CREWES

S-waves generated by explosive sources in boreholes

Saul Guevara and Gary Margrave

5-Dec-2013

NSERC CRSNG

Carbon Management Canada

UNIVERSITY OF CALGARY

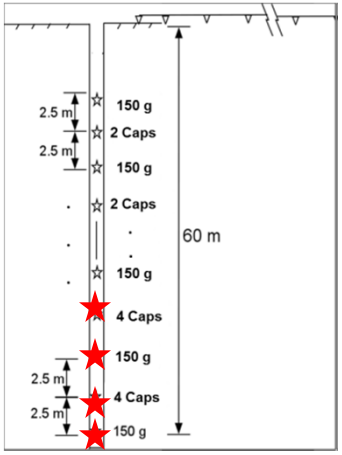
Outline

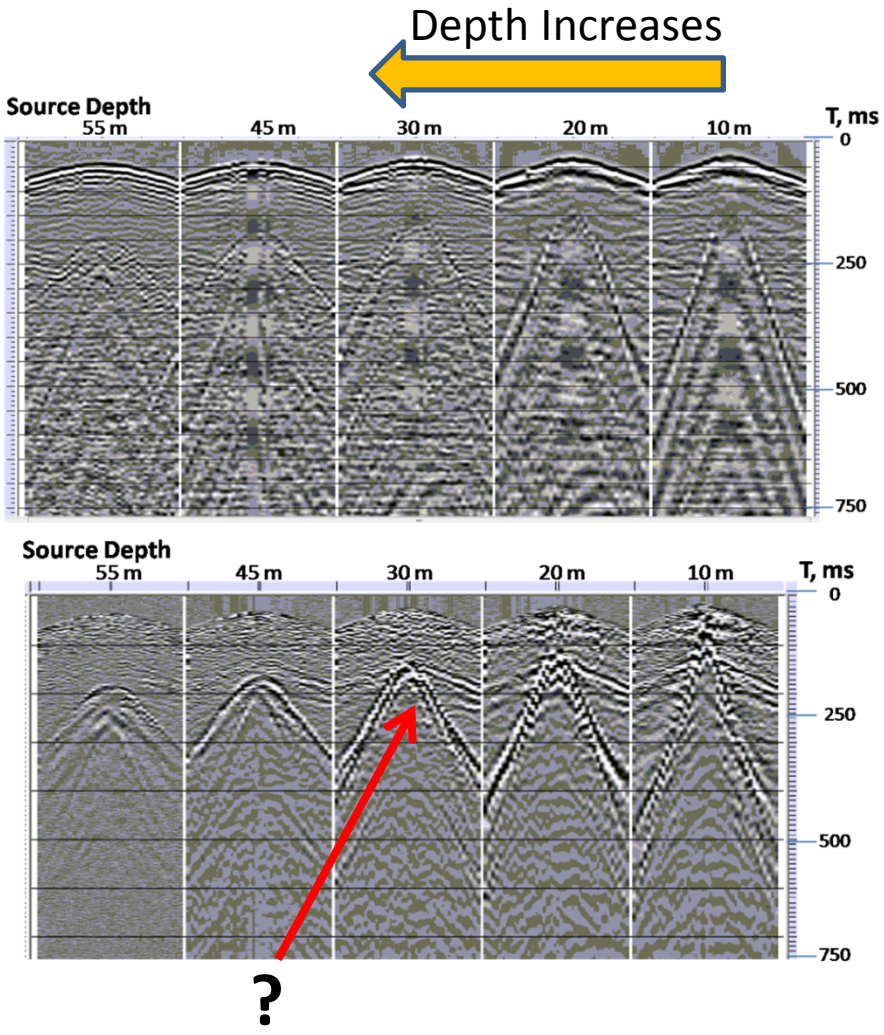
- Introduction: Why near surface S- waves and explosive sources
- A case history and the theoretical model.
- Numerical modeling of sources in boreholes.
- The Priddis experiment preliminary results.
- Conclusions.

Introduction

- The objective of this study is to investigate on using shear-wave arrivals from explosive sources.
- An application: shear-wave to obtain a velocity model of the near-surface.
- For statics correction of S-wave.

A previous experiment: uphole data from Colombia



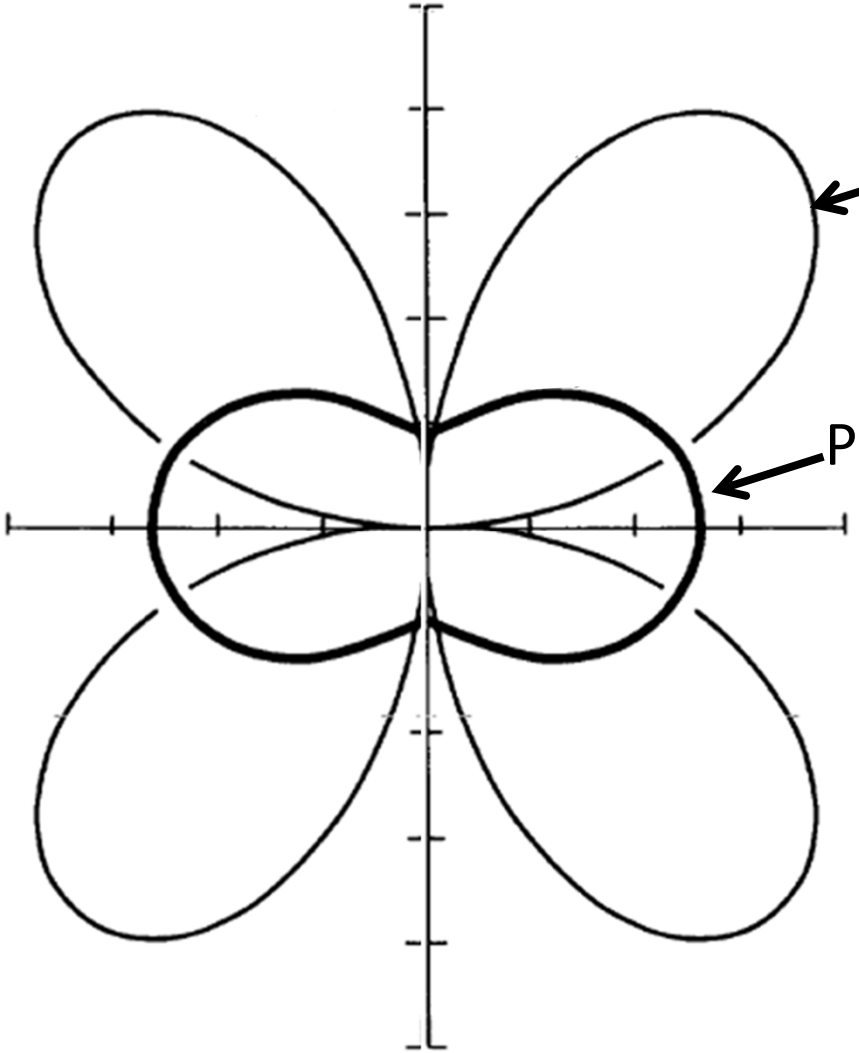


Vertical component

Horizontal component

Theoretical Radiation Pattern

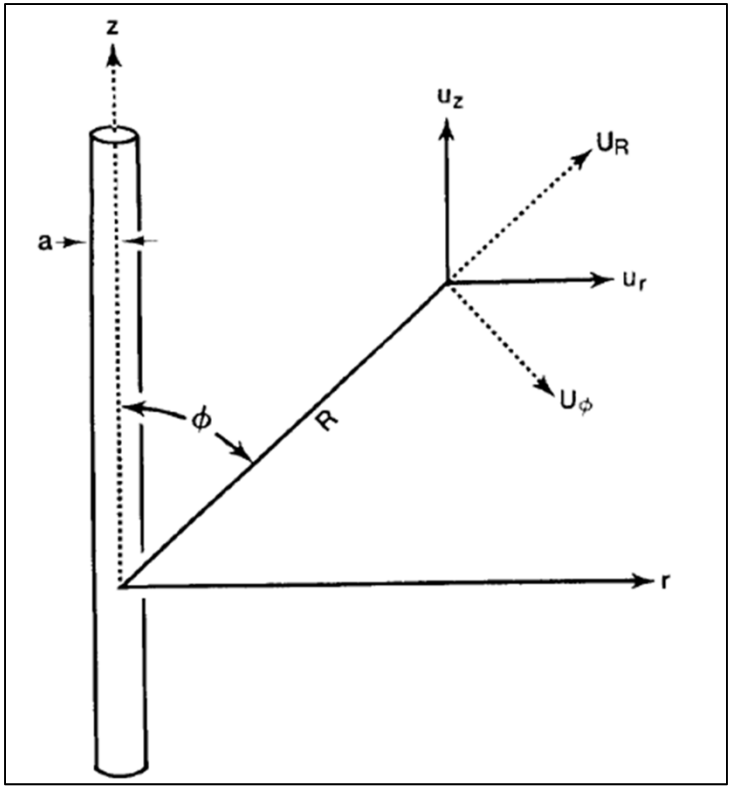
explosion in vertical fluid-filled borehole



After Lee and Balch, 1982

Theoretical seismic radiation

Volume displacement source in a fluid-filled borehole



(Lee and Balch, 1982, Geophysics.)

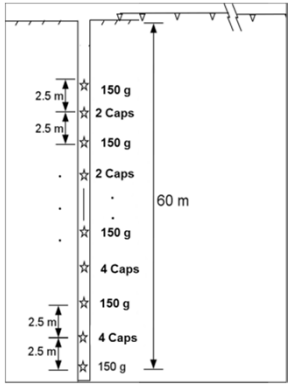
Particle displacement in the solid are given by:

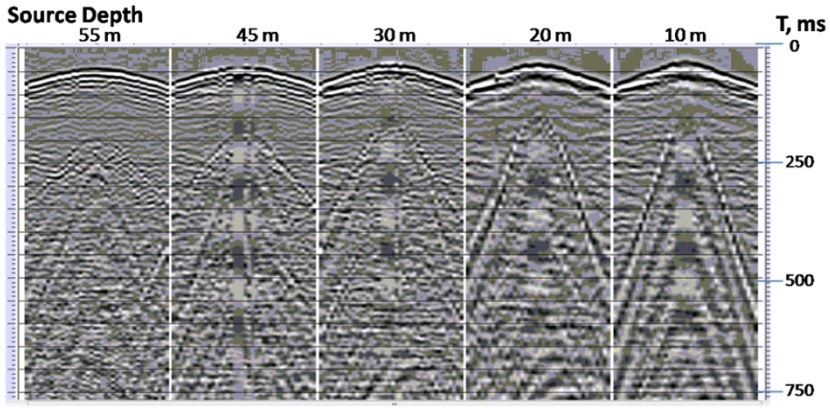
$$U_R = \frac{\rho_1 V_0 (1 - 2\beta_2^2 cos^2\,\phi/\alpha_2^2) G'(t - R/\alpha_2)}{4\pi\rho_2(\rho_1/\rho_2 + \beta_2^2/\alpha_1^2 - \beta_2^2 cos^2\,\phi/\alpha_2^2)\alpha_2 R}$$

$$U_\phi = \frac{\rho_1 V_0 \sin\phi \cos\phi\, G'(t - R/\beta_2)}{2\pi\rho_2(\rho_1/\rho_2 + \beta_2^2/\alpha_1^2 - cos^2\,\phi)\beta_2 R}$$

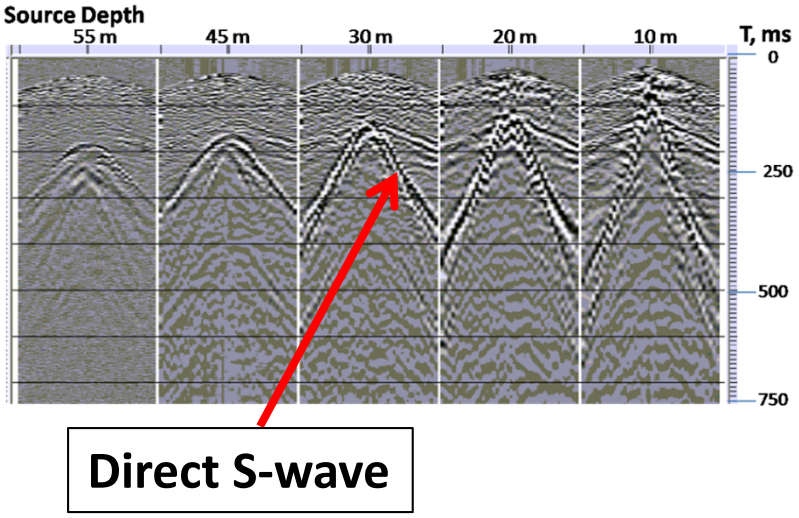
V_0 : volume displacement of the source,
Subscript 1: inside the borehole; 2: outside.
α : P-wave velocity.
β : S-wave velocity.
G : Source variation with t.

A previous experiment: uphole data from Colombia



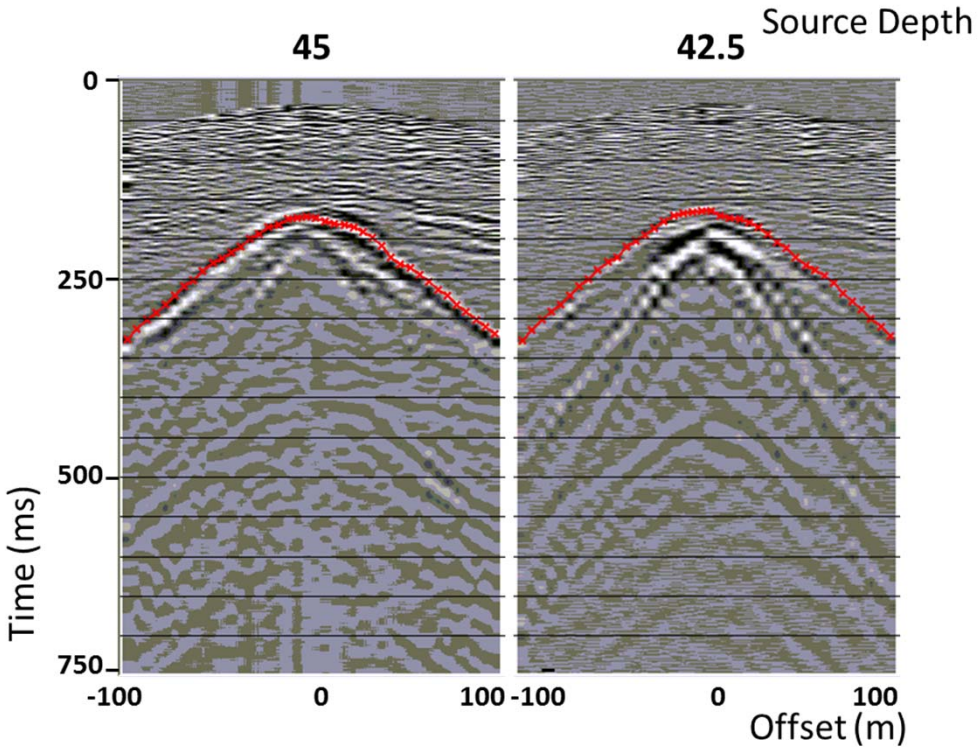


Vertical component



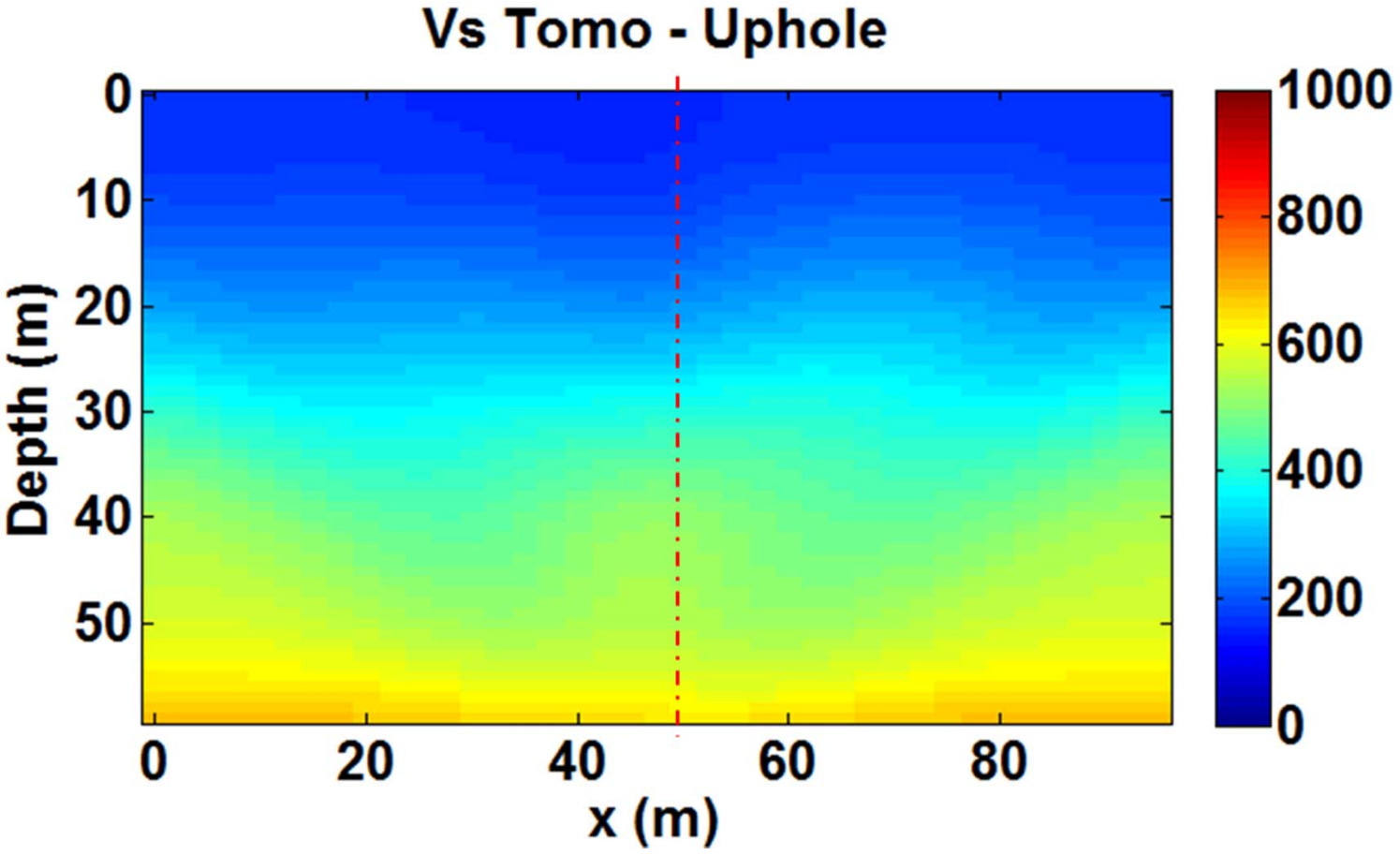
Horizontal component

Surface and uphole S-wave picking

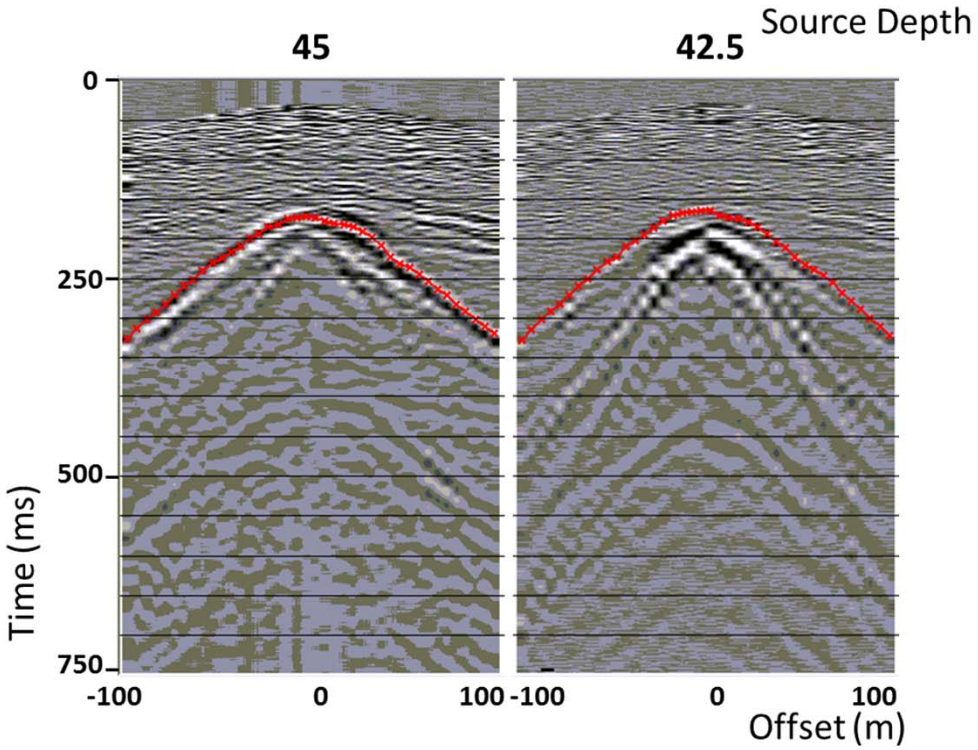


Uphole Horizontal Component:
Direct arrivals

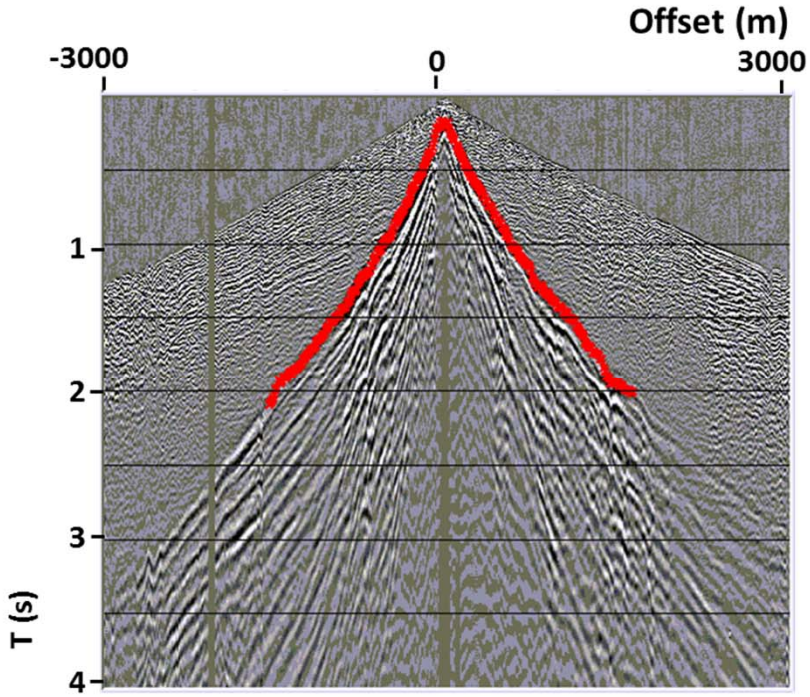
Tomography from the uphole



Surface and uphole S-wave picking

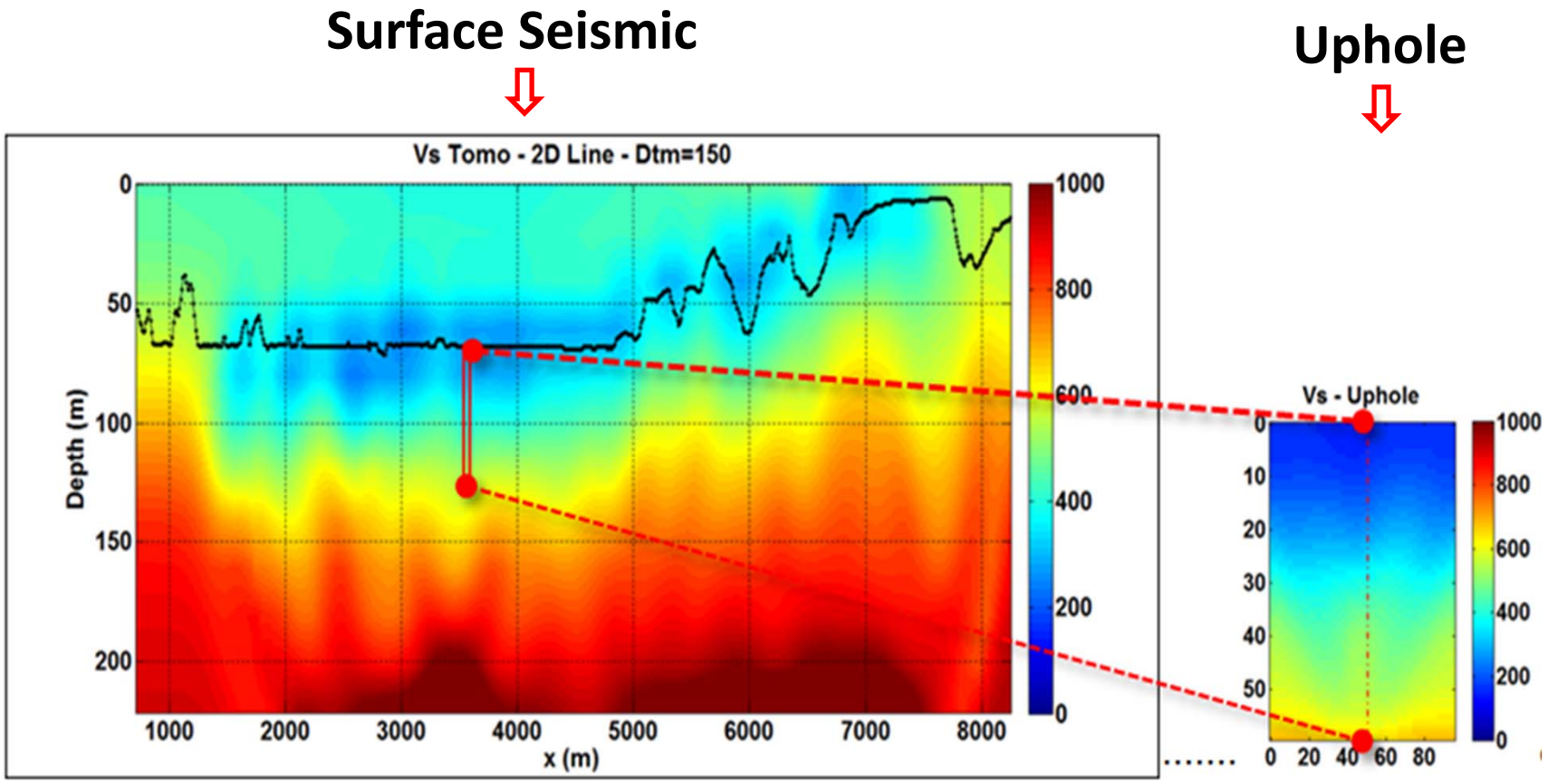


Uphole Horizontal Component:
Direct arrivals



Surface Horizontal Component:
Refractions

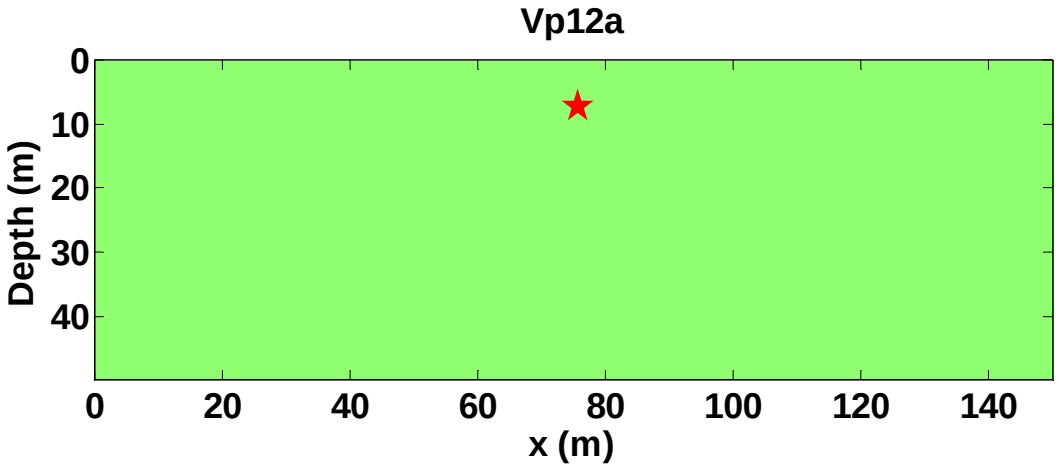
Near surface S-wave velocity using tomography



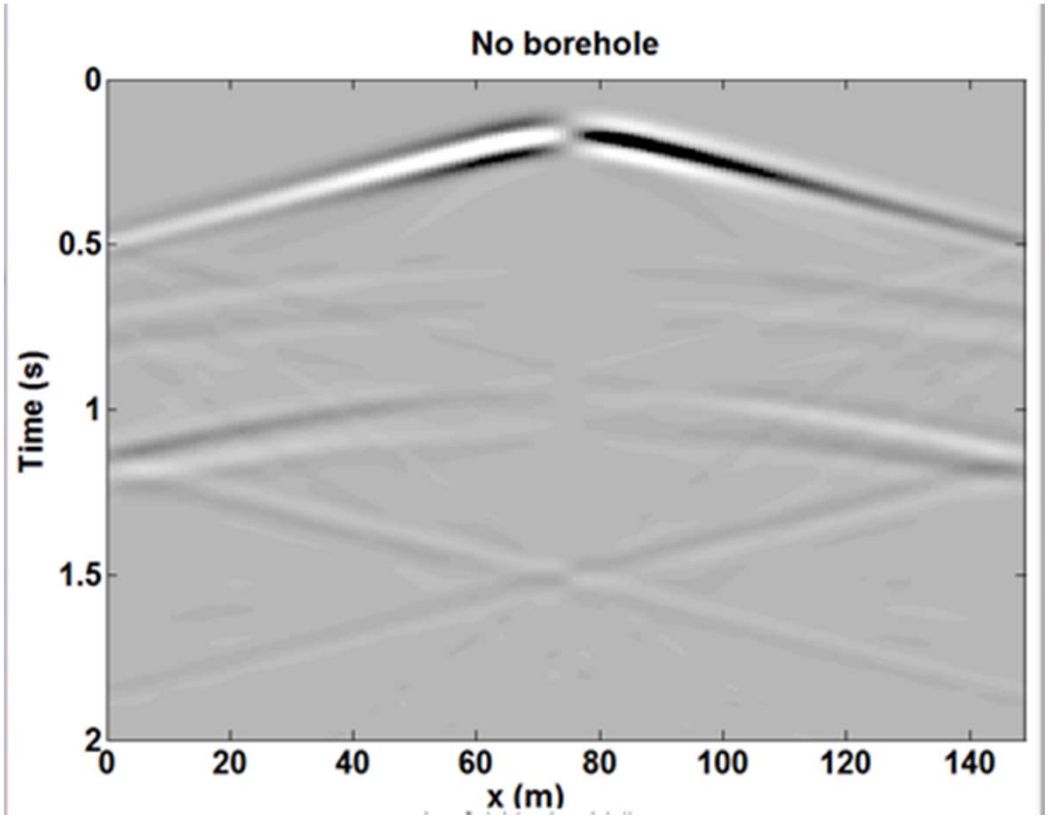
Numerical Modeling

- Three models are compared:
  - An explosive source without borehole.
  - Explosive source in a vertical borehole.
  - Explosive source in a tilted borehole.

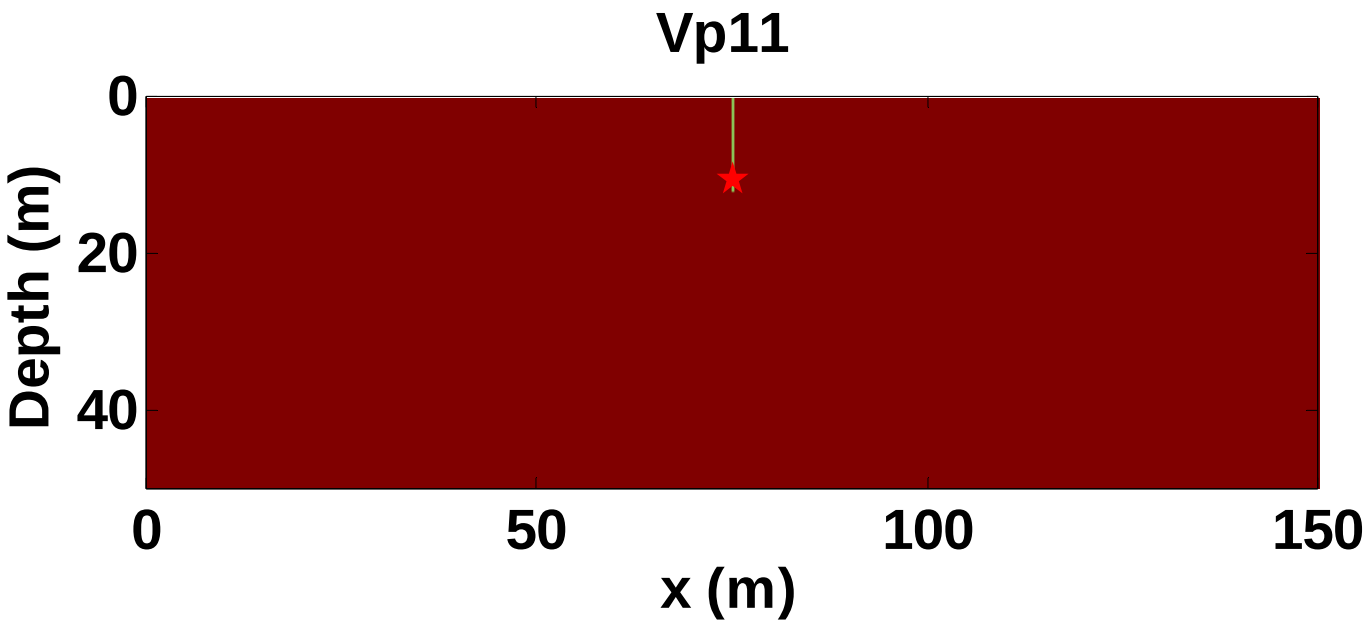
Model 1: No borehole



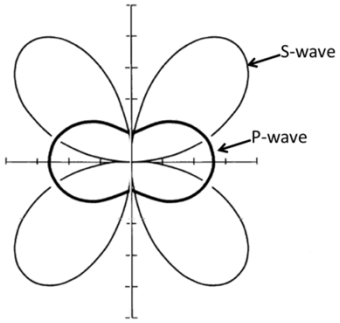
No borehole

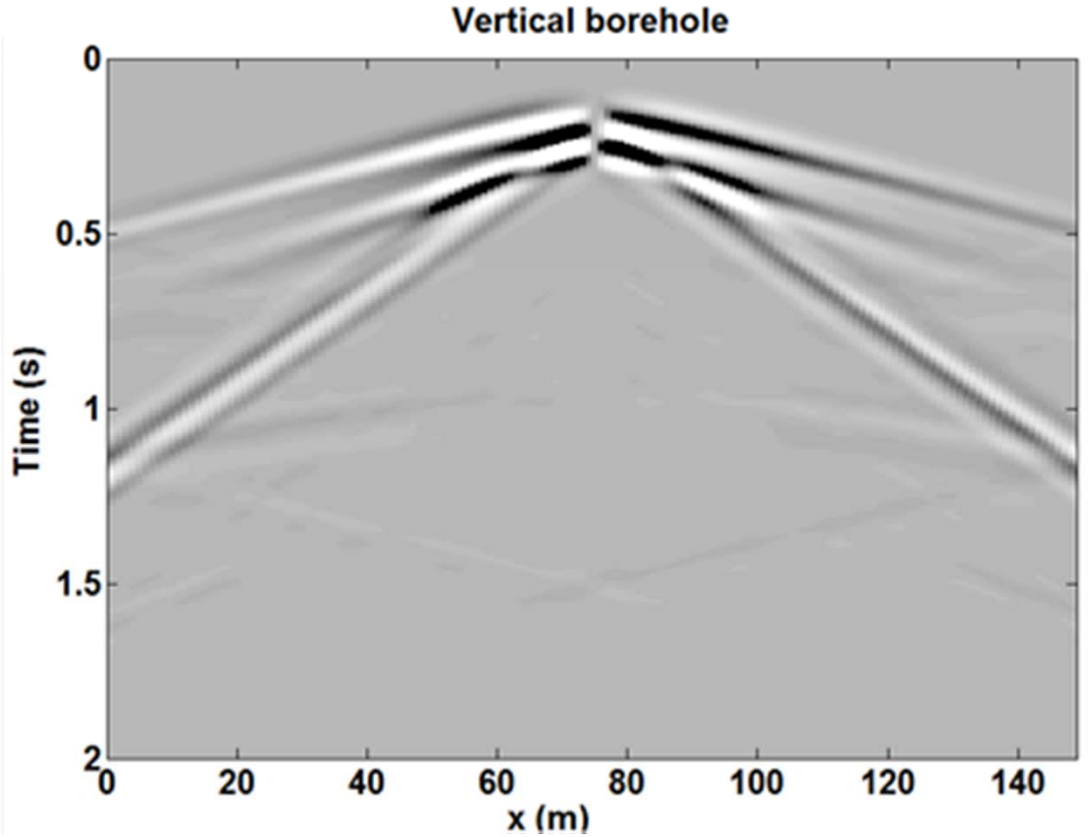


Model 2: Vertical borehole

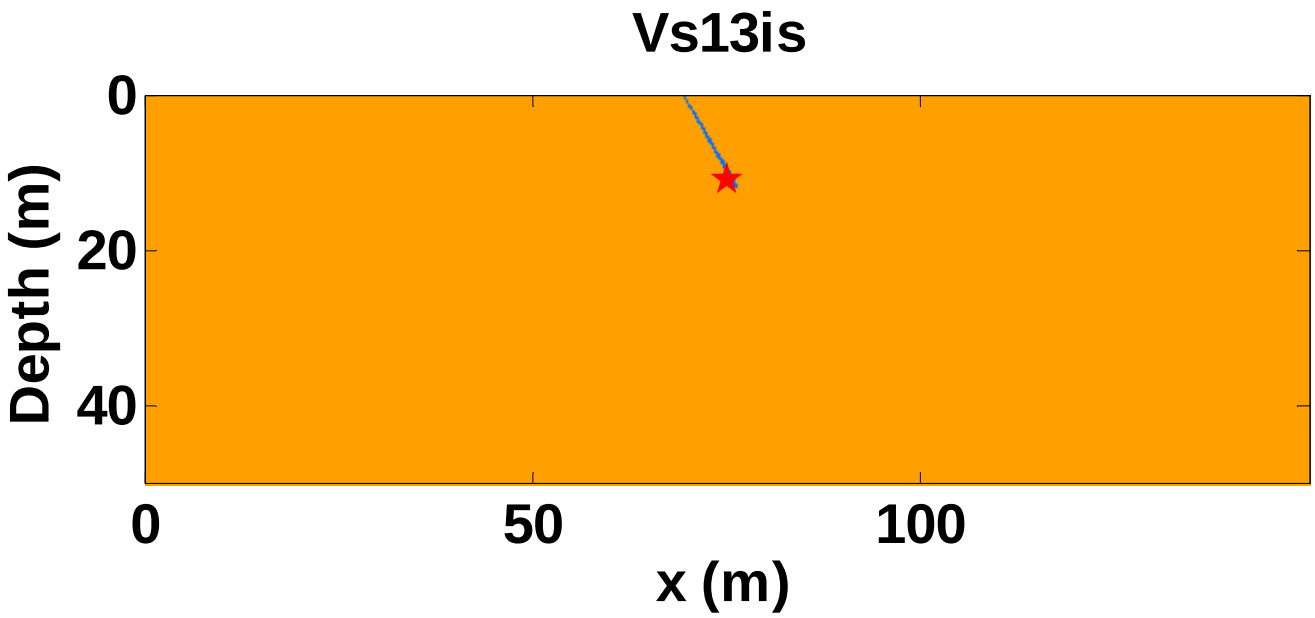


Vertical

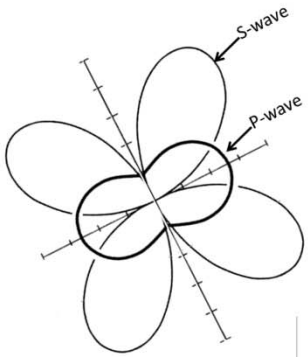

S-wave
P-wave

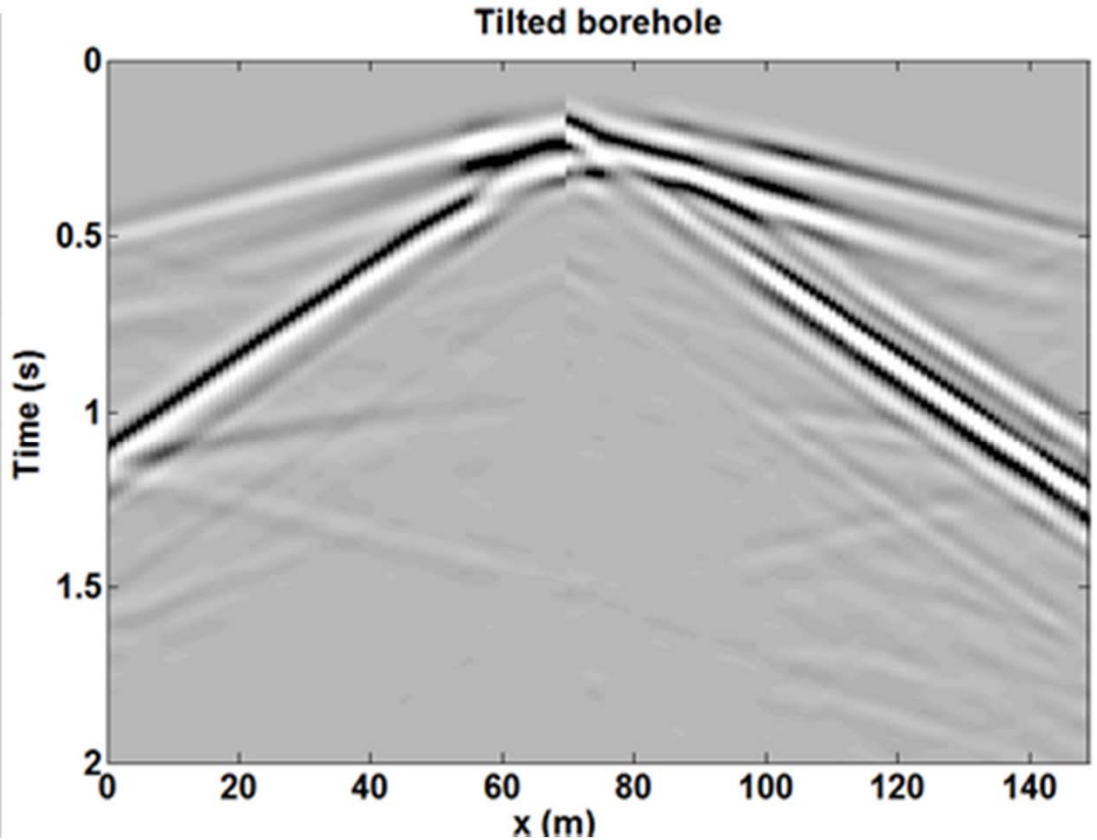

Vertical borehole
Time (s)
0
0.5
1
1.5
2
0
20
40
60
80
100
120
140
x (m)

Tilted borehole



Tilted

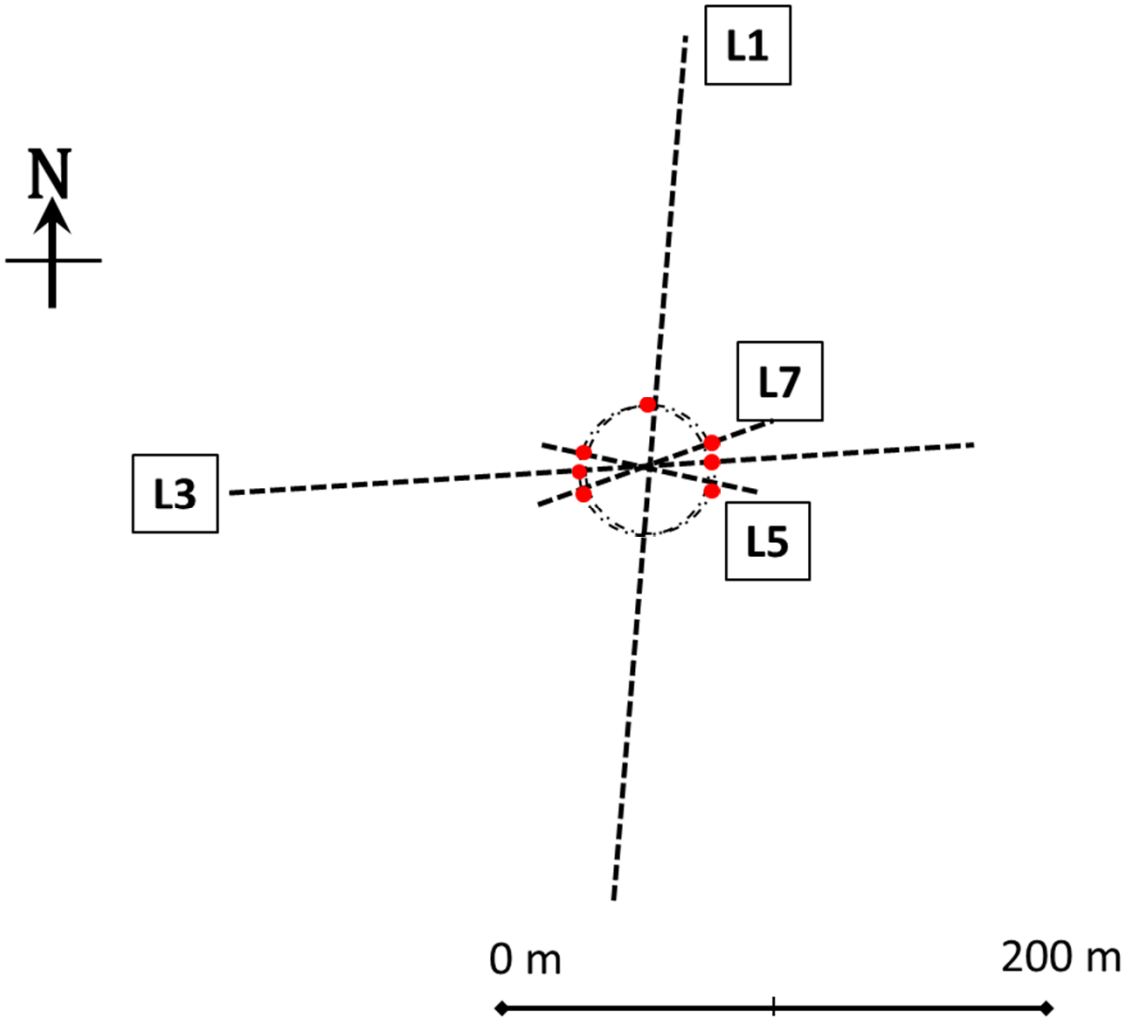

S-wave
P-wave


Tilted borehole
Time (s)
0
0.5
1
1.5
2
0
20
40
60
80
100
120
140
x (m)

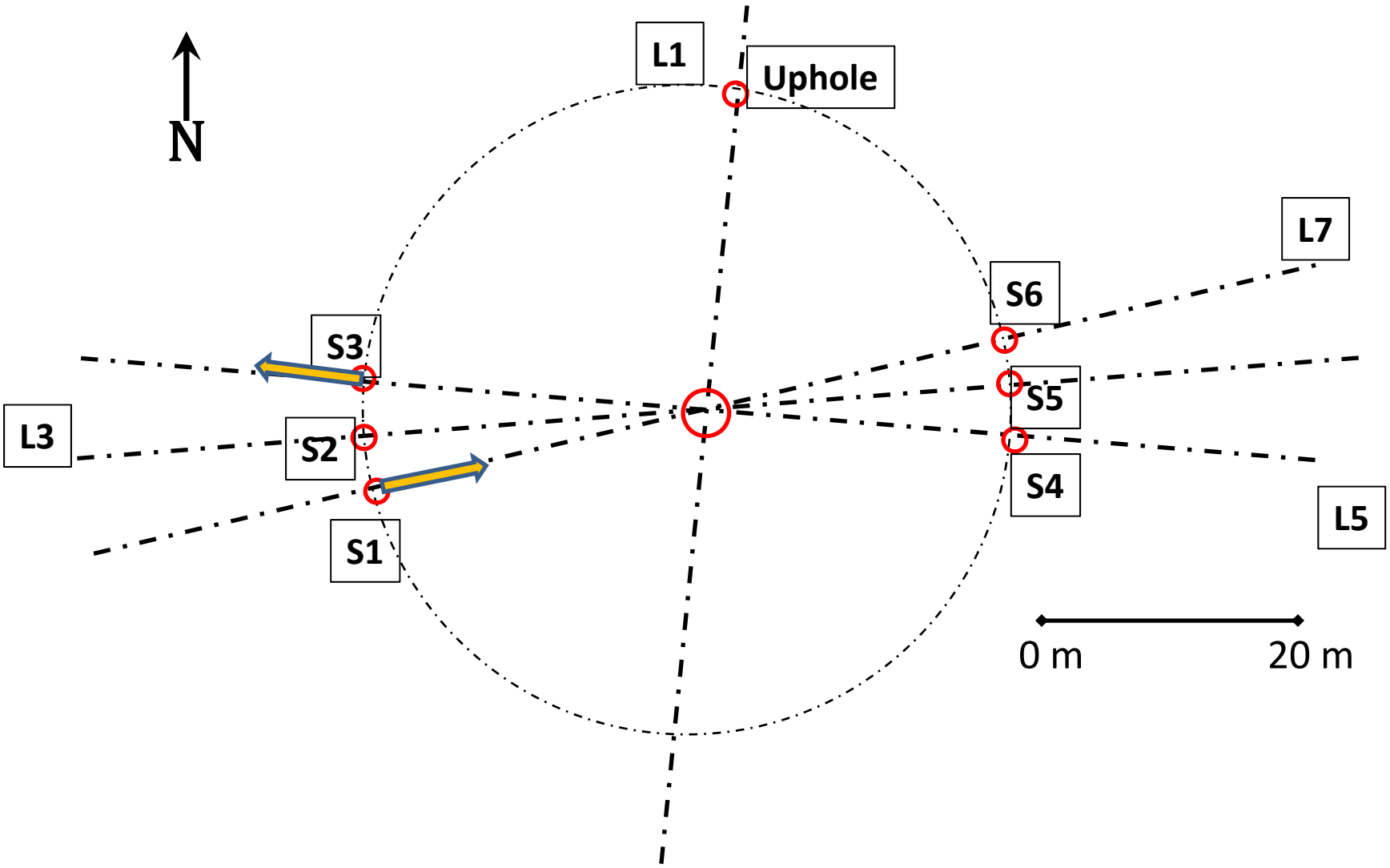
The Priddis Experiment

- Two kinds of explosive source test were carried out:
  - single shots vertical and tilted, and
  - An uphole survey.
- A number of receiver arrays were available.

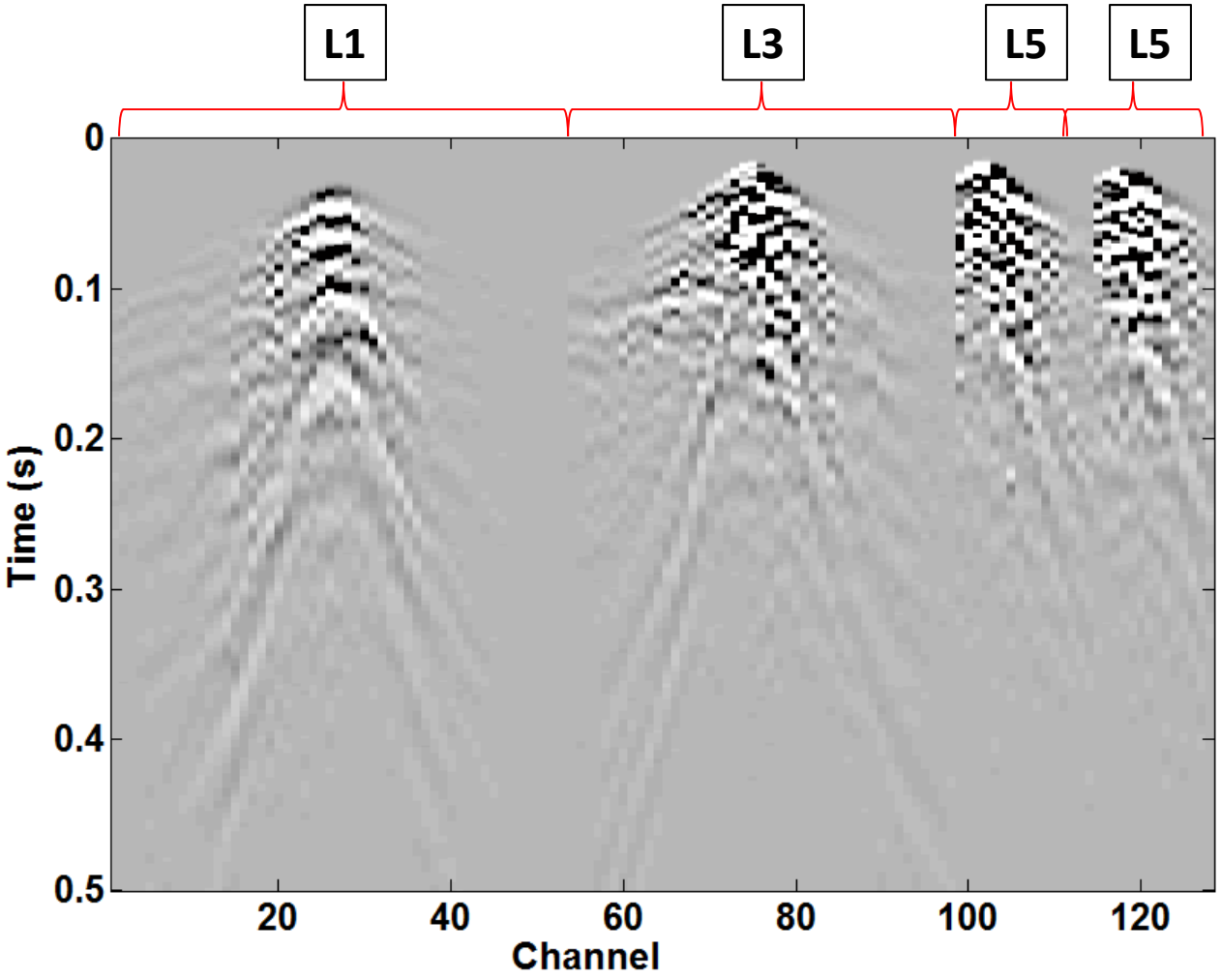
Priddis Experiment: surface layout



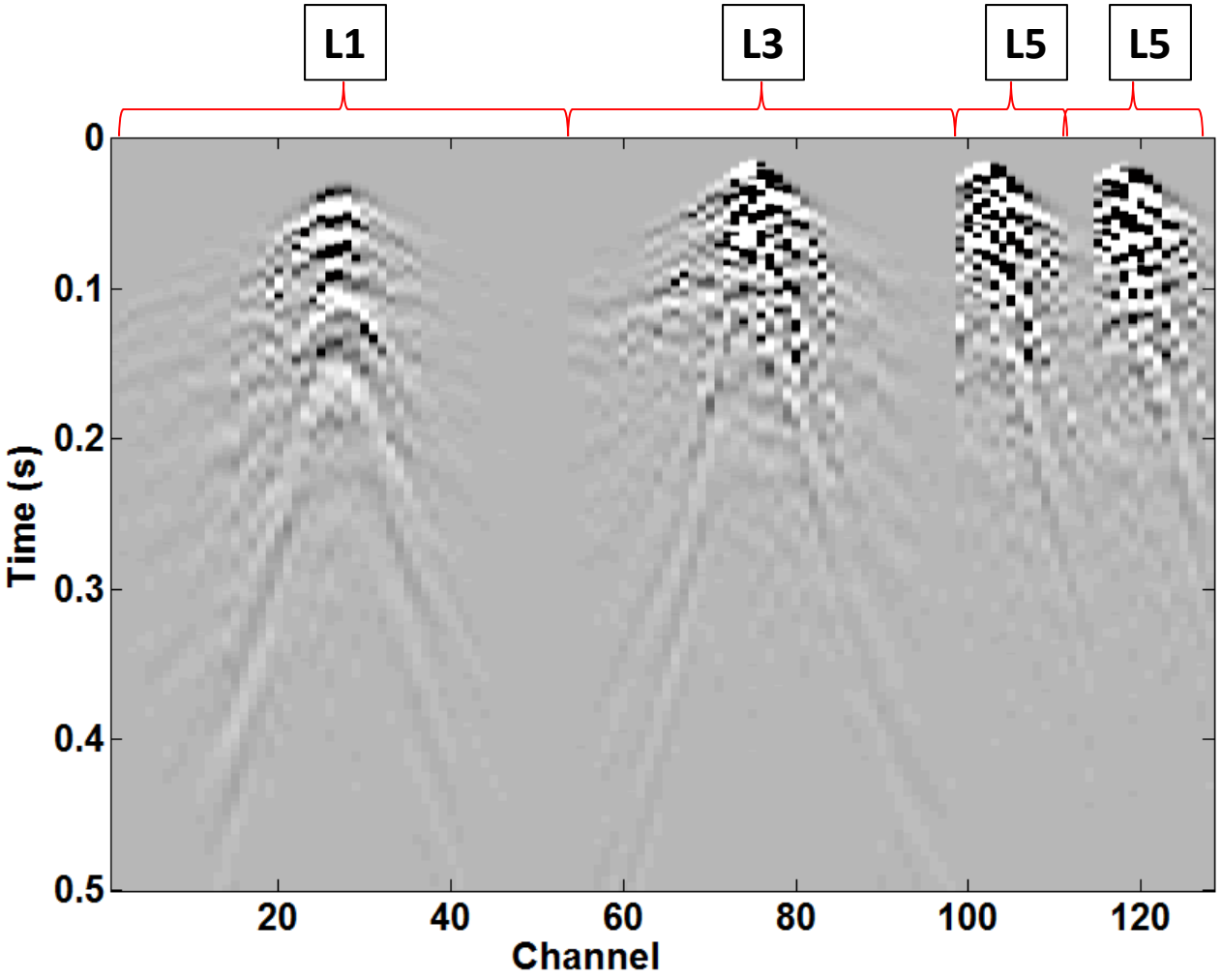
Explosive sources



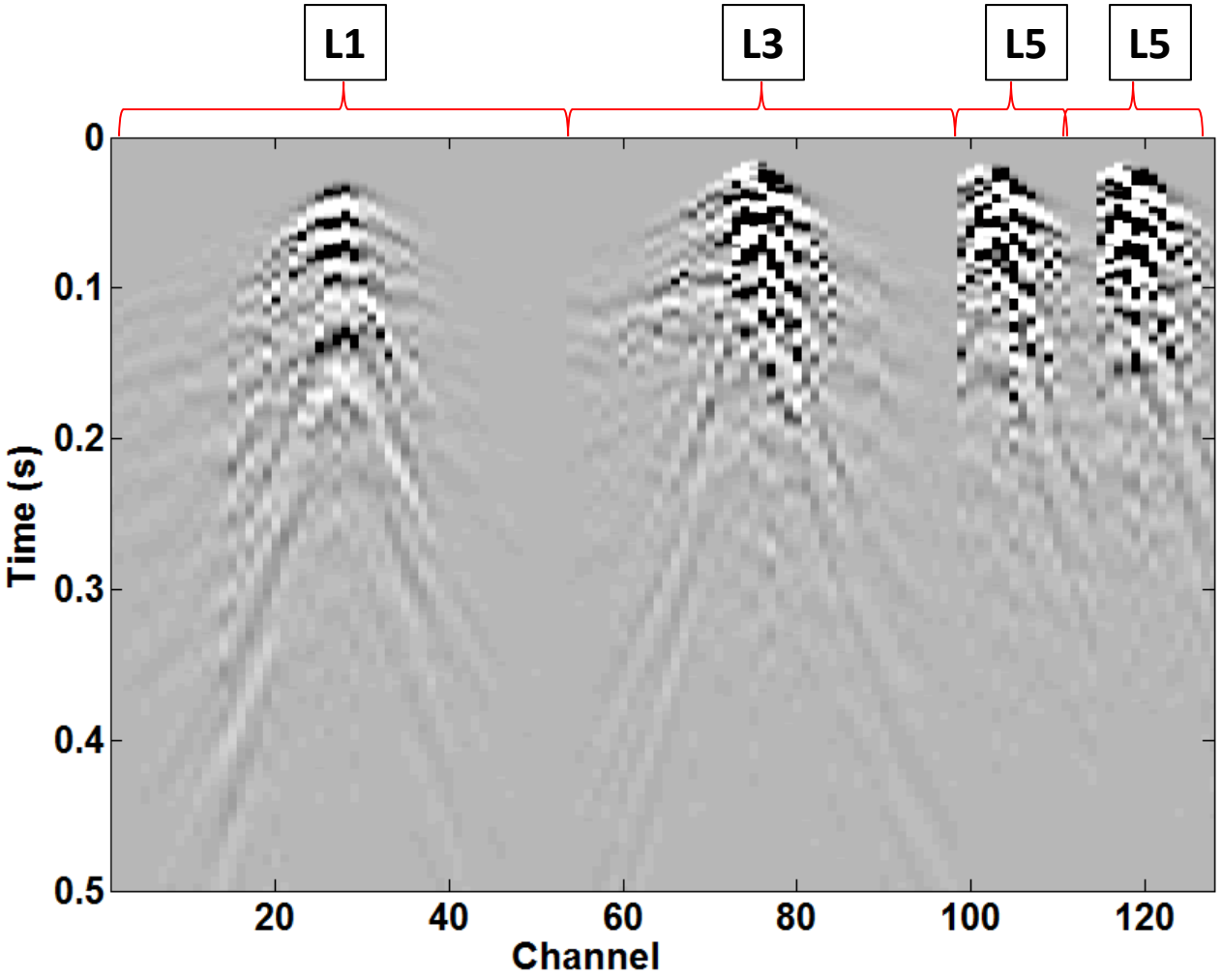
S1: Tilted East



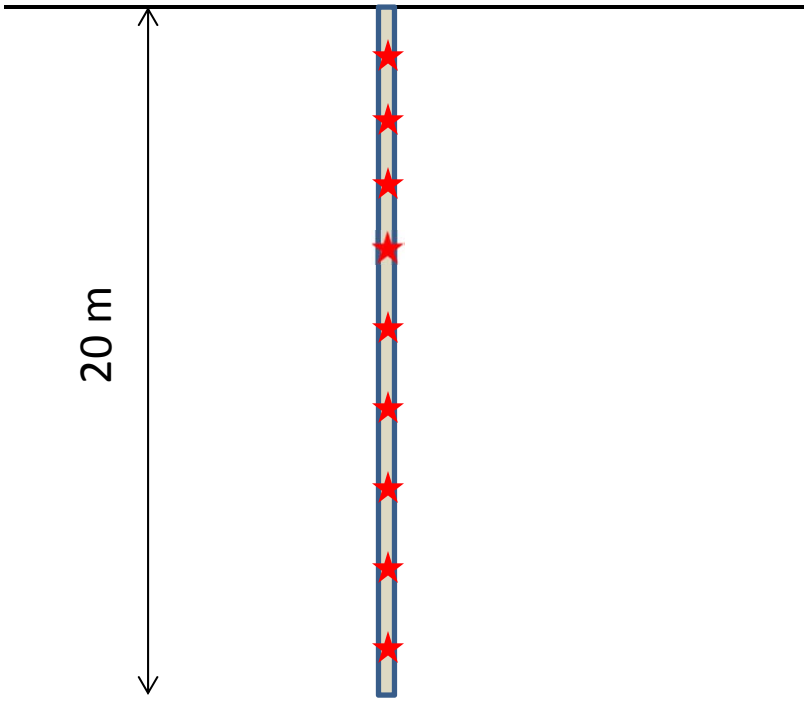
S2: Vertical



S3: Tilted West

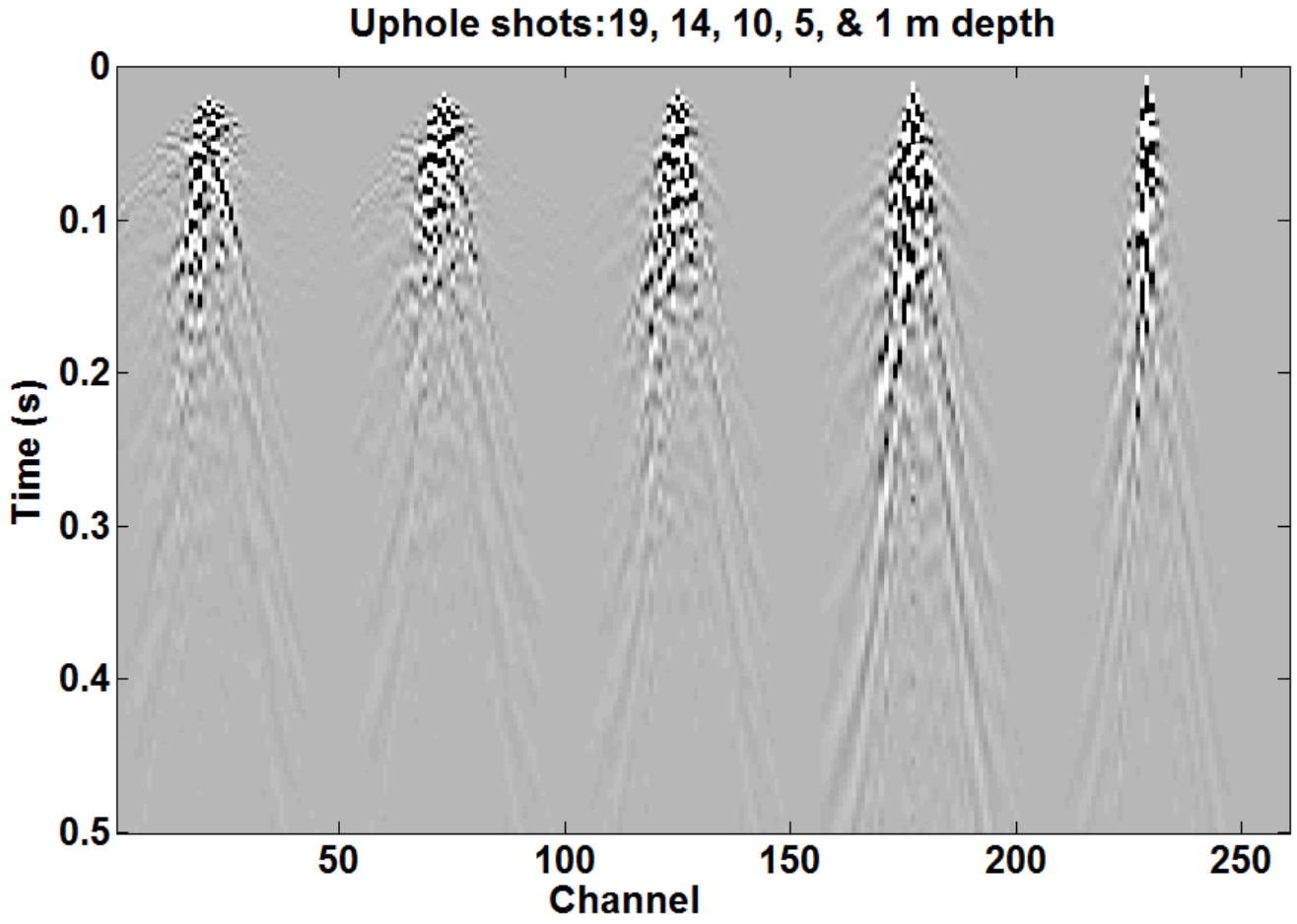


The uphole experiment

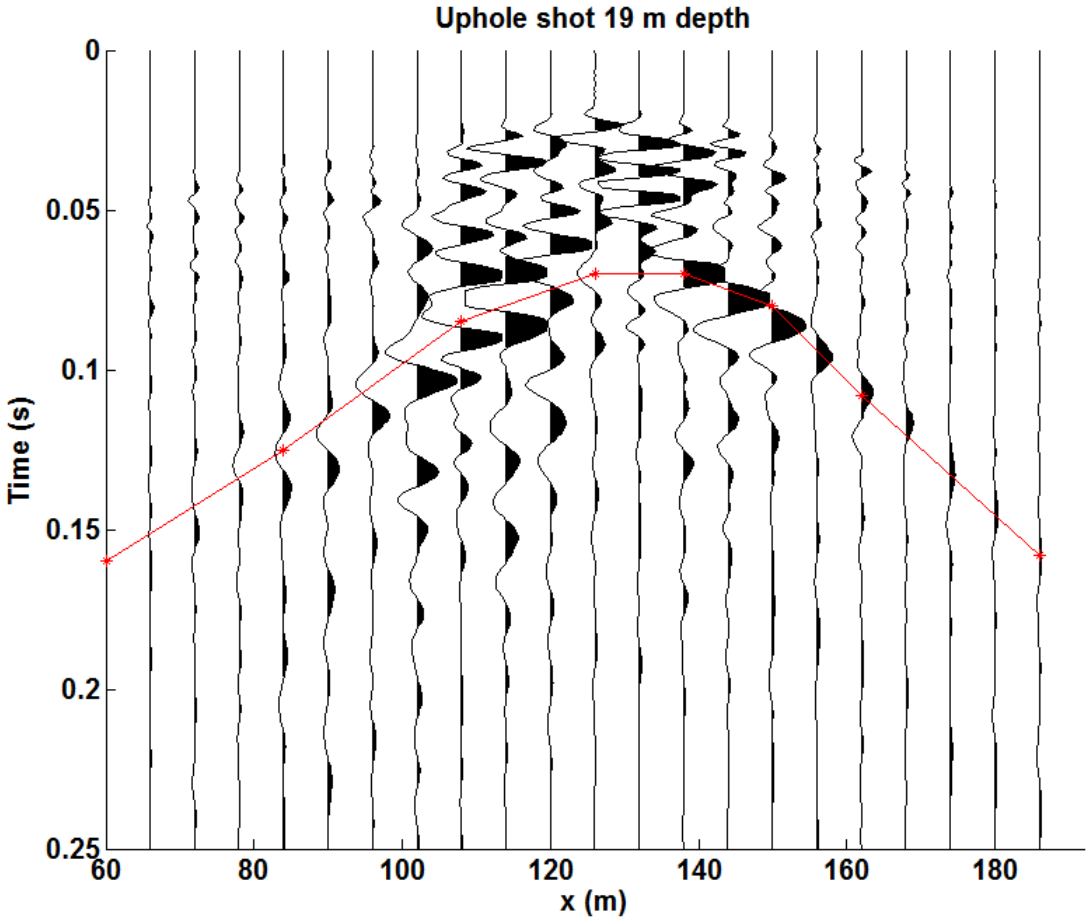


Uphole Horizontal component:

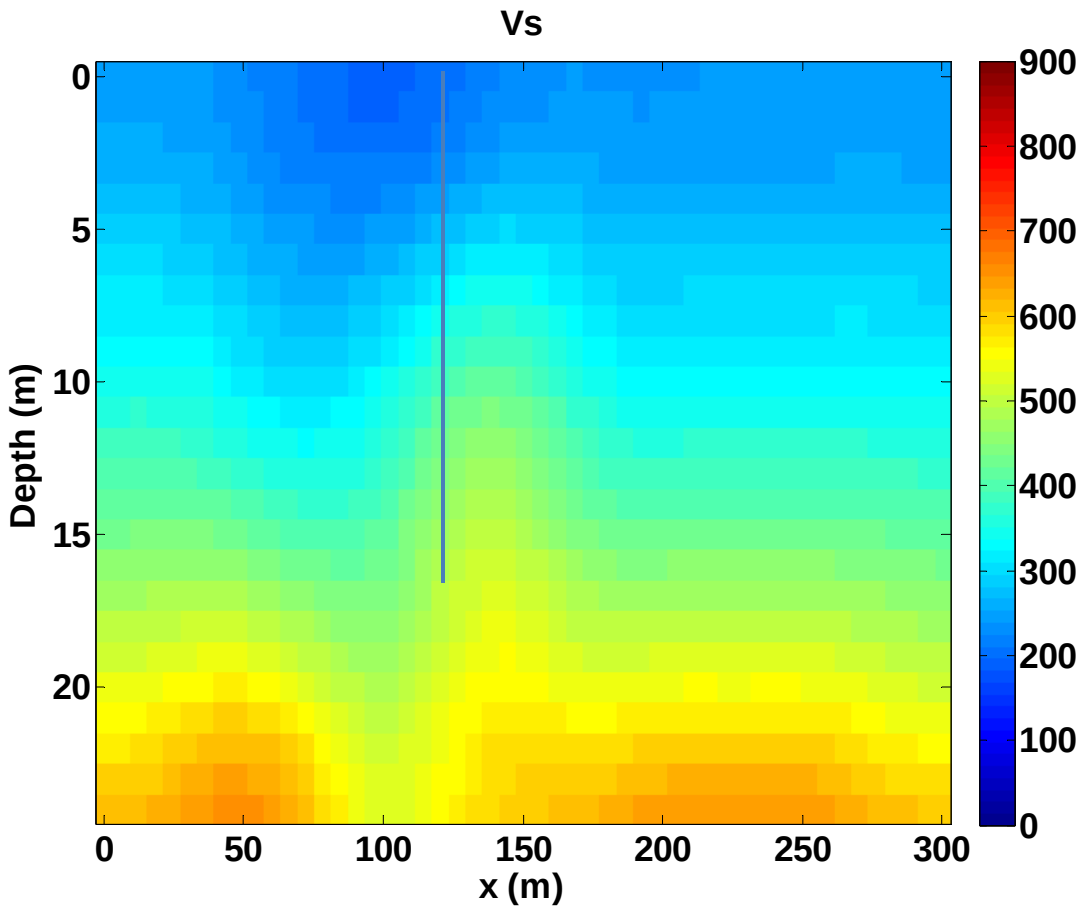
Shots 19, 14, 10, 5 and 1 m



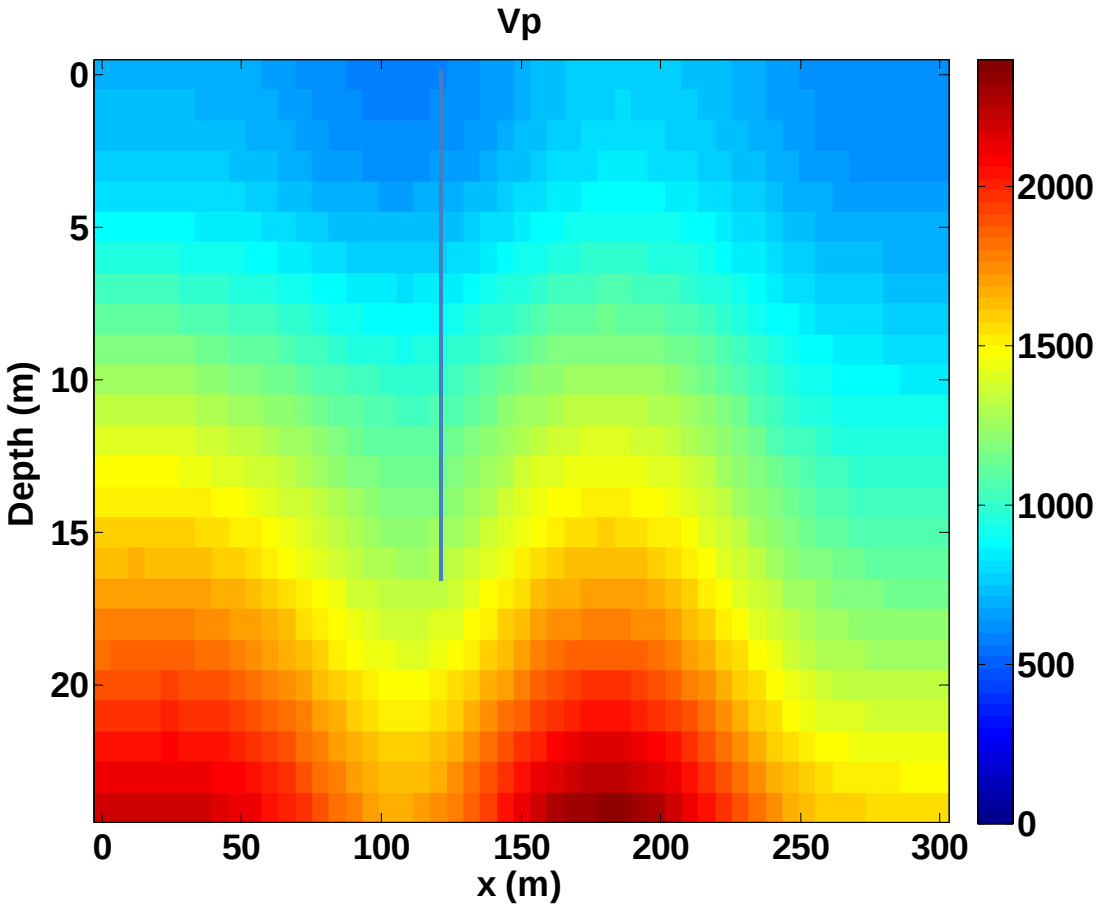
Uphole 19 m -Picking



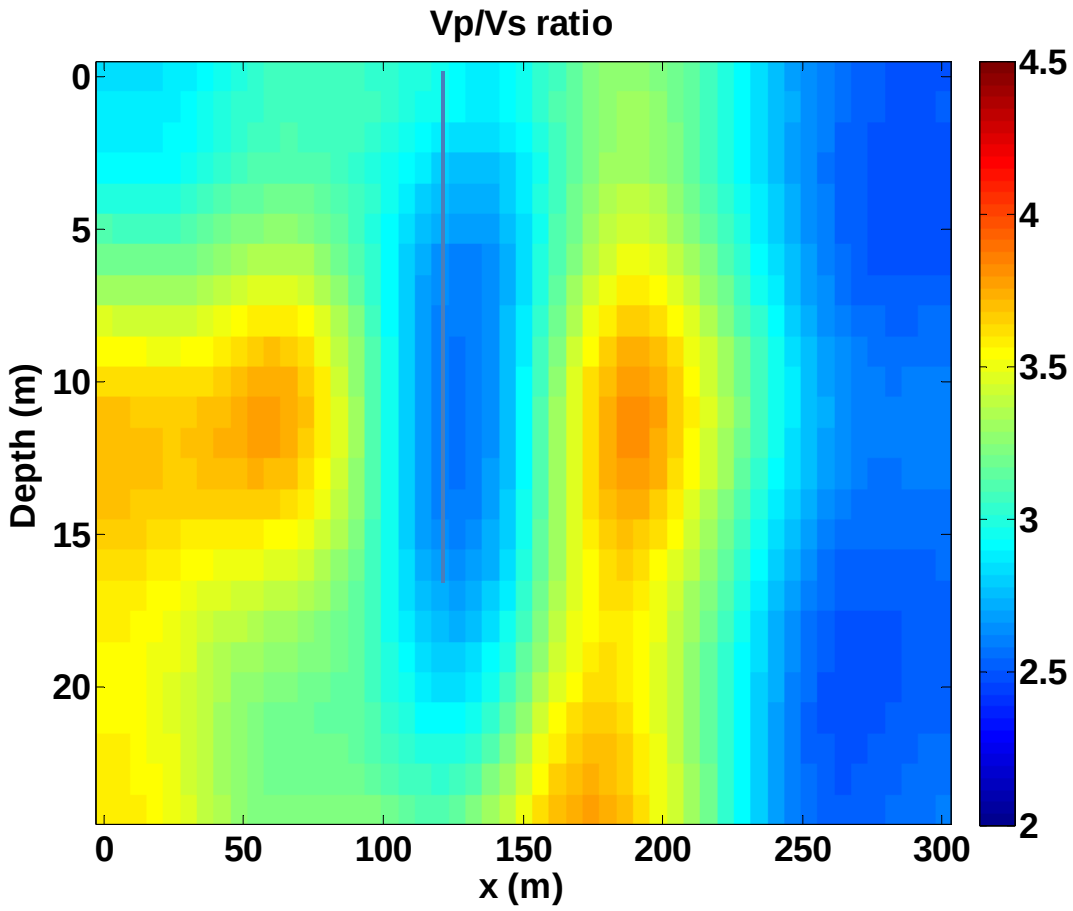
S-wave velocity from tomography



P-wave velocity from tomography



Vp/Vs ratio


Vp/Vs ratio
Depth (m)
0
5
10
15
20
0
50
100
150
200
250
300
x (m)
4.5
4
3.5
3
2.5
2

Conclusions

- S-waves generated by explosive sources can provide useful information for elastic waves exploration.
- Can provide a better model of the very shallow surface, important for statics correction.
- Issues related to wave-modes separation.
- Priddis experiment have data for extended analysis and further potential for testing.

Acknowledgements

- The CREWES sponsors.
- The CREWES staff.
- Carbon Management Canada

CREWES

NSERC CRSNG

Carbon Management Canada

UNIVERSITY OF CALGARY

CREWES

Thanks