**Narration from the animation**

**Mexico: Earthquakes & Tectonics**

On September 19, 1985, a magnitude 8.1 subduction-zone great earthquake occurred beneath the coast of Michoacan Mexico,. Despite the 350 km distance from the earthquake epicenter to Mexico City, most of the 9,500 fatalities and 30,000 serious injuries occurred there. earthquake prompted Mexico to both strengthen its building codes and to develop an earthquake alert system for all of Southern Mexico.

To understand how a subduction-zone earthquake could cause such devastation so far away in the Mexico City Basin, let’s start by looking at the tectonic setting.

The Cocos Plate dives beneath the North American Plate at rates of 5 to 7 cm/year offshore of Michoacan, Guerrero, and Oaxaca. The 2,700 km-long Middle America Trench marks the subduction boundary from Southwestern Mexico to Costa Rica. In the past 40 years Mexico has had 50 earthquakes larger than magnitude 6 with epicenters concentrated near the plate boundary. During that interval, a dozen magnitude 7 or larger earthquakes occurred in the subduction zone. Red circles mark epicenters above the site where fault rupture began and yellow shows the rupture area.

*The Guerrero seismic gap* is a potential hazard zone. How can we understand the *relative* energy released by a great earthquake of magnitude 8 or 9, like the 1985 earthquake, compared to smaller yet still damaging earthquakes??

The energy released by earthquakes increases by a factor of approximately 32 for each unit increase in magnitude. As an analogy, if breaking a single strand of spaghetti represents a magnitude five earthquake, then we need to break *thirty two* to represent a magnitude six, 1,024 strands for a magnitude seven, and nearly *33,000 noodles* to represent a magnitude eight. To represent the energy released in a magnitude nine earthquake, like Japan in 2011, we would need to break more than a million noodles! **Chile 1960 was even bigger.**

Most people think of an earthquake as a sudden release of energy at the epicenter. In reality, an earthquake is caused by sudden displacement of rock across a fault at a given depth within the earth at the hypocenter, shown in this view of the top of the subducting plate. For great earthquakes, the displacement at the hypocenter is just the beginning. In 1985 the rupture displaced an area 180 km long.

Lets zoom in now to a cross section to view the plate interaction. The dense oceanic plate dives beneath the more-buoyant continental plate at a rate of about 6 cm/yr. Because tectonic plates are elastic like a spring, converging plates build energy at the leading edge of the continent. Locked by friction, the upper plate is forced back and shortened, raising the land surface. GPS, not available in 1985, is now able to measure that deformation. During a megathrust event, the force of the converging plates overcomes friction and causes the overriding plate to move up the fault surface. If it breaks all the way to the trench, as it did in Japan in 2011, the leading edge will lurch seaward, uplifting the seafloor, forming a mound of seawater that spreads out as a tsunami.

The disaster of 1985 surprised seismologists who thought a subduction-zone earthquake would not produce such sudden ground motion, or strong accelerations 350 km away in Mexico City.

Here’s why: if the seismic waves were traveling through uniform material, shaking would be half as strong at 13 km, a quarter as strong at 27 km, and an eighth as strong at 50 km. Mexico City recorded up to 1G of acceleration, an amount shown in this shake-table demonstration. Acapulco, on bedrock closer to the epicenter, had only moderate shaking.

What explains the much stronger ground shaking in Mexico City?
Mexico City sits on, the remnants of a dried up lake that once surrounded the Aztec capital, Tenochtitlan, now a sediment-filled basin surrounded by hard, volcanic-bedrock mountains. Short-period seismic waves produced weak ground motion as they passed through the bedrock but once inside the lake basin the waves slowed and were amplified causing the soft sediment to shake like Jello in a bowl. In the broad Mexico City Basin the seismic waves became trapped and reverberated for many minutes in a phenomenon known as basin amplification as the waves bounced off the bedrock becoming slower and bigger in the sediment. The sediment “resonated” with a 2-second period for over a minute. The period of oscillation, or shaking is the time between two peaks.
In the bedrock seismic waves oscillated with a 1-second period but slowed to a 2-second period with higher amplitude as the waves reverberated in the basi

Before earthquake codes, buildings were not always engineered to withstand back-and-forth accelerations. All buildings have a natural, period, or resonance which is the number of seconds it takes for the building to naturally vibrate back and forth. If the period of ground motion matches the natural resonance of a building, it will undergo the largest oscillations possible and suffer the greatest damage, Small buildings resonate naturally in one-second periods. A high-rise building, on the other hand, naturally resonates with a longer period. For example, a b 30-story building resonates at a period of 3 seconds, and a 50-story building at a period of 5 seconds. The result of the two-second period was that buildings of 8 to 20 stories with similar natural periods suffered the most damage while short buildings and skyscrapers were relatively undamaged.

In 1991 seismic stations were deployed only in the state of Guerrero, an area identified as the most hazardous for proximity to Mexico City, and the Seismic Alert System (SAS) was initially designed to provide warning only to Mexico City. It has since been expanded 626to issue warning to all large cities in the coverage area.

These one hundred seismograph stations are the backbone of the Seismic Alert system as they detect and record ground motion and transmit the data to a central control system that rapidly analyzes the data to determine magnitude and location. For a moderate sized event, a “preventive” warning goes out only to government authorities select users like hospitals and the Mexico City subway. For larger earthquakes, a broader alert is broadcast via TV, 658 Radio, and loudspeakers to notify people of impending shaking.

On April 18th 2014, the Seismic Alert System was put to the test. A magnitude 7.2 earthquake just north of the Guerrero Gap was recorded by coastal seismometers that immediately determined the epicenter, depth, and magnitude. The large size automatically prompted a public alert to be issued to all cities within the coverage area. The 18 million people in the Mexico City Basin received the earthquake early warning 71 seconds before ground shaking arrived. In seventy one seconds , people can move to safety, machinery can be shut off, rail and road traffic stopped, and emergency personnel & equipment readied for response.

Public education has been essential to the success of this program.