Could natural nuclear reactors have boosted life on this and other planets?

December 5 2011, By Clara Moskowitz

Reactions similar to those inside this nuclear power plant in Georgia arose spontaneously around 2 billion years ago in the Oklo region of Gabon, Africa. Credit: U.S. Nuclear Regulatory Commission

While modern-day humans use the most advanced engineering to build nuclear reactors, Nature sometimes makes them by accident.

Evidence for a cluster of natural nuclear reactors has been found on Earth, and some scientists say our planet may have had many more in its ancient past. There's also reason to think other planets might have had their own naturally occurring nuclear reactors, though evidence to confirm this is hazy. If they did exist, the large amounts of radiation and energy released by such reactors would have had complicated effects on any life developing on this or other worlds, experts say.

Natural nuclear reactors occur when deposits of the radioactive element uranium build up in one spot, and eventually ignite a self-sustaining nuclear chain reaction where uranium divides, in a process called fission, producing other elements. The reaction releases a powerful punch of energy. This energy could prove beneficial and highly detrimental to developing life, depending on the circumstances.

Only example

The only known examples of natural nuclear reactors on Earth were discovered in the Oklo region of Gabon, Africa, in 1972. French miners discovered that the uranium samples they extracted were depleted in the rare isotope uranium 235, the only naturally occurring material on Earth capable of sustaining fission reactions. It was as if the material had already gone through a nuclear reaction and been used up.

In fact, that's the scenario most supported by studies. Scientists think a concentration of uranium 235 there went critical around 2 billion years ago and underwent fission, just as it does inside man-made nuclear reactors.

"As far as we know, we only have evidence of natural reactors forming and operating at the one site in Gabon, but that demonstrates that it's possible, and our calculations suggest it was much more probable earlier in Earth's history," said Jay Cullen of the University of Victoria in Canada.

Cullen and Laurence A. Coogan, a colleague at the University of Victoria, researched how likely these reactions were when Earth was much younger, based on how much uranium in a given area is necessary for the material to go critical and start a self-sustaining fission reaction. They found that during the Archean epoch, between around 2.5 billion and 4 billion years ago, natural nuclear reactors could have been

relatively frequent.

"It certainly seems more than likely that these sorts of reactors would have been much more common in the Earth's early history because the amount [of uranium] you need is actually quite small," Cullen told Astrobiology Magazine.

However, because there is such a poor geologic record left from so long ago, scientists have very little way of confirming this idea.

The spark of life

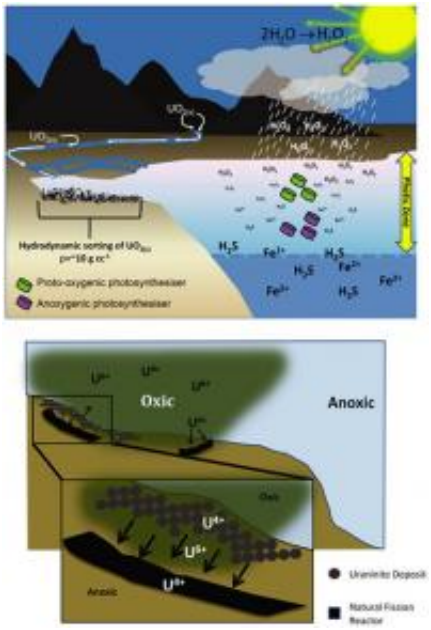
If natural nuclear reactors were present on early Earth, they could have had interesting effects on any nascent life.

In 1972, French miners in Gabon, Africa discovered evidence that a natural nuclear reactor had formed about 2 billion years ago from a concentration of the fissionable element uranium 235. Credit: NASA/ Robert D. Loss, WAISRC

The ionizing radiation released by a nuclear reaction can damage DNA, the precious instruction code built into every cell of life. If organisms

were living too close to the site of a reactor, they could have been wiped out completely. However, life hanging out on the outskirts of a nuclear reactor might have received a smaller dose of radiation — not enough to kill it, but enough to introduce mutations in its genetic code that could have boosted the diversity in the local population.

"The ionizing radiation would actually provide some genetic variation," Cullen said. “That’s the quantity that natural selection is going to act upon, and it might help to promote change in organisms with time. I think that most people view ionizing radiation as a bad thing, but that’s not always necessarily so."



This cartoon shows a possible mechanism by which oxygenic photosynthesis could lead to formation of natural fission reactors. Credit: L. A. Coogan/ J. T. Cullen

Furthermore, the nuclear reactors themselves could have provided an

even greater boon to life by giving it the spark it needed to originate in the first place, some scientists think. Zachary Adam, now a graduate student at Montana State University in Bozeman, suggested the possibility in a 2007 paper in the journal Astrobiology, which he wrote as a graduate student at the University of Washington.

Scientists don't know for sure how life got started on Earth, but they think it required some kind of burst of energy to start it off. This energy would have been required to break the bonds of simple elements such as carbon, nitrogen, hydrogen and oxygen, so that they could recombine to form the first complex organic molecules.

Other researchers have suggested that a strike of lightning might have provided the requisite energy, but Adam thinks that the energy released by a natural nuclear reactor might have provided the catalyst.

"I think it is at least as possible as other ideas, if not more plausible, but I realize everyone is partial to their own ideas," Adam said.

Life elsewhere?

If natural nuclear reactors might have helped life arise on this planet, it's also possible they've played a role in seeding life elsewhere.

So far, scientists' limited knowledge of the geology of extrasolar planets means they can't say how common natural nuclear reactors might be on other worlds. Adam said that some elements on early Earth that might have helped these reactors form don't seem to be as abundant on the surfaces of other planets.

For example, the Moon's tidal forces on Earth, which used to be stronger than they are today due to the Moon's closer proximity long ago, played a vital role in causing heavy minerals like uranium 235 to collect in

dense patches on beaches, Adam said. The Earth had also differentiated into separate layers, including a crust and a mantle, which helped to separate out and concentrate the heavy radioactive elements.

These characteristics, especially crustal differentiation like that on Earth, don't seem to be as common among the other planets of the solar system, Adam said.

But not all experts are pessimistic about natural nuclear reactors on other worlds.

Plasma physicist John Brandenburg of Orbital Technologies Corp. analyzed results from NASA's Mars Odyssey Orbiter, which surveyed the surface of the Red Planet with various instruments, including a gamma-ray spectrometer. Brandenburg says the gamma-ray results show evidence of an abundance of radioactive uranium, thorium and potassium, especially in one particular spot on Mars, which he attributes to a major nuclear reaction taking place there around half a billion years ago.

"Basically it looked as though Mars was covered with a meters-thick layer of radioactive substances, and also the atmosphere was full of radiogenic products," Brandenburg said. "It's kind of a no-brainer at that point. There appears to have been a large radiological event on Mars and it appears to have been violent."

If such a huge nuclear event did occur, it would have been disastrous for any budding Martian life.

"It would have been a terrible catastrophe," Brandenburg said. "Whatever biosphere was on Mars at the time probably suffered a massive extinction event, and it really set back life on Mars."

However, many Mars geologists have greeted Brandenburg's proposal with skepticism.

"This hypothesis is not likely to be true," the University of Arizona's William Boynton, principal investigator for Mars Odyssey's gamma-ray spectrometer, wrote in an email. "Yes, we did find both thorium and uranium, and they are natural elements found everywhere. The amount varies, but the explanations are very mundane."

Boynton said he doubts that natural nuclear reactors like the ones in Gabon are common elsewhere.

"The natural reactor in Africa is real, but the reason it was of so much interest is that it is so rare," Boynton said. "I would say it is all but impossible that any natural reactor has happened anywhere else in the solar system. It may be it has only happened once on Earth!"

Source: Astrobio.net