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Reflection seismology: a very valuable method for environmental assessments

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Seismic Waves

A seismic wave is a form of acoustic energy that travels through the earth and all other materials. Such waves are generated by either earthquakes, explosions, or other processes that produce sound (vibrations, moving cars, waves breaking on shores, etc...).

There are 2 main groups of waves:
1) Two types of **body waves**
- **P Compressive waves** travel through air, water and solids
- **S Shear waves** travel through solids only

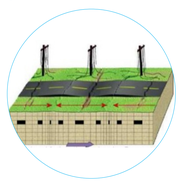
2) Surface waves travel along surfaces

The travel **velocity** of the waves depends of the wave type and the material in which they travel.

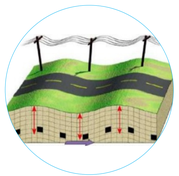
The velocity usually increases with depth, ranging from as low as 90 m/s (shear wave in Leda clay) to 13'000 m/s (p-wave in the lower mantle of the earth).

Types of Seismic Waves

Body waves

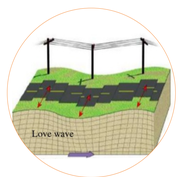


P-waves (compressional waves, or primary waves) travel as back and forth motions (compression and dilatation) through material. They can cause the ground to buckle and fracture.

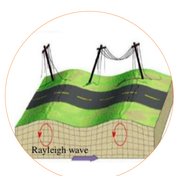


Shear waves (S-waves, or secondary waves) travel as up-and-down or sideways motions through material.

Surface waves



Love waves move the ground from side to side. The movement decreases with depth.

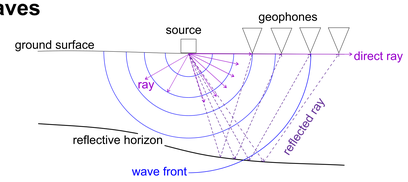


Rayleigh waves move the ground like rolling ocean waves in a retrograde elliptical motion (the motion follows the shape of an ellipse).

Propagation of Seismic Waves

Seismic waves travel away from the source. They could be visualized as a **wave front** (water waves on the left) or a ray like the sun's rays.

Direct rays or waves move directly from the source to the geophone as **direct P-waves** and as **surface waves**.



On the **shot gather** (right) their arrivals are observed as straight lines with a dip proportional to the velocity of the ground.

Reflected waves bounce off a reflective horizon in the ground which is a boundary between 2 different materials like clay, sand, gravel or rock. **Reflected waves** are forming bent lines or hyperbolas on the shot gather as they travel a longer distance before reaching the far geophones.

By the fact that shear waves travel much slower than P-waves they arrive at a later time, further down in the shot gather.

Refracted waves travel along the boundary of two materials at the speed of the faster material. They arrive ahead of the reflection on the most distant geophones.

Workflow and Processing of Seismic Reflection Data

1 **Field work**: collect seismic data with Minivib or Microvibe

2 display a shot gather for quality control while collecting the data

Processing of the digitized data is done using specialized computer and software:

assignment of geometry: enter location and distance information

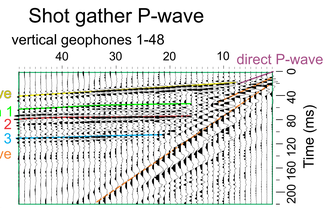
3 sorting of shot gathers into **common midpoint gather** (cmp)

4 find the best velocities through **semblance** analysis

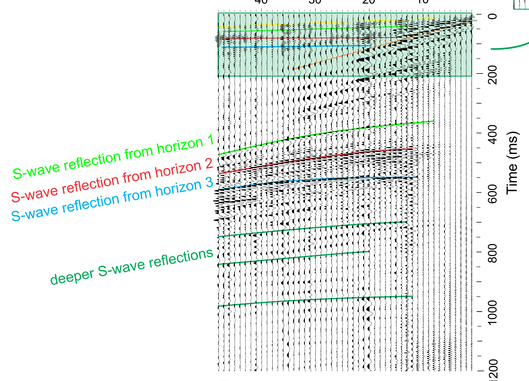
5 apply normal move-out (**nmo**) correction where reflections are flattened, and **stack** traces (sum all traces of one gather into one trace)

6 create **profile** by adding one stacked trace for each cmp

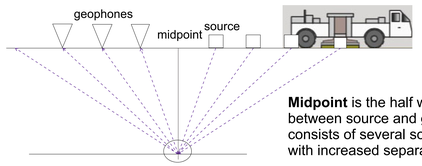
2 Shot gather P-wave



Shot gather S-wave

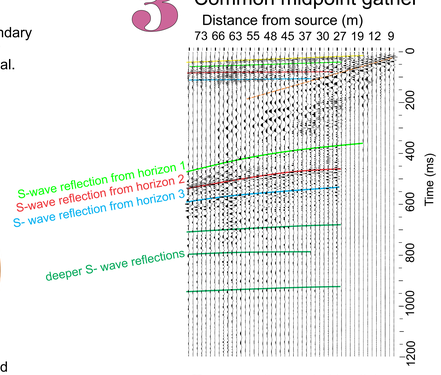


2 **Shot gathers** are scrutinized during recording in the field as quality control.



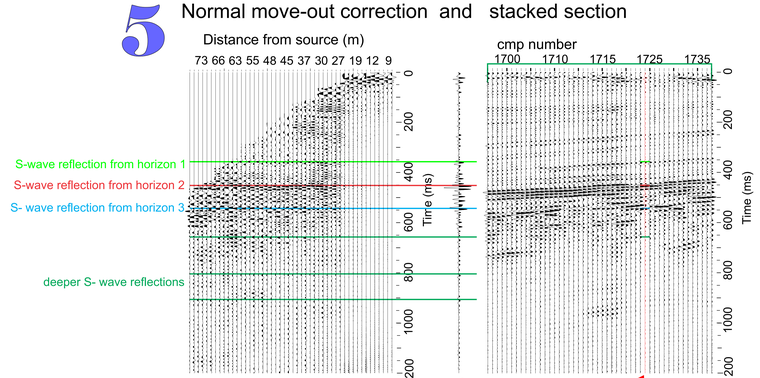
Midpoint is the half way distance location between source and geophone. One midpoint consists of several source - geophone pairs with increased separation.

3 Common midpoint gather



3 cmp gather sorted by distance

5 Normal move-out correction and stacked section

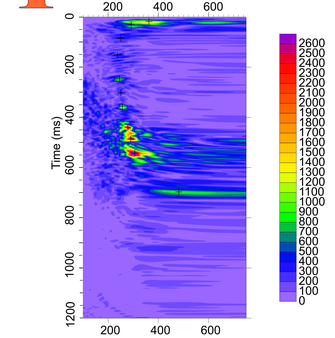


5 **nmo corrected cmp gather** where hyperbolic reflections have been flattened, using velocities determined from the semblance

sum of all traces

summed traces from neighbouring locations

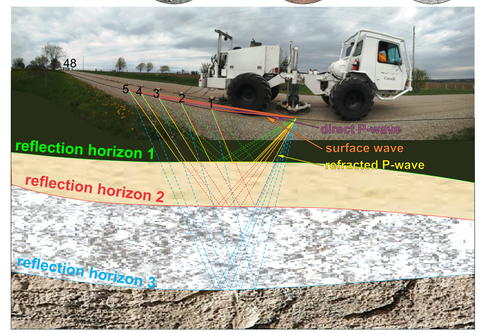
4 Velocity Semblance



4 **Velocity semblance** shows strongest amplitudes for time - velocity pairs. Warm colours depict high energy which show the optimum summation velocities.

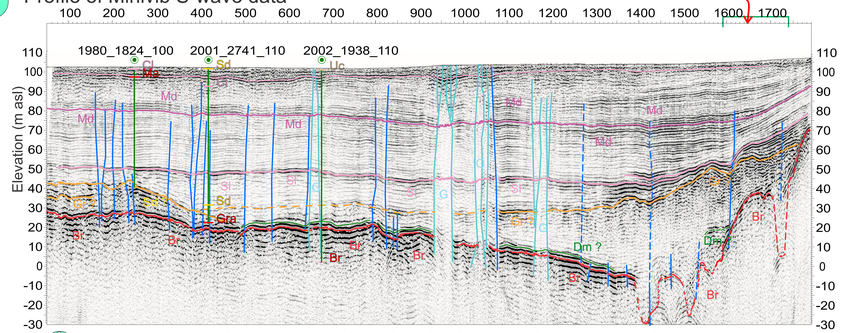
This is a way to determine the velocity of the wave through the ground and to estimate depths of echo-reflections.

1 Data collection



1 **Field work** with **Minivib** collecting data in Southern Ontario. Direct wave rays and reflected wave rays travel path are shown schematically.

6 Profile of Minivib S-wave data



6 **Shear wave profile** with borehole information, interpreted lithology, faults and possible water-escape zones.

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