Did Ancient Eruptions Form Life's Building Blocks?

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Talk of the Nation

When Stanley Miller conducted his famous experiments on the origins of life in the 1950s, he left many of the results unanalyzed. One such experiment mimicked the conditions of a volcanic eruption — and modern analysis of those samples by chemist Jeffrey Bada has revealed a rich array of amino acids, the building blocks of life.

IRA FLATOW, host:

This is SCIENCE FRIDAY. I'm Ira Flatow.

Sometimes we forget that scientists are human and they might avoid unpleasant experiments. Presented for your consideration: one Stanley Miller. Back in the 1950s, Stanley Miller and his mentor, Harold Urey, performed a very famous experiment on the origins of life on Earth.

They filled flasks with the gases believed to have been present on the early Earth, things like ammonia and methane and hydrogen. They then shot sparks through the gases to mimic lightning bolts, and lo and behold, they found that their experiment had indeed produced a variety of amino acids, the building blocks of life.

Stanley Miller died a few years ago and left a lot of those experimental samples on the shelf, in boxes full of tiny sealed glass vials, carefully labeled. Some of them were from experiments he never analyzed, including one experiment that mimicked the conditions of an erupting volcano.

Why did he not open those vials? Perhaps Miller didn't like the way they smelled. Perhaps they smelled like sulfurous rotten eggs.

Now, over 50 years later, some of his former students have gone through those volcanic samples, analyzing even the smelly sulfurous ones, and they've made a startling discovery that Miller missed but might change our view about the chemical evolution of life on Earth.

And they've published the results in this week's Proceedings of the National Academy of Sciences. Joining me to talk about what they found is my guest, Jeffrey Bada, distinguished professor of marine chemistry at the Scripps Institute of Oceanography in La Jolla. He joins us by phone. Welcome to SCIENCE FRIDAY.

Dr. JEFFREY BADA (Scripps Institution of Oceanography): Well, thanks, glad to be with you.

FLATOW: Do you - can you give us your insight why Stanley Miller never opened those vials?

Dr. BADA: Well, you know, I wish I could tell you definitely, but my suspicion is for two reasons. Number one, he had told several of us that he hated working with H2S, hydrogen sulfide, because it just smelled so bad, it made him sick.

And so that may be one reason. The other reason is that he did this experiment when he was at Columbia University, only for a couple of years. And he was obviously very busy at that point, traveling to Europe and getting ready to move, in fact, out here to U.C. San Diego. So it may have been a combination of that.

But anyway, he prepared these samples in his meticulous way, labeled them, including the notebook page where we could find all the details of the experiment, and then just put them in this little box and stowed them away.

FLATOW: And so what made you decide to open them?

Dr. BADA: Well, I'd found out by chance, in 2007, that Stanley had saved extracts from all his original experiments. I had known Stanley since 1965, and I was a very close friend of his. But he never told me anything about saving extracts from his original experiments.

And it was only by chance that another colleague happened to mention that when he was in Stanley's office, Stanley pointed to this cardboard box and said: That contains samples from my original experiments.

And when I found this out, I realized, since I'd inherited everything in Stanley's lab and office, that I must have the box. And so I looked through my lab, and sure enough here is this dusty cardboard box labeled discharge samples. And I opened it up and inside were all these other little boxes, clearly labeled with each of his early experiments.

And the first thing we did was analyze this one set of boxes that was associated with an experiment that he carried out in his thesis work in '53 that involved a different kind of apparatus, one that had a configuration that in our opinion looked more like a volcanic-type discharge than the spark discharge sample, system that he'd used that we sort of call the classic apparatus that you see in textbooks.

And we analyzed that and found that it contained a wide diversity of amino acids that had never been reported before in these kinds of experiments. And we published that in Science in 2008.

My attention then turned to this, the experiment labeled 1958, because he had clearly said that one of the gases in the mixture was hydrogen sulfide. And he'd never conducted an experiment before with hydrogen sulfide. And very few experiments had actually been conducted with hydrogen sulfide.

So I thought: Okay, this is the next logical set to analyze, and it was a real eye-opener when we found that it contained probably the most diverse set of amino acids ever produced in this kind of experiment.

FLATOW: And so the theory being that this was mimicking volcanic outgasing on the planet at the time.

Dr. BADA: Right. We know that hydrogen sulfide, along with other gases like methane and ammonia, were probably being belched into the atmosphere continuously by early volcanic systems.

You have to remember that the Earth at this time probably had no continents, and the only thing that would have been covering the surface of the Earth, that covered the oceans, actually, were little volcanic island archetype systems like the Hawaiian Islands.

And so these things would have been belching out reduced gases, and also, as we saw in great detail last year with the Icelandic volcano, volcanic eruptions are accompanied by really intense lightning.

So the idea is these gases are belched out of the volcano and immediately subjected to a discharge. And so you'd have synthesis not on a global scale but on these local scales.

So you'd have millions of these little tiny localized prebiotic factories operating on the surface of the early Earth.

FLATOW: And so this is something Stanley could have discovered if he had analyzed the samples himself?

Dr. BADA: Well, I don't think so, because the analytical heat techniques he had available at the time, paper chromatography, were - was very limited in what could be detected.

And in all these early experiments, the largest number of amino acids that he could clearly detect was on the order or five or so. And so that shows you the limitation of the technique he had at the time.

In comparison, today we have these powerful high-performance liquid chromatography and mass spectrometry techniques that allow us to detect hundreds of compounds in a mixture and, you know, determine that they're present based on their mass spectra.

And so when we did this, we could clearly see a lot of compounds that he would have just never probably thought of trying to find because, number one, they weren't present in very large amounts, and second of all, he may not have even had the standards, the knowns, to compare it with.

FLATOW: So that - does that make us rethink this whole primordial soup idea, that it was not so much as the soup on the ground but the chemicals in the volcanoes might have been...

Dr. BADA: Well, you remember the scenario about how amino acids are synthesized. When you send a spark, like the spark discharge, through a mixture of gases like methane, ammonia, hydrogen sulfide, what you do is manufacture, in that process, what we call precursor reagents: hydrogen cyanide, aldehydes and ketones, things like formaldehyde, acid aldehyde and sulfur derivatives.

And these then rain out of the, quote, atmosphere and end up in solution, in the water phase, where they undergo the actual synthesis reactions that make amino acids. So the amino acids are made in the liquid phrase. The reagents are made in the gas phase.

So the great thing about a volcano is that you have these reduced gases coming out of the volcano, and they're processed immediately into reagents. And these then rain out in the vicinity of the volcano, perhaps in tidepools or any or other bodies of water surrounding the volcano, and there they undergo this further chemistry to produce amino acids and other compounds.

I think I should emphasize that amino acids are just an indicator that you've got synthesis taking place. There are many, many other types of compounds that are synthesized in this process.

FLATOW: So what is the take-home message here, Dr. Bada? In the minute weve got left, what is the new thing that we should learn from this?

Dr. BADA: Well, I think it demonstrates that it's really easy to make key biomolecules like amino acids. And this then provides an inventory of raw material to set the stage for further reactions that lead to more complexity and eventually into something that would - we could call a living entity.

FLATOW: And the fact that we find some of these same types of chemicals on meteorites, that's important too?

Dr. BADA: Well, I think it shows you that this chemistry is universal. One of the interesting things that we point out in the paper is the relative abundances of the amino acids that we find in this hydrogen sulfide experiment, is almost a direct overlay with the relative abundances founds in certain meteorites, mainly carbonaceous chondrites like the famous Murchison meteorite.

And so what this is telling us is that the kind of chemistry that's being duplicated in this experiment is being duplicated under natural conditions someplace in the early solar system.

FLATOW: And would that mean there might be either life occurring in those places also, or we're bringing those precursors here, or both?

Dr. BADA: Well, I think it shows, again, the ability, the robustness of how you - how organic compounds is made. Wherever you have the proper conditions, you're going to make organic compounds.

Whether you can actually transport intact those organic compounds to the Earth in significant quantities, or some other planet, we really don't know right now. My suspicion is, is that you have both (unintelligible) from space with organic-rich meteorites such as Murchison, and also home-grown synthesis, via processes like we've just been discussing.

FLATOW: Are there any more vials left to open?

Dr. BADA: Oh, there'e probably 300 vials. He saved everything. There's experiments in there that he uses other combinations of reagents, other - there are some ones that has metals in them. About probably two-thirds of the vials he never reported the analyses of, and we've looked in his archived material that's in his library here, and I see no evidence in some of these cases that he ever saved - if he did analysis - that he ever saved them, and he certainly didn't publish it.

FLATOW: So you've got some work to do.

Dr. BADA: So we have a lot of other interesting stuff to look at.

FLATOW: All right, and we'll have you back on. Please check in when you keep opening those vials.

Dr. BADA: Okay, thanks.

FLATOW: Thank you very much. Jeffrey Bada is a distinguished professor of marine chemistry at the Scripps Institution of Oceanography in La Jolla, talking about Stanley Miller's vials.

They've got hundreds of them, two-thirds of them never opened. That'll be really interesting to see what's happening.

We're going to take a short break, and when we come back, we're going to switch gears and talk about something completely different. We're going to talk about a journey deep below the Pacific through the sea-floor crust, the Earth's crust, toward the mantle.

But first, Clovis will be coming up. So stay with us. We'll be right back after this message.

I'm Ira Flatow. This is SCIENCE FRIDAY from NPR.