Oklo Natural Nuclear Reactor

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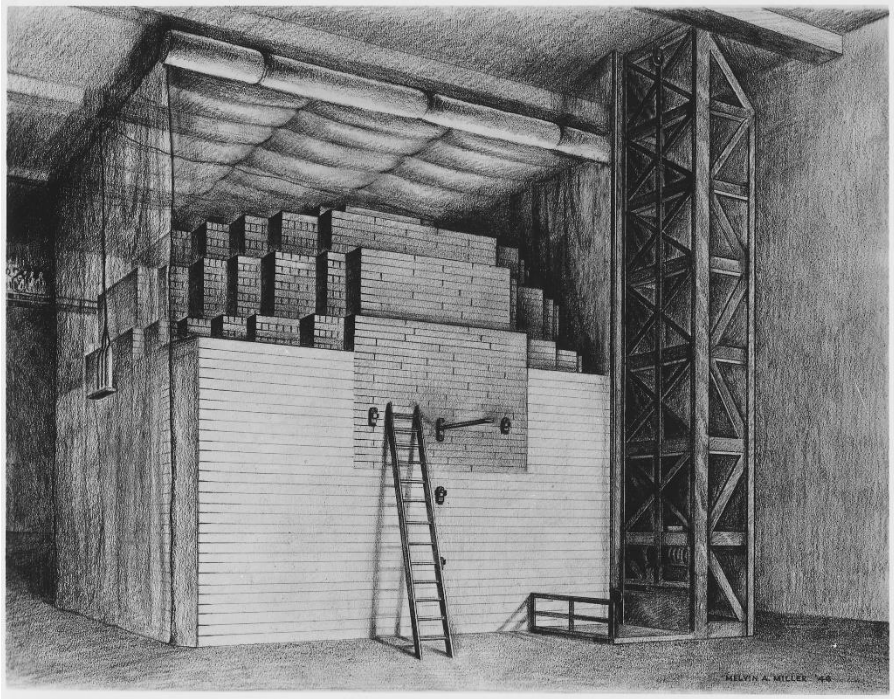
Outline

- Before Oklo
- Discovery of the Oklo anomaly
- Explanation of anomaly
- Operation of Oklo
- Implications of Oklo research

Aerial view of the Oklo open mine pit in Gabon, Africa.

Before Oklo

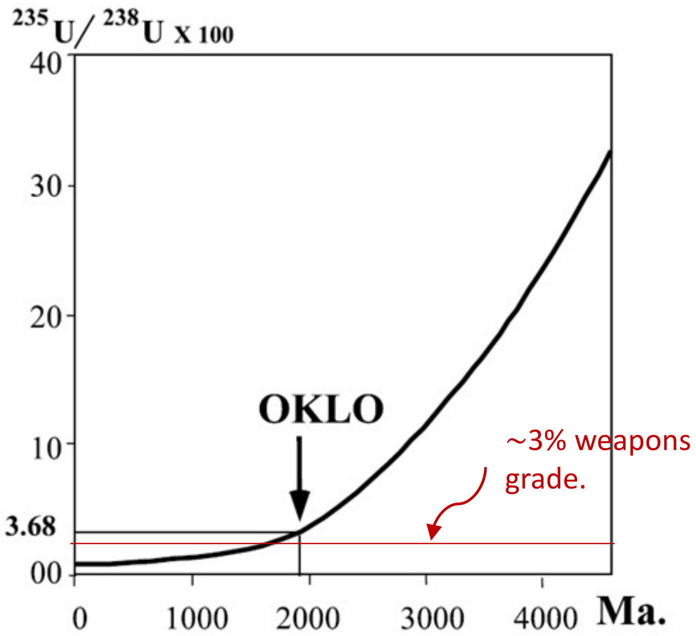
- **(1942)** Chicago Pile goes online, and is self-sustaining.
- **(1953)** George W. Wetherill & Mark Inghram find evidence of neutron induced fission in a Congo pitchblende.
- **(1956)** A chemist by the name Kuroda sketches out the requirements necessary for natural nuclear fission.
- From 1957 until mid 1973 no known natural fission detected.



Chicago Pile-1, the first self-sustaining manmade nuclear reactor.

Kuroda's Requirement

- **Quantity**: Abundance of fissile uranium ^{235}U isotope.
- **Size**: Uranium deposit should exceed the average length that fission-inducing neutrons travel (~2/3 meter).
- **Moderator**: Neutron moderator, a substance that can slow down neutrons produced through fission.
- **Lack of poisons**: Elements that absorb neutrons should not be present (boron, lithium, etc).



Isotopic amount of ^{235}U as a function of millions of years ago [1]

Uranium Isotope	Absorption cross section
U-235	680.9 barns

Reported cross section for uranium-235 [2]

Oklo Anomaly

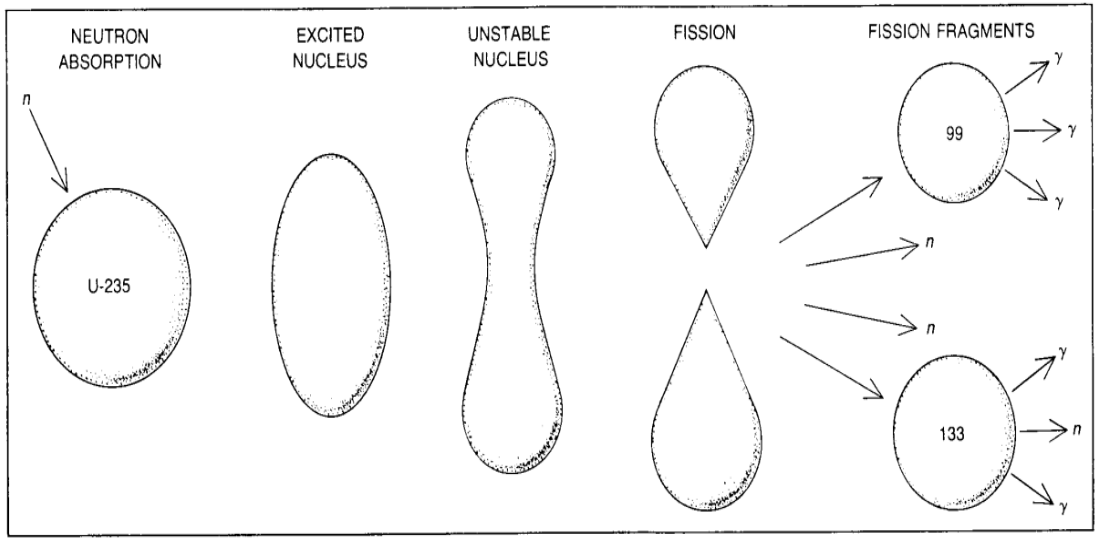
- French uranium enrichment center detects anomaly in isotopic ratio for UF_6.
- Analysis reveals isotopic abundance of ^{235}U in sample core from Gabon is **0.6000%** instead of **0.7202%**.[3]
  - Corresponds to approximately 200 kilograms of missing ^{235}U.

^{238}U	99.2744
^{235}U	0.7202
^{234}U	0.0054

Percent present day abundances of common uranium isotopes [4]

Explanation of Oklo Anomaly

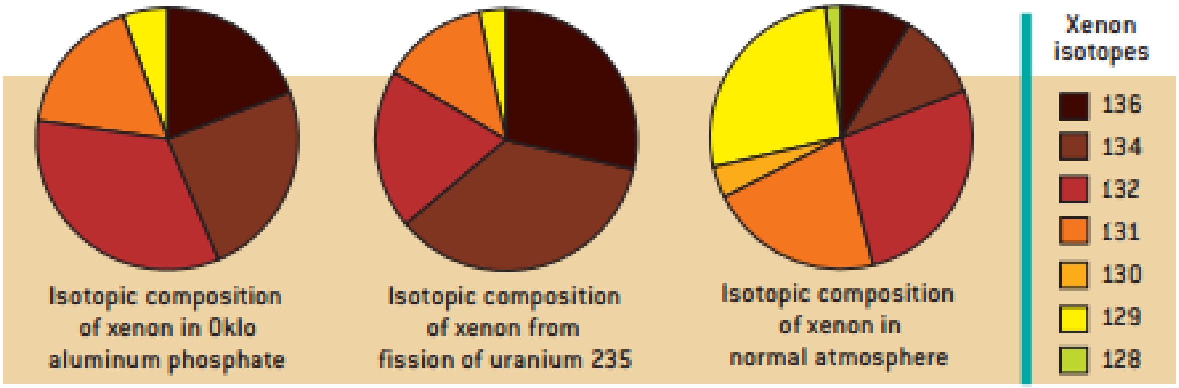
- CEA and International Atomic Energy Agency form committee for investigation.
- Analysis of fission products in Oklo ores confirms natural nuclear reaction occurred approx. 2 billion years ago.
  - Telltale products:
    - Neodymium-144 & -145
    - Thorium-232
    - Bismuth



Fission of a nucleus of ^{235}U [5]

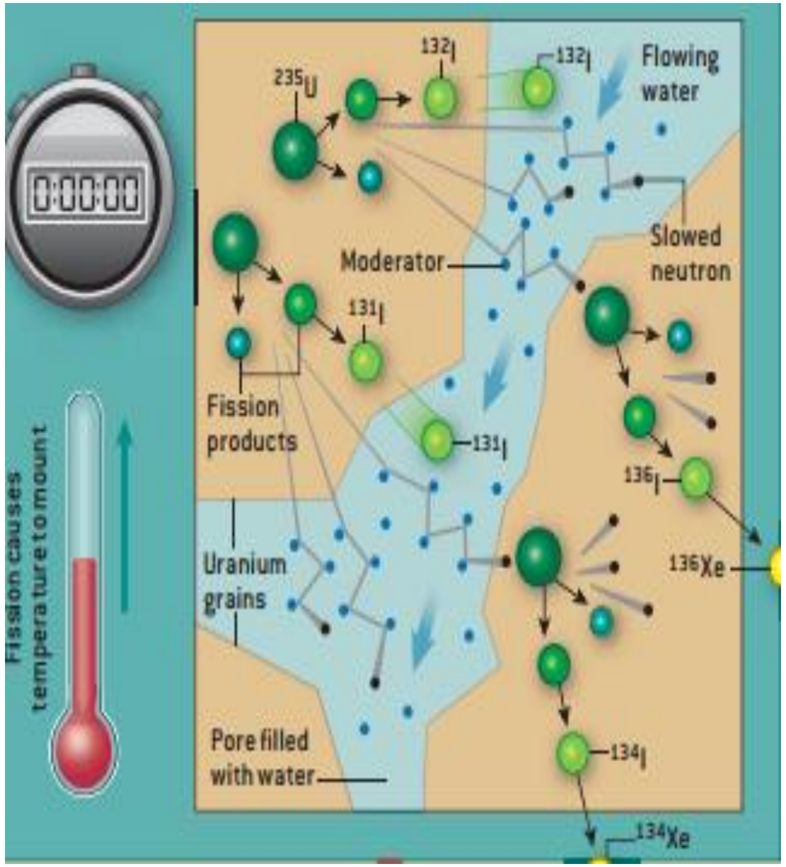
Operation of Oklo

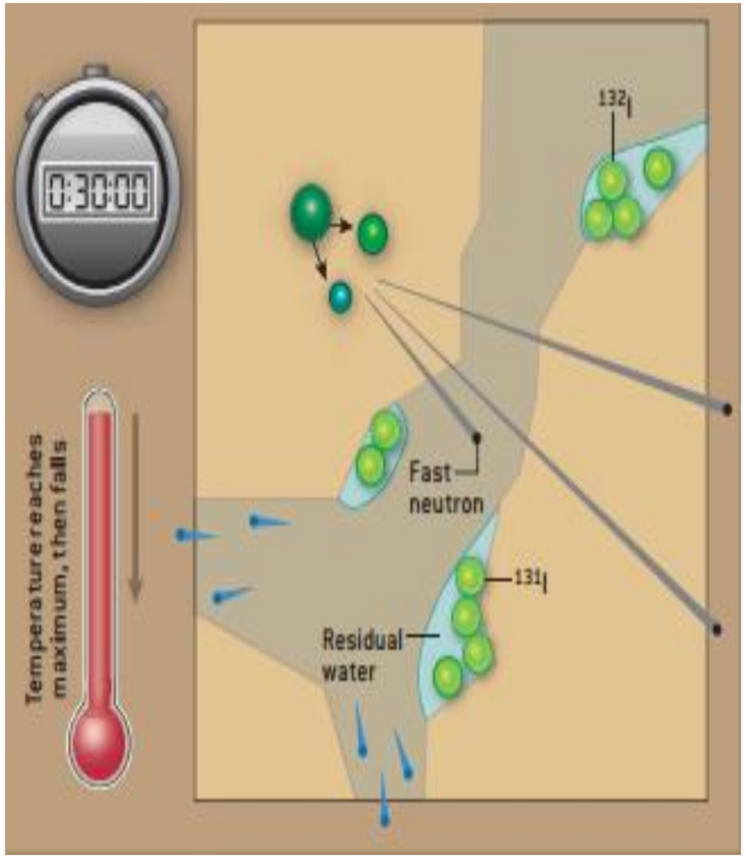
- Isotopic analysis of xenon proposed by Kuroda.
- Analysis performed by Meshik *et. al* found abundance of xeon-131 & 132 isotopes in aluminum phosphates.
- Confirmed self-regulating pulsed operation
  - Time “on” ~30 minutes
  - Time “off” ~2.5 hours

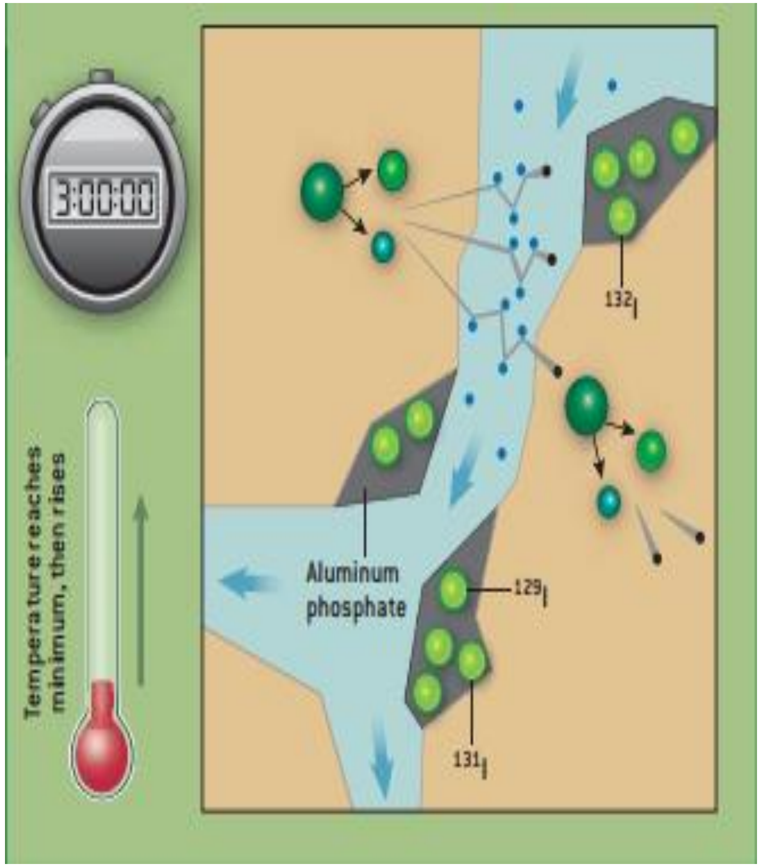


Xenon isotopic composition in aluminum phosphate, fission reaction, and normal atmosphere [6]

Operation of Oklo







Operation of Oklo

- Total energy released was approximately 15,000 megawatt-years, with an average power output of less than 100 kilowatts. [7]
- Operation of this nature continued between 100-300 thousand years without any meltdowns or uncontrolled nuclear reaction leading to an explosion. [7]

Implications of Oklo research

- Oklo data allows for the research into possible shifts in fundamental constants of nature such as the fine structure constant.
  - Investigate the cross section of neutron capture for samarium-149 [6]

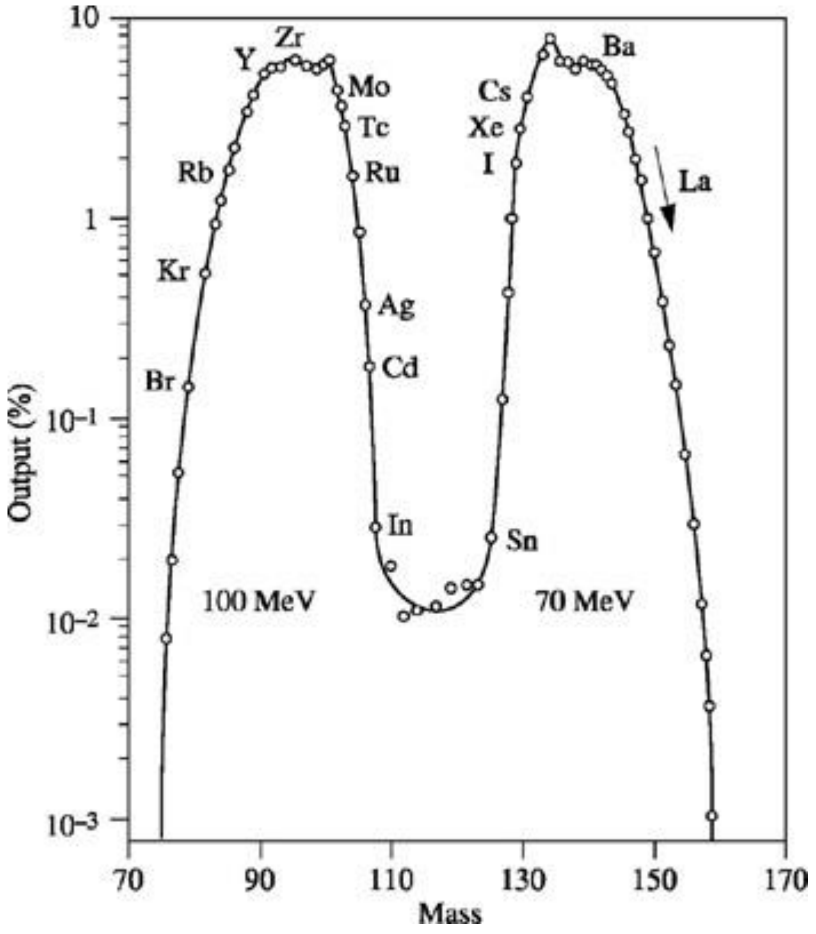
- Demonstrates a way to store nuclear waste by use of aluminum phosphates.

Questions?

Refs.

- [1] "Nature's Nuclear Reactor ...", Evelyn Mervin http://blogs.scientificamerican.com/guest-blog/natures-nuclear-reactors-the-2-billion-year-old-natural-fission-reactors-in-gabon-western-africa/
- [2] Cross section of Uranium, https://www.ncnr.nist.gov/resources/n-lengths/elements/u.html.
- [3]"Oklo Reactors and Implications for Nuclear Science", E. Davis, C. Gould, E. sharapov, arXiv 2014.
- [4] Isotopes of Uranium, https://en.wikipedia.org/wiki/Isotopes_of_uranium
- [5] "A Natural Fission Reactor", George A. Cowan, July 1976.
- [6] "On the Nuclear Physical Stability of Uranium Minerals", P.K. Kuroda, The" Journal of Chemical Physics, 1956
- [7] "The Workings of an Ancient Nuclear Reactor", A. Meshik, Scientific American, 2005.

Backup 1



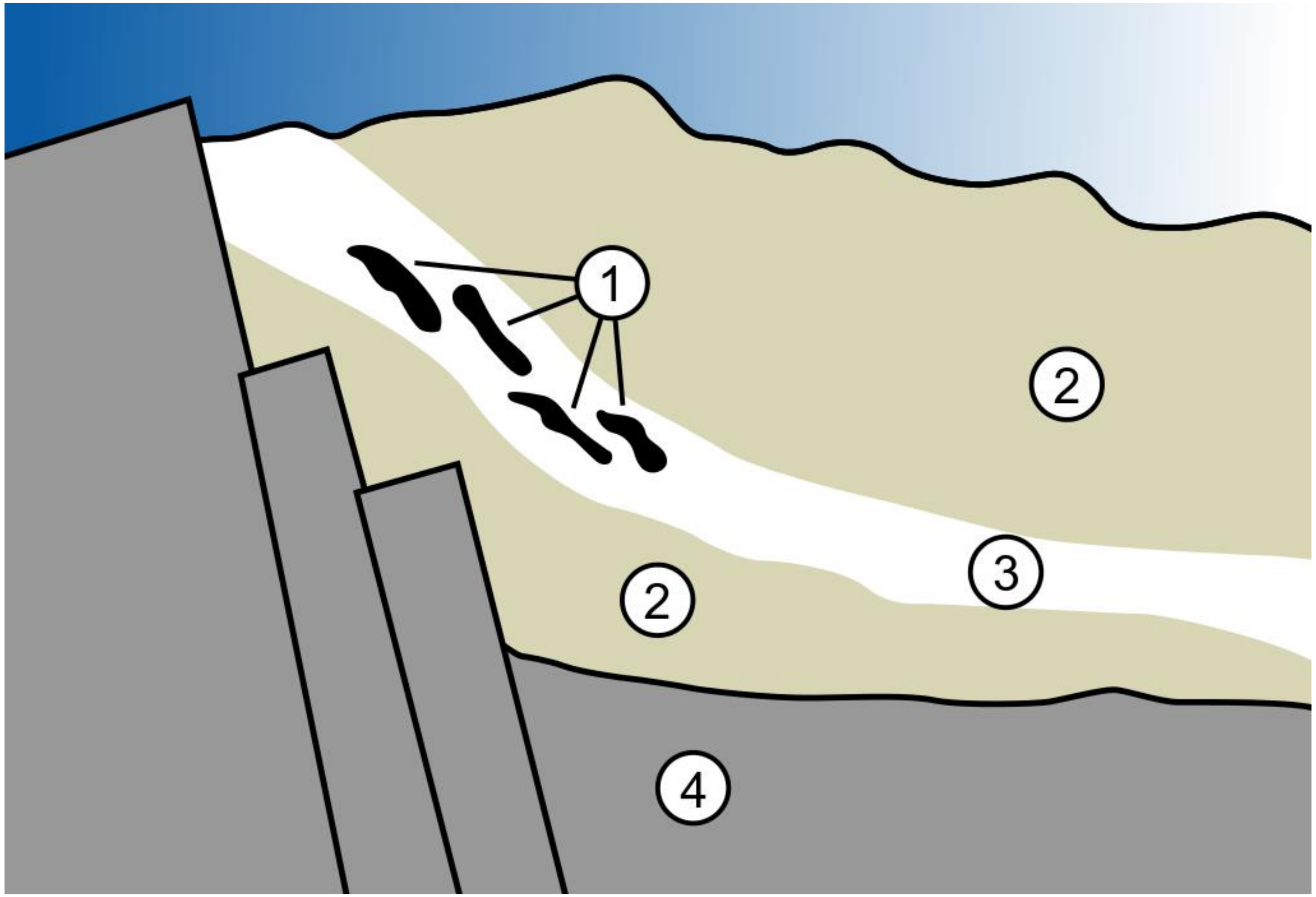
- Fission Products of Uranium-235.

http://www.globalspec.com/reference/55304/203279/chapter-13-nuclear-ceramics-fuels-absorbers-and-inert-matrices

Backup 2

- Decay of fission products:
- I-132 -> beta minus -> Xe-132
  - Likewise for I-131,I-133,I-134,I-136
  - Decay time, respectively: 8 days, 2 hours, 20 hours, 52 minutes, 80 seconds

Geology of Gabon



1. Nuclear reactor zones
2. Sandstone
3. Uranium ore layer
4. Granite

https://en.wikipedia.org/wiki/Natural_nuclear_fission_reactor#/media/File:Gabon_Geology_Oklo.svg