ERTH3021

Aspects of 2D and 3D Seismic Reflection

Steve Hearn

This document contains various images intended to supplement lecture and practical material. It is not intended as a stand-alone document.

This material is explicitly provided for educational purposes only, to students of ERTH3021. All other usage is prohibited.
Outline

Seismic Reflection

Seismic Resolution

Seismic Sources and Geophones

CMP Stacking

Seismic Processing

Example Images
Outline

Seismic Reflection

Seismic Resolution

Seismic Sources and Geophones

CMP Stacking

Seismic Processing

Example Images
Sound waves heard in music typically have frequencies in the range 0 – 20000 Hz
Seismic exploration uses low-frequency sound waves (frequencies in the range 0 – 300 Hz)
Seismic Reflection

Source

Geophone
Outline

Seismic Reflection

Seismic Resolution

Seismic Sources and Geophones

CMP Binning

Seismic Processing

Example Images
Desirable Spectral Characteristics

- broad bandwidth
- stable pulse
- high dominant frequency
- short wavelength
- good resolution
Earth Scattering Limit

- Petroleum
- Coal

Frequency (Hz)
### Bowen Basin Model

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>V (m/s)</th>
<th>(\rho) (g/cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 m</td>
<td>1700</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>3300</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>3544</td>
<td>2.6</td>
</tr>
<tr>
<td>150 m</td>
<td>2241</td>
<td>1.3</td>
</tr>
</tbody>
</table>

### Resolution Modelling

- **Seismic Section**

![Seismic Section](image)

- **Bowen Basin Model**

![Bowen Basin Model](image)
Influence of High Frequencies

\[ f_H = 60 \text{ Hz} \]

\[ \lambda_D = 50 \text{ m} \]

\[ 120 \text{ Hz} \]
\[ 27 \text{ m} \]

\[ 240 \text{ Hz} \]
\[ 17 \text{ m} \]

\[ 480 \text{ Hz} \]
\[ 14 \text{ m} \]
Outline

Seismic Reflection
Seismic Resolution
Seismic Sources and Geophones
CMP Stacking
Seismic Processing
Example Images
Dynamite

Explosive Mass = M

Anelastic Deformation

Elastic Wave Propagation
Dynamite Bandwidth

Large Charge

Small Charge
Dynamite Pulse Shape

Large Charge

Small Charge
Dynamite
Dynamite

- Expensive
- Sub-Weathering Source
- High Frequencies > 350 Hz
- Best Seismic Resolution
- Best Source for Mine Planning
Vibroseis
Vibroseis

- Cost Efficient
- Surface Source
- Restricted High Frequencies
- Restricted Seismic Resolution
- Suited for Petroleum Exploration
Envirovibe

More manoeuvrable than a conventional vibrators, but geophysically competitive, with good depth penetration for CBM and shallow-intermediate petroleum targets.
Mini SOSIE
Mini SOSIE

- Inexpensive
- Useful in Populated Areas
- Limited Seismic Resolution
- Good for Coal Exploration
Faraday’s Law
Moving Coil Microphone
Geophone
Laying Geophones and Spread
Dogbox
Outline

Seismic Reflection

Seismic Resolution

Seismic Sources and Geophones

CMP Stacking

Seismic Processing

Example Images
Poor-Man’s Seismic

\[ c = 0.4 \]
2D CMP Stacking

\[ c = 0.4 \times 5 \]
CMP Stacking with Noise

\[ c = 0.4 \times \sqrt{5} \]
2D Shot Record
2D Shot Record
Shot 5
Shot 6
Shot 8
Fold = \( \frac{\text{Number of Channels} \times \text{Geophone Spacing}}{2} \times \frac{\text{Shot Spacing}}{2} \)
2D CMP Stack Fold

\[
\text{Fold} = \frac{12 \times 1}{2} = 6
\]
Since coal interfaces have high reflection coefficients (generally > 0.3), the required stack fold is lower than for petroleum targets.
CMP Stack Fold

Typical 2D Petroleum Survey

Fold = \frac{240 \times 20}{2 \times 40} = 60

Normal sedimentary interfaces have lower reflection coefficients (generally < 0.1). Hence a higher stack fold is required.
3D CMP Stacking
3D Recording Geometry
3D Recording Patch
3D Shot record
Shot 103
Shot 151
Shot 152
Grasstrees 3D Survey

Receiver Spacing: 15m
Receiver Line Spacing: 48m
Live Patch: 12 Lines x 36 Receivers

Shot Line Spacing: 75m
Bin Size: 7.5m x 7.5m
CMP Fold: 12
Outline
Seismic Reflection
Seismic Resolution
Seismic Sources and Geophones
CMP Stacking
Introduction to Seismic Processing
Example Images
Making Stacked Images

Shot Records

Seismic Processing

Stacked Image
Seismic Processes

Geometric
- Amplitude Equalisation
- Statics Correction
- CMP Stacking

Image Enhancement
- Filtering
- Deconvolution
- Migration
Seismic Processes

Geometric
- Amplitude Equalisation
- Static Correction
- CMP Stacking

Image Enhancement
- Filtering
- Deconvolution
- Migration

The following real-data example illustrate two processes, Static Correction and Deconvolution.
Static Errors

2500 m/s

750 m/s

2500 m/s
2D Image with Static Errors
Static Correction
Deconvolution
The following slides explain why the Migration process is needed, including a couple of real-data examples.
CMP Assumption
CMP Reality
Migration for structural correction

FIG. 1.1-9. Top is 11 kilometers of reflection data from a survey line across the Japan trench (Tokyo University Oceanographic Research Institute). Bottom shows the result of migration processing. (Ottolini)
Migration for image enhancement

Can you see the fault plane?
It should be more obvious now
Outline

Sound Waves

Seismic Resolution

Seismic Sources and Geophones

CMP Stacking

Seismic Processing

Example Images
Coal Seismic Section
Seismic Image of a Fault
Seismic Image of a Seam Split
3D Visualisation
3D Attribute Maps

Amplitude

Gradient

Semblance

Frequency
Summary

Seismic reflection is an excellent tool for geological imaging.

CMP stacking provides boost needed for a high quality image.
Summary

2D Seismic Reflection suitable for initial exploration

3D Seismic Reflection provides improved geological model
Summary

Resolution of image depends on bandwidth of seismic waves

Dynamite is the best source for high-resolution imagery
Summary

For petroleum targets > 1500m the resolution advantage of dynamite is lost.

Vibroseis is the most effective onshore source for conventional petroleum targets (> 1500 m).
Summary

Airgun is the most effective offshore source

Mini-SOSIE cost effective for initial coal exploration (2D and 3D)
Summary

Seismic processing converts shot records to seismic images

Geometrical processes

Image enhancement
Aspects of 2D and 3D Seismic Reflection

Steve Hearn

This document contains various images intended to supplement lecture and practical material. It is not intended as a stand-alone document.

This material is explicitly provided for educational purposes only, to students of ERTH3021. All other usage is prohibited.