EARTH: All Stressed Out by Daniel Pendick

To experience the drama of plate tectonics -- the jostling of the giant plates that carry continents and oceans -- try this experiment: Sit in a comfortable chair, hold your hand out, and watch your fingernails grow. That's about the average speed of a tectonic plate. But wait around long enough, and even the tortoise crawl of plate tectonics will have dramatic and deadly consequences. Though plate tectonics is a global phenomenon and virtually invisible to us in our daily lives, it introduces enormous stresses in the crust where we live. From time to time, stressed-out crust releases the stress in sudden fits: earthquakes.

More frequently than time to time, actually. If you imagine the Earth as a giant bell, it's ringing with earthquakes every second of the day -- from the many imperceptible clinks of microquakes to the deafening gong of very occasional but "great" earthquakes (those of magnitude 8.0 or greater). The U.S. Geological Survey estimates that several million temblors, most undetectable, happen every day.

 The great earthquake of 1906 devastated

San Francisco, killing 700

Most earthquakes happen near the boundaries of tectonic plates, both where the plates spread apart and where they crunch or grind together (although large temblors also strike from time to time in the normally stable interior of continents). Along plate boundaries, the brittle outer part of the Earth fractures along faults. As plates move, blocks of crust shift along the faults. The infamous San Andreas fault is not a single crack where the North American and Pacific plates slide past each other. It's the largest of a thicket of faults that collectively absorb the motion of the plates.

There are various kinds of faults that do the day-to-day dirty work of plate tectonics. The San Andreas is a "strike-slip" fault. (See animation below.) Along this seam, the plates slide past each other like cars traveling opposite directions on a highway. The other major family of faults are called "dip-slip" faults. (See animation below.) On these, blocks of crust either push together or pull apart, with one block sliding either up or down a sloped fault plane. The fault that let loose the 1994 Northridge earthquake was a dip-slip fault, at which a block of crust slid up the shallow ramp of another.

Stress builds up in fault zones when crustal blocks stick together. In fact, faults are stuck, or "locked," most of the time, although some also show slow, barely detectable slippage called "aseismic creep." The important distinction for people between the different kinds of slip has to do with that word, seismic, from the Greek for "shaking." Fault creep is aseismic (that is, not seismic) because it doesn't generate vibrations in the crust called seismic waves. But when a fault is stuck, the rocks on either side of it store the building stresses until a critical limit is reached, and the rocks move suddenly along the fault, releasing the stresses like a spring uncoiling. This pumps seismic waves into the surrounding rock

Seismic energy travels through the crust in the form of waves. There are two basic kinds of seismic waves: body waves and surface waves. Body waves travel outward in all directions, including downward, from the quake's focus -- that is, the particular spot where the fault first began to rupture. Surface waves, by contrast, are confined to the upper few hundred miles of the crust. They travel parallel to the surface, like ripples on the surface of a pond. They are also slower than body waves.

Following an earthquake, the body waves strike first. The fastest kind are the primary waves, or P-waves. (See animation below.) People often report a sound like a train just before they feel a quake, which is the P-wave moving as an acoustic wave in the air. Then the secondary, or S-waves, arrive.

A person in a building perceives the arrival of S-waves as a sudden powerful jolt, as if a giant has pounded his fist down on the roof. Finally, the surface waves strike. In very strong earthquakes, the up-and-down and back-and-forth motions caused by surface waves can make the ground appear to roll like the surface of the ocean, and can literally topple buildings over.

Seismologists have developed various ways to measure the strength of earthquakes. The first and most well-known is the Richter magnitude scale, developed earlier this century by California seismologist Charles Richter. The calculation of Richter magnitude is based on the maximum strength of the vibrations (measured by a seismograph) and the distance of the instrument from the epicenter of the earthquake. The Richter scale is logarithmic, which means that each increase in magnitude indicates a tenfold increase in the strength of the quake. A magnitude-6.0 earthquake, for instance, is ten times stronger than a magnitude-5.0. In terms of the energy released, the differences are even greater. A magnitude-6.0 earthquake releases 32 times the seismic energy as a magnitude-5.0.

But Richter magnitude is only accurate for earthquakes up to about 310 miles (500 kilometers) from the instrument that detects it. Seismologists have developed other magnitude scales based on measurements of body waves or surface waves. But these, too, are not accurate for all earthquakes. Body-wave magnitudes, for example, aren't accurate for very strong earthquakes. Another system has come into wide use, called "moment magnitude," which takes into account the actual area of fault ruptured and gives a more consistent measure of earthquake size across the spectrum -- from minor jiggles to devastating jolts.

Seismic waves weaken with increasing distance. All things being equal, the strongest groundshaking occurs at the epicenter of the quake -- the point on the surface directly above the focus of the earthquake. (The focus can be a few miles below the ground or, more rarely, as deep as 435 miles. Beyond that depth, rocks are too hot and malleable to store strain, and they simply deform, like a block of soft clay.) In the most powerful earthquakes, groundshaking can actually exceed the acceleration of gravity and toss boulders into the air, as happened during the great Assam (India) earthquake of 1897.

Groundshaking is not the only hazard people face during earthquakes. They can also trigger landslides. In 1692, the town of Port Royal, Jamaica, slid into the sea and came to rest 50 feet below the surface. Marine sediment quickly entombed the town, turning it into an undersea Pompeii: In 1959, archaeologists found a pot of turtle soup in one buried home, still sitting in its copper kettle. During quakes, blocks of crust also shift along fault lines, either horizontally or vertically. During the 1906 San Francisco earthquake, the west side of the San Andreas fault slid 21 feet northward. During the 1964 Alaska quake, some points on dry land rose nearly 40 feet and parts of the seafloor dropped 50 feet.

Another hazard is liquefaction. This happens when loose, moist soil or sand is shaken so hard that individual grains separate, turning the earth into a soft, fluid slurry that can swallow entire buildings. And ground motions in regions of soft sediment are drastically amplified relative to surrounding areas, so that much greater earthquake damage results, such as that in the Marina District of San Francisco following the 1906 and Loma Prieta (1989) earthquakes. The port zone of Kobe, Japan, was also damaged severely by liquefaction during the 1995 earthquake.

Though some scientists dream of discovering warning signals that would allow the evacuation of a city just before a large earthquake, the focus of earthquake preparation today is on making sure that buildings and other structures are engineered to withstand the maximum likely shaking without collapsing completely. So, if it's not possible to prevent earthquakes or flee from them, there's still hope of minimizing the death and destruction they visit on the cities of a restless and jittery planet