The Core of the Matter

Copenhagen, Denmark, early 1930s

Inge Lehmann, Chief of the Seismology Department at the Royal Danish Geodetic Institute, looks closely at the seismograms of a powerful earthquake that shook New Zealand on June 16, 1929. The seismograms were recorded in three Soviet cities. They showed P waves arriving at the seismic stations about 19 minutes after the earthquake.

Something wasn't right. These cities—7,300 to 9,200 miles (11,748-14,806 km) from the quake—shouldn't have felt P waves this strong. Like other seismologists, Lehmann knew that Earth was made of three layers—crust on the outside, a mantle beneath the crust, and a core in the center—and the waves had to flow through it. So what was wrong?

Flashback

In the early 1900s, seismologist Richard Dixon Oldham found that when an earthquake occurred, P and S waves showed up on seismograms all over the world. He realized that seismic waves could be used to learn about Earth's interior.

Seismic waves travel at different speeds, depending on the type of rock they're moving through. When the seismic energy hits a new layer of rock, some of it gets reflected back towards the surface and some of it moves through the new layer at a different speed and direction. Oldham thought that if he could figure out where and how fast certain waves traveled, he could figure out how Earth was layered.

Oldham made an interesting observation: Waves traveling through the center of Earth arrived at seismic stations a few minutes later than they should have. He concluded that the waves must be slowing down somewhere in middle of the planet. Oldham discovered Earth had a core made of different material than the other layers.

More Research Needed

As seismologists continued to study earthquake waves, they found more evidence for a core in the center of Earth. They found that P waves took longer than expected to appear because they were reflecting off the core.

Geologists soon noticed that P and S waves weren't registering on some seismometers. Seismologists speak of distances in terms of degrees, rather than miles or kilometers, away from the earthquake. For example, 180° is halfway around the earth, or about 12,000 miles (19,312 km). They noted that many P and S waves arrived at stations up to about 103° in any direction from the earthquake, and many P waves between 143° and 180° away. But there were no P waves between 103° and 143°.

The core was casting a "seismic shadow." When the P waves hit the core, some were changing direction in such a way that none came out in this area. Seismologists call this area the shadow zone (see diagram, right).

The other interesting thing seismologists noticed was that the S wave shadow zone was even larger than the P wave's. There were no S waves arriving past 103°. S waves didn't seem to be traveling through the core at all.

Seismologists knew that although P waves can travel through solids, liquids, and gases, S waves can only travel through solids. Because the P waves slowed down when they entered the core, and the S waves didn't seem to travel through the core at all, seismologists concluded that the core must be liquid.

Return to the 1930s

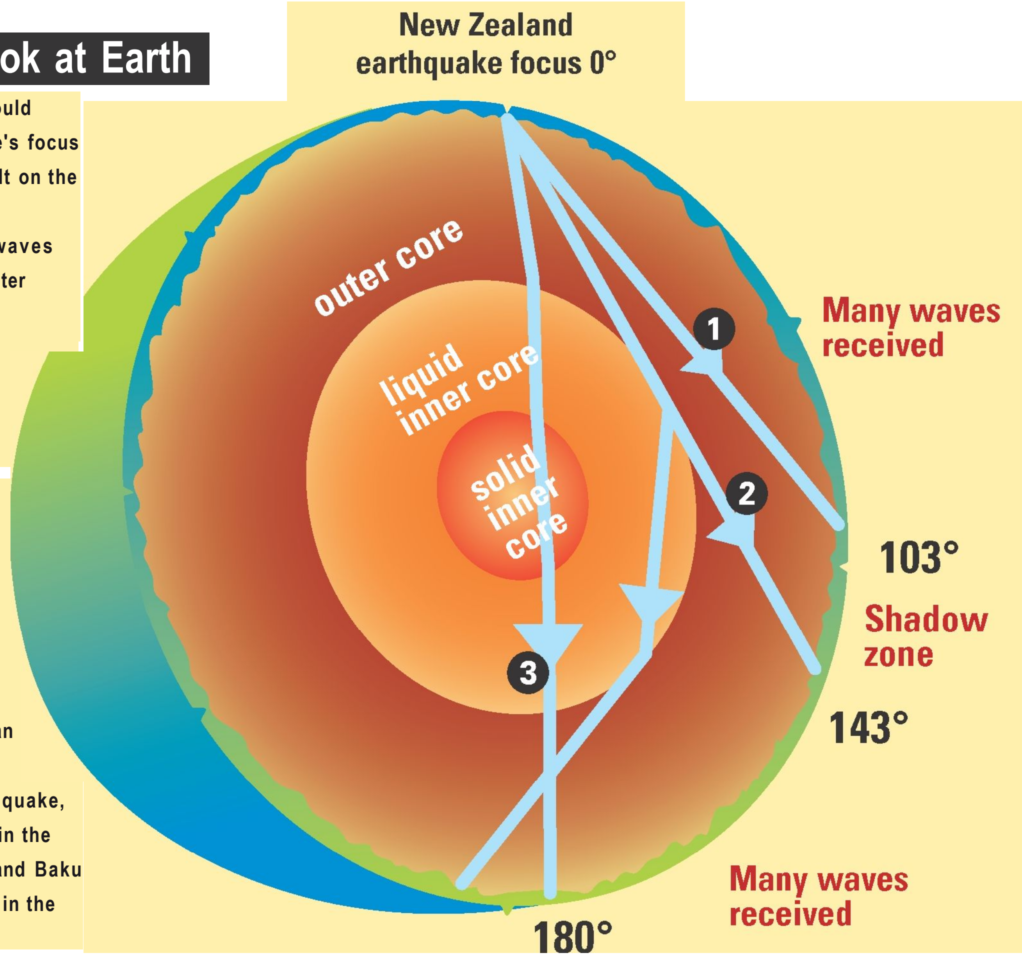
Inge Lehmann knew all of this when she studied the New Zealand earthquake seismograms and that's why she found them troubling.

First of all, they clearly showed P waves arriving in the shadow

An Inside Look at Earth

A "direct P wave" should move from the earthquake's focus through the earth to be felt on the other side (line 1.. But scientists found some P waves were reflecting off the outer core (line 2) . They also noted that P waves traveling through the solid inner core speed up (line 3) .

The shadow zone (between 103° and 143°) is the area on the earth in which P waves don't show up on seismographic data. This zone changes location depending on the site of an earthquake's focus. In the case of the New Zealand quake, the waves didn't register in the Russian cities of Irkutsk and Baku because they are located in the shadow zone.



zone. Other seismologists had ignored these waves. They explained these as P waves that had reflected back and forth, bouncing around inside the earth until they got to the shadow zone. But surely, Inge thought, such a wave would lose its energy and be too weak to show up on seismograms in the shadow zone.

Secondly, some of the waves going through the core were arriving at stations sooner than expected. This suggested that something was speeding them up.

In 1936, Inge Lehmann came up with an explanation:

A hypothesis will here be suggested ... although it cannot be proved from the data at hand. We take it that, as before, the earth consists of a core and a mantle, but that inside the core there is an inner core in which the [speed of the wave is greater] than in the outer core.

An inner core could explain the mysterious P waves arriving in the shadow zone. These waves had been reflected off the boundary between the outer and inner cores. An inner core could also explain the waves that were traveling too quickly. They had been sped up when they entered the denser material.

Over the next 40 years, seismologists were able to prove that Lehmann was correct. They also changed our understanding of the inner core. Using earthquake data, seismologists were able to determine its thickness (800 miles/1,287 km) and show that unlike the outer core, the inner core is solid.

Activity

AROUND THE BEND **Get a clear glass of water filled halfway with water and a straw. Dip the straw in the water and look at it from the side. What's happening at the point where the water meets the straw? According to the information on these pages, what might the straw represent in terms of an earthquake?**