contributing that's new, this idea of bubbles from bubbles."

In the open ocean, says Bird, trillions of trillions of bubbles pop every second. The aerosols formed by bursting daughter bubbles are what we know as sea spray, which can carry dissolved gases, salt, thermal energy, and other materials into the atmosphere.

"This has huge implications for predicting cloud formation and looking at global climate models," he says. "If we have a better sense of what's going on in the ocean in terms of when a bubble pops and what kind of aerosol distribution it makes, that can lend itself to better predictions. A lot of uncertainty in climate modeling is cloud formation and air and sea interaction. And that comes back to bubbles and aerosols. It's a way of reducing uncertainty in models to make better predictions."

WEB EXTRA A video about the science of bubbles is at bu.edu/bostonia.

Understanding how bubbles pop can help a variety of industries as well, Bird says, such as glassmaking, which can use the knowledge to prevent the formation of small bubbles. "They could change the process by changing the properties of the material they're working with, some parameter like temperature or viscosity," he says.

Bird uses liquids such as water, solutions of water and glycerol, or silicon oil to create bubbles in the lab. One of his next projects is to study the thickness of the liquid film at various points of a bubble. "From an applications point of view, the two most important attributes of a popping bubble are the speed at which the film retracts and the size distribution of the aerosols that are created," he says. "And both attributes strongly depend on the bubble thickness. People now recognize that the thickness can change quite dramatically from the top to the sides. Still, this thickness has yet to be accurately measured and related to the fundamental forces at play."

Bird says scientists have been studying popping bubbles at least since the late 19th century. The British physicist Lord Rayleigh studied bubbles popping on paper, but wouldn't have observed the formation of daughter bubbles on such a porous surface. "It could have been described very elegantly, even without the high-speed cameras," Bird says. "Maybe they noticed it, but didn't think much of it.

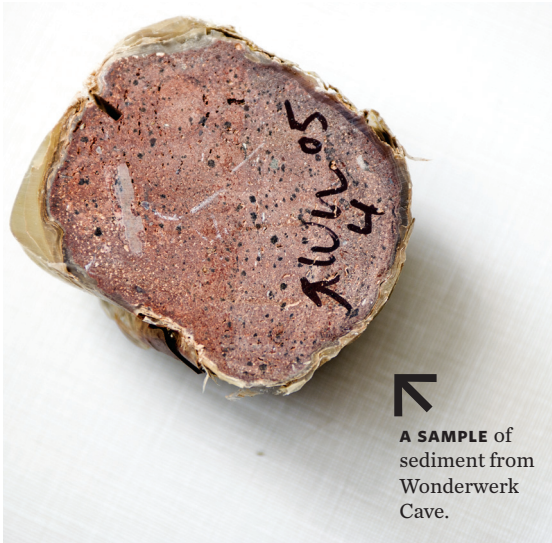
"And I'm sure that there are a million problems like that out there. I've talked to people about bubbles, like the grandmother sitting next to me on the plane, and she said, 'Oh, yeah, I see that all the time in my kitchen.'"

» Understanding how bubbles pop has implications for climatology and public health.

We Have Ignition

BU ARCHAEOLOGISTS CHANGE THE DATE OF EARLIEST MAN-MADE FIRE

BY AMY SUTHERLAND



KALMAN ZABARSKY

A SAMPLE of sediment from Wonderwerk Cave.

Until recently, most archaeologists put the date of the first man-made fire at about 800,000 years ago. Then, last year, Francesco Berna and Paul Goldberg got the test results on samples of bone and ash dug from a cave in South Africa, and the date of man's original flames jumped backwards at least another 200,000 years.

For anthropologists, man's first fire is much more than a cause for a Boy Scout merit badge: it could help us understand how our species evolved. Once early man had flames at his command, he not only had a source of heat, but a means to cook food. By unlocking nutrients in food, cooking made for a much better diet that not only boosted overall health, but may have contributed to other modern human traits, such as increased brain size and pair bonding, as the prominent prima-

tologist Richard Wrangham has argued. Berna and Goldberg's discovery bolsters Wrangham's theory that our evolutionary predecessor, *Homo erectus*, was building fires and cooking far sooner than was previously thought.

The evidence of fire was found in Wonderwerk Cave, a deep, tunnel-like cave on a high plateau in South Africa that has produced a wealth of archaeological artifacts. Goldberg, a College of Arts & Sciences professor of archaeology and geoarchaeology, joined a team there led by Michael Chazan, a University of Toronto professor, in 2004.

During that trip Goldberg took a sample of sediment from the cave floor that Berna, a CAS research assistant professor of archaeology, examined in Goldberg's Laboratory of MicroStratigraphy, which uses Fourier transform infrared spectroscopy to identify microscopic samples of sediment. The sediment was found to contain burnt bone and ash, which was sent to experts at the Hebrew University for dating.

» Remnants of man-made fire are often destroyed by wind or rain; in a cave, they can be washed away.

Berna and Chazan returned to the site last year and collected additional samples. "There were claims by Peter Beaumont before us that there was fire in this cave, but no one really proved it," Berna says. "My analysis proves that there was fire there."

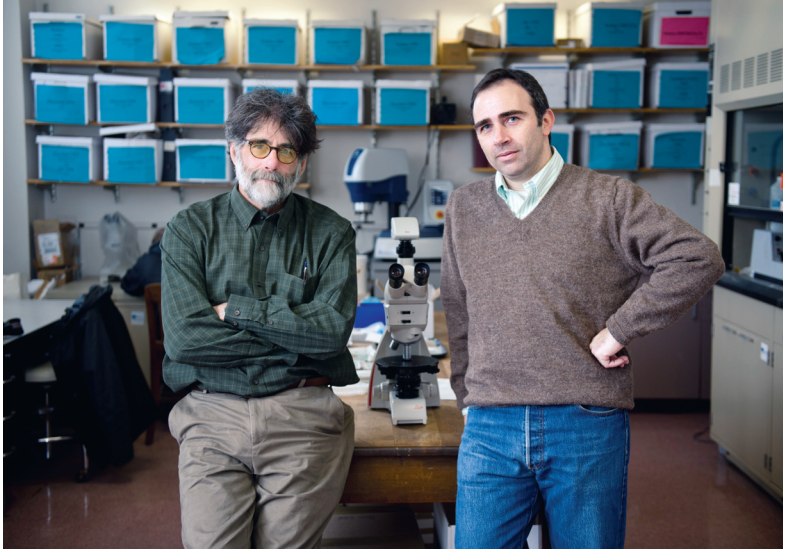
The discovery is the latest to come out of Goldberg's lab, which is the only lab of its kind in the country. In December, Goldberg and Berna were part of a team that published evidence of the earliest man-made bedding, which included fossilized remains of 77,000-year-old sedges and aromatic leaves at another site in South Africa. Prior to their find, the oldest bedding uncovered was at a site in Israel, believed to be approximately 23,000 years old.

While archaeology has traditionally been largely concerned with artifacts such as stone tools and pottery, geoarchaeology focuses on the rocks, soils, and sediments in which those objects are found. It is a forensic science that draws equally from geology and archaeology. Goldberg and Berna examine sediments for microscopic clues of human activity and past climatic conditions.

"We have to realize that the sediments in archaeological sites should be considered as artifacts," Goldberg says. "At some sites they throw the sediments down the side of the hill, which is kind of crazy."

Goldberg started his lab in 1995 with just one microscope. Today, he and Berna are involved in projects around the globe, including digs in France, Italy, Israel, China, Germany, Montserrat, the United States, and Canada. Goldberg recently traveled to France to begin analyzing the sediment attached to the foot of a Neanderthal skeleton at the Musée de l'Homme in Paris. He hopes the sediment will enable him to ascertain exactly what layers of the dig at the La Ferrassie site in the Dordogne region the skeleton came from. When the skeleton was unearthed at the turn of the 20th century, archaeologists were not yet in the habit of recording in detail where objects had been found.

To study sediments from archaeological sites, Goldberg and Berna collect clumps of earth and encase them with resin, which renders them stone-like. That hardened earth is then cut into ultrathin slices that can be examined under a microscope. There they can see intact remnants of the past in their true context, such as wood ash crystals left by a fire.



CYDNEY SCOTT

ARCHAEOLOGISTS Paul Goldberg (left) and Francesco Berna discovered evidence of a cooking fire in a South African cave dating from 1.2 million years ago.

DAVID HOFFMAN

Berna specializes in looking for microscopic evidence of man-made fire. That evidence is often maddeningly hard to come by. Remnants are frequently destroyed by wind or rain. In caves, seeping water can wash them away. Goldberg was part of a team of researchers that debunked the evidence for what was then considered to be among the earliest man-made fire, at the Zhoukoudian site in China, where Peking Man, the first example of what proved to be *Homo erectus*, was discovered. Their research found that the remains were organic-rich, but were deposited by running or standing water and not the result of burning, in situ or not.

At Wonderwerk, the location of the ash discovered was relatively deep in the cave: more than 30 yards from the entrance, out of reach of wildfires, rain, and wind. The ash was also found at an earlier surface level of the cave, some five feet below the current surface.

"When the whole picture came together, that they had had controlled fire, I got goose bumps," Berna says.

Now the two archaeologists are researching what they believe could be an even earlier fire in Wonderwerk, dating back 1.7 million years. Since new evidence of man-made fire typically sets off a controversy among archaeologists, Berna and Goldberg expect debate over their recent discovery. "We have strong evidence of potential fire in the cave," Goldberg says. "I think most people will come down on our side."

KALMAN ZABARSKY