Seismic methods: Seismic reflection - I

Reflection reading:
Sharma p130-158; (Reynolds p343-379)

Reflection surveying

- Sensitive to impedance contrasts
- Use near-normal incidence i.e. P-waves

Target scale:
10’s m: Ground water, engineering and environmental studies
km’s: Oil exploration
10’s km: Crustal structure
Shot gathers

(a) 

(b) 

Common midpoint gathers

To enhance signal to noise we use more than one shot

Reflections from the same point are recorded by different source-station pairs

- Common depth point gather

For dipping layers the reflection points are “smeared”

- Common midpoint gather
Collecting Common midpoint gathers

Sequentially move shot and receiver string across the surface

Fold
- The number of times the same point on a reflector is sampled
- In this case: 6 fold (though 12 geophones)

Typical values
- 1-6 engineering studies
- 50, 100 or even 1000 in hydrocarbon exploration

Note: Looks very similar to the shot gather because the shot gather was for a horizontal reflector
3D surveys

Collect data on a grid rather than along a line

Produces a data cube rather than a line

Seismic reflection processing

Flow overview

These are the main steps in processing

The order in which they are applied is variable
Four geophones: A, B, C, D, recording samples 1, 2, 3, 4...
- The recording device stores samples in the order recorded
- Demultiplexing is separating all the samples to produce a time sequence for each geophone

Industry standards (SEG) usually allows for painless translation of the data
Preprocessing

Gain recovery

“Turn up the volume” to account for seismic attenuation

1. Could calculate the energy/amplitude loss using geometric spreading and apply a correction

2. **Automatic gain control (AGC)** apply a gain to equalize amplitude along the trace

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Static corrections

Correct for surface topography and the weathered surface layer

**Surface topography**

Time correction to each trace:

\[ t_g = \left( E_g - E_d \right) / V \]

**Source depth**

\[ t_s = \left( E_s - E_d \right) / V \]

Total correction

\[ t_c = t_s + t_g \]

Shift each trace by this amount to line up deeper reflectors
Static corrections

To make corrections we need to know the velocity of the surface weathered material.

**Uphole traveltime**

\[ V = \frac{d}{t_{\text{uh}}} \]

**Refraction studies**

Used to determine near surface velocities and variations in the thickness of the weathered layer.

Finally, **Data smoothing statics**

- An automated process which lines up adjacent peaks
- Can only be applied when reflections are already within a wiggle

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**An example**

![Pre-correction](image)

![Post-correction](image)

Fig. 4.17 Effect of applying residual static corrections on CDP reflection data recorded at a waste-dump site in Zealand, Denmark. Time section (a) before application of statics and (b) after application of statics (After Fink, 1994.)
Reflectivity and convolution

The seismic wave is sensitive to the sequence of impedance contrasts

→ The reflectivity series \( R \)

We input a source wavelet \( W \) which is reflected at each impedance contrast

The seismogram recorded at the surface \( S \) is the convolution of the two

\[
S = W \ast R
\]

Doing the convolution:

1. Convolve source wavelet and reflectivity series by multiplying the first sample of the source wavelet \( 1 \) by the first component of the reflectivity series \( 1 \) to give the first constituent of the output response.

2. Move the source wavelet array on one sample and convolve; hence \( \{1 \times 1\} \times \{-1\} = \{-1\} = -1 \)

3. Move the source wavelet array on one sample and convolve; hence \( \{1 \times 0\} \times \{-1\} = \{-1\} = -1 \)

4. Move the source wavelet array on one sample and convolve; hence \( \{1 \times 1\} \times \{-1\} = \{-1\} = -1 \)

5. Move the source wavelet array on the sample and convolve; hence \( \{1 \times 1\} \times \{-1\} = \{-1\} = -1 \)
Convolution

Reflectivity series

Source wavelet

Output

Recorded waveform

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Convolution

Reflectivity series 1 \(\frac{1}{2}\) \(\frac{1}{2}\)
Source wavelet \(\frac{1}{2}\) \(-\frac{1}{2}\) 1

Output 0 1 0

Recorded waveform

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Convolution

Reflectivity series
\[
\begin{array}{c}
1 \\
\frac{1}{2} \\
\frac{1}{2}
\end{array}
\]

Source wavelet
\[
\begin{array}{ccc}
\frac{1}{2} & -\frac{1}{2} & 1
\end{array}
\]

Output
\[
\begin{array}{cccccc}
0 & 1 & 0 & \frac{3}{4} & 0 & \frac{1}{4}
\end{array}
\]

Recorded waveform
Convolution

Reflectivity series

| 1 | ½ | ½ |

Source wavelet

| ½ | -½ | 1 |

Output

| 0 | 1 | 0 | ¾ | 0 | ¼ | 0 |

Recorded waveform

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