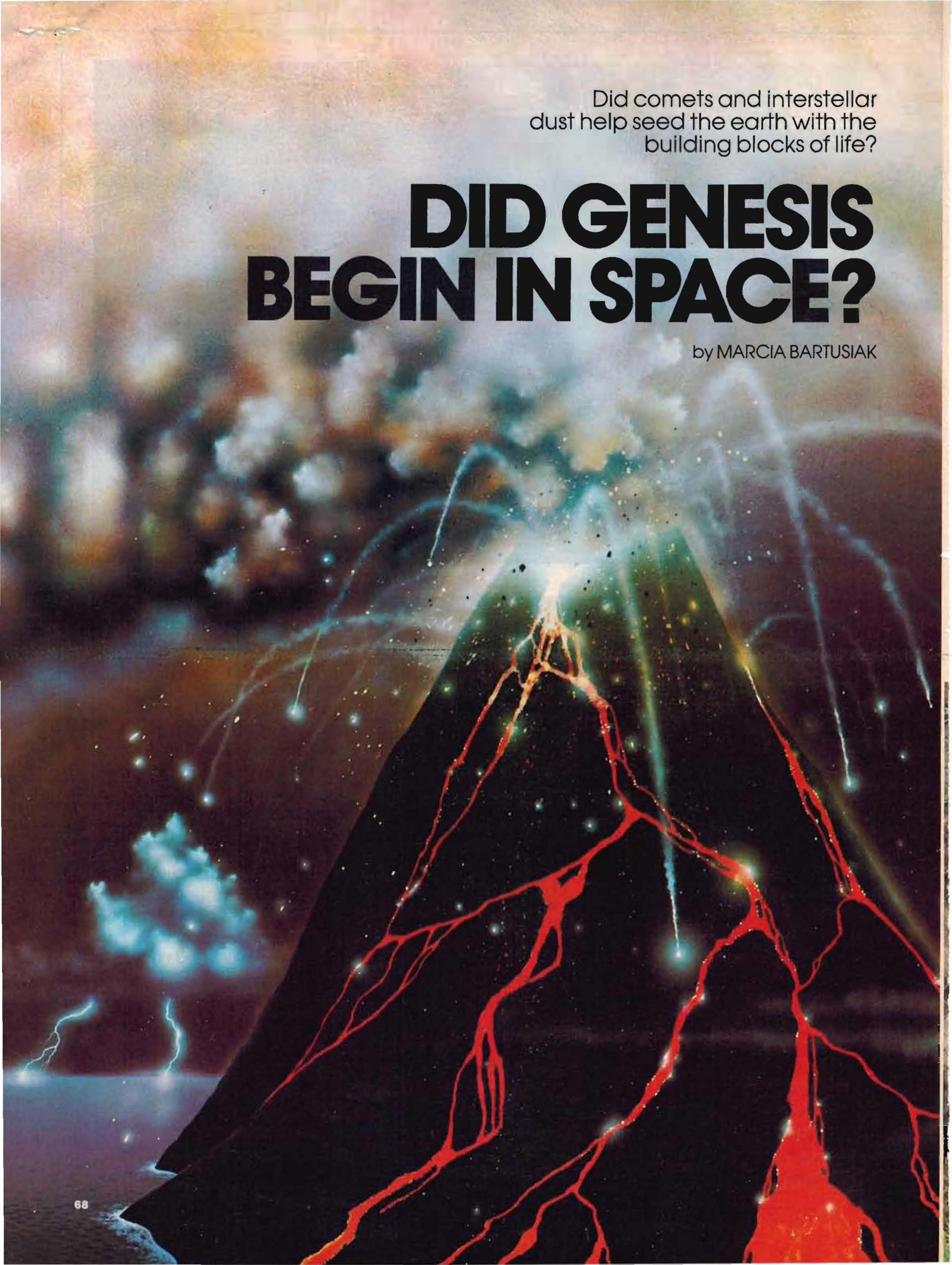
Did comets and interstellar dust help seed the earth with the building blocks of life?

DID GENESIS BEGIN IN SPACE?

by MARCIA BARTUSIAK



Fiery volcanoes dominated the landscape of the newly born earth some 4 billion years ago, spewing gases that formed the first atmosphere. Then came the endless rains, forming ponds, seas, and finally oceans. Energized by lightning, the heat from lava, and ultraviolet radiation from the sun, the volcanic gases reacted chemically to form more complex organic compounds. Raining down into the sea, they created a dilute "primordial soup" of organic matter that included amino acids—the building blocks of proteins—and the nitrogen bases that are a key ingredient of DNA.

This vivid version of the beginnings of life, widely accepted by scientists for several decades, may be only part of the story. The latest findings and theories about the composition of comets and interstellar gases—fruits of a new scientific discipline called astrochemistry—are providing some competition for the notion that the organic compounds from which life sprang were assembled on earth. "I believe that nature probably had half a dozen ways to form that initial pool of organic matter," says David Buhl, a space scientist at NASA's Goddard Space Flight Center in Maryland. Some precursors of life, say Buhl and others, could have arrived from outer space eons ago.

During the first 500 million years of the earth's history, the solar system was cluttered with more comets and meteors than exist today; many of them undoubtedly crashed into the planets and their moons. Scientists at NASA's Ames Research Center in California have suggested that comets could have generated a large part of the earth's early atmosphere either by vaporizing during entry or by plunging into the earth's mantle, where they later released gases into the primitive air. This may have provided the methane, carbon monoxide, and hydrogen cyanide necessary to start the formation of more complex organic compounds. As evidence that comets could have been a major contributor to the earth's inventory of volatile materials, the Ames

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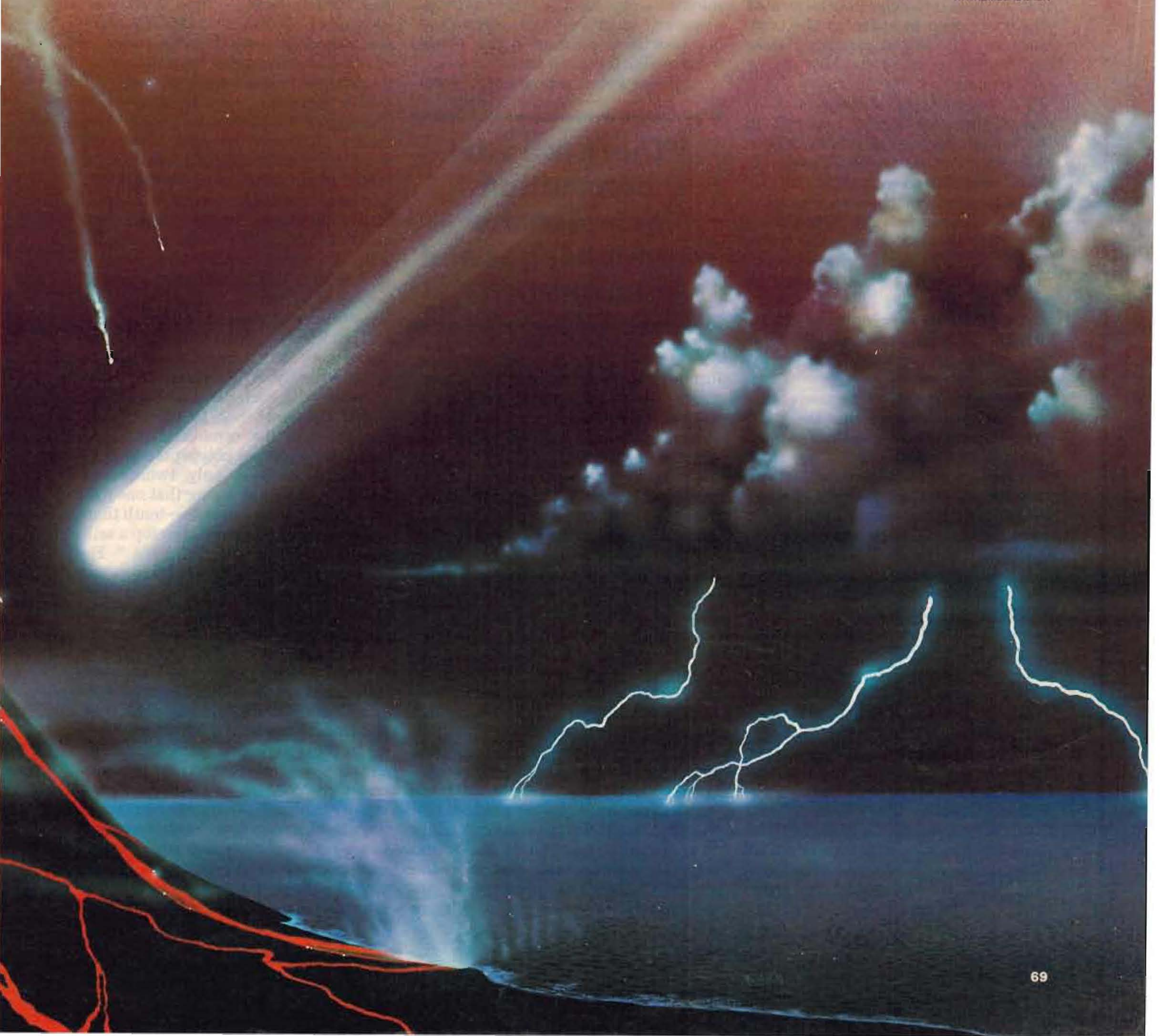

scientists point to the estimated ratio of hydrogen to carbon in comets, which is similar to that in the earth's crust.

Biochemist Juan Oró, of the University of Houston, who first suggested 20 years ago that comets and carbon-rich meteorites helped seed the planet with the starting materials for life, estimates that 10 quadrillion tons of simple organic compounds were deposited by comets, 10,000 times as much as all the organic matter on the earth today. Says Oró, "Such an amount was more than enough to generate primitive living systems." Oró and others have also come to suspect that comets, believed to be "dirty snowballs" of frozen gases and rocky debris, are even richer in prebiotic material. Experiments indicate that complex molecules may be formed on comets deep in space by the bombardment of charged particles "blowing" from the sun in the solar wind, or by cosmic rays.

There may be still another extraterrestrial source of organic material. In the past two decades, astronomers have discovered that nearly 60 different molecular compounds exist amidst the interstellar dust and gas concentrated in the spiral arms of the Milky Way galaxy. Each kind of molecule has a distinctive "signature," characteristic radio or infra-red frequencies that it emits after absorbing energy from the dust cloud. The ever growing list includes water, carbon monoxide, dimethyl ether, formaldehyde, hydrogen cyanide, and alcohol.

"This wide variety of organic chemicals makes one suspect that there is a vital connection between the interstellar gas and the earth," says Buhl. "Comets are the most obvious link since they are refrigerated samples of a molecular cloud that coalesced to form our own solar system. If the comets fell into the right environment early enough, they could have provided earth with a head start on the way towards life."

Scientists are hoping that space probes to Halley's comet during its next visit, in 1986, will shed some light on the comet theories. They are also looking for clues in Brownlee particles, tiny grains believed to be of unearthly origin that Donald Brownlee, a University of Washington astronomer, has been collecting from the stratosphere and deep-sea sediments. They may be the first samples of cometary dust.

While the chemicals in interstellar space (and maybe in a comet) are diverse, amino acids have yet to be found in the celestial dust clouds. But experiments at Leiden University in The Netherlands suggest that they may be there, perhaps clinging to the interstellar grains.

In performing those experiments in the Laboratory for Astrophysics at Leiden, J. Mayo Greenberg and Louis Allamandola create a bit of outer space on earth. They inject typical gases detected in the dust clouds—water, ammonia, methane, and carbon monoxide—into a quart-sized vacuum chamber cooled to −441 degrees Fahrenheit and containing a glass surface, or "cold finger," that mimics the core of an interstellar dust particle. Explains Greenberg, "We inject the gases, have them freeze on the cold finger, and irradiate them just as the distant stars in space do." Over many days, the pseudo-cosmic dust is repeatedly warmed a few degrees with ultraviolet rays, then cooled; one hour of irradiation in the laboratory equals a thousand years in space.

As the experiment proceeds, the simple molecules collide and combine, forming more complex molecules—many of them identical to the organic substances detected by radio astronomers. In the process the finger also becomes coated with a solid that does not evaporate when warmed to room temperature. Says Greenberg: "This we call our yellow stuff, because it is generally discolored yellow or brown."

"There is a vital connection between the interstellar gas and the earth"

Allamandola, a physical chemist, estimates that anywhere from 40 to 80 per cent of the interstellar dust may consist of the mysterious substance. Detailed chemical analysis is still needed to identify the constituents of the "stuff," but Greenberg suspects it includes the highly complex organic molecules—perhaps even amino acids—that are the precursors of life.

Dismissing comets as a negligible source of material, Greenberg and Allamandola speculate that the interstellar grains—which are about one 100-thousandth of an inch across—could have dusted the earth with water and large organic molecules even before the planet acquired its primitive atmosphere. "The motion of the stars through the Milky Way is such that the earth passes through a dusty spiral arm once every hundred million years," Greenberg points out. "The probability is very high that when the earth passed through a sufficiently dense cloud, 10,000 tons of concentrated organic dust would be deposited on the planet each year for a period between one million and ten million years." That would make a layer about as thick as paper over the entire earth's surface. Adds Greenberg: "It could have happened three times before life's start."

Some of the impetus for discussing new routes in chemical evolution has been provided by paleobiologists, whose most recent findings have pushed estimates of when life started further and further back in time. Last year an analysis of fossil remnants that were discovered in some ancient rocks in Australia revealed that bacteria-like organisms were flourishing on earth 3.5 billion years ago, only about a billion years after the earth was formed. That means that even simpler life forms must have existed much less than a billion years after the earth was born, and some scientists wonder if the molecules necessary for life could have evolved that quickly in the primordial soup. The logical conclusion to this line of reasoning is that complex molecules deposited by comets or interstellar dust were needed to speed things up.

Cyril Ponnamperuma, director of the Laboratory of Chemical Evolution at the University of Maryland, has little patience with such conclusions. "Time is not of the essence," he says. "When we simulate the conditions of early earth, we generate polypeptides—links of amino acids—in only twenty-four hours. Now we are seeing that one million years, perhaps even one-tenth that, would be enough time to develop a self-replicating molecule like DNA." He agrees that comets probably conveyed some organic material to earth, but thinks that a primordial ocean would generate nine times as much.

Can scientists assign precise roles to primordial soup, comets, and interstellar dust in the drama of Genesis? Patrick Thaddeus, an astrophysicist with the Goddard Institute for Space Studies in New York City, is skeptical. As he points out, "All the traces of that process were gobbled up long ago by living organisms." Others hold out hope. Says Buhl, "With space probes planned to go out to comets and with the advances expected to be made in astronomy, I believe we'll get some firm answers within the next fifty years." ▣