

IMAGING

Brilliant X-rays Reveal Fruits of a Brilliant Mind

Passages written by the ancient Greek mathematician Archimedes, hidden for nearly 800 years, returned to view over the past 2 weeks, thanks to researchers at the Stanford Synchrotron Radiation Laboratory (SSRL) in Menlo Park,



Rare find. This Medieval prayer book conceals seven treatises by Archimedes, two of them unique.

California. The scientists used the synchrotron's hair-thin beam of x-rays to light up the Archimedes text, which was originally copied by a 10th century scribe onto goatskin parchment. Three centuries later, a monk scraped off the Archimedes text, turned the pages sideways, and copied Greek Orthodox prayers onto the recycled pages. Although Stanford's analysis of the text hasn't yet revealed any obvious revolutionary surprises, researchers did find a new geometric drawing as well as several previously missing passages.

"Nothing usually jumps out with Archimedes," says William Noel, the curator of manuscripts and rare books at the Walters Art Museum in Baltimore, Maryland, who is leading the restoration effort. "It takes blood, sweat, toil, and tears to get at what is there." Nevertheless, he adds, "people will be talking about what we are discovering now in 100 years' time and still arguing about it."

Few dispute that Archimedes was one of the world's greatest mathematicians. Today, he's known primarily for the legendary exclamation of "Eureka!" when he realized he could measure the volume of objects by figuring out how much water they displace. But he also helped create a rudimentary form of calculus 20 centuries before Newton and Leibniz put quill to paper. He came up with a way to calculate the value of pi and was the first to tackle the

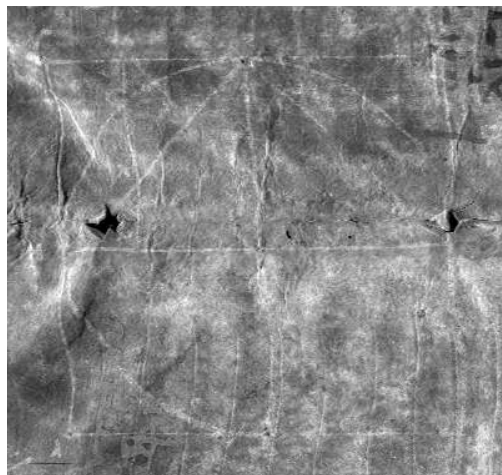
concept of infinity. And Archimedes's understanding of physics helped him invent the catapult and other defenses that his city-state of Syracuse used to repel Roman invaders until 212 B.C.E., when the city was finally overcome and Archimedes was killed.

The 174-page hidden manuscript, known as the Archimedes palimpsest, was discovered in 1906 by Danish classics professor John Heiberg, who used a magnifying glass to painstakingly decode the nearly invisible underlying text. But much remained undeciphered, and the book soon disappeared into a private collection. The manuscript resurfaced in October 1998 when it was sold at auction to an anonymous buyer for \$2 million. By then it had been severely damaged by mold. Forged gold leaf paintings, completely covering four pages, had also been added, probably in hopes of increasing the prayer book's value.

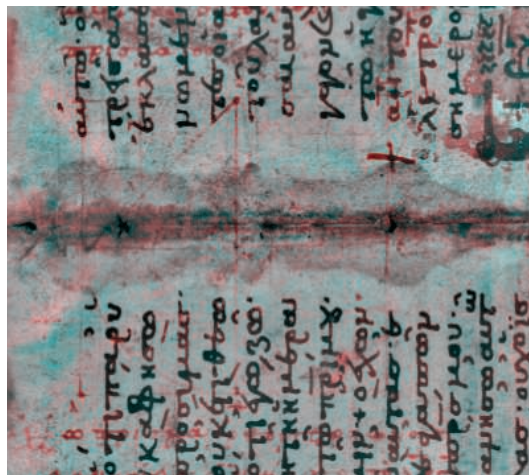
The day after the book's sale, Noel read about the auction in a *New York Times* article that mentioned the book's dealer. Noel e-mailed the dealer, who eventually put him in contact with the owner, who later agreed to lend the book to the Walters Art Museum for restoration and imaging. Noel says that the owner has paid for the entire project, although the amount spent has not been made public.

ultraviolet light were unable to peer beneath the forged paintings or to resolve other passages in the faint text. In 2003, Uwe Bergmann, a physicist at SSRL, came up with the idea of scanning synchrotron x-rays over the document to reveal elements such as iron and calcium in the residual ink. The energy of the x-rays is tuned to kick out inner electrons from those elements, Bergmann explains. That disruption triggers outer electrons to drop into the vacancies, giving up their excess energy as x-rays with a characteristic energy for each element, which are then captured by a detector. Computer programs then convert the steady stream of detected x-rays into gray-scale or color-enhanced images to reveal the hidden text.

The current round of imaging was successful, Noel says, and revealed numerous previously hidden passages, which can be viewed at www.archimedespalimpsest.org. In one section on mathematical propositions in a treatise titled *Method of Mechanical Theorems*, for example, Archimedes used infinite numbers to help him calculate volumes of particular objects. Although much of that text had been revealed by multispectral imaging, "there have been gaps in our reading," says Reviel Netz, a historian of ancient science at Stanford University in Palo Alto, California. "It seems the new [x-ray] images will definitely contribute to settling the reading."



Eureka. Synchrotron x-rays tuned to reveal calcium brought to life text and drawings (left) that multispectral imaging had shown to be lurking beneath later writings by Byzantine scribes (right).



Noel and his colleagues from Johns Hopkins University in Baltimore, Maryland, and the Rochester Institute of Technology in New York originally used multispectral imaging to reveal much of the underlying Archimedes text. Although largely successful, the visible and

The new x-ray technique "is absolutely fabulous" for recovering palimpsest texts, says Nigel Wilson, a classics scholar at Oxford University in the U.K. It's particularly exciting, he says, because many palimpsests remain to be studied. **—ROBERT F. SERVICE**

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