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**Susan Elizabeth Hough: Richter's Scale**

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## CHAPTER 1



### The Magnitude of the Problem

... it is good to have measured myself, to recognize my limitations.

—Charles Richter, journal entry, June 20, 1926

PIONEER settlers on the westernmost American frontier most likely settled into bed comfortably on the night of December 15, 1811. The Mississippi River valley had been enjoying an Indian summer: nighttime temperatures hovered near forty-five degrees Fahrenheit. The quiet and comfort of the settlers' slumber would, however, be shattered a few short hours later by the most portentous seismic disruption that had ever been witnessed by people who called themselves Americans. An eyewitness close to the seat of the disturbance described the scene around him: trees "bending as if they were coming to the ground—again, one rises as if it were to re-instate, and bending the other way, it breaks in twain, and comes to the ground with a tremendous crash." Astonishingly, this account described not the mainshock that shattered the still night around two-thirty, but rather its largest *aftershock*, which struck near dawn. And the account is remarkable. Rarely do trees snap in two even in strong earthquakes; it happens only in the most severe shaking the earth can dish up. (Even severe hurricane winds will generally yank a tree out of the ground rather than snap it in two.)

Between the wee hours of the morning of December 16, 1811, and February 7 of the following year, the midcontinent would be rocked by four enormously powerful earthquakes—the initial mainshock and its largest aftershock as well as subsequent large shocks on January 23 and February 7, 1812, and many thousands of smaller aftershocks. Waves from the largest shocks rippled outward with gusto through the midcontinental region. Although newspaper accounts reveal that these waves did not, as some still

like to report, ring church bells in Boston, they did plenty else. Soft sediments along the Mississippi River gave way; the waters of the mighty river sloshed like waves in a bathtub, even reversing course for a brief time following the February 7 quake. Farther afield the attenuated waves still had enough power to crack brick walls in St. Louis, topple chimneys in Louisville, swing cabinet doors in Cincinnati, and damage plaster walls as far away as coastal South Carolina. The bell of St. Philip's church in Charleston, South Carolina, was set into motion. The enormous disruption and reach of these earthquakes led many to believe—even as late as the end of the twentieth century, after other large quakes had struck California—that the largest New Madrid earthquakes, as they came to be known, were the largest temblors to ever visit the contiguous United States.

The 1906 San Francisco earthquake caused substantially more loss of life and property damage, yet its overall effects seem to pale in comparison with those of the New Madrid earthquakes. According to pioneering geologist Grove Karl Gilbert, who investigated the effects of the 1906 earthquake, at distances of just twenty miles from the surface break, only an occasional chimney was overturned; by seventy-five miles the waves had lost their destructive punch altogether. (Because the rupture was several hundred miles long, damage extended over this full distance lengthwise along the San Andreas Fault.) Compare that with the collapsing riverbanks, reversing rivers, and damage as far as six hundred miles away caused by the New Madrid earthquakes.

But how do you measure an earthquake? This seemingly simple question proves complicated beyond all expectation. Prior to the 1930s, the best scientific minds in the world had no answer. In fact, they had barely begun to pose the question. Earlier scientists had devised methods to rank the severity of shaking based on its effects at different locations, but never a way to size up the temblors themselves. The difference is fundamental, essentially the same as that between the apparent brightness of a star in the nighttime sky here on Earth and its inherent luminosity—how brightly it shines up close. The effects of an earthquake depend on not only the distance from the fault to any given site, but myriad other factors as well. Seismic waves travel much more efficiently through the older and less complex rocks that make up the crust of central North America than they travel in California. Thus an earthquake of a given magnitude will pack a much greater punch in the former region than in the latter. And relative to the places most Californians now live, early American settlers were clustered in proximity to waterways, where earthquake shaking is

significantly amplified by loose and wet sediments. The New Madrid earthquakes therefore hit eyewitnesses especially hard. As modern seismologists first endeavored to estimate the relative size of these earthquakes and of the 1906 earthquake, their results seemed reasonable: the San Francisco quake was the smaller.

I will leave a longer discussion of the New Madrid sequence for a later chapter and focus on the more fundamental question, how do you measure an earthquake? Nowadays, of course, any basic seismology textbook explains how earthquakes are measured, although basic texts still offer far more simplifications than subtleties of the methodology. It might surprise many readers to learn that these subtleties still rear their pesky heads within the corridors of research science, and not only for historical earthquakes for which we have limited data. When a powerful earthquake struck near Sumatra on the day after Christmas of 2004, global earthquake monitoring networks reported an initial magnitude estimate of 8.1; the estimate rose to 8.5 within hours and again to a staggering 9.0 a few hours later. Magnitude 9 earthquakes are, mercifully for us all, rare events: on average they strike perhaps once every few decades. (Although, one must note, the earth is not bound by averages: the 1960 Chilean and 1964 Alaska earthquakes were magnitude 9.5 and 9.2, respectively, still the largest two earthquakes in modern times, and a scant four years apart.) The low initial magnitude estimates for Sumatra reflected the fact that, while sophisticated global earthquake monitoring networks have been developed in recent decades, these networks and systems had never before been put through their paces with an earthquake of such portentous magnitude. The low initial estimates may have contributed to an underestimation of the tsunami potential: the bigger the earthquake, the larger the volume of water it can displace. (In retrospect, however, even a magnitude of 8 should have been sufficient to sound the alarms, had alarm systems been in place.) As the world watched with horror, the earthquake unleashed a deluge of biblical proportions, giant waves that swept over the coasts of Indonesia and Thailand before traveling the full width of the Bay of Bengal to inundate the coasts of southern India, Sri Lanka, and the Maldives.

Weeks after the earthquake a team of respected seismologists, Seth Stein and Emile Okal, began to circulate the results of their detailed analysis, which yielded an even higher magnitude estimate: 9.3. Although the analysis of Stein and Okale appears to have been beyond reproach, and was soon corroborated by other researchers, many seismologists expressed a reluctance to adopt the value because it had been estimated with a kind of data that are not available for earlier great earthquakes, specifically those

in 1960 and 1964. Were equivalent data available for the earlier quakes, their magnitude estimates would very likely increase as well. Since one cannot make these calculations, most scientists reasoned, better to provide consistently determined estimates for all three temblors and thus an accurate description of their relative sizes. The alternative would be to upgrade Sumatra to a 9.3 while, by necessity, leaving Alaska at a 9.2, even though most scientists strongly suspect (but cannot prove) that Alaska was the larger of the two.

One begins, perhaps, to get an inkling of the magnitude of the problem. The business of sizing up earthquakes has been a surprisingly complex journey of discovery within the seismological community—one that traces its earliest roots to the years before modern seismometers were invented but began to gain traction only with Charles Richter's pioneering efforts in the 1930s. Earthquakes are, as it turns out, not only unruly but also terribly complicated beasts, the nature of which scientists began to understand only in the closing years of the nineteenth century. This is perhaps a surprising part of the story: prior to 1900, give or take a few years, scientists did not understand that an earthquake is, fundamentally, the abrupt movement of large parcels of the earth's crust along mostly flat surfaces known as faults. Prior to the closing years of the nineteenth century, scientists had advanced any number of other theories to explain the fundamental nature of earthquakes, for example underground explosions or electrical disturbances.

Once one understands that earthquakes involve motion along faults, one understands why size matters. That is, although earthquakes are generally named after the city they most heavily impact, they in fact occur along extended patches of faults, and the bigger the patch, the bigger the earthquake. Thus did the catastrophic 2004 Sumatra quake involve a patch of fault whose width was approximately 150 kilometers and whose length reached a staggering 1,500 kilometers. A map of California provides a useful sense of scale: the state measures about 1,000 kilometers from north to south. This one earthquake, then, unzipped a segment of fault equivalent to the full length of California, stem to stern, and then some. That's one big earthquake.

One returns again, however, to the question: how big is big? The previous paragraphs provide the answer (9.0), and explain that this reflects the size of the fault, but what does "magnitude 9" mean? Some quantities in science are relatively simple in the scheme of things. Take temperature, for example. Temperature fundamentally indicates the average energy of molecules in a substance. Nobody but a scientist thinks of temperature this

way, but temperature is a familiar metric, one that can be reported as a simple numerical reading from a simple mechanical scale. The scale is moreover set, or calibrated, in a way that is easy to explain, in particular the Celsius scale: at sea level on planet Earth, water freezes at 0 degrees C and boils at 100 degrees C. On the Celsius scale, 100 is thus a physically meaningful number.

So, too, are we able to measure any number of other things: mass, force, speed. Such estimates become complicated only when bodies travel at close to the speed of light, in which case Einstein's theory of relativity begins to do strange things to the universe we know and love. But short of this most extreme situation, simple mechanical devices and scales suffice to measure quantities like force and mass. Scientists speak of these quantities as *parameters*: well-defined quantities that can be measured. An earthquake, on the other hand, is not a fundamental parameter as much as a process. The difference between measuring the mass of an object and the magnitude of an earthquake is a little like the difference between measuring the speed of one car and measuring the traffic on the New Jersey turnpike. The speed of one car is a parameter; the traffic on the turnpike is . . . something else.

Later chapters will delve further into both the nature of earthquakes and the first scale developed by scientists to measure them: Richter's scale. This book is, however, not only a story about earthquakes or the Richter scale, but also the story of Charles Francis Richter, the man. Richter is, even today, the only seismologist living or dead whose name is a household word throughout the world—a measure (so to speak) of immortality that stems directly from the scale that bears his name. This is a story about Richter as an individual as well as his relationship with the world, including his professional colleagues. At least by some accounts, Richter's fame generated a certain degree of resentment among fellow scientists who saw the public acclaim more as a consequence of grandstanding than of profound scientific achievement.

Were these sentiments, which persist to the present day, fair? How did the name *Richter scale* come about? Should it have been simply the *Richter* scale, or should the names of other seismologists be attached as well? Did he properly acknowledge the contributions of colleague Beno Gutenberg? Was Richter, in the words of one later novelist, a “real SOB” who “screwed” Gutenberg out of his rightful share of fame? Such questions are difficult to answer. If it is easy to misunderstand the Richter scale, it is vastly easier to misunderstand Richter—his motivations in his interactions with the media as well as the many other facets of his enormously complicated life. Remarkably little has been written about the man, for

reasons that become apparent as our story progresses. For starters, Richter was apparently not his name at birth, and therein lies the beginning of a tale of a childhood marked from the very beginning by both internal and external turbulence.

Scientists in general have a reputation for being a breed apart. It would be a magnitude 8 understatement to say that Charles Francis Richter was no exception. He was a nerd among nerds: regarded as peculiar and intensely private even by scientists' standards. And we're talking about people who put red-and-white bumper stickers on their cars that read, "If this sticker is blue, you're driving too fast."

Richter's circle of close friends and colleagues remained remarkably small throughout his life. Even his nuclear family was more nuclear than most: born into a household that included only maternal grandparents, mother, and older sister, the configuration expanded over the years only so far as to include his wife and her son from a previous marriage. Richter's wife had a sister who had two children, a son and a daughter; Richter had no children of his own, no close cousins, no nieces or nephews on his side of the family tree. His stepson never married and never had children of his own.

Richter's career had a similar nuclear quality: it began where it would eventually end, at the Caltech Seismological Laboratory in 1927, in fact before the Seismological Laboratory became part of Caltech. Hired as an assistant for a job he considered temporary, Richter never intended to become a seismologist—let alone the most famous seismologist of all time. In his mind the job represented only a brief diversion, a holding pattern in the years immediately following his completion of a Ph.D. in atomic physics. He had, not only from the outset but even decades later, every hope of some day returning to his chosen field of theoretical physics. Some biographies claim he yearned to return to astronomy, but according to what Richter wrote, astronomy had been his first scientific passion as a boy but became only a lifelong avocation from his undergraduate years onward. His formal education focused first on chemistry, and later physics.

And yet a seismologist he remained: a Seismo Lab seismologist from the start, a Seismo Lab seismologist when he retired in 1970. Few scientists in any field have careers like his, beginning and ending at a single institution. This aspect of Richter's life emerges more and more clearly as the story progresses. For now, suffice it to say that, in technical terms, Charles Richter was a homebody of nearly unprecedented proportions, even among scientists. His personal as well as his professional comfort zone, which

emerges as a consequence of his extraordinarily complex and at best marginally stable personality, never stretched far beyond the boundaries of Southern California, the only home he ever really knew.

One can point to an additional key to Richter's enigmatic reputation and legacy: For a scientist of his stature, he worked with very few students or younger colleagues throughout his career. In academia one's students are one's children: they carry one's ideas, reputation, name (to some extent), and memory into both the larger world and the future. (The familial analog is widely recognized by scientists. I was once surprised and flattered to hear an eminent seismologist introduce me as a "granddaughter of sorts": my Ph.D. advisor had been one of his Ph.D. students.) Scientists tell stories about their advisors to their friends and students. Thus do oral histories—portraits of scientists as individuals as well as professionals—begin to take shape within the scientific community, if not the larger world.

Even in seismological circles Richter thus remains enigmatic. He was loathe to speak about himself, had few close colleagues his own age, few students or protégés of any sort; he spent his entire career at a single institution. Those who did know Richter are, moreover, reluctant to speak at length about the man they knew as Charlie. To some extent this reluctance bespeaks ambivalence, yet many also feel a sense of loyalty to the memory of a man they had grown to care about. Here again, the more one starts to understand the man, the more one understands the reluctance. Richter was both peculiar and private, easily hurt and famously unable to laugh at himself. The few colleagues who knew him at all well are reluctant to help paint a portrait that, viewed out of context, places undue emphasis on his abundant follies and foibles.

The few personal tidbits that are known in scientific circles tend to do just that: they suggest that Charles Francis Richter, inventor of the Richter scale, was something of a kook. He was an avid nudist; he dabbled in poetry. He sometimes showed up at work wearing two ties; when he wore only one it always sported a creative collection of stain spots. He was not in the least amused by the clever song, composed by one of his colleagues, that was performed at his retirement party. And, from some: if there were cameras around, you could count on Charlie to be there.

Every mortal has follies, every mortal has foibles; no mortal deserves to be defined by them. What is the measure of a man? Earthquakes might be difficult to measure, but they are easy to size up in comparison to the man who first measured them. To paint a full portrait—as full a portrait as is possible—of Charles Francis Richter, one must delve directly into the follies and foibles about which people have been so loathe to speak. As one



makes this journey, the portrait begins to emerge at last: a man with a keen sense of humor but unable to laugh at himself; a man who never felt a strong calling to seismology but became the world's most famous seismologist; a man whose relationships with women were complicated from the day of his birth but stayed married to one woman—albeit not entirely faithfully—until her death in 1972.

The portrait of Richter includes far more than one man's fair share of tribulations: a family history rife with emotional instability, a childhood with few of the usual support systems that provide a sense of stability, personality quirks that suggest a nearly textbook set of symptoms of a profound neurological disorder, suggestions of physical ailments that would have had further deleterious effects on his sense of well-being. Many a lesser man has crumbled in the face of lesser demons than those that haunted Charles Richter's every waking hour. His difficulties did derail him for a time, nearly ending his research career before it began. Yet in the end, the work that he took on reluctantly would prove to be his salvation. It was via his work in seismology, most notably his Herculean efforts to develop the magnitude scale, that Richter was able to harness his not inconsiderable intellectual horses. Although he would never succeed in eradicating his demons, observational seismology provided such an effective outlet for his enormous drive, intellect, and talent, that he was able to make seminal contributions to the young field of seismology. In the process, he turned his name into a household world that everybody knows and almost nobody understands.

Existing brief biographies of Charles Richter, on the Web and in encyclopedias, tend to say little more than "Charles Francis Richter was born on a farm outside of Cincinnati, Ohio, in 1900. In 1935 he invented the Richter Scale." The unspoken lines that come between and after those sentences would fill a book. This is that book.