

Times Standard

Not My Fault: Ground roll is real, but we still aren't sure exactly what it is

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Is this real? No, this is the author's attempt to generate an AI image using the Claude app. It illustrates Kay Escarda's story of looking out her bedroom window during the 1954 M6.5 Fickle Hill earthquake and seeing terrified cows running across the rolling land.

Last December, I requested your stories of unusual happenings during earthquakes. Those reports contributed to the poster a group of us are presenting at next week's annual meeting of the Seismological Society of America. I received many observations including sounds and smells, earthquake lights, odd animal behavior, and trees bending into impossible positions, but the area I decided to focus on is seeing the ground roll "like waves on the ocean." I'm calling these reports Visible Ground Roll (VGR) and it's time they are given more attention.

I've mentioned VGR in previous columns, and your reports were just the impetus I needed to dig in more deeply. Ground rolling observations go back to some of the earliest written accounts of earthquakes. The Institute of Geophysics, Academia Sinica has compiled a list of earthquakes in China that begins in 1177 BCE, and a number of ancient events include descriptions that sound like VGR. Of particular note is the Shaanxi earthquake during the Ming dynasty in 1556, considered one of deadliest earthquake of all time. It caused caves to collapse where many people lived and was followed by wide-spread crop failures. At least 500,000 died

from a combination of direct impacts of shaking and ensuing famine and plague. A common descriptor of survivors is seeing the ground roll.

I first became interested in ground roll as part of the team re-examining the December 1954 Fickle Hillk earthquake (Not My Fault 8/30/35). I collected reports from people who were here when that earthquake occurred. Some people sent newspaper clippings or had written accounts from relatives, but the majority were eyewitness observations from people now in their late 70s to 90s who experienced it when they were children.

My current tally is nearly 40 reports from people who ranged in age from 3 to their early teens when the earthquake occurred. The reports came in individually via email, letters, and phone calls. I didn't provide any prompts as to what kind of observations I was looking for, just asked whatever they could remember. That earthquake occurred just before noon the week before Christmas and many of my correspondents were outside at the time. Nearly half of them reported being awestruck by the site of the ground undulating, what I am now calling VGR.

This wasn't the first time I've heard VGR reports. It was something introduced in my first seismology class when we learned about intensity scales. Intensity is a qualitative measure of how shaking strength varies and the Modified Mercalli scale used "waves seen on the ground surface" as an indication of the strongest shaking levels. Charles Richter's "Elementary Seismology" textbook published in 1958 states "there is almost certainly a real phenomenon of progressing or standing waves" observed by people during some earthquakes. He does qualify his statement that illusions can affect observations.

I was never surprised when people told me of seeing the ground rolling. I haven't seen it myself and am a bit jealous of those who have and have always considered such observations to be accurate. After the April 1992 Cape Mendocino earthquake, I spent a lot of time developing a survey questionnaire to provide a more quantitative way of measuring intensity. We asked all sorts of questions, looking for variables that showed an increase with the strength of shaking and that questionnaire would eventually become the basis of the USGS "Did You Feel It?" web page. It never occurred to me to include a question about VGR. At that time, it was something never considered in serious seismology circles.

The 1954 earthquake reports nudged me to rethink the phenomenon. So many people seventy years afterwards had vivid memories of the ground rolling. They often didn't recall many of the things that we associate with strong earthquakes such as loud noises or items falling off shelves. What stuck out were seeing chimneys fall down, cracks in the ground, their parents being frightened, and seeing VGR.

A quick survey of the literature revealed very little. There was one paper written in 1970 by a seismologist who had observed VGR during the great 1960 Chile earthquake. He acknowledged that most members of the seismology community were not believers and ascribed such observations to an agitated state of mind during an earthquake that distorts perceptions. But he was very clear about his own observations and thought it might be caused by gravity causing the solid ground to slosh analogous to oscillations in a body of water.

While absent in professional journals, there was a plethora of ground roll reports in newspapers and other media after strong earthquakes. No catalog of VGR observations exists so as part of

our poster, I began collecting these sightings by on-line searches and requests through print and social media. There were accounts from other pre-instrumental earthquakes such as the 1692 Port Royale Jamaica earthquake where not only did the ground roll but liquefaction so severe that people sank into the ground, and the 1811-1812 New Madrid earthquakes in Missouri and Arkansas that caused the Mississippi to temporarily flow backwards.

The list of more recent VGR earthquakes includes some of the largest earthquakes of all time – 1960 Chile (M9.5), 1964 Alaska (M6.4), and 2001 Japan (M9.1). Ten California earthquakes made my list, three on the North Coast. It includes earthquakes in the greater Los Angeles area, Santa Barbara, Coalinga, and Loma Prieta among other. I'm sure a more thorough search will add more events. Most, but not all reports were from relatively shallow earthquakes with a component of reverse or thrust fault slip.

I turned to Dave Wald at the USGS to see if he could find accounts in the USGS "Did You Feel It?" database. The DYFI web page (<https://earthquake.usgs.gov/data/dyfi/>) went live in 1999 with an intensity questionnaire. It does not include any questions on VGR, but respondents can add additional comments. A quick search brought up 57 with possible visible wave reports. I haven't had the time to look in detail at which events triggered VGR comments but there is no clear relationship between how strongly the earthquake was felt and seeing the ground roll.

The big question is what physical phenomenon is behind these visual reports. We looked more closely at two earthquakes with seismic records from the same area as VGR sightings. Strong motion instruments were operating in Eureka during the 1954 M6.5 earthquake and in Coalinga when the 1983 M6.7 Coalinga earthquake. The recordings show ground displacements on the order of a few inches in height with ten-second periods that could be detected by the human eye. This is the seismic surface wave portion of the record and Rayleigh waves that have both vertical and horizontal displacement could be the culprit.

Our group consensus is that VGR is real, the cause may be Rayleigh waves, but much work remains to be done. VGR does not correlate with shaking strength and is rightfully not included in current intensity formulations. Our preliminary tabulation of VGR events suggests that shallow thrust earthquake sources may be more likely to produce visible ground rolling. I haven't heard of any ground roll reports from recent strike-slip North Coast earthquakes including the 1994 and 2024 Mendocino fault earthquakes and the 2021 M6.0 Mendocino triple junction event. It's likely that eyewitness reports may become exaggerated, and I doubt that the rolling was twenty feet high as one 1954 person recounted. While not useful in determining earthquake size, I think VGR is a very cool phenomenon and may be most useful as an education tool to draw public interest and awareness of what an amazing planet we live on.

Charles Richter had it right as he did in many things seismic – VGR is real, we aren't quite sure about the exact physical cause, and the earthquake experience may distort people's perceptions. VGR is certainly worthy of a bit more exploration.

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