

THE NEW YORKER

A REPORTER AT LARGE

THE MARTIAN CHRONICLERS

A new era in planetary exploration.

by Burkhard Bilger

APRIL 22, 2013

- [Print](#)
- [More](#)

Share

Close

-
- [Reddit](#)
- [Linked In](#)
- [Email](#)



The view from inside Gale Crater, the landing place of the rover Curiosity. Eight months after touching down safely, the rover has already found an ancient lake bed laced with carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur—the building blocks of life.

There once were two planets, new to the galaxy and inexperienced in life. Like fraternal twins, they were born at the same time, about four and a half billion years ago, and took roughly the same shape. Both were blistered with volcanoes and etched with watercourses; both circled the same yellow dwarf star—close enough to be

warmed by it, but not so close as to be blasted to a cinder. Had an alien astronomer swivelled his telescope toward them in those days, he might have found them equally promising—nurseries in the making. They were large enough to hold their gases close, swaddling themselves in atmosphere; small enough to stay solid, never swelling into gaseous giants. They were “Goldilocks planets,” our own astronomers would say: just right for life.

The rest is prehistory. On Earth, the volcanoes filled the air with water vapor and carbon dioxide. The surface cooled, a crust formed, and oceans condensed upon it. In hot springs and undersea vents, simple carbon compounds bubbled up to form amino acids and peptides. The first bacteria moved through the ooze; then came blue-green algae, spreading across the planet like a watery carpet, drinking in sunlight and exhaling oxygen, giving breath to everything that came after. Geologists call this the Great Oxygenation Event—the most momentous change in the planet’s history. It seems inevitable now: life’s triumphant march toward complexity, toward us. But like most creation stories this one is also a cautionary tale. It has both a Heaven and a Hell.

In 1877, when the Italian astronomer Giovanni Schiaparelli drew the first detailed map of Mars, he imagined the planet as an earthly paradise. He labelled one region Eden, another Elysium, others, on later maps, Arcadia and Utopia. Peering through his telescope on the roof of the Palazzo di Brera, in Milan, Schiaparelli had seen what looked like oceans, continents, and water channels swim into view. “The planet is not a desert of arid rocks,” he wrote. “*It lives.*” And his successors often took him at his word: the sharper their telescopes, the blurrier their vision. They saw mountains of ice and rivers of snowmelt, William Sheehan writes in his 1996 book, “The Planet Mars: A History of Observation and Discovery.” They saw fertile oases and a moss-green equator. They saw an irrigation system so linear and “trigonometric,” as the astronomer Percival Lowell put it, that it could only be the work of a highly intelligent race. Some even saw a Hebrew word for Almighty—*Shajdai*—spelled out on the planet’s surface. “True, the magnitude of the work of cutting the canals into the shape of the name of God is at first thought appalling,” the San Francisco *Chronicle* noted in 1895. “But there are terrestrial works which to us today seem no less impossible.”

By the time humanity got its first closeup view of Mars, a little less than a century after Schiaparelli mapped it, the planet had come to seem like a second, more exotic Earth. Books like “The Martian Chronicles” described a place of eerie desert grandeur, inhabited by slender, tawny beings given to strange hallucinations—Taos without the tourists. And though infrared studies suggested that its surface had seventy times less water than Earth’s driest desert, biologists still hoped for the best. “Given all the evidence presently available, we believe it entirely reasonable that Mars is inhabited with living organisms and that life independently originated there,” a study by the National Academy of Sciences concluded in March, 1965.

Four months later, NASA’s Mariner 4 spacecraft swung past the planet’s northern hemisphere and sent back a series of images. They were a grainy black-and-white—two hundred by two

hundred pixels, converted from lines of numbers—but they left a clear impression. Where Arcadia and Elysium lay, there was a desolate waste, pocked with craters. It didn't look like Earth. It looked like the moon.

The search for life on Mars is now in its sixth decade. Forty spacecraft have been sent there, and not one has found a single fossil or living thing. The closer we look, the more hostile the planet seems: parched and frozen in every season, its atmosphere inert and murderously thin, its surface scoured by solar winds. By the time Earth took its first breath three billion years ago, geologists now believe, Mars had been suffocating for a billion years. The air had thinned and rivers evaporated; dust storms swept up and ice caps seized what was left of the water. The Great Desiccation Event, as it's sometimes called, is even more of a mystery than the Great Oxygenation on Earth. We know only this: one planet lived and the other died. One turned green, the other red.

Still, we keep going back. Like a delinquent sibling, Mars is all we've got—the next Earth-like planet may be in the Tau Ceti system, seventy trillion miles away—and its virtues nearly redeem its vices. Mars has sunlight, water, carbon, and nitrogen. Its surface is no more unpleasant than the inside of a volcanic vent, where bacteria thrive. It may yet have life. On November 26, 2011, NASA sent the world's most sophisticated mobile science lab to explore it: the robotic rover Curiosity. The project's scientists were quick to lower expectations: they were just looking for places that might once have been habitable, they said. Yet Mars, even dead, may answer some very old questions about life: What sets its machinery in motion? Why here and not there? Why us and not them?

The command center for NASA's Mars missions is at the Jet Propulsion Laboratory in Pasadena, California. Hidden in the foothills of the San Gabriel Mountains, along a scrubby arroyo north of Los Angeles, it's an oddly bucolic setting for an endeavor so cerebral. On the paths between buildings, mule deer wander about, nibbling at potted plants and twitching their ears as rumpled engineers shuffle past, lost in calculation. When I was a boy, my father, who is an electrical engineer, used to do research at Caltech in the summer, and he sometimes took me to J.P.L. on weekends. The place had all the glamour of the space age then, with its glassy offices and swooping pavilions, moon rovers and rocket ships. It hasn't changed much, but the buildings now have a shopworn air—the fate of all shiny things. The lab's budget was slashed in the early eighties, its planetary missions nearly scrapped. Only military research has kept J.P.L. alive.

The morning of August 4, 2012—"Landing Day Minus One," as the NASA engineers called it—began with a briefing from a few of the project leaders. The rover was scheduled to touch down in less than forty-eight hours, after the most complex and technically daring landing sequence in the history of the space program. Most of NASA's successes are built on repetition. Curiosity's guidance system dated back to the Apollo days; its supersonic parachute came from the Viking missions of the late nineteen-seventies. But its signature component—a landing system

known as the Sky Crane—was brand-new. It hadn't even been tested on Earth: the Martian gravity and atmosphere could only be simulated on a computer. "A cockamamie device," one NASA researcher called it, in private. "A lot of us are crossing our fingers and gritting our teeth. Failure, unfortunately, is an option."

In the eight and a half months since the Curiosity mission had taken off from Cape Canaveral, it had escaped Earth's gravity, circled halfway around the sun, and traversed three hundred and fifty-two million miles of deep space. Now it had to home in on a patch of ground four miles wide by twelve miles long. It was a dart flung at a dartboard twenty thousand feet away. On a screen behind the lectern at the briefing, Doug McCuistion, the director of the Mars program, projected a poster with a halftime score on it: Mars 24, Earth 15. Of the thirty-nine spacecraft sent before Curiosity, less than forty per cent had reached the planet. "Mars is hard," he said.

NASA's solution, as usual, was to bury the problem in experts. At last count, more than seven thousand people had worked on Curiosity. The spacecraft had four main components: a rocket to lift it into space; a cruise stage to carry it to Mars; a landing shell to glide through the upper atmosphere; and the Sky Crane to hover above the surface and lower the rover to the ground. The first three stages, shaped by flight, were fairly sleek. But the Sky Crane and rover were strange, hybrid creations. "If you had seven thousand people design a car, you'd get something that looks like a Pontiac Aztek," Adam Steltzner, the leader of the entry, descent, and landing team, told me. The Sky Crane was a splayed, skeletal thing, with rocket thrusters for legs and cables spooling out of its belly. It looked like a robotic spider. The rover was more of a camel, with a knobby-kneed chassis and a long, many-jointed neck, surmounted by a binocular head. It was powered by a nuclear generator and bristled with lasers, scoops, cameras, and mechanical claws. "My fiancé says it looks like it was designed by a bunch of thirteen-year-old boys," one engineer told me.

She wasn't wrong, exactly, just off by a few decades. All nine of Curiosity's principal investigators were middle-aged men. Lined up behind the lectern in polo shirts or jacket and tie, they could have been spliced seamlessly into an old Apollo newsreel. But elsewhere in the hierarchy lay a horde of engineers who'd come to J.P.L. from all over the world since the moon landings. Miguel San Martín, the chief engineer for Curiosity's guidance, navigation, and control systems, grew up in Buenos Aires and Patagonia, listening to shortwave broadcasts about the Viking missions. Vandí Tompkins, the lone woman among the sixteen rover drivers, came from a small town in India. Their work bore witness to the undimmed romance of space, and to the wonders that an epic government program can still accomplish. Curiosity had taken ten years to build and cost two and a half billion dollars. And within forty-eight hours it would crash or land.

While I was at J.P.L., I heard talk of a survey, perhaps apocryphal, which asked astronauts if they'd go to Mars on a one-way trip. Three-quarters supposedly said yes. ("The pilgrims on the Mayflower didn't hang around Plymouth Rock waiting for a ship to take them back," the Apollo astronaut Buzz Aldrin later told me.) The Curiosity engineers seemed a less fanatical lot, but many

had spent years perfecting a single component—a thruster, say, or a winch—on which the whole project might hinge. Some were even living on Mars time, adding forty minutes to every day, till they were awake at night and asleep when the sun was out. “When you put it all together, there are centuries, if not millennia, of individual human investment in this thing,” Steltzner said. “So it’s a big deal, on a personal level, for all of us.” When I asked how he felt, he frowned. “I’m rationally confident and emotionally terrified,” he said. “We think we’ve crushed this fucker. But Mars, more often than not, has something waiting for us.”

The Sky Crane was Steltzner’s baby, so he had more to lose than most. The landing also happened to coincide with another long-term project of his, now approaching its final descent: his wife, Trisha, was nine months pregnant. (“I have a birth-minus-one-month daughter on the way” was how Steltzner put it.) Trisha, who works in education and outreach at J.P.L., considered this bad timing. But the twin arrivals seemed to have only energized her husband. Rather than cocoon himself at home and get some distance from his cockamamie device, Steltzner had become something of a poster boy for it. This was due, in part, to his hair. He wore it in a gelled and rakish pompadour, to go with his razored sideburns and ostrich-skin boots. Rangy and broad-shouldered, he lent a rockabilly swagger to even his most technical briefings. He’d pause for effect, peering darkly at the assembled press, then liken his team to modern-day knights sallying forth to “vanquish the dragons and demons” of Mars.

I’ve known Adam for several years, but it was still startling to see him up at the lectern. When I first met him, through an old friend in Los Angeles, I took him for a brilliant poser. He was charming and quick, with a vanity made bearable by his genuine affection for people. But he didn’t seem to belong to the sober breed I’d grown up with around my father. He was more like an actor playing a rocket scientist in summer stock. And yet, by all accounts, Steltzner is a remarkable engineer. He has a gift for visualizing designs—for seeing snapshots of the whole while others wrestle with details—and for drawing them out of the people around him. His flamboyance seems to set them at ease. He’s a champion of the odd concept and the improbable fix, the quirky solution that’s both elegant and logical. “It looks crazy,” he told me, pointing to a diagram of the Sky Crane on his computer. “It doesn’t look safe. Everyone that sees it says that. So there’s no shelter for us. There’s no fucking shelter. If it doesn’t work, they’ll eat us alive.”

That Steltzner was even at J.P.L. was something of a fluke—proof that Mars can pull the most wayward souls into its orbit. As far as he could recall, the first time he gave any serious thought to astronomy was in 1984, when he was twenty-one years old. He was living in Mill Valley then, playing bass in a rock band called Stick Figures. He was a college dropout and small-town playboy (he briefly dated the model Carré Otis), an assistant manager at an organic market and an occasional grower of weed. He had few skills and fewer prospects. Late one night, he was coming home from a gig in Marin County when he noticed that Orion was in the wrong place in the sky.

He'd seen it earlier that night, hanging above the lights of Port Richmond. Now it was over by the Golden Gate Bridge, but the Big Dipper hadn't moved. How could that be?

He vaguely remembered something about diurnal motion—the circling of stars overhead in relation to the Earth's rotation. But he'd never taken an astronomy course and had flunked high-school math for lack of attendance. His parents hadn't put much stock in formal education. His father was an heir to the Schilling spice fortune—a gifted, troubled man who could never quite settle on a career and slowly fell to drink. His mother co-founded a hippie nursery school. It was she who taught Adam to smoke his first joint. The family lived in bohemian splendor among the artists and musicians of Sausalito, in an Arts-and-Crafts mansion above the bay that's long since been sold. (It's now worth two and a half million dollars.) “The thing about inherited wealth is that the past is always better than the future,” Steltzner told me. “My dad had been trained to wait around for his dad to die and inherit money. And that's what I was trained to do. But, frankly, there wasn't going to be any money left.”

Nothing could live up to his father's corrosively critical eye, so he did his best to act as if nothing were at stake. He skipped school and climbed trees, broke into buildings and tooted around on his dirt bike. He perfected the art of buttboarding—sitting on his skateboard and careering down hills with no helmet and no brakes—and staged rock-throwing wars with other shiftless kids in empty lots. Between the ages of seven and seventeen, Steltzner broke thirty-two bones and got a hundred and seventy-two stitches. He can rattle them off in sequence, like body percussion: left arm, right arm, broken jaw, broken nose, mountain bike, BMX, skateboard, street luge, snapped finger, split brow, sprained joint, severed pinky. The last came from trying to slice through a bike lock with a hacksaw. The finger was reattached but still has very little feeling.

By that night in Mill Valley, when Steltzner looked up at Orion and wondered why it had moved, there was little reason to believe that he'd find the answer. He'd shown no intellectual promise since the age of seven, when a vicar at his parochial school declared him somewhat dim and advised his father to send him to trade school. Still, those stars stuck in his mind. A few weeks later, he went to the local community college to sign up for an astronomy class. Told that he had to take physics first, he reluctantly agreed, only to discover that he had a knack for it. More than a knack, really. “I just fucking dominated,” he told me. “There were tests where the average was thirty per cent and I would have a ninety-eight. I was the *dude*.”

He went on to earn a bachelor's in mechanical engineering from the University of California, Davis, where he was salutatorian and spoke at graduation. He won a full scholarship to Caltech for his master's, then followed his first wife to the University of Wisconsin for his Ph.D. Academic life agreed with him. It was social, collaborative yet intensely competitive, and it kept his fear of commitment safely at bay. “It was a kind of protected play,” he told me. “You get graded, you can mark your progress, but you're not quite playing for keeps.” It was NASA that taught him to do that, he added, then glanced at the Sky Crane on his computer again. “I may have

overcompensated,” he said.

Steltzner came to J.P.L. from Wisconsin in 1999, just in time for the Mars program’s last gasp. Or so it seemed. For a while after the Mariner 4 mission, astronomers had grown more upbeat about the planet. True, it was a wasteland. But it wasn’t quite as grim as it first appeared. The spacecraft had photographed less than one per cent of the surface, and the next few missions managed only flybys as well. It wasn’t until 1971, when Mariner 9 fell into orbit around Mars, that scientists got a good long look at it. The spacecraft flew less than a thousand miles above the surface—six times closer than Mariner 4—with what passed for a high-resolution camera back then: one pixel per hundred metres. In a little less than a year, it sent back more than seven thousand images.

If nothing else, Mars was spectacular. Great eruptions had shaped it, great windstorms sanded it. It had mesas, ice fields, and oceans of dunes. It had a rift valley four times deeper than the Grand Canyon and a mountain three times taller than Everest. (Its peak, sixteen miles high, was the only feature visible from space for a month after Mariner 9 arrived; the rest of Mars was covered by the largest dust storm ever observed by astronomers.) It was a planet of superlatives, of knife-edged landscapes never dulled by rain or burrowing roots. It wasn’t like the moon after all. It was more like Utah.

Four years later, when NASA sent two spacecraft to the planet’s surface—Viking 1 to the equator, Viking 2 to the north pole—its scientists no longer expected to find intelligent life. But they were after more than just pictures. Both landers had mechanical arms, to gather soil samples, and built-in labs to check for biological activity. Viking 1 was scheduled to land on July 4, 1976: the nation’s Bicentennial. “Barring the catastrophe of a nuclear war,” the *Times* editorial page declared that summer, “by the time of this nation’s Tricentennial, Mars could be sustaining a human population.”

It didn’t go quite as planned. The landing sites, when seen from orbit, were so rough that the two spacecraft spent weeks scanning for alternatives. By the time they finally touched down, the Bicentennial celebrations were over. Viking 1 ended up in a field of volcanic rubble; Viking 2 in Schiaparelli’s Utopia, a spot as flat and barren as a bocce court. The atmosphere was a hundred times thinner than Earth’s, the temperature at daybreak around a hundred and eighteen degrees below zero. Even so, when the first soil tests came back, NASA analysts popped a bottle of champagne. Two of the samples, when mixed with radioactive nutrients, gave off bursts of radioactive carbon dioxide—a sign that the nutrients had been metabolized. Some scientists still defend those results: the soil may have had microbes living on ice beneath the surface, they say. But the landers found no other signs of biological activity, nor any organic compounds. If anything, the soil seemed inimical to life: there was so much iron in it that any whiff of oxygen was quickly bound into rust. The planet was red for a reason.

“The Mars program has never fully moved past Viking emotionally,” Steltzner told me. Even if the planet had life, scientists now knew, finding it would be extremely hard. So they didn’t go back to the surface for twenty years. The lull of the late seventies gave way to the budget cuts of the eighties, which led to the “Faster, Better, Cheaper” era of the nineties—an attempt to build spacecraft more efficiently with the help of industrial partners like Lockheed Martin. NASA finally returned to Mars in 1997, with the Pathfinder lander and its roving sidekick, Sojourner (they mostly found more volcanic rocks). But the technical achievement was bracketed by disasters. The Mars Observer, launched in 1992, dropped out of sight three days before it was scheduled to enter orbit. The Mars Climate Orbiter, launched in 1998, incinerated in the planet’s atmosphere, owing to a mixup in measuring units between the ground crew and the onboard computer. A month later, the Mars Polar Lander touched down on the south pole and was never heard from again.

“It doesn’t take a lot not to be good enough,” Tommaso Rivellini, one of the engineers who worked on Pathfinder and the Polar Lander, told me. “There really are millions of things that have to go right. We just went a little too fast, a little too far.” As the Polar Lander was heading toward Mars, NASA was already working on its next mission: a spacecraft that would land on the planet, pick up soil samples, and send them back to Earth in a rocket. Now that project was scrapped as too risky. By the time Steltzner started working with Rivellini, in 2000, NASA had just two small rovers in development: Spirit and Opportunity. Steltzner calls them “a Hail Mary pass.”

If Viking was a technical triumph and a scientific letdown—its findings were “the great bummer of Mars,” one NASA scientist told me—Spirit and Opportunity were the reverse. Their landing system, borrowed from Pathfinder, was almost laughably simple: Rivellini and Steltzner just wrapped the rovers in air bags. When the two spacecraft arrived at Mars, in the winter of 2004, their landers dropped down on parachutes, then dropped the rovers like beach balls onto the surface. Once the balls stopped bouncing, the rovers shucked off their shells and emerged into the Martian light. It was an undignified entrance, but more than worth it. “I expected to find what we’d always found—a bunch of basalt,” John Grotzinger, a geologist at Caltech who was an adviser on the project and is now chief scientist for the Curiosity mission, told me. “And that’s pretty much what Spirit did find. But then Opportunity landed. When the first pictures arrived, we were joking that NASA must be sending these down from the Western U.S. Then the mineralogical data came in, and we started to go, ‘No way. No way.’ ”

Grotzinger is Steltzner’s opposite number in the Mars program: one man wonders how to get there, the other what we’ll find. The two get along well and occasionally have dinner or share a bottle of wine, but they have very different sensibilities. “He’s fairly charming, as scientists go,” Steltzner told me. “But he’s not brash by any stretch of the imagination.” Still, it’s Grotzinger who has led the more adventurous life. An expert in geobiology, he has spent his life tracking down Earth’s most ancient fossils in some of its most remote locations. If life ever existed

on Mars, he believes, it was most likely microscopic and lived more than three and a half billion years ago. But even on Earth, fossils that old are vanishingly rare. “You can count them on one hand,” Grotzinger says. “Five locations. You can waste time looking at hundreds of thousands of rocks and not find anything.”

Now fifty-five, Grotzinger has worked in Siberia, Namibia, Oman, and Arctic Canada, among other locations. He has rafted rivers in Yakutsk, dodged grizzly bears and black flies around Great Slave Lake (his record for fly bites is two hundred in a single night), and scouted rock formations on the Skeleton Coast, sometimes hiking more than twenty miles a day. The long months of solitude and open sky have given him a lean, wind-bitten look and a laconic style rare among NASA’s high-strung engineers. Watching him at work, in the days leading up to the landing, I was reminded of Henry Fonda in one of his early Westerns: squinting at the horizon and chewing over his options while the townsfolk galloped off in a dozen different directions.

To find the very oldest fossils, Grotzinger told me, you have to look for the conditions that formed them. If a site has water and heat, look for organic carbon; if it has organic carbon, look for the remains of microorganisms. But there’s a catch: water erodes organic matter as readily as it creates it. The signs of life are self-erasing. Ever since Darwin, scientists have been lamenting the gaps in the fossil record. Dinosaur bones and petrified trees aren’t that hard to find, but beyond a certain age—roughly six hundred million years ago, when the Cambrian era began—the evidence abruptly vanishes. “Record failure,” Grotzinger calls it. If life on Earth is four billion years old, the geologist J. William Schopf wrote in his 2001 book, “Cradle of Life,” four-fifths of it is largely undocumented. It’s like a history of the United States that begins in 1963.

What we do know about life’s origins is owed, in no small part, to a geologist named Stanley Tyler. In the summer of 1953, Tyler was fishing from a dinghy along the northern shore of Lake Superior when he noticed an odd outcrop nearby. Tyler had been mapping the iron bed that runs from northern Minnesota through southern Ontario, countless tons of which have been turned into cars in Detroit. Known as the Gunflint Formation, its deposits are usually rust red from the oxides in them. But this outcropping was glossy black and covered in knotty protrusions. Back at his lab at the University of Wisconsin, Tyler sliced a thin section of the stone and placed it under a microscope. When he shone a light up through it, he could see fine-grained particles of silica, known as chert, mixed in with what looked like coal. But there was something else, too: hundreds of hollow spheres and filaments. They looked like bacteria.

Tyler later showed photographs of his findings to Elso Barghoorn, a young paleobotanist at Harvard, who identified them as fossil microbes and fungi. (They have since been shown to be cyanobacteria.) The two scientists went on to document scores of samples from the site, showing that the bacteria had lived in great menageries and left behind weird, “cabbage-like structures” in the rock, as Schopf puts it. (He was a doctoral student of Barghoorn’s.) These were sensational findings. The Gunflint deposit was nearly two billion years old—in a stroke, it had quadrupled the

known history of life. Yet Barghoorn, embroiled in personal troubles, sat on the results for several years. By then, Tyler was dead, and a rival geologist, Preston Cloud, had sniffed out the site and done some analysis of his own. A prickly two-step ensued. When Barghoorn got wind of Cloud's work, after *Science* asked him to peer-review it, he kept the journal waiting for two weeks while hastily completing his own manuscript, with Schopf's help. Then he called Cloud to tell him that—what do you know?—he was ready to publish, too. “Seeing is believing!” Cloud replied, but he eventually agreed to let Barghoorn publish first. The two papers appeared in the journal two months apart, in February and April of 1965.

What followed was a Precambrian stampede: a race across the globe to find the world's oldest fossils. Barghoorn focussed on Australia, Cloud on Death Valley, others on China and Brazil, trailing graduate students behind them. Grotzinger was only a boy then, but he has an insider's view of that era: Preston Cloud was his uncle. When Grotzinger was still a geology student, and had just finished a postdoc at Columbia, he spent a winter in California learning to surf and visiting Cloud at U.C. Santa Barbara. It was there that he caught the bug for geobiology, he says, and his uncle's approach to it. “Barghoorn was satisfied just to look for the oldest fossils,” he says. “Cloud was interested in how those fossils tied into the evolution of the planet—how microorganisms changed the environment.” How did life beget life?

Late in the fall, during a rare lull in his work on the Mars program, Grotzinger and I took a drive to Death Valley—due east from his house in lush San Marino, across the front range of the San Gabriels, past Apple Valley and Barstow, and down into the great basin of the Mojave. Grotzinger often takes his geology students there, to a field school run by Caltech. Its ridges and outcrops are like a terrestrial anatomy lesson, he says—the planet's muscle and bone, peeled back and exposed to the dissecting sun. It's the closest thing in North America to a Martian landscape.

“The continent is literally being torn apart out here,” Grotzinger said, when we'd reached the Cajon Pass, on the eastern slope of the mountains. On either side of the road, along the jagged crease of the San Andreas, the land rose and fell like crumpled butcher paper. “You get mountains and valleys and mountains and valleys as it pulls apart,” Grotzinger said. “And the rocks vary from quite young to some of the oldest in North America.” Standing at the southern end of Death Valley, you could easily imagine yourself at Gale Crater—Curiosity's destination on Mars. A rim of jagged rock circled the horizon, its sides washed down to an alluvial plain below. Stony ridges gave way to tumbled boulders, slopes of sifted gravel, and then sand, blown into shifting dunes. Temperatures in Death Valley have been known to reach a hundred and thirty degrees, and rainfall averages less than two inches a year. Yet it was in places like this that Cloud and Barghoorn found the oldest signs of life. “They discovered the secrets of preservation,” Grotzinger said.

It usually began with standing water: a tide pool or pond or salty shallow, wet enough to breed bacteria but not so wet as to wash them away. These were common enough; the hard part was

keeping the water off the bacteria once they died. Membranes are delicate things. They can hold their structure for two or three weeks, at most, before they dissolve. To preserve them for more than a billion years—to make fossils out of ephemera—a site first has to coat its remains in a fixative: a thin layer of waterproof sediment that will slowly harden into stone. This “magic mineral,” as Grotzinger calls it, is usually silica, like the chert in the Gunflint.

In the half century since Cloud and Barghoorn began scouring the globe for similar sites, the history of life on Earth has been traced back nearly three and a half billion years. But the bigger story lies in the pattern behind the deposits they found. Biologists now believe that cyanobacteria, which produce oxygen through photosynthesis, probably first appeared around 2.7 billion years ago, but the Great Oxygenation didn’t begin for nearly half a billion years. In between, most of the Earth’s great iron deposits were laid down. To Cloud, this sequence made sense. The early oceans must have been full of soluble iron, he reasoned. As the bacteria produced oxygen, the two compounds reacted to form iron oxide, which precipitated onto the seafloor in great layers of rust. When the oceans ran out of iron, the oxygen was free to accumulate in the air. And that’s when Earth truly came alive.

Why not Mars? Its red sands are also full of iron, turned to rust by atmospheric oxygen. But somewhere along the way the planet ran out of air. Did an asteroid hit it, blasting the greater part of its atmosphere into space? Was its magnetic field disrupted as the magma in its mantle cooled, exposing it to solar winds? Was Mars, at half Earth’s diameter, simply too small to keep its invisible grip on the air? Whatever the answer, a planet once strikingly similar to ours has become a thoroughly alien place.

That’s why the pictures transmitted by Opportunity, nine years ago, were so startling. Instead of a gravelly desert, they showed craggy outcrops; instead of dark basalt, pale sediment. This wasn’t a lava flow. It looked like windblown soil from the bed of a lake or pond—the kind of place most likely to harbor life and preserve its remains. “That was when I realized that I was in this for good,” Grotzinger told me. “This wasn’t just a little detour.”

Oppportunity has been trundling around Mars ever since, though it was designed for only a ninety-day mission. (Spirit got stuck in a sand trap in 2009 and quit transmitting nearly a year later.) It never found the lake bed, or organic material of any kind. But together with a pair of equally long-lived satellites—Mars Odyssey and the Mars Reconnaissance Orbiter, which were launched in 2001 and 2005 and are still circling the planet—it gradually restored NASA’s technical reputation. “We were pretty full of ourselves,” Steltzner told me. “And NASA was pretty full of us, too.” The next step was to send a full-scale mobile laboratory to Mars. This time Steltzner’s team would have carte blanche in creating the landing system.

Thanks to its two new satellites, NASA could now pick out surface details the size of a kitchen table. It could identify soil types, verify the presence of water ice and dry ice at the poles, and

even track traces of water underground. This opened up dozens of promising new sites for the mission. The problem was landing on them. Some were littered with boulders; others bristled with sandstone spires or were perched above steep canyons. As unerring as NASA spacecraft could be, landings were accurate only to within fifteen hundred square miles. Air bags eased some of the uncertainty: they'd bounce off any obstacle they hit. But the new rover would be five times as large as its predecessors—an S.U.V. to their golf carts. “Air bags scale very, very poorly,” Steltzner says. “The surface area of a sphere goes up with the square of the radius, so suddenly the wrapper is twenty-five times as large. And now it's heavier, and the stress on the fabric goes up with the radius, too. It's a self-eating watermelon of despair.”

The traditional way to land a large spacecraft is to give it long legs and powerful thrusters. But legged landers tend to be tippy, and the rover still has to get down to the ground. Besides, the Mars Polar Lander came to grief with that system. A NASA inquiry later suggested that when the lander's legs unfolded, its computer mistook the vibrations for touchdown and shut off its thrusters—a hundred and thirty feet above the surface. For a while, NASA flirted with a design called a palette lander, which looked like a bug squished flat. (Its thrusters would be built to crumple on impact, so it could get away with short legs and low clearance.) But Steltzner didn't like that, either. “I super didn't like it,” he told me. “I hated it.” The palette lander would come in fast and low, on terrain that was impossible to predict. It could skitter and catch an edge, trip on a rock and flip, or suffer a thousand other mishaps. It was a computer modeller's nightmare.

The solution came to the team on a sweltering September morning in 2003, in a marathon meeting at J.P.L. Steltzner is happiest in situations like this: surrounded by whiteboards and brilliant minds, brainstorming ideas and winnowing them down. His house in Altadena, a modest bungalow surrounded by exotic fruit trees that he and his wife planted, often serves as a late-night design-and-disputation forum, with a full bar in the living room. (When I visited on the day of the Curiosity landing, the mirror above the mantel was covered in half-erased equations.) The session at J.P.L. went on for three days, then reconvened two weeks later, to make sure that everybody hadn't gone crazy. “The manager guys were literally squirming in their seats,” Rivellini said. “They kept trying to guide the conversation back to legged landers, but we just didn't want any of it.”

What they did want was “Rover on a Rope.” This was an idea first floated for the sample-return mission. It involved lowering the rover to the ground on cables while the landing shell was still attached to its parachute. The concept had been deemed too hard to control: the rover would swing like a pendulum as it flew, and its radar was too inaccurate to find safe anchorage. But that was then, Miguel San Martín said. His guidance-and-navigation team had reengineered the thrusters to make the lander more maneuverable. Its radar was much improved, and the new software they'd programmed could stabilize anything swinging beneath it. “It was one of those

‘Aha!’ moments,” Rivellini recalls. “The whole team just got it.” (The final patent would have nine names on it, Steltzner says, but it could have had many more.) If the guidance system was that good, why not get rid of the parachute earlier, and jettison the landing shell? That would leave a small, mobile craft that could maneuver on thrusters alone, hover near the surface, and lower the rover down. “With just a little bit of extra work,” Rivellini said, “we can get rid of the air bags and land this thing right on its wheels.”

The Sky Crane, as the new lander was called, turned NASA’s previous design philosophy on its head. It swapped a simple, sloppy, but proven technology (air bags) for a complex, precise, and unproven one. “We wanted an all-access pass to Mars,” Steltzner told me. Since the lander was now much more maneuverable, it could target a much smaller area—around fifty square miles—and avoid most obstacles within it. It could land big rovers or small, on flat terrain or sloped, in all kinds of weather. But only if everything worked—if the cables didn’t jam or the thrusters misfire or the radar malfunction or the rocket engine explode. For every one thing that could go wrong with air bags, the Sky Crane had a thousand. “The thing I’m most scared about is the thing I don’t know,” Steltzner told me. “Where does it live? It lives in the complexity of the beast that we’ve created—in the gremlin of self-generated complexity.”

At J.P.L. one afternoon, Steltzner showed me a scale model of the final design, with its spidery legs. Built by a man named Hirai Isao, who makes most of NASA’s models, it looked and felt like a high-end Star Wars toy (cost: five thousand dollars); a smaller version was already licensed for mass production. “You can just imagine what they could do with it,” Steltzner said, playing with its cables and tiny articulations. “It could have these beautiful die-cast parts, and little L.E.D.s where the thrusters are.” He was careful to speak in the conditional: there was once a toy Polar Lander, too, but Mattel stopped making it when the mission failed. “The rover is called Curiosity,” he said, “but we secretly named the descent stage Audacity.”

The morning of the landing dawned bright and clear in Southern California, as it did on the next planet over. “It’s a fine Martian day,” Doug McCuistion, the Mars program director, declared. “The sun’s coming up at Gale Crater. It’s gonna be warm. It’s gonna be sunny.” He grinned at the cameramen clustered around the lectern, the journalists now gathered in force in J.P.L.’s von Kármán Auditorium, with satellite vans parked outside. “This is it: the Super Bowl of planetary exploration. One yard left.”

McCuistion’s weather report was more than just scene setting. Curiosity was landing on Mars in an uneasy season, when the planet was swinging closer to the sun on its eccentric orbit, stirring up an already volatile climate. Compared with the sluggish air on Earth, the Martian atmosphere is in constant motion: between the surface and six feet above it, temperatures can vary by as much as sixty degrees. The air is so thin that the first glimmer of sun can throw it into violent convection, lofting up into towering thermals, twisting into dust devils, and collapsing back down as they cool.

Any loose dust picked up along the way will absorb still more heat, creating a feedback loop that can send storms surging across the face of the planet.

NASA keeps a set of sharp eyes on these developments through Odyssey and the Mars Reconnaissance Orbiter, and more than a dozen climate specialists who sift through the data they send back. (One of them, Bruce Cantor, of Malin Space Science Systems, in San Diego, has spent fourteen years tracking every dust storm on the planet.) Using weather models adapted from ones designed for Earth, they can now predict even the wind flurries inside Gale Crater. “What happens in the Mars movies, where people get swirled up in dust devils—that’s not going to happen,” Ashwin Vasavada, a planetary scientist tasked with coordinating NASA’s weather predictions for the landing, told me. “If you’re being hit by an atmosphere that’s only one per cent of the Earth’s, you’re less likely to get knocked down. But it’s still running at the same wind speed. It can still blast the paint off.”

Luckily, the rover was built to withstand such battering, and the landing site was well clear of dust storms for now. Gale Crater lies just south of the equator, near the Martian equivalent of northern Australia. The site was chosen from four finalists among the dozens identified by NASA, each with its own enticements. Holden Crater, in the southern highlands, is part of a former river system more than a thousand miles long and has what looks like a lake bed; Mawrth Vallis, one of the planet’s oldest valleys, has iron-rich silicas like those at the Gunflint; Eberswalde Crater, north of Holden, has a vast river delta with clay soils that seem to have accumulated over centuries. Gale is in some ways a poor second choice. Deltas like the one at Eberswalde, with their silty, gently deposited sediments, are often the best places to preserve organic remains. “I wanted to go to Eberswalde!” Steltzner told me. “It would have been more difficult. It’s three kilometres higher, and the terrain is tougher—spires and mesas. But the risks were acceptable: just a few percentage points higher.”

The choice came down to biology versus geology. Eberswalde had its delta; Gale had Mt. Sharp—a three-and-a-half-billion-year-old peak in the middle of the crater, with layered deposits like a textbook on Martian prehistory. Eberswalde might be the best place on Mars to find organics, but if none were found it had relatively little to teach us. Gale was less likely to have organics, but it was guaranteed to be geologically fascinating.

To Steltzner, the final decision seemed overcautious and uninspired: “If you’re into seeing how a dead planet was beaten up for a couple of billion years, cool. But it’s a couple of notches down from the fantastic school.” But to Grotzinger, Mt. Sharp was always the main attraction. Three and a half miles high, with no evidence of folding, faulting, or plate tectonics, it was like nothing on Earth. “This thing, it just seems incongruous,” he told me. “You can’t imagine how it formed.”

At first, Grotzinger thought of the crater as nothing but a runway for the rover. But a couple of

months before the landing, he decided to take a closer look. The crater was much too large for his team to study in detail: ninety miles in diameter, roughly the size of Connecticut and Rhode Island combined. So Grotzinger cropped out a hundred and fifty square miles around the landing area and divided it into quadrangles of about a mile on a side. Then he posted the satellite data online for any qualified geologist to map. It was an informal version of what NASA has always done: crowdsourcing.

When the results came back, Grotzinger began to see patterns he hadn't noticed before. There was an alluvial fan at the base of the mountain, for instance, that had some of the same sediments as Eberswalde. If they were lucky, Grotzinger now thought, Gale could have the best of both worlds: a crater that might once have been habitable and a mountain that could explain why it no longer is. But first they had to get there.

8: 26 P.M.: *The control room is locked down. For the next two hours, no one will leave until the rover lands. As Steltzner's team settles into its seats, a sly, defiant voice comes over the loudspeaker: "Why begin, then cry for something that might have been?" The singer is Frank Sinatra. The song, chosen by Steltzner and San Martín, is a Nelson Riddle arrangement recorded in 1966: "All or Nothing at All."*

Space exploration is science; landings are theatre. Steltzner's team would monitor every second of the descent, but this was far from a live event. Curiosity's signals would need fourteen minutes to travel the hundred and fifty-five million miles to Earth. By the time they reached the control room, the rover would already be on the ground—intact or in pieces. Steltzner's team had little left to do but watch, and be watched. Dressed in matching blue polos, they enacted the landing in a room like an amphitheatre, with box seats above it for V.I.P.s. Reports were made, rituals repeated. Bobak Ferdowsi, a flight director who changed his hair style for every milestone in the mission, had buzzed the sides of his head and dyed it with stars and stripes. He was henceforth known as Mohawk Guy. Lucky socks were worn, lucky beards unshaven, a marble moved from jar to jar to mark the mission's last day in space. Since 1964, salted peanuts have been eaten in the control room—a tradition born after a probe finally reached the moon on the seventh try. The lucky streak has long since ended, but peanuts are still passed around.

10:24: *Eighty-one miles above the surface of Mars, the landing shell plunges into the atmosphere. Shaped like a spinning top, it moves at more than thirteen thousand miles an hour. As it falls, it ejects two tungsten ballasts, a hundred and sixty-five pounds each, which tilt it backward to create lift. The shell now traces S-curves through the sky, guided by four pairs of thrusters.*

Seven minutes of terror: that was how Steltzner and his team liked to describe the descent to Mars. Between entering the top of the atmosphere and touching down, the lander had seven minutes to reach Gale Crater, find clear ground, and deposit the one-ton rover, with only an onboard computer to guide it. A few months earlier, NASA had made an animated film of the

sequence, with a Wagnerian soundtrack and special effects worthy of a Transformers movie. As the spacecraft hurtled through space, firing thrusters and shedding components, Steltzner and his teammates glowered at the camera and narrated each stage, statistics flashing around them: “Six vehicle configurations. Seventy-six pyrotechnic devices. Five hundred thousand lines of code. ZERO margin of error.”

10:26: The friction of the Martian air, thickening around the lander, fires the shell to nearly three thousand degrees. A heat shield along the bottom, made of phenolic carbon, incinerates as it falls, glowing like a miniature sun.

“You and I are sitting at the edge of an event horizon, like a black hole,” Steltzner had told me the day before. “Sunday night, we’ll slip into it, and at least two universes will be awaiting us on the other side: the one where we succeed and the one where we fail. People are scared shitless now. But if we stick the landing, all of a sudden they’ll be saying, ‘Hey, how about doing the next one the same way?’ ” He’d spent a lot of sleepless nights in the past few years, working through problems and e-mailing his teammates at four in the morning. “That’s when he does his worrying,” his wife told me. “I’ll say, ‘What are you thinking about?’ And he’ll say, ‘I’m thinking about the airflow over a 747.’ ” Yet he’d slept better the night before than he had in two years. Curiosity was on its own now, and he’d done what he could. The rest was up to space-time.

10:29: Seven miles above Mars, the supersonic parachute bursts open, yanking back the shell with a force of six Gs. Fifty-two feet wide and a hundred and sixty feet long, the chute can generate sixty-five thousand pounds of drag. Within a minute, it has slowed the shell down from nearly nine hundred to less than two hundred miles per hour.

The Martian atmosphere is a rocket scientist’s nightmare: thick enough to burn up a spacecraft but too thin to stop it. Only thrusters could slow the lander to its target velocity of 1.7 miles per hour. But if they came too close to the ground, they’d kick up a cloud of dust that would fall back on the rover and gum up its works. Hence the Sky Crane. “It is the result of reasoned engineering thought,” Steltzner insisted in the NASA film. “But it still looks crazy.”

10:31: The heat shield has been jettisoned, the parachute cut loose, the Sky Crane’s thrusters ignited. Less than a mile above the crater, it sweeps the surface with ground-probing radar and begins its descent: a hundred miles per hour, fifty, twenty. When it’s sixty feet in the air, cables unspool beneath it, lowering the rover to Mars.

Steltzner wanted no ambiguity now, no room for doubt. With the team ready to explode around him, he waited for triple confirmation. “Tango delta nominal,” an engineer called out: the rover had transmitted its final location and velocity (zero). “RIMU stable,” another said: the inertial navigators were at full stop. A third engineer was now supposed to count down silently from ten, to make sure the rover stayed in contact and the Sky Crane didn’t fall on top of it. (“I knew there was still lots of death waiting for us in the final stages,” Steltzner later said.) But in the back of the

control room a team member named Jonathan Grinblat couldn't help himself. Before the count was done, he began to bounce up and down in his seat and pump his fists above his head: "Yesss!" Then the whole team was on its feet, nearly drowning out the final call: "Touchdown confirmed. We're safe on Mars."

In the giddy days that followed, NASA nearly made up for the celebration it missed, thirty-six years earlier, when Viking was late for the Bicentennial. "TOUCHDOWN, NASA!" the front page of the *Times* declared, below a picture of Steltzner's team leaping around. *GQ* featured them in its "Men of the Year" issue, and Bobak Ferdowsi, the Mohawk Guy, woke up to find himself a celebrity, with twenty thousand new Twitter followers and half a dozen marriage proposals. ("You are my ideal man. i.e.: smarter than me with better hair.") He would later march in President Obama's Inaugural Parade.

The more stirring sight, though, came on the morning after the landing, at J.P.L. The press corps had thinned out by then, and a succession of anonymous engineers took to the lectern. Pale and baggy-eyed after weeks of worry, they presented their data one by one, nearly breaking down with joy and relief. They described how the component they'd made—their camera/radar/thruster/gyro—seemed to be operating just as it should. How years of single-minded labor had paid off in the end. How thousands of disparate parts and nearly as many scientists had come together in building this strange beast, and managed to convey it safely to another planet. How no one had let anyone down.

For most of them, it was a bittersweet moment. The landing was an unalloyed success—"It's almost creepy how well it went," Steltzner said—but it had left them without a job. NASA's budget depends on federal appropriations, and for the first time in a decade there was no money to go to Mars: a sample-return mission, originally slated for 2016, had been cancelled after the financial crisis. Within a few months of the rover's landing, a pair of new missions were hastily approved: a stationary lander, scheduled to launch in three years, which will study the planet's deep geology, and another rover to follow four years later. But neither will come close to Curiosity's technical challenges. And though private firms like SpaceX and Orbital Sciences are launching their own missions, "they're basically like NASA technology from the nineteen-sixties," Miguel San Martín told me. He laughed. "I'm convinced this is the last job I'll ever have."

He was wrong, of course. San Martín is now helping to develop a mission to land on a comet and send back samples. Rivellini is working on a new supersonic parachute, and others have shuffled into similar slots at J.P.L. But the team that created the Sky Crane—a device of disciplined bravado born of a decade of close collaboration—is gone. They're NASA's version of the 1997 Florida Marlins: dismantled as soon as they won the World Series.

Steltzner saw this coming. On the night of the landing—after he'd crashed the press conference with a conga line of engineers; after Nichelle Nichols, who played Lieutenant Uhura

on “Star Trek,” had hugged everyone in sight; after Buzz Aldrin had grumbled that at least the attention was off the moon for once, and the landing team had stumbled off to a nearby bar where they would celebrate till dawn—Steltzner went home early and crawled into bed. Then he clutched his pregnant wife and wept.

By the time I saw him again, in November, he had a new daughter. Olive was born under a blue moon three weeks after the Mars landing, in a delivery nearly as seamless as the Sky Crane’s. (The Steltzner coat of arms, ironically, has a stork on it.) He cradled her as we talked, and helped his ten-year-old, Caledonia, practice her violin on the side. He’d recently been made head of J.P.L.’s new office of Entry, Descent, Landing, and Small Body Access, but he was having a hard time focussing. “When you’re under such constant stress for years, the absence of it is quite hard to deal with,” he said. “It’s like I’ve been on a slow adrenaline drip. How do I get it up to concentrate on anything?”

He was an engineer at heart, he said. “To me, the science that comes out of Curiosity is much less compelling than the gesture of getting there—of flexing our collective toolmaker’s muscles to go and grab that science and get that rover to that place.” Yet he also knew that future missions might depend on the rover’s discoveries. If there were organic molecules on Mars, a sample-return mission might head to the planet after all—if not in 2016, then 2018 or 2020. And if living organisms were found? “Hell, we’d just be throwing shit up there all the time,” he said, his eyes lit with possibility. “Bad news: there’s nothing else on the planet that can hold a candle to this. Good news: a major mission like this always changes the future.”

That week, at J.P.L., I spent a morning with Vandī Tompkins, the rover driver. A slender, effervescent forty-year-old, with a Ph.D. in robotics from Carnegie Mellon, Tompkins spoke in a dizzying rush of perfectly articulated detail. The rover was taking its first soil sample that week, but she was even more excited about the arsenal of instruments that she could use to analyze it. Curiosity came equipped with lasers, spectrometers, and a gas chromatograph. It had a radiation detector, an X-ray crystallographer, and a complete weather station. It could vaporize a rock and identify its minerals from the spectrum of light they emitted, or drill a sample and tease apart its chemical constituents. It was like a Hummer with a half-dozen scientists crammed inside.

“It’s like being there,” Tompkins said. She and the five other drivers on her shift do most of their work while the rover is asleep. Every night, it shuts down its engine for eight hours to recharge its batteries with its nuclear generator. But first it sends its coordinates to Earth, along with panoramic pictures and occasional videos. These get downloaded into simulation software that Tompkins helped write. Wearing 3-D glasses, she can then program the next day’s activities, driving the rover around a virtual crater with detailed renderings of the terrain. If necessary, she can even test out the sequence at J.P.L., using an actual rover on a faux Martian landscape called the Mars Yard. Once complete, the program is beamed back to Mars, and the cycle starts over.

When I arrived that morning, the rover was parked a few yards from where it had landed, in front of a small rock dubbed Rocknest_3. Its first three months had been spent mostly on diagnostics: the robotic equivalent of hopping in place and shaking your arms before a marathon. Built for a two-year mission, the robot was more likely to last ten, with components hardened against cosmic rays and extreme temperature swings. Its weakness was its computers: they had less processing power than a PlayStation and were prone to software glitches. (The system had to be rebooted in early March, after some memory was corrupted.) Even when things were working flawlessly, NASA didn't take any chances: every instrument had to be calibrated, every action reviewed by teams of scientists. Merely moving a few feet to poke a rock could take three days, with the rover snapping pictures of its arm from every angle. "This is a two-and-a-half-billion-dollar mission," Tompkins said. "If you're responsible for losing one day, it's like three million dollars. And if anything goes wrong you can't stop it. There is no panic button."

She handed me a pair of 3-D glasses, and I watched as she practiced a "touch and go." This involved driving forward a few inches, measuring a rock with a pair of calipers, then driving away. Having written the rover simulation, driven Opportunity for three years, and practiced in the Mars Yard, Tompkins was at one with her software. She zoomed in on the rover and spun it around for different perspectives, hands tapping unconsciously on the keyboard and the mouse. She unfolded its seven-foot arm, then worked at positioning the calipers with the fewest possible moves. It was important to keep the jostling to a minimum, since the rover was still carrying a soil sample. Two days earlier, it had scooped some sand from a drift, sieved it to a fineness of less than a hundred and fifty microns, and dropped a portion half the size of a baby aspirin into a funnel on its back. The funnel led to a carousel of seventy-four quartz vials in its belly. Each vial, in turn, could be heated, irradiated, zapped with a laser, filled with solvents, or spun in a centrifuge. The hard part was deciding which tool to use. "The rover is like a Swiss Army knife," Grotzinger said. "You don't need all the gadgets out at once."

Like Viking, Curiosity started off with some false positives. Its first air and soil tests showed strong traces of methane, a compound usually produced by living things. But when the instruments were flushed out and new samples tested, the methane all but disappeared—just a contaminant brought over from Earth. Grotzinger had suspected as much, so he never released the results (though they were hinted at in the press). What he hadn't expected was the sheer quantity of usable data the rover was producing. It had barely moved, yet NASA analysts were already swamped—ten thousand tests by mid-November, eighteen hundred laser shots on a single rock. "I'm not sure that we can absorb everything the robot is teaching us," he told me. "That's absolutely mind-blowing."

The fog of data did make one thing clear: the crater alone was worth the trip. By October, Curiosity had found traces of calcium, often associated with water; by Thanksgiving, a streambed. Then, shortly before Christmas, the rover drove toward an area the team called Yellowknife Bay.

On thermal satellite images, the soil here seemed to retain its heat unusually well—a sign that it might contain clay or other hydrated minerals. “That’s when the world changed,” Grotzinger told me. As red earth gave way to gray and what looked like a shoreline, veins of a powdery white mineral appeared in the ground. When the rover zapped the powder with its laser, it turned out to be gypsum, a mineral that tends to form in bodies of water. By early March, the results were no longer in doubt: Curiosity had found a lake bed.

Yellowknife Bay was named for an area in the Canadian Arctic where Grotzinger worked as a young man, which has rock formations nearly four billion years old. The Martian version is half a billion years younger—about the same age as the oldest fossils on Earth. Grotzinger now believes that it was once filled with freshwater, fed by a network of streams that flowed down from the crater’s edge and spread out below. The lake bed is formed of a fine-grained mudstone, rich in clay. When the rover drilled a sample from it and heated it up in its onboard lab, it found traces of carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur—the building blocks of life. Just as promising was the presence of sulfates and sulfides, which some microbes consume as an energy source. Grotzinger compares these minerals to batteries: positively and negatively charged compounds that together can spark the beginnings of life.

Curiosity isn’t equipped to find fossils or microbes—it would need a high-powered microscope for that, or the ability to send samples back to Earth. But Yellowknife seems to be the next best thing: the first truly habitable site outside of our planet. The rock there isn’t unduly salty or oxidized, and it has a neutral pH—neither acidic nor alkaline. The water that flowed there was sweet. “It’s the kind that we humans would have been happy to have a glass of, if we were stranded in the desert,” Grotzinger said. The rover will spend the rest of the spring drilling and sampling the site, in search of organic compounds, then head for higher ground. It has a whole mountain left to explore.

There once were two planets, well accustomed to life and death. One had seven billion people on it; the other had none. Still, in some places they were hard to tell apart. “This is the terminus,” Grotzinger told me that day in Death Valley, when we’d climbed the ridge above the field camp. “This is where mountains go to die.” Below us, in the shimmering lake bed, nothing moved: no bird or bug or blade of grass. What could lead from here to a teeming biosphere, I wondered, but also to an empty rock like Mars? The answer, Grotzinger thought, was within the rover’s view. When he thought of Curiosity at Gale, it reminded him of John Wesley Powell, the great nineteenth-century geologist and explorer, peering over the edge of the Grand Canyon for the first time. “The rock layers are signals,” Grotzinger said. “Everything we see on Mars is a carrier signal, and the data is embedded in it.”

Six miles east of Yellowknife stood Mt. Sharp—like a great codebook of Martian geology. Grotzinger knew from satellite images that there was a layer of crystalline red hematite near the

bottom, then a layer of clay about a hundred and sixty feet above it, then a layer of sulfates above that. All three were associated with water, and all three might have organic remains. But the mountain's most interesting feature was much higher up, at around twenty-three hundred feet. That was where the motley sediments of ancient Mars were succeeded by layer upon unvarying layer of brownish rock, two miles high. Below that line the planet once had liquid water; above it nothing but dust.

"It might take us two years to crawl up there," Grotzinger said. "But I hope that one day we'll cross that boundary, and on the other side the Great Desiccation will have happened, and we'll find the geochemical evidence for it—whether the water seeped into the subsurface, or gathered at the poles, or escaped into space." You could see a similar dividing line here, he said, farther down on the ridge: muddy brown metamorphics, formed in the Earth's crust, giving way to darker, chunkier sediments, clotted with seashells. This was the Precambrian-Cambrian boundary, six hundred million years old. It marked the moment when the atmosphere finally built up enough oxygen to sustain organisms like us; when the slow waltz of geology gave way to the racing pulse of biology—burrowing, breeding, evolving, dying.

After we'd hiked down to the valley again, Grotzinger pulled an ice chest from the back of his S.U.V. and set out a picnic of salami and cheese, hard rolls, and ripe tomatoes. The valley seemed barren now, he said, but in the spring, after a dusting of rain, it would be bright with cactus blossoms and yellow creosote. When he camped here with his students, he could sometimes hear kangaroo rats or kit foxes moving beyond the firelight. On a clear night, with the stars and planets blazing above you, it could be breathtakingly beautiful, he said. "You look at enough pictures from Mars, and you really start to appreciate the Earth." ♦

PHOTOGRAPH: COURTESY NASA/JPL-CALTECH/MSSS/DAN WINTERS

- [Print](#)
- [More](#)

Share

Close

-
- [Reddit](#)
- [Linked In](#)
- [Email](#)

Subscribe now to get more of *The New Yorker's* signature mix of politics, culture, and the arts.