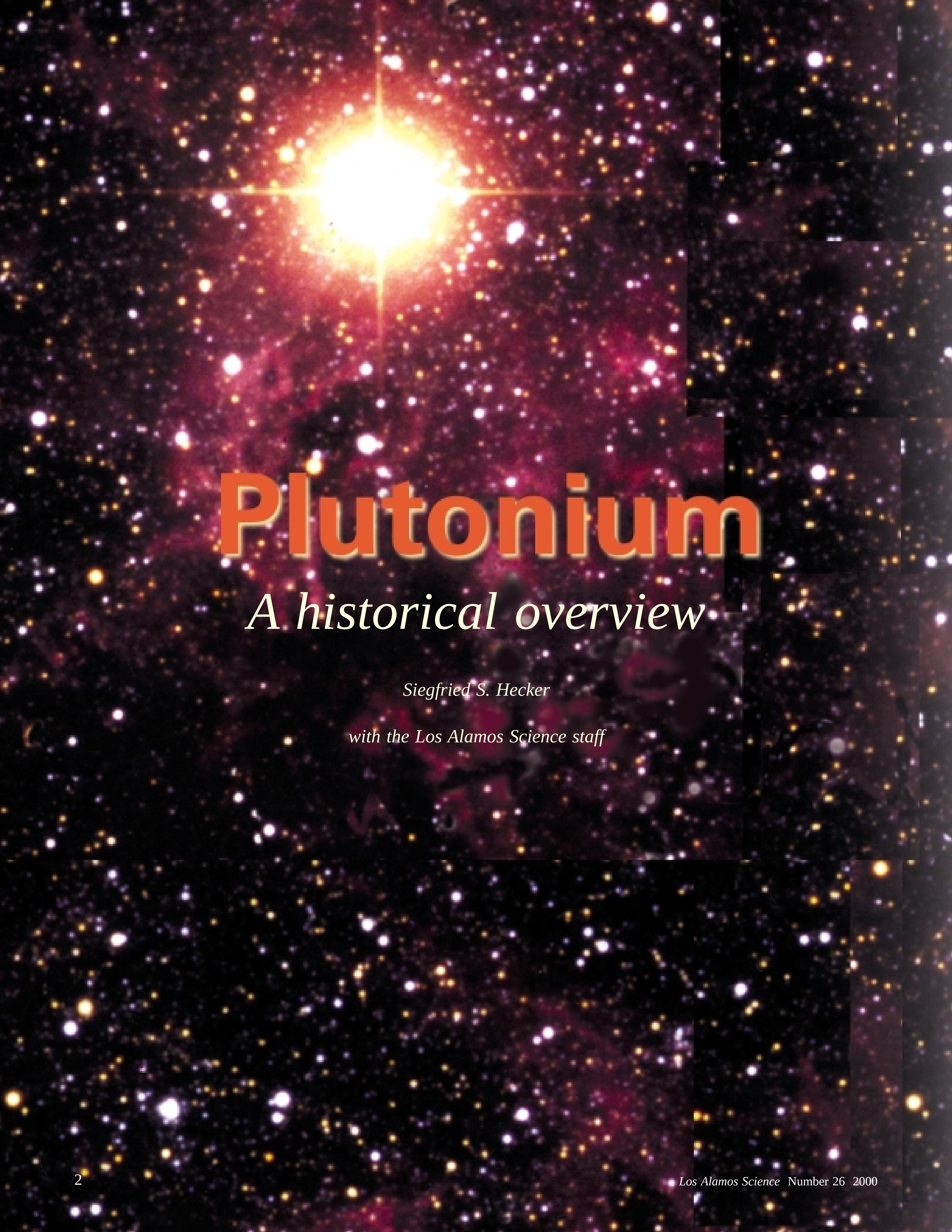

Plutonium

A historical overview

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with the Los Alamos Science staff

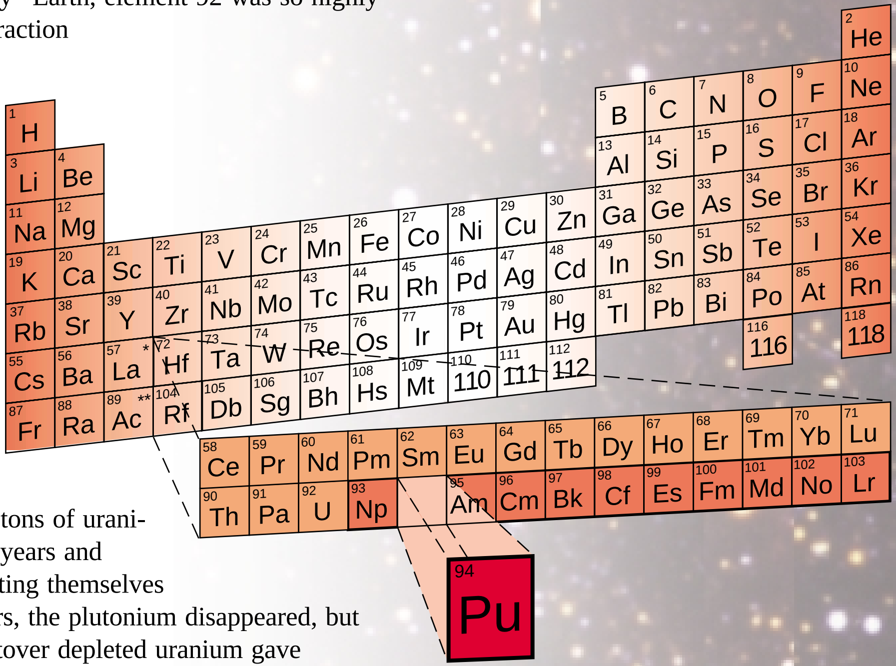
In the Beginning

Plutonium is often thought to be a manmade material. Yet in the beginning, before the solar system had formed, this very heavy element was produced in the blowoff from the supernovae in our galaxy—the exploding stars that made all the heavy elements in the Sun and the planets. The lighter elements through iron are typically produced by thermonuclear reactions in the hot, dense cores of dying stars. After a stellar core collapses and the star explodes, the r-process (for rapid neutron capture) takes over, boosting a small fraction of "seed" elements to higher and higher atomic numbers through discrete steps: first neutron capture and then the radioactive decay process called β-decay.

When the r-process turns itself off, plutonium (element 94) is as prevalent as uranium (element 92), and surprisingly, the fissile isotope uranium-235 that fuels fission reactors is more prevalent than uranium-238, which is the more abundant isotope on Earth. After capturing material from supernovae, the precursor to our solar system condensed to form the Sun and the planets. By that time, the elements heavier than uranium had long decayed away. Even plutonium-239, the relatively long-lived fissile isotope in nuclear weapons and fission reactors, has a half-life of only 24,400 years and was therefore all but gone when Earth finally formed.

The mine in Oklo, Gabon.

The story might have ended there, but Earth's crust contained large quantities of natural uranium. At the time of "early" Earth, element 92 was so highly enriched in uranium-235 (the isotopic fraction was about 32 percent) that it might have posed a severe threat for a "criticality accident" had it not been diluted by vast quantities of neutron-absorbing matter. Remarkably, a fission reactor did form spontaneously about 2 billion years ago in Oklo, Gabon (west-central Africa). Natural uranium was then 10 times more enriched with uranium-235 than it is now and could easily sustain a fission chain reaction once conditions were right to concentrate it into rich ore bodies. The natural reactors formed in Oklo fissioned more than 10 tons of uranium-235 over several hundred thousand years and created 4 tons of plutonium before shutting themselves down. Over the following 2 billion years, the plutonium disappeared, but the peculiar isotopic composition of leftover depleted uranium gave the secret away.



Plutonium has been created twice in the history of our planet—each time by life itself. It was plant life buried in water-saturated sedimentary rocks that concentrated uranium into ore bodies, sequentially oxidizing and reducing uranium oxide. Without the evolution of life and deciduous plants, the Oklo reactor would not have formed. By 1941, the evolution of intelligent life had led to the formation of plutonium—a second time. ■