

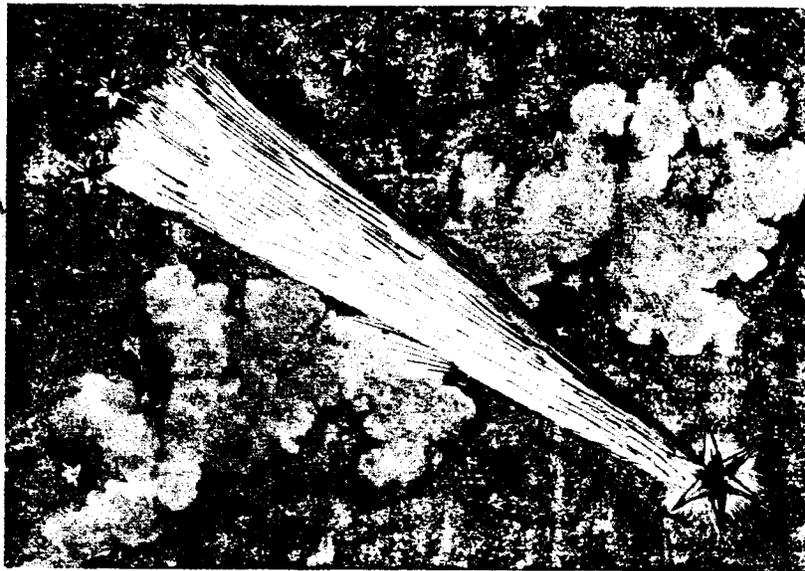
*The Sciences*

# WORLDS IN COLLUSION *July/Aug*

*How Galactic Disturbances Trigger Earthly Upheavals*

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by MICHAEL R. RAMPINO



The Comet of 1532, page from a commonplace book

**V**OLCANIC FLOODING began some sixty-six million years ago on the inland plain that was to become part of western India. A plume of molten rock rising from deep within the earth had created an extensive network of fissures in the crust, through which lava surged for more than a million years. Each new wave formed a simmering blanket over the cooled residue of the previous eruption, until the pile grew to a thickness of one and a quarter miles. Today, the congealed remains are known as the Deccan basalts, or the Deccan traps, a two-hundred-thousand-square-mile landscape of soot-colored rock, eroded in places to reveal its layers.

This unusual paroxysm caused a succession of land and atmospheric changes. The volcanic eruptions released sulfur-rich aerosols into the atmosphere, darkening the sky and cooling the climate. And they weakened the underlying crust so that, during the next two million to three million years, the Indian subcontinent split from the continental plate that now holds the Seychelles, to the southwest. Rising currents of molten rock in the mantle thrust magma between the two landmasses, pushing them apart and creating the two-thousand-mile-wide Arabian Sea. All in all, it was a time of extraordinary activity

—more intense than the earth had experienced for some thirty million years.

And it was mirrored by an even greater commotion in space. In fact, the perturbations on Earth were gentle compared with the powerful disturbances taking place throughout the solar system. The sun and its planets, in the course of their normal movement through the Milky Way, were ascending into the thick of the galaxy's clouds of interstellar gas and dust, and the tremendous gravitation exerted by this galactic material jarred the entire solar system. The force was not strong enough to jolt the planets in their orbits, which are held securely in place by the sun's gravitation. But it upset the far-flung comets of the Oort cloud, which circle the solar system far beyond Pluto's orbit, and sent some of them tumbling, like apples shaken from a tree, toward the sun.

The upheaval in space and the geological activity in western India sixty-six million years ago were connected by more than coincidence. Some of the comets shaken loose by the sun's swing through the galaxy rained on Earth and upset the measured pace of tectonic and volcanic activity. Several geological discoveries in the past few years indicate that Earth has withstood such comet

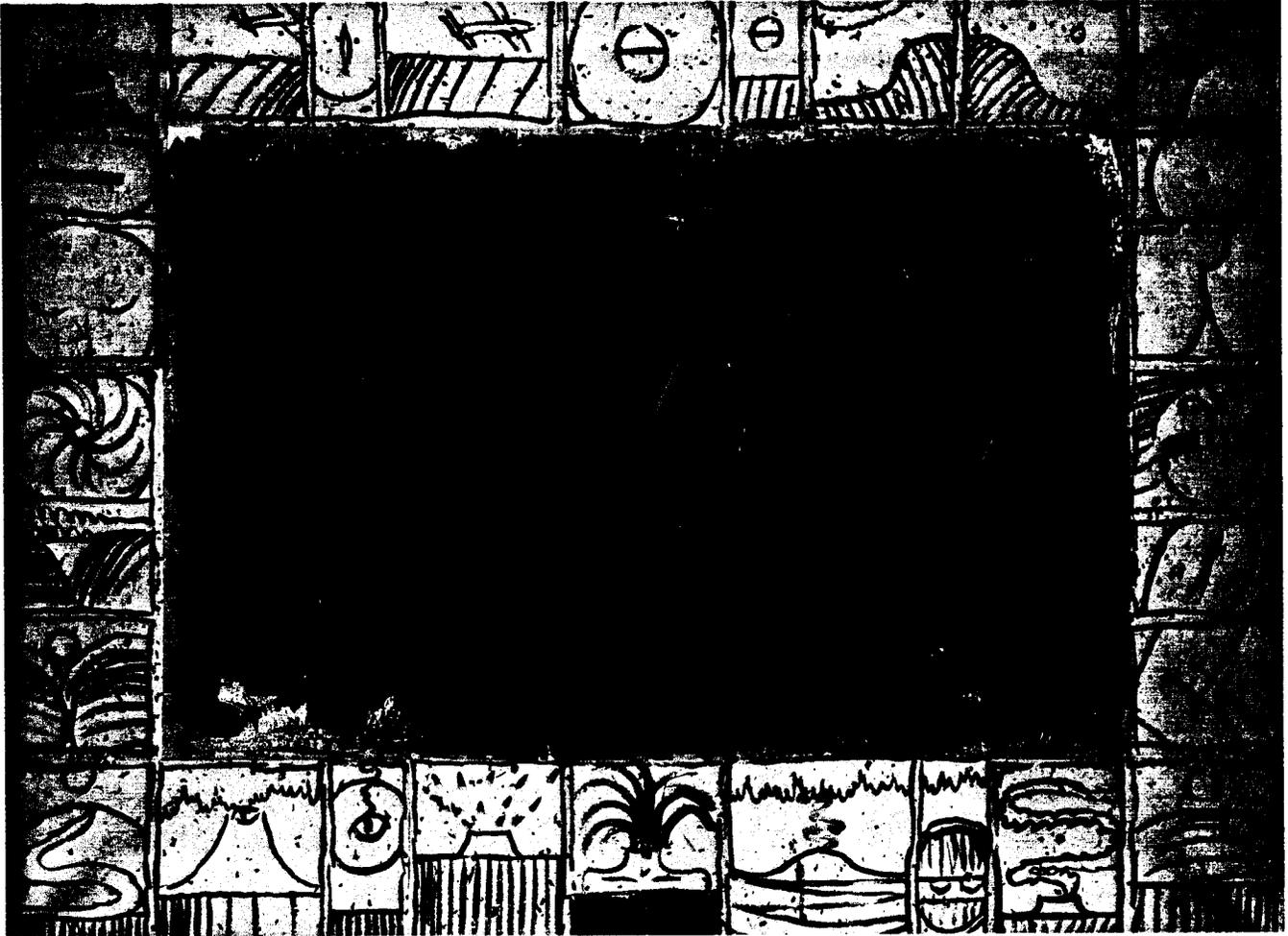
showers at regular intervals and that each one has marked the beginning of a period of sweeping terrestrial change. The discoveries suggest a retelling of Earth's history, in which the planet's own geological cycles are part of a larger, galactic cycle of destruction and renewal.

THE NOTION that there might exist some time-piece by which the planet measures its crustal movements has been hinted at by geological discoveries made during the past two hundred years. In 1795, the Scot James Hutton published his *Theory of the Earth*, which ini-

den and violent catastrophes and revolutions of the whole earth, and its inhabitants."

Lyell's pronouncement, though it put to rest, for a time, the issue of how quickly change occurs, did not keep later geologists from debating the question of whether erosion, deposition, mountain building, and changes in sea level occur in cycles. After all, even gradual change could repeat itself in regular intervals. The American geologist Joseph Barrell mused over the possibility early in the present century. "Nature," he wrote, "vibrates with rhythms, climatic and diastrophic, those find-

CREATION PERIODS!



Pierre Alechinsky, Aztec Volcano, 1971

tiated the view of a dynamic planet that has altered its features through cycles of uplift and erosion stretching back to the uncharted beginnings of geological time. Hutton's ideas led geologists to debate whether these changes proceed steadily or in spurts with long periods of stasis punctuated by cataclysms of mountain building, rising oceans, and the splitting and foundering of continents. Catastrophists pointed to the clearly marked boundaries of fossils left in rock strata as evidence of sudden, drastic changes, whereas gradualists attributed the demarcations to the incompleteness of the fossil record. In the end, gradualism carried the day, as Charles Lyell triumphantly proclaimed in his monumental *Principles of Geology* (published in three volumes between 1830 and 1833): "All theories are rejected which involve the assumption of sud-

ing stratigraphic expression ranging in period from the rapid oscillation of surface waters, recorded in ripple-marks, to those long deferred stirrings of the deep-imprisoned titans which have divided the earth's history into periods and eras." Yet, as pleasing as the cadenced natural world of Barrell might have sounded, there existed at the time no solid evidence of rhythmic cycles in Earth's history.

In 1927, the issue was taken up by Arthur Holmes, an English geologist who advocated the theory that the continents drift about the globe on currents of hot rock. Holmes was one of the first to date rock layers by measuring their relative amounts of radioactive uranium and its stable by-product, lead. (Because uranium decays into lead at a steady rate, the ages of rocks can be determined

by comparing quantities of the two elements, enabling scientists to tell when episodes of mountain building occurred and, by studying fossils in dated layers, when oceans flooded vast regions of the continents.) After collecting dates from only a dozen rock layers, Holmes began to suspect that the oceans rose and fell once every thirty million years and, coincidentally, that each episode of mountain building was separated by the same span of time. Ultimately, he concluded that geological change occurred in cycles. The theory failed to win acceptance, in part because it was based on such a small collection of dates. Yet, because of Holmes's eminence, the notion that the earth has some "pulse" was not entirely forgotten.

**T**HE MODERN THEORY of plate tectonics, largely set forth in the 1960s, has brought a fresh understanding of geological change. The theory is based on the knowledge that the planet's surface is divided into about a dozen tectonic plates that continually shift positions. By studying the movements of these plates, scientists have learned how continental drift, volcanism, and mountain building are interrelated. A cycle of change is thought to begin in the mantle when slow-moving waves of hot rock, known as convection currents, somehow shift and create a hot spot, or high-temperature zone, which sends a plume of magma into the crust above. The plume opens fissures in the crust, through which lava can flow. (The Deccan traps are but one of nine such lava eruptions that have occurred during the past two hundred and fifty million years. On the eastern coast of North America, two hundred million years ago, a hot spot, or a series of hot spots, cracked the crust from Nova Scotia to North Carolina.)

Typically, after the lava has flowed for a few million years, the crust cracks completely along one of the fissures. Underlying convection currents feed fresh supplies of magma through this rift, thereby separating the halves of the broken crustal plate and laying new rock between them in a process known as seafloor spreading. Water fills the low-lying landscape (the Atlantic, for example, was formed from the rift that separated the Americas from western Europe and Africa), and the plates continue moving apart, driven by the convection currents that keep them forever adrift.

Moving plates collide with one another in two ways, both of which lead to the creation of mountain ranges. In one case, the two plates simply buckle upon impact, pushing up such mountains as the Himalayas. In the second type of collision, known as subduction, one plate absorbs the impact by diving into the mantle, beneath the other plate. The edge of the submerging plate melts into magma, which rises through fissures in the overlying continent and forms volcanic mountains, such as the Andes. Yet a third type of mountain building is performed in the interior regions of plates by plumes of magma rising from mantle hot spots. Because a hot spot remains stationary beneath the moving plate, the plume does not always erupt through the same spot in the crust. As the plate carrying the Indian subcontinent has moved northward, for example, the hot spot that instigated the Deccan eruptions sixty-six million years ago has fired a number of volcanoes across the Indian Ocean, the most recent of which is the island of Réunion.

Although geologists once assumed that plate move-

ments and volcanism proceeded at roughly constant rates, they have lately come to recognize significant variations in velocity. Studies during the past twenty years have revealed that periods of fitful activity, associated with surges in volcanism, alternate with intervals of relatively slow plate movement, with each phase of energetic activity marking the beginning of a new cycle of change. Yet until recently, the question remained whether these cycles have any underlying rhythm.

**T**HE FIRST CLEAR EVIDENCE that earthly processes occur in measured pulses came not from a study of volcanism or plate tectonics but from a consideration of marine extinctions. In the early 1980s, scientists began to look more closely at the question of how extinctions occur. Two University of Chicago paleontologists, David M. Raup and J. John Sepkoski, Jr., compiled a master list of marine species that have died out during the past two hundred and sixty-eight million years, and noted that the chronology has been punctuated with brief periods during which many species disappeared at once. Surprisingly, these mass extinctions followed a regular schedule, occurring about every twenty-six million years.

Raup and Sepkoski's research suggested the existence of some rhythmically recurring force powerful enough to wipe out many species in one blow. Such a cataclysmic occurrence might be expected to have had profound effects on the planet itself, as well as its inhabitants—reasoning that inspired Richard B. Stothers, of NASA's Goddard Institute for Space Studies, and me to search for similarly timed rhythms in the geological record. We reviewed Raup and Sepkoski's data and attempted to bring the evidence for periodicity into even finer focus. By disregarding minor extinctions, in which fewer than one out of ten families of marine life had died out, we identified a cycle closer to thirty million years than to Raup and Sepkoski's twenty-six million. We later analyzed extinctions of terrestrial reptiles and mammals and found these animals also perished every thirty million years or so.

The next step was to search for periodicity in episodes of volcanism, seafloor spreading, and plate movement, and in the rise and fall of sea levels and in intervals of climate change. Dates from basalt flows around the world suggest that peak episodes of volcanism typically last a few million years and that they alternate with longer periods of relative calm. Intervals of seafloor spreading, which can be inferred from studies of ocean-floor rocks, apparently also have occurred spasmodically, with long periods of gradual movement punctuated with brief stretches of relatively intense activity lasting a few million years. Rapid plate movement and mountain building occur in spurts lasting a few million years, too, as geologists know from the ages of rocks in mountain ranges, which indicate when the plates collided and the mountains pushed upward. The same stratigraphic record demonstrates that both climate and sea level sometimes change drastically over a few million years, then remain relatively constant for tens of millions of years.

In all of these cases, there is, in fact, a strong underlying cycle of about thirty million years. The cycles for different geological processes do not all begin and end at once but overlap as they move with the same thirty-million-year rhythm. That is, the cycle of seafloor spread

ing appears to follow close behind that of volcanism and just ahead of sea level change and mountain building. This periodicity is statistically significant at a level of roughly one percent (which means that, after running thousands of random sets of dates through a computer, we found only one in a hundred that displayed as strong a cycle). Clearly, then, the planet itself, as well as the life upon it, has followed the beat of some regular pulse.

**T**HERE IS NO KNOWN MECHANISM within the earth that could initiate these thirty-million-year cycles. Geologists believe that convection currents in the mantle direct all tectonic and volcanic processes. But no one knows what would cause these currents, which usually flow at the same slow pace at which a thumbnail

grows, to periodically surge and instigate a new round of activity. Thus, it may be that the timekeeper for the earth's cycles is extraterrestrial.

In the late 1970s, Luis W. Alvarez, a Nobel Prize-winning physicist, and his son, Walter, a geologist at the University of California at Berkeley, found unusually high levels of the metallic element iridium in rock layers dating from the end of the Cretaceous period, when the dinosaurs and most other forms of life became extinct. Because iridium is rare in the earth's crust but plentiful in meteorites, the Alverezes concluded that, some sixty-six million years ago, the planet was struck by a meteorite or comet massive enough to stir up a worldwide rain of dust and debris. This global dust veil, they think, darkened the atmosphere for months, making photosynthesis im-



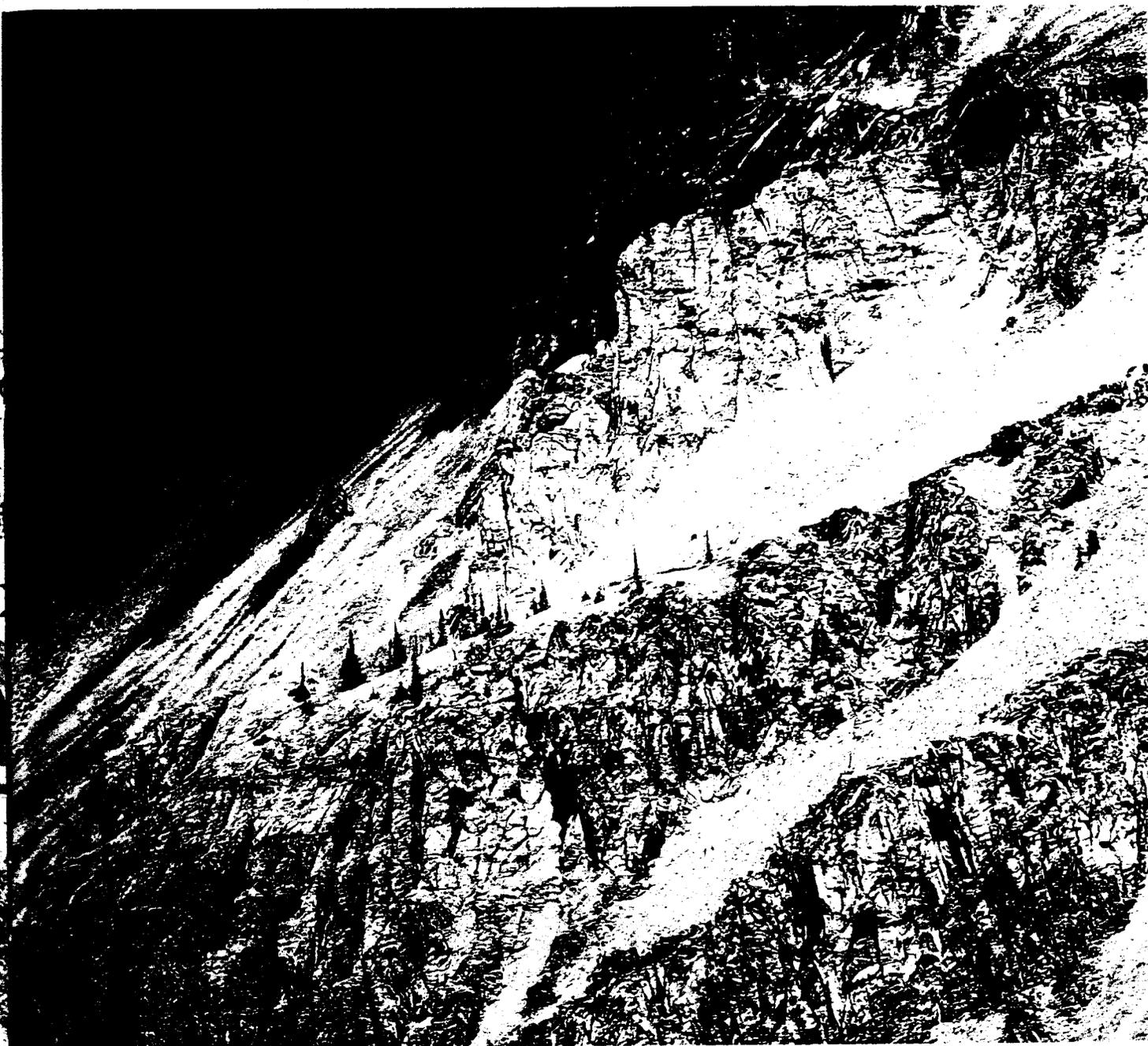
*Ben Schonzeit, The Continental Divide, 1975*

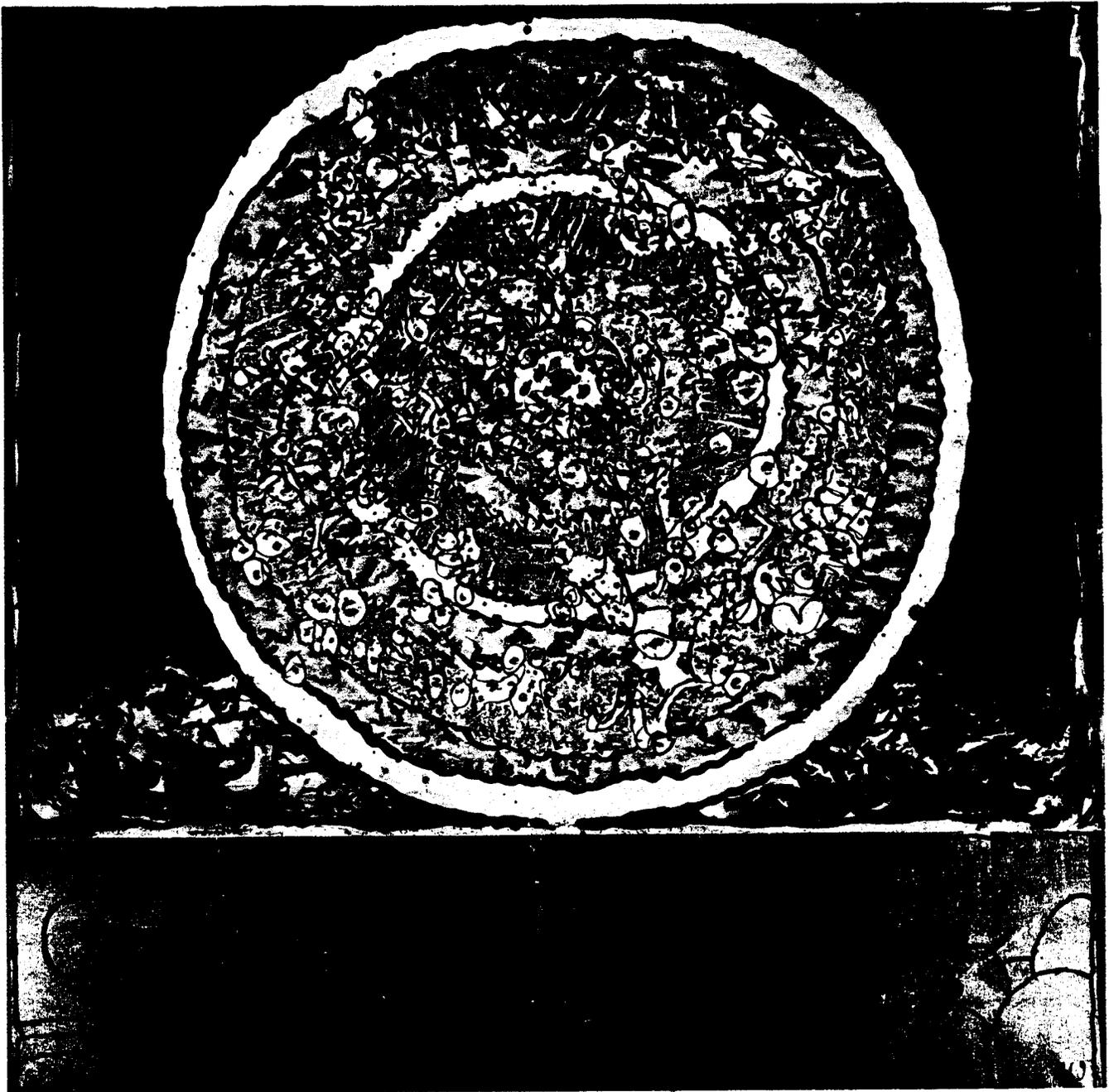
possible. Most species of plants would have died out, depriving the dinosaurs, and other animals, of sustenance.

In all of geology and paleontology, there is no more energetically debated notion. Skeptics point to evidence that indicates the dinosaurs already were in decline before the end of the Cretaceous, and say that such an explosion would have killed off only the last survivors. Others argue that the spurt of powerful volcanic activity that built the Deccan traps could just as well have precipitated the iridium layer, by drawing the rare element from deep within the earth and spewing it into the atmosphere. Although the Alvarezes' theory has gained ground with the discovery of two unusual substances in the iridium layer in some parts of the world—pellets, called microspherules, thought to be once molten droplets produced by a mete-

rite impact, and grains of quartz and feldspar etched with parallel lines that indicate they were shocked in an extraordinary explosion—the debate continues.

The iridium layer has now been dated at nearly one hundred sites around the world. Concentrations of the substance also have been found in rock laid down close to the times of at least two other mass extinctions, thirty-seven million years ago and three hundred and sixty-five million years ago. And scientists continue to search for other stratigraphic evidence that huge meteorite impacts have triggered changes in life on Earth. This work is tedious, partly because the impact layers typically are no thicker than an inch, and also because the amount of iridium in any layer is so slight that it must be meticulously measured in parts per trillion.





*Pierre Alechinsky, Star and Disaster, 1969*

Presuming that the iridium was deposited periodically by meteorites or comets, Stothers and I have considered whether such impacts caused the recurring cataclysmic geological events. Perhaps a huge meteorite could pack enough punch to perturb the planet's usually measured inner workings. Large meteorites have left scars impressive enough to indicate how forcefully they can collide with Earth; witness the sixty-mile-wide Popigai crater, in Siberia, and the Manicouagan crater, in Quebec, at least forty miles across. A projectile five miles in diameter, about the size of the one the Alvarezes have postulated, could excavate a crater one hundred miles across and at least ten miles deep. The late Nobel Prize-winning chemist Harold C. Urey calculated that an object this size (about the size of Halley's comet, minus its gaseous tail and coma), hurtling toward Earth at thirty miles a second,

would, on impact, release a million times more energy than the combined force of an average year's earthquakes. Such a concussion could create a hot spot—either by the sheer force of the impact or by stirring up convection currents in the mantle—and thereby set in motion a chain of volcanism, plate movement, mountain building, and sea level and climate changes. Somewhat as a rear end collision abruptly accelerates a slow-moving automobile, a great impact would jog the progress of geological change.

In 1982, the Canadian geologist Richard Grieve compiled a list of one hundred and three known meteorite craters worldwide. (The planet is thought to have withstood hundreds more large meteorite impacts, but most craters have been buried or erased by sedimentation and erosion or are hidden under the oceans.) Using the forty-one most precisely dated craters on Grieve's list, Stothers

and I found that most of them had been created in clusters every thirty million years or so for the past two hundred and fifty million years. Because the crater periodicity coincides so well with the cycles of volcanism, plate movement, mountain building, and sea level and climate changes, our finding strongly suggests that clusters of impacts, recurring about every thirty million years, are the clock by which geological cycles are timed.

SCIENTISTS HAVE PROPOSED more than one mechanism to explain why comets might bombard Earth at regular intervals, but all have to do with perturbations of the Oort cloud—the halo of billions of comets, ranging in size from small chunks of ice to objects the size of Halley's comet, thought to circle the solar system. (The Oort cloud is impossible to detect from Earth, because it is so far away and its constituent comets are so small. Its existence was inferred in 1950, by the Dutch astrophysicist Jan Hendrik Oort, from the motions of comets that have been observed to pass by Earth.)

There is, for example, the well-publicized hypothesis that the sun is orbited by a dim, as yet undiscovered companion star that periodically exerts a strong gravitational pull upon the Oort cloud, sending its comets hurtling toward Earth. This dim star, called Nemesis by one of the first scientists to imagine it, would have to circle the solar system in a wide and quite eccentric orbit for it to disturb the Oort cloud just once every thirty million years or so. The hitch is that such a large orbit would be so unstable that it is unlikely Nemesis could have remained paired with the sun for even a fraction of Earth's existence. Nevertheless, scientists at the University of California at Berkeley continue to search for the "death star."

Another theory holds that an undiscovered tenth planet circling the sun beyond the orbit of Neptune periodically upsets the innermost part of the Oort cloud. "Planet X" also would need to have a rather strange trajectory to account for Earth's thirty-million-year cycles. Theoretically, it could have a shifting orbit that always tilted at an angle to the orbits of the planets and the innermost comets of the Oort cloud (which move in the same circular horizon around the sun), so that it would intersect the comet belt only once every thirty million years. Yet this scenario also seems somewhat contrived. Like Nemesis, Planet X would be a unique celestial object, and most astronomers are hesitant to suggest that our solar system is special enough to contain it.

A far simpler and more plausible explanation for comet showers on Earth can be found in the solar system's oscillatory revolution around the galaxy. The Milky Way is a collection of some two hundred billion stars, laced with cosmic gas and dust, that has spun itself into a disk about one hundred thousand light-years across, but only six thousand light-years thick. If viewed from the side, it would appear to be a thin, concentrated band of stars and gas clouds. Face on, it would look like a great cosmic pinwheel, with hooklike arms curving out from the center. The solar system is located about halfway out on one of these arms.

Like much of the stellar traffic circling the Milky Way, the solar system bobs up and down through the disk. The powerful gravitational pull exerted by the galaxy's massive clouds of gas and dust dictate this motion, much in

the way that Earth's gravity keeps a pendulum swinging. When the solar system is at a point above the disk, gravitation pulls it back toward the galactic midline, but with no friction to stop it, the solar system continues moving through to the other side. Then, when it reaches a point below the disk, it is pulled back in the other direction. The solar system weaves back and forth at least eight times during its two-hundred-and-fifty-million-year revolution around the galaxy. Viewed from the side, over billions of years, the sun with its planets, like the other stars bobbing in the Milky Way, would appear to move like a painted horse on an amusement park carousel.

According to this theory, the Oort comets stand a strong chance of being upset once every thirty million years or so, for a stretch of a few million years, depending on the density of interstellar clouds near the point at which the solar system crosses the galaxy's midline. This explains why comet showers, and the geological activities they instigate on Earth, would not be strictly periodic. In fact, the variation in the cycles of volcanism, plate movement, mountain building, and sea level and climate change is about what should be expected, given what we know about the uneven distribution of interstellar clouds in the galactic disk. The likelihood that the cycles of geological activity on Earth and the solar system's movement through the galaxy could coincidentally display exactly the same periodicity is less than one in ten thousand.

The solar system recently has completed an ascent through the galaxy's midsection and now is rising about twenty-five light-years above it. After traveling upward for another twelve million years or so, it will drop back down and cross the galactic midline again, about twenty-seven million years from now. Three newly formed craters on Earth, measuring more than five miles across, and several microspherule layers found in deep sea sediments suggest that, during the past few million years, there has been an unusual number of comet impacts. And, appropriately, the past five million years of Earth's history have seen increased tectonism and volcanism, low sea level, cool climates, and surges in the rate of seafloor spreading. Rates of extinction also have been high at times during this period. Thus, the astronomical and geological evidence converge to suggest a relatively recent disturbance of the Oort cloud, just as the galactic-carrousel theory would predict.

All of this might sound like a return to the ideology of the nineteenth-century catastrophists, who believed that all geological change occurs in sudden and violent bursts. But in fact, the galactic-carrousel theory may provide the basis for finally unifying the concepts of catastrophism and gradualism. In this new view, swift and slow changes proceed hand in hand. Cometary impacts not only have sudden and violent effects, they also set in motion the gentler forces of global tectonics that take millions of years to play themselves out. Together, both cataclysmic and gradual changes have molded, and will continue to mold, the distinct features of planet Earth. ●

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