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Not My Fault: For the love of seismograms

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I love seismograms. I can't read music and my foreign language skills are pathetic but one glance at a seismogram and I can make up a credible story of what happened.

Most days I update the Humboldt daily earthquake recording (707 826-6020) giving me a feel for the ebb and flow of earthquake activity. It's been a quieter than average earthquake year (so far), but there were two M7.0s and a 7.3 in the past ten days that caught my attention.

For the recording, I note locations, magnitudes, and impacts and, for notable quakes, some background information. These earthquakes in the Southwestern Pacific didn't cause damage and were too small to pose a tsunami threat. But I like trans-Pacific seismic records, so just for my own pleasure, went to the "Make Your Own Seismogram" web site. The UC Berkeley Seismology Lab maintains an easy-to-use web interface to view records from the 105 stations currently operating in Berkeley's network. I usually choose the Jacoby Creek Station closest to Arcata – just click https://ncedc.org/ftp/outgoing/userdata/quicklook2/JCC.BHZ.current.png for the most recent 24-hour record.

The November 11th M7.3 record was a thing of beauty. The geologic structure of the Pacific is remarkable uniform. A roughly 4-mile-thick crust overlays the much denser mantle and there is little lateral variation. Earthquake waves traveling across the Pacific are guided by this structure and the surface waves for this record were spectacular.

If our planet were a uniform body with no changes in composition, density, or elastic properties, it would be easy to predict what seismograms should look no matter how far away you are. You would see three groups of waves: push-pull P waves that always arrive first, A weaker set of P and S waves that reflect off of the underside of the earth's surface might be visible, but it would be easy to predict their arrival times too.

Seismology is a relative newcomer to the geophysical toolbox. The earth's magnetic field had been under scientific study since the 16th century and De Magnete, published in 1600, is one of the first published scientific treatises. Many expeditions traveled the globe in the 19th century to collect gravity measurements.

Zhang Heng, a Chinese polymath widely versed in science and arts, is credited with inventing the first seismic instrument nearly 2000 years ago. His instrument could detect ground shaking and the direction waves were coming from but provided no record. The first seismographs, instruments that measure ground deformation as a function of time, weren't widely used until the dawn of the 20th century. The 1906 San Francisco earthquake was the first major quake to be recorded on instruments around the globe.

The first generation of seismologists faced a daunting task. They knew the earth wasn't uniform – gravity measurements and surface geology made that clear. And the records from 1906 showed that seismic wave arrivals were far different than what would be predicted by a uniform earth. There were more arrivals (we call them phases), blips of energy where waves were reflected. And at just a little more than halfway round the globe away from California, those initial P and S waves vanished.

After 1906, seismology became its own discipline, and the primary tools were paper records from seismographs. Pouring over the tiny wiggles, these scientists and their grad students noted every arrival time and the character of every tiny blip. These were compiled into a complex graph called a travel-time curve. Form the travel-time curve, one can work backward and create an earth structure that explains all of the arrivals.

By 1930, three of the earth's main divisions were clear: a relatively thin crust made up of lighter weight rock, a denser mantle, and an even denser core. It took my seismic hero Inga Lehman to discover the fourth.

Lehman was an extraordinary woman, gaining a graduate degree in computational mathematics and becoming Chief of the Seismological Department of the Royal Danish Geodetic Institute in 1928. She liked seismograms even more than I do and was certainly much more adept at reading them. She found very faint arrivals nearly lost in the seismic squiggles and painstakingly mapped them out. In 1936 she published a paper titled P', her notation for the seismic wave that travels into the earth's core and is bent by an even deeper layer. It was the first clear evidence of the earth's inner core.

Inga Lehman was a visiting scientist in the late 60s at Berkeley when I was finishing my undergraduate degree in geophysics. She shared an office with a good friend who recalls her being "a smiling person who always greeted me with small talk." She was in her 80s at the time. She continued to work actively for another decade and finding more details of earth structure, dying at the age of 105.

I often think of Inga Lehman when I look at a seismogram and appreciate how much information is tucked within the wiggly lines. Some of that information is accessible even to an untrained eye. The November 11 M7.3 is a classic shallow earthquake. You can easily see the initial sharp pulses of energy of the body waves and then the sinuous oscillations of the much larger surface waves as they form beats traveling across the Pacific. The two 7s were much deeper earthquakes. The initial pulses look very similar but where the big surface waves should be, there is nothing. An earthquake 300 to 400 miles beneath the surface just doesn't excite the surface enough to produce anything easy to see.

I am glad I came from the generation of students who had to put their time in processing the analog paper records of my time. We had to think visually and train our brains to look for subtle changes in frequency and amplitude. No one uses analog data anymore and artificial intelligence can now glean more information than the human eye. But the aesthetic is lost and I'm not sure the new generation of seismologists love seismograms as much as I do.

Anyone can make a seismogram from Berkeley's 105 seismic stations at
https://ncedc.org/bdsn/make_seismogram.html

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