The Oklo natural reactors in Precambrian rocks, Gabon, Africa

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The reactor that began without human intervention

Can a uranium deposit begin self-sustaining nuclear reactions without human intervention? In 1972, while analyzing uranium which had been mined in Gabon, Africa, some French scientists discovered some uranium which had an abnormally small percentage of the isotope U-235 as compared to U-238. In most uranium 0.72% is U-235, and no natural uranium had ever previously been discovered which was more than 0.1% different from 0.72%. In trying to explain why the particular ore they were analyzing was different, the French scientists were led to the hypothesis that a fission chain reaction had occurred in this ore, hence a natural reactor had existed long before man ever discovered fission or built a nuclear reactor. Since they also hypothesized that the reactor was about 2 billion years old, it is of interest to biblical creationists to find out whether the numerical data that were gathered could also be explained in a biblical time frame or whether it is evidence for accelerated nuclear decay.

According to the Geologic Time Table, of conventional historic geology, the Oklo surface rocks are Precambrian strata. Thus, they would represent the rocks present before the Cambrian "explosion" which shows the sudden appearance of multi-celled plants and animals. In many creationist models, the Precambrian rocks at Oklo would be either the lowest lying sediments from the Flood, or else the pre-Flood rocks. Since the reactors were found in some steeply dipping sandstone sediments (figure 1), their exact time of placement is not certain, and the nuclear reactions could have occurred after the sandstone deposition, but they would represent an early stage of earth history in any credible scenario.

At Oklo, the first reactor zones discovered were in a strip mine. In 1975 a scientific meeting was held in Gabon, which included some sessions on benches in the strip mine next to the reactor deposits. Participants observed the exposed rocks inside the strip mine including uranium oxide deposits. Since the conference, more than a dozen reactor zones have been discovered at Oklo, and others about 20 km south of Oklo (figure 2). Today, water fills the Oklo mine's pit, which was permitted to flood, even covering the sites of the reactors, after the mine's uranium ore had been exploited.

The fission process

Nuclear fission begins when a nucleus deforms. The deformation may be produced when a nucleus absorbs a neutron, resulting in an excited nucleus with extra energy. The situation is often compared to a charged liquid drop. As the drop oscillates it may assume a peanut shape, which, because of the positive charge on both ends, then splits in two. The nuclear force of attraction between nuclear particles is short ranged, hence after the drop is split apart the only force left is the repulsive electrical force, and the two parts must repel each other. The two fragments then emit neutrons and photons. The neutrons may go on to cause more fissions. If the number of neutrons is enough, a self-sustaining chain reaction will result, which we call a nuclear reactor. One result of all this fission is a lot of fission fragments, i.e. smaller nuclei produced when the uranium splits. Any viable theory explaining the Oklo deposits must therefore be able to explain and correlate two sets of data. One is the amount of different forms (isotopes) of the fission-product elements remaining in the reactor at Oklo at present, and the other is the amount of uranium found in the ore. Both of these sets of data, plus a theory, gives us estimates of the amount of fission that has occurred, and both sets of data must result in the same estimate if the theory is correct.

Reactor geometry—can it work?

Some of the natural reactors are very thin slab-like deposits. They are, in fact, too thin to support a self-sustained nuclear reaction. However, compactification of sedimentary

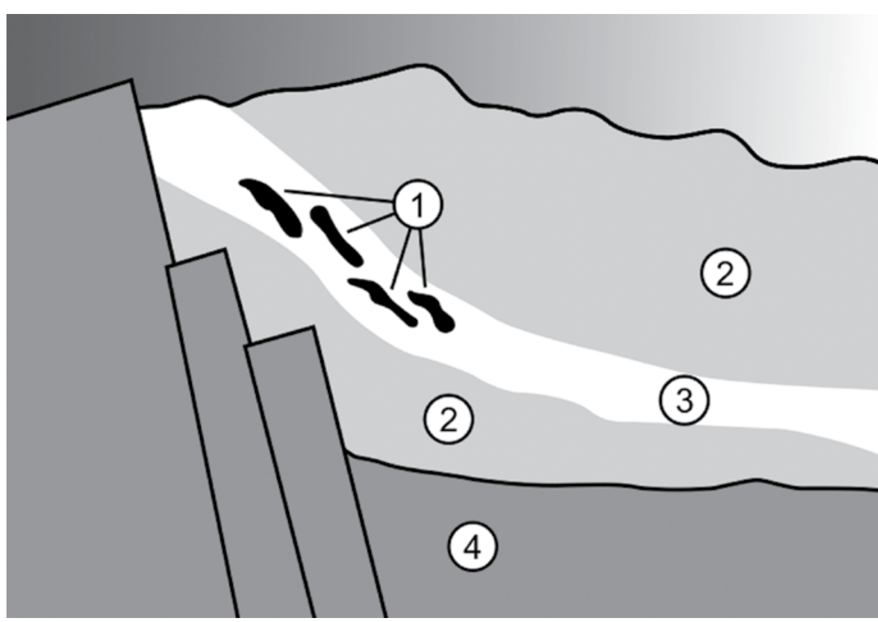

Figure 1. The natural nuclear fission reactors of Oklo: (1) Nuclear reactor zones, (2) Sandstone, (3) Uranium ore layer, and (4) Granite. (Image courtesy of the US Department of Energy (DoE)).

deposits over time typically reduces the thicknesses of strata by 50% or more, especially as the sediments dry out and/or expel water from pores.[1–4] Whether the deposits originally had the right configuration to support sustained nuclear reactions is thus a difficult question.

The evidence from element abundances

There are approximately thirty elements and many isotopes of these elements which are produced as a result of fission. A large fraction of these elements were found in the Oklo ore, still present and immobilized. In most of the reactor zones, another fraction of the fission products probably dissolved and moved away due to water percolating through the ore. Studies by several workers seem to indicate that elements susceptible to ground water action, such as rubidium, strontium, cesium, barium, and cadmium, have been carried away. One element which did not leach away and was particularly suitable for numerical studies is the rare earth element neodymium.[5]

From these studies of neodymium we can estimate the number of fissions which must have occurred to produce the neodymium. We can also calculate independently, from the percentage of the uranium left at present as U-235 and the actual concentration of uranium, the amount of uranium that must have fissioned. These two ways of calculating the number of fissions must agree. In both creationist and evolutionary (old-earth) models, the answer comes out wrong—the apparent amount of fission that should have occurred does not come out equal to the amount that should have occurred to produce the neodymium. Part of the discrepancy is due to fission of Pu-239, decay of Pu-239 to U-235, fast neutron induced fission of U-238, and possible changes in the size and shape of the ore. When these factors are taken into account, the data are consistent with the hypothesis that a reactor produced the elements at Oklo, but the actual, detailed numerical comparison depends on mostly unknown distributions and their changes over time.

An examination of element abundances in the remnant rocks show that the reactors operated by using surface and ground waters to moderate and reflect fission neutrons in order to sustain the chain reaction. Relatively recent work by Meshik *et al*.[6] indicates that the reactors may have cycled on and off as groundwater concentrations were changed by the heating caused by the reactor and then replenished after the reactor shut down. Meshik *et al.* thought that the reactors may have operated for a half hour until accumulated heat boiled away the water, then shutting down for a couple of hours.[7]

How much energy did the reactors produce?

The reactor power production turns out to be a bit different in various models. The total amount of energy that the Oklo reactor produced may have been as small as 440 MW-years according to the creation model with a young-earth assumption, and 15,000 MW-years in the conventional model with a 2-billion-years-ago assumption. By comparison, modern electric-power reactors, rated at 2000 to 3000 MW of thermal power, would have produced these amounts of energy in 2 months and 5 to 6 years, respectively, operating at full power. The evolution model requires more energy to have been produced since 2 billion years ago the percentage of uranium that is U-235 would have been 3% instead of 0.72%, with the result that more fission had to occur. If one assumes accelerated decay has altered the relative uranium isotope abundances, then one can accommodate a larger power level for the reactors.

This also brings up another apparent discrepancy. It is commonly stated by nuclear engineers that an ordinary water reactor with 0.72% U-235 fuel would not be able to maintain a self-sustaining nuclear reaction. However, this is not really a restriction on the Oklo reactor since: 1) the reactor does not have to produce continuous electrical power, but can instead operate in spurts, with the time in between being used to allow fission product “poisons” to decay; and 2) the RATE project results indicate that decay constants are variable and hence the actual percentage of 0.72% U-235 may not have been the actual value of this percentage even at the relatively recent ages suggested by creationist models.

Evidence for changing constants

Whether self-sustaining nuclear reactions are possible is dependent on several factors, including the leakage rate of neutrons from the reactor and the possible presence of so-called poisons. The presence of small amounts of boron or vanadium in the Oklo ore would have absorbed neutrons and thus served to prevent the chain reactions from ever occurring. Steve Lamoreaux and his Los Alamos colleague Justin Torgerson reported that the Oklo data are consistent with a slightly different value of the fine structure constant than today’s value.[8,9] However, the amount they specified

Image courtesy of the US Department of Energy (DoE)

Figure 2. One of the uranium concentrations at Oklo.

was very small, only 4.5 x 10^{-6}%, and subject to possible future refinements. The data also provide constraints on changes in the strong coupling constant of nuclear forces.

Summary

In summary, study of the isotope abundances in Oklo reactor zones is not easy but definitely provides constraints on models of the history of radioisotopes on Earth.

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Did the early Earth's atmosphere contain oxygen?

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Evolutionists have claimed that the early atmosphere during the Archean, older than 2.5 Ga within their timescale, contained no oxygen.[1,2] Oxygen in the atmosphere will oxidize any developing organic molecule and make it non-biological. After about 2.4 Ga, the evolution of photosynthetic bacteria caused atmospheric carbon dioxide to be replaced by oxygen, which rapidly accumulated to form a substantial portion of the current atmosphere oxygen. Evolutionists term this the Great Oxidation Event (GOE).

However, the timing of the GOE has been under debate.[2,3] Some believe that the GOE occurred a billion years earlier. One of the problems in resolving the debate is that the Archean is so long ago and the evidence is sketchy and difficult to interpret. Moreover, evolutionists assert that billions of years of evolution has obscured the molecular vestiges of the early events.

Evidence is available from the rocks of the Precambrian that both support the claim of no oxygen and also refute that claim.[4] One piece of evidence claimed for an oxygen-less atmosphere is the ratio of sulfur isotopes, which being of different masses fractionate during phase changes. It has been assumed that large anomalous sulfur isotope ratios mean that sedimentary rocks older than 2.4 Ga are strong evidence for ultraviolet photolysis of volcanic sulfur dioxide in an oxygen-less atmosphere. But, a new study now suggests that anomalous sulfur ratios can be caused by reactions between powders of amino acids and sulfate at temperatures between 150 and 200°C.[5] So, the deduction from sulfur isotopes is now equivocal.

Banded iron formations (BIFs) also provide evidence for plenty of oxygen before the supposed GOE.[6] BIFs are fine layers of alternating iron oxide and chert that cover large areas and are found especially in the Precambrian but also in the Phanerozoic.[7] They supposedly date them to the age of the oldest rock at about 3.8 Ga old, well before the GOE. Some geologists note that the oxygen in the iron oxides of BIFs is about 20 times that of the current atmosphere. Since the BIFs were deposited in water, the implication is that the atmosphere contained plenty of oxygen even 3.8 Ga ago. This suggests that the atmosphere has always been oxygenated. No wonder uniformitarian geologists consider the origin of BIFs an enigma.[8] Many scientists are having a hard time accepting the implications of BIFs, that oxygen existed in the early Archean, and have instead suggested alternative mechanisms to produce them in a reducing atmosphere.

New study claims significant oxygen 3.5 billion years ago

A recent report reinforces the notion that the atmosphere contained oxygen well before the GOE, in fact about one billion years before, some 3.46 Ga ago within the evolutionary/uniformitarian timescale.[9] Primary hematite, directly deposited and not a result of subsequent events, was found in iron rich sedimentary rocks in northwest Australia dated at 3.46 Ga. Such hematite can form in two ways. In an oxygen-less atmosphere, ultraviolet light reaching the earth's surface, strikes iron hydroxide minerals and triggers a reaction that drives the water away forming hematite.

However, hematite can also form by the oxidation of iron without ultraviolet light. This is the type of hematite formation claimed for the hematite/chert sedimentary rocks supposedly formed about 3.5 Ga ago. These sedimentary rocks were sandwiched between two thick volcanic layers (greater than 3 km) that strongly suggest they were formed in deep water, at least 200 m, and possibly up to 1,000 m, deep. This deduction was based on:

1. the lack of erosion surfaces in the rocks,
2. the absence of textures from waves or currents,