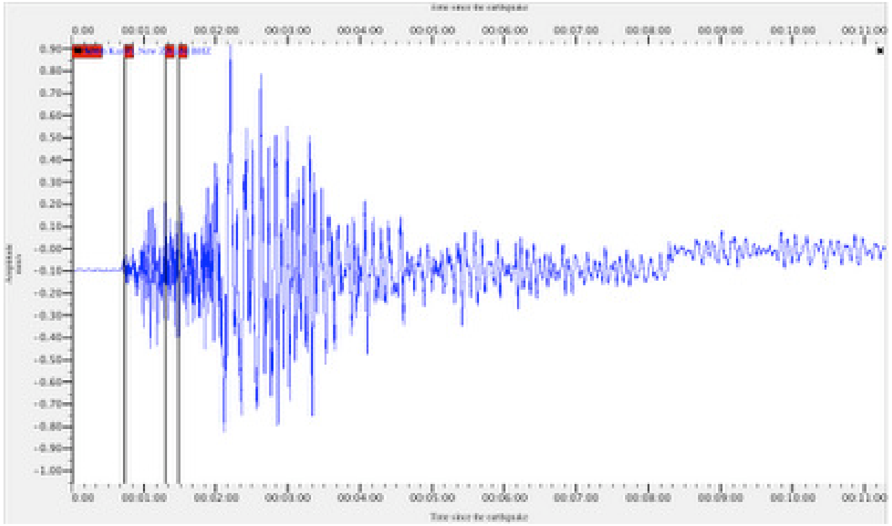
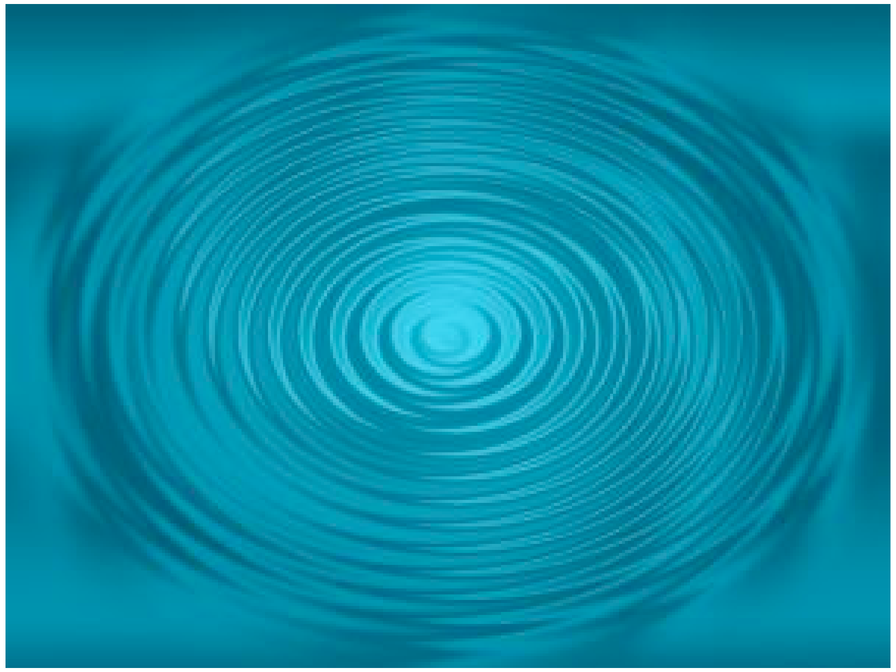
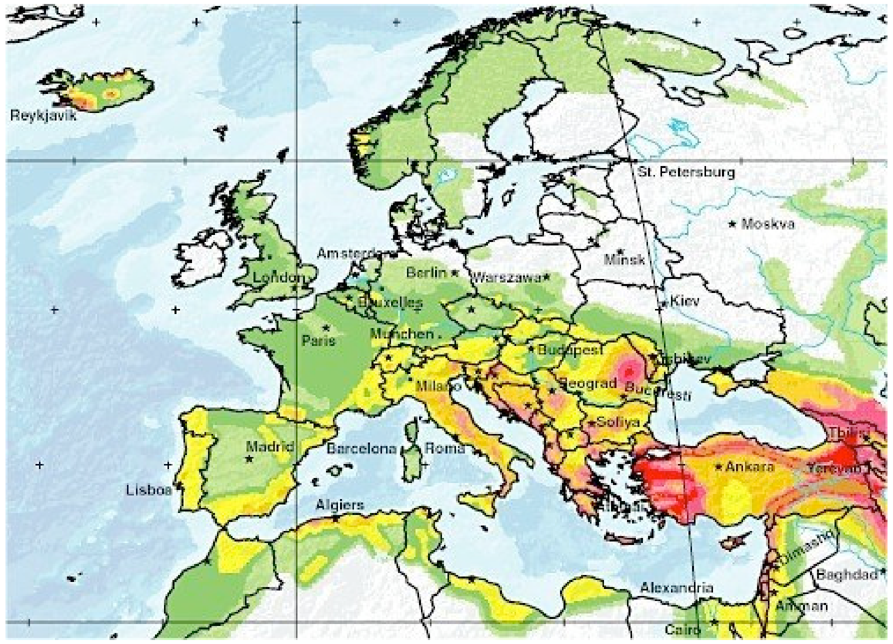
- Seismic waves are propagating vibrations that carry energy from the source of the shaking outward in all directions.
- Seismic waves that are set up during an earthquake are more complex than those on the pond.



ChristChurch (NZ), 22.02.2011 at 8.06.48 AM (magnitude 6.2)



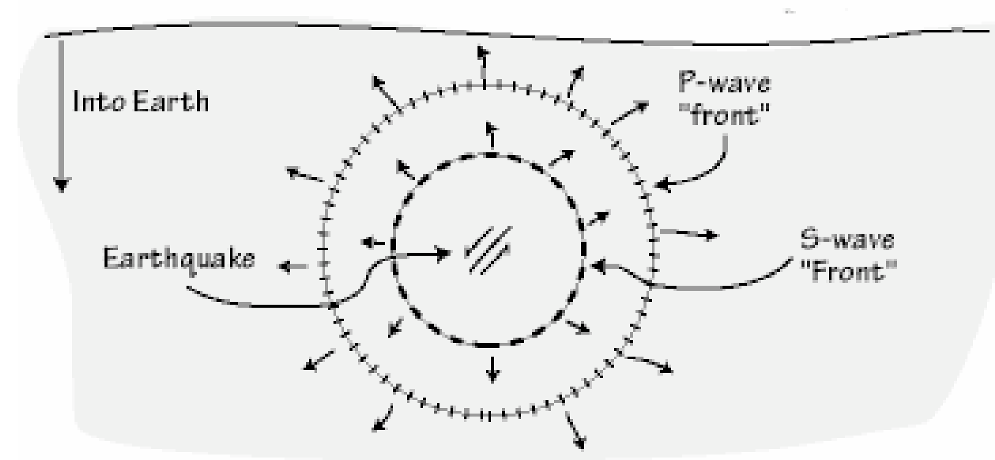
Circles on water



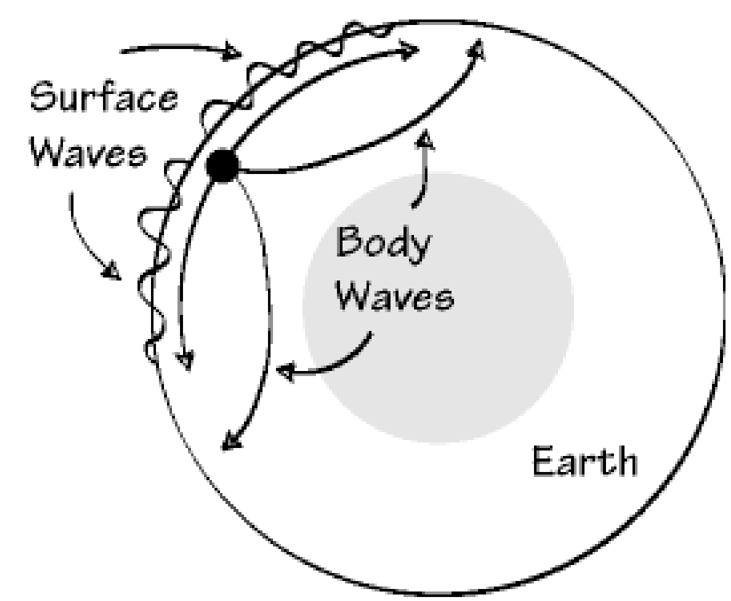
European earthquake potential hazard

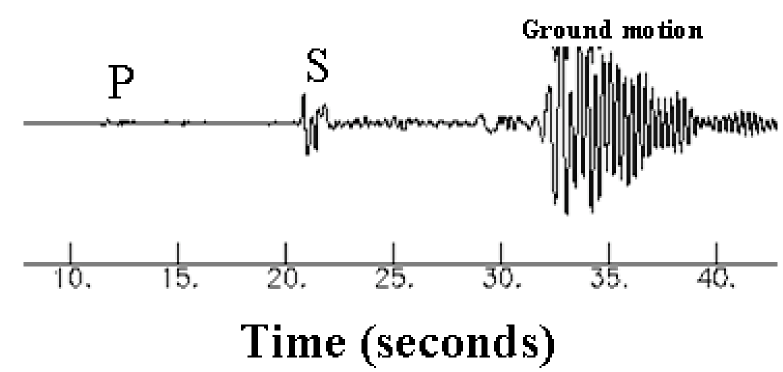
P and S waves

- There are different kind of seismic waves. The most important ones are
  - Compressional or P (primary)
  - Transverse or S (secondary)
  - Love
  - Rayleigh



- An earthquake radiates P and S waves in all directions.
- The interaction of the P and S waves with Earth's surface $\rightarrow$ surface waves.
- P and S waves travel at different speeds (used to locate earthquakes)





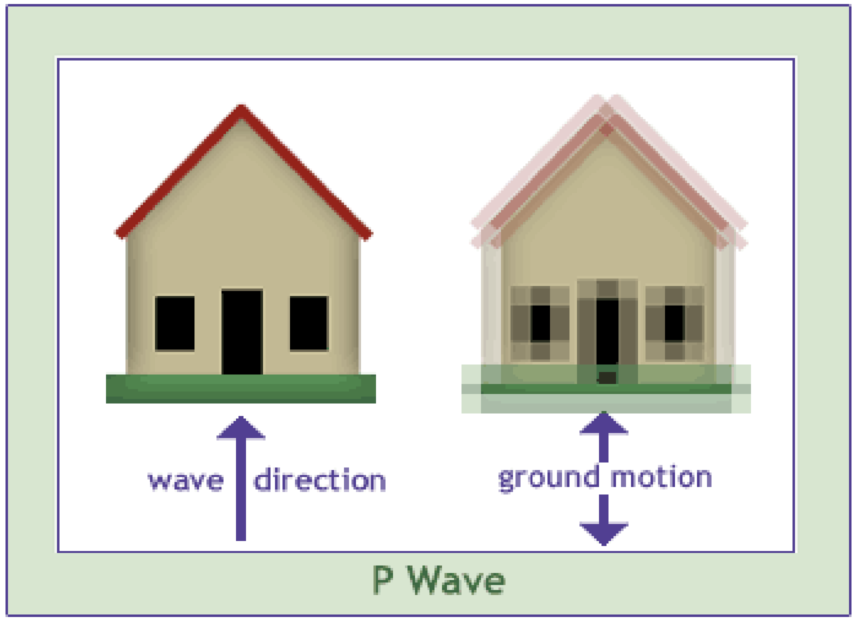
P and S waves - continues

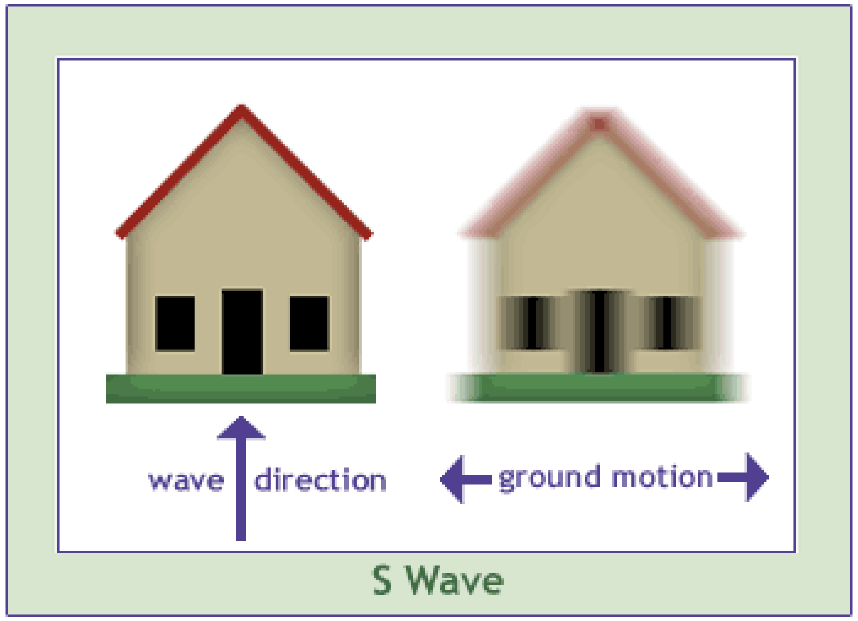
P-Waves (Compressional)

- The ground is vibrated in the direction the wave is propagating.
- Travel through all types of media.
- $C_P = \sqrt{(\lambda + 2\mu)/\rho}$ (P-wave velocity)
- Typical speed: $\sim 1 \to 14$ km/sec

S-Waves (Transverse)

- The ground is vibrated in the perpendicular direction to that the wave is propagating.
- Travel only through solid media.
- $C_S = \sqrt{\mu/\rho}$ (S-wave velocity)
- Typical speed: $\sim 1 \to 8$ km/sec





Much of the damage close to an earthquake is the result of strong shaking caused by S-waves.

The Mathematical Model

Equilibrium equations for an elastic bounded medium subjected to an external force $\mathbf{f}$

$$\begin{cases} \rho\partial_{tt}\mathbf{u} - \nabla \cdot \underline{\sigma}(\mathbf{u}) + 2\rho\zeta\,\partial_t\mathbf{u} + \rho\zeta^2\mathbf{u} = \mathbf{f} & \text{in } \Omega \times (0, T], \\ + \text{B.C.s} & \text{on } \partial\Omega \times [0, T], \\ + \text{I.C.s} & \text{in } \Omega \times \{0\}. \end{cases}$$

- $\mathbf{u}$ displacement of the medium
- $\underline{\epsilon}(\mathbf{u}) = \frac{1}{2}(\nabla\mathbf{u} + \nabla\mathbf{u}^\top)$ strain tensor
- $\underline{\sigma}(\mathbf{u}) = \lambda\nabla \cdot \mathbf{u}\,\underline{I} + 2\mu\underline{\epsilon}(\mathbf{u}) = \underline{\underline{\mathbf{D}}}\,\underline{\epsilon}(\mathbf{u})$ stress tensor
- ρ material density, λ, μ Lamé elastic coefficients
- $2\rho\zeta\,\partial_t\mathbf{u} + \rho\zeta^2\mathbf{u}$ viscous forces

In applications the decay factor ζ is typically $\approx 0.01 s^{-1}$