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Not My Fault: What seismology can tell us about underground nukes

Lori Dengler/For the Times-Standard
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I'm a baby boomer. But my generation could just as easily be caused the nuclear generation – the first to grow up under the threat of nuclear annihilation. I was in kindergarten when the first hydrogen bomb was tested. Nuclear tests and the fear of nuclear war was the backdrop of my youth and coming of age.

My connection to the nuclear age became more personal in college. Several of my professors were funded by Defense Department grants and the atomic age was an important contributor to the unfolding of plate tectonic theory – the grand unifying framework of earth sciences. The reason? In the early 1960s, the United States and the Soviet Union signed a treaty banning nuclear weapon tests in the atmosphere. When nukes went underground, seismology suddenly became very important.

Project Vela Uniform was launched in 1961 to monitor underground testing. The first priority was to establish the first global seismic network. A goal of the network was not only to monitor areas where nuclear tests might be conducted but also develop methods to discriminate between a natural earthquake and an underground explosion and to determine the yield or size of the explosion from its seismic signal.

Seismologists needed high quality recordings of both earthquakes and explosions and a detailed picture of earthquake structure to understand how the seismic signals were modified as they traveled through the earth. Prior to 1961, there were regional networks but they operated independently and used different types of instruments. The World Wide Standard Station Network (WWSSN) established standard instruments at 120 locations around the globe.

The WWSSN was an incredible boon to earth scientists. For once they could look at global seismicity in a systematic way. The data confirmed much that previous networks had hinted at - the concentration of earthquake activity around the Pacific rim and along oceanic ridges and the striking depth pattern of earthquakes that we now recognize as the signature of subduction zones. One of my Berkeley professors was able to uncover details of the structure within the earth's mantle, recognizing a slow velocity zone that was one of the first hints of the asthenosphere – a warm, less rigid zone within the mantle that allows the plates above to move.

A number of researchers tackled distinguishing nuclear explosions from earthquakes. It turns out that explosions, even very big ones like a hydrogen bomb, are fundamentally different than earthquakes. First of all, nuclear tests are located on land at relatively shallow depths. It costs money to drill deep holes, so you don't want to drill any deeper than you have to. Most have been between 5000 and 9000 feet – the intent, not always achieved, to avoid venting of radioactive materials into the atmosphere. If the depth of a suspect seismic event is tens of miles beneath the surface, it can be ruled out.

Earthquakes release energy by rupturing the fault and displacing the rock on either side. They produce three types of seismic waves – the initial compressional of P-wave that you feel as a sharp up and down movement, the stronger transverse secondary S-wave that moves from side-to-side and the slower but large amplitude surface waves. Explosions are a point source pushing outward in all directions. The result is a very strong initial P-wave, and hardly any S-waves or surface waves. By comparing the relative amount of P-wave and surface wave energy, it is pretty easy to nail the explosion. When I taught the introductory earthquake class at Humboldt, I included two seismograms on the final exam and most students had no problem telling which one was the explosion.

Last Saturday when my computer screen started to flash alerting me to an earthquake of magnitude 6 or larger, I noted the location – North Korea – and immediately thought nuclear test. The Korean peninsula is not seismically active and the epicenter popped up in the Punggye-ri Nuclear Test Site right next to the previous five North Korean tests. It didn't take long for seismic organizations to publish seismograms confirming the telltale pattern of an explosion.

What was surprising was the size of the North Korean test. The USGS estimated a magnitude 6.3. Giving a magnitude to a nuclear detonation can be misleading as an explosion is nothing like an earthquake. But the size of the P-waves recorded on instruments around North Korea allowed seismologists to make an equivalent energy estimate. Converting a magnitude into yield is problematic as it depends on how the device was loaded into the hole and the nature of the surrounding material. Early yield estimates have ranged between 50 and 110 kilotons of TNT – three to ten times larger than previous North Korean tests and certainly large enough to support the North Korean contention that this was a fusion bomb.

Science can uncover what likely happened in North Korea on September 3, but what will happen next is in the hands of politicians on both sides of the Pacific. It has brought a chilly reawakening of my childhood fears and, as I felt so many years ago, I have no ability to influence the outcome.

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