Ringing Earth's Bell

What makes our planet constantly quiver?

By RICHARD MONASTERSKY

Put an ear to the ground and you will hear the muffled fusion of thousands of sounds. The rumble of a delivery truck, the clatter of high-heeled shoes, the chatter of moles, and the crashing of distant ocean waves all contribute to the din underfoot. Buried deep amid that cacophony is the faintest of reverberations, an inaudible incessant pulse coming, oddly enough, from Earth itself.

Two teams of Japanese researchers recently discovered this planetary ringing, which has set seismologists around the world searching for an explanation. Unlike the bursts of vibrations from earthquakes, the mystery vibrations appear to resonate continuously and may offer new insights that extend beyond Earth to other planets, say scientists.

"It's the most exciting thing that's going on right now," says Barbara A. Romanowicz, the head of the Seismological Laboratory at the University of California, Berkeley. "It opens up the possibility of looking at the internal structures of planets, for example Mars."

The discovery of the new-found phenomenon came from studies of Earth's so-called free oscillations, the same kinds of vibrations that ring out from a bell. Every bell has its own particular tone, regardless of how it's struck. A wooden mallet, a brass rod, or even the gentle stirrings of the wind all elicit the same chorus of frequencies that gives a bell its natural tone.

Earth, too, oscillates with its own natural frequencies whenever it gets struck by a big earthquake. The largest tremor of the century, a 1960 Chilean monster measuring magnitude 9.5, caused the planet to ring for days on end before the vibrations subsided, says Toshiro Tanimoto of the University of California, Santa Barbara.

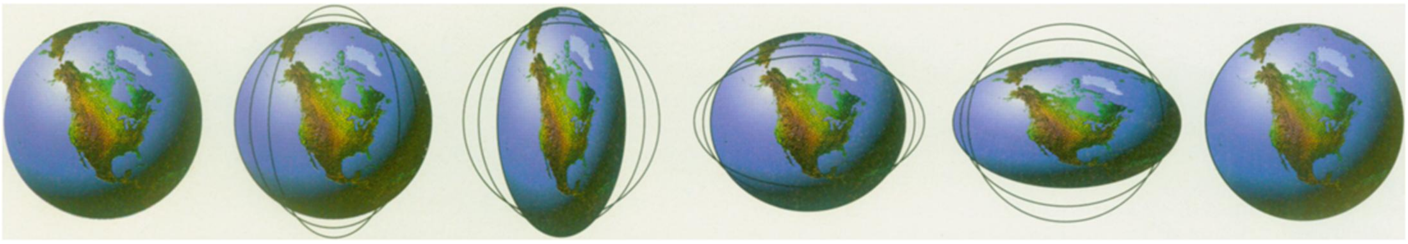
The oscillations differ from the short-period seismic waves that tear apart cities and then fade quickly. The free oscillations have long periods ranging typically from a few minutes to nearly an hour. They swell and deflate Earth's surface so slowly that people don't notice the ground warping beneath them. After the 1960 earthquake, for instance, residents of Cincinnati couldn't tell that their homes were rising and falling by a centimeter every 54 minutes.

In the past, seismologists had thought that these slow planetary stirrings came only with energetic quakes. But researchers are now starting to tune into extremely feeble free oscillations that ring all the time.

This new insight into Earth's behavior began with an astronomer named Naoki Kobayashi from the Tokyo Institute of Technology who was more interested in distant worlds than in his home planet. Kobayashi had previously studied the pulsing oscillations of the sun, a branch of inquiry that has revealed important details about the star's interior. Recognizing that seismology offers a useful window into the sun and Earth, he wondered whether similar techniques could probe the innards of Mars and Venus.

At first glance, seismology seems a poor tool to use on such planets. Mars and Venus both lack plate tectonics—the ever shifting patchwork of surface blocks whose movement drives most quakes on Earth. Researchers believe that these two planets have far fewer, if any, quakes.

So Kobayashi wondered whether some other source of energy could set Mars and Venus ringing. He focused on the atmosphere, because both bodies have fierce winds that scour their surfaces. When Kobayashi estimated the effects of these gusts, he found that the atmospheric turbulence was strong enough to create free oscillations on both planets. The expected vibrations are tiny, but he calculated that modern instruments should be able to observe them.



Earth as instrument: After an earthquake, the planet vibrates in a manner similar to a ringing bell. The simplest pattern causes the globe to expand and contract at the equator and poles in football shapes. Atmospheric winds may trigger more complex forms of vibration.

Realizing that winds on Earth could potentially have the same effect, Kobayashi alerted Kazunari Nawa, a seismologist at Nagoya University who was studying records from an extremely sensitive gravity meter stationed at the South Pole. This gravimeter offered an ideal way to look for subtle motions of Earth's surface. The instrument contains a sphere of niobium levitated by a magnetic field. The gravimeter senses the rising and falling of Earth's surface because the movement slightly alters the force holding up the sphere.

After searching the South Pole data, Nawa found weak but continuous oscillations, about a trillionth of the strength of gravity at Earth's surface, picked up by the gravimeter. He published his initial finding last year in a Japanese journal.

Nawa and his colleagues went on to

analyze more gravimeter data from the South Pole, as well as from stations in Brazil, Alaska, Canada, Hawaii, Peru, California, Australia, and Tonga. Pervasive free oscillations showed up at all sites, except the seismically noisy Tonga station. Naoki Suda of Nagoya University, Nawa, and Yoshio Fukao of the University of Tokyo reported their findings in the March 27 SCIENCE.

Earthquakes do not appear to be the source of these motions, according to their analyses. The pattern of simulated oscillations produced by quakes did not match features in the gravity record from the South Pole.

A separate team sounded out the oscillations using a different approach. Tanimoto, Kobayashi, and their colleagues examined records collected by seismometers during times when the globe was quietest, so they would have the greatest chances of detecting something subtle. "Seismologists normally are looking for earthquakes," says Tanimoto. "What we did was completely reverse things. Whenever there was a big earthquake, we threw out the data. We tried to avoid earthquake effects as much as possible."

The researchers pored over a catalog of recent quakes and excluded data for several days following each sizable event. During the relatively rare calm intervals, the researchers found almost imperceptible oscillations with periods ranging from 2 to 8 minutes, they report in the May 15 GEOPHYSICAL RESEARCH LETTERS. The seismometers measure how quickly the ground moves, rather than how far it moves. To give a sense of these stirrings, Tanimoto says that they raise and lower Earth's surface by only 2 millionths of a centimeter, little more than the diameter of a single molecule.

The news of Earth's continual unrest made seismologists skittish at first. "Everyone was pretty skeptical about it in the beginning," says Hiroo Kanamori of the California Institute of Technology in Pasadena.

Indeed, the journal NATURE rejected Kobayashi's report describing the detection of these oscillations.

Seismologists initially worried that earthquakes were causing the oscillations, but Tanimoto's procedure for removing quakes allayed those concerns, says Kanamori. "His test was pretty stringent. He could only find 60 days or so out of 8 years that he thought were completely free."

Other researchers, however, remain unconvinced. The earthquake catalog that Tanimoto used overlooked some quakes ranging from magnitude 5.2 to 5.4, says Pierre Ihmlé of the Institute of Geophysics in Zurich. Ihmlé contends that some of the seemingly incessant vibrations probably stem from these quakes, which would have remained in Tanimoto's data. "I do not think that these authors have a true discovery yet," he says.

Some seismologists have fretted that the oscillations were effects of small earthquakes. They reasoned that the hundreds and thousands of minor earthquakes around the globe every week could be jabbing Earth enough to make the planet quiver constantly.

Tanimoto, Kobayashi, and their colleagues addressed this point by calculating the effects of earthquakes smaller than magnitude 5. When they added up all the energy released by such events, the tally came up short. "We don't think that the cumulative effects of small earthquakes can do it because they're just too small," says Tanimoto.

Gregory C. Beroza of Stanford University agrees. "The background seismicity, all the magnitude 5, 4, 3, and 2 earthquakes, would not be enough to explain their observations," says Beroza, one of the few people who has previously explored oscillations during quiet times.

Seismologists at the University of California, Berkeley are currently trying to confirm the recent discoveries. If their analyses also detect the incessant oscillations, "then it essentially opens up a whole new field," says Romanowicz. She adds, "You have to figure out what they might be due to."

In their SCIENCE paper, Suda, Nawa, and Fukao challenge other researchers with their understated yet provocative conclusion: "The observed 'background' free oscillations represent some unknown dynamic process of Earth."

In a commentary in the same issue, Kanamori offers a list of factors that might cause such incessant vibrations. The most obvious candidate is the wind, as originally hypothesized by Kobayashi. Vertical air currents plowing into Earth would provide enough energy to trigger the planet's jitters. Indeed, there are some subtle indications that the oscillations pick up strength during winter, when winds blow fiercest, says Kanamori.

At this early point in the investigation, however, researchers must also consider geological forces as a source of the vibrations. "It would be exciting if these observations lead to the discovery of some slow, deep process," says Kanamori.

He and others speculate that plate tectonic movement may be involved. The energy could come from magma rising up at mid-ocean ridges—the place where new rock bonds onto the existing plates. Conversely, the phenomenon could reflect the last gasps of disappearing surface plates as they slide into Earth's interior.

Whatever the process, it would have to be slow. When plates jerk forward quickly, they produce earthquakes. Yet, geologists know that plates must also move in less dramatic ways because they migrate farther than would be expected just from ordinary earthquakes. The creeping motion of plates—sometimes termed silent quakes—may play a role in triggering the newly observed oscillations.

Many of the Japanese researchers favor the wind hypothesis at this point. "It is not a big effect locally, but it occurs all over the surface of the planet. Winds hitting everywhere on the surface of Earth can excite these motions because they have lots of energy," says Tanimoto.

The search for an answer has caused seismologists to reach far beyond their field into meteorology. Researchers have suggested to Tanimoto that rain or snow could cause the oscillations, although he says both factors impart less energy to Earth than does the wind. One colleague even joked that the nearly 6 billion humans stomping around the planet could be the cause.

To pinpoint the source of the planetary pulsing, seismologists will have to change their tactics. Previous studies have lumped records from distant areas together in order to maximize the chances of detecting the oscillations. In the future, researchers could look at individual recordings from specific locations, says Kanamori.

Tanimoto and his colleagues are studying seasonal variations to see if the oscillations actually do wax and wane with the winds. They are also starting to look at barometer records to see whether patterns of atmospheric pressure correspond to the observed oscillations.

In the meantime, Kobayashi has kept his sights set on other planets. If winds are stirring up oscillations on Earth, they may be agitating other rocky bodies with atmospheres, he says.

In past missions to the moon, seismometers were left on the surface to pick up vibrations from the occasional meteorite strike. Planetary scientists may not have to wait for such impacts during future missions to Mars. If the Martian atmosphere is causing the planet to ring constantly, seismologists can use these oscillations to determine the density of the different layers inside Mars.

A combined Russian-French mission to Mars, launched in November 1996, carried a seismometer onboard, but the craft failed during flight, says Philippe Lognonné of the Institute of Earth Physics in Paris. A group of European nations now plans to include even more sensitive seismometers on a probe scheduled to lift off for the Red Planet in 2005.

"This device can detect free oscillations on Mars if our prediction is valid," says Kobayashi.

If so, the man whose ideas shook up seismologists around the globe will have helped detect the pulse of another world. □