GEOL 2112

Week 2 Lecture Notes

Structure of the Earth: Seismology

Reading:

1st Year Geology Text – Review chapter on Earthquakes

Fowler – Chapter 4.1, 4.2 (skip 4.2.8)

2009/01/06 01:52:05 48.37N 89.53W 1.0* 1.4MN 16 km W from Thunder Bay,ON

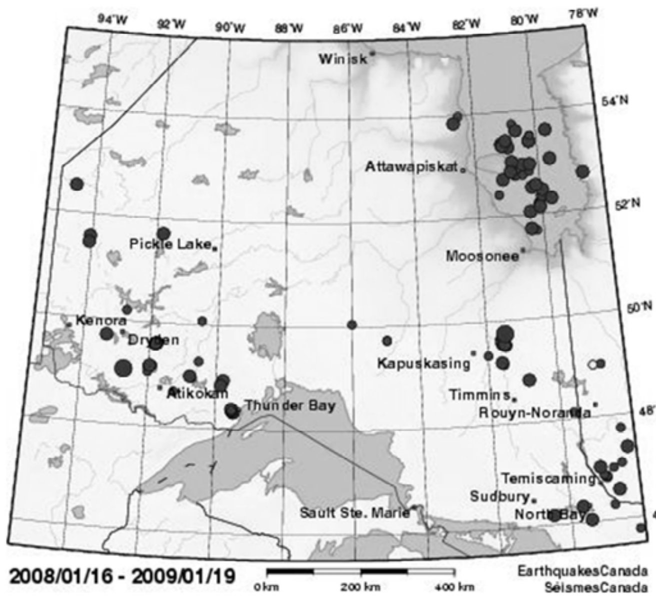
2008/11/19 03:41:02 48.39N 89.54W 1.0* 2.0MN 16 km W from Thunder Bay,ON

2008/11/09 10:57:49 48.37N 89.52W 1.0* 1.8MN Felt 15 km W from Thunder Bay,ON
2008/11/09 09:48:50 48.37N 89.53W 1.0* 2.1MN Felt 15 km W from Thunder Bay,ON
2008/11/09 09:44:44 48.37N 89.53W 1.0* 1.8MN Felt 15 km W from Thunder Bay,ON
2008/11/09 09:31:22 48.37N 89.52W 1.0* 2.1MN Felt 15 km W from Thunder Bay,ON
2008/11/09 09:24:09 48.37N 89.52W 1.0* 2.1MN Felt 15 km W from Thunder Bay,ON

2008/10/24 13:10:34 48.34N 89.46W 1.0* 2.1MN Felt 12 km SW from Thunder Bay,ON
2008/10/23 16:54:15 48.34N 89.48W 1.0* 2.3MN Felt 14 km SW from Thunder Bay,ON

2008/10/19 21:47:27 48.35N 89.53W 1.0* 1.6MN 15 km W from Thunder Bay,ON
2008/10/19 20:41:46 48.40N 89.55W 1.0* 0.1ML 15 km W from Thunder Bay,ON
2008/10/19 04:05:07 48.33N 89.48W 1.0* 2.3MN Felt 14 km SW from Thunder Bay,ON
2008/10/13 18:55:22 48.33N 89.51W 1.0* 1.8MN 16 km SW from Thunder Bay,ON

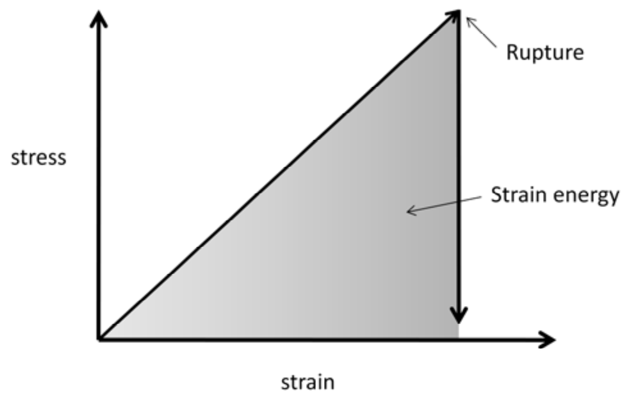
MN - Nuttli, or body wave magnitude. Used for earthquakes in eastern Canada.



http://earthquakescanada.nrcan.gc.ca

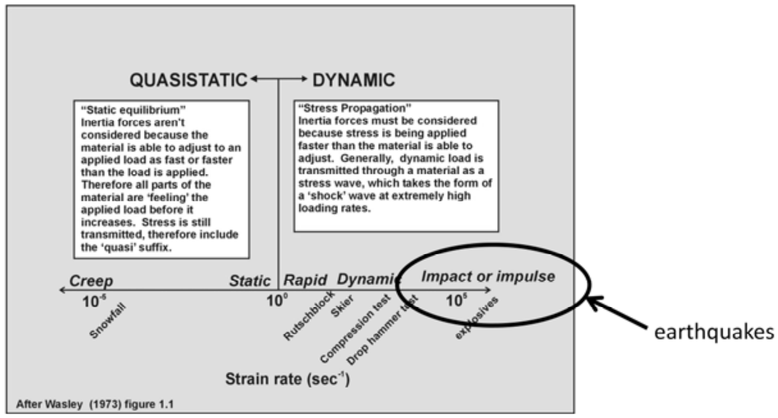
Earthquake = trembling or shaking of the ground caused by sudden release of **energy** stored in rocks below the earth's surface

'energy' is strain energy resulting from the stress along faults



- Note: continual slip along a fault allows strain to relax , so it won't accumulate enough energy to cause an earthquake

Strain energy travels from one place to another via stress waves – provided that the strain rate is in the dynamic range



A stress wave transmits energy and momentum away from source of loading *without* bulk translation of mass, at a finite velocity in any given material

Seismic Wave Demonstrations and Animations

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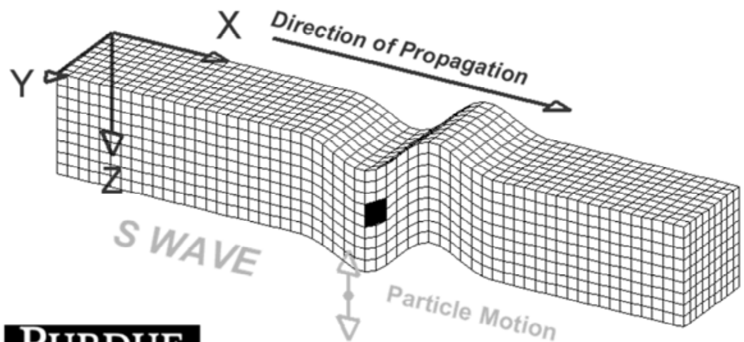

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Earth & Atmospheric Sciences

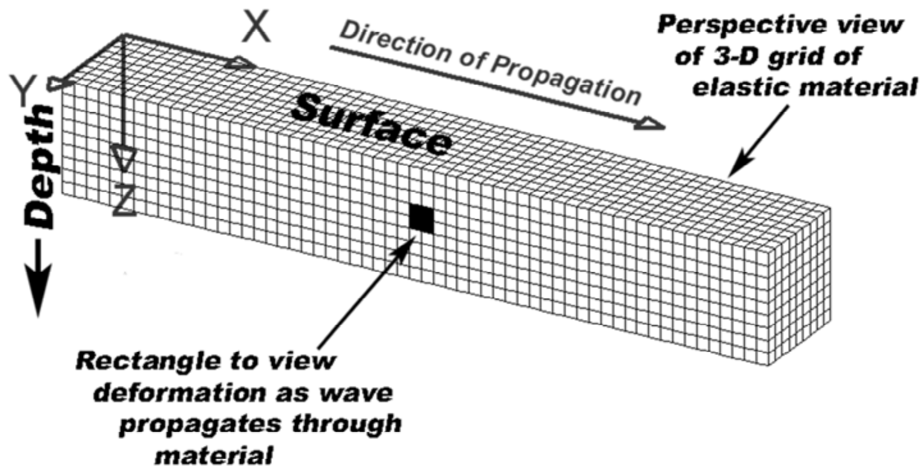
Seismic Body Waves

Wave Type (and names)	Particle Motion	Other Characteristics
P, **Compressional**, Primary, Longitudinal	Alternating compressions ("pushes") and dilations ("pulls") which are directed in the same direction as the wave is propagating (along the raypath); and therefore, perpendicular to the wavefront.	P motion travels fastest in materials, so the P-wave is the first-arriving energy on a seismogram. Generally smaller and higher frequency than the S and Surface-waves. P waves in a liquid or gas are pressure waves, including sound waves.
S, **Shear**, Secondary, Transverse	Alternating transverse motions (perpendicular to the direction of propagation, and the raypath); commonly approximately polarized such that particle motion is in vertical or horizontal planes.	S-waves do not travel through fluids, so do not exist in Earth's outer core (inferred to be primarily liquid iron) or in air or water or molten rock (magma). S waves travel slower than P waves in a solid and, therefore, arrive after the P wave.

Seismic Surface Waves

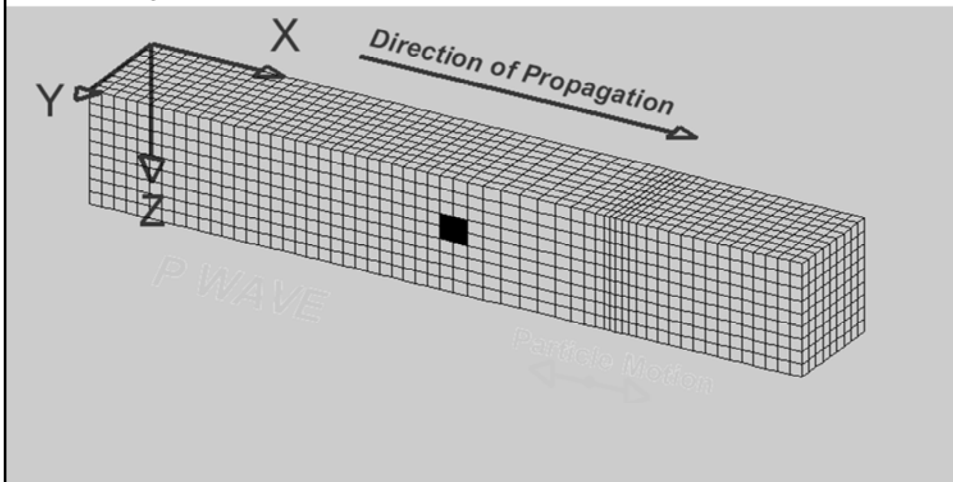
Wave Type (and names)	Particle Motion	Other Characteristics
L, **Love**, Surface waves, Long waves	Transverse horizontal motion, perpendicular to the direction of propagation and generally parallel to the Earth's surface.	Love waves exist because of the Earth's surface. They are largest at the surface and decrease in amplitude with depth. Love waves are dispersive, that is, the wave velocity is dependent on frequency, generally with low frequencies propagating at higher velocity. Depth of penetration of the Love waves is also dependent on frequency, with lower frequencies penetrating to greater depth.
R, **Rayleigh**, Surface waves, Long waves, Ground roll	Motion is both in the direction of propagation and perpendicular (in a vertical plane), and "phased" so that the motion is generally elliptical – either prograde or retrograde.	Rayleigh waves are also dispersive and the amplitudes generally decrease with depth in the Earth. Appearance and particle motion are similar to water waves. Depth of penetration of the Rayleigh waves is also dependent on frequency, with lower frequencies penetrating to greater depth. Generally, Rayleigh waves travel slightly slower than Love waves.

3-D Grid for Seismic Wave Animations



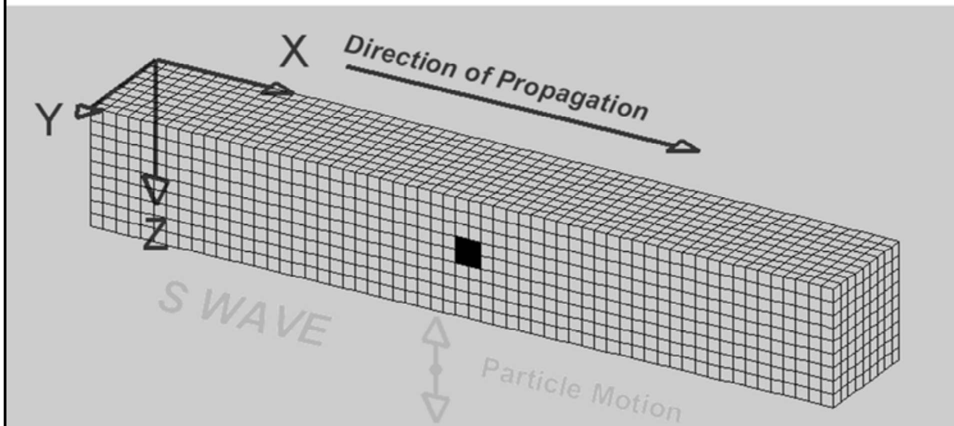
No *attenuation* (decrease in amplitude with distance due to spreading out of the waves or absorption of energy by the material) *dispersion* (variation in velocity with frequency), or *anisotropy* (velocity depends on direction of propagation) is included.

Compressional Wave (P-Wave) Animation



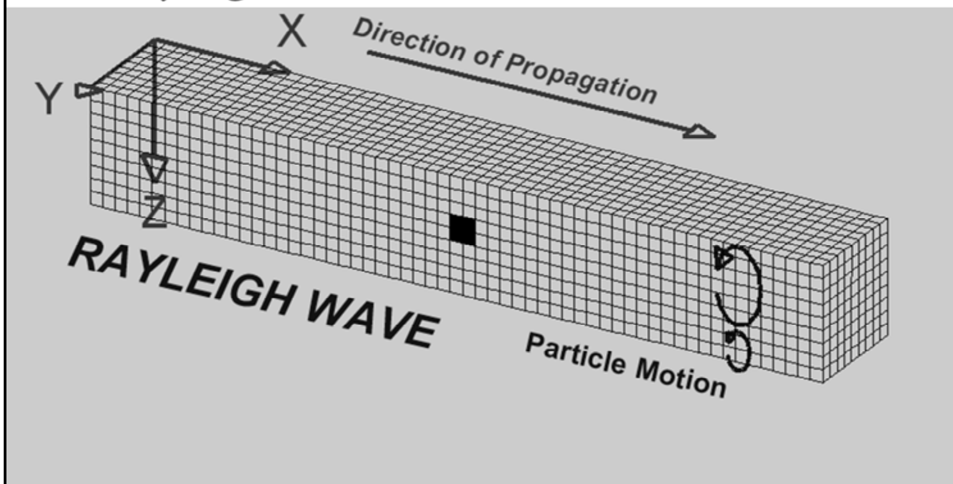
Deformation propagates. Particle motion consists of alternating compression and dilation. Particle motion is parallel to the direction of propagation (longitudinal). Material returns to its original shape after wave passes.

Shear Wave (S-Wave) Animation



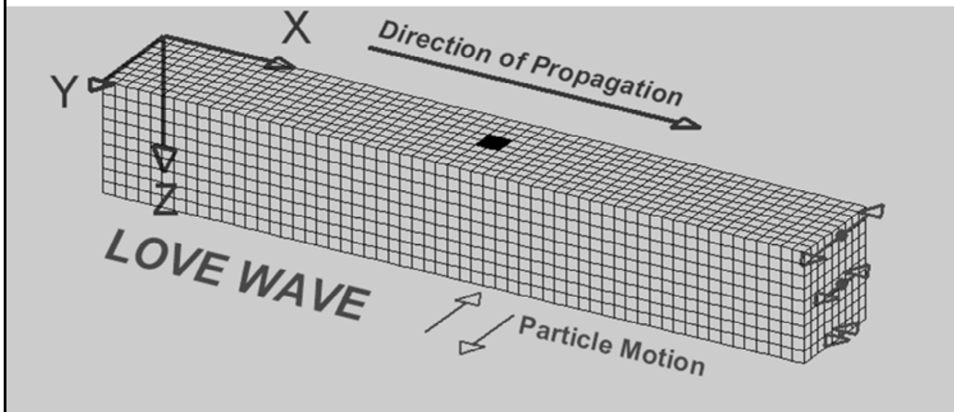
Deformation propagates. Particle motion consists of alternating transverse motion. Particle motion is perpendicular to the direction of propagation (transverse). Transverse particle motion shown here is vertical but can be in any direction. However, Earth's layers tend to cause mostly vertical (SV; in the vertical plane) or horizontal (SH) shear motions. Material returns to its original shape after wave passes.

Rayleigh Wave (R-Wave) Animation



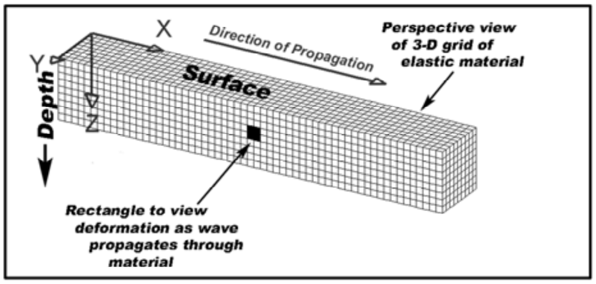
Deformation propagates. Particle motion consists of elliptical motions (generally retrograde elliptical) in the vertical plane and parallel to the direction of propagation. Amplitude decreases with depth. Material returns to its original shape after wave passes.

Love Wave (L-Wave) Animation



Deformation propagates. Particle motion consists of alternating transverse motions. Particle motion is horizontal and perpendicular to the direction of propagation (transverse). To aid in seeing that the particle motion is purely horizontal, focus on the Y axis (red line) as the wave propagates through it. Amplitude decreases with depth. Material returns to its original shape after wave passes.

Consider *how* this is actually happening in a material



The mechanical description, and formulations for wave speed and interactions with boundaries relies on there being an atom or molecule at each intersection in the grid above, and that the gridlines are the forces associated with bonding.

Consider porous materials or structures – like snow or the CB – are these assumptions valid?