CHAPTER V

WELCOME TO THE ANTHROPOCENE

Dicranograptus ziczac

IN 1949, A PAIR OF HARVARD PSYCHOLOGISTS RECRUITED TWO dozen undergraduates for an experiment about perception. The experiment was simple: students were shown playing cards and asked to identify them as they flipped by. Most of the cards were perfectly ordinary, but a few had been doctored, so that the deck contained, among other oddities, a red six of spades and a black four of hearts. When the cards went by rapidly, the students tended to overlook the incongruities; they would, for example, assert that the red six of spades was a six of hearts, or call the black four of hearts a four of spades. When the cards went by more slowly, they struggled to make sense of what they were seeing. Confronted with a red spade, some said it looked "purple" or "brown" or "rusty black." Others were completely flummoxed.

The symbols "look reversed or something," one observed.

"I can't make the suit out, whatever it is," another exclaimed. "I don't know what color it is now or whether it's a spade or heart. I'm not even sure now what a spade looks like! My God!"

The psychologists wrote up their findings in a paper titled "On the Perception of Incongruity: A Paradigm." Among those who found this paper intriguing was Thomas Kuhn. To Kuhn, the twentieth century's most influential historian of science, the experiment was indeed paradigmatic: it revealed how people process disruptive information. Their first impulse is to force it into a familiar framework: hearts, spades, clubs. Signs of mismatch are disregarded for as long as possible—the red spade looks "brown" or "rusty." At the point the anomaly becomes simply too glaring, a crisis ensues—what the psychologists dubbed the " 'My God!' reaction."

This pattern was, Kuhn argued in his seminal work, *The Structure of Scientific Revolutions,* so basic that it shaped not only individual perceptions but entire fields of inquiry. Data that did not fit the commonly accepted assumptions of a discipline would either be discounted or explained away for as long as possible. The more contradictions accumulated, the more convoluted the rationalizations became. "In science, as in the playing card experiment, novelty emerges only with difficulty," Kuhn wrote. But then, finally, someone came along who was willing to call a red spade a red spade. Crisis led to insight, and the old framework gave way to a new one. This is how great scientific discoveries or, to use the term Kuhn made so popular, "paradigm shifts" took place.

The history of the science of extinction can be told as a series of paradigm shifts. Until the end of the eighteenth century, the very category of extinction didn't exist. The more strange bones were unearthed—mammoths, *Megatherium,* mosasaurs—the harder naturalists had to squint to fit them into a familiar framework. And squint they did. The giant bones belonged to elephants that had been washed north, or hippos that had wandered west, or whales with malevolent grins. When Cuvier arrived in Paris, he saw that the mastodon's molars could not be fit into the established framework, a "My God" moment that led him to propose a whole new way of seeing them. Life, Cuvier recognized, had a history. This history was marked by loss and punctuated by events too terrible for human imagining. "Though the world does not change with a change of paradigm, the scientist afterward works in a different world" is how Kuhn put it.

In his *Recherches sur les ossemens fossiles,* Cuvier listed dozens of *espèces perdues,* and he felt sure there were more awaiting discovery. Within a few decades, so many extinct creatures had been identified that Cuvier's framework began to crack. To keep pace with the growing fossil record, the number of disasters had to keep multiplying. "God knows how many catastrophes" would be needed, Lyell scoffed, poking fun at the whole endeavor. Lyell's solution was to reject catastrophe altogether. In Lyell's—and later Darwin's—formulation, extinction was a lonely affair. Each species that had vanished had shuffled off all on its own, a victim of the "struggle for life" and its own defects as a "less improved form."

The uniformitarian account of extinction held up for more than a century. Then, with the discovery of the iridium layer, science faced another crisis. (According to one historian, the Alvarezes' work was "as explosive for science as an impact would have been for earth.") The impact hypothesis dealt with a single moment in time—a terrible, horrible, no-good day at the end of the Cretaceous. But that single moment was enough to crack the framework of Lyell and Darwin. Catastrophes *did* happen.

What is sometimes labeled neocatastrophism, but is mostly nowadays just regarded as standard geology, holds that conditions on earth change only very slowly, except when they don't. In this sense the reigning paradigm is neither Cuvierian nor Darwinian but combines key elements of both—"long periods of boredom interrupted occasionally by panic." Though rare, these moments of panic are disproportionately important. They determine the pattern of extinction, which is to say, the pattern of life.

THE path leads up a hill, across a fast-moving stream, back across the stream, and past the carcass of a sheep, which, more than just dead, looks deflated, like a lost balloon. The hill is bright green but treeless; generations of the sheep's aunts and uncles have kept anything from growing much above muzzle-height. In my view, it's raining. Here in the Southern Uplands of Scotland, though, I'm told by one of the geologists I'm hiking with, this counts only as a light drizzle, or *smirr.*

Our goal is a spot called Dob's Linn, where, according to an old ballad, the Devil himself was pushed over a precipice by a pious shepherd named Dob. By the time we reach the cliff, the *smirr* seems to be smirring harder. There's a view over a waterfall, which crashes down into a narrow valley. A few metres farther up the path there's a jagged outcropping of rock, which is striped vertically, like an umpire's jersey, in bands of light and dark. Jan Zalasiewicz, a stratigrapher from the University of Leicester, sets his rucksack down on the soggy ground and adjusts his red rain jacket. He points to one of the light-colored stripes. "Bad things happened in here," he tells me.

The waterfall at Dob's Linn.

The rocks that we are looking at date back some 445 million years, to the last part of the Ordovician period. At that point, the globe was experiencing a continental logjam; most of the land—including what's now Africa, South America, Australia, and Antarctica—was joined into one giant mass, Gondwana, which spanned more than ninety degrees latitude. England belonged to the continent—now lost—of Avalonia, and Dob's Linn lay in the Southern Hemisphere, at the bottom of an ocean known as the Iapetus.

The Ordovician period followed directly after the Cambrian, which is known, even to the most casual of geology students, for the "explosion" of new life forms that appeared.* The Ordovician, too, was a time when life took off excitedly in new directions—the so-called Ordovician radiation—though it remained, for the most part, still confined to the water. During the Ordovician, the number of marine families tripled, and the seas filled with creatures we would more or less recognize (the progenitors of today's starfish and sea urchins and snails and nautiluses) and also plenty that we would not (conodonts, which probably were shaped like eels; trilobites, which sort of resembled horseshoe crabs; and giant sea scorpions, which, as best as can be determined, looked like something out of a nightmare). The first reefs appeared, and the ancestors of today's clams took on their clam-like form. Toward the middle of the Ordovician, the first plants began to colonize the land. These were very early mosses or liverworts, and they clung low to the ground, as if not quite sure what to make of their new surroundings.

At the end of the Ordovician, some 444 million years ago, the oceans emptied out. Something like eighty-five percent of marine

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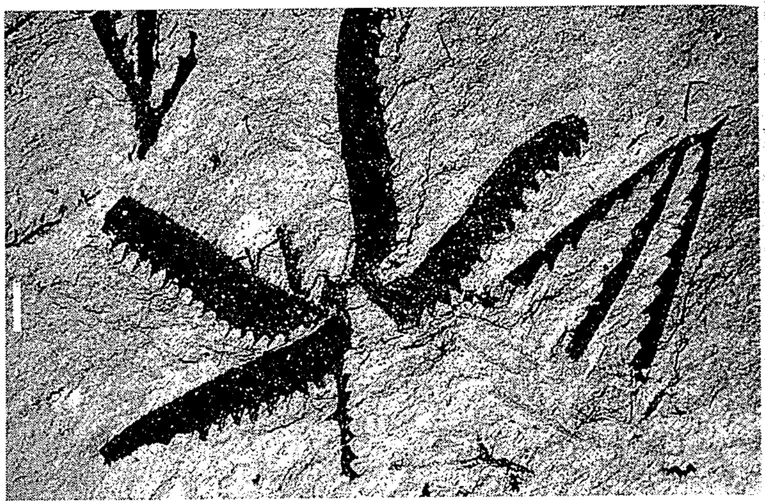
*A useful mnemonic for remembering the geologic periods of the last half-billion years is: Camels Often Sit Down Carefully, Perhaps Their Joints Creak (Cambrian-Ordovician-Silurian-Devonian-Carboniferous-Permian-Triassic-Jurassic-Cretaceous). The mnemonic unfortunately runs out before the most recent periods: the Paleogene, the Neogene, and the current Quaternary.

species died off. For a long time, the event was regarded as one of those pseudo-catastrophes that just went to show how little the fossil record could be trusted. Today, it's seen as the first of the Big Five extinctions, and it's thought to have taken place in two brief, intensely deadly pulses. Though its victims are nowhere near as charismatic as those taken out at the end of the Cretaceous, it, too, marks a turning point in life's history—a moment when the rules of the game suddenly flipped, with consequences that, for all intents and purposes, will last forever.

Those animals and plants that made it through the Ordovician extinction "went on to make the modern world," the British paleontologist Richard Fortey has observed. "Had the list of survivors been one jot different, then so would the world today."

ZALASIEWICZ—MY guide at Dob's Linn—is a slight man with shaggy hair, pale blue eyes, and a pleasantly formal manner. He is an expert on graptolites, a once vast and extremely diverse class of marine organisms that thrived during the Ordovician and then, in the extinction event, were very nearly wiped out. To the naked eye, graptolite fossils look like scratches or in some cases tiny petroglyphs. (The word "graptolite" comes from the Greek meaning "written rock"; it was coined by Linnaeus, who dismissed graptolites as mineral encrustations trying to pass themselves off as the remnants of animals.) Viewed through a hand lens, they often prove to have lovely, evocative shapes; one species suggests a feather, another a lyre, a third the frond of a fern. Graptolites were colonial animals; each individual, known as a zooid, built itself a tiny, tubular shelter, known as a theca, which was attached to its neighbor's, like a row house. A single graptolite fossil thus represents a whole community, which drifted or more probably swam along as a single entity, feeding off even smaller plankton. No one knows exactly what the zooids looked like—as with ammonites, the creatures' soft parts resist preservation—but



Graptolite fossils from the early Ordovician.

graptolites are now believed to be related to pterobranchs, a small and hard-to-find class of living marine organisms that resemble Venus flytraps.

Graptolites had a habit—endearing from a stratigrapher's point of view—of speciating, spreading out, and dying off, all in relatively short order. Zalasiewicz compares them to Natasha, the tender heroine of *War and Peace*. They were, he says, "delicate, nervous, and very sensitive to things around them." This makes them useful index fossils—successive species can be used to identify successive layers of rock.

Finding graptolites at Dob's Linn turns out, even for the most amateur of collectors, to be easy. The dark stone in the jagged outcropping is shale. It takes only a gentle hammer-tap to dislodge a chunk. Another tap splits the chunk laterally. It divides like a book opening to a well-thumbed page. Often on the stony surface there's nothing to see, but just as often there's one (or more) faint marks—messages from a former world. One of the graptolites I happen across has been preserved with peculiar clarity. It's shaped like a set of false eyelashes, but very small, as if for a Barbie. Zalasiewicz tells me—doubtless exaggerating—that I have found a "museum quality specimen." I pocket it.

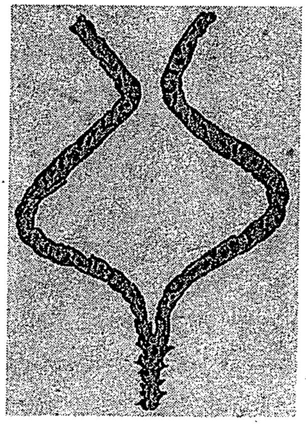
Once Zalasiewicz shows me what to look for, I, too, can make out the arc of the extinction. In the dark shales, graptolites are plentiful and varied. Soon I've collected so many, the pockets of my jacket are sagging. Many of the fossils are variations on the letter *V*, with two arms branching away from a central node. Some look like zippers, others like wishbones. Still others have arms growing off their arms like tiny trees.

The lighter stone, by contrast, is barren. There's barely a graptolite to be found in it. The transition from one state to another—from black stone to gray, from many graptolites to almost none—appears to have occurred suddenly and, according to Zalasiewicz, *did* occur suddenly.

"The change here from black to gray marks a tipping point, if you like, from a habitable sea floor to an uninhabitable one," he tells me. "And one might have seen that in the span of a human lifetime." He describes this transition as distinctly "Cuvierian."

Two of Zalasiewicz's colleagues, Dan Condon and Ian Millar, of the British Geological Survey, have made the hike with us out to Dob's Linn. The pair are experts in isotope chemistry and are planning to collect samples from each of the stripes in the outcropping—samples they hope will contain tiny crystals of zircon. Once back at the lab, they will dissolve the crystals and run the results through a mass spectrometer. This will allow them to say, give or take half a million years or so, when each of the layers was formed. Millar is Scottish and claims to be undaunted by the *smirr*. Eventually, though, even he has to acknowledge that, in English, it's pouring. Rivulets of mud are running down the face of the outcropping, making it impossible to get clean samples. It is decided that we will try again the following day. The three geologists pack up their gear, and we squish back down the trail to the car. Zalasiewicz has made reservations at a bed-and-breakfast in the nearby town of Moffat, whose attractions, I have read, include the world's narrowest hotel and a bronze sheep.

Once everyone has changed into dry clothes, we meet in the sitting room of the B & B for tea. Zalasiewicz has brought along several recent publications of his on graptolites. Settling back in their chairs, Condon and Millar roll their eyes. Zalasiewicz ignores them, patiently explaining to me the import of his latest monograph, "Graptolites in British Stratigraphy," which runs sixty-six single-spaced pages and includes detailed illustrations of more than 650 species. In the monograph, the effects of the extinction show up more systematically, if also less vividly than on the rain-slicked hillside. Until the end of the Ordovician, V-shaped graptolites dominated. These included species like *Dicranograptus ziczac*, whose tiny cups were arranged along arms that curled away and then toward each other, like tusks, and *Adelograptus divergens*, which, in addition to its two main arms, had little side-arms that stuck out like thumbs. Only a handful of graptolite species survived the extinction event; eventually, these diversified and repopulated the seas in the Silurian. But Silurian graptolites had a streamlined body plan, more like a stick than a set of branches. The V-shape had been lost, never to reappear. Here writ very, very small is the fate of the dinosaurs, the mosasaurs, and the ammonites—a once highly successful form relegated to oblivion.



A drawing of the graptolite *Dicranograptus ziczac*, shown several times larger than actual size.

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WHAT happened 444 million years ago to nearly wipe out the graptolites, not to mention the conodonts, the brachiopods, the echinoderms, and the trilobites?

In the years immediately following the publication of the Alvarez hypothesis, it was generally believed—at least among those who considered the hypothesis more than "codswallop"—that a unified theory of mass extinction was at hand. If an asteroid had produced one "chasm" in the fossil record, it seemed reasonable to expect that impacts had caused all of them. This idea received a boost in 1984, when a pair of paleontologists from the University of Chicago published a comprehensive analysis of the marine fossil record. The study revealed that in addition to the five major mass extinctions, there had been many lesser extinction events. When all of these were considered together, a pattern emerged: mass extinctions seemed to take place at regular intervals of roughly twenty-six million years. Extinction, in other words, occurred in periodic bursts, like cicadas crawling out of the earth. The two paleontologists, David Raup and Jack Sepkoski, were unsure what had caused these bursts, but their best guess was some "astronomical and astrophysical cycle," having to do with "the passage of our solar system through the spiral arms of the Milky Way." A group of astrophysicists—as it happened, colleagues of the Alvarezes at Berkeley—took the speculation one step farther. The periodicity, the group argued, could be explained by a small "companion star" to the sun, which, every twenty-six million years, passed through the Oort cloud, producing comet showers that rained destruction on the earth. The fact that no one had ever seen this star, dubbed with horror-movie flair "Nemesis," was, to the Berkeley group, a problem, but not an insurmountable one; there were plenty of small stars out there, still waiting to be cataloged.

In the popular media, what became known as the "Nemesis Affair" generated almost as much excitement as the original asteroid hypothesis. (One reporter described the story as having everything but sex and the royal family.) *Time* ran a cover article, which was soon followed by another disapproving editorial in the *New York Times*. (The editorial pooh-poohed the notion of a "mysterious death-star.") This time, the newspaper was onto something. Though the Berkeley group spent the next year or so scanning the heavens for Nemesis, no glimmer of a "death star" was discovered. More significantly, upon further analysis, the evidence for periodicity began to fall apart. "If there's a consensus, it's that what we were seeing was a statistical fluke," David Raup told me.

Meanwhile, the search for iridium and other signs of extraterrestrial impacts was faltering. Together with many others, Luis Alvarez had thrown himself into this hunt. At a time when scientific collaboration with the Chinese was practically unheard of, he'd managed to obtain rock samples from southern China that spanned the boundary between the Permian and Triassic periods. The end-Permian or Permo-Triassic extinction was the biggest of the Big Five, an episode that came scarily close to eliminating multicellular life altogether. Luis was thrilled to find a layer of clay nestled between the bands of rock from southern China, just as there had been at Gubbio. "We felt sure that there would be lots of iridium there," he would later recall. But the Chinese clay turned out to be, chemically speaking, mundane, its iridium content too infinitesimal to be measured. Higher-than-normal iridium levels were subsequently detected at the end of the Ordovician, in rocks from, among other places, Dob's Linn. However, none of the other telltale signs of an impact, such as shocked quartz, turned up in the right time frame, and it was determined that the elevated iridium levels were more plausibly—if less spectacularly—attributed to the vagaries of sedimentation.

The current theory is that the end-Ordovician extinction was caused by glaciation. For most of the period, a so-called greenhouse climate prevailed—carbon dioxide levels in the air were high and so, too, were sea levels and temperatures. But right around the time of the first pulse of extinction—the one that wreaked havoc among the graptolites—CO_2 levels dropped. Temperatures fell and Gondwana froze. Evidence of the Ordovician glaciation has been found in such far-flung remnants of the supercontinent as Saudi Arabia, Jordan, and Brazil. Sea levels plummeted, and many marine habitats were eliminated, presumably to the detriment of marine organisms. The oceans' chemistry changed, too; among other things, colder water holds more oxygen. No one is sure whether it was the temperature change or one of the many knock-on effects that killed the graptolites; as Zalasiewicz put it to me, "You have a body in the library, and a half a dozen butlers wandering around, looking sheepish." Nor does anyone know what caused the change to begin with. One theory has it that the glaciation was produced by the early mosses that colonized the land and, in so doing, helped draw carbon dioxide out of the air. If this is the case, the first mass extinction of animals was caused by plants.

The end-Permian extinction also seems to have been triggered by a change in the climate. But in this case, the change went in the opposite direction. Right at the time of extinction, 252 million years ago, there was a massive release of carbon into the air—so massive that geologists have a hard time even imagining where all the carbon could have come from. Temperatures soared—the seas warmed by as much as ten degrees—and the chemistry of the oceans went haywire, as if in an out-of-control aquarium. The water became acidified, and the amount of dissolved oxygen dropped so low that many organisms probably, in effect, suffocated. Reefs collapsed. The end-Permian extinction took place, though not quite in a human lifetime, in geologic terms nearly as abruptly; according to the latest research by Chinese and American scientists, the whole episode lasted no more than two hundred thousand years, and perhaps less than a hundred thousand. By the time it was over, something like ninety percent of all species on earth had been eliminated. Even intense global warming and ocean acidification seem inadequate to explain losses on such a staggering scale, and so additional mechanisms are still being sought. One hypothesis has it that the heating of the oceans favored bacteria that produce hydrogen sulfide, which is poisonous to most other forms of life. According to this scenario, hydrogen sulfide accumulated in the water, killing off marine creatures, then it leaked into the air, killing off most everything else. The sulfate-reducing bacteria changed the color of the oceans and the hydrogen sulfide the color of the heavens; the science writer Carl Zimmer has described the end-Permian world as a "truly grotesque place" where glassy, purple seas released poisonous bubbles that rose "to a pale green sky."

If twenty-five years ago it seemed that all mass extinctions would ultimately be traced to the same cause, now the reverse seems true. As in Tolstoy, every extinction event appears to be unhappy—and fatally so—in its own way. It may, in fact, be the very freakishness of the events that renders them so deadly; all of a sudden, organisms find themselves facing conditions for which they are, evolutionarily, completely unprepared.

"I think that, after the evidence became pretty strong for the impact at the end of the Cretaceous, those of us who were working on this naively expected that we would go out and find evidence of impacts coinciding with the other events," Walter Alvarez told me. "And it's turned out to be much more complicated. We're seeing right now that a mass extinction can be caused by human beings. So it's clear that we do not have a general theory of mass extinction."

THAT evening in Moffat, once everyone had had enough of tea and graptolites, we went out to the pub on the ground floor of the world's narrowest hotel. After a pint or two, the conversation turned to another one of Zalasiewicz's favorite subjects: giant rats. Rats have followed humans to just about every corner of the globe, and it is Zalasiewicz's professional opinion that one day they will take over the earth.

"Some number will probably stay rat-sized and rat-shaped," he told me. "But others may well shrink or expand. Particularly if there's been epidemic extinction and ecospace opens up, rats may be best placed to take advantage of that. And we know that change in size can take place fairly quickly." I recalled a rat I once watched drag a pizza crust along the tracks at an Upper West Side subway station. I imagined it waddling through a deserted tunnel blown up to the size of a Doberman.

Though the connection might seem tenuous, Zalasiewicz's interest in giant rats represents a logical extension of his interest in graptolites. He is fascinated by the world that preceded humans and also—increasingly—by the world that humans will leave behind. One project informs the other. When he studies the Ordovician, he's trying to reconstruct the distant past on the basis of the fragmentary clues that remain: fossils, isotopes of carbon, layers of sedimentary rock. When he contemplates the future, he's trying to imagine what will remain of the present once the contemporary world has been reduced to fragments: fossils, isotopes of carbon, layers of sedimentary rock. Zalasiewicz is convinced that even a moderately competent stratigrapher will, at the distance of a hundred million years or so, be able to tell that something extraordinary happened at the moment in time that counts for us as today. This is the case even though a hundred million years from now, all that we consider to be the great works of man—the sculptures and the libraries, the monuments and the museums, the cities and the factories—will be compressed into a layer of sediment not much thicker than a cigarette paper. "We have already left a record that is now indelible," Zalasiewicz has written.

One of the ways we've accomplished this is through our restlessness. Often purposefully and just as often not, humans have rearranged the earth's biota, transporting the flora and fauna of Asia to the Americas and of the Americas to Europe and of Europe to Australia. Rats have consistently been on the vanguard of these movements, and they have left their bones scattered everywhere, including on islands so remote that humans never bothered to settle them. The Pacific rat, *Rattus exulans*, a native of southeast Asia, traveled with Polynesian seafarers to, among many other places, Hawaii, Fiji, Tahiti, Tonga, Samoa, Easter Island, and New Zealand. Encountering few predators, stowaway *Rattus exulans* multiplied into what the New Zealand paleontologist Richard Holdaway has described as "a grey tide" that turned "everything edible into rat protein." (A recent study of pollen and animal remains on Easter Island concluded that it wasn't humans who deforested the landscape; rather, it was the rats that came along for the ride and then bred unchecked. The native palms couldn't produce seeds fast enough to keep up with their appetites.) When Europeans arrived in the Americas, and then continued west to the islands the Polynesians had settled, they brought with them the even-more-adaptable Norway rat, *Rattus norvegicus*. In many places, Norway rats, which are actually from China, outcompeted the earlier rat invaders and, in so doing, ravaged the bird and reptile populations the Pacific rats had missed. Rats thus might be said to have created their own "ecospace," which their progeny seem well positioned to dominate. The descendants of today's rats, according to Zalasiewicz, will radiate out to fill the niches that *Rattus exulans* and *Rattus norvegicus* helped empty. He imagines the rats of the future evolving into new shapes and sizes—some "smaller than shrews," others as large as elephants. "We might," he has written, "include among them—for curiosity's sake and to keep our options open—a species or two of large naked rodent, living in caves, shaping rocks as primitive tools and wearing the skins of other mammals that they have killed and eaten."

Meanwhile, whatever the future holds for rats, the extinction event that they are helping to bring about will leave its own distinctive mark. Not yet anywhere near as drastic as the one recorded in the mudstone at Dob's Linn or in the clay layer in Gubbio, it will nevertheless appear in the rocks as a turning point. Climate change—itself a driver of extinction—will also leave behind geologic traces, as will nuclear fallout and river diversion and monoculture farming and ocean acidification.

For all of these reasons, Zalasiewicz believes that we have entered a new epoch, which has no analog in earth's history. "Geologically," he has observed, "this is a remarkable episode."

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OVER the years, a number of different names have been suggested for the new age that humans have ushered in. The noted conservation biologist Michael Soulé has suggested that instead of the Cenozoic, we now live in the "Catastrophozoic" era. Michael Samways, an entomologist at South Africa's Stellenbosch University, has floated the term "Homogenocene." Daniel Pauly, a Canadian marine biologist, has proposed the "Myxocene," from the Greek word for "slime," and Andrew Revkin, an American journalist, has offered the "Anthrocene." (Most of these terms owe their origins, indirectly at least, to Lyell, who, back in the eighteen-thirties, coined the words Eocene, Miocene, and Pliocene.)

The word "Anthropocene" is the invention of Paul Crutzen, a Dutch chemist who shared a Nobel Prize for discovering the effects of ozone-depleting compounds. The importance of this discovery is difficult to overstate; had it not been made—and had the chemicals continued to be widely used—the ozone "hole" that opens up every spring over Antarctica would have expanded until eventually it encircled the entire earth. (One of Crutzen's fellow Nobelists reportedly came home from his lab one night and told his wife, "The work is going well, but it looks like it might be the end of the world.")

Crutzen told me that the word "Anthropocene" came to him while he was sitting at a meeting. The meeting's chairman kept referring to the Holocene, the "wholly recent" epoch, which began at the conclusion of the last ice age, 11,700 years ago, and which continues—at least officially—to this day.

"'Let's stop it,'" Crutzen recalled blurting out. "'We are no longer in the Holocene; we are in the Anthropocene.' Well, it was quiet in the room for a while." At the next coffee break, the Anthropocene was the main topic of conversation. Someone came up to Crutzen and suggested that he patent the term.

Crutzen wrote up his idea in a short essay, "Geology of Mankind," that ran in *Nature*. "It seems appropriate to assign the term 'Anthropocene' to the present, in many ways human-dominated, geological epoch," he observed. Among the many geologic-scale changes people have effected, Crutzen cited the following:

- Human activity has transformed between a third and a half of the land surface of the planet.
- Most of the world's major rivers have been dammed or diverted.
- Fertilizer plants produce more nitrogen than is fixed naturally by all terrestrial ecosystems.
- Fisheries remove more than a third of the primary production of the oceans' coastal waters.
- Humans use more than half of the world's readily accessible fresh water runoff.

Most significantly, Crutzen said, people have altered the composition of the atmosphere. Owing to a combination of fossil fuel combustion and deforestation, the concentration of carbon dioxide in the air has risen by forty percent over the last two centuries, while the concentration of methane, an even more potent greenhouse gas, has more than doubled.

"Because of these anthropogenic emissions," Crutzen wrote, the global climate is likely to "depart significantly from natural behavior for many millennia to come."

Crutzen published "Geology of Mankind" in 2002. Soon, the "Anthropocene" began migrating out into other scientific journals.

"Global Analysis of River Systems: From Earth System Controls to Anthropocene Syndromes" was the title of a 2003 article in the journal *Philosophical Transactions of the Royal Society B.*

"Soils and Sediments in the Anthropocene" ran the headline of a piece from 2004 in the *Journal of Soils and Sediments.*

When Zalasiewicz came across the term, he was intrigued. He noticed that most of those using it were not trained stratigraphers, and he wondered how his colleagues felt about this. At the time, he was head of the stratigraphy committee of the Geological Society of London, the body Lyell and also William Whewell and John Phillips once presided over. At a luncheon meeting, Zalasiewicz asked his fellow committee members what they thought of the Anthropocene. Twenty-one out of the twenty-two thought that the concept had merit.

The group decided to examine the idea as a formal problem in geology. Would the Anthropocene satisfy the criteria used for naming a new epoch? (To geologists, an epoch is a subdivision of a period, which, in turn, is a division of an era: the Holocene, for instance, is an epoch of the Quaternary, which is a period in the Cenozoic.) The answer the members arrived at after a year's worth of study was an unqualified "yes." The sorts of changes that Crutzen had enumerated would, they decided, leave behind "a global stratigraphic signature" that would still be legible millions of years from now, the same way that, say, the Ordovician glaciation left behind a "stratigraphic signature" that is still legible today. Among other things, the members of the group observed in a paper summarizing their findings, the Anthropocene will be marked by a unique "biostratigraphical signal," a product of the current extinction event on the one hand and of the human propensity for redistributing life on the other. This signal will be permanently inscribed, they wrote, "as future evolution will take place from surviving (and frequently anthropogenically relocated) stocks." Or, as Zalasiewicz would have it, rats.

By the time of my visit to Scotland, Zalasiewicz had taken the case for the Anthropocene to the next level. The International

Commission on Stratigraphy, or ICS, is the group responsible for maintaining the official timetable of earth's history. It's the ICS that settles such matters as: when exactly did the Pleistocene begin? (After much heated debate, the commission recently moved that epoch's start date back from 1.8 to 2.6 million years ago.) Zalasiewicz had convinced the ICS to look into formally recognizing the Anthropocene, an effort that, logically enough, he himself was put in charge of. As head of the Anthropocene Working Group, Zalasiewicz is hoping to bring a proposal to a vote by the full body in 2016. If he's successful and the Anthropocene is adopted as a new epoch, every geology textbook in the world immediately will become obsolete.