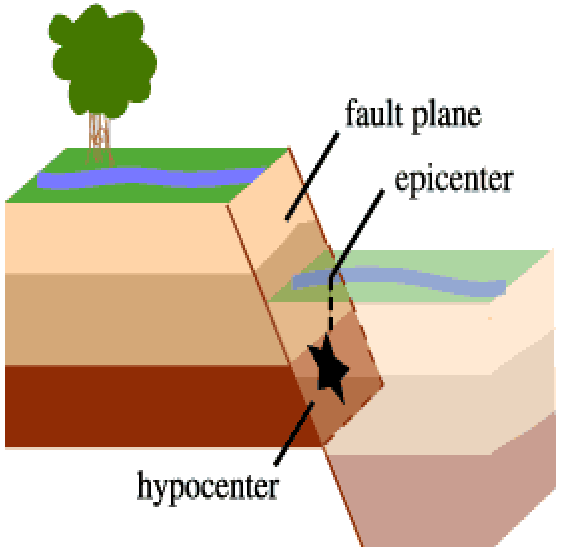
EFFECT OF EARTHQUAKES OF SOIL AND FOUNDATIONS

A DEMONSTRATION SESSION

WHAT IS AN EARTHQUAKE?

AN EARTHQUAKE IS A SHAKING OF THE GROUND CAUSED BY THE SUDDEN BREAKING AND MOVEMENT OF LARGE SECTIONS (TECTONIC PLATES) OF THE EARTH'S ROCKY OUTERMOST CRUST. THE EDGES OF THE TECTONIC PLATES ARE MARKED BY FAULTS (OR FRACTURES). MOST EARTHQUAKES OCCUR ALONG THE FAULT LINES WHEN THE PLATES SLIDE PAST EACH OTHER OR COLLIDE AGAINST EACH OTHER.



The shifting masses send out shock waves that may be powerful enoughto

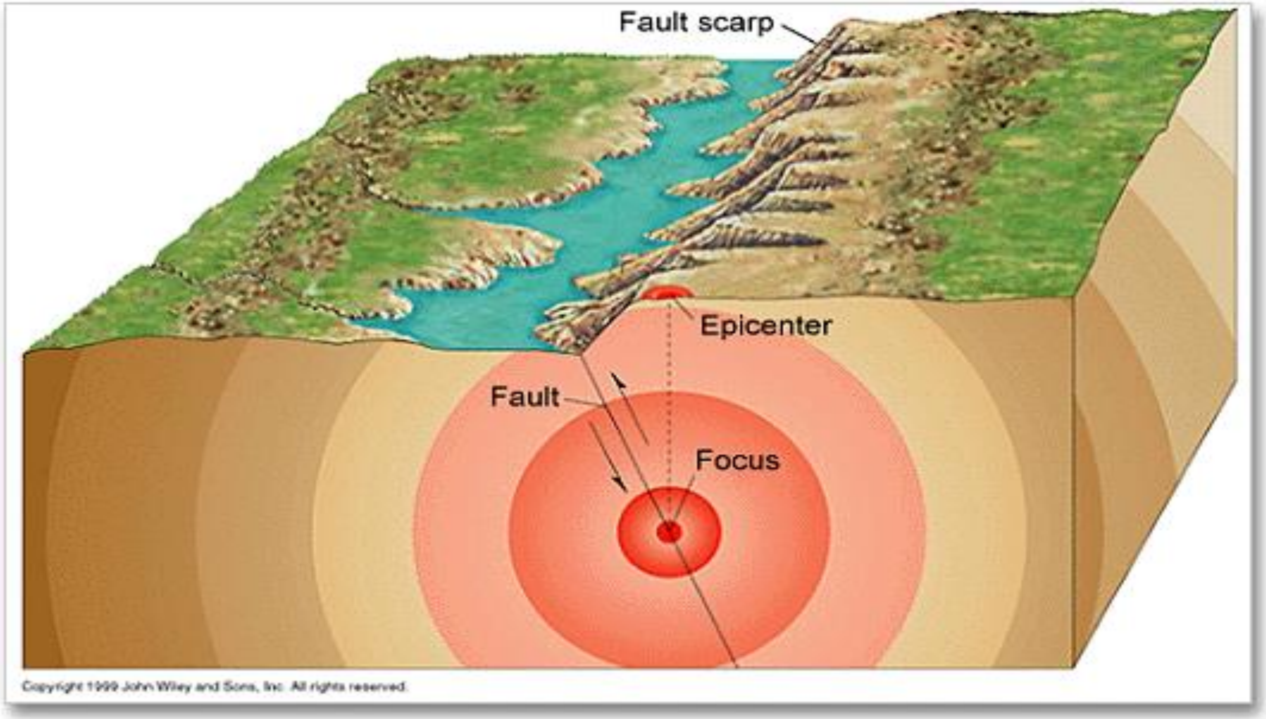
- ALTER THE SURFACE OF THE EARTH, THRUSTING UP CLIFFS AND OPENING GREAT CRACKS IN THE GROUND AND
- CAUSE GREAT DAMAGE ... COLLAPSE OF BUILDINGS AND OTHER MAN-MADE STRUCTURES, BROKEN POWER AND GAS LINES (AND THE CONSEQUENT FIRE), LANDSLIDES, SNOW AVALANCHES, TSUNAMIS (GIANT SEA WAVES) AND VOLCANIC ERUPTIONS.

Where;

Fault or fault plane = the surface where when two blocks of the earth suddenly slip past one another

Hypocenter = the location below the earth's surface where the earthquake starts

Epicenter = the location on the surface of the earth directly above the hypocenter


Fault scarp
Epicenter
Fault
Focus
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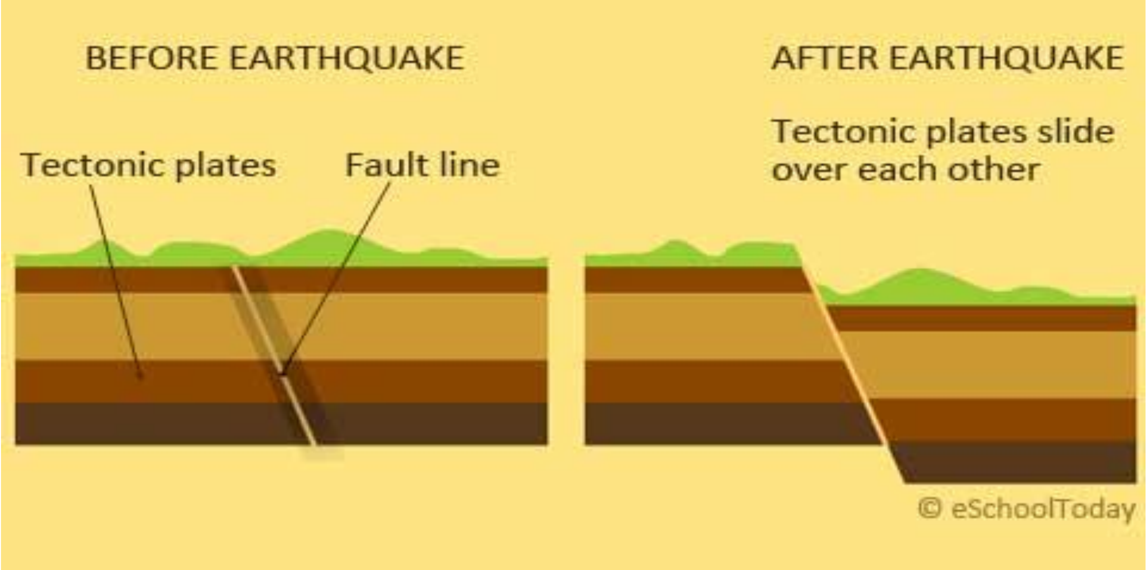
BEFORE EARTHQUAKE
AFTER EARTHQUAKE
Tectonic plates
Fault line
Tectonic plates slide over each other
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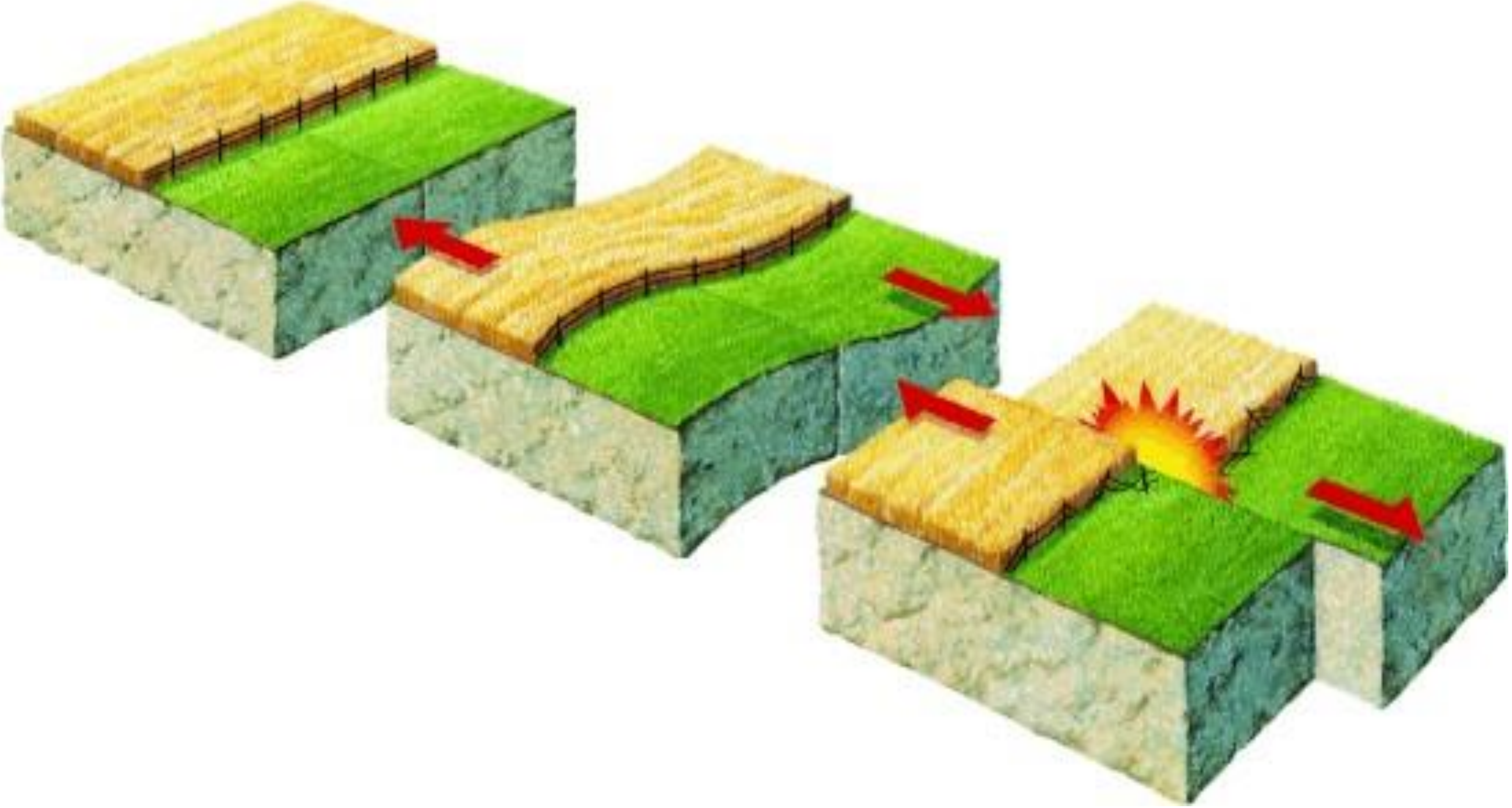
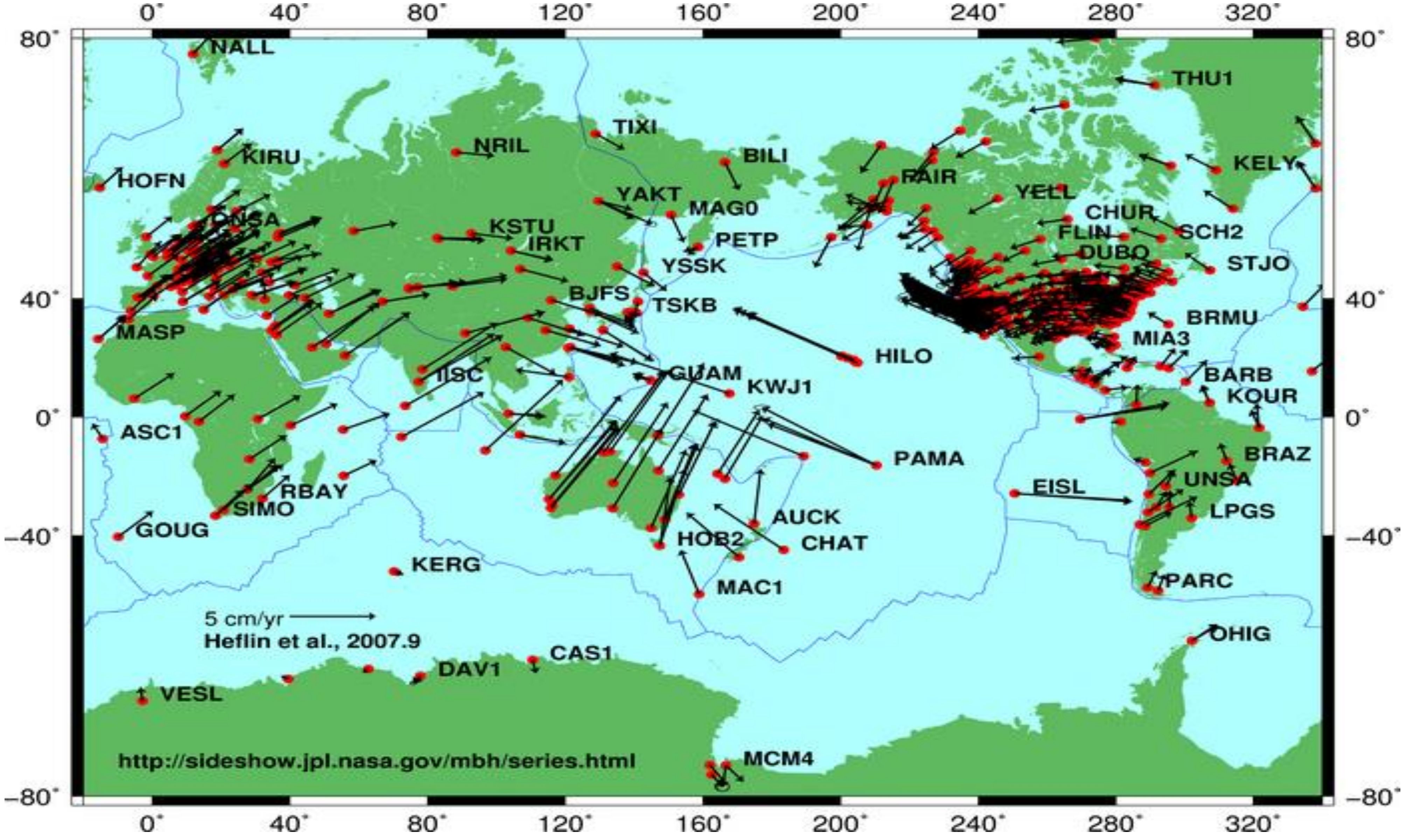


Determining the Depth of an Earthquake

Earthquake depth range of 0 - 700 km is divided into three zones: shallow, intermediate, and deep. Shallow earthquakes are between 0 and 70 km deep; intermediate earthquakes, 70 - 300 km deep; and deep earthquakes, 300 - 700 km deep.

The most obvious indication on a seismogram that a large earthquake has a deep focus is the small amplitude, or height, of the recorded surface waves and the uncomplicated character of the P and S waves. Although the surface-wave pattern does generally indicate that an earthquake is either shallow or may have some depth, the most accurate method of determining the focal depth of an earthquake is to read a depth phase recorded on the seismogram. The process involves rather complicated analysis and measurements with the aid of published travel-time curves or depth tables.

An earth map showing positions of earthquakes



Waves generated by an earthquake:

During an earthquake the following waves are generated;

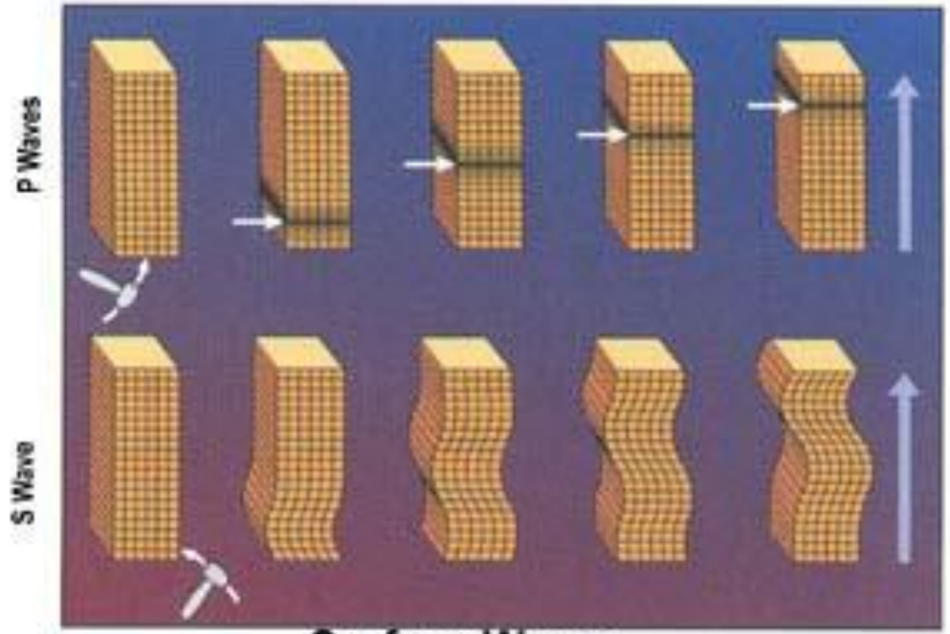
1-The body waves

- 1-1-Primary waves
- 1-2-Secondary waves

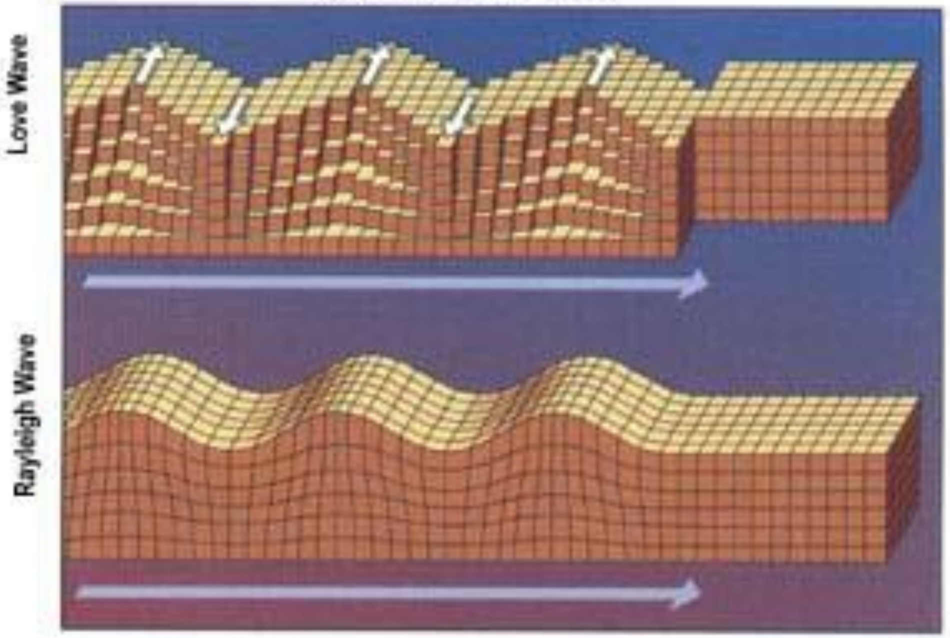
2-The surface waves

- 2-1-Rayleigh waves
- 2-2-Love waves
- 2-3-Stoneley waves
- 2-4-Free oscillation waves

Body Waves

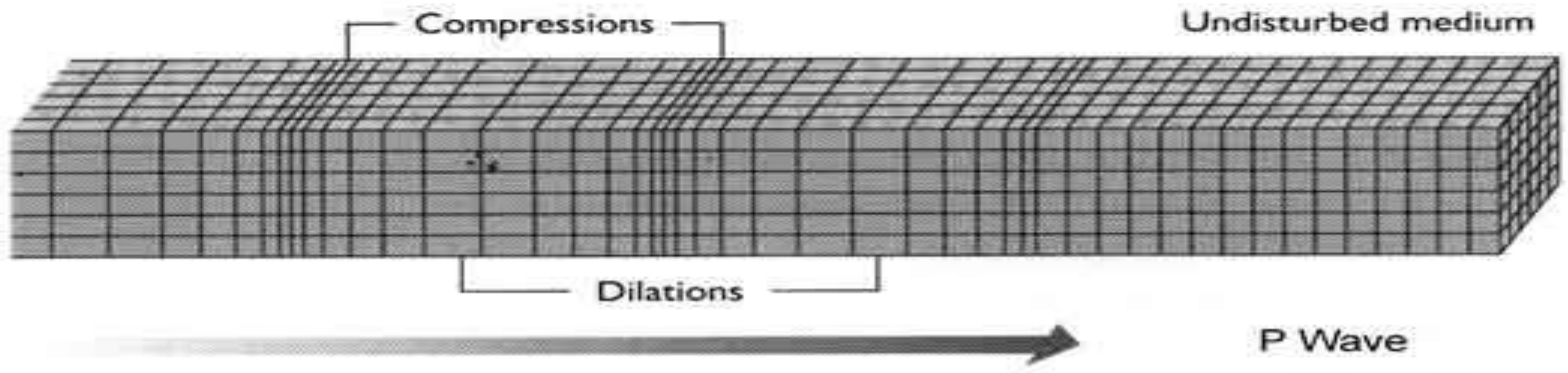


Surface Waves



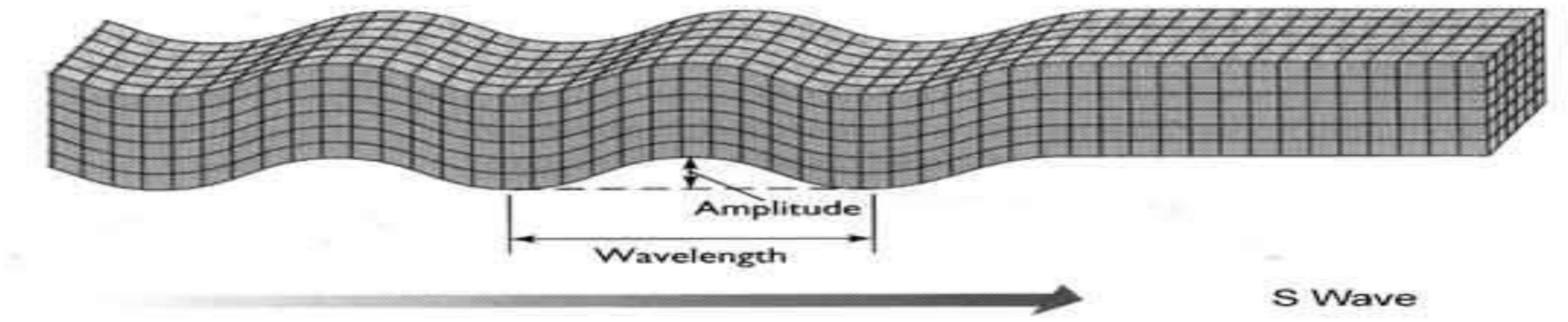
The primary Waves

PRIMARY WAVES (P-WAVES) ARE COMPRESSIONAL WAVES THAT ARE LONGITUDINAL IN NATURE. P WAVES ARE PRESSURE WAVES THAT TRAVEL FASTER THAN OTHER WAVES THROUGH THE EARTH TO ARRIVE AT SEISMOGRAPH STATIONS FIRST, HENCE THE NAME "PRIMARY". THESE WAVES CAN TRAVEL THROUGH ANY TYPE OF MATERIAL, INCLUDING FLUIDS, AND CAN TRAVEL AT NEARLY TWICE THE SPEED OF S WAVES. IN AIR, THEY TAKE THE FORM OF SOUND WAVES, HENCE THEY TRAVEL AT THE SPEED OF SOUND. TYPICAL SPEEDS ARE 330 M/S IN AIR, 1450 M/S IN WATER AND ABOUT 5000 M/S IN GRANITE.



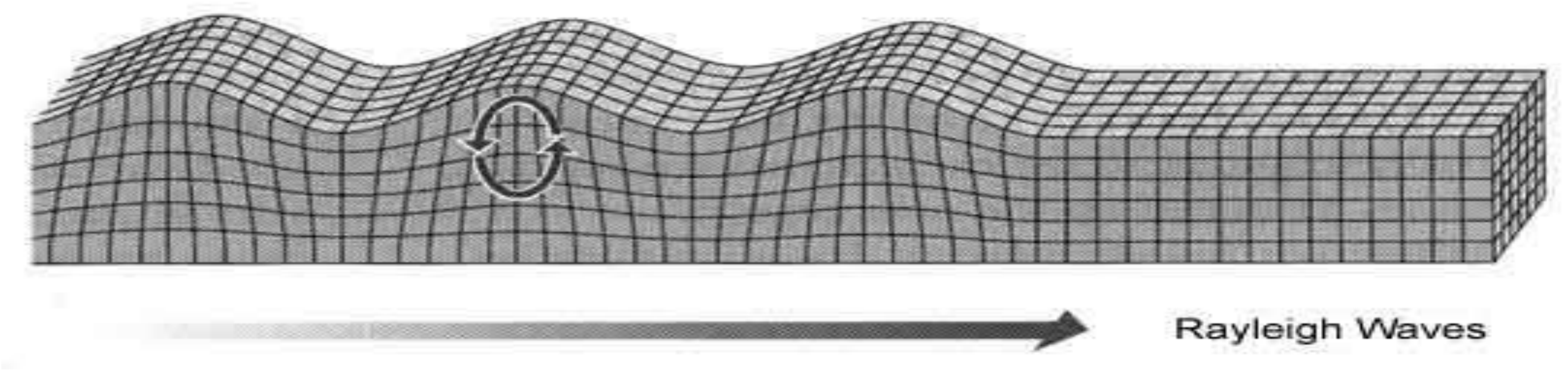
The shear waves

SECONDARY WAVES (S-WAVES) ARE SHEAR WAVES THAT ARE TRANSVERSE IN NATURE. FOLLOWING AN EARTHQUAKE EVENT, S-WAVES ARRIVE AT SEISMOGRAPH STATIONS AFTER THE FASTER-MOVING P-WAVES AND DISPLACE THE GROUND PERPENDICULAR TO THE DIRECTION OF PROPAGATION. DEPENDING ON THE PROPAGATION DIRECTION, THE WAVE CAN TAKE ON DIFFERENT SURFACE CHARACTERISTICS; FOR EXAMPLE, IN THE CASE OF HORIZONTALLY POLARIZED S WAVES, THE GROUND MOVES ALTERNATELY TO ONE SIDE AND THEN THE OTHER. S-WAVES CAN TRAVEL ONLY THROUGH SOLIDS, AS FLUIDS (LIQUIDS AND GASES) DO NOT SUPPORT SHEAR STRESSES. S-WAVES ARE SLOWER THAN P-WAVES, and speeds are typically around 60% of that of P-waves in any given material.



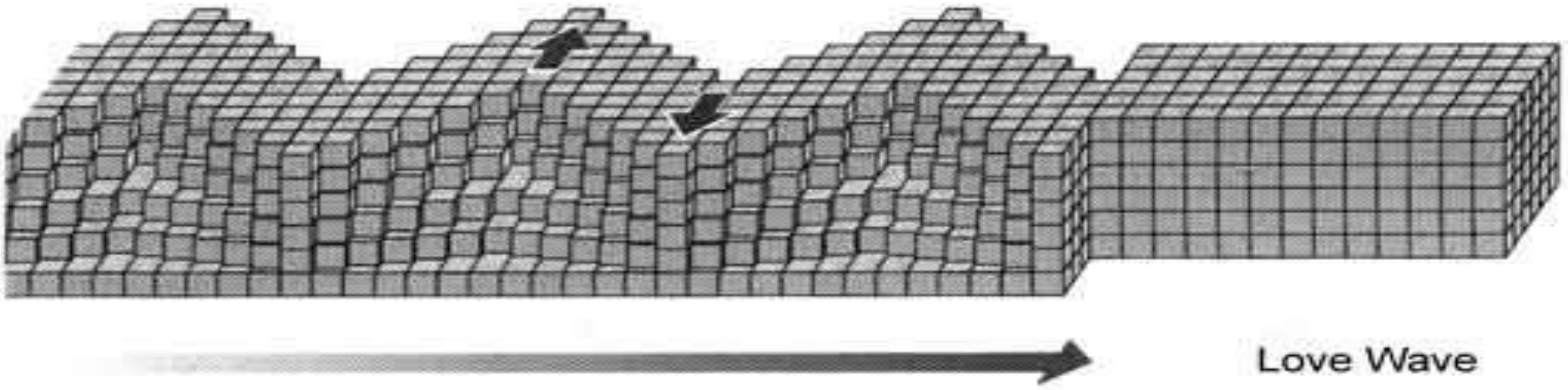
Rayleigh waves

RAYLEIGH WAVES, ALSO CALLED GROUND ROLL, ARE SURFACE WAVES THAT TRAVEL AS RIPPLES WITH MOTIONS THAT ARE SIMILAR TO THOSE OF WAVES ON THE SURFACE OF WATER (NOTE THAT THE ASSOCIATED PARTICLE MOTION AT SHALLOW DEPTHS IS RETROGRADE, AND THAT THE RESTORING FORCE IN RAYLEIGH AND IN OTHER SEISMIC WAVES IS ELASTIC, NOT GRAVITATIONAL AS FOR WATER WAVES).. THEY ARE SLOWER THAN BODY WAVES, ROUGHLY 90% OF THE VELOCITY OF S WAVES FOR TYPICAL HOMOGENEOUS ELASTIC MEDIA. THE EXISTENCE OF THESE WAVES WAS PREDICTED BY JOHN WILLIAM Strutt, Lord Rayleigh, in 1885



Love waves

LOVE WAVES ARE HORIZONTALLY POLARIZED SHEAR WAVES (SH WAVES), EXISTING ONLY IN THE PRESENCE OF A SEMI-INFINITE MEDIUM OVERLAIN BY AN UPPER LAYER OF FINITE THICKNESS. THEY ARE NAMED AFTER A.E.H. LOVE, A BRITISH MATHEMATICIAN WHO CREATED A MATHEMATICAL MODEL OF THE WAVES IN 1911. THEY USUALLY TRAVEL SLIGHTLY FASTER THAN RAYLEIGH WAVES, ABOUT 90% OF THE S WAVE VELOCITY, AND HAVE THE LARGEST AMPLITUDE.



Stoneley waves

A Stoneley wave is a type of boundary wave (or interface wave) that propagates along a solid-fluid boundary or, under specific conditions, also along a solid-solid boundary. Amplitudes of Stoneley waves have their maximum values at the boundary between the two contacting media and decay exponentially towards the depth of each of them. The equation for Stoneley waves was first given by Dr. Robert Stoneley (1894 - 1976), Emeritus Professor of Seismology, Cambridge.

Free oscillation waves

Free oscillations of the Earth are standing waves, the result of interference between two surface waves traveling in opposite directions.

Methods for scaling an earthquake

Richter magnitude scale

THE **RICHTER MAGNITUDE SCALE** (ALSO **RICHTER SCALE**) ASSIGNS A MAGNITUDE NUMBER TO QUANTIFY THE ENERGY RELEASED BY AN EARTHQUAKE. THE RICHTER SCALE, DEVELOPED IN THE 1930S, IS A BASE-10 LOGARITHMIC SCALE, WHICH DEFINES MAGNITUDE AS THE LOGARITHM OF THE RATIO OF THE AMPLITUDE OF THE SEISMIC WAVES TO AN ARBITRARY, MINOR AMPLITUDE.

AS MEASURED WITH A SEISMOMETER, AN EARTHQUAKE THAT REGISTERS 5.0 ON THE RICHTER SCALE HAS A SHAKING AMPLITUDE 10 TIMES THAT OF AN EARTHQUAKE THAT REGISTERED 4.0, AND THUS CORRESPONDS TO A RELEASE OF ENERGY 31.6 TIMES THAT RELEASED BY THE LESSER EARTHQUAKE

Earthquake Magnitude Scale

Magnitude	Earthquake Effects (in general);	Estimated Number Each Year
2.5 or less	Usually not felt, but can be recorded by seismograph.	900,000
2.5 to 5.4	Often felt, but only causes minor damage.	30,000
5.5 to 6.0	Slight damage to buildings and other structures.	500
6.1 to 6.9	May cause a lot of damage in very populated areas.	100
7.0 to 7.9	Major earthquake. Serious damage.	20
8.0 or greater	Great earthquake. Can totally destroy communities near the epicenter.	One every 5 to 10 years

Earthquake Magnitude Classes

Earthquakes are also classified in categories ranging from minor to great, depending on their magnitude.

Class	Magnitude
Great	8 or more
Major	7 - 7.9
Strong	6 - 6.9
Moderate	5 - 5.9
Light	4 - 4.9
Minor	3 -3.9

The following describes the typical effects of earthquakes of various magnitudes near the epicenter. The values are typical only. They should be taken with extreme caution, since intensity and thus ground effects depend not only on the magnitude, but also on the distance to the epicenter, the depth of the earthquake's focus beneath the epicenter, the location of the epicenter and geological conditions (certain terrains can amplify seismic signals).

Magnitude	Description	Mercalli intensity	Average earthquake effects	Average frequency of occurrence (estimated)
Less than 2.0	Micro	I	Microearthquakes, not felt, or felt rarely. Recorded by seismographs.[16]	Continual/several million per year
2.0–2.9	Minor	I to II	Felt slightly by some people. No damage to buildings.	Over one million per year
3.0–3.9		II to IV	Often felt by people, but very rarely causes damage. Shaking of indoor objects can be noticeable.	Over 100,000 per year
4.0–4.9	Light	IV to VI	Noticeable shaking of indoor objects and rattling noises. Felt by most people in the affected area. Slightly felt outside. Generally causes none to minimal damage. Moderate to significant damage very unlikely. Some objects may fall off shelves or be knocked over.	10,000 to 15,000 per year

<table>
<tr><td>4.0–4.9</td><td>Light</td><td>IV to VI</td><td>Noticeable shaking of indoor objects and rattling noises. Felt by most people in the affected area. Slightly felt outside. Generally causes none to minimal damage. Moderate to significant damage very unlikely. Some objects may fall off shelves or be knocked over.</td><td>10,000 to 15,000 per year</td></tr>
<tr><td>5.0–5.9</td><td>Moderate</td><td>VI to VIII</td><td>Can cause damage of varying severity to poorly constructed buildings. At most, none to slight damage to all other buildings. Felt by everyone.</td><td>1,000 to 1,500 per year</td></tr>
<tr><td>6.0–6.9</td><td>Strong</td><td>VII to X</td><td>Damage to a moderate number of well-built structures in populated areas. Earthquake-resistant structures survive with slight to moderate damage. Poorly designed structures receive moderate to severe damage. Felt in wider areas; up to hundreds of miles/kilometers from the epicenter. Strong to violent shaking in epicentral area.</td><td>100 to 150 per year</td></tr>
<tr><td>7.0–7.9</td><td>Major</td><td rowspan="3">VIII or greater[17]</td><td>Causes damage to most buildings, some to partially or completely collapse or receive severe damage. Well-designed structures are likely to receive damage. Felt across great distances with major damage mostly limited to 250 km from epicenter.</td><td>10 to 20 per year</td></tr>
<tr><td>8.0–8.9</td><td rowspan="2">Great</td><td>Major damage to buildings, structures likely to be destroyed. Will cause moderate to heavy damage to sturdy or earthquake-resistant buildings. Damaging in large areas. Felt in extremely large regions.</td><td>One per year</td></tr>
<tr><td>9.0 and greater</td><td>At or near total destruction - severe damage or collapse to all buildings. Heavy damage and shaking extends to distant locations. Permanent changes in ground topography.</td><td>One per 10 to 50 years</td></tr>
</table>

(Based on U.S. Geological Survey documents.)

Effect of earthquakes on soil and foundations

1-The sandy soil (soil liquefaction)

Soil liquefaction describes a phenomenon whereby a saturated or partially saturated soil substantially loses strength and stiffness in response to an applied stress, coming from an earthquake shaking or other sudden change in stress condition, causing it to behave like a liquid. In soil mechanics the term "liquefied" was first used by Hazen in reference to the 1918 failure of the Calaveras Dam in California.

In soil mechanic language a state of 'soil liquefaction' occurs when the effective stress of soil is reduced to essentially zero, which corresponds to a complete loss of shear strength. This is initiated by cyclic loading (e.g. repeated change in stress condition – coming from wave loading of an earthquake shaking).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2-The quick clay

Quick clay is a water-saturated gel, which in its solid form resemble a unique form of highly sensitive clay. This clay has a tendency to change from a relatively stiff condition to a liquid mass when it is disturbed as from earthquake shock waves. This gradual change in appearance from solid to liquid is a process known as spontaneous liquefaction. The clay retains a solid structure despite the high water content (up to 80 volume-%), because surface tension holds water-coated flakes of clay together in a delicate structure. When the structure is broken by a shock or sufficient shear, it turns to a fluid state.

Quick clay has been the underlying cause of many deadly landslides. In Canada alone, it has been associated with more than 250 mapped landslides. Some of these are ancient, and may have been triggered by earthquakes.

Some photos for the disaster


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And finally last but not least

What Should I Do Before, During, And After An Earthquake?

What to Do Before an Earthquake!!!

- Make sure you have a fire extinguisher, first aid kit, a battery-powered radio, a flashlight, and extra batteries at home.
- Learn first aid.
- Learn how to turn off the gas, water, and electricity.
- Make up a plan of where to meet your family after an earthquake.
- Don't leave heavy objects on shelves (they'll fall during a quake).
- Anchor heavy furniture, cupboards, and appliances to the walls or floor.
- Learn the earthquake plan at your school or workplace.

What to Do During an Earthquake!!!

- **Stay calm!** If you're indoors, stay inside. If you're outside, stay outside.
- If you're indoors, stand against a wall near the center of the building, stand in a doorway, or crawl under heavy furniture (a desk or table). Stay away from windows and outside doors.
- If you're outdoors, stay in the open away from power lines or anything that might fall. Stay away from buildings (stuff might fall off the building or the building could fall on you).
- Don't use matches, candles, or any flame. Broken gas lines and fire don't mix.
- If you're in a car, stop the car and stay inside the car until the earthquake stops.

Don't use elevators (they'll probably get stuck anyway).

What to Do After an Earthquake!!!

- Check yourself and others for injuries. Provide first aid for anyone who needs it.
- Check water, gas, and electric lines for damage. If any are damaged, shut off the valves. Check for the smell of gas. If you smell it, open all the windows and doors, leave immediately, and report it to the authorities (use someone else's phone).
- Turn on the radio. Don't use the phone unless it's an emergency.
- Stay out of damaged buildings.
- Be careful around broken glass and debris. Wear boots or sturdy shoes to keep from cutting your feet.
- Be careful of chimneys (they may fall on you).
- Stay away from beaches. Tsunamis sometimes hit after the ground has stopped shaking.
- Stay away from damaged areas.
- If you're at school or work, follow the emergency plan or the instructions of the person in charge.
- Expect aftershocks.


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