Meet Oklo, the Earth's two-billion-year-old only known natural nuclear reactor

By Laura Gil

Samples of Oklo donated to Vienna's Natural History Museum.
(Photo: Ludovic Ferrière/Natural History Museum)

"We want people to learn about natural radioactivity, to make them aware of the fact that radioactivity is all around us, that it's natural, and that at low levels it's not dangerous."

— Ludovic Ferrière, Curator of the Rock Collection, Natural History Museum, Vienna, Austria

Physicist Francis Perrin sat at a nuclear-fuel-processing plant down in the south of France, thinking to himself: "This cannot be possible." It was 1972. On the one hand, there was a dark piece of radioactive natural uranium ore, extracted from a mine in Africa. On the other, accepted scientific data about the constant ratio of radioactive uranium in ore.

Examination of this high-grade ore from a mine in Gabon was found to contain a lower proportion of uranium-235 (U-235) — the fissile sort. Only a tiny bit less, but enough to make the researchers sit back and scratch their heads.

The physicists' first, logical response to such an unusual ratio of U-235 was that this was not natural uranium. All natural uranium today contains 0.720% of U-235. If you were to extract it from the Earth's crust, or from rocks from the moon or in meteorites, that's what you would find. But that bit of rock from Oklo contained only 0.717%.

What did this mean? At first, all the physicists could think of was that the uranium ore had gone through artificial fission, i.e. that some of the U-235 isotopes had been forced to split in a nuclear chain reaction. This could explain why the ratio was lower than normal.

But after complementary analyses, Perrin and his peers confirmed that the uranium ore was completely natural. Even more bedazzling, they discovered a footprint of fission products in the ore. The conclusion: the uranium ore was natural *and* had gone through fission. There was only one possible explanation — the rock was evidence of natural fission that occurred over two billion years ago.

"After more studies, including on-site examinations, they discovered that the uranium ore had gone through fission on its own," said Ludovic Ferrière, curator of the rock collection at Vienna's Natural History Museum, where a part of the curious rock will be presented to the public in 2019. "There was no other explanation."

For such a phenomenon to have happened naturally, these uranium deposits in western Equatorial Africa must have had to contain a critical mass of U-235 to start the reaction. Back in those days, they did.

A second contributing factor was that, for a nuclear chain reaction to happen and be maintained, there needed to be a moderator. In this case: water. Without water to slow the neutrons down, controlled fission would not have been possible. The atoms would simply not have split.

“Like in a man-made light-water nuclear reactor, the fission reactions, without anything to slow down the neutrons, to moderate them, simply stop,” said Peter Woods, team leader in charge of uranium production at the IAEA. “The water acted in Oklo as a moderator, absorbing the neutrons, controlling the chain reaction.”

The specific geological context in what today is Gabon also helped. The chemical concentrations of total uranium (including U-235) were high enough, and the individual deposits thick and large enough. And, lastly, Oklo managed to survive the passing of time. Experts suspect there may have been other such natural reactors in the world, but these must have been destroyed by geological processes, eroded away or subducted — or simply not yet found.

“That’s what makes it so fascinating: that the circumstances of time, geology, water came together for this to happen at all,” Woods said. “And that it was preserved until today. The detective story has been successfully solved.”

A rock sample in the IAEA’s home city

Rock samples from Oklo, some of them recovered during drilling campaigns, are stored in the headquarters of France’s nuclear power and renewable energy company Orano. In early 2018, two half split drill-core samples were donated to Vienna’s Natural History Museum. The donation was made possible by the financial contribution of Orano and France’s Alternative Energies and Atomic Energy Commission (CEA), with the support of the French Permanent Mission to the United Nations and the International Organizations in Vienna. IAEA scientists helped when the sample was delivered to Vienna by monitoring radioactivity levels and facilitating the rock’s safe handling.

The two samples emit a radiation of approximately 40 microsieverts per hour if you stand 5 centimetres away from them, which roughly compares to the amount of cosmic radiation a passenger would receive on an eight-hour flight from Vienna to New York. The museum, which receives 750 000 visitors a year, is used to dealing with radioactive samples since it already displays a number of slightly radioactive rocks and minerals.

“We want people to learn about natural radioactivity, to make them aware of the fact that radioactivity is all around us, that it’s natural and that at low levels it’s not dangerous. Radioactivity is in the floors and walls of our homes, in the food we eat, in the air we breathe, and even in our own body,” said Ferrière. “What better way to explain this than by showing a real sample from Oklo, where nuclear fission occurred naturally billions of years ago?”

The permanent exhibition will show different sources of background radioactivity. Perhaps a world map with the distribution of radioactivity, a radiation detector or Geiger counter or a cloud chamber, will allow visitors to see exposure to natural radiation for themselves.

“Rocks are like books. You can look at the cover and get some basic information, but it’s when you open them that you get the full story,” Ferrière said.

Ludovic Ferrière, curator of the rock collection, holds the Oklo reactor in Vienna’s Natural History Museum. A sample of Oklo will be displayed permanently in the museum as of 2019.

(Photo: L. Gil/IAEA)