How Agates Do Not Form,

by Donald Kasper

A rebuttal of the Dr. Peter Heaney interview

“How do agates form?” by Nancy Marie Brown

Nancy Marie Brown
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"Agates are enormously complicated—even beyond what the agateers like Robert Proctor appreciate," says Peter Heaney. He glances toward the array of cut and polished agates lining the windowsill and shelves of his office. "Even in mineralogical terms, this is complicated stuff—or it would have been solved a long time ago."

Rebuttal: Agates are not quartz. They are clay-calcite-mixed silica-hydrate rocks. If you don’t know what they are made of and ignore their mineral inclusions, you cannot constrain how they form.

According to Proctor, Heaney, an associate professor of geosciences at Penn State, is "one of the world's foremost authorities on agate geochemistry." He's also one of the only ones.

Rebuttal: No. Heaney did a PhD thesis dealing some time ago with agate silica, and since has studied other things like moganite rocks. He is not a current authority on agates and is doing no continuing research on them and has never studied their geochemistry.

Heaney laughs. "It's not something you do as your direct line of research," he admits. Heaney is funded by the Department of Energy to research a problem in designing geothermal power plants. "The hot water pumped from deep within the earth contains a lot of dissolved silica," he explains. "It clogs up the pipes." How can you stop the silica from sticking to the pipes?

Rebuttal: The pipes have no agate. They have calcium and granular silica scale.

It's like asking, How do you stop an agate: For the secret to making an agate, Heaney believes, is how silica (silicon dioxide, or SiO_2) dissolves in water.

Rebuttal: Agates do not form due to hydrothermal systems. There is no hydrothermal mound, vent, hot spring, fumarole, geyser on earth that has agate on a macroscopic scale.

Only on a 200 micron scale. As for 2, 3, 4 inch agates, never. These mounds have opal-A. Agates do not contain opal-A, for those who look.

An agate starts with a cavity, a void in the rock. The best are found in basalt, a young volcanic rock. "Volcanic rocks that erupt to the surface and harden contain a lot of water and carbon dioxide, which will bubble out," Heaney says. "It's exactly the same as how Swiss cheese is formed. The rock is filled with holes."

Rebuttal: This is false. Agates are only found in lava rocks and rocks intruded with volcanic ash. Agates are not found in one granite void on this planet, so a weathering model has to explain why weathering only occurs with lava rocks and not granite rocks. This is called hyperextension, claiming one specific thing and equating it to a vast generality. Lava that erupts to the surface does not contain water. It contains supercritical fluid, which is a very different thing.

Rebuttal: Agates are found in basalts, andesites, dacites, rhyolites, and trachytes. They are also found in bimodal basaltic-rhyolites. Saying they are only found in basalts is false. They also form in vein systems, not just gas voids.

Gerald Lang and Jennifer Anne Tucker, Penn State Digital Photography Studio

Water containing silica percolates through the rock. "The minerals in the water begin to crystallize out."

Rebuttal: Water does not percolate through solid rock and dump silica in voids that are round. It dumps silica in cracks, preventing flow. It dumps silica in joints and breccias. Yet, in basalt, it is only found in rounded amygdule form. A better explanation is the exsolution of the lava separates feldspar and quartz, and that quartz masses form agate.

Rebuttal: Geodes have lava shells that represent the host lava they formed in. Silica capture hardens that lava during vesiculation so that the accumulated silica and captured lava weather out of the silica poor host rock.

Rebuttal: Water does not percolate around with silica in solution. Quartz is virtually insoluble in water. Ground water has humic acid but agates do not and water is not found in agate cores, just rims exposed to weathering. Agates are not found in soils in weathering profiles, Larger agates are not found successively deeper in weathering profiles, you never hunt for agates in soil unless it is volcanic ash, and agates are not found in granites or schists or shales or coals or sandstones or any metamorphic rocks such as serpentines.

Rebuttal: The only sedimentary rocks on earth with agates were exposed to overlaying volcanic ash as the silica source.

One of the minerals is quartz. Studying agates with by transmission electron microscopy and by x-ray diffraction, Heaney found that 90 percent of an agate is quartz. "But I found there's another mineral that has the same chemical composition, SiO_2, and a different structure: moganite. It's like carbon, which can crystallize into both diamond and graphite. Ten percent of an agate will be this other structure, moganite. I think that's an important key to understanding how agates form.

Rebuttal: This is a disgusting slight-of-hand twisting words to present disinformation to make a weathering model work. Agates are rocks with as little as 40% quartz, and are commonly found with inclusions that formed as the agates formed. Pretending they are 90% quartz is a lie based on bashing them to pieces and picking out the quartz. Yes, the pure quartz is mostly quartz, but that is not the whole rock specimen. When people are told agates are quartz, they don't know the presenter is not talking about the whole specimen, only specific bits of the specimen, which is disingenuous.

Rebuttal: Saying an agate is made of mostly quartz is like saying that since a house has silica windows, houses are made of silica. A reasonable person would not say that, but to make a weathering model work, proponents have to dumb down the vast complexity of agates to a bunch of quartz.

Rebuttal: There is alpha- and beta-moganite. Heaney uses Raman to study moganite, which cannot tell the two apart. In reflectance infrared, alpha is found in agate banding, and beta- is found in pyroclastic rocks, jaspers, and as special structures in agates.

"When you examine an agate with a light microscope, you observe that it consists of fibrous crystals. They nucleate on the wall and radiate inward like spokes on a bicycle wheel. Usually the first layer is a very fine-grained material, chalcedony, which is a mixture of quartz and moganite. Then you have coarse-grained quartz layers—pure quartz, no moganite.

Rebuttal: Chalcedony is granular quartz. A chert is a chalcedony. Agates have no granular quartz. Those confusing chalcedonies and agates do so not understanding that silica rocks containing quartz and beta-moganite are granular too, and these intermix with agates. There is just way too much overgeneralization and mixing of geologic systems to one thing when discussing agate genesis.

Rebuttal: When I look at an agate under a microscope I see tubes of celadonite with opal-C and opal-BC (opal-beta-cristobalite) halos. I see microspheres of beta-moganite. I see tubes-of-escape with beta-moganite, and quartz cores of beta-quartz (both in quartz). I see waterlines of opal-C, the only place you can find it in volcanic rocks. I see spheroids of iron

and manganese. I see acicular fans and needles of calcite called zeolites for 150 years, while spot reflectance infrared confirms no agate on earth has zeolites. I see pendant structures of beta-moganite and moss structures of opal-CT. I see implosion structures of clinoptilolite coming in volcanic ash. I see geodes with shells rich in sanidine and beta-cristobalite. I see intruded celadonite moss accumulations. I see jasper floors of beta-moganite. I see green structures of celadonite and nontronite. I see water that leached in forming opal plumes and chains of opal microspheres during agate genesis. I see melanophlogite in California coastal agates, along with bitumen. Heaney sees quartz and “moganite” which he presumes is alpha-moganite. 3 orders more complexity in agates exist than Heaney cares to be aware of. He lives in a world of quartz var agate, which is the classification used in 1830, the age of Dana. The science has moved on, but the understanding of many sits there, unable to learn and move on. Keep in mind the Dana and Heddle classifications of agate was determined studying permian European agates, and not young, Western U.S. tertiary agates that still show their inclusion structures. Most European agate structures are lost to weathering involving clay intrusion into the fiber layers. Their volcanic ash is gone, so they only have agates in lava voids, hence the myth started from what they saw, a small part of the agate story.

"Why do you see these two different layers? They're both silicon dioxide. What is changing is the crystal structure.

Rebuttal: Notice Heaney does not know why there are fiber silica layers and quartz crystal layers in agates. That is from heat of crystallization creating pauses with deposition of crystal quartz. But agates are rocks full of many other minerals including opal-C, opal-CT, alpha-moganite, beta-moganite, alpha-quartz, beta-quartz, calcite, and clays such as celadonite and nontronite. The key mineral missing is opal-A, not found in any agate on earth as that is the only opal that forms from weathering,

"Another curious thing about the agate fibers is that they twist. They grow in a helical fashion.

Rebuttal: Only alpha-quartz with alpha-moganite do that. Beta-moganite is immiscible in agate silica.

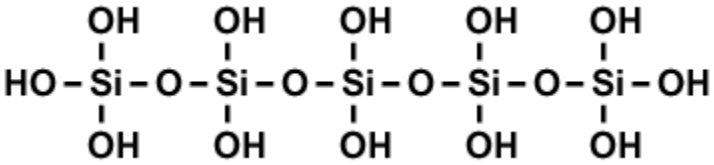
"A third part of the mystery is the crystallographic direction the fibers are growing. The chalcedony fibers grow perpendicular to the normal growth direction."

These repeating changes in crystal size, type, and direction, Heaney believes, causes the characteristic banding pattern of the agate, the colors coming from trace elements like iron or manganese. "You see oscillation in grain size at many different scales in agates. It's like a Russian doll. There's hierarchical layering. I'm not aware of any completely non-biological mechanism that accounts for this kind of layering in natural materials. How do you explain it?

Rebuttal: Quartz crystals grow in salty solution with up to 80% salt, and boiling. Agates form in negligible salt under 3%, and no boiling. The reason the quartz grows differently is that the growth is not mediated by surface tension as supercritical fluid has no surface tension. All acicular minerals are prima facie evidence of one of 4 geologically important supercritical fluids. For agates, supercritical fluid ("water") and supercritical CO2 are the key ones. Carbon dioxide defines carbonate formation.

Rebuttal: There is no fiber banding. This was known by the Germans back to the 1800's. Fiber twist causes periodic light extinction. That is a lighting effect, not structural layering.

"I think that the silicate that precipitates onto the walls has to be a little bit polymerized. Not long strings of molecules, as in a protein, but repeat units of five to ten molecules. If the concentration of silica in water gets high enough, the silica polymerizes. This is how it happens—;" He crosses to the blackboard and writes:



"The oxygen serves as a bridge between two silicon atoms.

Rebuttal: There is no such thing as sticky physics. All agates of this planet have wall lining except when they don't like in chevron agates where the bands meet to the walls at an angle of about 30 degrees. You cannot dissolve any quartz in any amount in water and throw it at a wall and watch it stick. This is childish. How does silica do it? Supercritical fluid vapor deposition at a temperature over 374 C, probably at about 425 C. No surface tension. No boiling.

Rebuttal: Inside wall banding you can get horizontal banding. It is never wall-to-wall. This is the fluid dumped on the void floor when the supercritical fluid goes subcritical. Then two phases of water form, a liquid and a vapor phase. Waterline base, crystal quartz druze or banded top, with many variations based on the transition time or if lingering or reheating occurs.

Rebuttal: Siloxane bridge formation is the definition of syneresis involving the dewatering and hardening of a silica gel.

"These polymers get pulled out of the solution and get incorporated into the crystal very quickly. When things are polymerized, they'll crystallize very rapidly. You've overcome some of the initiation energy needed to make the crystal. And because the crystallization occurs so quickly, mistakes are made and weird minerals like moganite are formed.

Rebuttal: Moganite forms in many silica rocks like cherts that had no void stage and formed by nucleation and accretion in soft rock or sediment. Beta-moganite is immiscible in agates, forming microspheres and microdiscs.

"Soon, though, the polymers get depleted from the solution, leaving isolated $Si(OH)_4$ units. You can crystallize perfect quartz crystals without moganite from these, but it's very slow. At room temperature, you can let the solution sit for two years before you'll see the beginning of the crystallization process."

Rebuttal: This comment hides the fact that moganite cannot be made in a lab. Using high-pressure vessels that are heated to supercritical temperature you can make banded agate. Then you get silica banding, that starts forming immediately. From that, transition time in lava flows through supercritical provides as little as 8 days. Thick flows give you up to about 500 years. This is not weathering or a geologic age of 75 million years. There is no millions of years in agate formation.

Between the crystal fibers are channels that work by capillary action to pull water into the center of the hole in the rock. "If you have a continuous supply of water feeding silica to the system," Heaney says, "then when the concentration gets higher, the silica will begin to polymerize again and it will begin to crystallize rapidly again. That's why I think an agate has its banding pattern.

Rebuttal: This is goofy physics. How do you pressurize fluid and silica into a void by surrounding it when the built-up pressure has nowhere to go but the pressurized exterior? Pressure going in and out concurrently is not possible. How does silica accumulate? By feldspar-quartz exsolution (separation) right out of the melt as the lava cools. This is why agates are only found in lavas with these feldspars and quartz. Quartz rocks like granites and schists and shales have zero agate.

"This has not been experimentally shown," Heaney says. "You'd have to make an agate, and no one has ever made an agate, though Robert thinks we should try." Heaney and a Russian mathematician, an expert in fractal geometry, are submitting a grant proposal to simulate this oscillating pattern of crystal growth on a computer.

Rebuttal: This is false. The Russians made agates in supercritical fluid platinum spheres with water and silica. Fractal study is a fad.

"There is a competing theory that I don't like at all," Heaney adds, "and it's one that Robert favors. You have a gel, a silica jello embedded in the rock, and by adding chemicals you produce periodic bands in it. You can make a silica gel in the lab very easily. You can even get the banding. But when you let the gel dry, it dries to an amorphous or non-crystalline form of silica." While high temperatures or pressures might cause the gel to crystallize, those forces do not come into play. "We know agates form close to the surface of the earth,

at low pressures and temperatures," Heaney says, "and not only in volcanic rock, but in dinosaur bones."

Rebuttal: Silica cannot crystallize in the presence of air, at room temperature or without supercritical fluid in making an agate. Agates require reducing conditions. No thought has been put into the constraints of agate formation. Agate gels in a lab make Liesegang bands, which are diffusion bands. These bands have no relationship to agate bands. Saying the bands are the same is just wrong. Agates don't have bands, they have light extinction layers and quartz intergrowth layers. Agate and jasper precipitate in wood and bones only when they are deposited in volcanic ash. The ash is the silica source.

We also know agates invariably outlast their surroundings. The encasing rock—or bone—weathers away, leaving just a roundish, rough-coated lump waiting to be picked up and cut and polished.

Rebuttal: Quartz is insoluble in water and therefore does not weather. Therefore, rainwater weathering cannot dissolve silica and make agate. Over time of geologic ages, clays intrude into the fiber layers resulting in what many mistake for a chert nodule.

Conclusion: Dr. Peter Heaney is a victim of cliché thinking.