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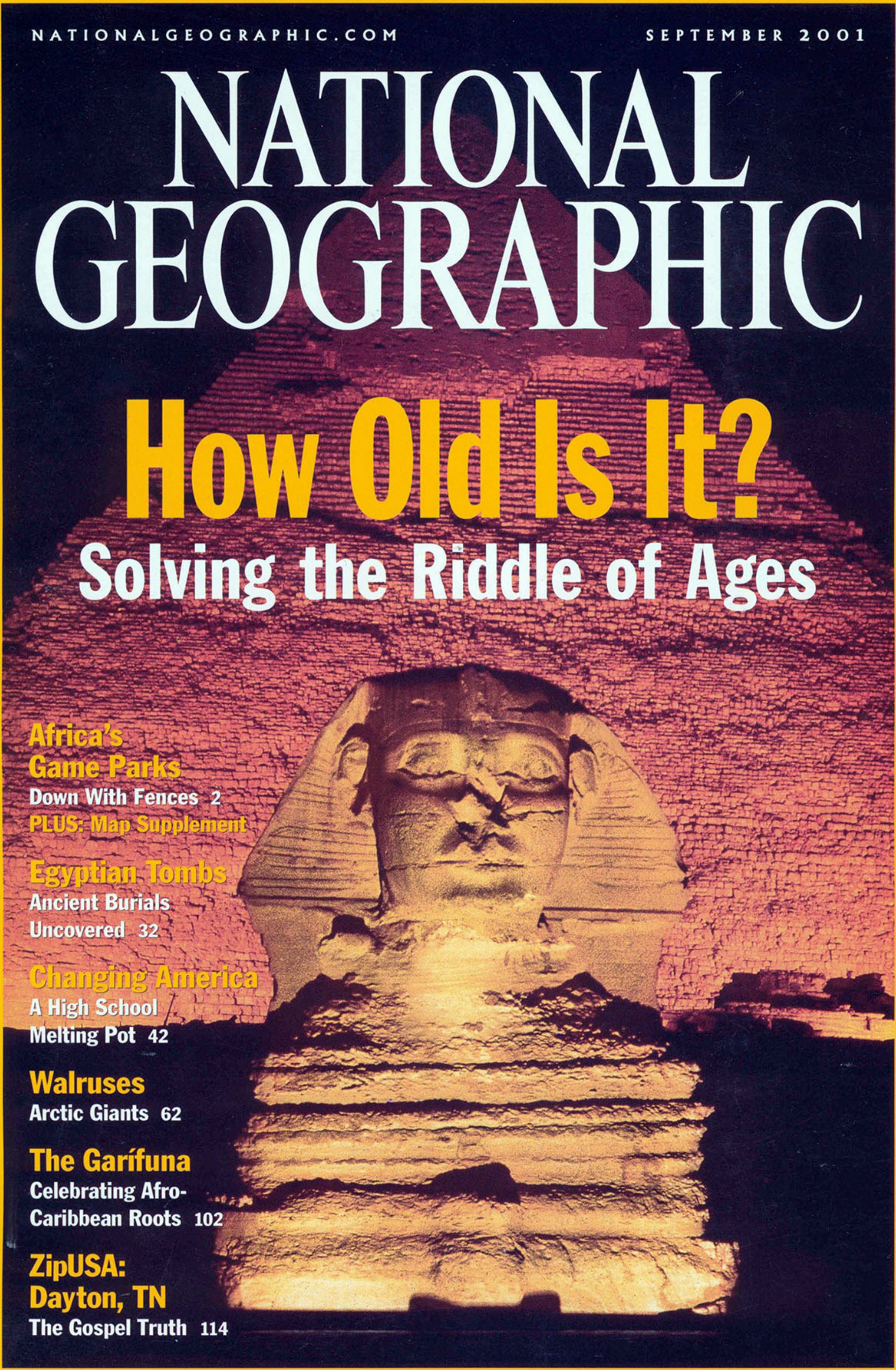

How Old Is It?
Solving the Riddle of Ages

fronds, ornamented disks, and other oddities collectively known as Ediacaran.

Paleontologists aren't sure which, if any, of these creatures are the forerunners of later animals. What they do know is that in the early Cambrian the earliest fossils of most of the major groups of animals turn up. By dating fossil-bearing rocks from around the world, Bowring and his colleagues have shown that the burst of evolution known as the Cambrian explosion began around 530 million years ago. Short of the origin of life itself, that episode represents evolution's supreme scientific challenge.

Bowring was on Great Colinet Island to test a theory championed in 1998 by Paul Hoffman, a geologist from Harvard, about what triggered the Cambrian explosion. The theory suggests that evolution was given a hard push when the planet fell into an ice age that got out of control. Glaciers kept growing until they covered the entire Earth, and life died back to almost nothing. After a few million years volcanic eruptions had released enough carbon dioxide to create a greenhouse effect that raised the planet's temperature. The glaciers melted, and the rising ocean created vast shallow seas that life could recolonize, giving evolution a tremendous jolt.

This "snowball Earth," as Hoffman and others call it, may have lasted ten million years. And if it did exist, it should have left its mark on Great Colinet Island. "This is one of the few places in the world where you can find glacial deposits that you could hope to date, because they're interlayered with volcanic rocks," Myrow explained. Using the zircons in the volcanic rocks, the geologists were hoping to bracket the ice age—to find ash layers as close to the bottom and the top of the glacier-delivered rocks as possible. This could possibly tell them not just how old the ice age is but also how long it lasted.

We split up to hunt for zircons. I went with Myrow and Bowring. We climbed to the flat grassy top of the island. We hiked through bogs, past nests of flecked gull eggs, over mats of dwarf spruce trees. The struggle was worth it. Scrambling down among boulders battered by waves, Myrow spotted two layers of good volcanic rock, one of them 6 meters below the bottom of the glacial deposits and one of them 1.2 meters into them.

"Oh baby, it's all ash," he shouted. Bowring pointed to the rocks he wanted, and the two of them hammered away, with water pouring down the cliff onto their heads.

Bowring stuffed the samples into canvas bags and helped me load some of them into my backpack. The three of us started the long march back to the boat, to put the zircons on a plane, get them back to Bowring's lab in Massachusetts, put dates on them, and try to figure out if it was "snowball Earth" that triggered the Cambrian explosion.

Blair Hedges, a biologist at Pennsylvania State University, is investigating the origins of animals with a different kind of clock. I stood with him in front of a bank of humming freezers while he inspected an ice-encrusted tray of little tubes, each filled with tissue. Hedges is creating a refrigerated zoo, collecting tissues from animals scattered among the 35 major taxonomic groups known as phyla. In his trays he had tissue from scorpions, centipedes, peanut worms, octopuses, mollusks, jellyfish, sponges—"we've got about three-quarters of all the phyla right here," he said.

Those cells contain clocks of their own that can tell time for hundreds of millions of years. From generation to generation certain genes of a species mutate at relatively steady rates. If you compare the genes of two species, say humans and chimpanzees—and you know the rates at which their genes have been mutating—you can estimate how long it has been since their ancestors diverged from a common ancestor.

This kind of molecular clock, as it's known, has come into its own in the past ten years. In 1996 Hedges caused a stir by using molecular clocks to date the dawn of mammals. When paleontologists look at the record of mammal fossils, they see a burst of diversity just after dinosaurs became extinct 65 million years ago. It was this burst, they theorize, that produced most of the orders alive today—from hoofed mammals to bats to us primates. But when Hedges and his colleagues look beyond the fossil records at the genes of mammals, they see their roots extending back more than 100 million years.

Hedges is now investigating what molecular clocks have to say about the Cambrian explosion, which researchers such as Sam Bowring have determined took place 530 to 520 million years ago. Again, Hedges's results are far different

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from what fossil records show. He and his colleagues have compared genes from three animal phyla, and their molecular clocks point to an origin over a billion years ago—once more a doubling of evolutionary history.

The conflict between fossils and genes will take a long time to sort out. Critics of molecular clocks suspect that evolution can make them speed up or slow down. But Hedges counters that he and his colleagues can guard against this sort of variability, and when they do, their dates still hold up. As for the lack of fossils to support his dates, Hedges argues that the earliest forms didn't leave fossils behind, or at least any that have yet been discovered. Only around the start of the Cambrian did they get big enough for us to find.

Telling time is important not just to the history of life but to the history of the universe itself. Clocks that pin down the formation of the solar system can be found in meteorites that have fallen to Earth after wandering around the sun for billions of years. But for more ancient time telling, scientists cannot use any clock to be found on Earth. They have to look at the sky.

The sky was cloudy on the evening I met George Djorgovski, an astronomer from Caltech working in Hawaii, and rain was falling as we walked quickly across a dark lawn. "Can you believe we can look at stars in this weather?" he asked. We entered a small building and slipped into a room filled with bright fluorescent light and eight giant computer screens. Even if the sky was clear, we couldn't have seen the stars through the drawn blinds.

Djorgovski sat in front of three computer screens pushed next to each other. The computers are hooked up to data cables that run 48 miles from this room to the 13,800-foot-high summit of Mauna Kea—and to two of the finest telescopes in the world, at the W. M. Keck Observatory.

As the sun set, Djorgovski sent coordinates to technicians at the top of Mauna Kea, and the telescope he was using swung across the sky. A disembodied voice from one of the computers in the room said, "Exposure complete," and a white field filled with black spots appeared. One giant blob dominated the center of the picture—a ferociously bright object known as a quasar, with the intensity of trillions of suns. "That's our guy," said Djorgovski.

He touched the image of the quasar with one finger. "Just think," he said. "As the Earth formed, the light from this had already traveled two-thirds of its way here."

Quasars and galaxies are hurtling away from us as the universe expands. As they speed off, the light they emit lowers in frequency and shifts toward the red end of the spectrum—much as a train whistle drops in pitch as it passes

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How Old Is . . .

. . . the Grand Canyon?

Bottom layer: 2 billion years old
Top layer: 250 million years old

Dating techniques:
Bottom layer: Radiometric. Top layer: Fossils

Although the Grand Canyon's oldest known rocks are almost half the age of Earth, the Colorado River did not start carving the canyon itself until just five or six million years ago—a blink of the eye in geologic time.

. . . this Pyramid?

4,449 years old?

Dating technique: Star alignment

The Pyramid of Khafre may be about 70 years younger than usually thought, says a new theory, which shows that the northern alignment of the Pyramids at Gîza matches that of two polar stars visible during that era.

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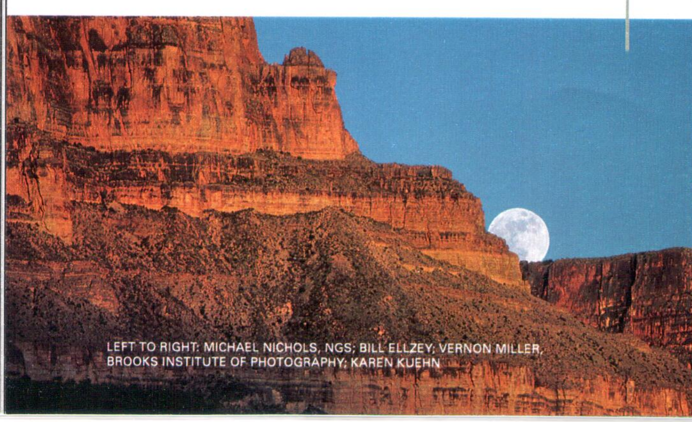

LEFT TO RIGHT: MICHAEL NICHOLS, NGS; BILL ELLZEY; VERNON MILLER, BROOKS INSTITUTE OF PHOTOGRAPHY; KAREN KUEHN