**Earthquakes and Magnitude**

We were beginning to get a vague idea of the Earth’s layered interior—though it really was only vague. Not until 1936 did a Danish scientist named Inge Lehmann, studying seismographs of earthquakes in New Zealand, discover that there were two cores—an inner one that we now believe to be solid and an outer one (the one that Oldham had detected) that is thought to be liquid and the seat of magnetism.

At just about the time that Lehmann was refining our basic understanding of the Earth’s interior by studying the seismic waves of earthquakes, two geologists at Caltech in California were devising a way to make comparisons between one earthquake and the next. They were Charles Richter and Beno Gutenberg, though for reasons that have nothing to do with fairness the scale became known almost at once as Richter’s alone. (It has nothing to do with Richter either. A modest fellow, he never referred to the scale by his own name, but always called it “the Magnitude Scale.”)

The Richter scale has always been widely misunderstood by nonscientists, though perhaps a little less so now than in its early days when visitors to Richter’s office often asked to see his celebrated scale, thinking it was some kind of machine. The scale is of course more an idea than an object, an arbitrary measure of the Earth’s tremblings based on surface measurements. It rises exponentially, so that a 7.3 quake is fifty times more powerful than a 6.3 earthquake and 2,500 times more powerful than a 5.3 earthquake.

At least theoretically, there is no upper limit for an earthquake—nor, come to that, a lower limit. The scale is a simple measure of force, but says nothing about damage. A magnitude 7 quake happening deep in the mantle—say, four hundred miles down—might cause no surface damage at all, while a significantly smaller one happening just four miles under the surface could wreak widespread devastation. Much, too, depends on the nature of the subsoil, the quake’s duration, the frequency and severity of aftershocks, and the physical setting of the affected area. All this means that the most fearsome quakes are not necessarily the most forceful, though force obviously counts for a lot.

The largest earthquake since the scale’s invention was (depending on which source you credit) either one centered on Prince William Sound in Alaska in March 1964, which measured 9.2 on the Richter scale, or one in the Pacific Ocean off the coast of Chile in 1960, which was initially logged at 8.6 magnitude but later revised upward by some authorities (including the United States Geological Survey) to a truly grand-scale 9.5. As you will gather from this, measuring earthquakes is not always an exact science, particularly when interpreting readings from remote locations. At all events, both quakes were whopping. The 1960 quake not only caused widespread damage across coastal South America, but also set off a giant tsunami that rolled six thousand miles across the Pacific and slapped away much of downtown Hilo, Hawaii, destroying five hundred buildings and killing sixty people. Similar wave surges claimed yet more victims as far away as Japan and the Philippines.

For pure, focused, devastation, however, probably the most intense earthquake in recorded history was one that struck—and essentially shook to pieces—Lisbon, Portugal, on All Saints Day (November 1), 1755. Just before ten in the morning, the city was hit by a sudden sideways lurch now estimated at magnitude 9.0 and shaken ferociously for seven full minutes. The convulsive force was so great that the water rushed out of the city’s harbor and returned in a wave fifty feet high, adding to the destruction. When at last the motion ceased, survivors enjoyed just three minutes of calm before a second shock came, only slightly less severe than the first. A third and final shock followed two hours later. At the end of it all, sixty thousand people were dead and virtually every building for miles reduced to rubble. The San Francisco earthquake of 1906, for comparison, measured an estimated 7.8 on the Richter scale and lasted less than thirty seconds.

Earthquakes are fairly common. Every day on average somewhere in the world there are two of magnitude 2.0 or greater—that’s enough to give anyone nearby a pretty good jolt. Although they tend to cluster in certain places—notably around the rim of the Pacific—they can occur almost anywhere. In the United States, only Florida, eastern Texas, and the upper Midwest seem—so far—to be almost entirely immune. New England has had two quakes of magnitude 6.0 or greater in the last two hundred years. In April 2002, the region experienced a 5.1 magnitude shaking in a quake near Lake Champlain on the New York–Vermont border, causing extensive local damage and (I can attest) knocking pictures from walls and children from beds as far away as New Hampshire.

The most common types of earthquakes are those where two plates meet, as in California along the San Andreas Fault. As the plates push against each other, pressures build up until one or the other gives way. In general, the longer the interval between quakes, the greater the pent-up pressure and thus the greater the scope for a really big jolt. This is a particular worry for Tokyo, which Bill McGuire, a hazards specialist at University College London, describes as “the city waiting to die” (not a motto you will find on many tourism leaflets). Tokyo stands on the boundary of three tectonic plates in a country already well known for its seismic instability. In 1995, as you will remember, the city of Kobe, three hundred miles to the west, was struck by a magnitude 7.2 quake, which killed 6,394 people. The damage was estimated at $99 billion. But that was as nothing—well, as comparatively little—compared with what may await Tokyo.

Tokyo has already suffered one of the most devastating earthquakes in modern times. On September 1, 1923, just before noon, the city was hit by what is known as the Great Kanto quake—an event more than ten times more powerful than Kobe’s earthquake. Two hundred thousand people were killed. Since that time, Tokyo has been eerily quiet, so the strain beneath the surface has been building for eighty years. Eventually it is bound to snap. In 1923, Tokyo had a population of about three million. Today it is approaching thirty million. Nobody cares to guess how many people might die, but the potential economic cost has been put as high as $7 trillion.

Even more unnerving, because they are less well understood and capable of occurring anywhere at any time, are the rarer type of shakings known as intraplate quakes. These happen away from plate boundaries, which makes them wholly unpredictable. And because they come from a much greater depth, they tend to propagate over much wider areas. The most notorious such quakes ever to hit the United States were a series of three in New Madrid, Missouri, in the winter of 1811–12. The adventure started just after midnight on

December 16 when people were awakened first by the noise of panicking farm animals (the restiveness of animals before quakes is not an old wives’ tale, but is in fact well established, though not at all understood) and then by an almighty rupturing noise from deep within the Earth. Emerging from their houses, locals found the land rolling in waves up to three feet high and opening up in fissures several feet deep. A strong smell of sulfur filled the air. The shaking lasted for four minutes with the usual devastating effects to property. Among the witnesses was the artist John James Audubon, who happened to be in the area. The quake radiated outward with such force that it knocked down chimneys in Cincinnati four hundred miles away and, according to at least one account, “wrecked boats in East Coast harbors and . . . even collapsed scaffolding erected around the Capitol Building in Washington, D.C.” On January 23 and February 4 further quakes of similar magnitude followed. New Madrid has been silent ever since—but not surprisingly, since such episodes have never been known to happen in the same place twice. As far as we know, they are as random as lightning. The next one could be under Chicago or Paris or Kinshasa. No one can even begin to guess. And what causes these massive intraplate rupturing’s? Something deep within the Earth. more than that we don’t know.