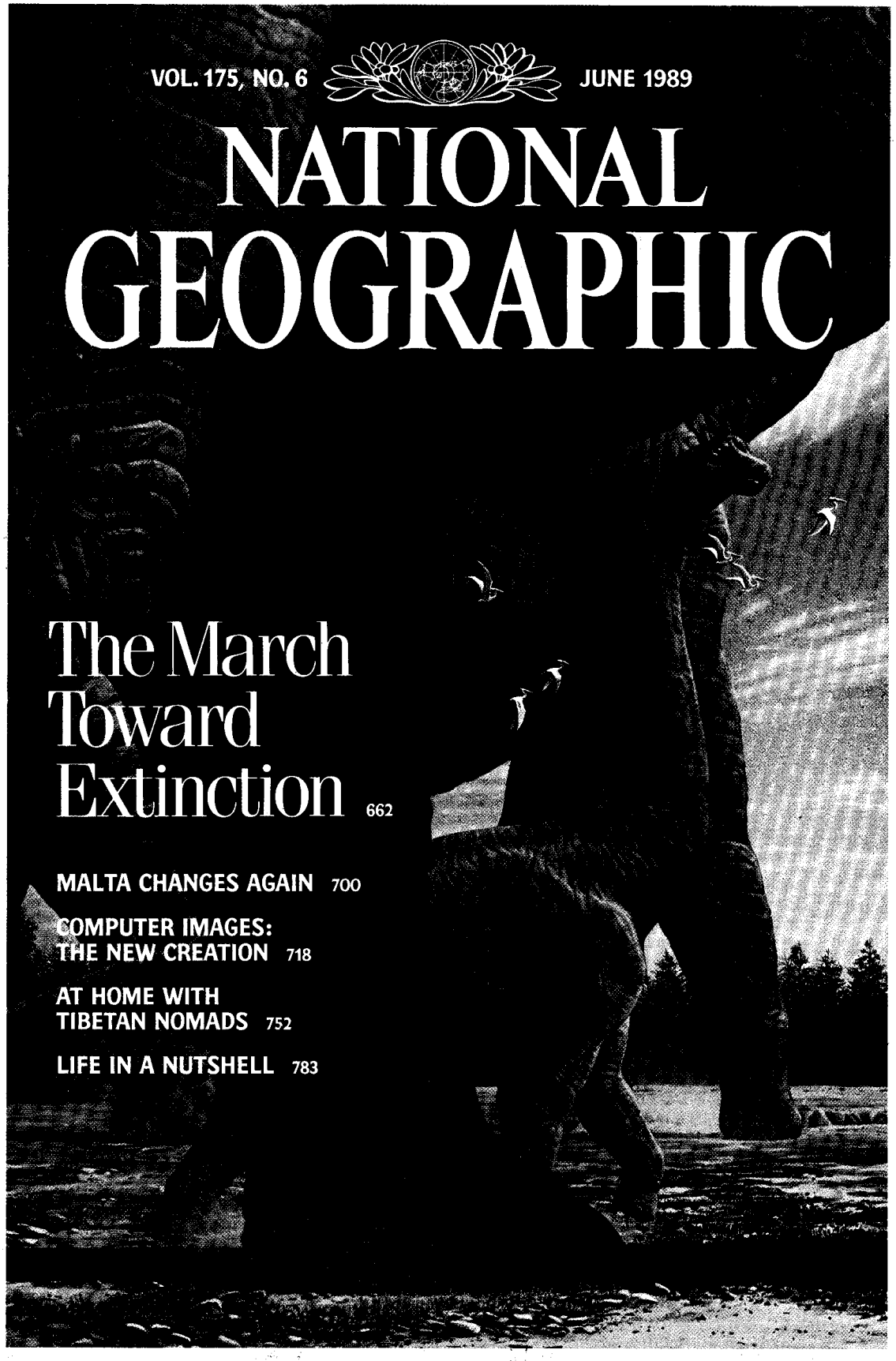
DOUBLE SUPPLEMENT: DINOSAURS AND OTHER VANISHED SPECIES

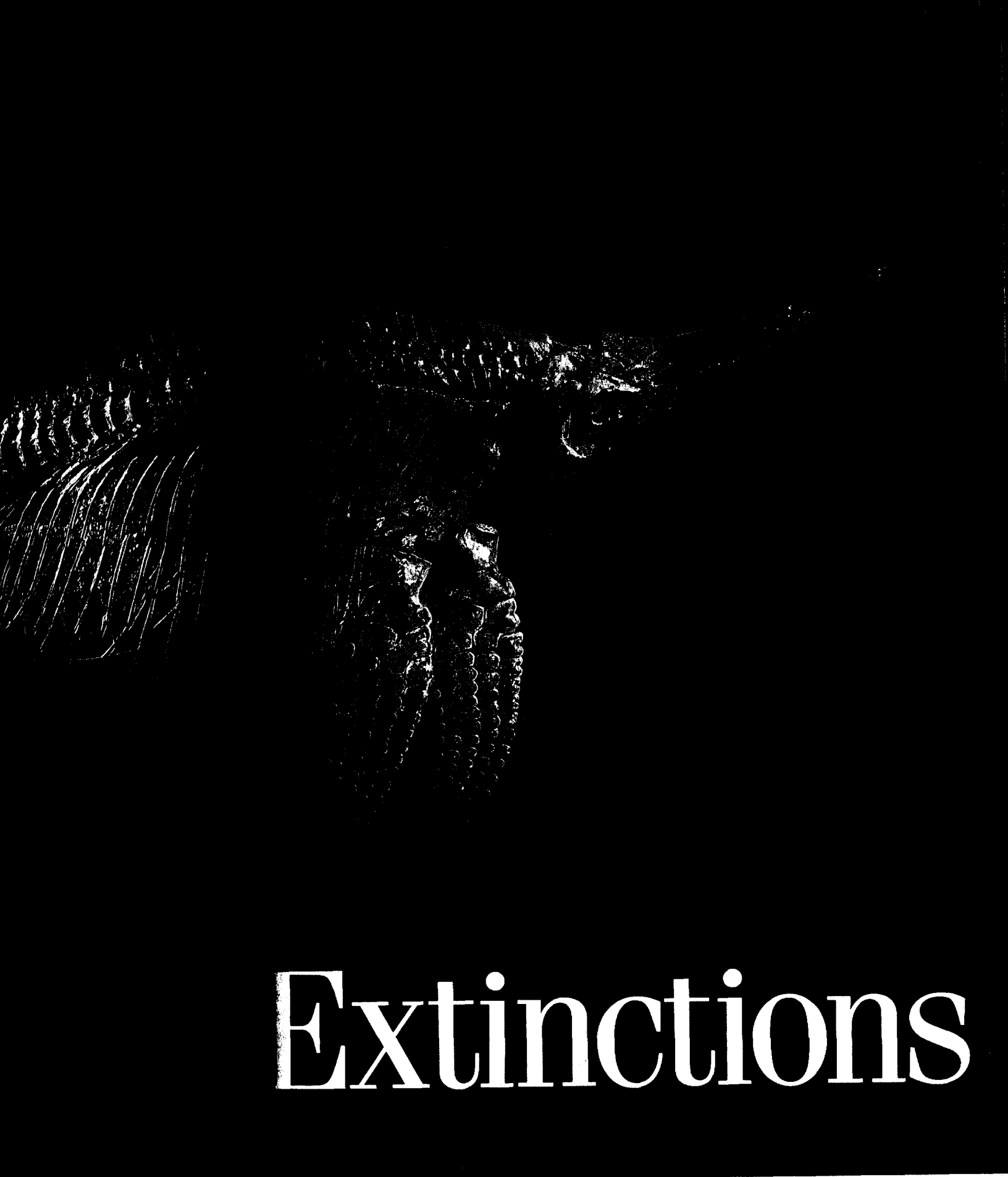
VOL. 175, NO. 6 JUNE 1989

NATIONAL GEOGRAPHIC



The March Toward Extinction 662

OFFICIAL JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY WASHINGTON, D.C.



Extinctions

HE WAS THE LAST of the free fliers, this ungainly bird his captors nicknamed Igor. His keepers now winc when they hear him called that. California condor are supposed to have local Indian names.

Chumash. Miwok. Pomo. For time beyond memory Indians throughout the West have regarded the condor as a god. His spirit, some say, inspired legends of the thunderbird, whose flight is responsible for the weather. Thunder is the flap of his wings, lightnin the flash from his eyes. Today Igor's eyes, as he perches in his pen at the San Diego Wild Animal Park, are the eyes of extinction.

Igor, officially titled AC-9, for adult condor number nine, was the last wild survivor of his species. Amid great controversy he was trapped in April 1987 and brought to wait—and, zoo officials hope, to breed—along with a few comrades, until the world might once again be safe for condors.

Igor's flying prowess fires public opinion. Since the 1930s millions o dollars have been spent to save California condors and preserve their habitat. That power has bought the condors time—to sit, remote from human contact, in this large fenced enclosure. Other creatures have no fared as well. Since Igor's capture the dusky seaside sparrow disappeared from the planet. During that same time as many as a hundred acres a minute of the world's tropical forests, among the most richly populated habitats on earth, have been destroyed. Ecologists can only speculate about how many unnamed, unknown creatures have vanished with the trees. An estimated million species will be lost in the next 25 years—a rate of one every 15 minutes.

THE JAWS of extinction threaten to snap shut on the California condor, foreground, a once widespread species reduced to about 30 birds by the presence of humans. Behind it looms the skull of Tyrannosaurus rex, *a victim of the mass extinction that ended the Cretaceous period. A little T-rex lives on in the anatomy of modern birds, which evolved from dinosaurs some 150 million years ago.*

Many scientists contend that our planet is experiencing its greatest mass extinction in 66 million years. At that time the dinosaurs vanished, along with between 60 and 80 percent of other animal species. Some small dinosaurs, however, already had evolved into the first birds. They made it through that extinction. So Igor's eyes are also those of experience.

Igor and his fellow condors bring me back into the present. For months I have been keeping company with fossils. Trilobites. Ammonites. Triceratops. Titanotheres. All were victims of at least 12 mass extinctions, five of them immense, that our planet has endured since the fossil record of animals began about 800 million years ago.

Mass extinctions. The concept has hit science like a fireball during the 1980s. Paleontologists had long realized that occasionally large numbers of species disappeared simultaneously from the fossil record. Those disappearances often marked the close of geologic periods. Yet the causes behind those great dyings had remained obscure. The fossil record was too imprecise, too difficult to read, too pocked with missing pieces and contradictory clues.

All that is changing. Innovative geochemical techniques are coaxing subtle secrets from ancient rocks. Fossils are being reexamined. Computers are finding provocative patterns in the extinctions. In the process the rules of evolution are being rewritten. And so is the four-billion-year history of life on the planet.

The excitement began in 1978 when a team from the University of California and Lawrence Berkeley Laboratory found a large enrichment of the element iridium in a pencil-thin, 66-million-year-old layer of rock from Gubbio, Italy. This iridium-rich clay lay right at the boundary between the Cretaceous period, when there were dinosaurs,

and the Tertiary, when t
sition the K-T boundary
Because iridium is rar
Berkeley scientists—Wa
Michel—proposed that e
(six miles) across. Wildly
been backed up by abun
globe. Most scientists no
object struck the planet
With Alvarez I hike a
boundary clay. He digs
"You are holding debr

PHOTOGRAPHED AT NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY

and the Tertiary, when there were none. (Scientists nickname this transition the K-T boundary.)

Because iridium is rare on earth but common in meteorites, the Berkeley scientists—Walter and Luis Alvarez, Frank Asaro, and Helen Michel—proposed that earth had been hit by an asteroid ten kilometers (six miles) across. Wildly controversial at first, the proposal has since been backed up by abundant and convincing evidence from around the globe. Most scientists now concur that at least one great extraterrestrial object struck the planet around the time the dinosaurs died out.

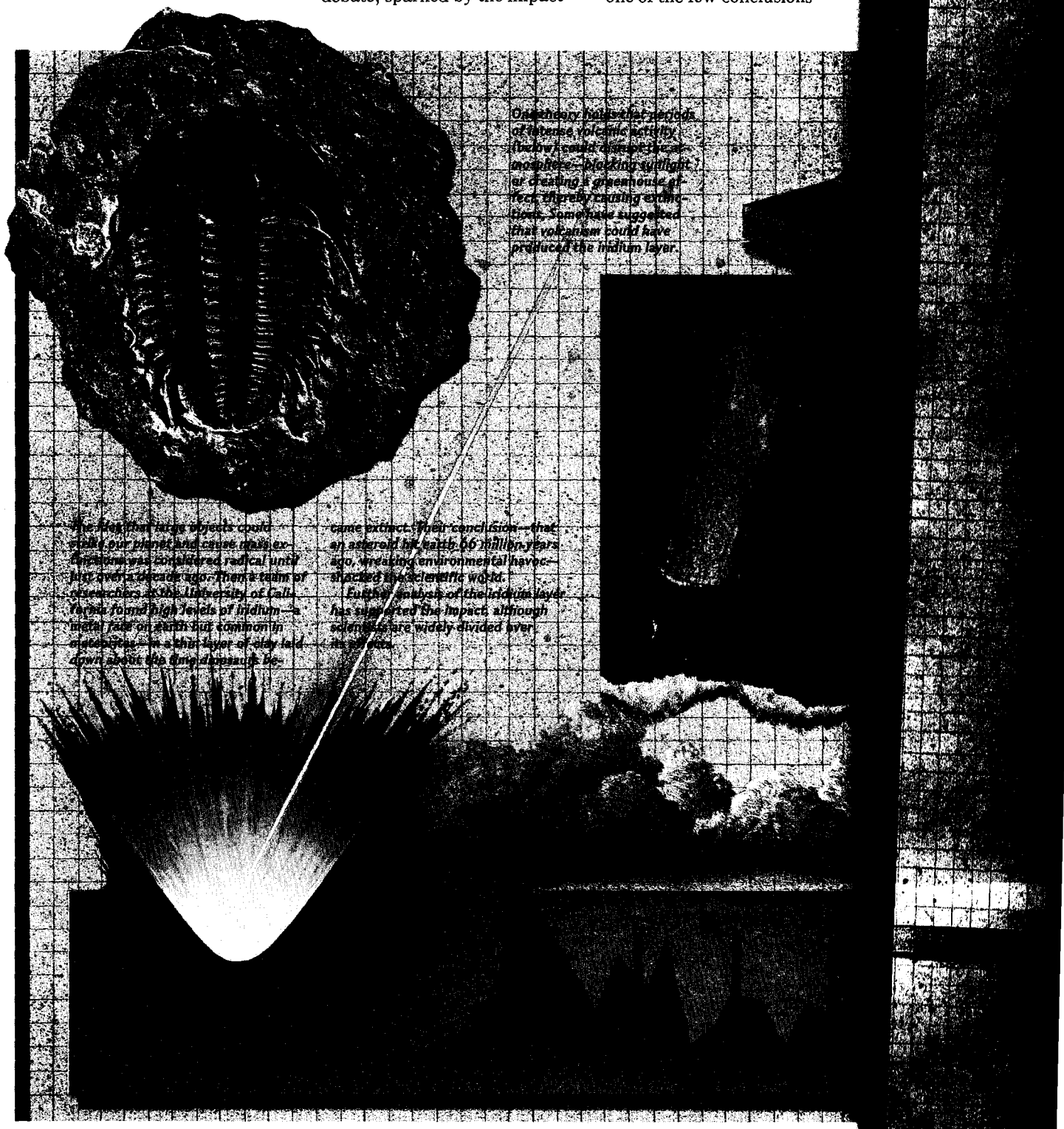
With Alvarez I hike an Italian mountain road to inspect the Gubbio boundary clay. He digs out a chunk and hands it to me.

"You are holding debris from the *(Continued on page 672)*

Mass extinction: the causes...

Through the study of fossil trilobites, below, and other creatures, scientists know that the story of life on earth has been punctuated by mass extinctions. But exactly how they occurred is a matter of unprecedented debate, sparked by the impact theory, lower left, and argued by scientists in fields as diverse as geophysics, astronomy, and paleontology.

"These are exciting times to be looking at extinction," says NAS geologist Bevan French, stating one of the few conclusions



One theory holds that periods of intense volcanic activity (below) could disrupt the atmosphere—blocking sunlight or creating a greenhouse effect, thereby causing extinctions. Some have suggested that volcanism could have produced the iridium layer.

The idea that large objects could collide with our planet and cause mass extinctions was considered radical until just over a decade ago. Then a team of researchers at the University of California found high levels of iridium—a metal rare on earth but common in meteorites—in a thin layer of clay laid down about the time dinosaurs became extinct. Their conclusion—that an asteroid hit earth 66 million years ago, wreaking environmental havoc—shocked the scientific world.

Further analysis of the iridium layer has supported the impact, although scientists are widely divided over its effects.

l scientists agree. d of the spectrum ho believe mass are triggered by lysmic events such ct of a celestial body of intense volcanic thers argue that the extinction process is gradual, brought on by environmental changes wrought by rapid tectonic, oceanic, and climatic fluctuations. Many scientists say the truth lies somewhere in between, as a combination of earthly and extraterrestrial causes.

By plotting episodes of mass extinction throughout geologic time, some scientists have detected an interval of roughly 26 million years (orange vertical bars) between extinctions. This suggests a celestial timetable for extinctions—a periodic comet shower, for example, triggered by the passing of a star or other celestial events. According to these calculations, life on earth is safe for another 12 million years.

-
uc-
the
en,

PAINTING BY LLOYD K. TOWNSEND; PRINCIPAL CONSULTANTS: STEVEN M. STANLEY, DEPARTMENT OF EARTH AND PLANETARY SCIENCES, JOHNS HOPKINS UNIVERSITY; J. J. SEPKOSKI, JR., DEPARTMENT OF GEOPHYSICAL SCIENCE, UNIVERSITY OF CHICAGO. PHOTOGRAPHS BY NATIONAL GEOGRAPHIC PHOTOGRAPHERS JAMES L. AMOS (FAR LEFT) AND JAMES P. BLAIR (BELOW); RICHARD ALEXANDER COOKE III (LEFT)

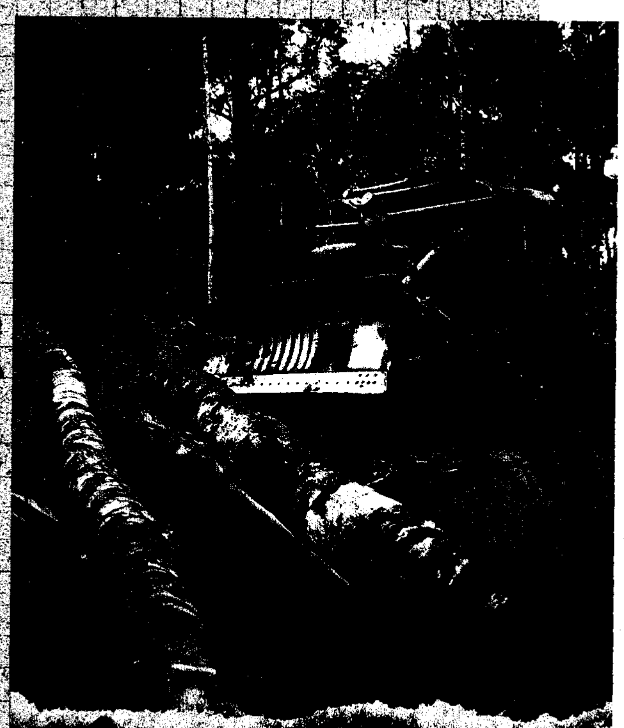
... the late Ordovician ... about 440 million ... warm water (green) ... the world. Most ... was submerged. Five million years later (large ...) continental ice ... had formed. Sea level had dropped, exposing vast areas of land, and cold water (blue) had expanded into the tropics. As a result, more than 20 percent of marine families perished. Such global climate changes are found throughout the fossil record.

... displacement of oxygenated water in shallows (green) by oxygen-poor water from the deep (gray) would devastate creatures adapted to the shallow environment. The impact of a meteorite could bring about such an overturn.

... episodes of mass extinction ... geologic time, some scientists have ... an interval of roughly 26 million years ... vertical bars) between extinctions. This ... a celestial timetable for extinctions—a ... comet shower, for example, triggered ... passing of a star or other celestial ... According to these calculations, life on ... safe for another 12 million years.

... may turn ... more deadly ... any comet. Not only does man have the power to kill other creatures, but he can also destroy their habitat, as

in the rain forests of South America (below). Many scientists warn that modern man is creating one of the greatest mass dyings of all time.



The victims and survivors

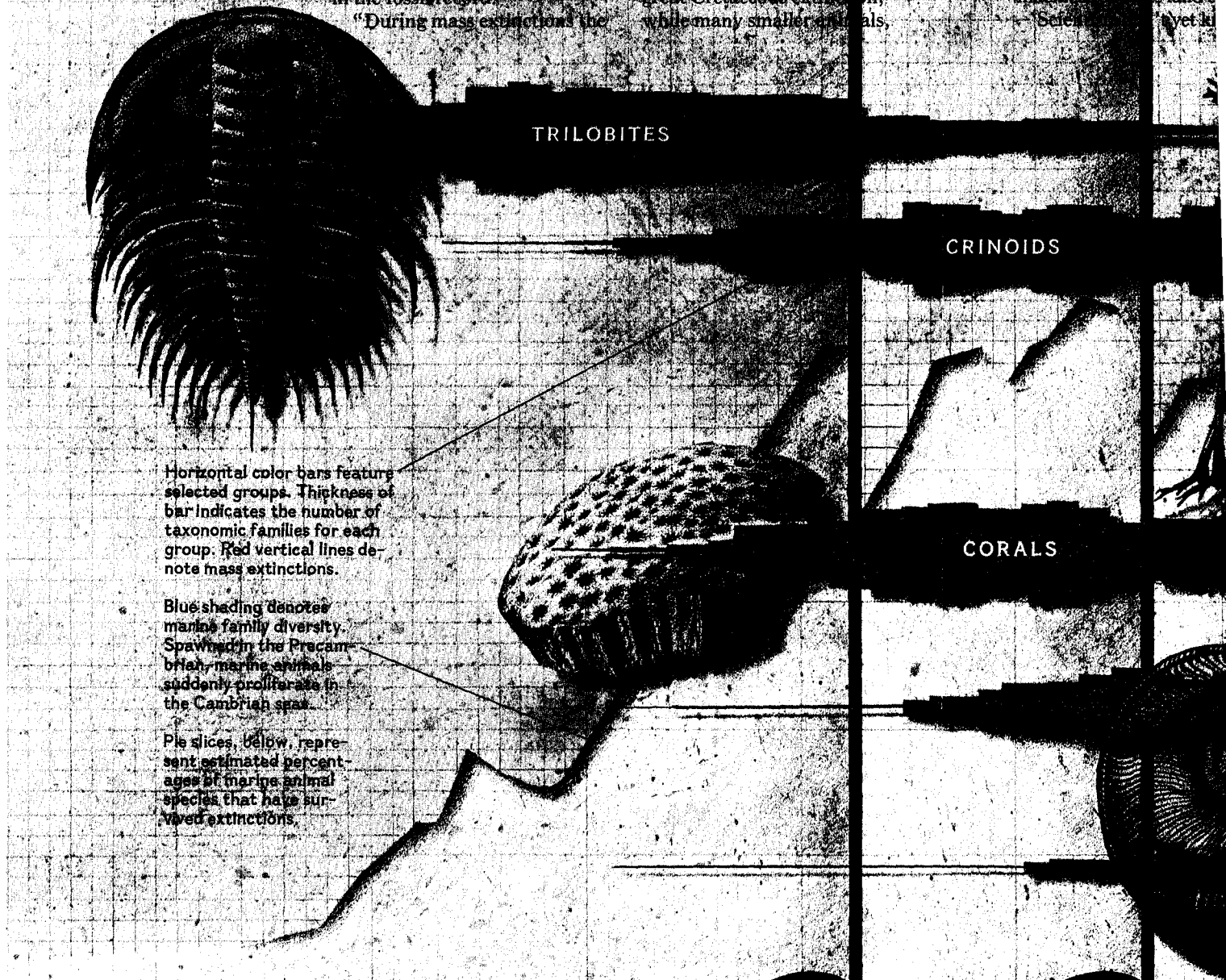
Extinction has claimed 99 percent of all species that have ever lived—many of them victims of "background" extinction, the piecemeal disappearance of species due to small-scale environmental changes. Others perished in one of earth's major mass extinctions (vertical bars) detected in the fossil record.

"During mass extinctions the rules change," says paleontologist Jack Sepkoski [illegible] University of Chicago. [illegible] had been advantageous [illegible] suddenly become a [illegible]

Tremendous [illegible] example, helped the [illegible] dominate for some [illegible] years. But they vanished [illegible] the great Cretaceous extinction, while many smaller [illegible]als,

including [illegible]nals, s

In gener[illegible] widespre
cies seem[illegible] rather m
tinctions [illegible] than th
endemic [illegible]l regio
ers and [illegible] are thos
live in t[illegible] climates
not m[illegible]t. The
is no[illegible] tinctio
mass[illegible]s land
Scien[illegible] yet k



Horizontal color bars feature selected groups. Thickness of bar indicates the number of taxonomic families for each group. Red vertical lines denote mass extinctions.

Blue shading denotes marine family diversity. Spawned in the Precambrian, marine animals suddenly proliferate in the Cambrian seas.

Pie slices, below, represent estimated percentages of marine animal species that have survived extinctions.

600 MILLION YEARS AGO | 500 | 400

CAMBRIAN | ORDOVICIAN | SILURIAN | DEVONIAN | CA

Stromatolite-producing cyanobacteria dominate the world for two to three billion years, then fall prey to a new arrival: animals.

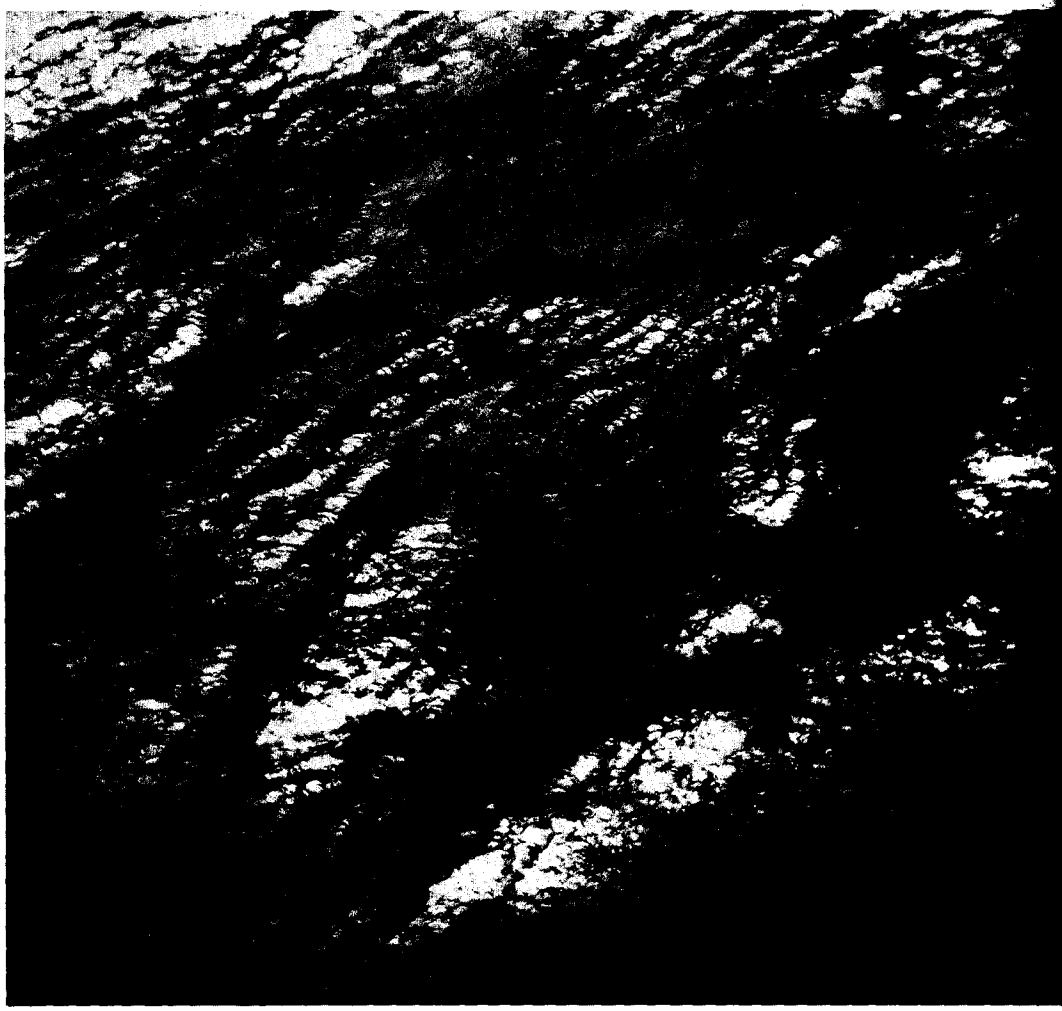
The ancestral supercontinent Gondwana rides over the South Pole in the Ordovician, triggering a period of profound glaciation. Early fish [illegible] vertebrates [illegible] bulky [illegible]

PERCENT VICTIMS

PERCENT SURVIVORS

PAINTING BY [illegible] CARROLL, NATI


MAMMALS
MAMMALS PROLIFERATE AFTER EXTINCTION OF DINOSAURS.
DINOSAURS
DINOSAURS RULE FOR 140 MILLION YEARS, THEN VANISH FROM FOSSIL RECORD.
VE TWO PERISH
GREAT PERMIAN EXTINCT
NEARLY WIPES OUT CRIN
OWLY DIVERSIFY
MIAN EXTINCTION.
FISH
FISH FAMILIES INCREASE DRAMATICALLY AFTER CRETACEOUS EXTINCTION.
AMMONOIDS
100
TOD
TRIASSIC
JUR
RETACEOUS
TERTIARY
QUATERNARY
900
800
700
600
500
400
300
200
100
0
NUMBER OF FAMILIES
In scientific classifications, a family can include one or many dozens of species. Since families (shown in the graphs at left) can survive an extinction even if all but one of their species dies out, the species losses, estimated in the pie charts at the bottom, are actually far greater than the family data suggest.
Many scientists believe the Cretaceous-Tertiary (K-T) extinction was caused by a meteorite impact. Victims include a host of marine species.
Some experts believe that earth is currently in the midst of a major mass extinction. It began with the megafauna wiped out by Ice Age hunters and continues today through habitat destruction and other human interventions.



(Continued from page 665) impact," he says. "In the first days a earth was hit, dust blanketed the entire world. It grew pitch-dark fo one to three months. If the impact was on land, it probably got bitte cold. If it hit at sea, the water vapor could have created a greenhous effect, making things hot. Hot nitric acid would have rained out of t atmosphere—a life-threatening rain that would have dissolved the shells of organisms."

That's not all. A surprising discovery by Wendy Wolbach, a gradu ate student at the University of Chicago, indicates that the world ma have turned even nastier, as it did last summer at Yellowstone National Park.

A red sun shines like the eye of an angry god through the pall of bil lowing smoke at Old Faithful. A rush of heat. A swirl of suffocating, sooty air. Suddenly on the hillside behind the famous geyser the gate of hell burst open, and a fire storm races down the slope. A million acres on fire. The worst conflagration to strike the vast Yellowstone ecosystem in history. An awesome, terrifying orgy of flame. Yet this holocaust is insignificant compared with what Wolbach believes hap pened that day 66 million years ago when earth was hit. The entire world caught fire.

Even as Yellowstone burns, Wolbach shows me her evidence in her Chicago office—scanning electron microscope pictures of soot partic

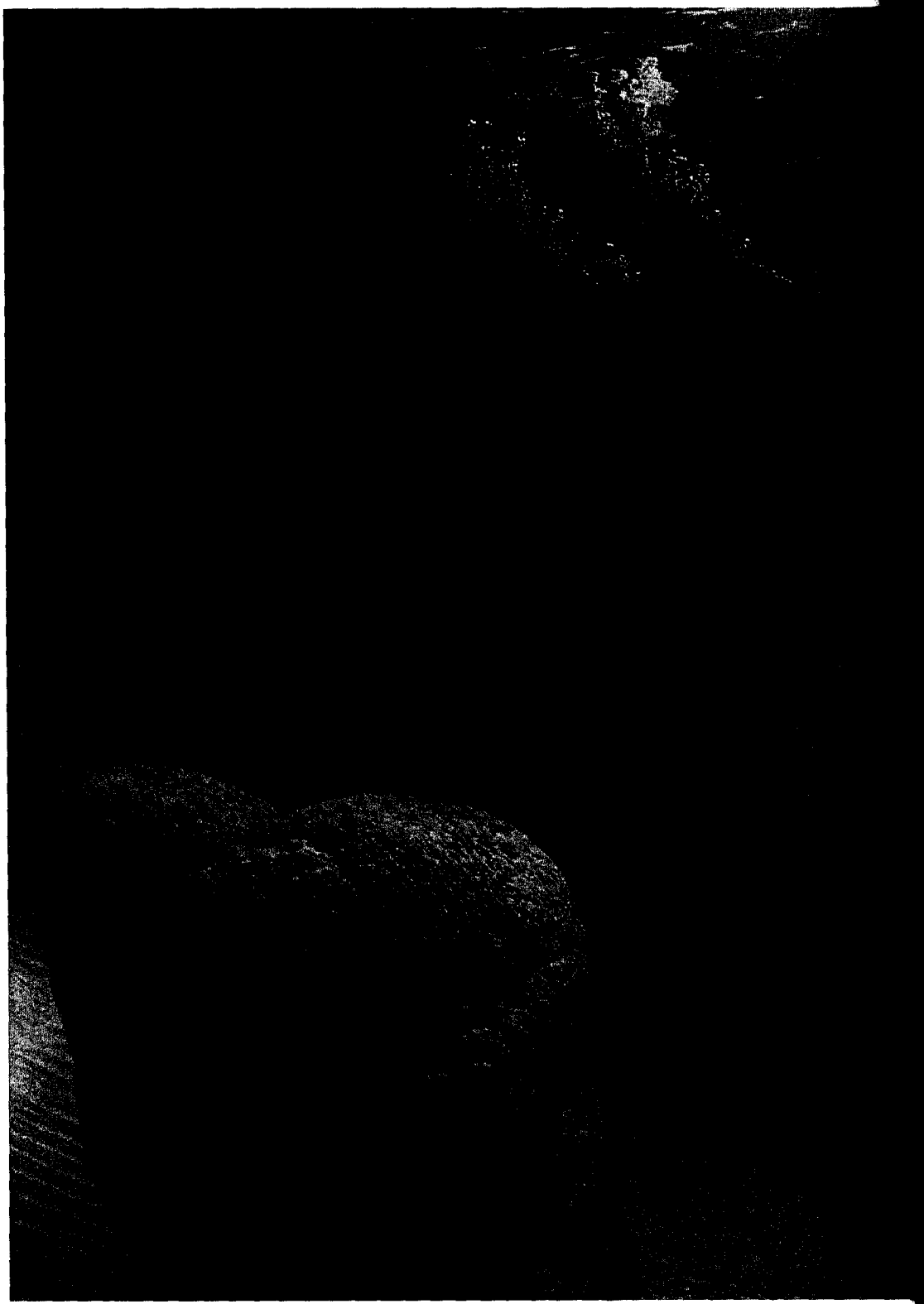
d with the iridium layer from three widely separated sites—
, Spain, and New Zealand.
ch's discovery stemmed from the curiosity of her research
cosmochemist Edward Anders, about what kind of extrater-
bject had struck the planet at the K-T boundary. A meteorite
asteroid belt? A comet? He suggested that Wolbach attempt
carbon in the iridium layer. Carbon would have trapped cer-
gases brought in by the impacting object. The isotopes of
es might provide chemical signatures to identify the intruder
ce.
surprise Wolbach has found an enormous enrichment of soot.
et the amount of soot we find," she says, "as much as 90 per-
he world's forests must have burned."
ed the impact of a ten-kilometer body would be equivalent to
mes the power of all the world's nuclear weapons, how could
ad so disastrously across the globe?
if it hit in the ocean, the impact would have created a crater
meters across," says Anders. "A huge plume would have
he atmosphere aside. The fireball would have had a radius of
housand kilometers. Winds of hundreds of kilometers an hour
ave swept the planet for hours, drying trees like a giant hair
wo-thousand-degree rock vapor would have spread rapidly. It
ave condensed to white-hot grains that could have started ad-
fires."
dition, lightning discharges like those in a volcanic eruption
ve ignited windswept fires on all landmasses that marched far
an those at Yellowstone.

CLUE to a killer's identity may remain in rugged central Quebec, where the Manicouagan crater was apparently blasted by a giant meteorite some 210 million years ago. That roughly coincides with a mass extinction of marine species at the end of the Triassic period. Sky-darkening dust from the impact may have played a role.

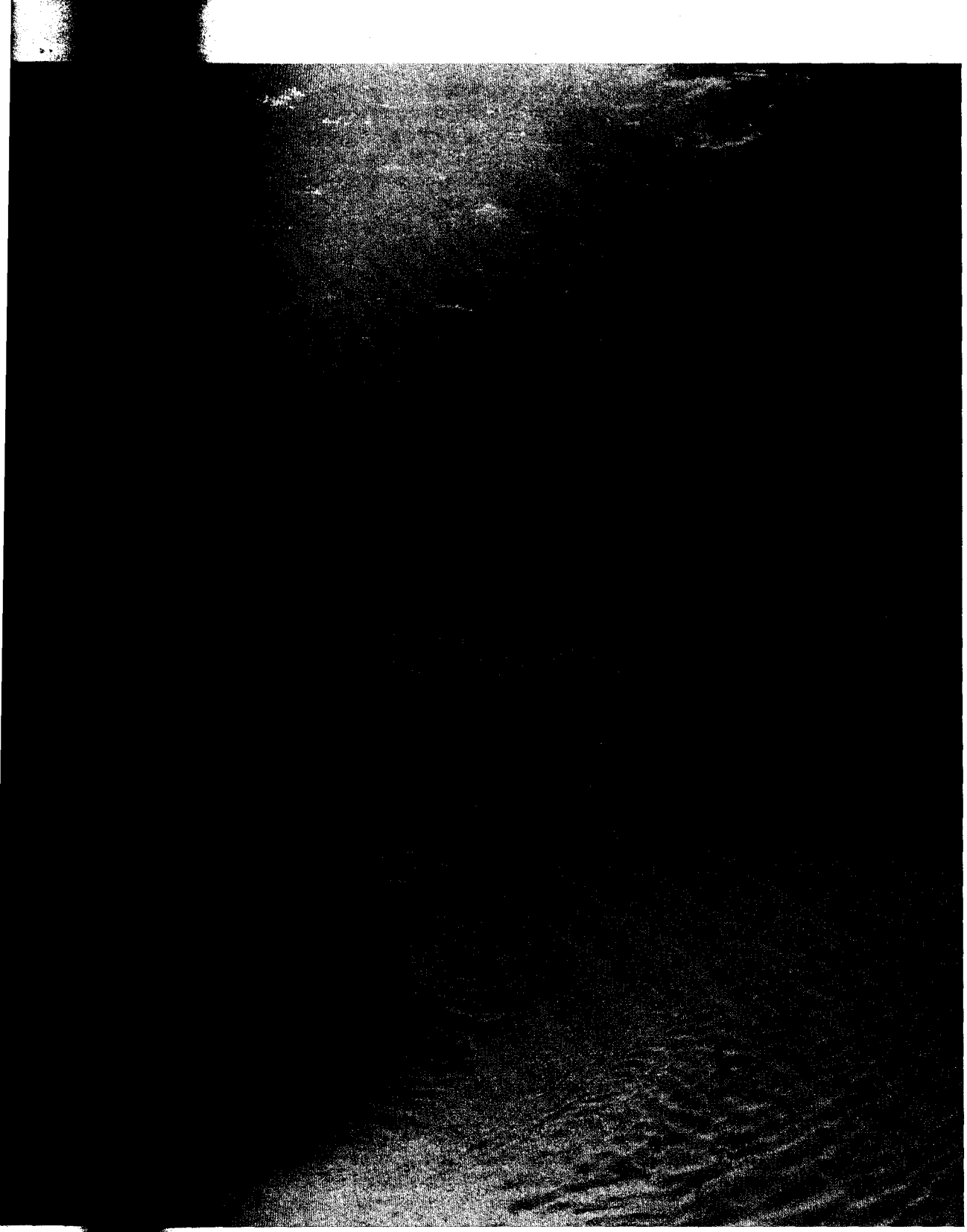
UCH DOOMSDAY SCENARIOS strain our belief. And many scientists refuse to accept that such catastrophes have caused the great dyings.

"We don't need an impact," I have heard over and over from paleontologists. "We can explain mass extinctions with earthly causes."

so they can. Falling sea levels. Ice ages. Collisions of conti-
Volcanism. Climate changes. Altered ocean chemistry. The
ial mechanisms for mass death are many.
matter what causes them, mass extinctions do occur. They force
perspective on the history of life.
lass extinctions change the rules of evolution," explains David
nski of the University of Chicago, one of the leading extinction
ists. "When one strikes, it's not necessarily the most fit that sur-
often it's the most fortunate.
hen their environment is disrupted, groups that had been healthy
uddenly find themselves at a disadvantage. Other species that had
barely hanging on squeak through and inherit the earth.
he best example is mammals. Dinosaurs and mammals originated
in ten million years of each other about 220 million years ago. But
40 million years dinosaurs ruled, while mammals stayed small and
mbled around hiding out in the underbrush. Mammals all basically
ed alike—squirrelly or shrewish and no bigger than a badger—
l the dinosaurs disappeared. Then they took off. Within ten million
s there were mammals of all shapes and life-styles: whales and
, carnivores and grazers. Mammals just couldn't do anything
resting until the dinosaurs were out of the way."



LIVING FOSSILS, stromatolites were recently discovered by geologists of the Carib bean Marine Research Center in shallow waters of the eastern Bahamas. T mounds are composed of sticky mats of cyanobacteria (formerly known as blue-gre algae) that cement sand and sediments. Appearing in rocks 3.5 billion years o



...romatolites are the earliest known communities of life. They declined dramatically ...tween 500 and 700 million years ago and survive today only in environments hos... ...le to predators, such as this area swept by swift channel currents and in hypersaline ...aters in Western Australia, where a community was found three decades ago.

the Carib-
amas. The
blue-green
years old,

June 1989

Mass extinctions thus promote new beginnings, new eras of ex mentation. If earth's slate of life were not episodically wiped clea how far might we have evolved beyond the primordial slime?

That slime surely suffered too. The first great extinction may h been a gas attack. As one microbiologist explains, "It was the wo case of pollution in earth's history."

What was this toxic waste, this obnoxious gas? Paradoxically, i was what today sustains all animal life: oxygen.

DESCENDANTS of the stromatolite builders, mats of modern cyanobacteria survive in environments too harsh for most life—such as in this 42°C (108°F) hot spring rivulet in Yellowstone National Park. No threat to the cyanobacteria, the wolf spider is a relative latecomer; his ancestors appeared about 400 million years ago.

At one time earth's oceans and at sphere were virtually oxygen-free, o anaerobic. Carbon dioxide dominat planet. Then, about three billion ye ago, certain bacterial members of th primordial slime invented the kind o photosynthesis that releases oxygen waste product.

Oxygen is a reactive, aggressive g shuts down or burns out organisms adapted to anaerobic life. So with ox the new aerobic bacteria could coerce their way into a place in the sunlight drive their competitors underground into extinction.

The waste built up. The oceans we oxygenated, then the skies.

No organism has so dominated the world as did those filamentous oxyge producing microbes. Wherever seas w warm and not too deep, they built diverse bacterial communities—moun shaped mats of microorganisms. The sils of those mats, called stromatolites, resemble great reefs of cabbage-shape mounds. Beds of layered stromatolites often several kilometers thick, swirl through rocks that were formed in shallow seas between 2.5 billion a 600 million years ago.

Then stromatolite populations crashed. Like the anaerobic life the displaced, stromatolites still exist but can be found only in isolated areas. What happened?

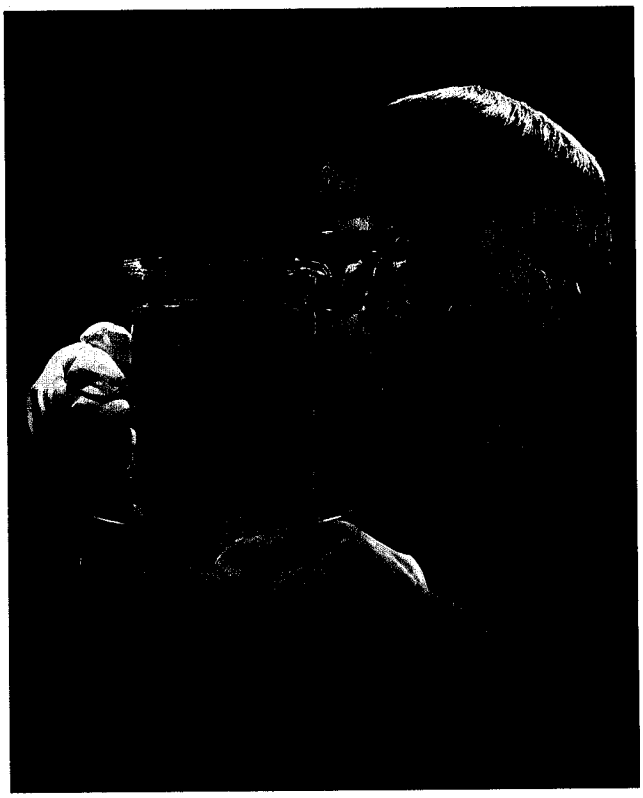
In a word, animals. Life began to feed on itself.

THE APPEARANCE of animals heralded the adoption of a ne survival strategy. Photosynthesis had enabled organisms make their own food from carbon dioxide and water. The new strategy bypassed that step. Why make your own food? Why not eat some organism that has already done t work? Eating someone else takes energy, however. You have to graze or hunt. That requires a high-powered aerobic, or oxygen-burning, metabolism. As the advent of oxygen made grazing animals possible, it made sitting ducks of the stromatolite builders.

Animal life exploded across the planet at the start of the Cambrian period, around 570 million years ago. Perhaps oxygen levels crossed a threshold that enabled animals to make shells and experiment with increasingly complex tissue.

or 25 million years life was unconstrained," says University of go paleontologist Jack Sepkoski. "If evolution had continued at te we see at the Cambrian-Precambrian boundary, we'd have p Newburg from New York to London."

the time Cambrian seas filled, about 545 million years ago, life volved nearly all the phyla, or basic body plans, that it uses y. But one body plan dominates the fossils of that great epoch: of trilobites.



ILLUMINATING *earth's dark ages, David Ward of Montana State University bathes cyanobacteria in ultraviolet light, causing chlorophyll to fluoresce. Its presence indicates photosynthesis, a process that literally changed the world 2.5 billion years ago. Such photosynthetic microbes released oxygen into the biosphere, allowing oxygen-based life to develop.*

PHANTOMS OF TRILOBITE DAYS haunt central Utah's House Range as geologist Pete Palmer drives me to the site of the first mass extinction of animals clearly documented by the fossil record. At least e times toward the end of the Cambrian, trilobites, distant cousins of eshoe crabs, were nearly extinhed by mysterious, perhaps global, sters. Their bodies litter this former loor with what Palmer calls "trilo- trash"—a head here, a tail there. "Trilobites were innocuous creaes," says Palmer, who works for the ological Society of America. "Most re somewhere between one and six hes long. They couldn't bite. They ren't vicious. Some were floaters, me swam. Mostly they were mud ubbers. Their mouths faced backrd. They had multiple legs that ought food to their mouth. They may ve scavenged soft fleshy stuff or eaten arine algae."

Trilobites lived in a flooded world. Sea levels were high. Minneapolis would have been coastal. The rocks of Utah's House Range were part of a limestone platform offshore, like today's Bahamas.

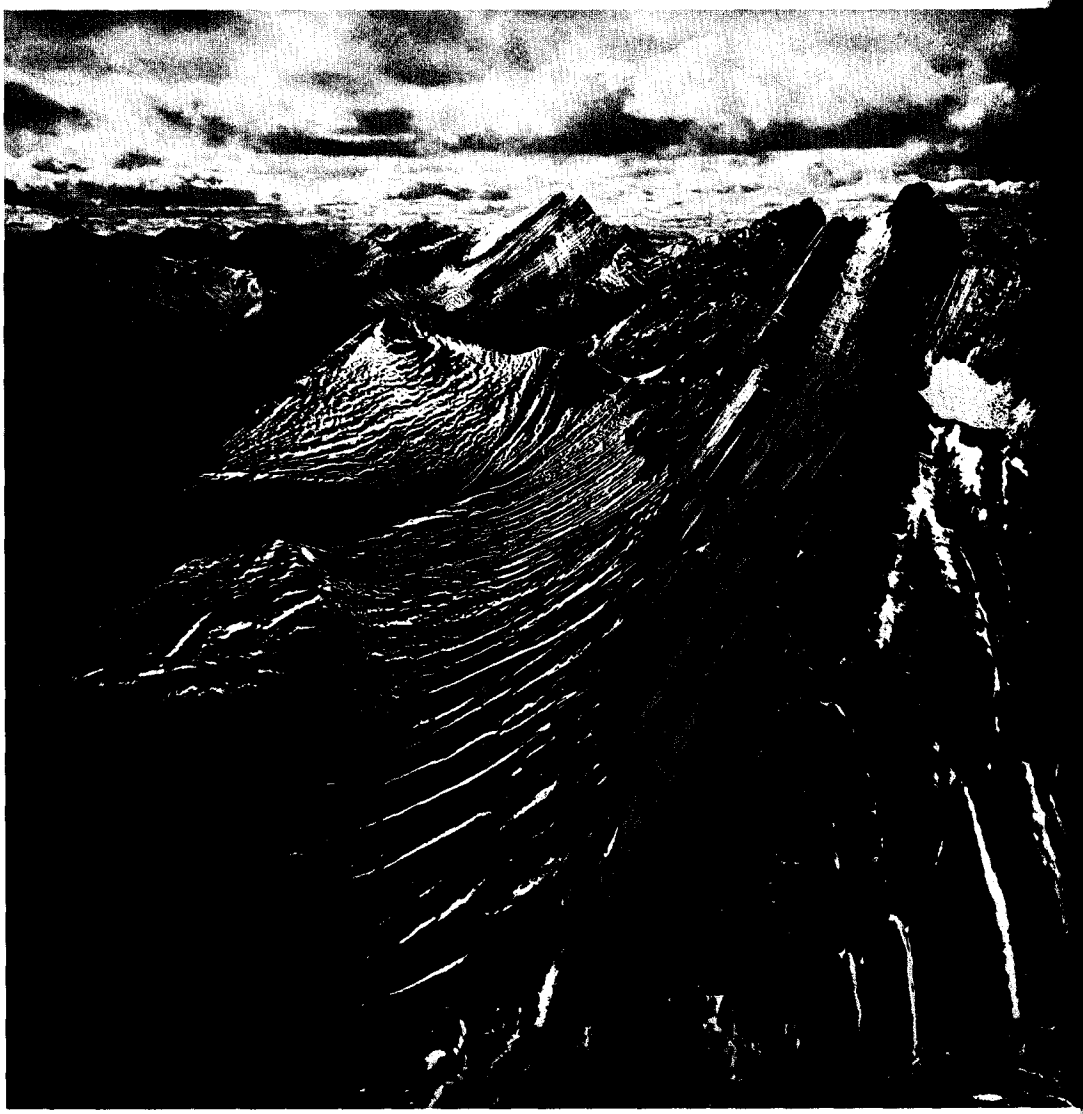
We drive dirt tracks into Little Horse Canyon, then climb up through what had been Cambrian muds to a gray limestone shelf. A line about as thick as my fingernail runs across the rock. Below the line all the trilobite trash is made up of "roundheads," Palmer's name for the roundheaded family that dominated the mud.

"This line coincides with a crisis," says Palmer. "We suddenly lose the roundheads. In the rocks just above us there's nothing but very primitive trilobites with square heads. They came in like the Mongol hordes. They had to be hiding out in some special local environment, maybe in the deeper, colder waters farther offshore. Once the world was theirs, they diversified rapidly.

"Then one day, bang. . . ."

Palmer points to a ledge high above our heads. "Up there the same thing happens to the squareheads. Then another group of trilobites appears by the millions. At the end of the Cambrian period, their descendants too are decimated and never come back strongly."

What happened?

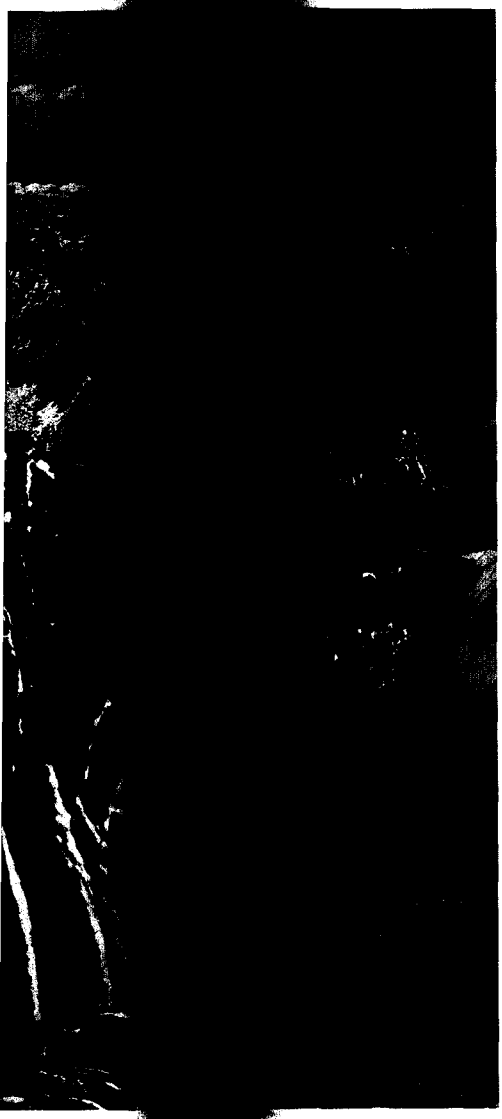


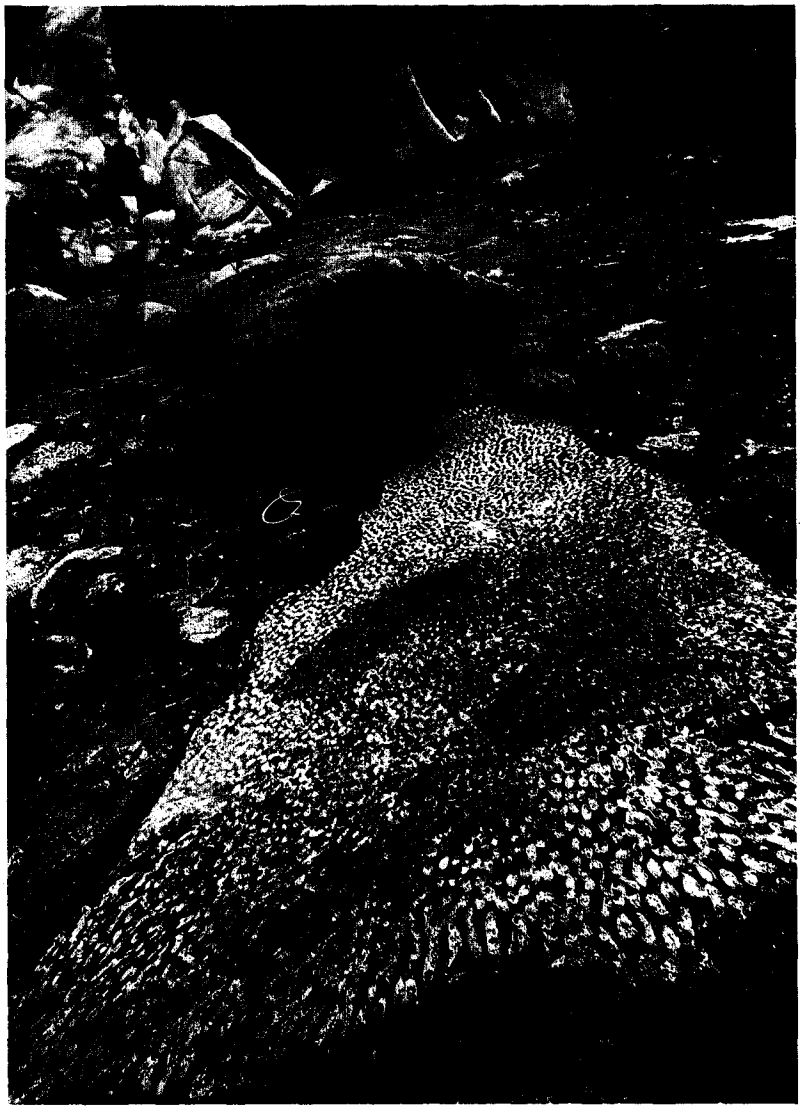
***FORMED** in the shallow sea that covered western North America 370 million years ago, limestone exposed in the Ancient Wall —a range in Canada's Jasper National Park— may hold fossilized answers to what caused a mass dying of reef-building invertebrates during the late Devonian period.*

"Maybe an extraterrestrial object splashed into the ocean," says Palmer. "Perhaps, like today, the seas were strongly stratified—wa oxygen-rich upper strata on top of cold, oxygen-poor deep water. If you threw that deep water onto these shallow shelves, you could ha devastated the trilobites living there. Those organisms couldn't sta even a few weeks of that."

That scenario could explain the squarehead survival. Being primi tive, they had been pushed to the cold, deep margins where no othe creatures could make a living. They had adapted to just those condi tions that exterminated their more advanced competitors.

AFTER THE CAMBRIAN, trilobites never bounced back. Sophi cated new predators, suggests University of Washington biologist Peter Ward, made their life-style obsolete. Nau loids, distant relatives of today's chambered nautilus, combined massive jaws with the ability to swim swiftl across the seafloor. "As the airplane revolutionized warfare, the nautiloids created havoc for mudbound creatures," says





EYE TO EYE with the Devonian disaster, Helmut Geldsetzer of the Canadian Geological Survey examines fossils exposed on an outcrop near the Lyell Icefield in British Columbia. He believes a sudden flooding of shallow seas by oxygen-poor water from the deep may have killed the reef builders. The cause, he suggests, "might be an asteroid impact."

ean," says
tified—warm
p water. If
u could have
ouldn't stand

Being primi-
ere no other
those condi-
.

back. Sophisti
Washington
bsolete. Nauti-
d nautilus,
swim swiftly
utionized
atures," says

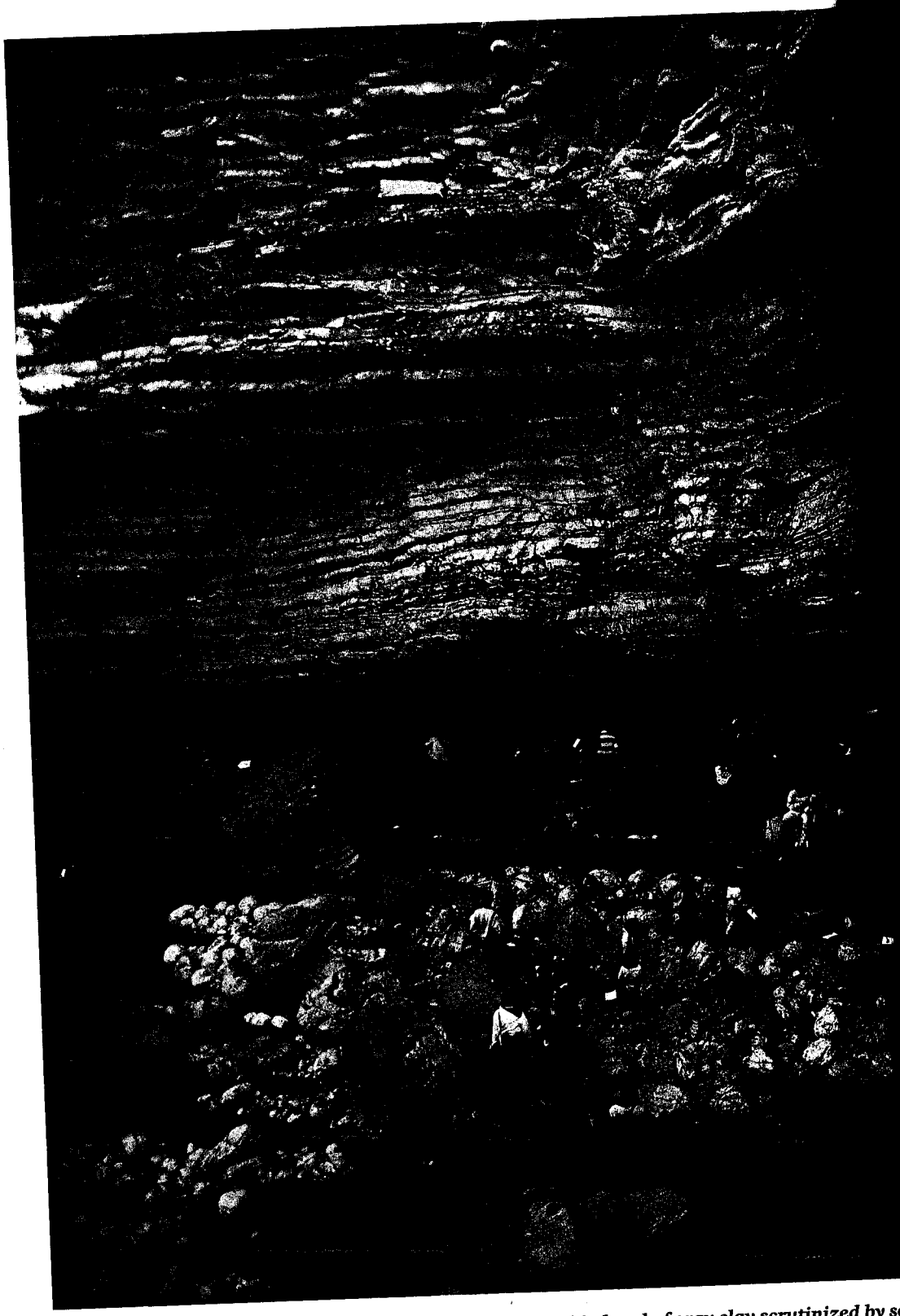
hic, June 1989

d. "The early trilobites only looked ahead. The ones that survived
looked up."

Reef life—aborted early in the Cambrian—evolved anew in the
dovician. Clams, starfish, and crinoids, lily-shaped animals that
de gardens out of sea bottoms, also emerged. Then around 440 mil-
n years ago this increasingly diverse global ecosystem collapsed.

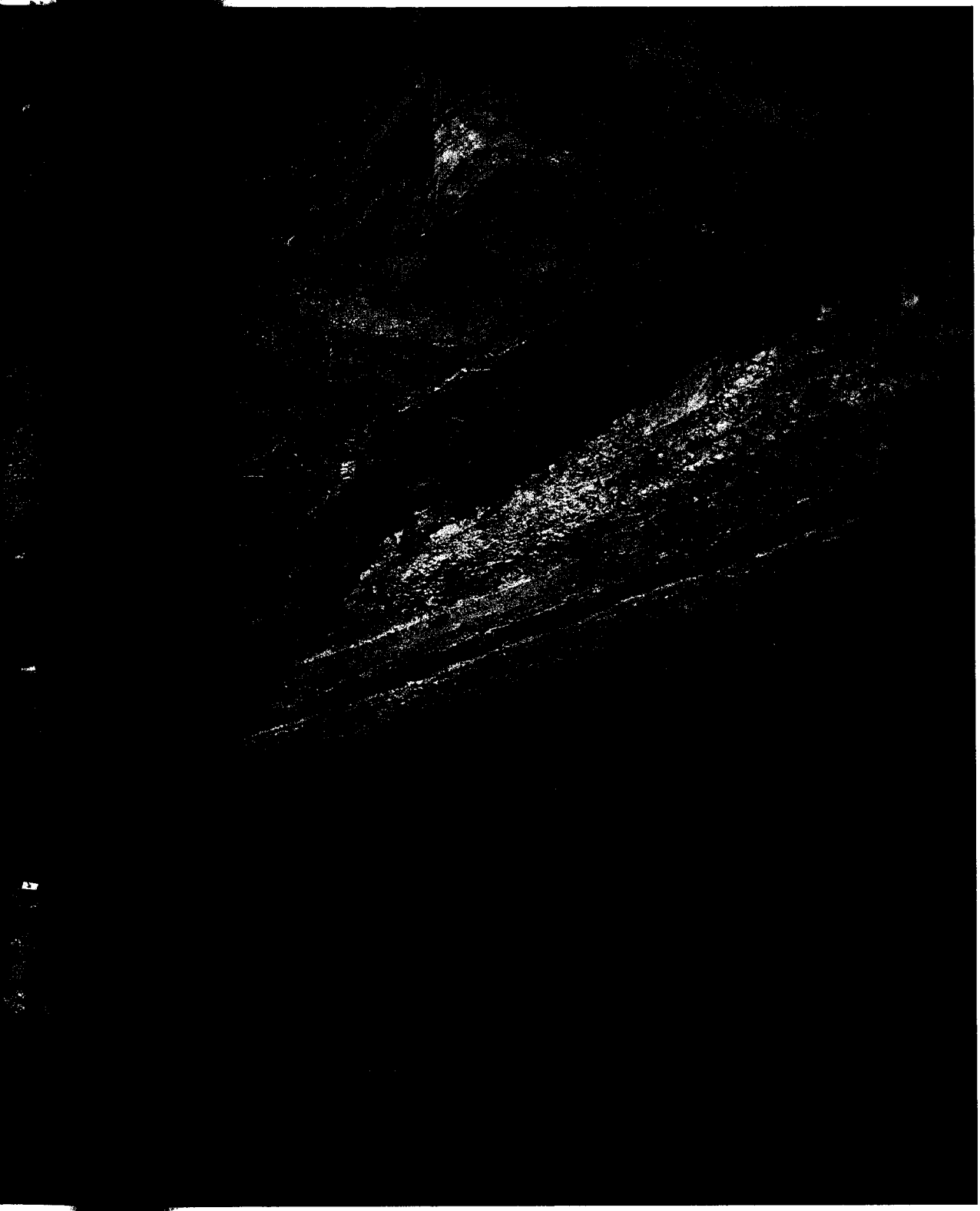
The most obvious villain in the massive Ordovician extinction was
e planet's own restlessness, the inner turmoil forever moving earth's
ntinents about. In the late Ordovician that turmoil drove a huge,
cient continent, Gondwana, over the South Pole. Immense glaciers
veloped, drawing their water from the oceans and chilling even the
opics. "The ice age literally drained the shallow seas," says paleon-
logist Peter Sheehan of the Milwaukee Public Museum.

Reef life was especially hard hit during the Ordovician extinction.
"Reefs are attractive but dangerous places to live," says David
Jablonski. "The web of interactions is so complicated that the entire
community can crash if just a few of its members go. Reefs are always
getting clobbered."



***LAYERS OF CONTROVERSY** surround a thin band of gray clay scrutinized by scien*
on this seaside cliff in Zumaya, Spain. Found worldwide, the layer marks the boun
between the Cretaceous and Tertiary periods. Experts studying the clay see

National Geographic, June

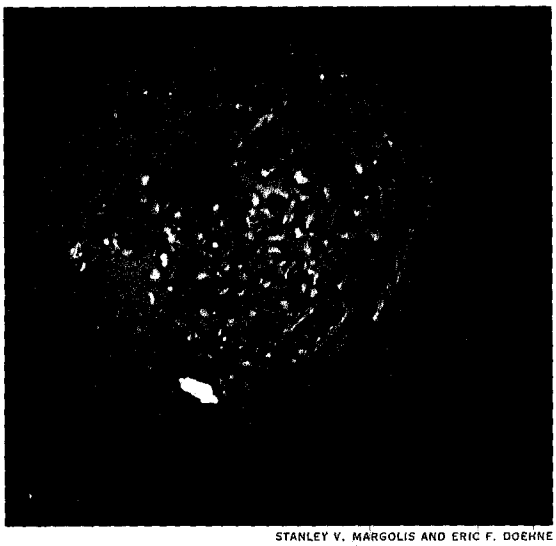


...ence of an impact—including high levels of iridium. Debate rages over the ...nection between the impact and the death of dinosaurs. But few scientists deny ...t extraordinary events are recorded in that narrow layer of sediment.

catastrophists heatedly disagree, arguing that the event was ab
worldwide, and occurred in the midst of a long warm spell.

"At most we are dealing with 20,000 years—and maybe just
stormy night," says Willi Ziegler, director of the Senckenberg
in Frankfurt.

With Charles Sandberg of the U. S. Geological Survey, Zieg
studied fossils of abundant small eel-like animals known as con
The shapes of conodonts changed often and distinctively enoug
ing the Devonian that scientists can date
precisely with them. Particular conodont
rock indicate whether the rock formed in
or shallow seas.



STANLEY V. MARGOLIS AND ERIC F. DOEHNE

EVIDENCE of impact, this tiny spherule collected from the K-T boundary layer at Zumaya is thought to be a melted fragment of the object that struck the earth 66 million years ago. The spherule, here magnified 5,000 times, contains platinum in the high concentration present in meteorites but not normally found on earth.

Ziegler and Sandberg's conodont analy
indicates great swings of sea level around
time of the extinction. They see shallow-
conodonts suddenly appearing in deep-se
rocks. They argue that storms, and perha
tsunamis, ravaged the planet, washing ne
shore life out to sea. In Nevada, which w
deepwater terrain, Sandberg has found h
boulders of coastal rocks that were appare
ripped seaward.

"We suspect this was caused by a come
shower or increasingly closer passes by an
oid or field of asteroids," says Sandberg.
asteroid's gravity could raise great tides.
ine the stress on marine life if sea levels w
30 meters, then dropped 60."

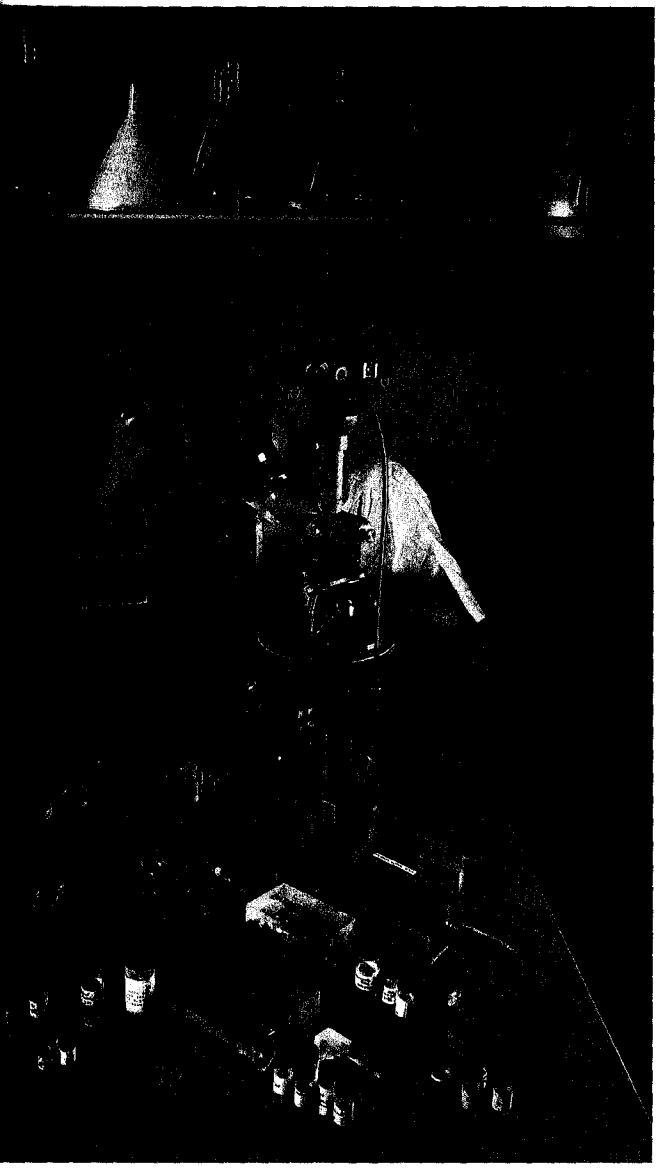
Wild thoughts? There are data from the Devonian to support e
speculation. The confusion grows worse with the next extinction,
which terminated the Permian period about 240 million years ago

THE PERMIAN was easily the greatest extinction of all ti
Perhaps 96 percent of all species disappeared. No one
claims strong evidence for an extraterrestrial extingui
The best guess today is that the planet itself did the ki

The Permian extinction was the first to affect terres
life significantly. During previous extinctions most life
confined to the water. But by the end of the Permian, coal swamp
proliferated, insects swarmed, and pig-size amphibians were roam
across earth's warm surfaces. Creatures known as mammal-like r
tiles dominated the land.

Mammal-like reptiles varied enormously. Early versions resem
lizards, but reconstructions of later species make me think of a do
faced tank with a short tail. They may have had fur, and to specia
their bone and teeth structure looks more mammalian than their s
taneously evolving reptilian cousins. For example, their limbs
extended directly beneath their bodies, rather than to the sides, as
the case with reptiles.

Even as the mammal-like reptiles were evolving during the Per
the forces of plate tectonics were forging the supercontinent Panga
joining all the planet's continents into a single colossal landmass.
but one continent the amount of shallow offshore water—among t
richest habitats on the planet—shrank drastically. Also, Pangaea
encroached on both poles, probably triggering a series of crippling

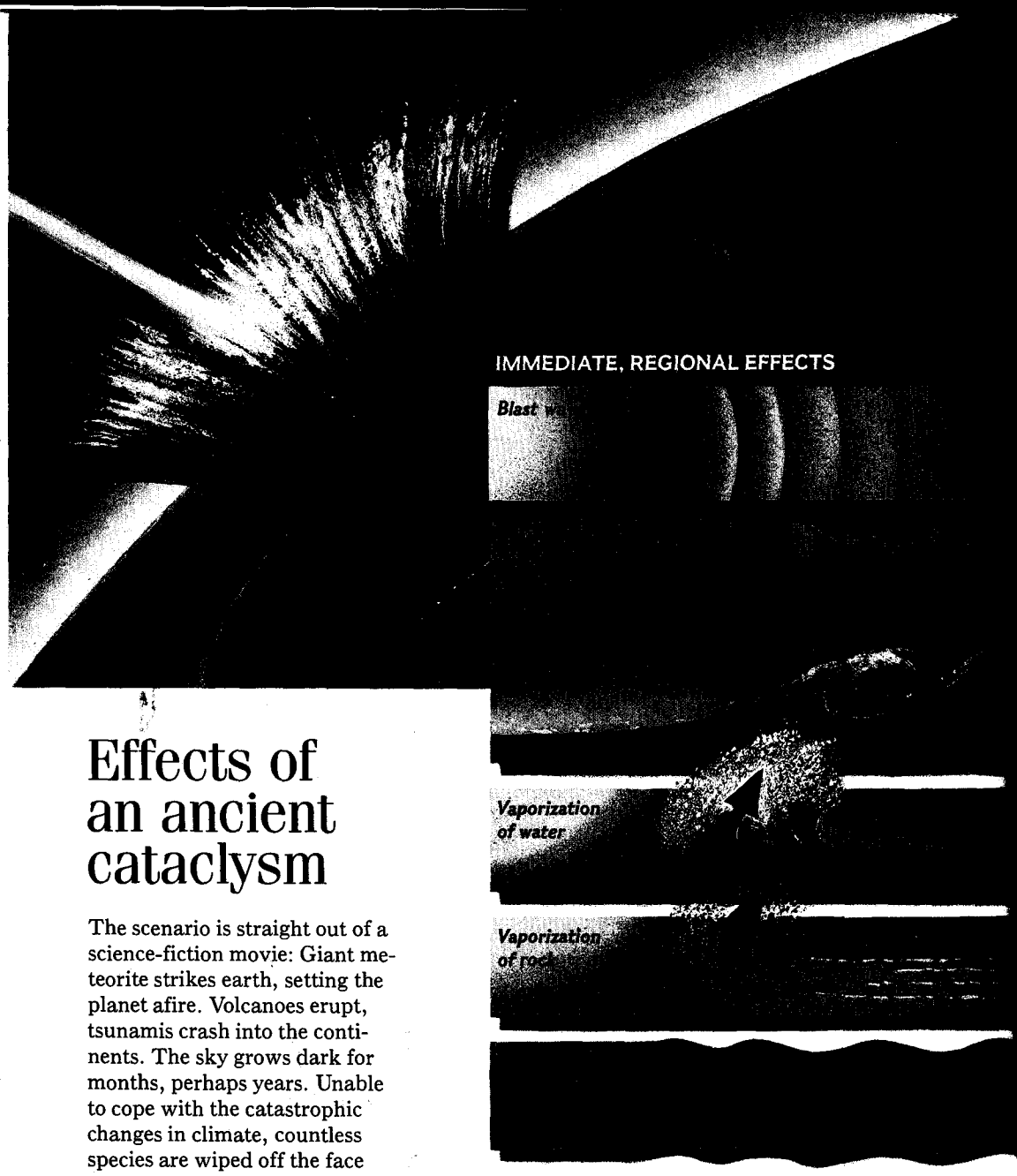


GEO-DETECTIVE Glen Izett of USGS was skeptical about the impact theory. Then his light-polarizing microscope revealed quartz grains in samples of the K-T layer (above) with the type of fractures caused by nuclear explosions or meteorite impacts. Judging from the size and abundance of "shocked" quartz grains he has found in the western U. S., Izett believes the impact occurred there.

n both hemispheres. According to paleontologist Bob Sloan of niversity of Minnesota, sea levels bobbed up and down by 200 rs; coastlines advanced and retreated 1,900 kilometers (1,200). Even tropical seas would have been chilled. On land climate progressively drier, the winters Siberian.

e mammal-like reptiles suffered at least six distinct mass extinc- during the last eight million years of the Permian, says Sloan, cating that the great die-offs may occur in pulses. Those pulses ct the Permian's strong climatic swings. The die-offs illustrate , paradoxically, extinctions can benefit life.

Look at what survived each pulse," says Sloan. "The survivors e always those that appear to be more warm-blooded and thus t better with cold climates. They also tended to have more compli- d jaws and teeth, as well as more efficient respiratory systems." Moreover, the survivors were small, establishing a pattern for subse- nt terrestrial extinctions. As Sloan says, "The surest route to



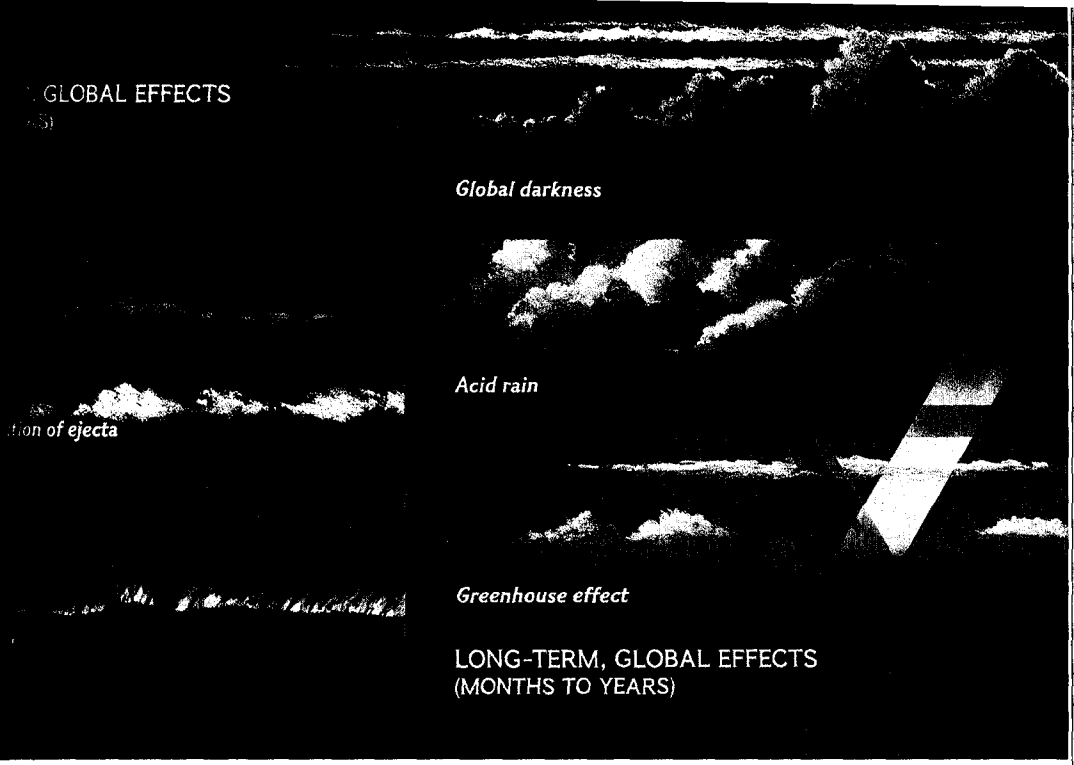
Effects of an ancient cataclysm

The scenario is straight out of a science-fiction movie: Giant meteorite strikes earth, setting the planet afire. Volcanoes erupt, tsunamis crash into the continents. The sky grows dark for months, perhaps years. Unable to cope with the catastrophic changes in climate, countless species are wiped off the face of the planet.

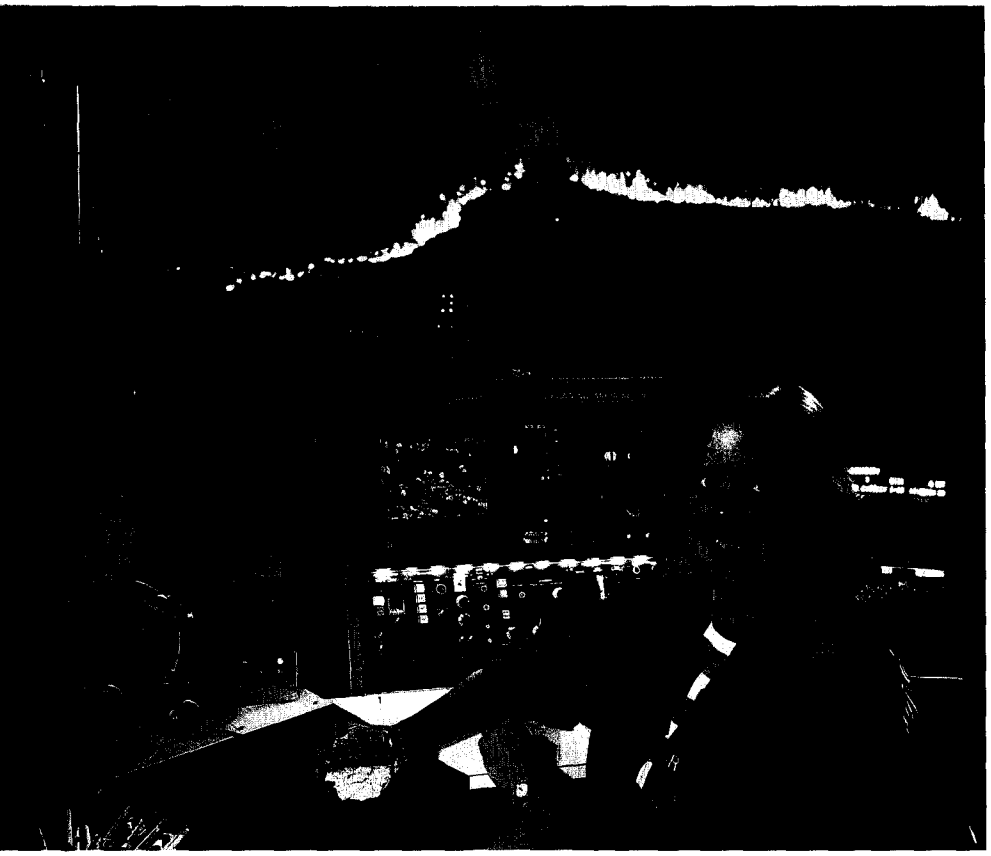
Yet that is the apocalyptic scene scientists suggest, as evidence grows that comets or meteorites may indeed be agents of *mass destruction on earth.*

In the moments following the impact of an object ten kilometers in diameter, experts believe, a blast wave similar to that of a nuclear explosion would destroy everything within several hundred kilometers, its intense heat and winds combining to set wildfires, perhaps even a global inferno. If the impact occurred on land, earthquakes would rock the continent for days. If at sea, huge tsunamis could destroy coastal habitats across the globe. Other immediate effects would include a horizontal "base surge" of melted and pulverized material and a plume of vaporized water and/or rock ejected into the stratosphere above the impact crater—the fine particles eventually darkening skies around the world.

Scientists are debating the long-term effects of such an impact. Most agree that an of strong acid rain would en Some believe a global dust would trigger an age of dark and cold. Others see a sharp greenhouse effect—particula if the object struck and vapo ized limestone in the ocean b sins, filling the atmosphere w massive quantities of carbon dioxide. This CO_2 layer wou trap heat, raising temperatur worldwide.



S OF YELLOWSTONE ing compared to a that raged 66 million , according to Wendy below, of the Univer- cago. Testing samples of the K-T layer from around the world, Wolbach found high levels of soot, suggesting a global wildfire started by an impact. Magnified on her screen is soot found in strata similar to those she holds from New Zealand. The light-colored rock at bottom is from the Cretaceous. A dark layer marks the K-T boundary, when 75 percent of animal species became extinct.



PAINTING BY LLOYD K. TOWNSEND. PRIMARY CONSULTANTS: EDWARD ANDERS, ENRICO FERMI INSTITUTE, UNIVERSITY OF CHICAGO; BEVAN M. FRENCH, NASA

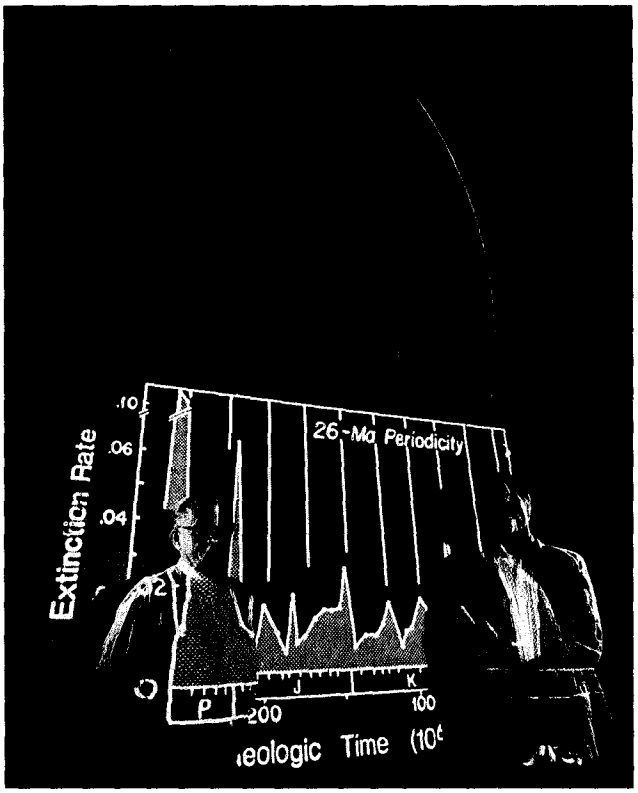
extinction is to be large." Big creatures need more food and ha
trouble finding hideouts.

One squat creature whose ancestors made it through the end
Permian was a tusked herbivore called *Lystrosaurus*. About as
as E. T., *Lystrosaurus* exploded across Pangaea after the Perm
largely because there wasn't much left big enough to eat it.

In the ensuing Triassic period evolution soon produced not o
large new mammal-like reptiles but also waves of new experim
Marine monsters called ichthyos
gan to prowl the seas, crocodiles
swamps. Flying pterosaurs took

The first dinosaurs also appear
Extremely fast and small, they of
were two-legged, probably resem
big pheasants on the run. Their u
posture freed their forelegs to be u
hands for grasping.

If not warm-blooded, most dino
had evolved high metabolic rates.
perhaps were covered with down,
later, feathers. Nevertheless, for a
dinosaurs waited in evolution's w
Although they were superior playe
dinosaurs could not, by themselve
place the mammal-like reptiles.



AT THE CLOSE of the Triass
period, about 200 milli
years ago, the dinosau
have gotten a little he
from the cosmos. In
wilds of central Que
sits the Manicouagan crater, half t
of Connecticut. The only radiomet
dating of remote Manicouagan put
impact several million years before the end of the Triassic. Howe
paleontologist Paul Olsen of Columbia University's Lamont-Doh
Geological Observatory suspects that the dates are wrong and tha
Manicouagan impact is the fingerprint of a global mass extinguish
from space.

"The fireball alone from an impact that size would have scorch
everything down to New Jersey," he says. It thus could have crea
the kind of global havoc suspected at the K-T boundary.

Whether or not they had cosmic good fortune, the dinosaurs too
charge of the land with the advent of the next period, the Jurassic.
During the Jurassic's 60 million years, the great reptiles developed
ereign size. The gargantuan *Brontosaurus* and related creatures
roamed river plains, browsing tall conifer trees. So did the armore
tractor-size *Stegosaurus*, although it might have had to stand on it
hind legs to nibble the branches. It had to stay ever alert for the hu
meat-eating *Allosaurus*.

These monsters vanished, along with many smaller dinosaurs a
marine creatures, when a profound but mysterious crisis struck at
end of the Jurassic. A new generation of low-browsing, beaked din
saurs emerged. What made them the evolutionary victors? Was the

abitat change? Why was life in the oceans also hard hit? The mass killer left almost no clues.

aurian life rebounded vigorously during the long warm eons of ing Cretaceous period. Then, about 90 million years ago, an- oorly understood pulse of extinctions struck both land and sea. dest spike of iridium has recently been reported for this mid- ous extinction, implying impacts from space. Because other ave not been uncovered for this boundary, the significance of spike is being challenged. But ay be a more surprising suspect nts of extinction—flowers. t this time blooming and fruit- plants, known as angiosperms, o explode across the land. By at- animals to spread their pollen ds, the angiosperms colonize . They also reproduce rapidly. versial dinosaur expert Robert r of the University of Colorado that the new generation of low- ng Cretaceous dinosaurs began g the world over to flowers. Dino- n overgrazing threatened many rowing plants with extinction— t for the angiosperms. Their ductive superiority helped flower- lants compete with the munching of oblivion.

turn, this contagion of angio- ns must have had an enormous ct on the dinosaurs' diets. Could linked to their mid-Cretaceous ction?

rtainly new dinosaurs evolved in ftermath. The late Cretaceous saw tbill dinosaurs prowling the swamps and forests. On the more open ns, especially in western North America, great herds of rhino-like *ceratops* and their relatives fed on the new vegetation. Back then a a across the Dakotas would have resembled a saurian version of to- 's Serengeti Plain. The lion of that world was the infamous *Tyran- saurus rex*.

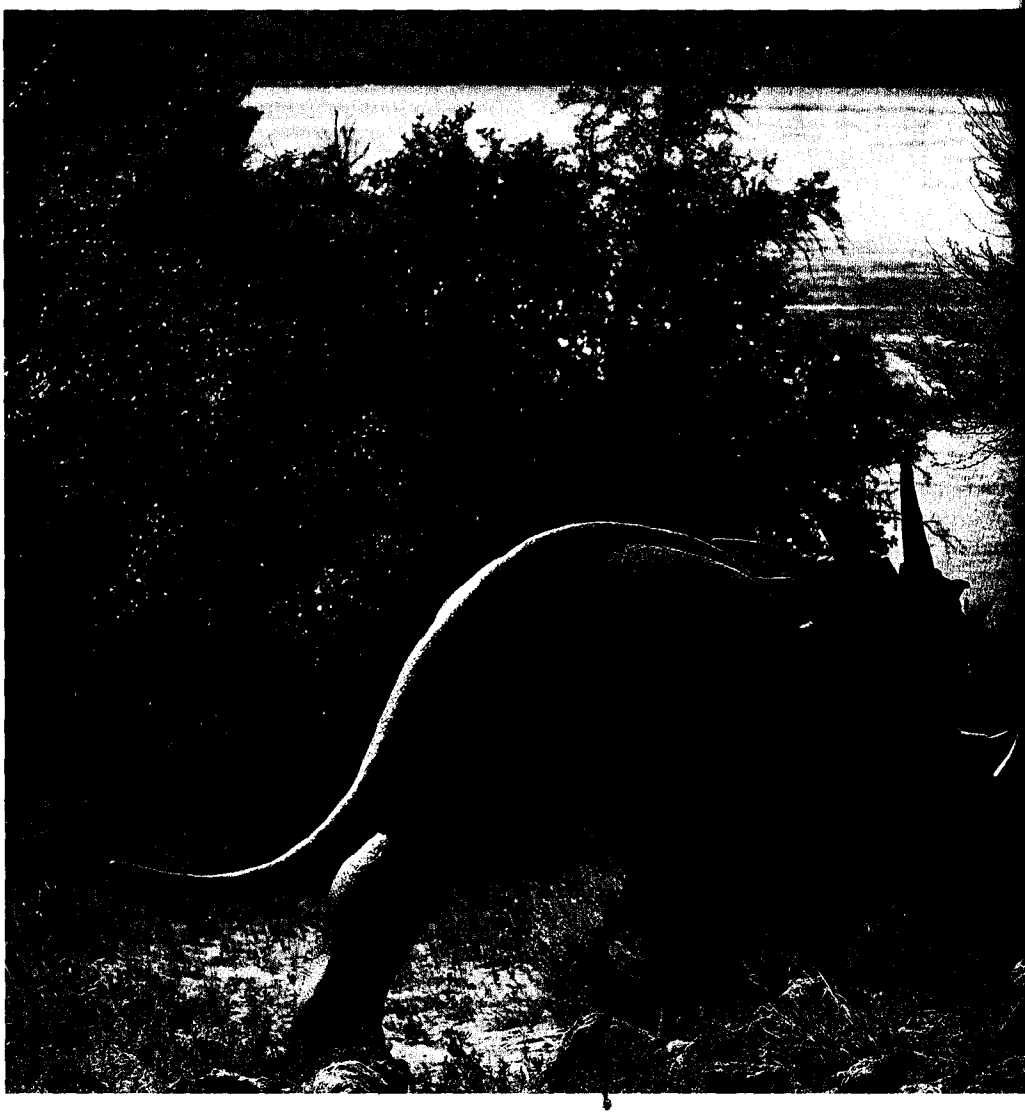
In all, at least 30 genera of dinosaurs—perhaps a hundred species—abited the planet during the final ten million years of the Creta- us. Some specialists argue that most persisted right up to the K-T oundary. Others brandish data indicating that all but 13 genera had rished well before the Cretaceous ended. Recent, hotly contested evi- nce suggests nine genera of dinosaurs may have straggled on into the llowing Paleocene epoch. Part of the answer to this debate lies buried the badlands of the Great Plains.

Ten thousand years ago in the badlands, runoff from the last gla- iers cut through the purplish gray and green soils of the Hell Creek ormation near the North Dakota-Montana border. As those eroding treams carved buttes out of the vast flatlands, they cut through and xposed for future geologists the last two million years of the Creta- ceous period. Hell Creek is the only place on earth that preserves in

***FIRE OR ICE?** Based on his studies of the fossil record, paleobiologist Steven Stanley of Johns Hopkins University (above) believes that global cooling explains most mass extinctions. He holds a* Spondylus, *a tropical bivalve that died out some 3 million years ago. At the other end of the spectrum, David Raup and Jack Sepkoski of the University of Chicago share the limelight with their theory that mass extinctions occur every 26 million years, perhaps as a result of periodic bombardment by comets.*

detail—with iridium and an abundance of fossils—the dying d
the dinosaurs.

On this July morning the bleak buttes are speckled by the co
T-shirts of scientists and volunteers sent by the Milwaukee Pu
Museum. Hammering and chiseling under a blazing badlands
Claudia Berghaus, Joan Mathys, and Carol Moertl extricate fr
of a *Triceratops* front leg bone. Doug Stephenson is perched hi
the butte, near the K-T boundary, working on scraps of a scap



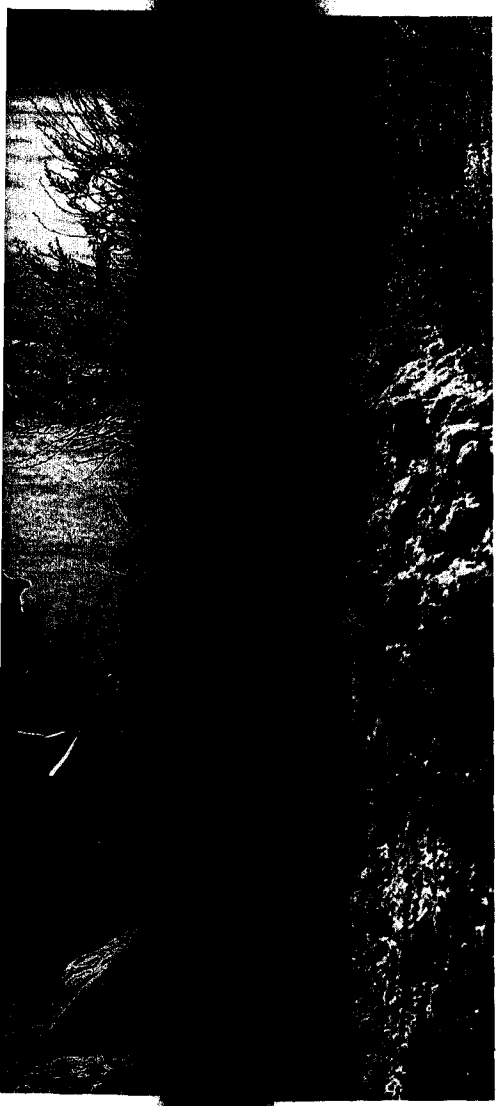
"I can't get over it," says Jay Warner, who is usually an engine
"Back in Milwaukee I was worried I wouldn't find a single bone.
found a piece of a turtle in my first five minutes, a dinosaur in ten.

"We want to know what the pattern of diversity was," explains
the museum project's coordinator, Peter Sheehan. "It has not beer
adequately shown that dinosaurs already were dying out before th
impact. We're trying to eliminate one of the two possibilities—the
whimper or the bang. A gradual pattern of decline is not what you
expect if an asteroid killed them."

Sheehan contends that past estimates of dinosaur diversity are

e dying days

by the colorf
aukee Public
adlands sun
tricate fragm
erched highe
of a scapula



y an engineer.
ngle bone. I
saur in ten."
," explains
has not been
ut before the
ilities—the
ot what you'd

ersity are

phic, June 1989

he better-known North American fossil sites have been mined roughly than other spots. Dale Russell of the National Museanada says dinosaur diversity in North America did not gnificantly before the boundary. In central Asia, another -rich area, it increased, while much of the world remains mpled.

past, fossil hunters usually collected only museum-quality s. They ignored the scraps, which may be the most valid indicators of the real abundance of late Cretaceous life.

The scrap that creates the most excitement on this day is not dinosaurian, nor even reptilian.

"We've got a mammal," announces museum paleontologist Diane Gabriel, bending over her sliver of a discovery, a jawbone from a marsupial. "It was probably slightly larger than a chihuahua. That means it was a giant for its time."

MAMMALS are rare in these late Cretaceous rocks, but in the eyes of the Minnesota paleontologist Bob Sloan they are far from insignificant. Sloan believes that 200,000 years before the K-T boundary a receding sea level had created a land bridge between North America and the long-isolated Asian continent. A plague of little Asian mammals invaded North America and began eating the same flowering plants that most dinosaurs ate.

"The mammals ate much less food per animal," says Sloan. "But there were so many of them. They ate the last of the dinosaurs out of house and home." Others suggest the dinosaurs' nemesis was a climate-induced change in vegetation.

In fact, the dinosaurs and their huge flying cousins, the pterosaurs, were among the few land-based animals to go extinct at the end of the Cretaceous. Turtles, crocodiles, many lizards, and most mammals de it through, perhaps because they did not eat much and were all enough to find refuges.

The cruelest K-T extinctions struck the seas. Most plankton, the prary food source, died out—understandable if months of darkness or lobal acid rain followed an impact. All large marine reptiles also anished, as did most denizens of the seafloor. Rudists, huge coral-ke clams whose shells built Cretaceous reefs, were obliterated. Ammonoids—lovely, coiled survivors of many past extinctions—died ut completely.

Not all these creatures disappear from the fossil record right at the

A SPIKED COLLAR and a rhino-like horn helped Styracosaurus *(left) fend off his number one enemy—*Albertosaurus*, a scaled down version of T-rex who stalked the late Cretaceous coastal swamps in what is now Dinosaur Provincial Park in Alberta, Canada. The Tyrrell Museum's lifelike replica is modeled on fossils found in the park.*

Whatever caused the extinction at the end of the Cretaceous, this vegetarian cousin of Triceratops *wasn't around to see it.* Styracosaurus *disappeared from the fossil record some 12 million years before the K-T boundary.*

K-T boundary. Some vanish earlier in steps. Thus other scien
argue that the K-T impact was not the cause of the dyings. "E
tems were decaying for at least two million years before the im
explains paleobiologist Steven Stanley of Johns Hopkins Unive

Stanley, a prominent theorist, sees long-term cooling as the
Yet there is no obvious reason for such cooling. The next ice ag
tens of millions of years away. Massive volcanic eruptions may
dropped global temperatures temporarily by injecting particles

atmosphere that blocked sunlight. Indeed, one of the greatest outp
ings of lava the world has known occurred at the K-T boundary.
basalt flow buried the Deccan region of India. However, many vo
nologists doubt that the relatively calm nature of lava eruptions w
propel much debris into the upper atmosphere.

Whatever cooled the planet, Stanley contends that the impact at
boundary probably was but a final insult to an already overstressed
global ecosystem.

As I was told by another paleontologist: "Things got bad, then t
got worse."

Impact enthusiasts have recently come up with a way to explain
multiple stages of K-T extinctions. Earth, they argue, was hit not b
one great object but rather by a shower of comets that bombarded
planet over several million years.

Erle Kauffman of the University of Colorado finds evidence for w
disarray in ocean chemistry beginning two million years before the

Those disruptions, he argues, were created when comets seas, generating tsunamis and overturns of deep anoxic or like those suggested for earlier extinctions. Those oceanic could have created global climate crises far worse than El experience today. The final terminating impact, says Kauffbably occurred on land, where it produced fire storms, soot, of dust.

major question surrounds the final impact. Where's the crater? are not always obvious.

largest impact and the largest in the past hundred million urred at the same time as the trusion of lava," observes Michael Rampino of New versity. "That's quite a coin- He and others suspect that t struck India, thereby causing Deccan basaltic lava flows. pino is right, the K-T crater buried beneath the basalt. sider the quiet farm town of Iowa. It sits over the center of meter-wide crater that glaciers th debris during the last ice us today the only striking fea- Manson is its tall grain eleva- ologists, however, have recently e crater below Manson at 66 years—perfect timing to make it killer.

scientists agree that 32 kilome- nuch too small to create the nvisioned by impact enthusi- ut some suspect Manson's crater larger. The 32-kilometer hole just an inner pit.

ourse, the impact may have the ocean. If so, the scarred sea- could have been buried by sedi- or been recycled into the planet's innards by plate tectonics.

TERROR of the trilobites, Anomalocaris (above, at center) did not last long, but many a trilobite shows wounds attributed to the predator. It was extinct by the end of the Cambrian, whereas trilobites hung on until the Permian mass extinction. The fossil of a Jurassic fish covered with armor-like scales is removed from a West German quarry (facing page).

JONATHAN BLAIR, D. L. BRUTEN, A. JENSEN; PHOTOGRAPHED AT PALEONTOLOGISK MUSEUM, OSLO, NORWAY (ABOVE)

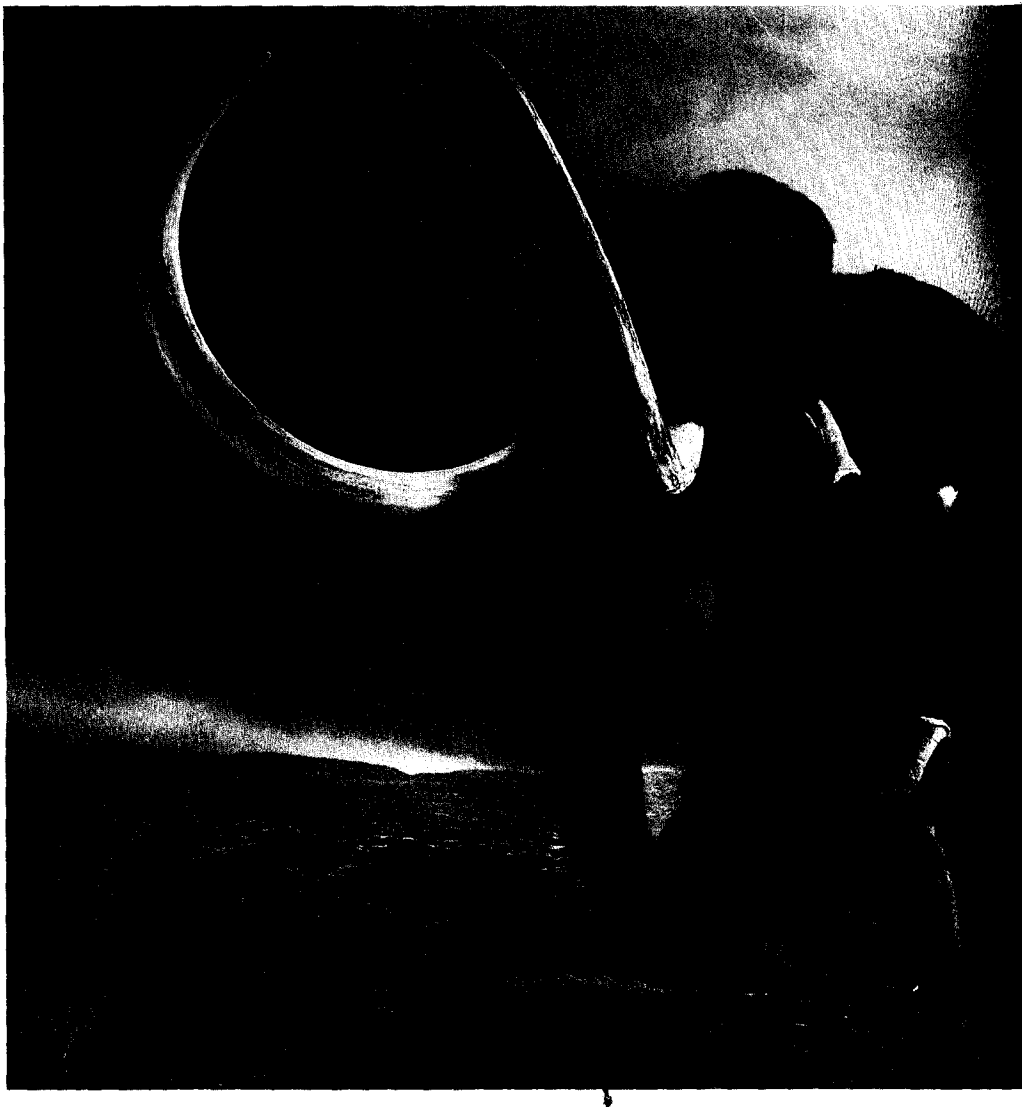
PERHAPS more controversial than the impact hypothesis itself is the notion that such showers occur regularly. Jack Sepkoski and David Raup of the University of Chicago have combed a century and a half of fossil record keeping and found a pattern. They see peaks of extinction about every 26 million years. Such regularity implies a cosmic driver to extinctions. No known earthly mechanism keeps such good time. Many scientists dispute Raup and Sepkoski's statistical methods; any concur, seeking astrophysical explanations.

The most obvious source for the calamities would be the dense cloud comets that astronomers believe surrounds the outer solar system. omething could periodically unsettle that cloud, flinging a battalion of mets toward the inner planets over several million years.

Three mechanisms have been proposed. A dense, dark companion

star orbiting our sun would toss out comets as it passed through
cloud. So might an unknown, tenth planet. Thirdly, our solar s
moves periodically up and down through the star-dense spiral
Milky Way galaxy. Perhaps our comet envelope is perturbed ea
we pass through that spiral arm.

Astrophysicists find dynamical problems with all three mech
Many argue that the showers strike randomly, not regularly. O
see a frequency not of 26 but of about 30 million years.



Both spacings fit the next era of extinctions, which hit between 3
and 40 million years ago. Those dyings eliminated herds of rhino-li
mammals and many sea creatures. Although iridium spikes correla
some of these die-offs, gradualists argue that a well-documented ch
ing of the seas did the killing.

Advocates of the 26-million-year period point to a mild extinctio
around 14 million years ago as evidence for the most recent bomba
ment. That places us today safely between showers. Those favorin
million-year or random spacing are less sanguine.

Michael Rampino points to three large craters—Bosumtwi in Gh

meters in diameter) and two in the Soviet Union, Elgygytgyn
eters) and Zhamanshin (13 kilometers)—that were created in
3.5 million years.
ould still be in a shower," says Rampino. "Halley's comet
part of it. We aren't out of the woods yet."
ing debris from the impact of a large celestial object 2.3 mil-
s ago has recently been found strewn across some 600 kilome-
e Pacific seafloor off Cape Horn.

"About 2.3 million years ago there was an abrupt shift in climate," notes geologist Frank Kyte, leader of the University of California at Los Angeles team that discovered evidence of the impact. "Huge continental ice sheets developed in the Northern Hemisphere."

Kyte notes that the climate had been deteriorating before this, our most recent ice age, set in. But he speculates that the injection of water vapor into the stratosphere could have formed a global cloud cover that reflected heat off the top of the atmosphere.

"No one would argue that impacts alone cause ice ages," adds Mike Rampino. "But might they push the climate into a new state?"

LAID LOW by the hand of man, the woolly mammoth appears to live again in a diorama presented at the Royal British Columbia Museum in Victoria. Museum technician Wally Bishop checks the musk-ox hair that covers this 11-foot replica, modeled after the beast that ranged over North America, Asia, and Europe during the Pleistocene. Many scientists believe the mammoth, like most of the epoch's megafauna, was hunted to oblivion in Europe and Asia, then became extinct as Ice Age hunters invaded North America across the Bering land bridge.

WHETHER OR NOT we fit a cosmic timetable for an extinction, we surely are in one today.

It began in North America about 11,000 years ago. Most large mammals were wiped out. Saber-toothed cats, mastodons, mammoths, huge ground sloths, short-faced bears, and dire wolves. All perished abruptly. What happened?

Some scientists argue that the climate grew drier. In western North America arid conditions dried up the food supply of large herbivores. As the herbivores disappeared, so did the carnivores that preyed on them.

The extinctions, however, were so
d—within five hundred to a thousand years—that many scientists
pect an alternate—or at least assistant—villain in this extinction:
mo sapiens. Man the hunter emerged from the Ice Age with lethal
w hunting technologies—snares, traps, and sharp-pointed weapons.
Today the impact of human technology on the biosphere worsens. It
terminates not just the big creatures but the tiny. Man has become
asteroid. A very big one.
It is easy to blame today's frightful extinctions on habitat destruction
developing countries. To be sure, the crisis is acute in Brazil and
Madagascar and the Philippines, where rapidly expanding populations

r economic development can erase a forest in weeks.
sing their inheritance," says botanist S. H. Sohmer of
eum in Honolulu. Just back from the Philippines,
ping local biologists bolster national awareness of the
er paints a dismal picture.
group I study, 42 percent of the species reported in
been collected since," he says. "The leveled forests are
by an aggressive plant called cogongrass. If the logging
burn agriculture don't stop soon, we'll wind up with en-
ered by it. Conceivably this archipelago, which once
world's richest biotas, will end up with only a handful

the wealthier countries to decry and then ignore these
But we have only to ask who buys the timber or beef
ests produce. Or who generates the acid rain that is wip-
ngland's sugar maples or
y's Black Forest.
States can look at Hawaii,
us regard as paradise but
ts consider the endangered-
of the world. Though occu-
n 0.2 percent of the nation's
waii contains 27 percent of
birds and plants. Seventy-
those U. S. species that
become extinct did so on

LAKAI SWAMP on the island
i a male *ʻoʻo-ʻaʻa* sings his
holy song alone.
's the best songster in the
," says state aviculturist Fern
"His call is unforgettable,
of the old Hawaiians."
t three years the mating calls
ve gone unheeded. For he is
species, the end of the line.
t not only a species," says
its entire family—all the
will be gone."
, in Honolulu's Bishop Mu-
hildren file past the celebrated yellow feather cape of King
a I. The cape was assembled from the plumage of the lost
in the late 18th century.
e feathers from 80,000 birds to make this cloak," says

waiian birds were flightless. Before humans the islands
mmalian predators, and wings grew less useful. Thus
s brought rats and dogs, native birds and eggs were easy
ted goats, pigs, and cattle ravaged avian habitats. Humans
orests.
lava tube on the island of Maui ornithologists Storrs Olson
ames of the Smithsonian Institution excavate soils depos-
the past 8,000 years. A dark layer high in the soil strata

PRIZED for its plumage, the Hawaiian ʻoʻo-ʻaʻa (top) was overhunted to adorn cloaks like one worn by chief Kiwalaʻo (facing page). After studying the fossil record in Maui's lava tubes, Helen James of the Smithsonian Institution (above) rates predators introduced by Polynesians—pigs, dogs, and rats—as more deadly agents of extinction.

A WHO'S WHO of extinction surrounds curator Iain Bishop at England's Tring Zoological Museum. He holds the one species still living—an endangered aye-aye from Madagascar. The Carolina parakeets (above) were collected in 1870, decades before they disappeared. Experts believe that species are presently dying at the rate of 100 a day.

1 Giant ground sloth
2 Aye-aye
3 Quagga
4 Moa
5 Passenger pigeon
6 Carolina parakeet
7 Tasmanian wolf
8 Toolach wallaby
9 Dodo
10 Great auk
11 Male heath hen
12 Female heath hen
13 Labrador duck

contains charcoal, which has been dated as being 825 years o think the charcoal correlates to the burning of the forests for ture," says James. "We see bird bones below the charcoal an nesian rat bones above. Later we get black rats and house mi nouncing the arrival of the Europeans."

New diseases arrived too. An avian pox, imported in 1964 pheasant from Nepal, most likely brought one of Hawaii's m al birds, the *'alala,* or Hawaiian crow, to the twilight of extinc

At the Olinda Endangered Species Captive Breeding Facili Maui nine of the last fifteen known Hawaiian crows await the season in their pens. Overnight someone has placed an offerin canic stone wrapped in a large leaf—beneath a statue of a Ha salamander god that stands on the lawn of the station.

"The offerings began when the crows were brought here in says Fern Duvall, who is in charge of the facility. "We must as that someone is trying to help the crows reproduce.

"Actually, the Hawaiians did not think the 'alala was a bird he continues. "It behaves in remarkable ways. It feeds with its like a parrot. It shrieks, growls, and moans. It makes noises m a tiger. When the feather hunters heard it in the fog-bound fore they thought it was a spirit. If you killed an 'alala, you paid wi your life."

This season's courtship is beginning. In one pen a male, nam Keawe, and a female, Mana, are performing nest-building calls displays. Their efforts are doomed: Disease has left Mana steril ever, the mating ritual stimulates useful behaviors. Keawe's se could later fertilize other females. Mana could sit on a nest aban by another female.

The three other pairs of crows offer varying degrees of hope f building a captive population. Even so, the outlook for the 'alal bleak. There is simply no safe place for them in the wild at this t

I AM ANGRY as I rest from a hike on the slopes of the volcan Haleakala. In Hawaiian prehistory I would have been sitt a diverse forest rather than this overgrazed scrubland dom by prickly plants that cattle won't eat. Almost nothing, fr peacock that preened minutes earlier in my path to the cab butterfly that just now alighted on my arm, is native. Is th island slope, where only the rats and the pigs and the cactuses th microcosm of our future?

Other questions, fed by my fieldwork, arise. Hasn't this happe before—diversity suddenly becoming paucity—and each time did life recover to reach new heights of evolutionary creativity? In the picture is it really so terrible, what's happening today? Life will g No matter how bad we make things, some organisms will cope, su vive, then flourish. Isn't that the lesson of mass extinctions? Wha different about this one?

We are the difference. For the first time since life on earth bega four billion years ago, a living organism can begin to understand w is happening to this planet. We can see that the health of species is interconnected, that if we let too many disappear, we will go too. the first time, a living organism can consciously do something to h mass extinction. Perhaps most important, for the first time a living creature can gaze out across the species of the earth and say: This i beautiful. I care. I will not let it go.

ng 825 years old
he forests for ag
e charcoal and
and house mice

orted in 1964 wi
of Hawaii's most
vilight of extincti
Breeding Facility
rows await the b
aced an offering
statue of a Hawa
station.
rought here in 19
y. "We must assu
uce.
alala was a bird a
It feeds with its fe
makes noises mor
e fog-bound forest
ala, you paid with

pen a male, named
est-building calls a
left Mana sterile.
iors. Keawe's seme
sit on a nest abande

degrees of hope for
look for the 'alala i
the wild at this tim

pes of the volcano
ıld have been sittin
ed scrubland domin
most nothing, from
ıy path to the cabba
n, is native. Is this
ıd the cactuses thriv

Hasn't this happene
and each time didn'
creativity? In the b
today? Life will go
ıisms will cope, sur-
extinctions? What's

ife on earth began
n to understand wh
ealth of species is
', we will go too. Fo
lo something to halt
first time a living
th and say: This is

eographic, June 198