UNIVERSITY OF CALGARY

PHYSICAL SEISMIC MODELING OF A VERTICAL FAULT

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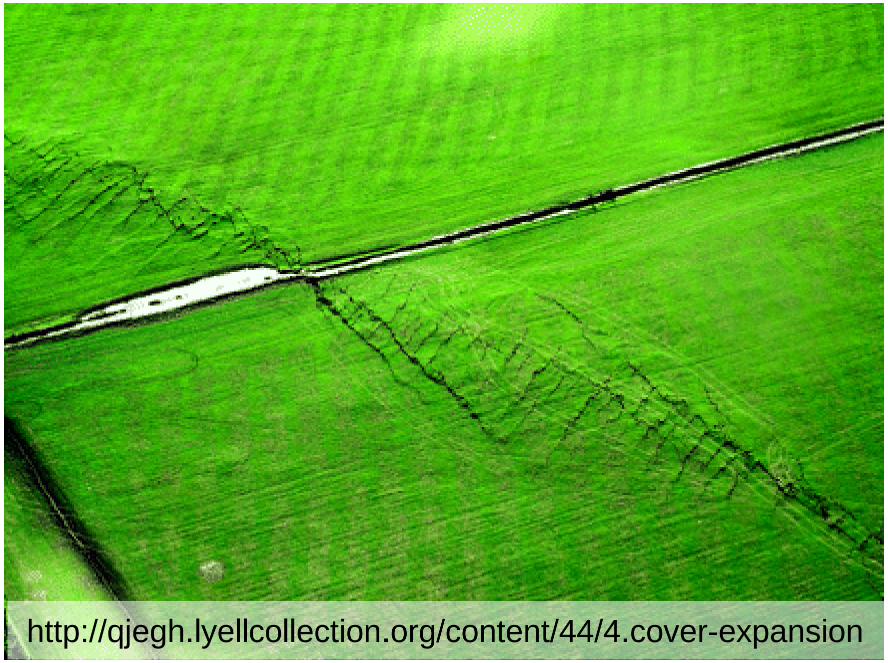
Outline

- Introduction
- Theory
- Physical modeling
- Results
- Future work

Introduction

1. **Investigate shallow fault zones**

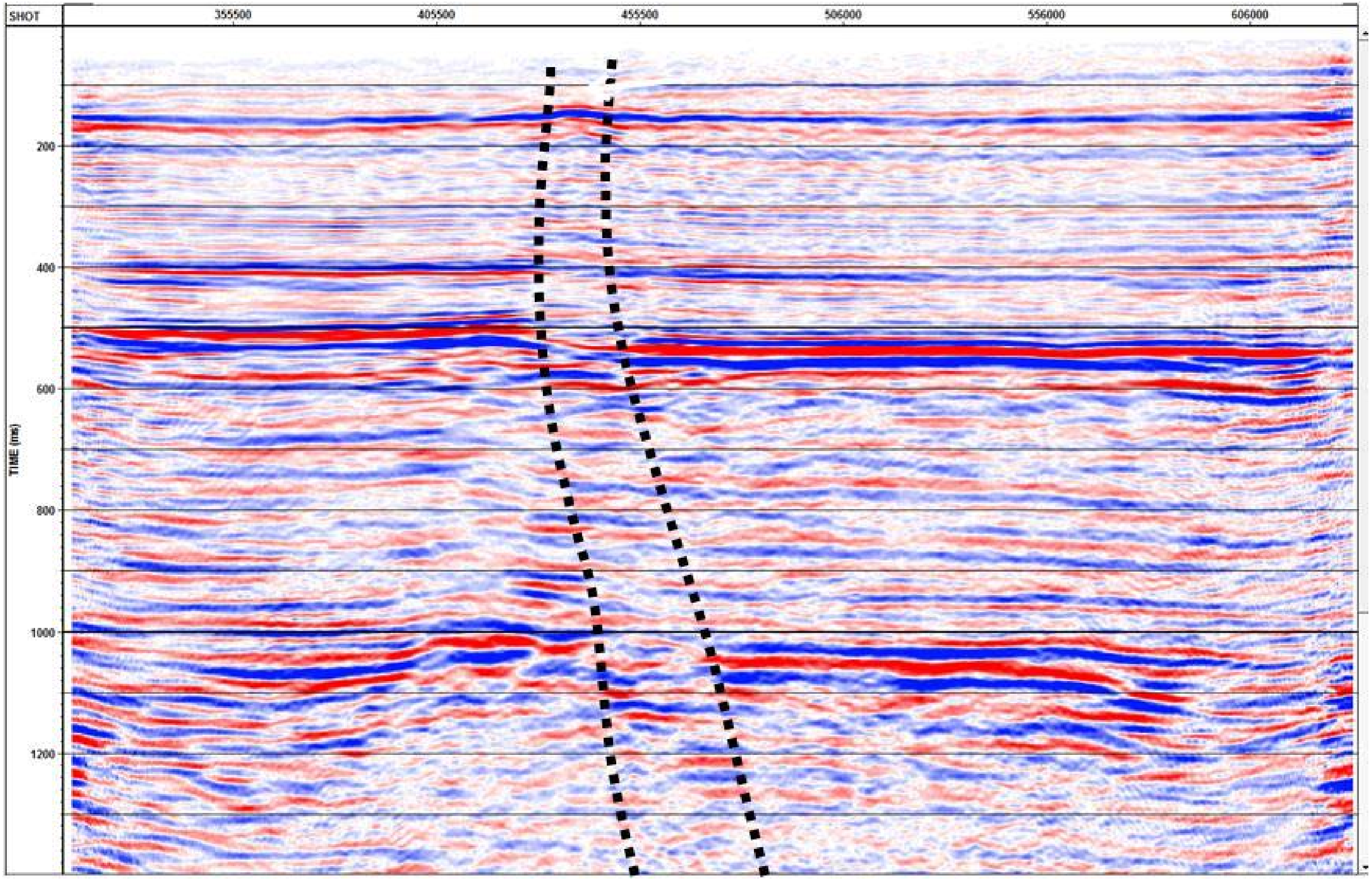
- Geotechnical Engineering
- Seismic Risk Assessment
- Petroleum industry



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

Introduction



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

Theory

- The quality of seismic imaging is constrained by resolution.

- Vertical Resolution: ¼ $\lambda = v / f$

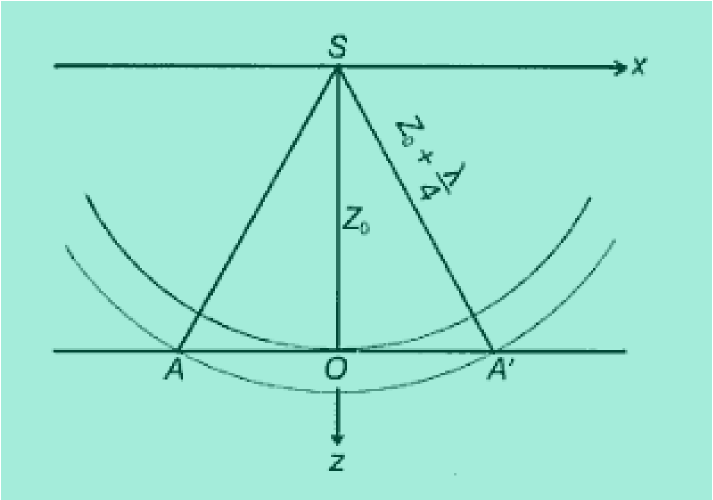
  - E.g. For 60 Hz dominant wavelength and a velocity of 1480 m/s: Fault throw ~ 3 – 6 m

Theory

- 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

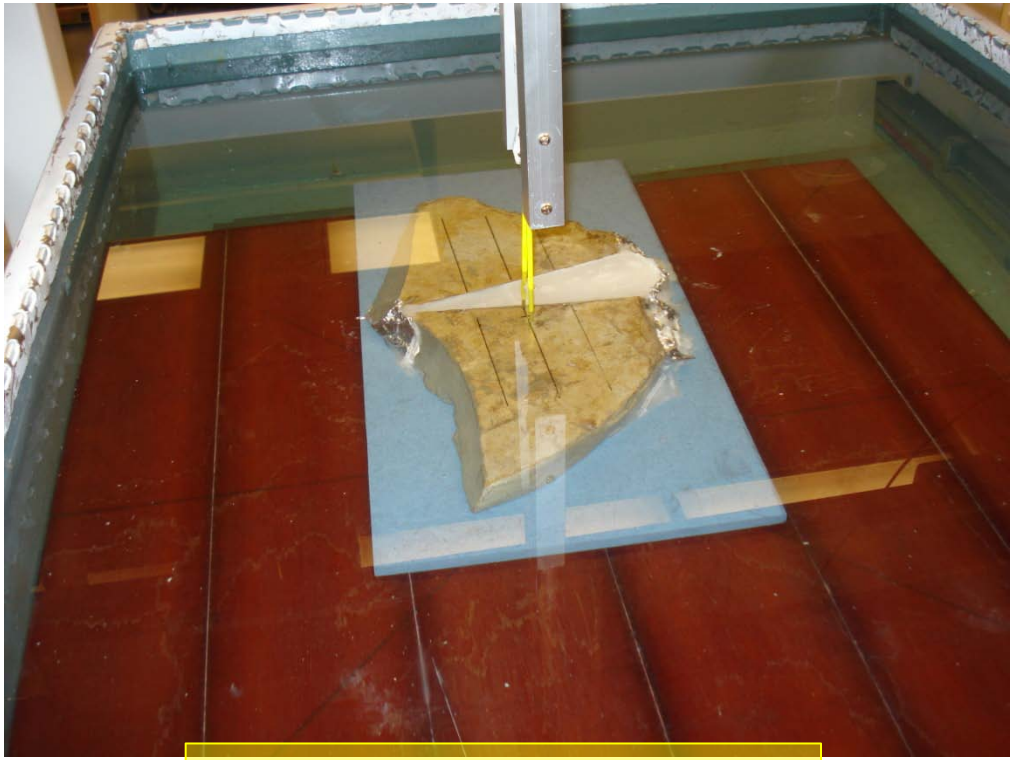
    for this case.



From Yilmaz, O., 1987, Seismic Data Processing: Society of Exploration Geophysicists, p. 470.

Physical modeling

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

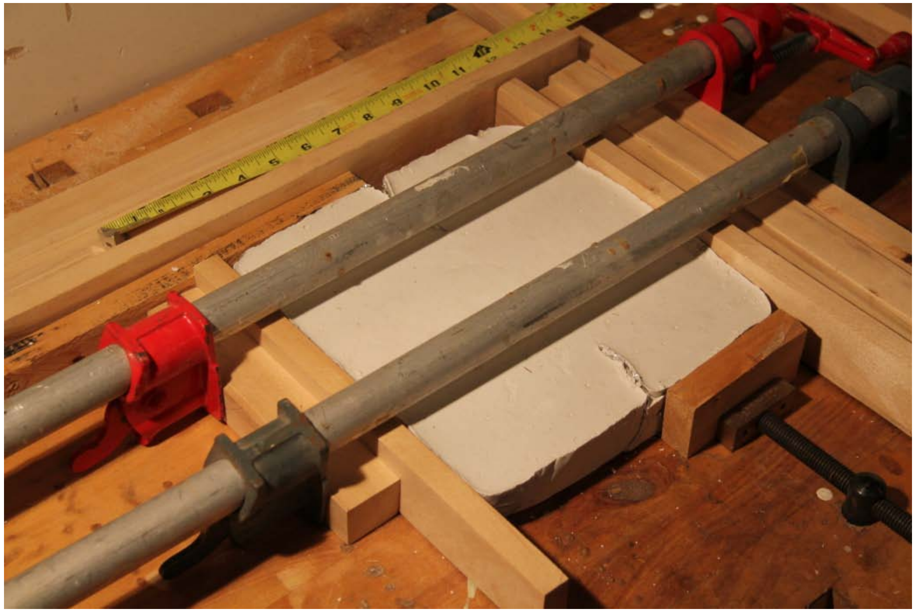


1 mm = 10 m !!!

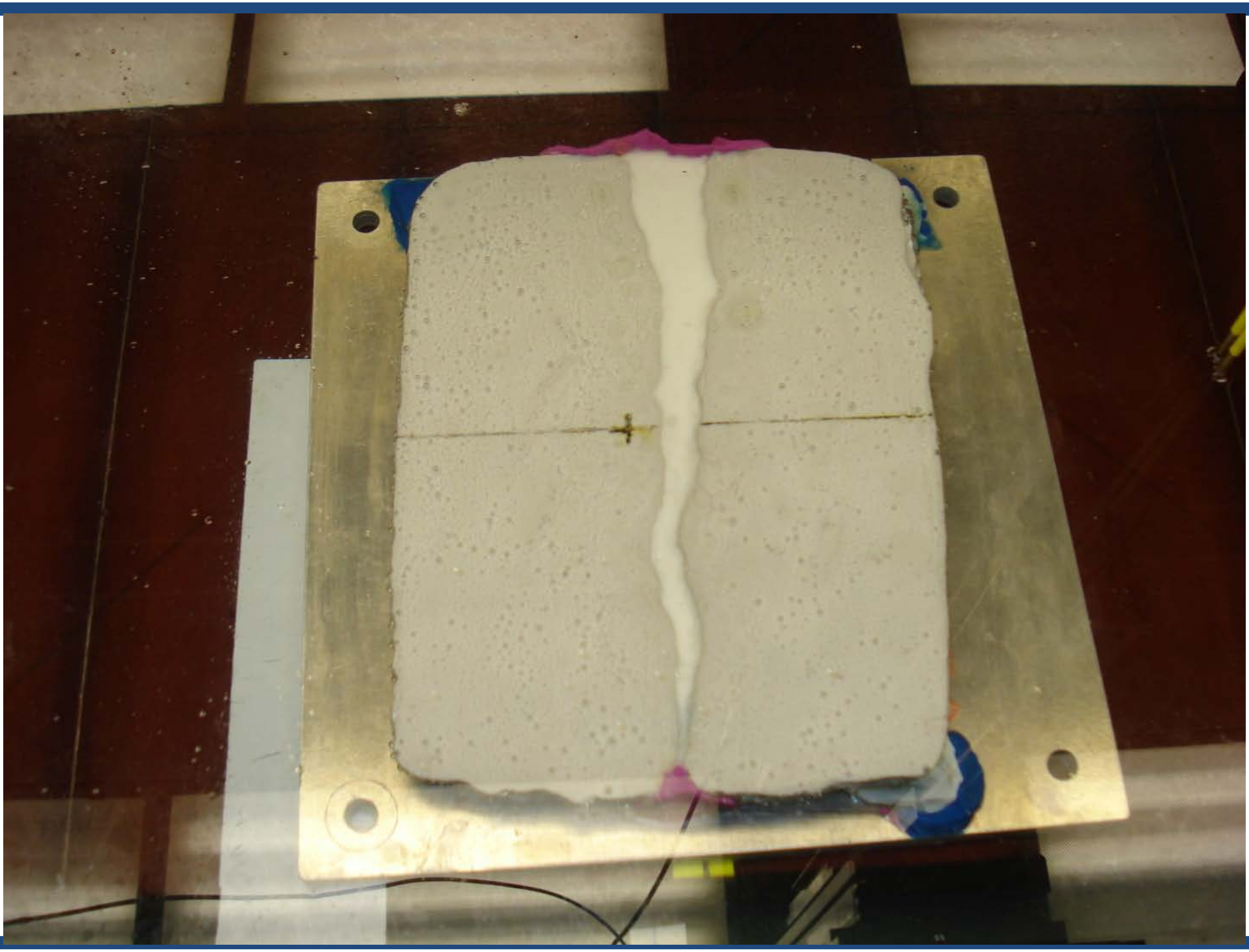
Physical modeling

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Model material	Fault zone infill	Model material	Fault zone infill	Model material	Fault zone infill	Model material	Fault zone infill	Model material	Fault zone infill
	Plaster of Paris	Lard	Sandstone	Epoxy	Limestone	Wax	Limestone	Water	Limestone	Liquid Acrylic
Density (g/cm^3)	1.3	0.98	2.6	1.7	2.9	1.1	2.9	1.0	2.9	1.2
Measured Velocity (m/s)	2035	1490	2965	2680	5100	1510	5100	1480	5100	2460

Physical modeling

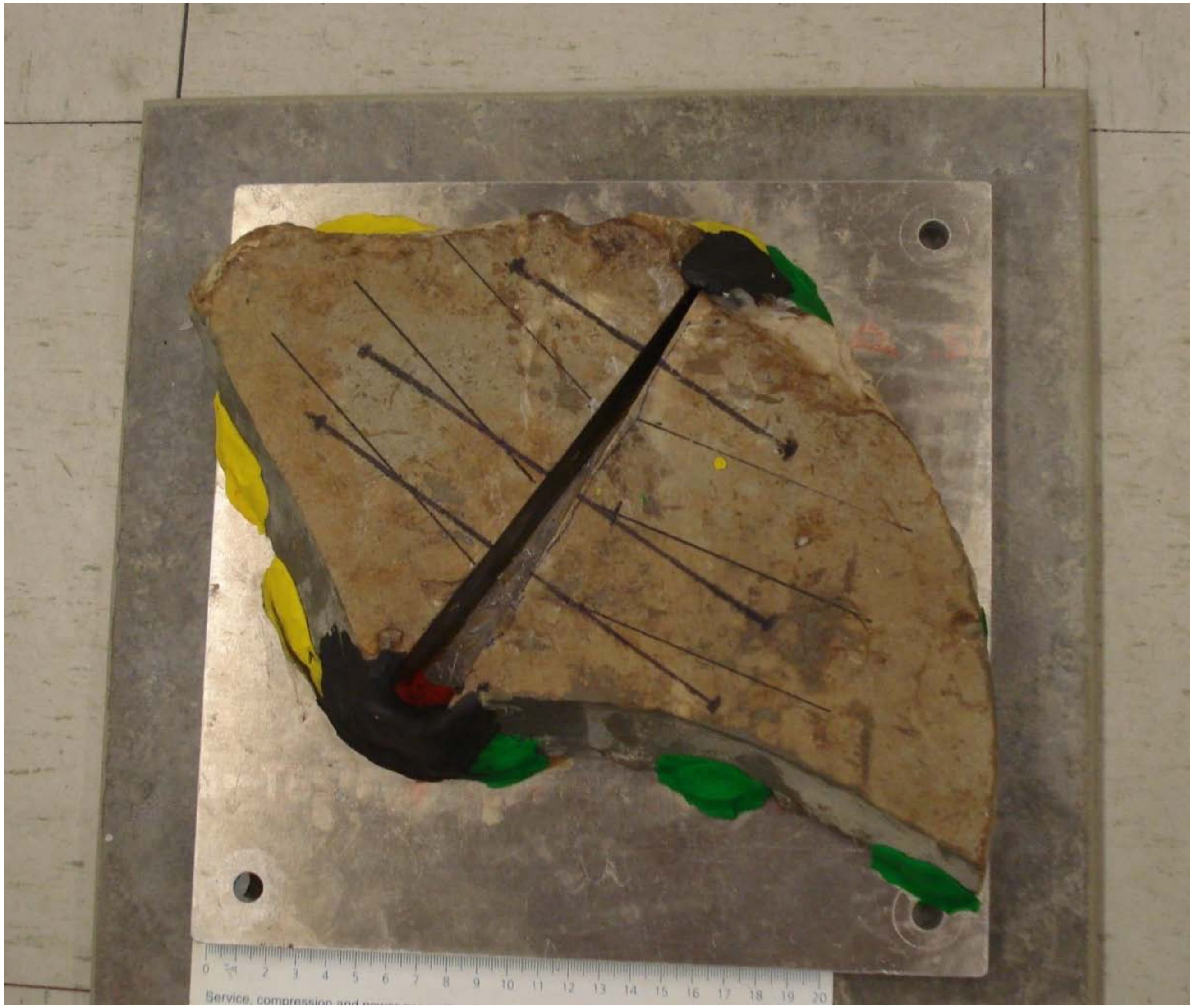


Physical modeling

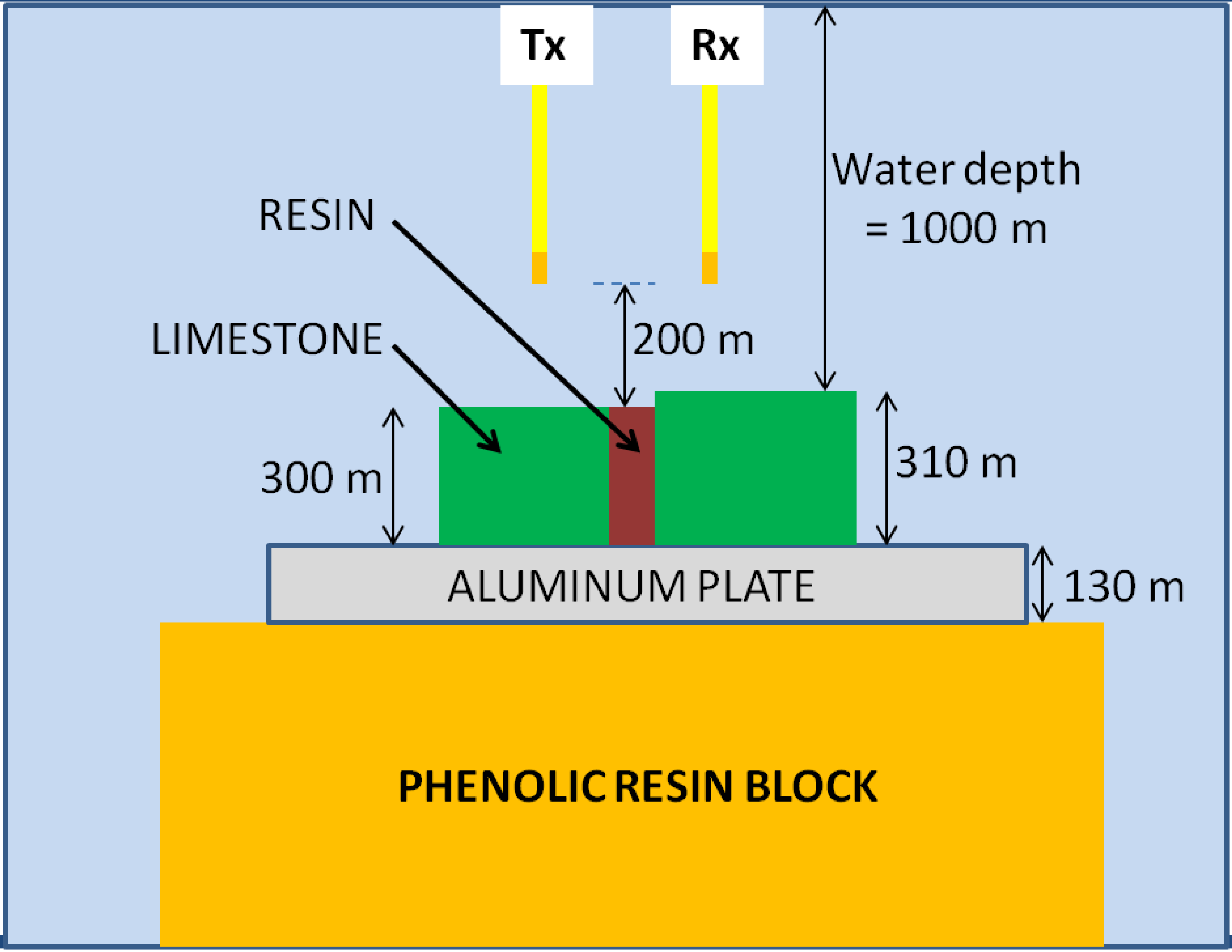


Physical modeling

Physical modeling



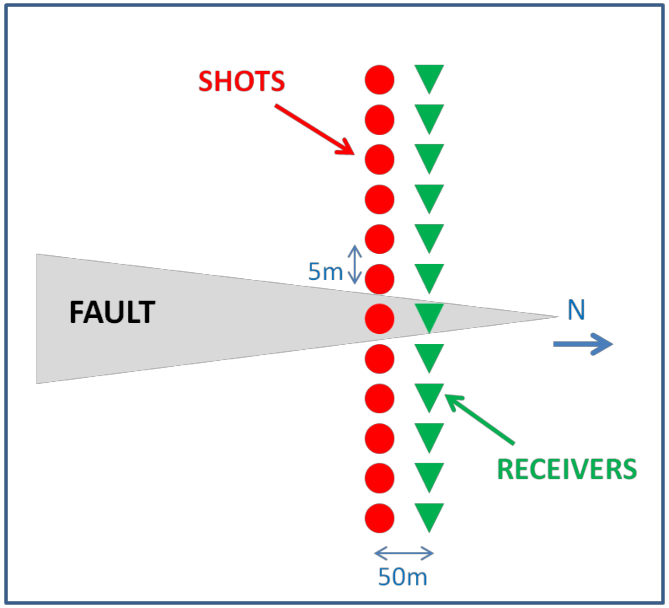
Physical modeling



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

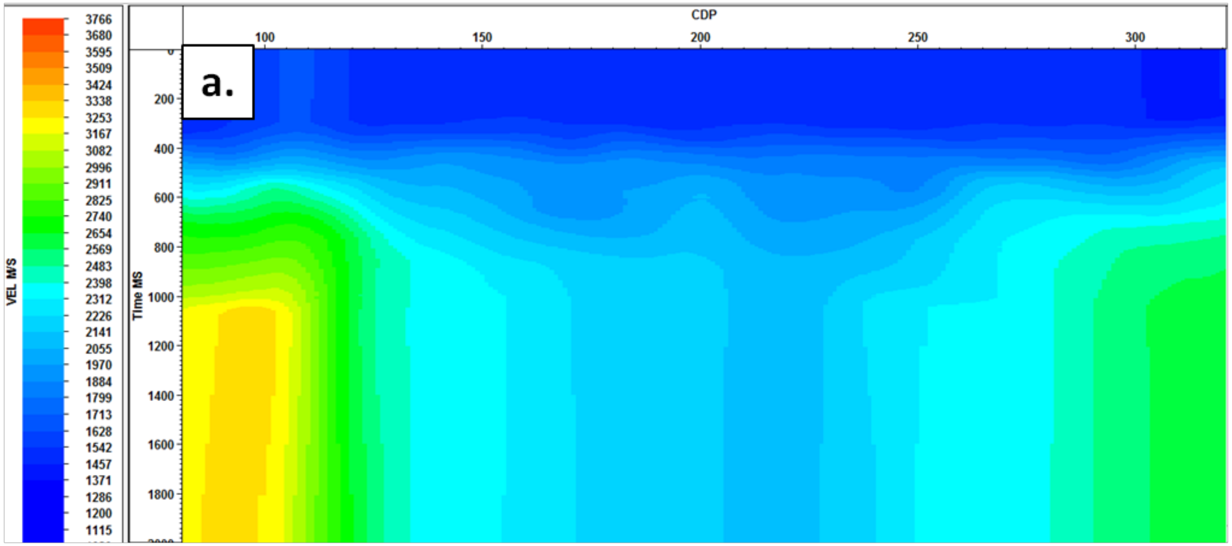
1. Bandpass filter
2. Top Mute
3. Spiking Deconvolution
4. Mean Scaling
5. FK Filter
6. Mean Scaling
7. 2D Kirchhoff migration
8. AGC and Bandpass

Common Shot Processing Flow

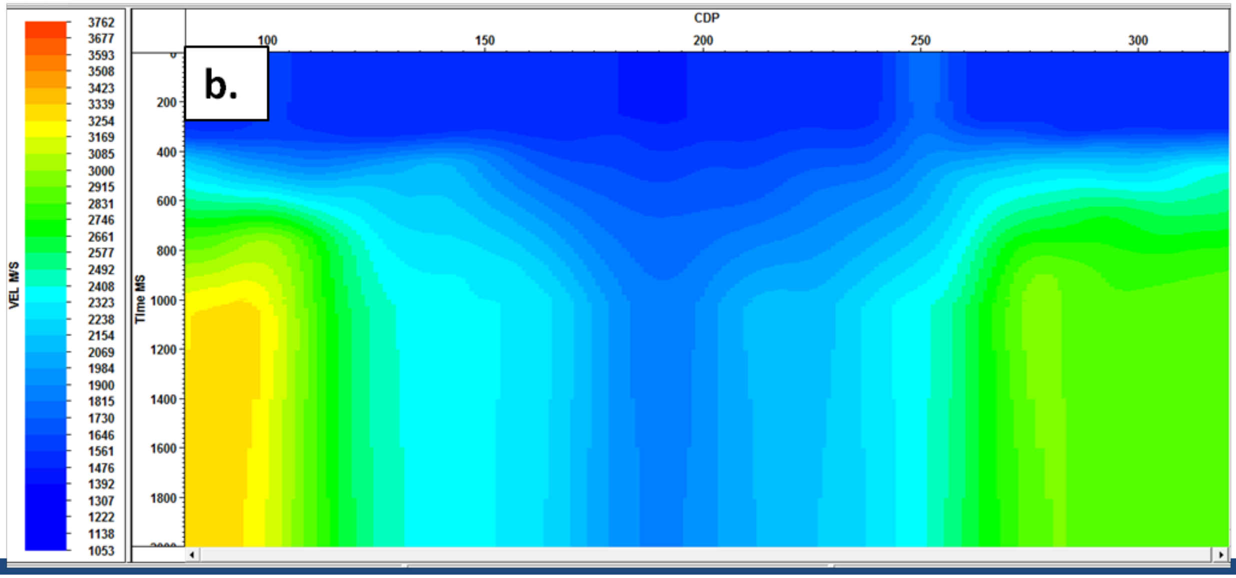
1. Geometry
2. Top Mute
3. Bandpass filter
4. FK Filter
5. Exponential Time Power
6. Spiking Deconvolution
7. Mean Scaling & Filter
8. Velocity Analysis
9. NMO & Stretch Mute
10. Stack
11. FK Filter
12. Kirchhoff Migration
13. AGC & Filter

Data Processing

Acrylic filled fault



Water filled fault

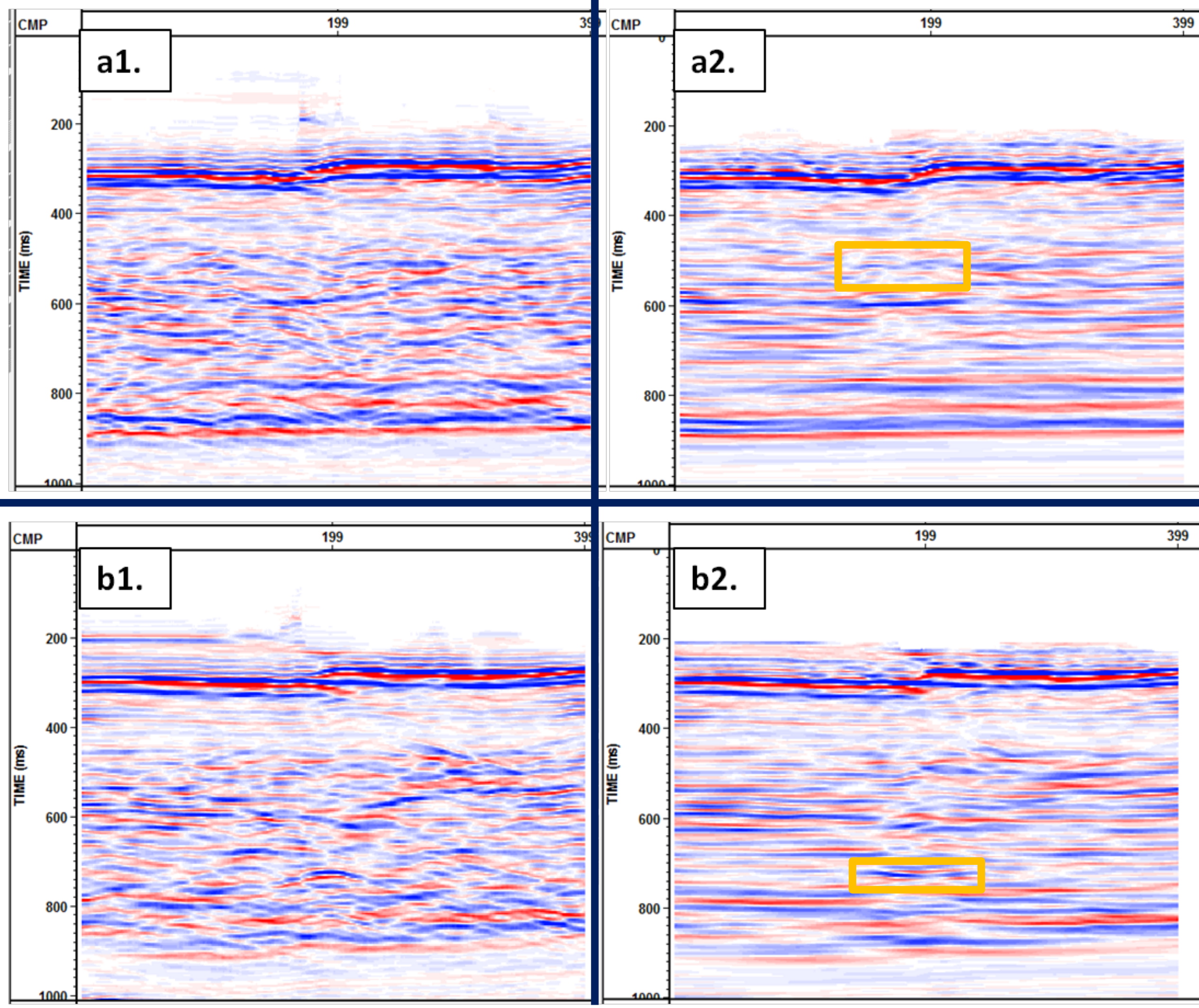


Data Processing

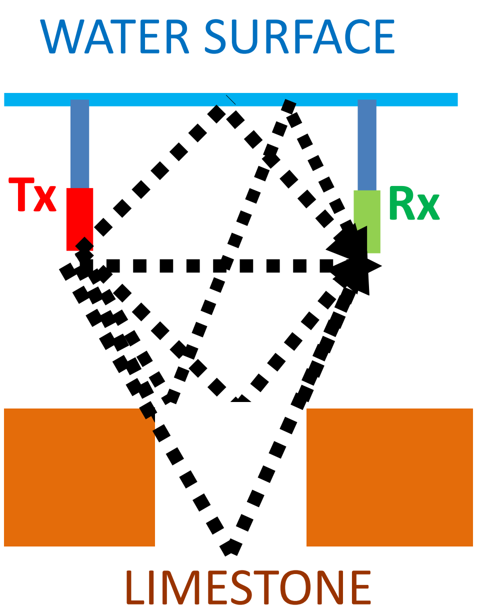
CMP Stack | Poststack Migration

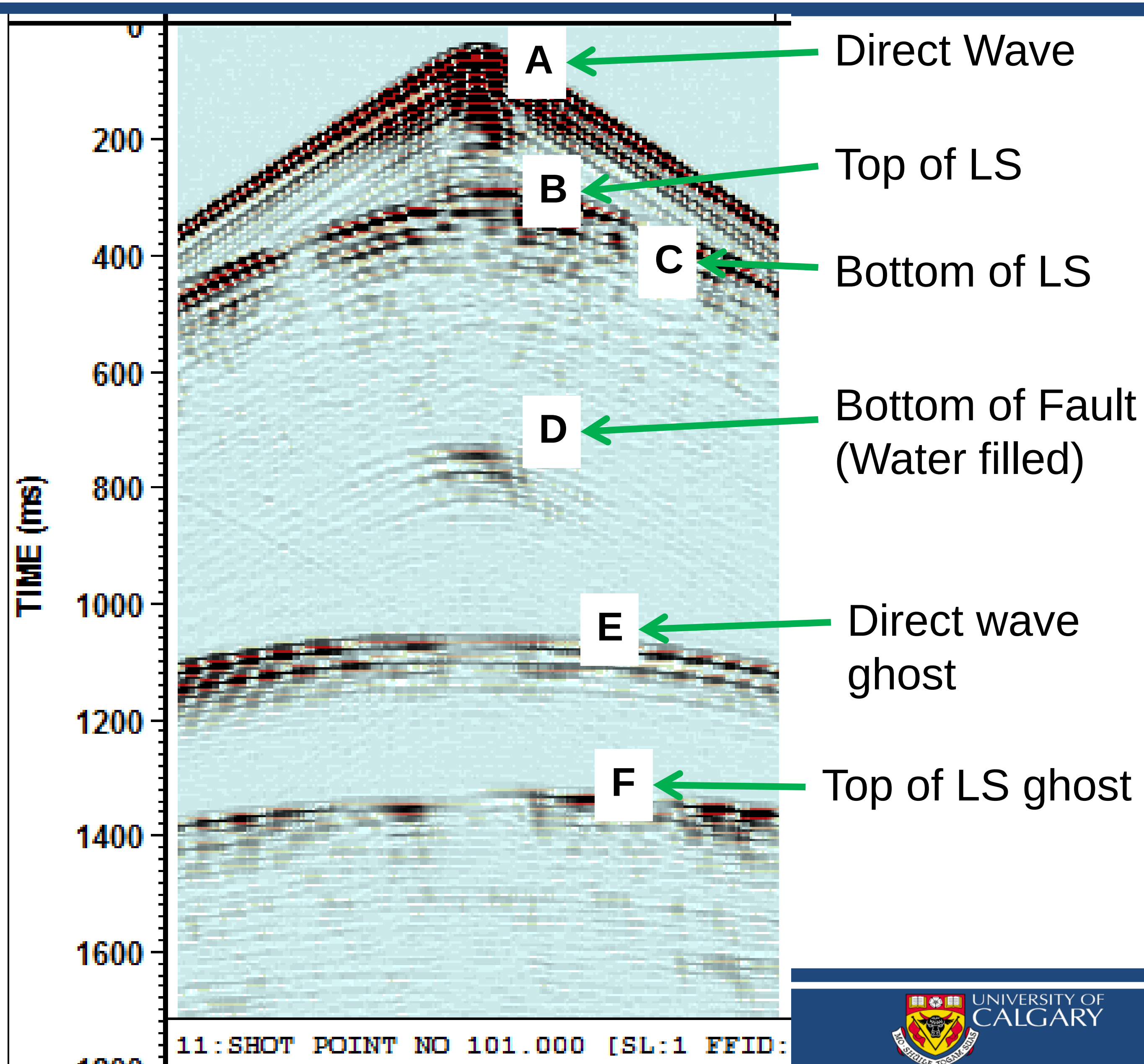
Acrylic filled fault

Water filled fault



Event Identification





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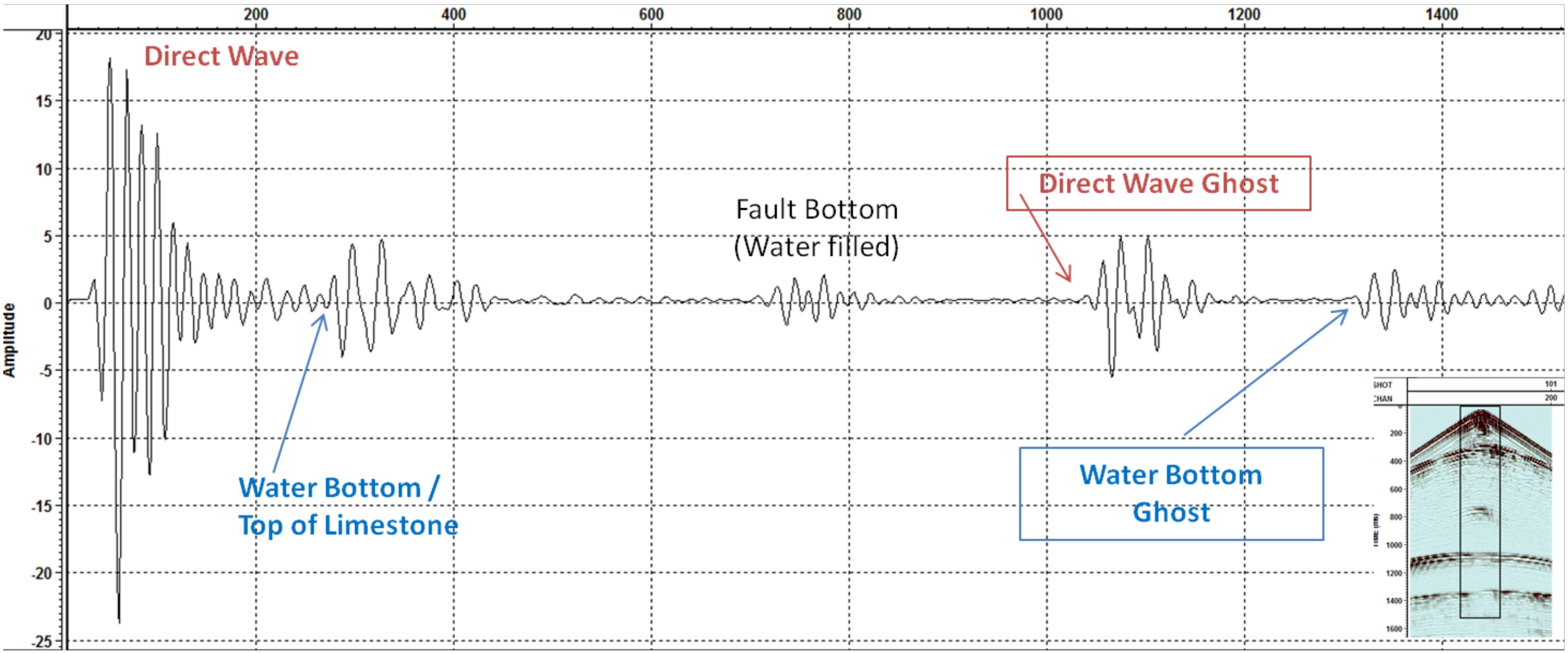
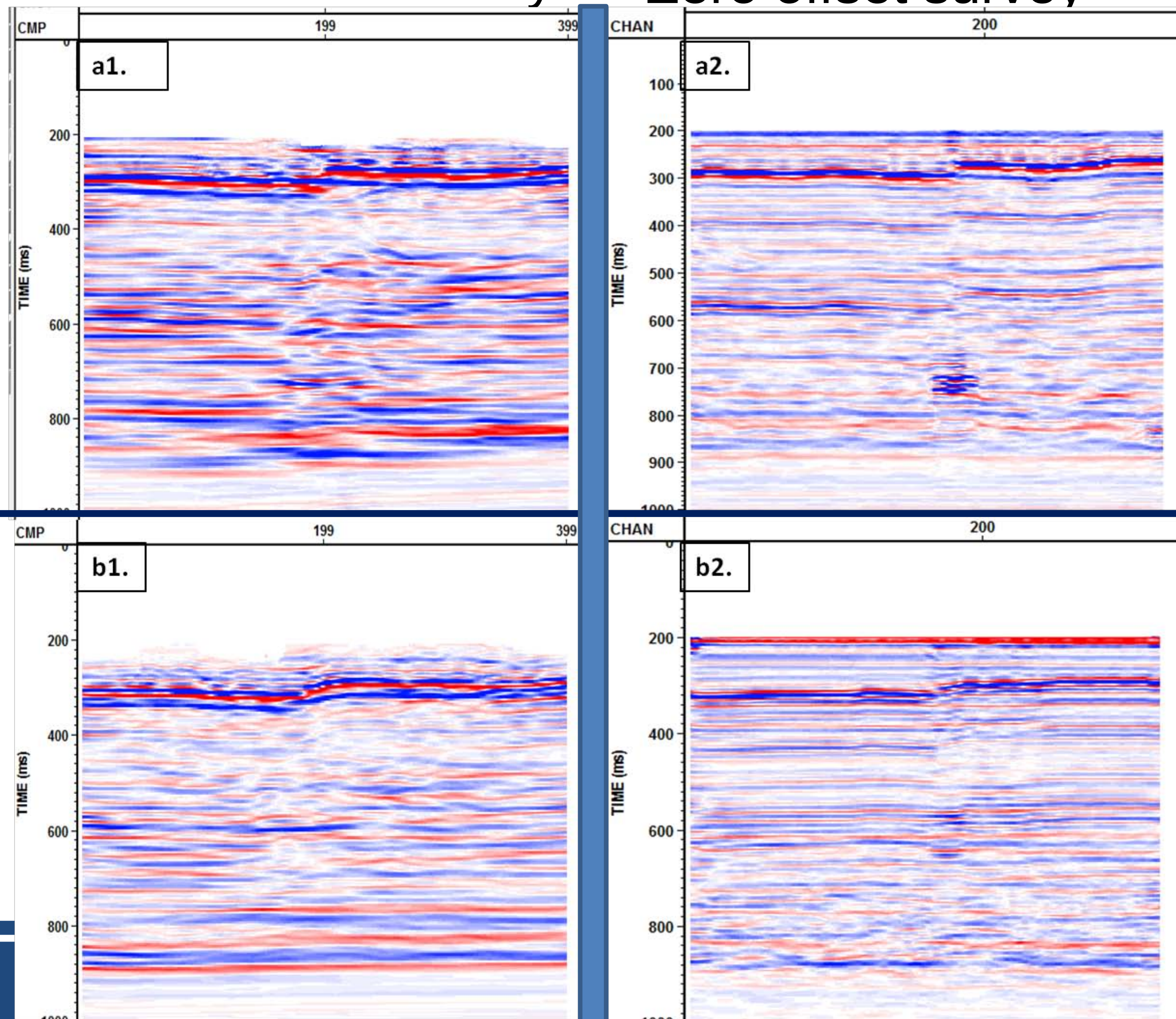


Imaged Results

Common shot survey | Zero offset survey

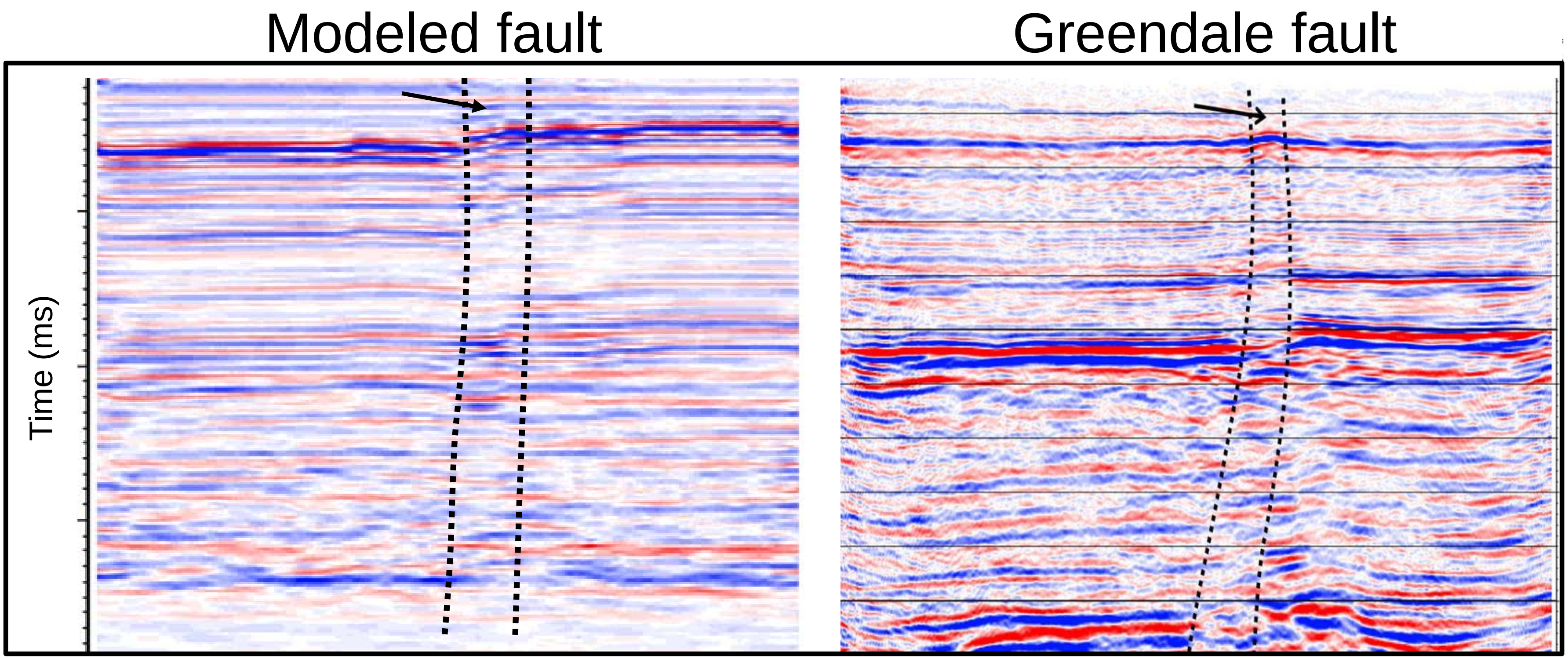
Water filled fault

Acrylic filled fault



CREWES

Results Comparison: The Greendale fault



Further Work …

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