers to indicate such a long period of occurrence where they would have to remain in a pliable, plastic state. Gels just cannot hang around a long time without hardening. This means that the agates and jaspers are not forming by what we call weathering, but by hot, hydrothermal water that is the last stage of a volcanic eruption.

The second big problem with the literature that most don't recognize is that the books on the agates, jaspers, and opals are usually written by the British and Germans. Does it matter? In terms of geology, there is a serious problem. In Europe, their lavas formed largely in marine conditions. These lavas are 350 million years old. Compare that to the southwest. Our lavas are not over 50 million years old. To find something at 200 million you have to go to eastern Arizona. There are some jaspers around Wickenburg, Arizona documented as marine that are quite old, as an exception. So what do the Europeans see? Their volcanic ash is all gone. The young lavas are all gone. 95% of their geologic record for these rocks has been wiped out. They have banded agates in lava. They publish the following—all agates form in vesicles in lava. It gets repeated in rock club meetings and geology textbooks. This model spreads worldwide.

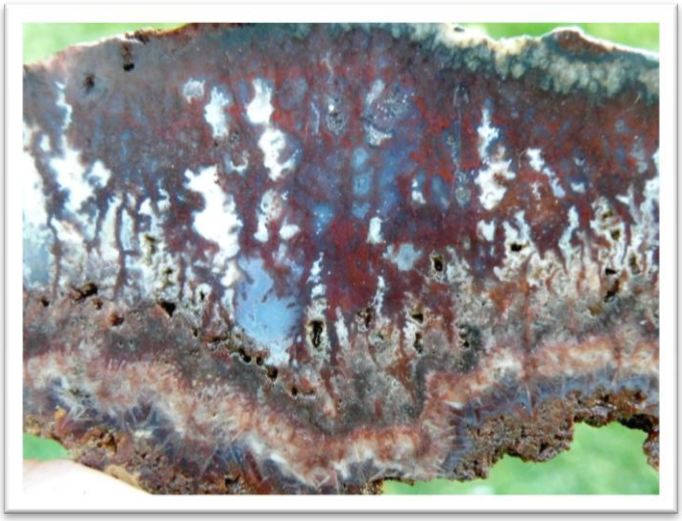
Let's look at how much of the agates in the southwest form in basaltic lava. Okay, let's start at zero. Let's think really hard to name one single place. Okay, nothing comes to mind. Yes, there is opal in the vesicular lava of Red Rock Canyon. Okay, another site. I will have to get back to you. To put it bluntly, this is another geomyth. It is the most commonly repeated myth of agate formation that is trivially refuted by looking at the agate and jasper sites we go to every weekend to collect. When was the last time you went out to a black lava flow to break lava for agates? How many times have you hunted scoria (vesicular) lava flows? Like me, the answer is probably never. Regardless of what we call it, this European geologic model of agate formation is just plain wrong for the Southwest. Agates form at the lava/ash contact zone where water is trapped.

The type of lava found in the Mojave Desert matters for agate and jasper occurrence. There are three types we can see in the field without taking back to a lab for detailed study to identify them.

First is black basaltic lava. Basaltic lava does not form agates, as we have seen. If agates and jaspers and opals are found, it is in association with the volcanic ash that alternated with basalt lava flows during eruptive episodes. This lava is so silica depleted, agates are only found in nodules here.

The second type of lava is rhyolite. It has flow patterns and is typically chocolate brown, light tan, purple, and light green from all the silica in it. These flows have abundant agate because it can form right out of the lava, an interesting separation that occurs with the presence of water in the lava. Rhyolite can do this because it has the highest silica content of all the lavas.

The third type of lava is andesite. This is red to gray with small crystalline specks in it. Andesite is so low in silica it never has agate or jasper except along faults, in veins, or related to other sources of silica such as volcanic ash. Hydrothermal solutions coming up faults due to regional volcanic activity heating groundwater will bring up dissolved silica. With iron, we get vein jasper. Without it, we get agates. With strong, hydrothermal activity and a minimum of salts, we get opal.



Hydrothermal jasper-agate from a fault vein in andesite in the Cady Mountains. Pitting at the bottom is partly dissolved barite when silica intruded into the vein. The barite is not an accident, coincidence, or a passive mineral. Sulfates such as barite, as well as calcite and rarely phosphates actively change the acidity (pH) of a system to cause silica precipitation.

Perhaps the saddest thing of all in the literature is the study of just agates, or just jaspers, or just opals. Each seems to be studied separately and is reflected in the books we read. I hope to correct this in my book, <u>A Southwestern Field Guide to the Agates, Jaspers, and Opals</u> because we need to study how they all form together in their chemical and geologic systems. So far, I have found 52 geologic systems these rocks are formed in. The days of claiming all form in lava voids is dead, and is perpetuated by ignorant, lazy, and sloppy writers. Aggregating these rocks up to make a single model of formation deprives us of all the geologic settings that occur, and leads to overly broad conclusions that confuses the mechanisms of formation.

My text is the first look at all three silicates together. It is the first to study all of the inclusions of the agates, jaspers, and opals as active, geochemical participants that can provide additional information to constrain the conditions of agate genesis. The book has over 600 theories of agates, jasper, and opal formation and the formation of their structures, backed by field studies, specimens, and the chemical and geologic literature. Based on these relationships we can use logic to make some conclusions about their formation. We can see some of the minerals that form these complex rocks particularly their interaction with the carbonates with which they are commonly associated for very specific, chemical reasons. There are over 650 terms in the Lexicon defining these silica rocks species and their identifiable inclusions and structures, including over 200 new terms for features that don't have names in the literature. I hope that you have a chance to learn from this assemblage of current literature, field studies, and photographs to make your next rockhounding adventure more enjoyable.

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