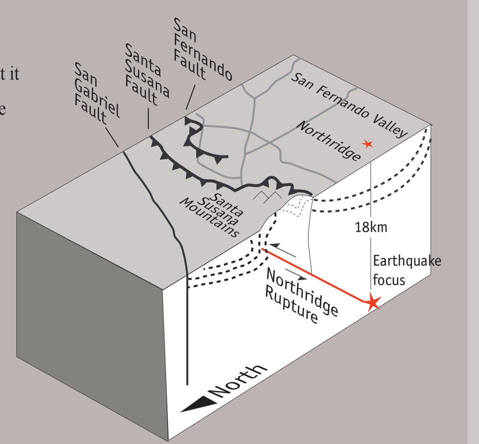
Exploring the Earth Using Seismology

THE NORTHRIDGE EARTHQUAKE

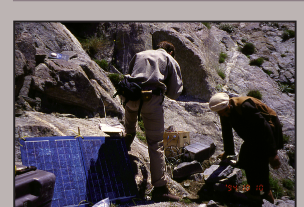
▲ The damage incurred due to the Northridge earthquake is over $20 billion.

In the early morning of January 17, 1994, a magnitude 6.7 earthquake changed the Northridge area east of Los Angeles forever. The quake left 51 people dead and 7,000 injured. It also caused over $20 billion in damage to buildings, highways and bridges. Although moderate in size, the Northridge earthquake was one of the costliest natural disasters in the United States.

The Northridge earthquake destroyed man-made structures and took lives, but it also helped build mountains. During the earthquake crustal material was moved 3 meters upward along a fault that ruptured 18km below the surface. On the surface, the Santa Susana Mountains north of Los Angeles rose by as much as 70 cm and moved almost instantaneously northwest by as much as 21 cm.



HOW ARE EARTHQUAKES RECORDED?



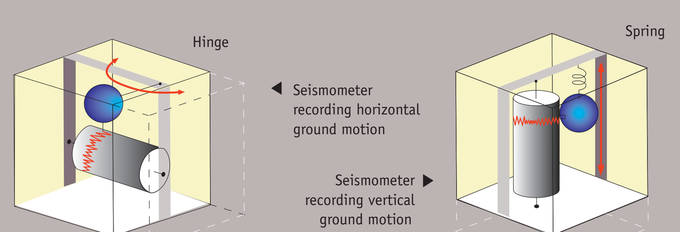
▲ Temporary seismograph installment

An important tool to study the Earth's interior is the seismograph. The seismograph is an instrument that records ground motion, or seismic waves, generated by earthquakes. Seismographs can be installed permanently or temporarily. Temporary installments are used to answer scientific questions of geological interest such as here near the base of the Nangar Parbat massif in northeast Pakistan.

Permanent installments are used to study the overall structure of the Earth's interior. Seismographs used in permanent installments are deployed at fixed locations around the world. Modern seismographs record and amplify seismic waves electronically, and can detect ground motion as small as 0.00000001 cm (distances of the order of atomic spacing.)

The principle by which a seismometer works can be thought of as a heavy mass freely attached to a frame fixed to the Earth. When seismic waves reach the seismometer, the frame moves along with the ground. The heavy mass inside the frame remains stationary because of its inertia. The relative motion between the frame and the mass is a measure the of ground motion.

▲ Seismometers are installed in a sheltered location with good coupling to the ground

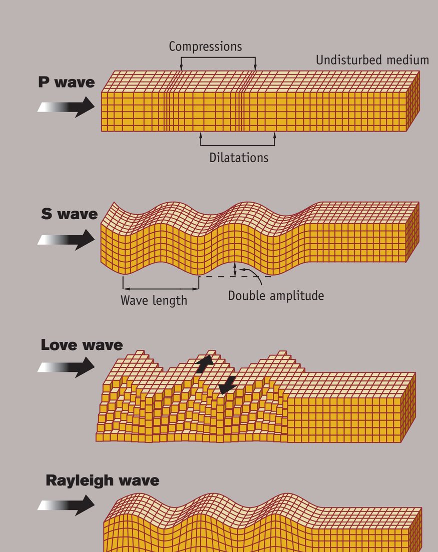


SEISMIC WAVES

During an earthquake seismic waves radiate outward in all directions. The waves that travel through the interior of the Earth are called body waves, while those that travel along the surface are called *surface waves*.

There are two main types of body waves: compressional waves (also called P waves) and shear waves (also called S waves). *P waves* travel by compressing and dilating the material through which they propagate. *S waves* travel by particles trying to slide past each other similar to when one shakes a rope up and down or from side to side. P waves can travel through solid and fluid materials, S waves can only travel through solids. P waves travel faster than S waves.

Surface waves are confined to the surface of the Earth. In one kind of surface wave (called Rayleigh wave), the particle motion is elliptical. In another kind of surface wave (called Love wave), the particle motion is sideways. Surface waves travel slower than P waves and S waves.



Introduction

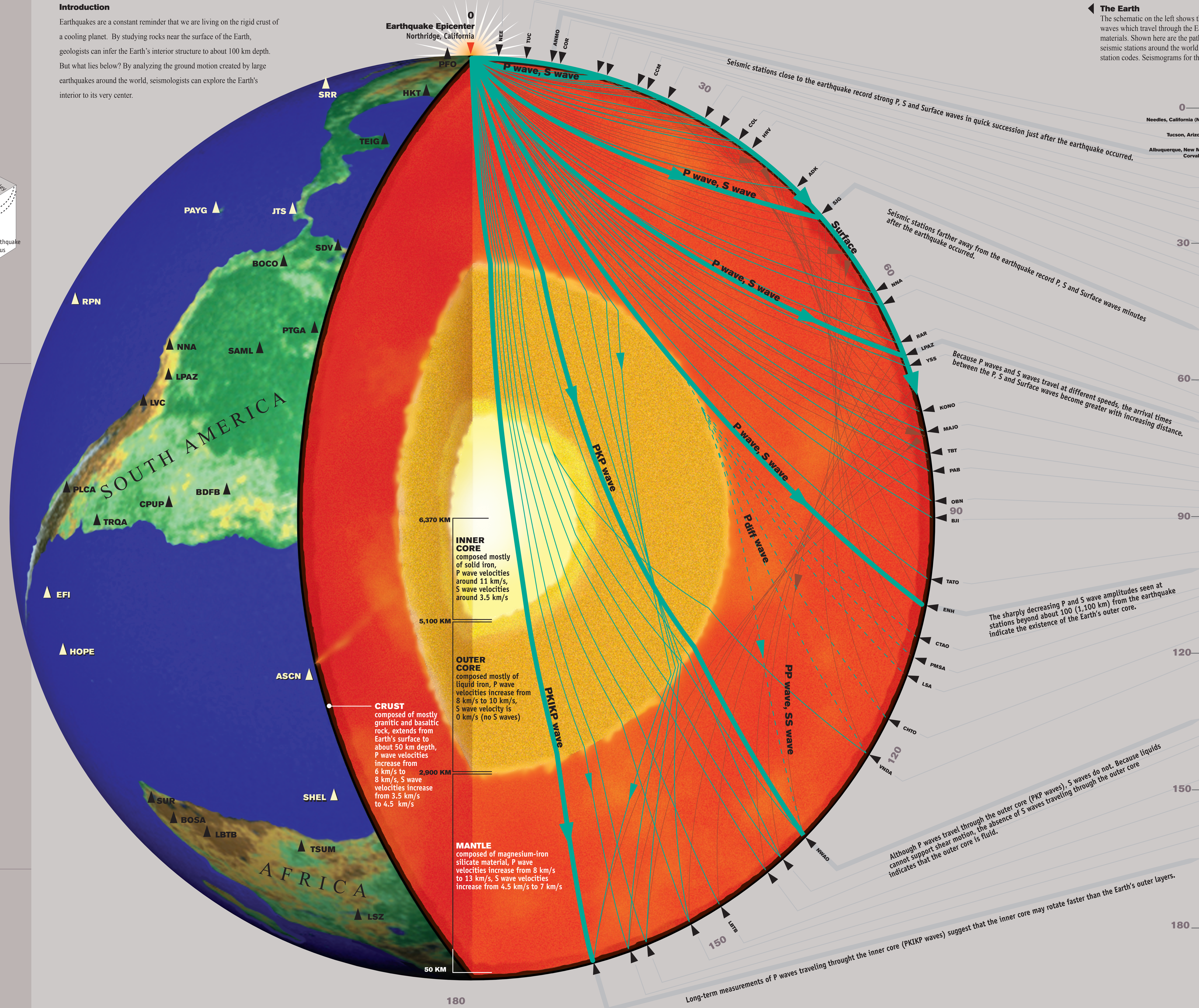
Earthquakes are a constant reminder that we are living on the rigid crust of a cooling planet. By studying rocks near the surface of the Earth, geologists can infer the Earth's interior structure to about 100 km depth. But what lies below? By analyzing the ground motion created by large earthquakes around the world, seismologists can explore the Earth's interior to its very center.

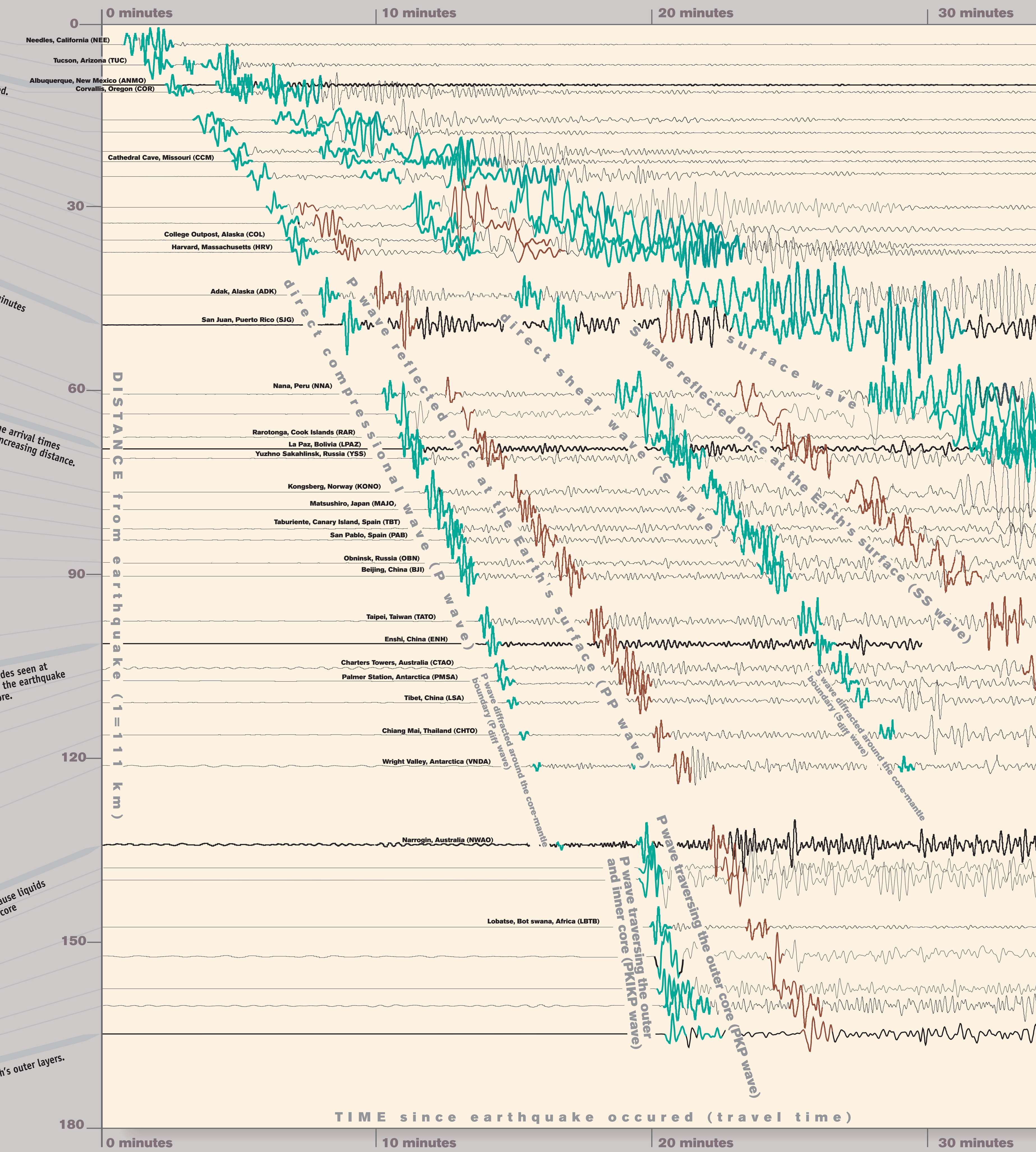
◀ The Earth

The schematic on the left shows the basic structure of Earth's interior. Energy released by earthquakes creates seismic waves which travel through the Earth and are reflected and refracted at boundaries that separate regions of different materials. Shown here are the paths for seismic waves from the 1994 Northridge earthquake that were recorded at seismic stations around the world. Seismic station locations are marked as triangles and some are labeled with their station codes. Seismograms for these seismic stations are shown on the right.

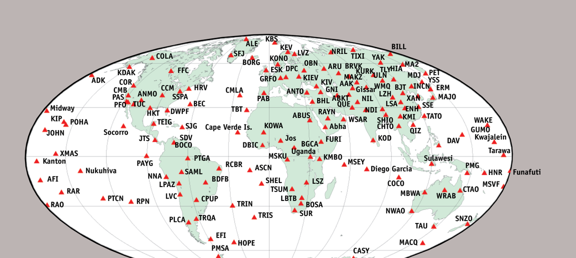
▼ The Seismogram Section

Below, each horizontal trace shows the arrival of seismic waves from the Northridge earthquake. The traces are the actual ground motion recorded at the seismic stations shown on the Earth. Some traces are labeled with the location of the seismic station at which they were recorded. The direct ray paths for P, S and Surface waves are shown in green. Seismologists compare the arrival times and amplitudes of seismic waves from many stations to infer the seismic velocity and hence the structure of Earth's deep interior.





GLOBAL SEISMOGRAPHIC NETWORK



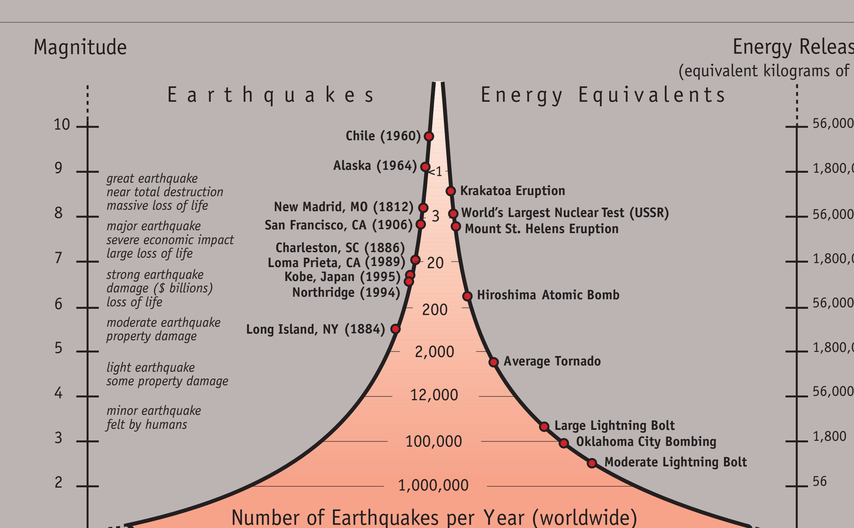
The Global Seimographic Network is an international scientific program to monitor the Earth and explore it's interior. Data from the network are used for scholarly research, education, earthquake hazard mitigation, and to verify compliance with the Comprehensive Test Ban Treaty.

HOW OFTEN DO EARTHQUAKES OCCUR?

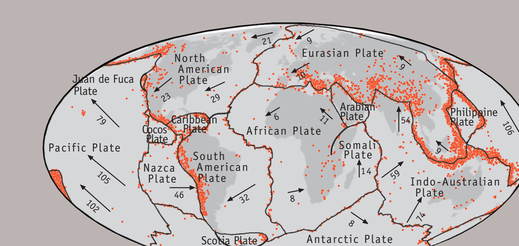
Large earthquakes occur about once a year. Smaller earthquakes such as magnitude 2 earthquakes, occur several hundred times a day. To create a mountain system might take several million medium size earthquakes over tens of millions of years.

We describe the size of an earthquake using the extended Richter Magnitude scale, shown on the left hand side of the figure. The larger the number, the bigger the earthquake. The scale on the right hand side of the figure represents the amount of high explosives required to produce the energy released by the earthquake.

The 1994 earthquake in Northridge, California, for example, was about magnitude 6.7. Earthquakes this size occur about 20 times each year worldwide. Although the Northridge earthquake is considered moderate in size, it caused over $20 billion in damage. The earthquake released energy equivalent to almost 2 billion kilograms of explosives, about 100 times the amount of energy that was released by the atomic bomb that destroyed the city of Hiroshima during World War II.



WHERE DO EARTHQUAKES HAPPEN?



Earth's outer surface, the Earth's crust, is broken into what geologists call tectonic plates. These plates move under, over, or slide past each other. The plates are driven by hot mantle materials that convect. The relative motion of plates is associated with earthquakes. Most earthquakes occur along the edges of large plates. The arrows on the map above indicate how fast the plates are moving in millimeters per year.

WATCH EARTHQUAKES AS THEY OCCUR

At the IRIS website (www.iris.edu) you can monitor global seismicity in near real-time, view records of ground motion, visit seismic stations around the world, and learn more about earthquakes.

the IRIS CONSORTIUM

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IRIS is a university research consortium dedicated to monitoring the Earth and exploring its interior through the collection and distribution of geophysical data. IRIS programs are conducted in partnership with the US Geological Survey, and are supported by the National Science Foundation and other federal agencies, universities, and private foundations.

Copies of this poster can be obtained from; the IRIS Consortium, 1200 New York Ave., NW, Suite 800, Washington, DC 20008 (202) 682-2220.

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