with the gas plentiful; when grown in low levels, the opposite was true. Such a clear result delighted the experimenters, which included a colleague of Berner's named David Beerling, now teaching at the University of Sheffield in England. Leaf stomata are readily observable on most well-preserved fossil leaves, and when the investigators turned to the fossil record, the results confirmed Berner's model results.

**LET US BRING THIS ALL TOGETHER. IT IS HERE PROPOSED THAT EACH OF** the greenhouse extinctions had a similar cause, and here we can summarize the sequential steps.

First, the world warms over short intervals of time because of a sudden increase of carbon dioxide and methane, caused initially by the formation of vast volcanic provinces called flood basalts. The warmer world affects the ocean circulation systems and disrupts the position of the conveyer currents. Bottom waters begin to have warm, low-oxygen water dumped into them. Warming continues, and the decrease of equator-to-pole temperature differences reduces ocean winds and surface currents to a near standstill. Mixing of oxygenated surface waters with the deeper, and volumetrically increasing, low-oxygen bottom waters decreases, causing ever-shallower water to change from oxygenated to anoxic. Finally, the bottom water is at depths where light can penetrate, and the combination of low oxygen and light allows green sulfur bacteria to expand in numbers and fill the low-oxygen shallows. They live amid other bacteria that produce toxic amounts of hydrogen sulfide, and the flux of this gas into the atmosphere is as much as 2,000 times what it is today. The gas rises into the high atmosphere, where it breaks down the ozone layer, and the subsequent increase in ultraviolet radiation from the sun kills much of the photosynthetic green plant phytoplankton. On its way up into the sky, the hydrogen sulfide also kills some plant and animal life, and the combination of high heat and hydrogen sulfide creates a mass extinction on land. These are the greenhouse extinctions.

The sequence of events outlined above can be considered a combined hypothesis for the cause of greenhouse extinctions and can be named the conveyer disruption hypothesis. There was obviously variability in each extinction, but if the extinctions are examined in a fashion similar to how taxonomists classify living organisms as a species, it seems quite clear that the mass extinctions considered here as greenhouse extinctions are a different beast than the K-T, our now sole known impact extinction.

What would Earth be like in the midst of such an event? Let us crank up a hypothetical time machine and visit one. We have a lot of choices of where to go, back in time: the mass extinctions ending the Cambrian, some 490 million years ago; the late Ordovician mass extinction, some 450 million years ago; several late Devonian mass extinctions, around 360 million years ago; the Permian mass extinction(s), ranging from 253 million to about 247 million years ago; the Triassic mass extinctions, ranging from 205 million to 199 million years ago; the Toarcian mass extinction, some 190 million years ago; the Jurassic–Cretaceous mass extinction, some 144 million years ago; Cenomanian–Turonian mass extinction, some 93 million years ago; and the Paleocene thermal event, some 55 million years ago. All are united by cause, increased carbon dioxide in the atmosphere, leading to change in ocean currents, and eventual anoxia. Just because we get to see some dinosaurs, let's go back to near the end of the Triassic period, to the site in Nevada that begins this book:

No wind in the 120-degree morning heat, and no trees for shade. There is some vegetation, but it is low, stunted, parched. Of other life, there seems little. A scorpion, a spider, winged flies, and among the roots of the desert vegetation we see the burrows of some sort of small animals—the first mammals, perhaps. The largest creatures any-where in the landscape are slim, bipedal dinosaurs, of a man's height at most, but they are almost vanishingly rare, and scrawny, obviously starving. The land is a desert in its heat and aridity, but a duneless desert, for there is no wind to build the iconic structures of our Saharas and Kalaharis. The land is hot barrenness.

Yet as sepulchral as the land is, it is the sea itself that is most frightening. Waves slowly lap on the quiet shore, slow-motion waves with the consistency of gelatin. Most of the shoreline is encrusted with rotting organic matter, silk-like swaths of bacterial slick now putrefying under the blazing sun, while in the nearby shallows mounds of similar mats can be seen growing up toward the sea's surface; they are stromatolites. When animals finally appeared, the stromatolites largely disappeared, eaten out of existence by the new, multiplying, and mobile herbivores. But now these bacterial mats are back, outgrowing the few animal mouths that might still graze on them.

Finally, we look out on the surface of the great sea itself, and as far as the eye can see there is a mirrored flatness, an ocean without whitecaps. Yet that is not the biggest surprise. From shore to the horizon, there is but an unending purple color—a vast, flat, oily purple, not looking at all like water, not looking like anything of our world. No fish break its surface, no birds or any other kind of flying creatures dip down looking for food. The purple color comes from vast concentrations of floating bacteria, for the oceans of Earth have all become covered with a hundred-foot-thick veneer of purple and green bacterial soup.

At last there is motion on the sea, yet it is not life, but anti-life. Not far from the fetid shore, a large bubble of gas belches from the viscous, oil slick–like surface, and then several more of varying sizes bubble up and noisily pop. The gas emanating from the bubbles is not air, or even methane, the gas that bubbles up from the bottom of swamps—it is hydrogen sulfide, produced by green sulfur bacteria growing amid their purple cousins. There is one final surprise. We look upward, to the sky. High, vastly high overhead there are thin clouds, clouds existing at an altitude far in excess of the highest clouds found on our Earth. They exist in a place that changes the very color of the sky itself: We are under a pale green sky, and it has the smell of death and poison. We have gone to the Nevada of 200 million years ago only to arrive under the transparent atmospheric glass of a greenhouse extinction event, and it is poison, heat, and mass extinction that are found in this greenhouse.

**THIS SHOULD THUS BE THE END OF THE BOOK. IMPACT ONLY RARELY** causes mass extinction. But it is the realization by an increasing number of us of just what *did* cause the other mass extinctions that should make every citizen stand up. The beauty of dinosaur stories is that no matter how ferocious or dangerous they are in the movies, that is all that they are: in the movies. Here, however, we have a process that is very real—mass extinction—and the understanding that conditions on Earth now in some ways seem similar to the causes of the mass extinctions of the past. Carbon dioxide is carbon dioxide, whether it comes from a smoking volcano or a smoking car. The question thus becomes one of whether the rate of carbon dioxide increase in our world is on par with the rate during those times when greenhouse extinctions occurred. Just how much danger are we in, anyway? To answer that, we need to look at the "natural" rates of carbon dioxide formation as well as the human rates and see if our modern world is so different from the deep past that it renders the current, rising carbon dioxide levels less dangerous than they were so many times in the past.

We have thus come to a point where the past meets present. What do modern events look like when examined through past-tinted glasses?