The Earthquake Observers

Disaster Science from Lisbon to Richter

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For Paul

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Introduction

> No tremor is felt, no liquid is spilled, without the direction in which it occurred being reported to the paper the next morning. . . . Day in, day out, today, tomorrow, eternally. Until the world truly comes crashing down.
>
> —Karl Kraus, "The Earthquake" (1908)[1]

I should admit from the outset that I have never felt an earthquake. What's more, unlike many of the nineteenth-century witnesses that people the following pages, I have no longing to experience one. Nor was I fascinated by seismology when I began to investigate its history; that came later. Instead, this book began with a metaphor: an earthquake of the mind.[2]

Nietzsche used the metaphor of the intellectual earthquake to describe the consequences of the ruthless empiricism of the nineteenth century. "As cities collapse and grow desolate when there is an earthquake, and man erects his house on volcanic land only in fear and trembling and only briefly, so life itself caves in and grows weak and fearful when the concept-quake [*Begriffsbeben*] caused by science [*Wissenschaft*] robs man of the foundation of all his rest and security, his belief in the enduring and eternal."[3] The nineteenth century's relentless scientific spirit had shaken traditional beliefs like an earthquake. The result was a sense of radical contingency and disorientation. Nietzsche may have judged this condition a "sickness," but not all his contemporaries agreed. The version of the metaphor that first piqued my curiosity appeared in a didactic allegory by the Austrian physicist Franz Serafin Exner. A young man sets out to explore the world and encounters novelties that contradict the wisdom inherited from his elders: "As in an earthquake, what begins to shake is just what we have since childhood grown used to regarding as the one solid thing in the world, and

so in an instant our previous faith proves to be false and one-sided."[4] For Exner, I found, this crisis was a requisite step on the way to intellectual maturity: acquiring a scientific mindset meant embracing the predicament of contingency with the help of probabilistic reasoning. So why, I wondered, did he resort to what appeared to be a symbol of nihilism? Similarly, in the 1930s, when Kurt Gödel demonstrated that the dream of a complete logical system could never be achieved, two of his most eminent central European colleagues likened the impact to an earthquake. "The work on formally undecidable propositions was received like an earthquake" wrote Karl Popper, while Karl Menger reflected that the "various edifices [of mathematics] are not secure against the earthquake of a contradiction."[5] As one commentator has suggested, the earthquake metaphor implies that the theorem caused "widespread confusion and despair."[6] By all accounts, however, philosophers like Popper and Menger readily embraced Gödel's idea and its radical implications. Why then the violent metaphor?

With further research, I began to suspect that the metaphor was more than metaphorical. There was a concrete sense in which earthquakes were losing the apocalyptic associations of an earlier age. Nineteenth-century scientists were enlisting ordinary people to record seismic events, from barely perceptible tremors to catastrophic shocks. Popular writers were discussing earthquakes as elements of a natural landscape with which people had to learn to live—much as Exner, Popper, and Menger believed that philosophy had to adapt to the instability of the modern intellectual landscape. And the notion of an "intellectual earthquake" was becoming vivid, as the human sciences probed the psychic effects of seismic events. Earthquake observers, in short, were confronting head-on the crisis Nietzsche identified: the mental plunge into the uncertain universe of modern science.

What I learned, in short, is that the world became shakier in the nineteenth century. By that I do not mean simply that political revolutions and industrialization were perceived in terms of precipitous, dizzying change. I mean that the earth was caught trembling more often than before. Reports of jerks, bumps, rumbles, and thuds proliferated. They passed from hand to hand in newspapers, letters, scientific transactions, and medical case studies. Certain countries and even towns acquired reputations for impressive instability. Travelers looked forward to the thrill of a first earthquake. People learned to suspect that the sound of a distant wagon rolling over cobblestones was the trembling of the earth itself—and they could check the morning papers to confirm it. "One could read ten times in a row that Herr Jonas Blau, Frau Isole Klümpel, Herr Isidor Käsler, Herr Wotan Kohn and

Herr Leo Kohn or Fräulein Sprinzel-Kohary were just sitting down to dessert when the glasses started to clatter."[7]

And then, sometime around the Great War, the trembling apparently subsided. The newspapers turned to larger cataclysms and more "worldly" matters. The din of Herr Blau and Frau Klümpel's glasses faded into silence.

Disaster Science

Disaster is, by definition, that which "cannot be comprehended *exactly*."[8] It is a hopelessly hybrid entity: inextricably entangling the natural and the social, freighting objectivity with subjectivity, and binding global science to local contingencies. This book shows how the earthquake as disaster—as an interface between nature and society—was made and unmade as a scientific object. Earthquakes furnished ideal conditions for geophysical research: they gave access to the planet's hidden structure and to the forces that had shaped the earth throughout its history. The problem, in an age before reliable seismographs, was how to turn an instant of panic and confusion into a field for the production of scientific evidence. This was the achievement of the permanent networks of seismic observers organized in the late nineteenth century. The result was a natural experiment at the nexus of human behavior and planetary physics.

In the nineteenth century, a scientific description of an earthquake was built of stories—stories from as many people, in as many places, in as many different situations as possible. "It will be obvious," wrote one nineteenth-century geologist, "that no single person can, from his own observations, estimate the area agitated by an earthquake, though much may be accomplished by the combined observations of many."[9] "Likely in no other field," admitted another, "is the researcher so completely dependent on the help of the non-geologist, and nowhere is the observation of each individual of such high value as with earthquakes."[10] In the chapters that follow, we will encounter the nineteenth century's most eloquent seismic commentators, including Alexander von Humboldt, Charles Darwin, Mark Twain, Charles Dickens, Ernst Mach, John Muir, Gertrude Atherton, and William James. We will also meet countless others whose names are long forgotten: citizen-observers, many of whom were women. Sometimes their stories told of fear and devastation, sometimes of excitement and curiosity, sometimes of wonder, incomprehension, disbelief, or uncertainty. As an observer in New Jersey put it when reporting a possible tremor to a local scientist, "You are interested in manifestations, which, otherwise unexplainable, are referred

to earthquakes." In this case, the observer had been reading peacefully when he was suddenly disturbed by a shaking, which "seemed to result from some giant having braced his feet well apart on the room overhead and then made an effort to sway the building." Others in the house had also noticed something odd; one assumed that a Mr. W. was chasing his wife through the house, or perhaps she was chasing him. "Had I known what was coming I should have been prepared for some careful observations as to time. . . . As I had never had a similar experience I did not realize what I was missing until too late."[11] Observers had to learn how to report such ambiguities, and seismologists had to learn how to work with them. Many of these earthquake reports have been preserved in archives, and they are a window onto an unusual dialogue. "Observe conscientiously," instructed an 1879 guide to earthquake observing, "but have no fearfulness with respect to us in the transmission of observations. All that is genuinely observed is welcome, even what is perceived in uncertainty, as long as it is marked as such."[12]

These were stories, above all, about individuals and communities and their relationships to the land they lived on. As a late nineteenth-century antiquarian from the Swiss village of Fleurier noted of the earthquake reports of a generation past, "These notes . . . do not have the dryness and banality of a newspaper report; they [stand out] for their candidness, originality, and local flavor, and it is not the least of their merits that they transport us to the simple and rustic Fleurier of old."[13] Quaint as they may at first appear, earthquake reports based on human observations ("felt reports") hold a rich ore of information. As we will see, it was on the basis of felt reports that earthquakes came to be understood as the result of horizontal movements of the earth's crust. It was also on this basis that scientists learned that earthquakes can be triggered by human activities (a phenomenon now known as induced seismicity). Felt reports profit from the familiarity of local observers with the normal state of their surroundings: locals are in the best position to recognize anomalies such as variations of groundwater levels, unusual weather, remarkable animal behavior, or changes in the surface of the land.[14] Their observations bear clues to the spatial variability of the impacts of earthquakes, which is a complex function of factors such as tectonic structure, soil type, and building style. Maps based on felt reports ("macroseismic intensity maps") shed light on the geography of seismic risk; they can help locate faults and guide reconstruction in order to mitigate future damage. What's more, such sources reveal how earthquakes have been perceived and interpreted in different times and places. Like recent surveys that have attempted to assess, for instance, whether earthquake victims in California and in Japan display different degrees of fatalism, nineteenth-century felt reports open windows onto the cultural determinants of risk perception.[15] As the Swiss Earthquake Service put it in 1910, "To study the relationship of man to earthquakes was from the start a special goal of Swiss earthquake research."[16] In short, the information gleaned encompassed a disaster's physical impacts, human responses, and the conditions under which knowledge of either was possible. In today's terms, the perspective of nineteenth-century seismology would be described as "integrated." It addressed both the physical and human factors that define today's notion of "vulnerability"—including regional seismicity, building standards, and the social conditions that affect a society's ability to cope with disasters. In other words, this nineteenth-century research made apparent one of the core lessons of recent environmental history and disaster studies: that "natural disasters" as such do not exist, that catastrophic consequences are always the outcome of an unfortunate conjunction of geophysical circumstances and human choices.[17]

Today, seismologists are increasingly aware of the uncertainty of seismic risk assessments. The potential violence of even weak earthquakes has been magnified in an age of gravity-defying engineering and nuclear power. Assessing local risk means analyzing seismic processes over the course of centuries. Scientists therefore need to dig beyond the last few decades of seismographic records, deep into the human records of the past. The observations of ordinary nineteenth-century people have been dug out of newspapers and archives and mined once again for clues to long-term patterns of seismicity. Even today, the most sophisticated seismographs alone cannot reveal how the impacts of earthquakes vary at a local level; and there are many effects to which seismographs are blind, such as building damage and topographical changes. Moreover, it has become clear that earthquakes pose a threat in continental interiors, far from the edges of tectonic plates. The causes of such "intraplate" earthquakes remain a mystery: the experts themselves insist that there are no experts on this subject. As we will see, seismologists are once again enlisting the public as earthquake observers.[18]

Until recently, disasters have been conspicuously absent from historians' accounts of modern science. The current field of disaster studies typically locates its origins in the 1970s, with the rise of the risk-management paradigm. Before that, the assumption goes, disasters were regarded as "purely physical occurrences, requiring largely technological solutions."[19] This limited vision has been matched by a studied disregard for disasters within the field of history of science. In laying out the mission of the discipline in the 1920s, George Sarton demoted wars, pestilence, earthquakes, and the like from world-historical events to superficial contingencies. For Sarton,

disasters were merely accidents that obscured the fundamental source of human progress: the work of science. Scientists "go on pursuing their life's work without seeming to be in the least concerned with the gigantic activities that surround them. Mere earthquakes or wars do not interrupt their work."[20] By contrast, recent research suggests that disasters have decisively shaped the historical trajectories of the modern sciences, creating a stage for the entrance of new classes of technical experts and new forms of expertise.[21]

Sarton represented one of two competing modernist tendencies, which have alternately pushed disasters toward visibility and invisibility. On one hand, the effort to orchestrate networks of citizen-observers to watch for earthquakes was a modernist project par excellence. It served the cause of popular enlightenment and informed plans for large-scale engineering. Still, the aim was not to offer false security. Scientists claimed to know little more about earthquakes than citizens themselves. They aimed not to suppress fear but to instrumentalize it. The goal was no less than to realign humanity's sense of its place in the cosmos. In the often quoted words of the geologist Eduard Suess, "the planet may well be measured by man, but not according to man."[22] Through their collaboration with the public, Suess and his colleagues intended, in short, to calibrate the human seismograph. This required nimble adjustments between geophysical gauges and lived experience. Only a science at once physical and human could ascertain how much fear a given shock induced and how much it actually warranted. What could be more characteristic of modernism's ambition of reconstructing society from the ground up than the impulse to rationalize fear itself?

Nonetheless, the hybrid science produced by this impulse offended modernist sensibilities. It undermined what Bruno Latour calls the modernist process of "purification," the separation of the analysis of nature from the analysis of society.[23] Making a science of disaster means constructing a basis for comparison, both geographic (how hard your town was hit versus mine) and historical (how much worse this one was than the one in your grandmother's stories). To this end, a science of disaster must constantly move back and forth between the natural and the social, the objective and the subjective, the global and the local. It must correlate geological formations and the built environment, instrumental data and human responses, planetary waves and local damage. Each informs the analysis of the other. Circa 1900, however, many scientists dreamed of a "modern" seismology, a "pure" science: one in which the objective, instrumental, mathematical, and global would no longer depend on the subjective, human, discursive,

and local. For this reason, some of the same innovations that made possible a science of disaster—the seismograph, the observatory, the mathematical physics of seismic waves—simultaneously threatened to spawn a science that had next to nothing to do with earthquakes *as disasters*. In this sense, the history of the making of disaster as a scientific object has always also been the history of its unmaking.

Imagining Lisbon

Immanuel Kant was a thirty-one-year-old philosophy student, still a year shy of his doctorate, when Europe was rocked by the Lisbon earthquake of 1755. Three thousand kilometers away in Königsberg, Kant would not have read the first news reports of the disaster for several weeks. Then, for months on end, the German papers were packed with stories of tragedy, chaos, and ruin.[24] Attempts at natural scientific explanations vied for space with reflections on God's vengeance. Eyewitness reports abounded, and Kant collected them eagerly. With uncharacteristic impatience, he penned three essays for his local paper. He was taking on "the useful role of a scientific publicist," attempting to turn discussion from theological interpretation to naturalistic explanation.[25] His account was to be "not a history of the misfortunes that people suffered, not a catalog of the devastated cities and the residents buried under their rubble. . . . I will describe here only the work of nature, the remarkable natural conditions that accompanied the dreadful event and their causes."[26] What followed was a compilation of terrestrial and atmospheric phenomena observed across Europe in the days before and after the great earthquake. In this way, in the judgment of later commentators, Kant produced the first work of modern seismology. In the assessment of Georg Gerland, the founder of the International Seismological Association in 1901, the value of Kant's essay lay precisely in its exclusion of the plight of the victims: "in this omission of the doubtless exciting, but seismologically irrelevant trappings: in this broad view . . . he gives the first truly scientific treatment of an earthquake. . . . Kant was the first to give a scientific analysis that intends to depict only 'the work of nature' and the causes of the events, one that was exemplary well beyond his own day."[27] Likewise, for the historian of philosophy Kuno Fischer, the significance of Kant's essay lay in having "focused squarely on the lawful necessity of nature." The literary critic Walter Benjamin, not otherwise known as a connoisseur of natural science, judged that Kant's essay "probably represents the beginnings of scientific geography in German. And certainly the beginnings of seismology."[28] These

verdicts have become part of the grand narrative of the Lisbon earthquake as a pivot of modern history. It figures as the origin of a secular, rational, statist modernity and a scientific approach to natural hazards. The conclusion appears inescapable: Kant brought Europe into the age of modern science by producing an account of disaster in which the human victims fell silent.

Hence the paradox that lurks within the history of the environmental sciences: Kant—the progenitor of a modern view of the knowing subject—founded a modern science of the earth precisely by eliminating the human subject from it. Kant's research on the Lisbon earthquake became part of the lectures that defined the field of "physical geography," to which the modern environmental sciences often trace their origin. Physical geography formed part of Kant's program of "pragmatic cosmopolitan knowledge," in which the human being figured strictly as "an object of experience in the world, and not as a speculative subject."[29] This demarcation kept natural knowledge at a safe remove from the implications of Kant's later critical philosophy, his inquiry into the conditions of mind and world that make human knowledge possible. As pragmatic rather than critical philosophy, Kant's physical geography treated nature—both the external world and human physiology—as passive raw material for human ambitions. "[Geography] teaches us to recognize the workshops of nature in which we find ourselves—nature's first laboratory and its tools and experiments."[30] The subsequent history of environmental thought is shot through with the tension between technical mastery and critical reflection that emerged with Kant's geography.[31]

Nonetheless, Kant's status as the founder of seismology is delectably ironic. For seismology soon departed radically from the course Kant had set. The human perspective, it turned out, could not be eliminated. The very empiricism that Kant urged in the study of earthquakes drove scientists of the late eighteenth to early twentieth centuries to collect the accounts of any and all witnesses. "Only through the cooperation of all," explained one researcher, "can a satisfying result by delivered."[32] In order to continue to work with eyewitness evidence, researchers had to investigate the capacities and limitations of their witnesses—as registers of seismic impact and as observers of nature in their own right. The eminently pragmatic science of earthquakes simultaneously cultivated the critical side of Kant's project: the investigation of the conditions of human knowledge.

Yet Kant implied that disaster itself could not be an object of scientific inquiry. To treat earthquakes as disasters, rather than as a strictly geophysical phenomenon, was to fall into what modern science characterized as the

deceptions of anthropomorphism: "the fatal intellectual fallacy . . . precisely the antithesis and the nullification of science."[33] Gerland defined modern seismology as a Kantian quest for pure knowledge, dignified by "the grandeur and the novelty of the task, the vast insight."[34] This sublime perspective on earthquakes was supposedly the exclusive achievement of the modern scientist. Only the uninitiated would perceive earthquakes as disasters.[35]

Since 1935, scientists have described earthquakes in the briefest of terms: an epicenter and a Richter magnitude, a neat, quotable number that can be calculated from the readings of just three measuring instruments. Charles Richter developed his magnitude scale in Southern California in the 1930s, where he and his colleagues had been trying to enlist the local population as earthquake observers. By inventing a purely instrumental definition of earthquake strength, Richter hoped to be "freed from the uncertainties of personal estimates or the accidental circumstances of reported effects."[36] His idea caught on fast, and for much of the remainder of the twentieth century it seemed that Richter had indeed, once and for all, eliminated the need for human observers and the uncertainties they introduced. With the onset of the Cold War, seismology's status swelled, fed by defense funding for the detection of nuclear tests.[37] There was no time to think about the science that was being swept away: a field of knowledge that depended on the self-reported observations of ordinary people in extraordinary situations.

The Observers

Who were the earthquake observers? When the earth trembled, all had equal claim to this title. Nonexperts were often in a position to make the best observations. Scientists were often reduced to the status of experimental subjects, reporting on the states of their own bodies and minds. The line between expert and amateur was remarkably fluid in nineteenth-century seismology. Motivations were similarly varied. Some earthquake observers were romantics, zealously exposing themselves to extreme conditions in a quest to reach the nexus of mind and nature within their own bodies. Some saw themselves as heroic explorers on the model of Alexander von Humboldt, who judged his own body his most valuable instrument.[38] Some were simply eager to be of use to science. All were participating in a culture of scientific observation and self-observation that crossed the divide between expert and lay.[39]

This culture was rooted in the new public spaces of the eighteenth and nineteenth centuries and the questions they raised about bodily discipline.

In gardens and spas, instruments were often on hand to test one's sensitivity to sunlight, local winds, and barometric pressure. The *Wettersäule*, for instance—an elaborate tower displaying temperature and air pressure—became a fixture of European urban parks and spa towns. Readers of a popular science magazine in 1912 were urged to seek for themselves "the 'geopsychic' rule governing their individual psychic lives" and to devise their own remedies.[40] As historians have argued, this culture of self-monitoring reflected anxieties about the transition to urban modernity and about European colonization in the tropics.[41] But it was also a source of new knowledge. In the age before high-precision portable instruments, satellites, and an extensive network of observatories, the geosciences learned a great deal from monitoring physiological responses to environmental conditions. The idea was to begin with one's own reactions to telluric forces, and work outward toward an understanding of the operations of the cosmos. In the words of Walt Whitman, a Humboldtian was someone "who, out of the theory of the earth and of his or her body understands by subtle analogies all other theories."[42] In these ways, seismology participated in certain nineteenth-century efforts to expand natural knowledge by moving beyond a mind-body dualism, such as romanticism, *Naturphilosophie*, sensory physiology, and Darwinian ecology. To be sure, viewing human sensibilities as a register of nature's operations ran the risk of anthropocentrism. Yet Humboldtians never suggested that environmental phenomena could be measured *solely* in terms of their effects on man. What's more, these habits of self-observation had the potential to foster a new sensitivity to environmental change. As the political theorist Jane Bennett observes, anthropomorphic analogies can remind us of "the outside-that-is-inside-too"; "a chord is struck between person and thing, and I am no longer above or outside a nonhuman 'environment.'"[43]

Observing the mutual effects of mind, body, and nature was also a way to come to terms with the expanding horizons of the nineteenth century. By tracking weather patterns, seasonal changes, or seismic waves, a curious individual could situate herself with respect to continents and oceans. Registering the personal effects of geophysical processes opened the imagination to unfamiliar geographic scales. Still, how could one be sure that certain bumps and jerks were signs of planetary convulsions and not local (or psychic) artifacts? How could one judge whether one seismic event was causally linked to another, distant one? Nineteenth-century seismology tracks an emerging curiosity about interactions between local and global scales.[44]

Just as local stories shed light on the making of a global science, the lives of individuals can illuminate the organization of a collective effort like earthquake observing. Here too I am following the lead of the historical actors. As we will see, it was often unclear whether the object of investigation in earthquake research was geophysical or human. The results frequently said as much about the social psychology of the community of observers as about local geology. Moreover, macroseismological networks were experiments not only in the scientific observation of unanticipated, fleeting events; they were equally experiments in human relations. In explicit opposition to the modern trend of bureaucratization, the charisma of individual scientists mattered greatly to their success.[45]

In these ways, nineteenth-century seismology looks unabashedly anthropocentric: it studied earthquakes by means of their human impacts and with human interests at heart. In fact, its primary variable, seismic intensity, could not be determined at all in uninhabited areas. Intensity is a measure of shaking in terms of its effects on buildings and people. Yet seismology did not stop at the human perspective. Instead, it was a project of translation: among scientists, citizens, and instruments. It successfully mediated between the technicalities of physical science and the everyday experiences of people living with environmental risk. To twenty-first-century sensibilities, the discourse of nineteenth-century seismology is a paradox: a language simultaneously scientific and vernacular.

Scientists today often despair of communicating effectively with the public about environmental risks. How, for instance, should seismologists explain that—according to the latest research on intraplate earthquakes—the absence of nearby faults is no sure sign of seismic safety? Where might scientists and citizens begin a conversation about the risk of induced seismicity from hydraulic fracturing? As one seismologist recently put it, "How do we convey the results of our research when our most recent results tell us that we know less than we used to think we knew?"[46] This book investigates the historical conditions of possibility for such a dialogue.

It is customary today to think of science as "technical" knowledge. In Thomas Kuhn's words, science requires "translation for the layman." Kuhn even claimed in *The Structure of Scientific Revolutions* that scientists owe their efficiency as problem solvers to the "unparalleled insulation of mature scientific communities from the demands of the laity and of everyday life."[47] But scientists have not always been content to express themselves in jargon. A vernacular language for science was the goal of the eighteenth-century Swedish botanist Carl Linnaeus, who designed his taxonomic system in

order to "make botany easy for people without schooling or wealth."[48] Nineteenth-century medical experts often eschewed Latinisms for the terms their patients used to describe their own experiences of illness. Nineteenth-century meteorologists formulated wind scales and cloud taxonomies on the basis of the lingoes of sailors and farmers. The brief heyday of earthquake-observing networks merits attention as a path not taken—as what Ted Porter has called a "living alternative" to the increasingly technical science of the twentieth century.[49]

Knowledge and Fear

To a world still reeling from the devastation and uncertainty unleashed by the 2011 earthquake and tsunami in Japan, "disaster science" may sound like a willful delusion. Indeed, the very idea is politically suspect. In the wake of natural catastrophes, rationalizing reforms have often been a mere pretext for the centralization of power.[50] In other cases, technical responses to catastrophe have provided false security, as in the tragic failure of Japan's sea walls to defend against the recent tsunami. In this context, disaster science seems like little more than a tool for the manipulation of popular fear. Jean Baudrillard has argued in this vein that any state capable of predicting and controlling natural catastrophes would be so coercive that its citizens would *prefer* a catastrophe.[51] Yet these twentieth-century perspectives on the relationship between science and catastrophe have obscured the history of quite a different and distinctively nineteenth-century project of disaster science.

As Lorraine Daston has pointed out, the makers of science policy today tend to frame their goal as the elimination of fear. Far better, she argues, to confront fear directly in a rational manner. Daston thus calls for a "debate about the philosophy of fear, traditionally the most unphilosophical of the passions."[52] The topic of fear is not new to political philosophers, who have long debated whether fear is more likely to cause action or paralysis, to inspire the excesses of revolution or the stranglehold of reaction.[53] Perhaps it is time for historians and philosophers of science to enter this discussion. The history of seismology suggests that fear plays a dual role in the sciences. It can motivate research that may ultimately provide a measure of control over the source of fear—in the form, for instance, of storm warnings, vaccines, or antidepressants. Even in the absence of practical interventions, however, scientific knowledge can respond productively to fear by helping us recognize, and come to terms with, the limits of our control.[54]

"Fear is implanted in us as a preservative from evil," wrote Samuel Johnson in 1751; "its duty, like that of the other passions, is not to overbear reason, but to assist it."[55] Similarly, David Hume posited that the mind produced hope and fear together in proportion to the probabilities of future joy or grief, like a prism decomposing a beam of light into two colors. In this sense, fear was itself a form of knowledge about the future. It was, moreover, a sentiment appropriate to the enlightened mind. One Hume scholar has described fear as "circumspect and open-minded. . . . It is the very opposite of that complacent reliance on acquired powers, on past prestige, on previous success, which is so detrimental to further advance and to open-minded recognition of new issues as they arise."[56] Hume noted, however, that fear was not always proportional to the objective likelihood of a grievous event; sometimes it reflected a subjective degree of uncertainty about the nature and existence of an evil.[57] Fear could thus signify a well-founded expectation of misfortune or a lack of information. In this way, the age of reason recognized that fear has epistemic value.

Like these eighteenth-century philosophers, those engaged in environmental politics today are often called on to evaluate the rationality of fear. Environmental conflicts often turn on the alleged tendencies of the public to over- or underestimate environmental risk: the problems of "anxiety," on one hand, and "apathy," on the other.[58] Experts frequently dismiss popular environmental concerns in gendered terms by contrasting their own coolheadedness with the public's "hysteria."[59] Unfortunately, we seem to have no language to describe a scale of more or less realistic forebodings. The Freudian notion of "anxiety" differs from "fear" in that it has no fixed object; it appears to be a state of mind incompatible with the exercise of rationality. Yet, as Iain Wilkinson notes, anxiety is not antagonistic to reason. Rather, "it is by so traumatising us with the knowledge of our own ignorance, that anxiety functions to alert us to, and prepare us for, the threat of danger."[60] Anxiety can be a spur to scientific inquiry. Nonetheless, the effect of greater knowledge is not necessarily a stronger sense of security. Despite the optimism of the Cold War sociology of disaster, one does not always gain comfort from "the healthy exercise of rationality involved in submitting the inconceivably terrible to scientific scrutiny."[61] On the contrary, sciences of natural disaster have taught us a great deal about the scope of our ignorance. In this vein, science can generate anxiety that successfully provokes public debate and political reform.[62] This book takes up the history of seismology with these concerns in mind. Following historians of the emotions, it considers how earthquake fears have been constructed and suppressed in

different places at different times.[63] It recovers a science that had no intention of suppressing fear, but sought instead to learn from it.

Organization

In order to capture both the local and global dimensions of earthquake science, the chapters that follow alternate in scale. Half of them treat local experiments in planetary science. These four cases—Scotland, Switzerland, imperial Austria, and California—were, to my knowledge, the only places where networks of ordinary citizens contributed decisively to the emergence of modern seismology.[64] The scale of these public efforts was remarkable: the Swiss Earthquake Commission gathered approximately seven thousand reports between 1878 and 1910, while the Austrians had over 1,700 observers reporting from all sixteen crown lands.[65] Elsewhere, as in Japan and Italy, seismological observations were made primarily by men of science; occasionally by civil servants like stationmasters, telegraph operators, or postmasters; or primarily by instruments.[66] These four episodes span the "long nineteenth century," from the first glimpse of a technocratic regime in the Napoleonic Era through the triumph of technocracy in the wake of the First World War.[67] Alternating with these local experiments are chapters that follow the international circulation of the stories of earthquake witnesses as they were reconstituted as evidence for a global science of disaster. One might object that an earthquake in Japan is hardly the same scientific object as an earthquake in Switzerland: a potential catastrophe in one case, often a mere curiosity in the other. Yet the very possibility of such comparisons is a consequence of nineteenth-century seismology's expansive framework. To the extent that catastrophes are experienced as exceptions to a normal course of events, they resist comparison. Other catastrophes pass virtually unnoticed: they are experienced as "normal" hazards, as part of the "acceptable" risk of modern industrial life.[68] Nineteenth-century seismology resisted these extremes. By charting an entire spectrum of experiences of hazard, from the mundane to the overpowering, it cleared a space for sustainable adaptations.

ONE

The Human Seismograph

The word "seismology" was coined in the 1850s, not long after the word "scientist"—both harbingers of a new age of technical expertise.[1] Earthquakes, however, did not fit easily into the emerging rubric of professional science, not least because they forced scholars to rely on the testimony of common folk. Already in the sixteenth century, when stories of the New World were first circulating in Europe, Michel de Montaigne remarked that earthquakes compelled Europeans to trust the word of "barbarians." In a crucial twist, however, Montaigne suggested that the barbarian might prove the more able witness: "a simple, crude fellow—a character fit to bear true witness; for clever people observe more things and more curiously, but they interpret them; and to lend weight and conviction to their interpretation, they cannot help altering history a little."[2] Echoes of Montaigne's charitable perspective could be found in subsequent European studies of earthquakes, in the virtues sometimes attributed to untutored observers. Well after Montaigne's death, earthquakes were still widely discussed across divides of birth and education. Eighteenth-century sermons and news articles engaged the public in scientific and theological debates about earthquakes.[3] Accounts of the New Madrid earthquakes of 1811–12 became "a form of conversation," in which settlers modeled their descriptions of tremors on narratives of sickness and health.[4] In the early nineteenth century, however, this inclusive conversation was breaking down. Earthquakes figured counterintuitively in new geophysical theories as the effects of elusive electrical forces.[5] Seismology seemed ready to become the esoteric subject of expert knowledge.

The history of seismology since 1755 is traditionally seen as a progressive liberation of natural knowledge from the subjective impressions of earthquake victims. After the Staffordshire quake of 1777, for instance, Samuel Johnson warned that the event would "be much exaggerated in popular