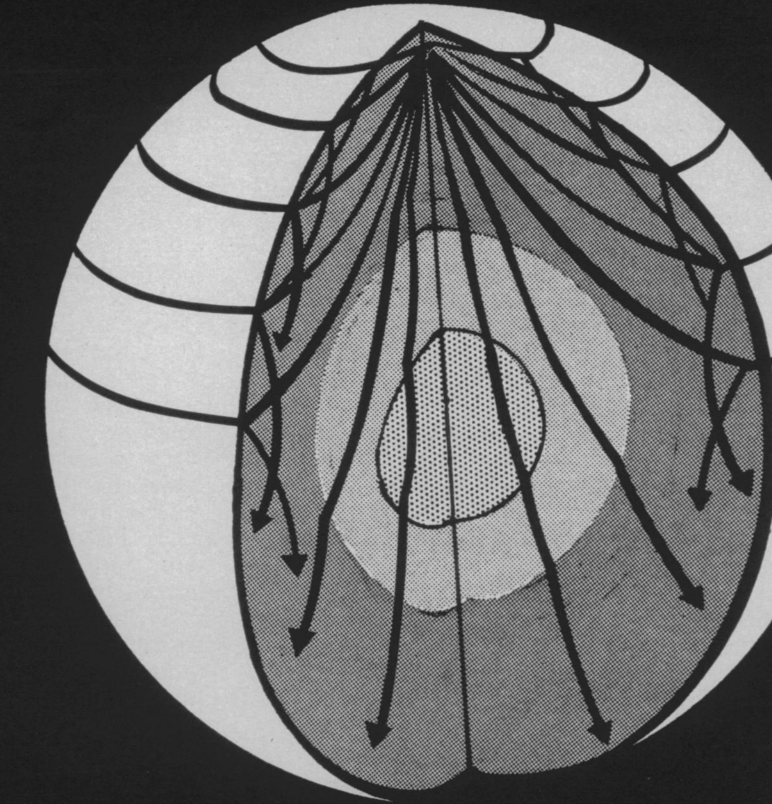
Probing the earth's inner core



Recent findings indicate that the earth's inner core has a consistency like that of hard rubber

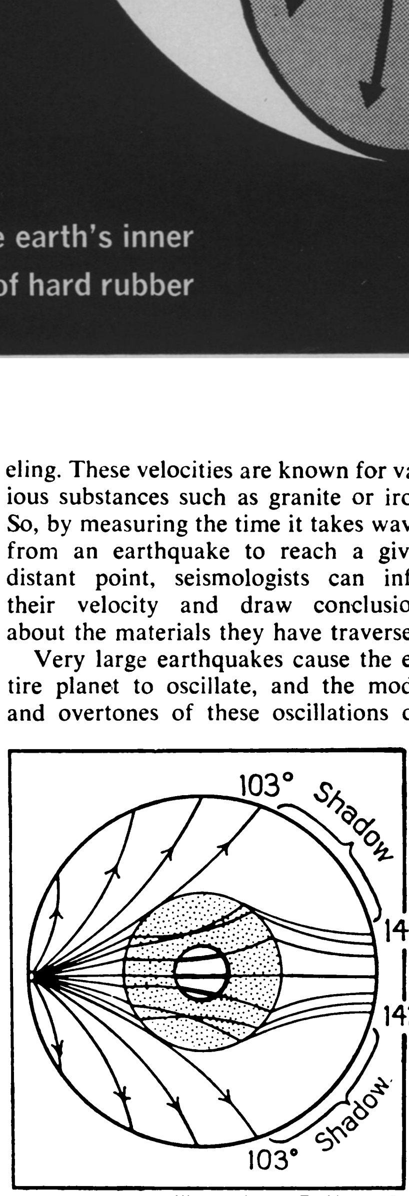
by Louise A. Purrett

In Jules Verne's day, the only way to find what lay at the center of the earth was to travel there. In his classic *Journey to the Center of the Earth*, Verne's characters did just that, traveling through a labyrinth of caverns. Scientists haven't yet found a secret passage to the earth's innards, but they have developed several ingenious, indirect methods of revealing the earth's composition.

With instruments to detect and measure seismic waves and the earth's oscillations, geophysicists are developing better and better models of the structure of the earth. The shape and composition of the mantle and outer core have been defined in general terms. In the past few months geophysicists have been probing into the inner core and have now evolved a fairly clear picture of its major characteristics.

Earthquakes produce two basic kinds of body waves—waves that travel through the body of the earth. Compressional waves travel through liquids and solids; shear waves can travel only through solids. The velocities of both kinds depend on the properties of the substance through which they are traveling. These velocities are known for various substances such as granite or iron. So, by measuring the time it takes waves from an earthquake to reach a given distant point, seismologists can infer their velocity and draw conclusions about the materials they have traversed.

Very large earthquakes cause the entire planet to oscillate, and the modes and overtones of these oscillations depend on the density and elasticity of the earth. In addition, the different concentric spheres each vibrate separately. Oscillations are thus a good way of defining density distribution within the earth.



Illustrations: E. Cherry Doyle

Wave paths from an earthquake.

It was found that, between 11,000 and 15,000 kilometers from the earthquake epicenter, compressional waves did not arrive at the predicted time, and beyond 11,000 the shear waves disappeared entirely. It was concluded that the shadow zone between 11,000 and 15,000 kilometers could be explained by a boundary zone at a depth of 2,900 kilometers which was reflecting and refracting the waves away. If this boundary marked a liquid core, the disappearance of shear waves, which cannot travel through liquids, could also be explained.

Once again, though, evidence arose to question the simple earth model that had evolved. Scientists began to detect waves within the shadow zone where there should have been none, and in 1936 the Danish seismologist I. Lehman proposed that these were waves that had penetrated the core and were reflected and refracted off still another, deeper boundary—an inner core. As the speed of the compressional wave appeared to increase in the inner core, the inner core has been presumed to be solid.

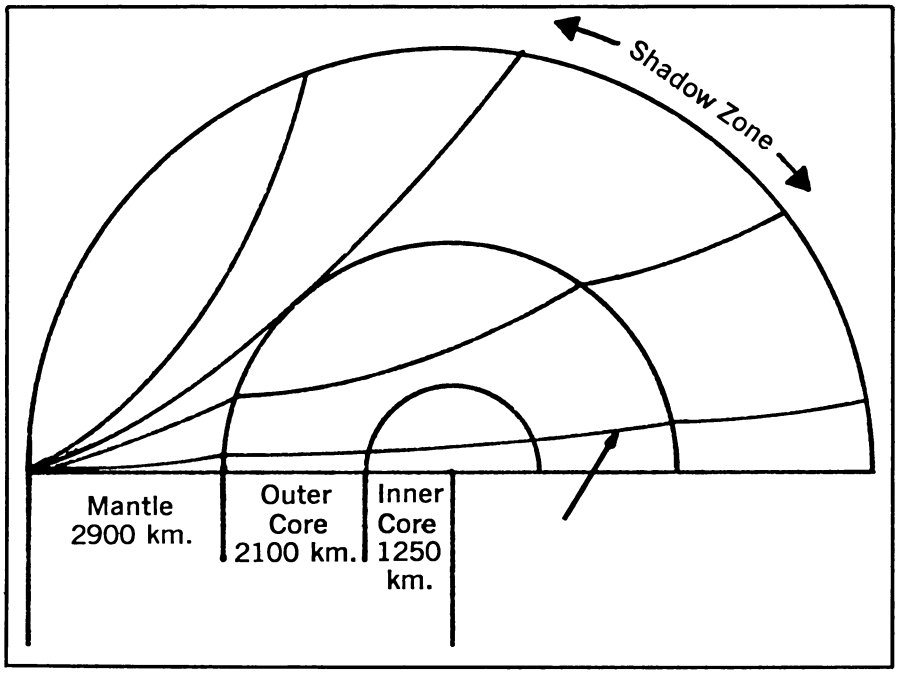
Little more was learned about the inner core until 1970, when three scientists used the Large Aperture Seismic Array in Montana to detect seismic waves reflected at a steep angle from the boundary of the inner core. The boundary must therefore be sharp, because a gradual transition zone would not reflect seismic waves. From the LASA data, the inner core's radius was calculated to be 1,250 kilometers; its density just inside the boundary less than 13,500 kilograms per cubic meter.

Meanwhile, Adam M. Dziewonski of the University of Texas at Dallas and Freeman Gilbert of the University of California at San Diego have been concentrating on the other approach, analyzing overtones of oscillations. Only observations of the overtones, rather than of the fundamental modes, Dziewonski believes, "will permit determination of the radial distribution of density in sufficient detail to provide an independent and meaningful estimate of the composition of the deep interior of the earth."

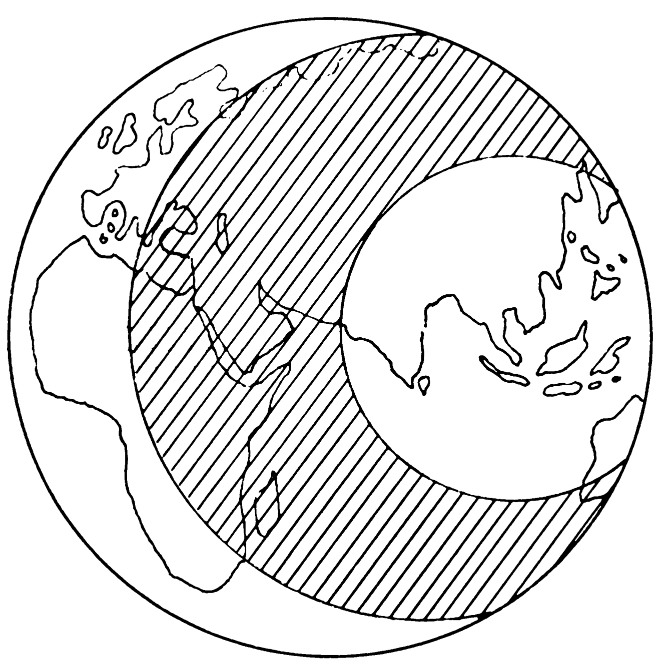
The oscillation method works mainly because there are already fairly good models of the earth's general structure. What the researchers do is begin with various reasonable earth models, compute the periods of oscillations that would result from the given density and elasticity distributions, and look for oscillations with these periods. If they appear as predicted, the earth model is confirmed; discrepancies can be explained by refining or modifying the model.

In June 1971, Dziewonski compared overtones having periods greater than 250 to 300 seconds observed by the World Wide Standard Seismograph Network with those predicted by various alternative earth models. The data could not be satisfied by an earth model with a liquid inner core, he concluded.

Then, in December, Dziewonski and Gilbert picked out particular oscillatory modes that had an appreciable part of their energy in the inner core. Frequencies of these modes depend in large part on the composition of the inner core. As before, they compared their observations with those calculated for earth models having liquid inner cores and earth models having solid inner cores. Once again, the conclusion was that the inner core must be solid.



Seismic waves may change direction or form as they travel through the earth: Three MIT scientists found shear waves that had traversed the inner core.



Shadow zone for an earthquake in Peru.

In passing, Dziewonski and Gilbert noted that it was believed that conclusive evidence of solidity of the inner core would come from observations of seismic waves that travel through the inner core as shear waves. Shear waves could not exist in a liquid core.

In the Feb. 11 NATURE, Bruce R. Julian, David Davies and Robert M. Sheppard of the Massachusetts Institute of Technology's Lincoln Laboratory report that they have observed seismic waves, using the LASA, that traveled through the inner core as shear waves. Whenever a seismic wave, compressional or shear, crosses a boundary, it splits into two waves, one compressional and one shear. The wave the Lincoln Laboratory researchers detected, says Julian, would have passed through the mantle and outer core as a compressional wave, through the inner core as a shear wave, then back out the outer core and mantle once again as a compressional wave. Because the wave emerges as a compressional wave, Julian explains, the scientists cannot know positively that it was a shear wave when it passed through the inner core. But they assume it must have been shear because the time at which it arrived is consistent with such a hypothesis.

The average velocity of the shear waves in the inner core, they estimate, was about 2.95 kilometers per second. This is not inconsistent with Dziewonski and Gilbert's findings, says Julian. He believes the inner core, like the outer core, is probably iron. But unlike the outer core, it is not liquid. Nor is it a really hard solid. It seems, says Julian, to have a consistency like that of gold, lead, or hard rubber. □