PHYSICAL SEISMIC MODELING OF A VERTICAL FAULT

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Outline

- Introduction
- Theory
- Physical modeling
- Results
- Future work
1. Investigate shallow fault zones
   - Geotechnical Engineering
   - Seismic Risk Assessment
   - Petroleum industry

2. Greendale fault
   - Surface Rupture, 28 km long (2010)
   - Average dextral displacement = 2.5 m
   - Average vertical displacement = 0.75 m
   - Deformation zone = 30 – 150 m wide
2D seismic acquisition (CREWES) following the Feb 2011 Christchurch earthquake. The Greendale fault zone is outlined.
Introduction

Goals:

1. Develop a simple physical model of a vertical fault, based on the Greendale fault

2. Investigate fault detectability in seismic surveys
The quality of seismic imaging is constrained by resolution.

Vertical Resolution: \( \frac{1}{4} \lambda = \frac{v}{f} \)

- E.g. For 60 Hz dominant wavelength and a velocity of 1480 m/s: Fault throw \( \sim 3 – 6 \) m
• **Lateral Resolution:**
  – Determined by the Fresnel zone
  – An area of constructive reflection accumulation surrounding a reflection point
  – Radius, \( R = (v/2)(t/f)^{1/2} \)
    Approx Radius = 50 m for this case.

Physical modeling

• University of Calgary Seismic Physical Modeling Facility, maintained by CREWES.

1 mm = 10 m !!!
# Physical modeling

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<thead>
<tr>
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<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
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<tbody>
<tr>
<td><strong>Model material</strong></td>
<td>Plaster of Paris</td>
<td>Lard</td>
<td>Sandstone</td>
<td>Epoxy</td>
<td>Limestone</td>
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<td><strong>Fault zone infill</strong></td>
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<tr>
<td><strong>Density (g/cm³)</strong></td>
<td>1.3</td>
<td>0.98</td>
<td>2.6</td>
<td>1.7</td>
<td>2.9</td>
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<tr>
<td><strong>Measured Velocity (m/s)</strong></td>
<td>2035</td>
<td>1490</td>
<td>2965</td>
<td>2680</td>
<td>5100</td>
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**Note:** This table presents data on different models, including their materials and densities, as well as measured velocities.
Physical modeling
Physical modeling
Physical modeling
Physical modeling

- **RESIN**
- **LIMESTONE**
- **ALUMINUM PLATE**
- **PHENOLIC RESIN BLOCK**

- Water depth = 1000 m
- 300 m
- 200 m
- 310 m
- 130 m

Diagram with labels:
- Tx
- Rx
Data Processing

• Data collected over fault gaps of 5, 10, 15 mm

• 2D poststack seismic data processing:
  – Zero offset survey
  – Common shot survey

Plan view of the zero-offset acquisition. The Tx-Rx pair moved in 5 m increments and have 50 m offset.
Data Processing Flow

Zero Offset Processing Flow

1. Bandpass filter
2. Top Mute
3. Spiking Deconvolution
4. Mean Scaling
5. FK Filter
6. Mean Scaling
7. 2D Kirchhoff migration
8. AGC and Bandpass

Common Shot Processing Flow

1. Geometry
2. Top Mute
3. Bandpass filter
4. FK Filter
5. Exponential Time Power
6. Spiking Deconvolution
7. Mean Scaling & Filter
8. Velocity Analysis
9. NMO & Stretch Mute
10. Stack
11. FK Filter
12. Kirchhoff Migration
13. AGC & Filter
Data Processing

Acrylic filled fault

Water filled fault
Data Processing

CMP Stack

Poststack Migration

Acrylic filled fault

Water filled fault

a1.

a2.

b1.

b2.
Event Identification

Direct Wave
Top of LS
Bottom of LS
Bottom of Fault (Water filled)
Direct wave ghost
Top of LS ghost

WATER SURFACE
LIMESTONE
Event Identification

Direct Wave

Fault Bottom (Water filled)

Direct Wave Ghost

Water Bottom / Top of Limestone

Water Bottom Ghost
Imaged Results

Common shot survey

Water filled fault

Zero offset survey

Acrylic filled fault
Results Comparison: The Greendale fault

Modeled fault

Greendale fault
1. The ghost reflections identified are interesting as they do not interfere with the primary data, and may be useful in further imaging focused only on the multiple data.

2. Would also like to test narrower fault zones than 5mm.

3. Numerical modeling may also be incorporated.
Conclusions

- Physical modeling provides a method to test seismic acquisition parameters for detecting fault resolvability.

- A great deal of consideration must be taken when designing a physical model to best represent a realistic geologic model.

- Processed model data images a shallow fault with a small vertical throw, and the width of the fault zone was resolved.
Acknowledgements

• Thanks to GEDCO for use of VISTA seismic processing software.

• Special thank you to CREWES sponsors for support

??? Questions ???
Data Processing: Velocity Analysis

Acrylic filled fault

Water filled fault