SURVIVING GALERAS

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SURVIVING GALERAS

THIS BOOK IS

DEDICATED TO MY FRIENDS,

COLLEAGUES, AND

FELLOW VOLCANO LOVERS

WHO LOST THEIR LIVES

ON GALERAS.

These superb creatures, these geological beasts, every man should see one up close at least once in his lifetime.

—Maurice Krafft

When I chose volcanoes for my field, Shaler said, "You have certainly selected the hardest." It was a missionary field, for in it people were being killed.

—Thomas A. Jaggar,
My Experiments with Volcanoes

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PROLOGUE

My colleagues came and went in the clouds. Banks of cumulus drifted across the peaks of the Andes, enveloping us in a cool fog that made it impossible to see anything but the gray rubble on which we stood. Perched at 14,000 feet on a cone of volcanic debris in southwestern Colombia, we were checking the vital signs of Galeras — gases, gravity, anything that would tell us whether the volcano might erupt.

As morning gave way to afternoon, the clouds occasionally dispersed, offering a heartening glimpse of blue sky and revealing Galeras's barren, imposing landscape. At the center of the tableau was the cone, 450 feet high, and its steaming crater. Surrounding the cone on three sides were high walls of volcanic rock, known as andesite. Forming an amphitheater 1.3 miles wide and open to the west, these ramparts were a subtle palette of dun, battleship gray, and beige. The top of the escarpment was composed of crumbling columns of hardened lava, the bottom a steep incline of rock and scree. All of it was the remnant of an earlier volcano that had collapsed thousands of years ago, spilling its contents down the mountain in a vast debris field. Occasionally I glimpsed in the west a forested, razorback ridge sloping toward the equatorial lowlands 9,000 feet below. That was the flank of an ancient volcano, which imploded 580,000 years ago after a massive eruption.

For miles around, the landscape was defined by these vestiges of earlier Galerases in various stages of decay and erosion.

Around one in the afternoon, I stood with four other geologists on the crater's lip and gazed into the steaming pit. Like the craters of most explosive volcanoes, this was not a cauldron of lava. It was a moonscape. Some 900 feet wide and 200 feet deep, the mouth of Galeras was a misshapen hole strewn with jagged boulders. Much of that rubble came from a hardened magma cap, or dome, that had been blown to pieces six months earlier in an eruption. At first glance, the crater seemed a sterile place, its colors running a dreary spectrum from dark gray to brown to beige. But on closer inspection the mouth revealed pockets of color — rust-hued swaths of rock breaking down in the heat and gases of the crater and canary-yellow patches of sulfur that had accumulated next to a gas vent, known as a fumarole. These vents were small fissures where high-pressure gases were released from the magma body beneath the volcano. The gases, which assaulted the nostrils with a melange of sharp, acrid odors right out of the chemistry lab, shot from the fumaroles with a hiss, obscuring the landscape in a swirl of vapors.

Galeras's fumaroles were relatively quiet that day, emitting a *whooshing* sound much like that of a steam machine used to clean buildings. When you step down into such a crater, the howl of the wind at 14,000 or 16,000 feet is instantly replaced by the eerie quiet of the earth's interior. The exception is when volcanoes are riven by high-pressure, high-temperature fumaroles. Then you feel as if you are planted behind a jet engine as it prepares for takeoff. Such fumaroles are not encircled by yellow sulfur crystals, which form at lower temperatures, but rather by a bathtub ring of expelled minerals in black, orange, blue, and white.

I divide volcanoes — and their craters — into two types, hot and cold. Galeras falls into the cold category, which has its own mix of discomforts. Chief among them are the thin air and the frequent shifting between overheating and freezing as you sweat during the ascent, then shiver when the sun disappears behind clouds and you work at high elevations. With hot, lower-altitude volcanoes, such as those in Costa Rica and Nicaragua, you sweat all the time, your clothes stiffening from the salt when they dry. Nearly all craters are awash with acidic gases so strong they can corrode the metal eyelets on your boots and leave your skin feeling as if it has been rubbed raw with Brillo pads.

That afternoon on Galeras, steam clouds often obscured my friend Igor Menyailov, a highly regarded Russian volcanologist who was sitting amid a jumble of rocks thrusting a glass tube into a fumarole. From deep inside the earth, gases streamed out of the vent at 440 degrees Fahrenheit and bubbled into solution in Igor's double-chambered collection bottle. Taken over time, these samples of sulfur and chlorine might reveal the volcano's secrets. Was the magma body rising? Was an eruption imminent? It was Igor's first time on Galeras, his first time in South America, so he could tell little about this particular mountain yet. But the fifty-six-year-old Russian — a short, handsome man who learned English by listening to black market recordings of Elvis Presley — looked content, smiling, smoking a cigarette, swiveling his head away from the shifting gas clouds as he talked with the Colombian scientist Nestor García.

Circling the rim of the crater, appearing and reappearing in the fog like a phantom, was the English volcanologist Geoff Brown, accompanied by the Colombian scientists Fernando Cuenca and Carlos Trujillo. Brown, a rangy, affable man who also had never set foot on Galeras till now, was taking the volcano's pulse with a sophisticated contraption called a gravimeter. One hundred million times more sensitive than a grocer's scale, the gravimeter gauges the forces of gravity on a mountain as it heaves under the power of rising, molten rock. Geoff was trying to map the innards of Galeras, hoping, like Igor, to determine if magma was on the move or if an eruption was likely. We all used different methods, but our goal was the same — to understand what makes a volcano tick, to forecast eruptions, to save lives. We all wanted to save lives.

I know now what a tricky and elusive thing memory can be, particularly after a calamity such as Galeras. I sustained a grave head wound, but was nevertheless able to piece together a picture of the last minutes before the eruption. Over the years, as I underwent sixteen operations, as Galeras greeted me every morning when I awoke, as I slogged through a recovery that continues to this day, I came to believe unshakably in my version of what had transpired on the crater rim before Galeras blew. But I am less certain now. Three of my colleagues, standing just feet from me, remember things differently. Are they right? Can their stories really be true? Some of my memories are vivid, others less so. But no matter. This is what I remember of the moments before Galeras exploded. About the eruption itself — well, we're all more or less in agreement on that.

On January 14, 1993, around 1:40 P.M., I was on the lip of the crater next to José Arlés Zapata, a young Colombian volcanologist. Three tourists, who had hiked up to see what the scientists were doing on the volcano, stood a few feet away. Near them, moving diagonally down the volcano's flank, were two geologists from the United States and one from Ecuador. I was in charge of this foray onto Galeras and just minutes before had asked these scientists to begin walking off the volcano. As a rule, I like to wrap up work on Andean volcanoes by early afternoon, since the heaviest clouds tend to obscure the peaks later in the day.

Igor Menyailov and Nestor García were in the crater, resting after taking their final samples. Geoff Brown, Fernando Cuenca, and Carlos Trujillo were on the crater's western rim, carrying out their last gravity readings. Geoff was too far away to hear me, so I just waved at him, indicating it was time to go.

A rock tumbled off the inside wall of the crater — a common occurrence that at first aroused no concern in me. But a second rock clattered down the crater mouth, then a third, and soon a cascade of stones and boulders rained onto the floor of the volcano. It was an earthquake or an eruption. Either way, we needed to flee.

"Hurry up! Get out!" I shouted in English and Spanish.

The volcano began to shake, and I turned to run down the scree-covered flank. I had made it only a few yards when the air was rent by a sound like a thunderclap or a sonic boom. Immediately afterward I heard a deafening *craaack*, the sound of the earth's crust snapping. Instinctively, I hunched my shoulders and hiked my backpack over my neck and head. I did not get far.

My fascination with volcanoes, now a quarter century old, taps into something universal and timeless. As they watched fountains of lava spew from Mount Etna in Italy or Popocatépetl in Mexico, the ancients believed they were witnessing a phenomenon linked to the origins of the universe. The flames and magma gushing from a volcano came from a place as mysterious as the heavens above. Small wonder that the Mayas, Aztecs, and Incas tossed virgins into the mouth of this beast; it was capable of destroying villages, towns, entire civilizations in an instant. Human sacrifice, they believed, would placate the monster.

To the Greeks, volcanoes were a direct conduit to Hades. The Romans believed the entrance to hell was in the Phlegraean Fields, next to Vesuvius, where gases poured out of hundreds of fumaroles. Vulcan — the Roman god of fire — lived deep inside a mountain on Vulcano, in the Aeolian Islands. There, at his underground forge, he rocked the earth and unleashed eruptions as he made weapons for Apollo, Hercules, and the other gods. The Icelanders, living on an island that was but a mound of volcanoes, believed hell's gateway was the crater of the massive fire mountain Hekla.

Like any grand and destructive spectacle, volcanoes have alternately attracted and terrified humanity through the ages. The difference between ordinary people and volcanologists is that, with us, the appeal far outweighs the terror. Ours is a counterintuitive endeavor. Most people flee from erupting volcanoes. We head straight for them.

From the moment I first set foot on a volcano — at Pacaya, Guatemala, in 1978, where I stared into a crater with dozens of hissing fumaroles — I have found it an exhilarating experience. The spectacle, especially at lava-spewing volcanoes, is impressive. On later visits to Pacaya, I watched as the volcano — with a big *KAVOOM!* — repeatedly launched blobs of magma as big as trucks 200 yards into the air, whereupon the projectiles disintegrated and fell back to earth in hundreds of glowing, baseball-size pieces. At that same volcano, a group of students and I witnessed a lava flow, 9 feet thick and a half mile long, slowly ooze out of Pacaya's flank. We tossed banana peels into the flow and watched them turn to ash with a hiss. Rocks tumbled out of the black stream, revealing the incandescent, orange-yellow core of the lava tongue. We clocked the flow's speed, about 15 feet per hour, and took its temperature, 1,970 degrees F. You could only insert the temperature probe when the wind was blowing away from your body; otherwise you started to cook.

Lava is pretty to look at but rarely dangerous. Eruptions are driven by the explosive power of pent-up gases. (Think of the cork blasting off a bottle of champagne.) But the lava that pours out of Kilauea and other picturesque Hawaiian volcanoes tends to be relatively fluid and depleted of its gases, hence not explosive. The volcanoes with thick, pasty magma — from which gases cannot readily escape — pose the greatest danger of eruption. On these mountains there often isn't a river of lava in sight.

The subtler, extraterrestrial beauty of these explosive volcanoes is, to me, no less stirring. Gases roar out of fumaroles. Hunks of basalt the size of small cars litter the landscape, vestiges of earlier eruptions. I always sense that, despite the barren surroundings, I am perched on a conduit to the most basic energy of the universe, a pipeline to the beginnings of the planet. No other place leaves me as keenly aware of man's powerlessness in the face of nature and the inconsequence of a single life.

I also take pleasure being in a place where, with good reason, few people ever set foot. The splendid loneliness of our work was brought home to me recently when I looked at a series of photographs of a colleague, David Johnston of the U.S. Geological Survey, sampling gases on the summit of Mount St. Helens on May 17, 1980, the day before it erupted. The volcano's northern flank was bulging out as much as 12 feet a day from the increasing pressure of rising magma. The governor had ordered the evacuation of nearly everyone within 8 miles of the volcano. Yet Johnston and another young volcanologist, Harry Glicken, rode a helicopter to the top of the volcano, landed on its swelling hide, and took gas samples.

The first picture, an aerial, shows the gray northern face of Mount St. Helens, with an arrow pointing to the area where Johnston was working. The second and third photographs, taken by Glicken with a telephoto lens, show a speck of a man, dressed in blue jeans, bending over a fumarole. That was Johnston. I can imagine the fear and excitement that stirred inside him as he hurried to collect his samples and get off the volcano, whose ever-distending flank promised that it would soon blow. He was alone on top of the mountain, riding the back of a monster.

By the next morning Johnston was dead. Studying the volcano from an observation post 5.7 miles from the summit, he was incinerated and buried in a blast as powerful as five hundred of the atomic bombs dropped on Hiroshima. Glicken was not killed at Mount St. Helens. He died eleven years later in an eruption in Japan.

My colleagues and I don't harbor a death wish. But despite the progress we've made in taking a mountain's measure using seismometers and other remote sensing devices, the best way to understand a volcano is still, in my opinion, to climb it. I study volcanic gases, which indicate how much magma is rising inside a volcano and how explosive it is likely to be. The most accurate way to sample gases is to descend into a volcano's crater and insert pipes into the fumaroles expelling steam, carbon dioxide, sulfur dioxide, and other compounds. This is dangerous work, as I know from personal experience and the loss of a dozen friends and colleagues. But the goal, which has driven me throughout my career and has taken me to more than a hundred volcanoes in two dozen countries, is a worthy one: to improve our ability to forecast eruptions.

All the volcanologists I admire, whether they've died in eruptions or lived to old age, share a passion for working *on* volcanoes. Most geologists are like pathologists, scrutinizing dead systems for clues of cataclysm and violent demise. Volcanologists are emergency room doctors. We work in the here-and-now, plunging into crises as the earth's fifteen hundred active volcanoes take turns popping off. We clamber on volcanoes because it is the best way to understand their behavior. But we're also hooked on the thrill of climbing into the crater, of confronting so monumental a force. No place on earth leaves me feeling as alive as a volcano does.

In the quarter century since I began studying geology, our knowledge of volcanoes has grown dramatically, testimony to how young the discipline is. Only in the last few decades has the cornerstone theory of plate tectonics become fully understood and accepted. I have witnessed and played a small role in these recent advances in our knowledge, yet a quarter century of work has not diminished my awe of the power of volcanoes and their role in creating our planet. Our atmosphere and our oceans appeared roughly 4.4 billion years ago, when the new planet — an accretion of star dust — began to vent gases and water through primitive volcanoes in the form of steam. Over the past 2.5 billion years, the earth's plates have collided, separated, collided again, and thrust under one another to create our landscape. Drive down the spine of the Appalachians and you are cruising over the remains of ancient volcanoes that ceased spitting magma more than 200 million years ago. Visit Yellowstone Park and you are in the midst of three gigantic calderas, circular depressions formed when a volcano ejects its contents and then collapses in on itself. The three eruptions in the Yellowstone Basin, which occurred from 2 million to 600,000 years ago, blasted out several thousand times more pumice, rock, and ash than the 1980 eruption at Mount St. Helens. One Yellowstone eruption alone created a caldera about 30 miles long and 50 miles wide.

West of Yellowstone, in eastern Oregon and Washington, sit the vast basalt canyonlands of the Columbia River. In this basin, about 16 million years ago, fissures in the crust opened up and, over the course of 1 million to 2 million years, oceans of magma poured out onto the surface from a source hundreds of miles inside the earth. Piling up in pancake-like layers, the basalt reached a depth of nearly 10,000 feet in some places. The accompanying ash and gas would have blocked some of the sun's rays, drastically lowering temperatures worldwide. But the Columbia River "flood basalts" were dwarfed by two earlier basalt outpourings in India and Siberia.

Those events, one occurring 248 million years ago and the other 65 million years ago, radically altered the earth's climate and may have played a role — possibly along with meteorite impacts — in the mass extinctions of dinosaurs and other animals.

Such calamities are almost beyond comprehension. Easier to grasp are the great eruptions of recent times, minuscule by comparison but still awesome in their destructive power. In the past 225 years alone, volcanic eruptions have killed at least 220,000 people. Only a handful died in lava flows; the rest perished in ways that do not readily come to mind. In 1783, in Iceland, the earth was split by a 17-mile volcanic fissure, which gushed ash, lava, and gases for several months. Nobody died in the actual eruption, but the poisonous fluorine gas that rushed out of the vents blanketed the countryside and killed half of the nation's cattle and three quarters of its sheep. In the ensuing famine 9,300 people died, one fifth of Iceland's population.

In 1815, in what was probably the largest eruption of the last 10,000 years, Tambora exploded on the island of Sumbawa in Indonesia. About 12,000 people died immediately, either incinerated by speeding clouds of gas and ash, known as pyroclastic flows, or drowning in huge volcano-induced waves, known as tsunamis. Later, at least 44,000 people — some say as many as 100,000 — perished of famine and disease on neighboring islands when thick layers of ash ruined crops and killed livestock. Volcanic aerosols and dust in the stratosphere made temperatures drop around the world, causing "the Year Without a Summer" in New England and creating the vivid red sunsets painted by the English artist J.M.W. Turner.

In 1883, also in Indonesia, Krakatau erupted, its blast heard as far as Rodrigues Island in the Indian Ocean, 2,900 miles away. An estimated 36,000 people died, most of them in towering tsunamis that swept the island of Sumatra.

Nineteen years later, in 1902, Mont Pelée erupted on the island of Martinique, unleashing a pyroclastic flow that sped down the mountain at 100 miles an hour and, in minutes, killed 27,000 people in the city of St. Pierre.

In 1985 a small eruption at Nevado del Ruiz in Colombia melted glaciers at the volcano's summit and created a mudflow that swept through the town of Armero, killing 23,000 people in several hours. Two days later I was on the scene, measuring the gases streaming out of Ruiz and flying over the entombed town. Scientists from both Colombia and the United States had warned of such a disaster but were ignored by local civil defense officials.

I left Armero keenly aware that if we don't improve our ability to forecast eruptions and educate local officials, another eruption will kill tens of thousands, perhaps hundreds of thousands, of people someday. Burgeoning populations, particularly in Third World countries, have pushed many people even closer to active volcanoes. Today, roughly 500 million people live within reach of an eruption. The famed eruption of Vesuvius in A.D. 79 killed several thousand people at Pompeii and Herculaneum. Dr. Peter Baxter, a good friend and the world's leading expert on how volcanoes kill, says that if a similar eruption occurred without warning today, and if the evacuation of Naples and its suburbs moved slowly, more than 100,000 people might perish in a few minutes.

Six years after the eruption at Galeras I stood again at the crater's rim, scarcely recognizing the blasted, gray pit spread out before me. The ledge on which Igor Menyailov and Nestor García knelt and sampled gases had disappeared. The western rim, where Geoff Brown, Fernando Cuenca, and Carlos Trujillo stood, had been partially blown away by the eruption. Portions of the crater's southwestern lip had collapsed. Even the outer flank of the crater, where I had run for my life, had changed, its lower reaches littered with boulders — some as big as washing machines — thrown from the volcano. The truth is that few places on earth are as mutable as a volcano's peak, where high-pressure gases force open new fumaroles and eruptions scour the crater's bottom and sides.

Gazing into the crater, I was struck by how tiny, in a geological sense, the eruption had been. As the steam from fumaroles drifted past me and wafted down Galeras's western flank, I reminded myself that the deadly eruption was a mere hiccup, a blast so small that geologists decades hence will find no sign of it. Yet the power of the eruption, to those of us who lived through it, was staggering. It wiped five of my colleagues from the face of the earth. It killed nine men, injured six others, and continues to ripple through the lives of dozens of people. It nearly killed me.

The volcano runs like a fault line through my days, dividing my existence into life before Galeras and life after.