Applications for rotational seismic data

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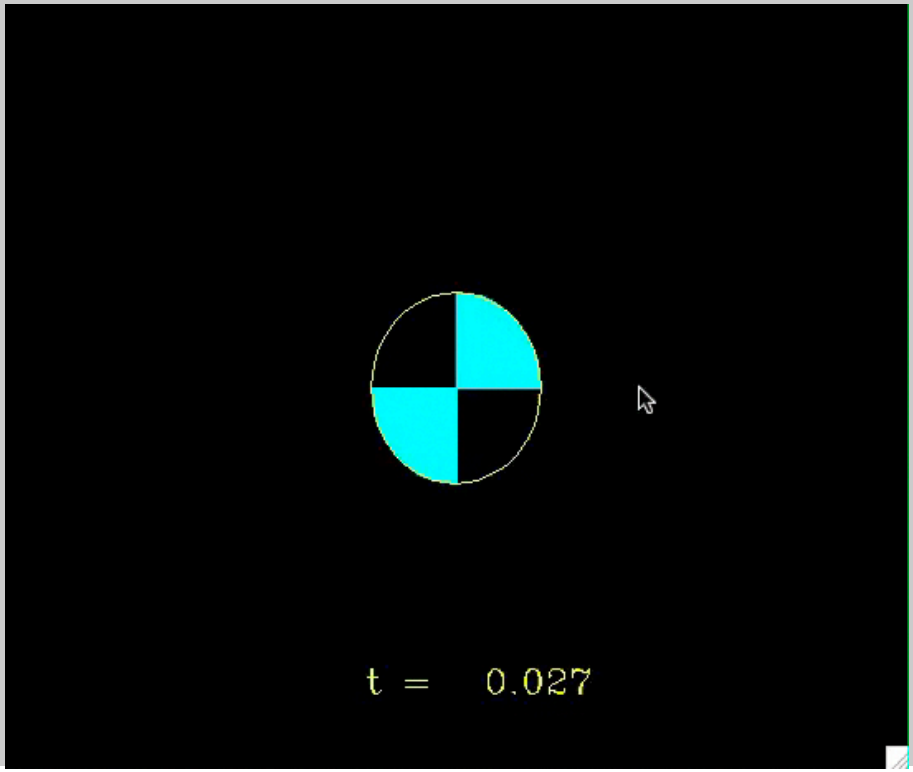
SEP-149, pp251-272

SEP meeting, 2013



Agenda

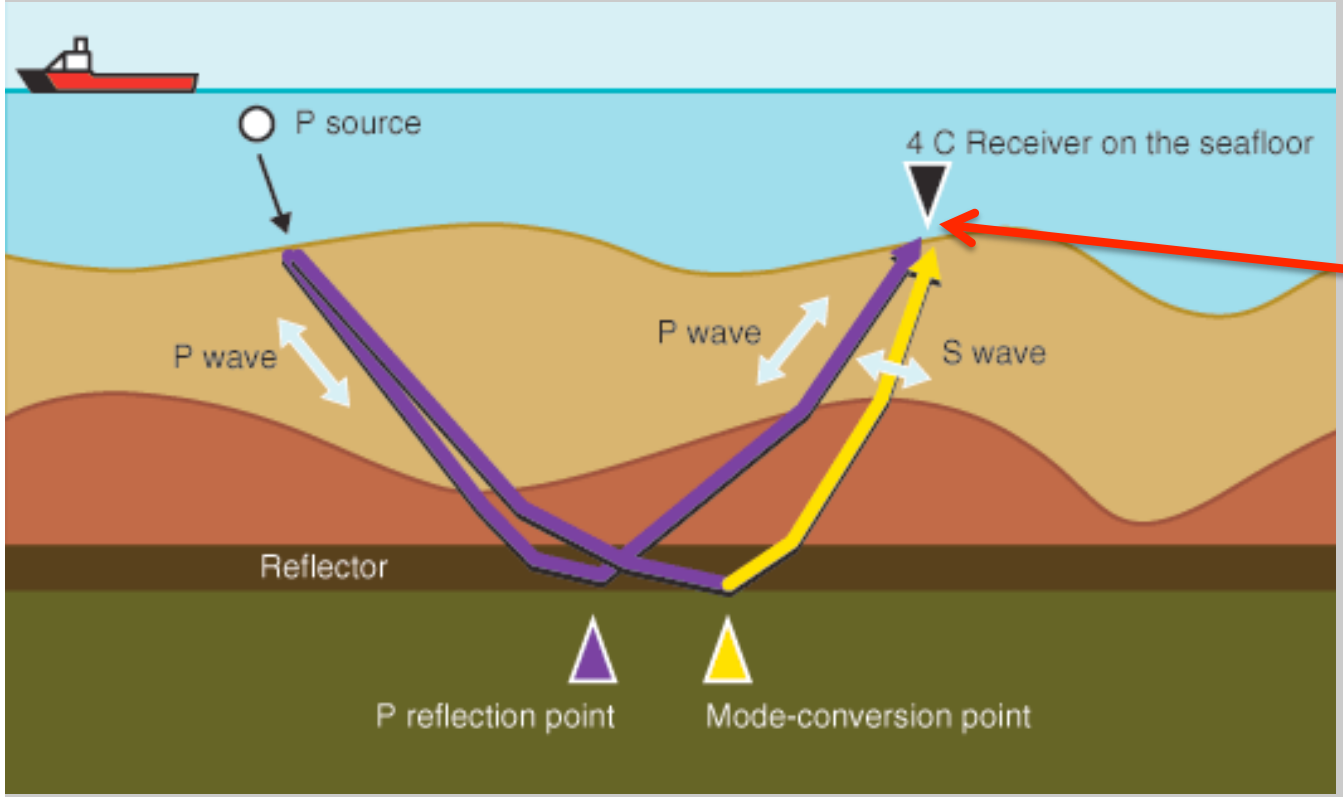
- Rotation data is great.
- You should all go and acquire rotation data.
- You should then give us the data.

Outline

- Vz noise in OBS acquisition
- Rotation sensors
- Synthetic modeling of OBS seven-component data
- Signatures of different wave types in seven-component data

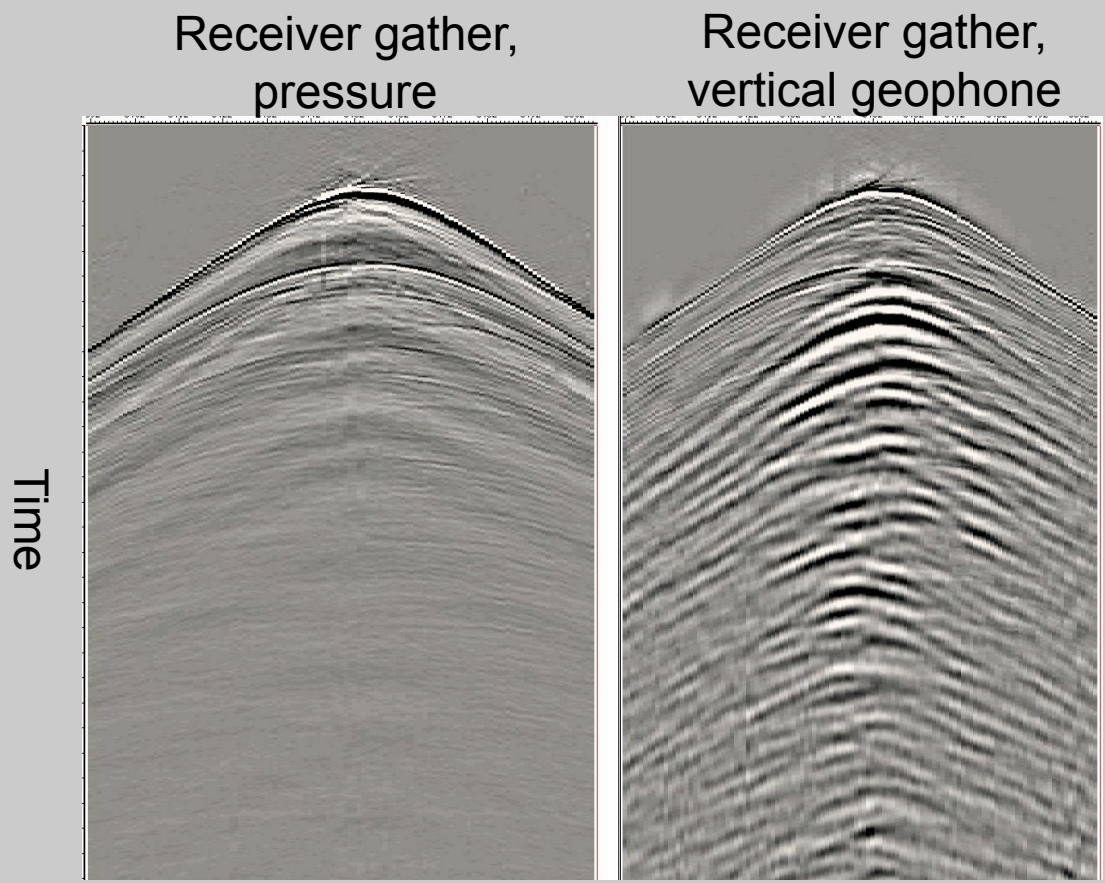
Cool animations coming soon…..

OBS acquisition



Receivers are located on an interface

V_z "shear induced" noise



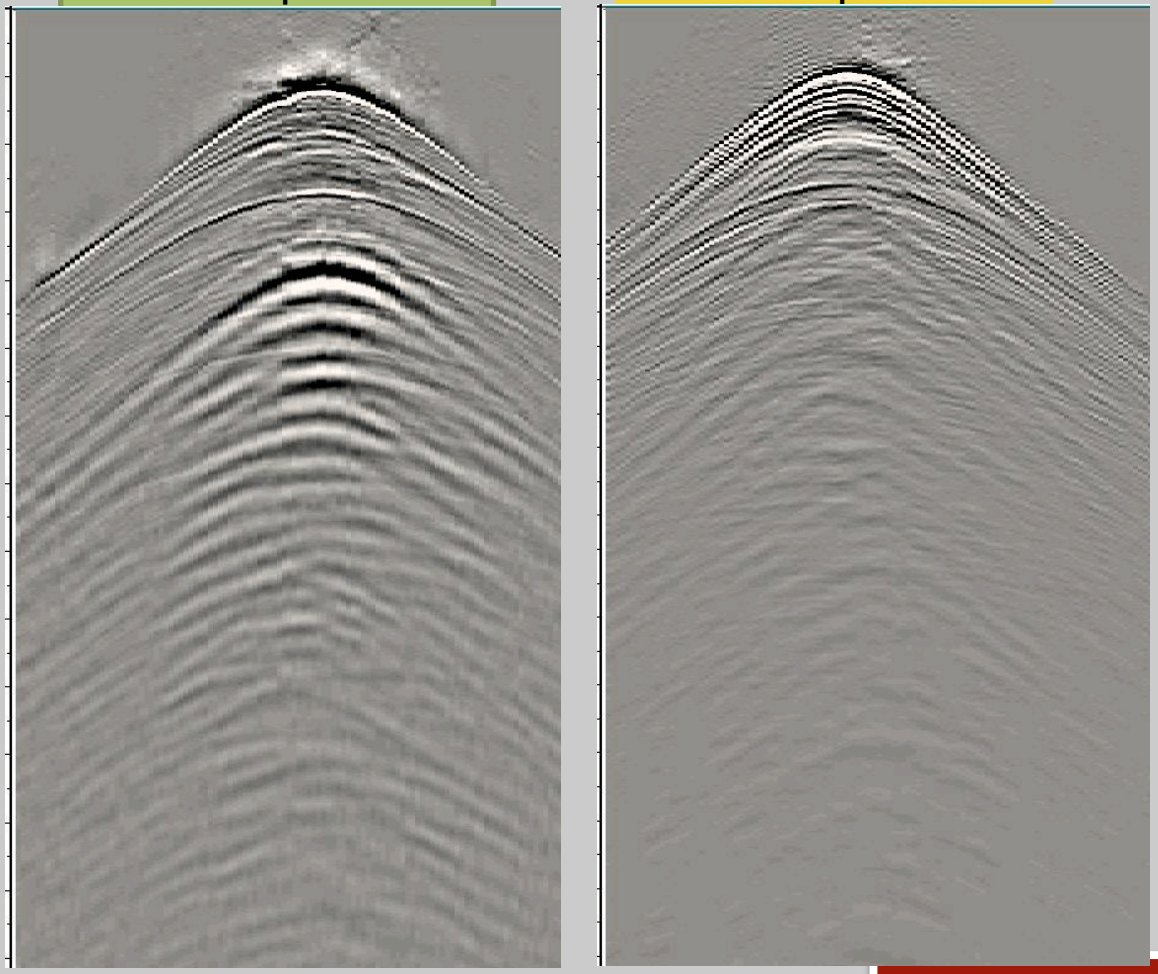
- Energy observed on vertical geophone that is not present on pressure
- Similar appearance to shear waves, although these are generally not present on the vertical component

Courtesy of Apache
Thanks to CGG for data distribution

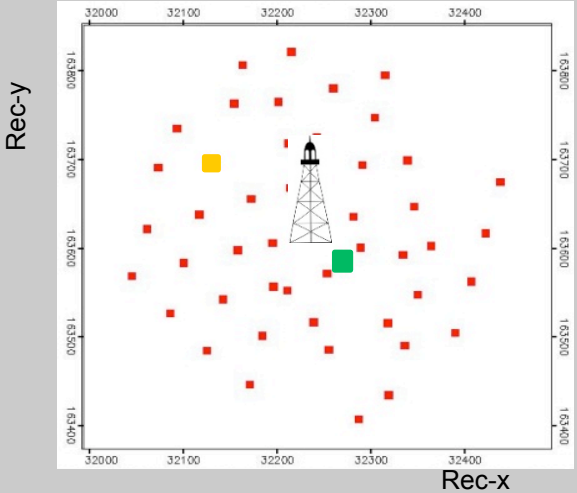
V_z "shear induced" noise

Receiver gather, vertical geophone, close to platform

Receiver gather, vertical geophone, far from platform

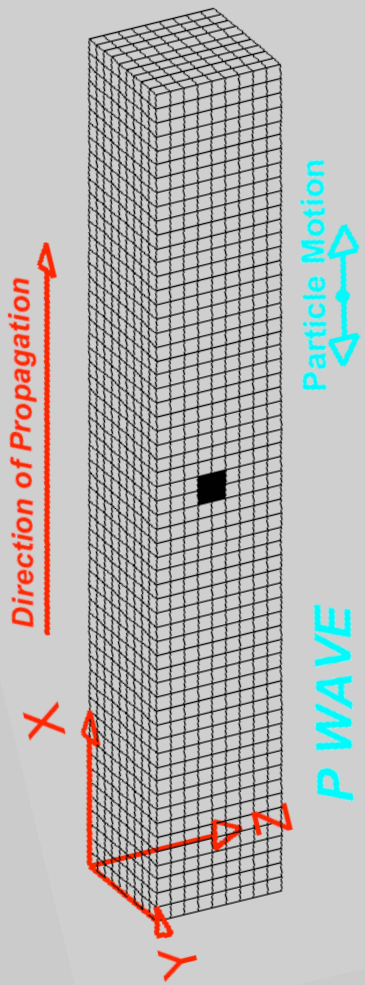


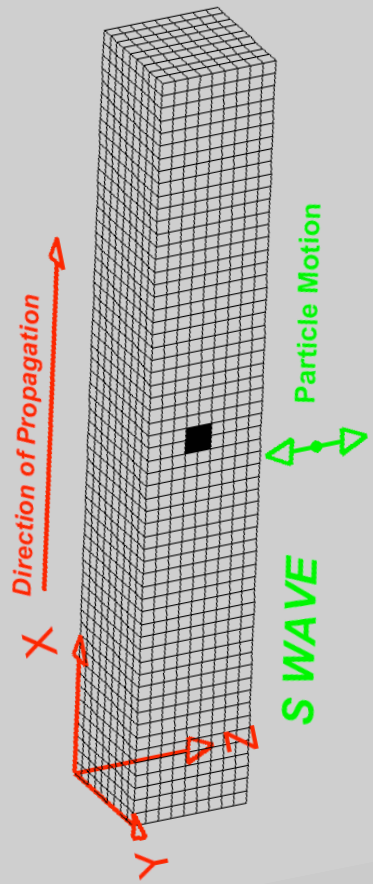
Node Position

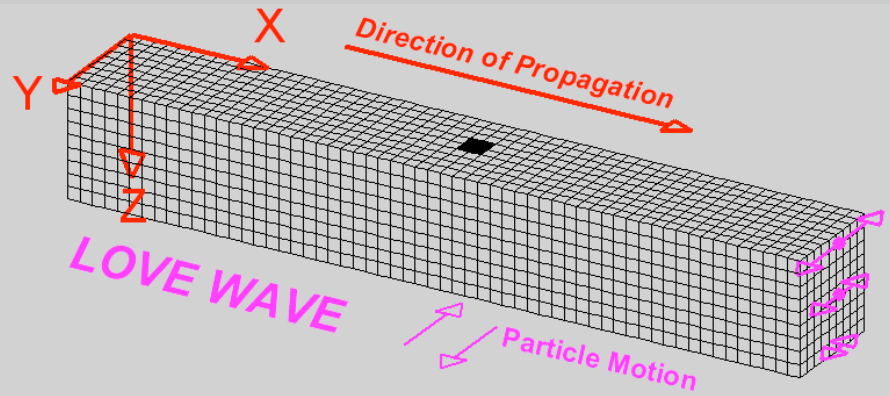


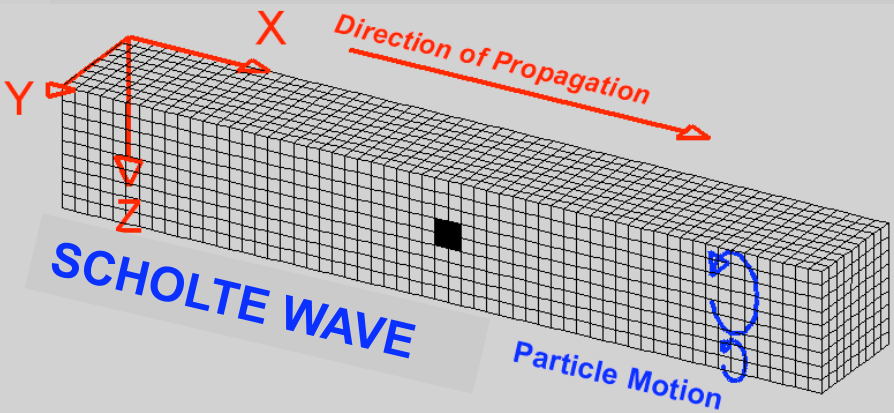
Courtesy of Apache
Thanks to CGG for data distribution

Body waves and surface waves









Michigan Tech. University website (http://www.geo.mtu.edu/Upseis/images)

V_z "shear induced" noise

1. Scattered surface waves
   - Feature of the wavefield
   - Can be modeled with elastic modeling

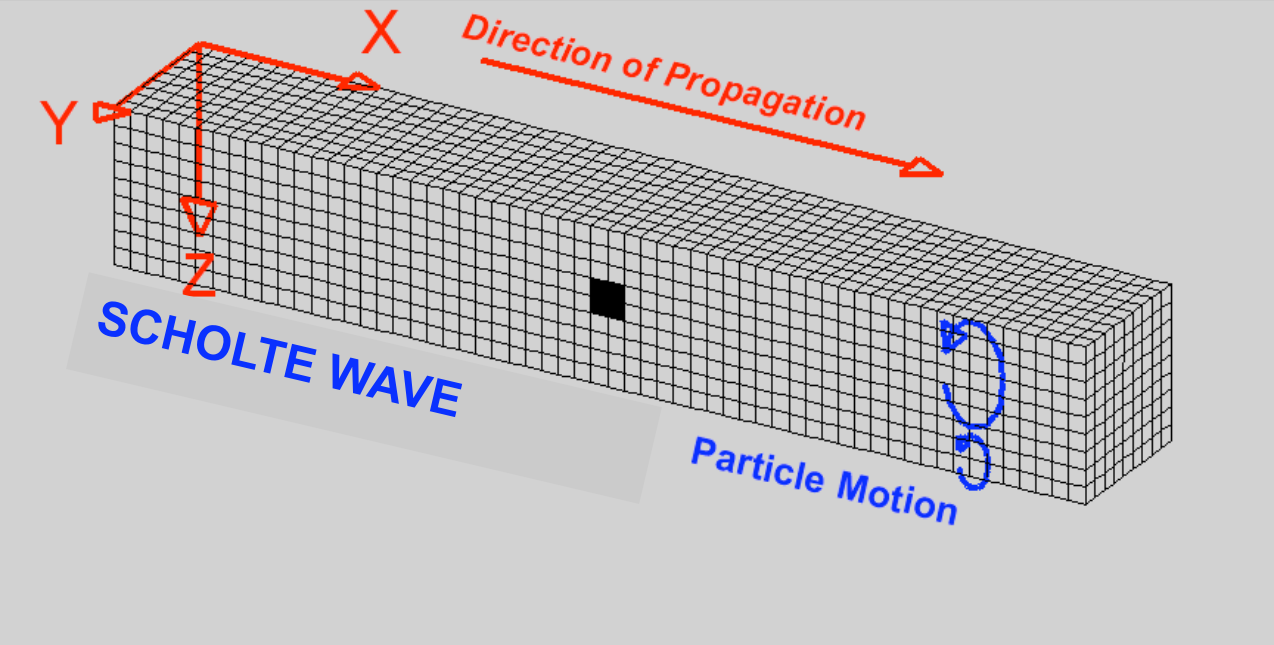
2. Vector infidelity: shear waves induce wobbling and bouncing of the node body.
   - Not a feature of the wavefield
   - Independent of external scattering
   - Cannot be modeled with elastic modeling

Separate phenomena, which can have the same effect on the data
Both occur mainly in soft, muddy water bottoms

(Thanks to Josef Paffenholz, Fairfieldnodal)

V_z "shear induced" noise

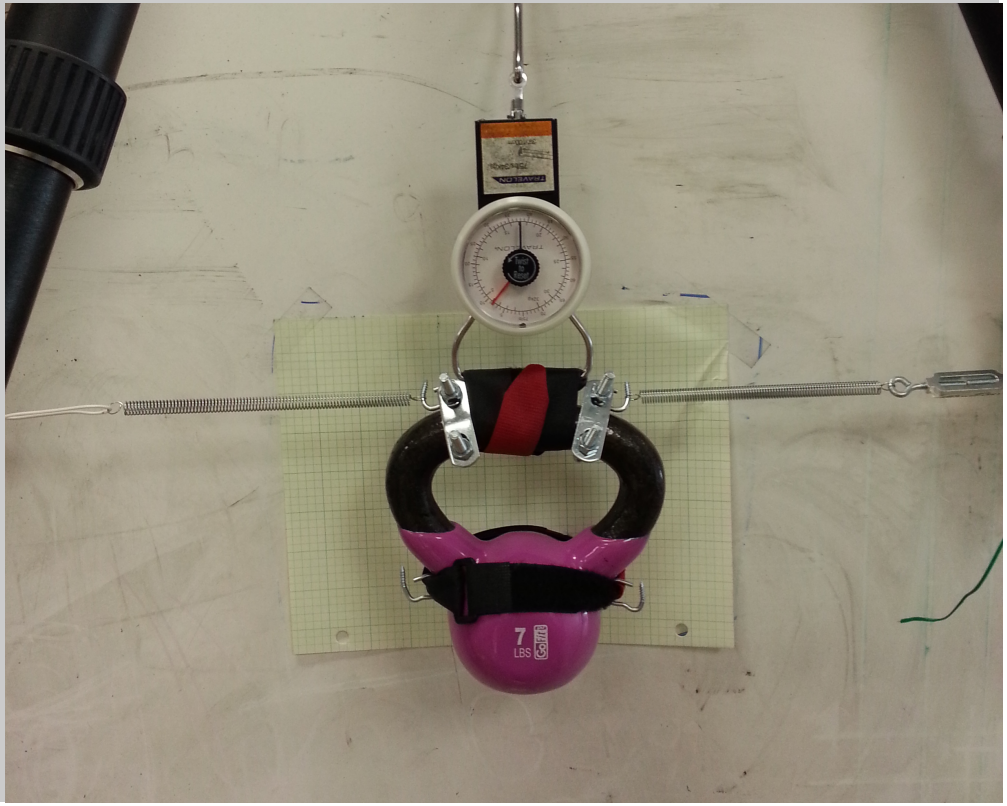
1. <u>Scattered surface waves</u>
   - Feature of the wavefield
   - Can be modeled with elastic modeling



Interface wave, mostly rotational motion

V_z "shear induced" noise

2. <u>Vector infidelity:</u> shear waves induce wobbling and bouncing of the node body
   - Not a feature of the wavefield
   - Independent of external scattering
   - Cannot be modeled with elastic modeling



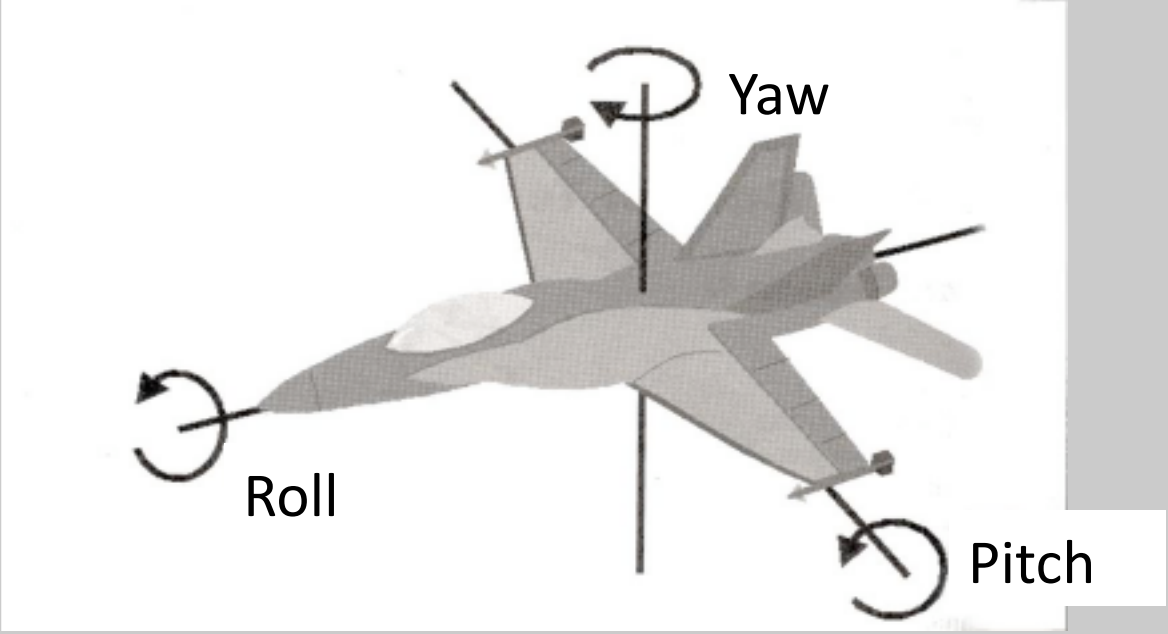
Rotation sensors

Geophones record motion along the axes ("3C"):

v_x, v_y , v_z

Rotation sensors record motion around the axes ("3θ"):

θ_x, θ_y, θ_z



Seven-component data

- Hydrophone
- 3C geophones
- 3C rotation sensors

1. Need motivation to put 3 extra sensors on a node (battery, data volume, channels, unit price, etc.)

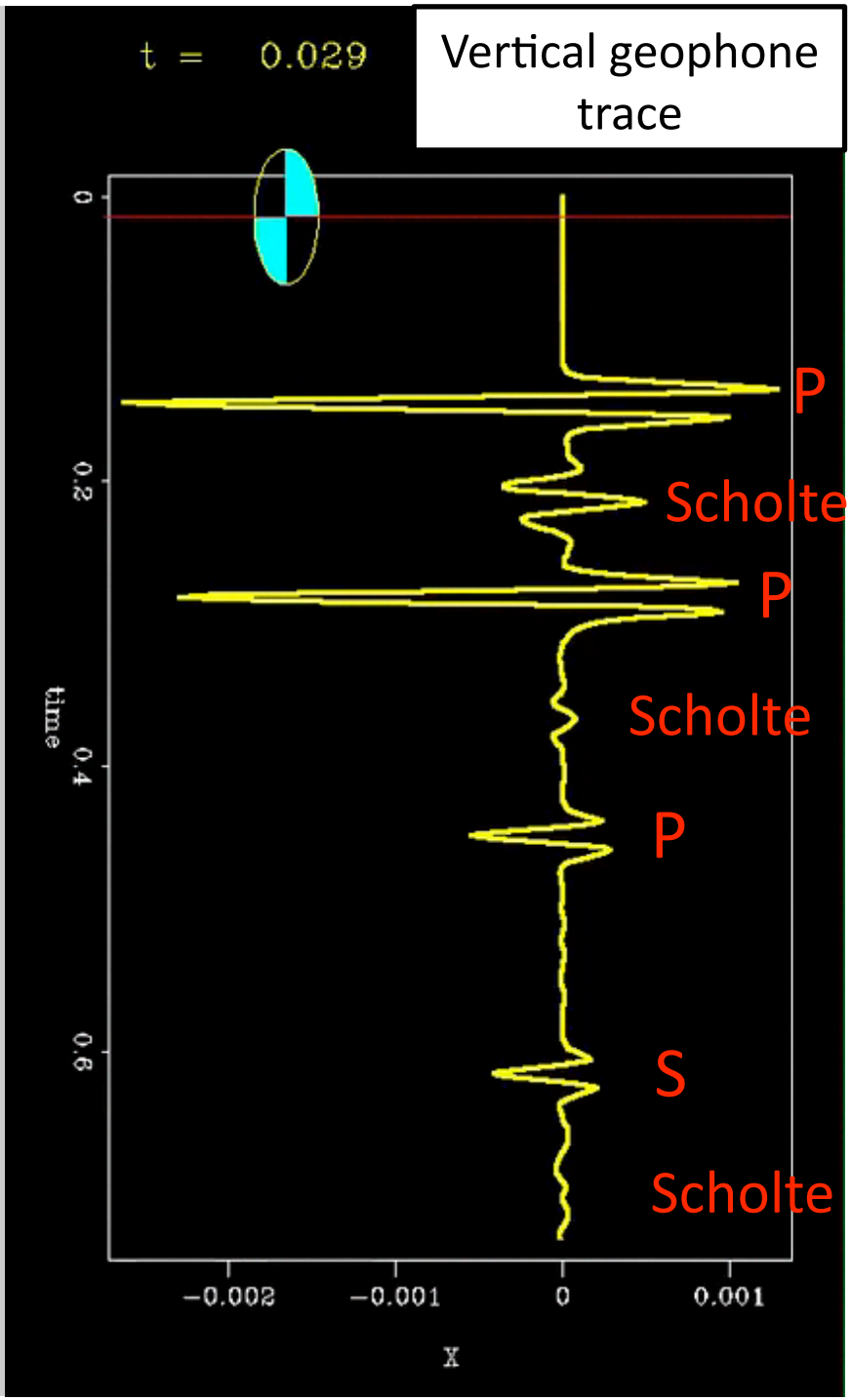
2. Need a good way to display 7C data

Thanks to Robert Brune for suggesting the beach-ball symbol.

Pressure → Size

Particle displacement → Motion of circle center

Rotation → Circle rotation



Applications for rotation data

- Muyzert et al., 74th EAGE annual conference: Interpolation of the vertical component for de-aliasing.
- Brune et al., 82nd SEG annual conference: Improve spatial sampling, shear wave selectivity, AVO, determination of propagation direction at a point array.
- Geokinetics, Schlumberger, Sandia Nat. Labs, Applied Technology Associates, Eentec, MetTech

Applications for rotation data

1. Identifying and attenuating V_z noise

2. Converted-wave AVO, application to gas hydrates rock physics modeling (Secondary project, appears in report)

Elastic modeling

u_x, u_y, u_z Meters

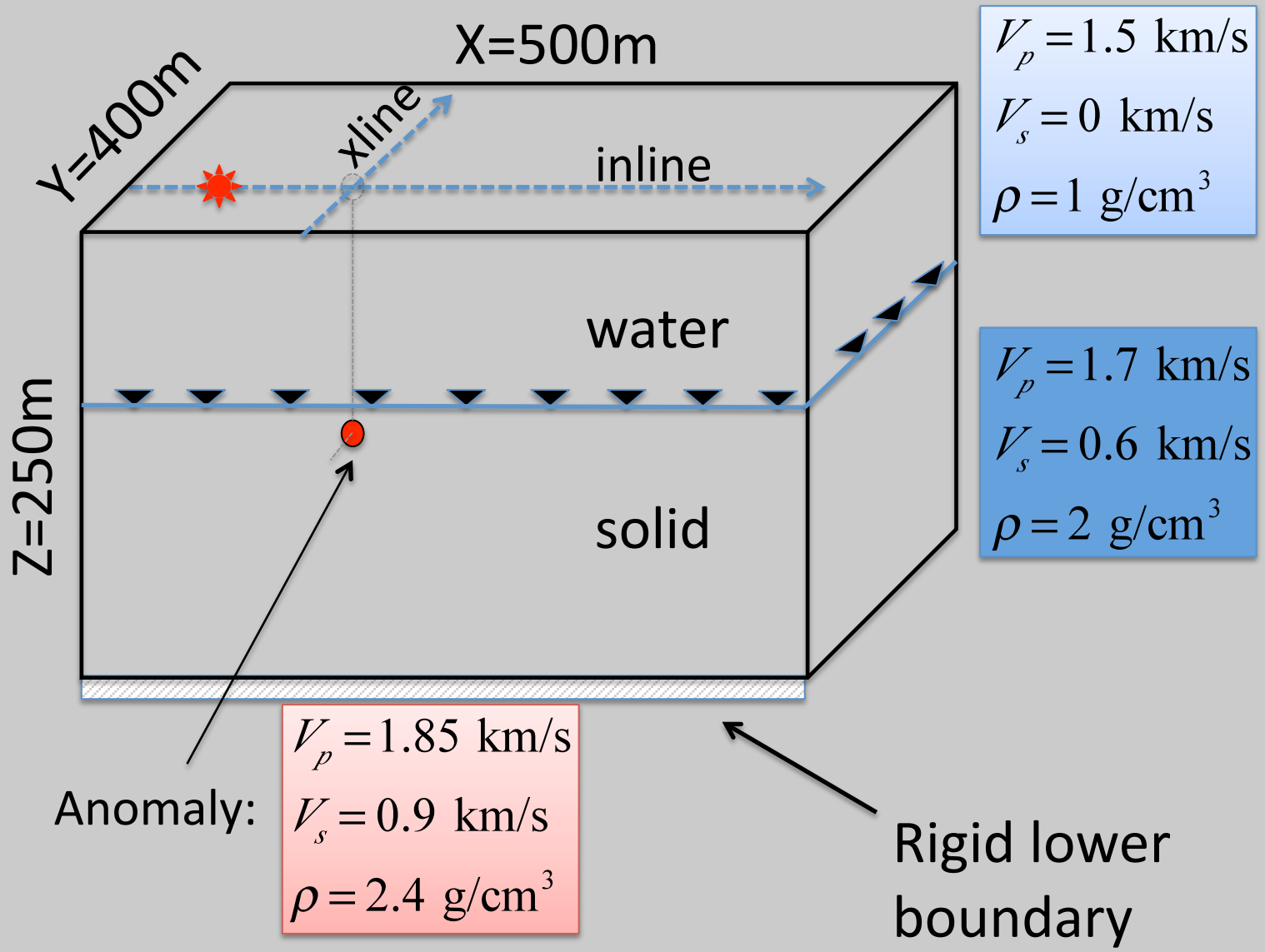
v_x, v_y, v_z Meters/sec (geophone)

$$P = (\lambda + \mu)\frac{\partial u_i}{\partial x_i} \approx \nabla \cdot \vec{u}$$ Bars (hydrophone)

$$\theta_k = \left(\frac{\partial u_i}{\partial x_j} - \frac{\partial u_j}{\partial x_i}\right)_{k \neq i,j} = \nabla \times \vec{u}$$ Radians

$$\vec{R} = \frac{d\vec{\theta}}{dt}$$ Radians/sec (rotation sensor)

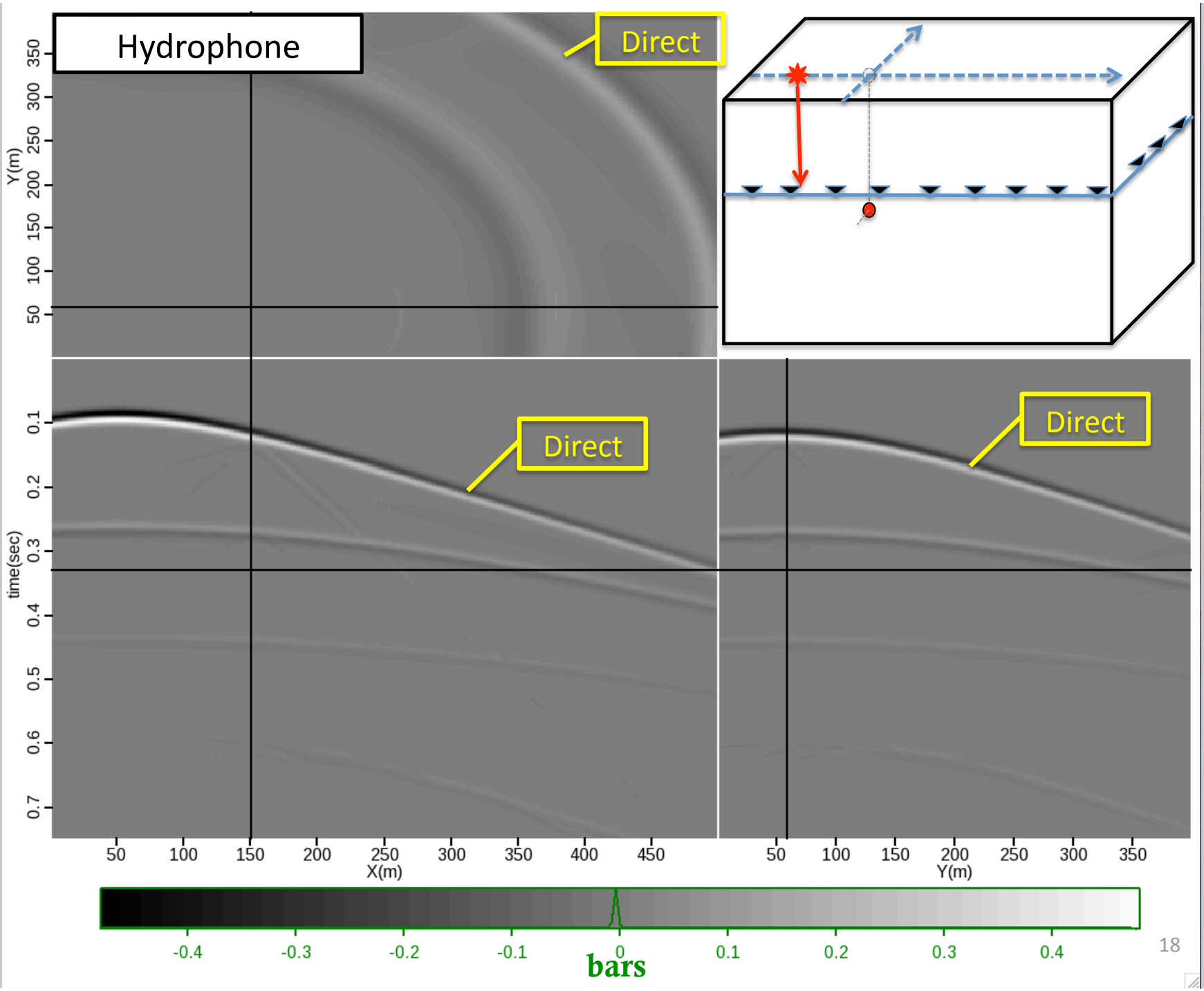
Modeling setup

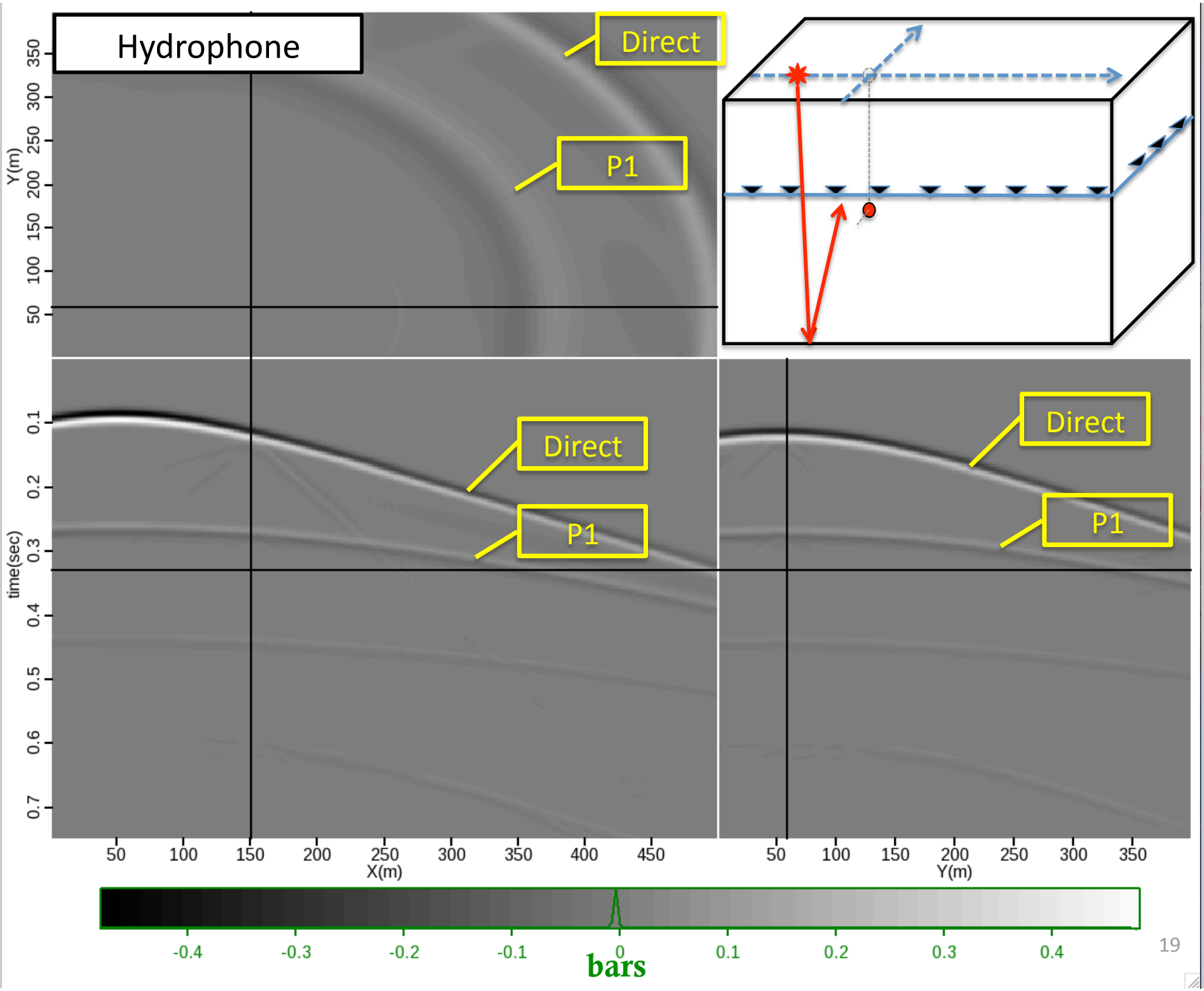


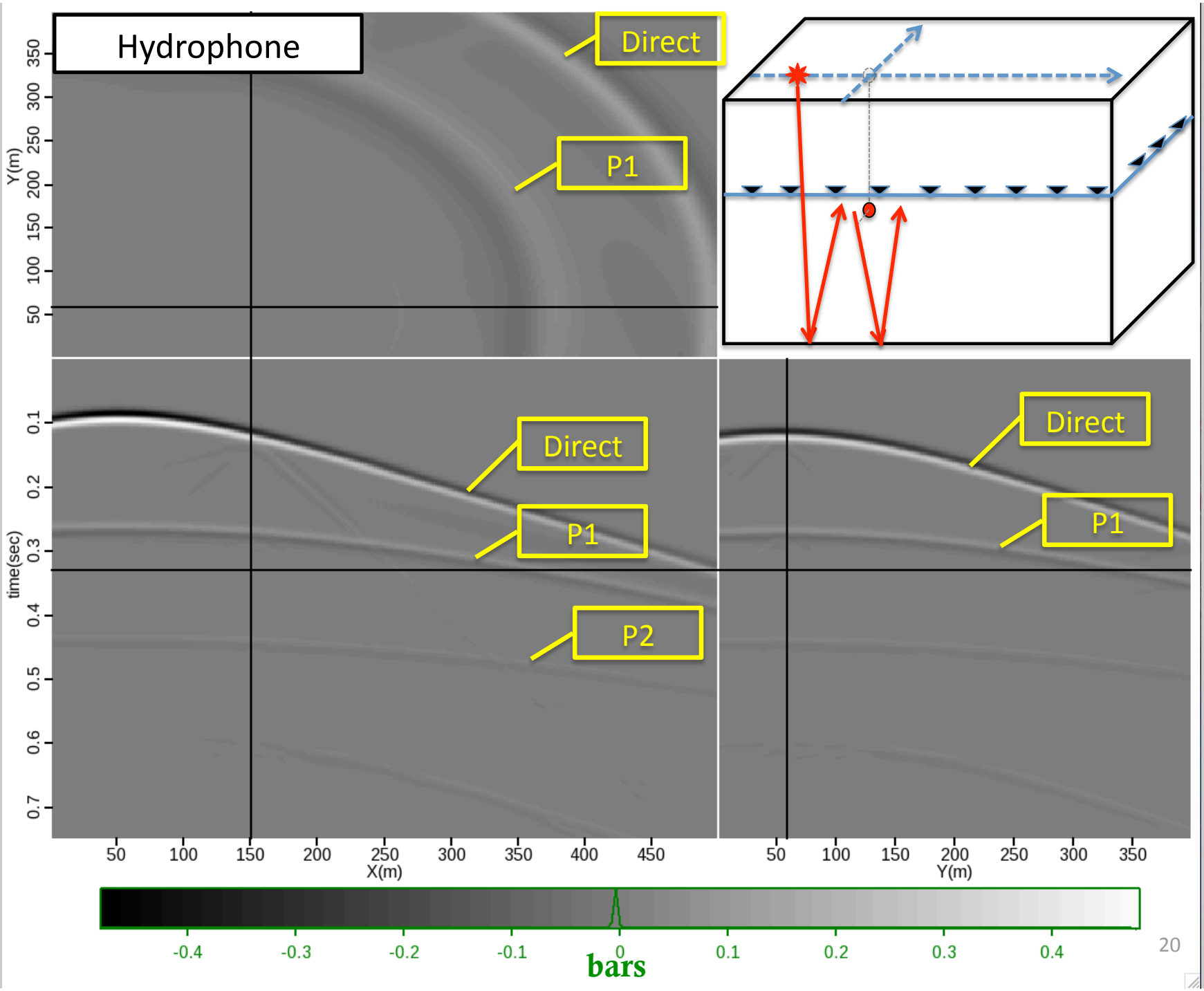
$V_p = 1.5$ km/s
$V_s = 0$ km/s
$\rho = 1$ g/cm^3

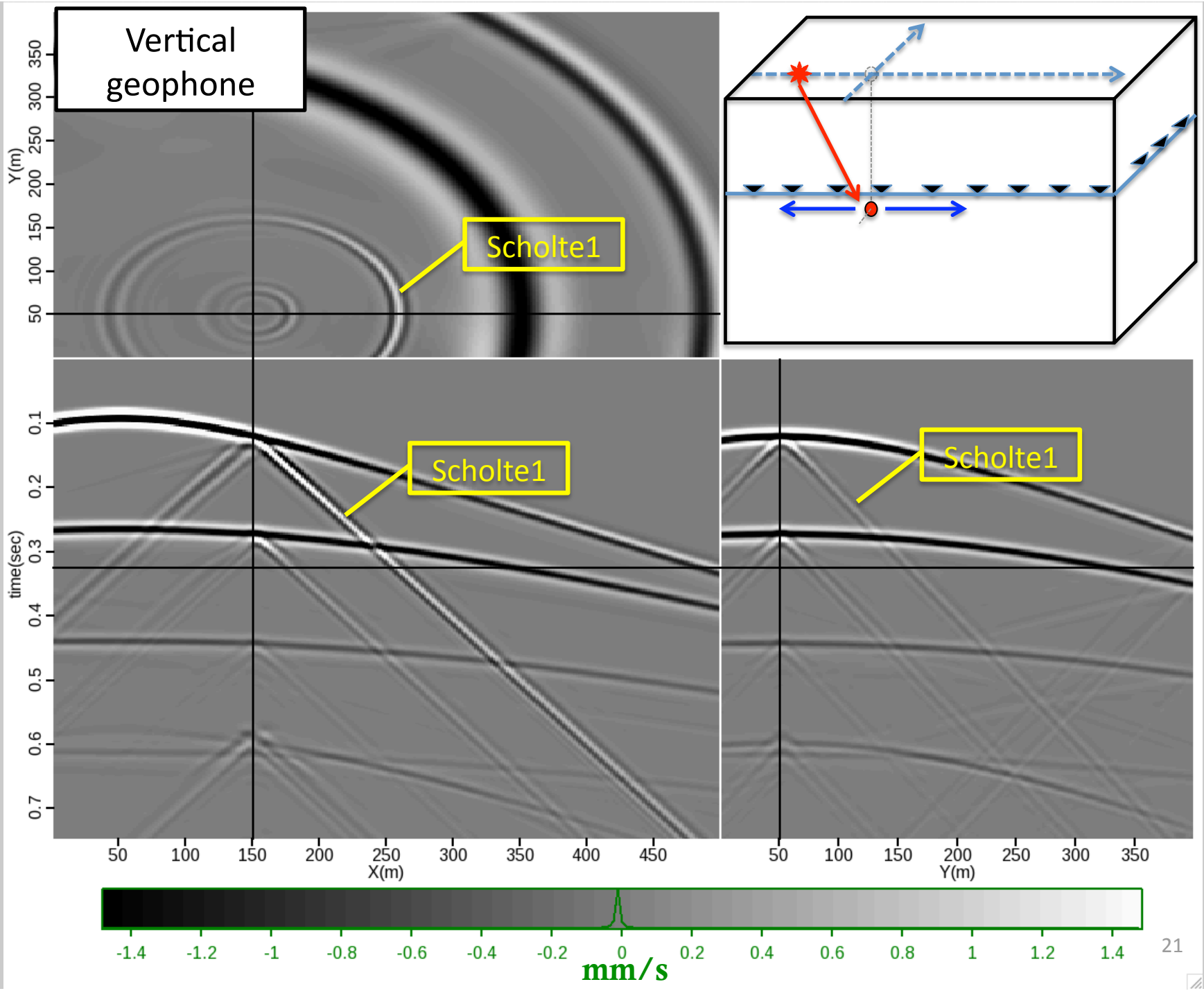
$V_p = 1.7$ km/s
$V_s = 0.6$ km/s
$\rho = 2$ g/cm^3

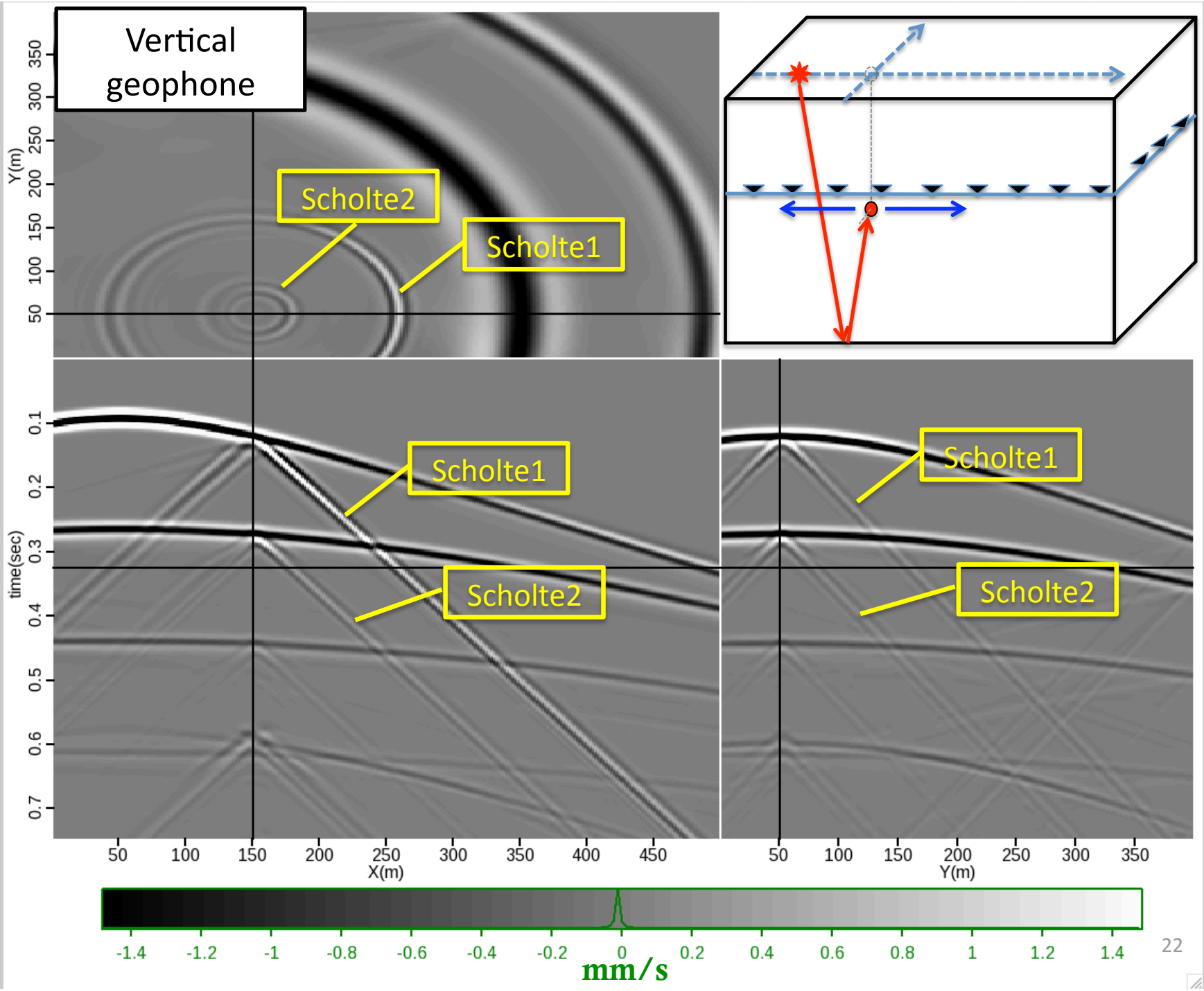
$V_p = 1.85$ km/s
$V_s = 0.9$ km/s
$\rho = 2.4$ g/cm^3

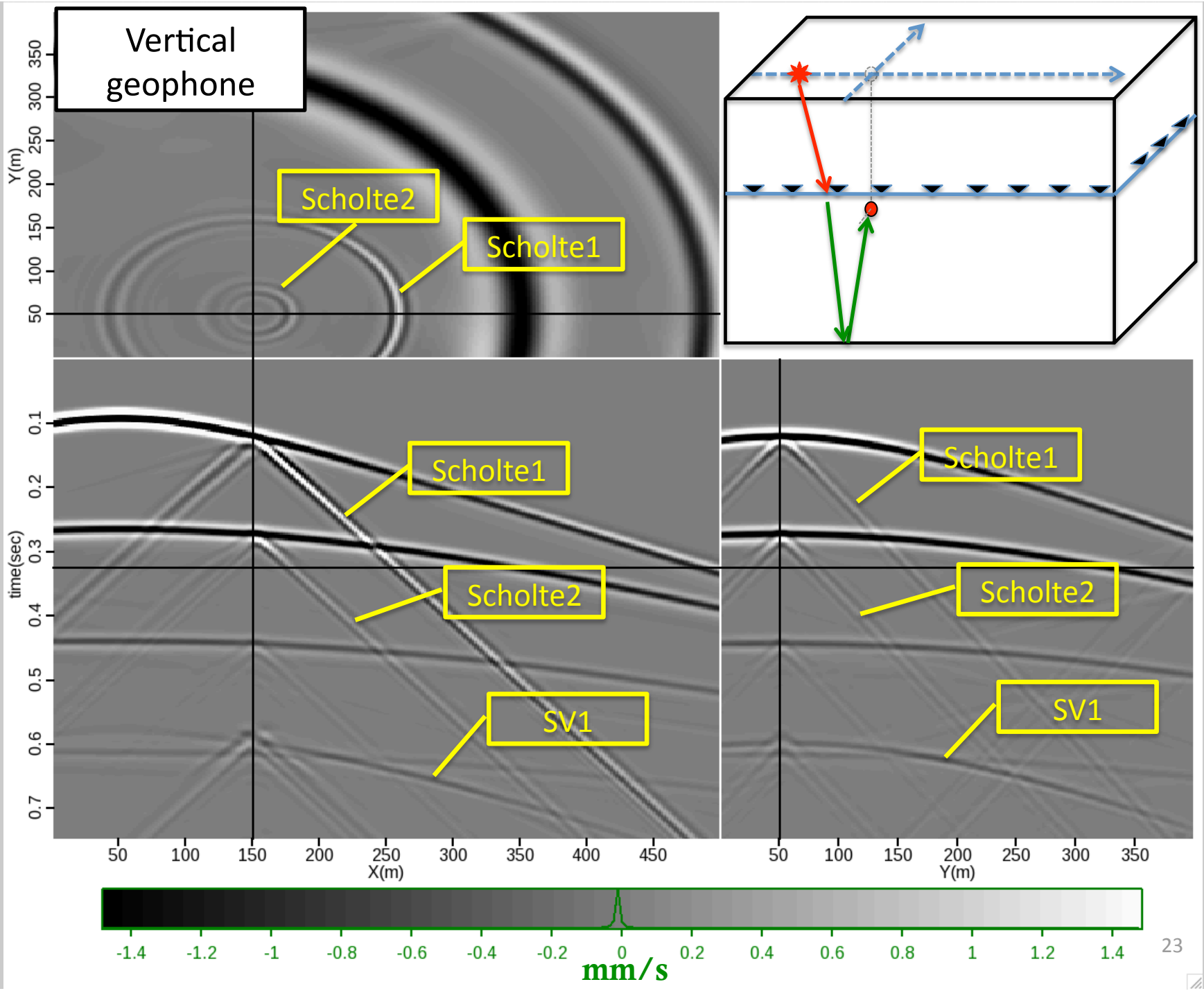

Hydrophone
Direct
Direct
Direct
Y(m)
50
100
150
200
250
300
350
time(sec)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
X(m)
50
100
150
200
250
300
350
400
450
Y(m)
50
100
150
200
250
300
350
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
bars

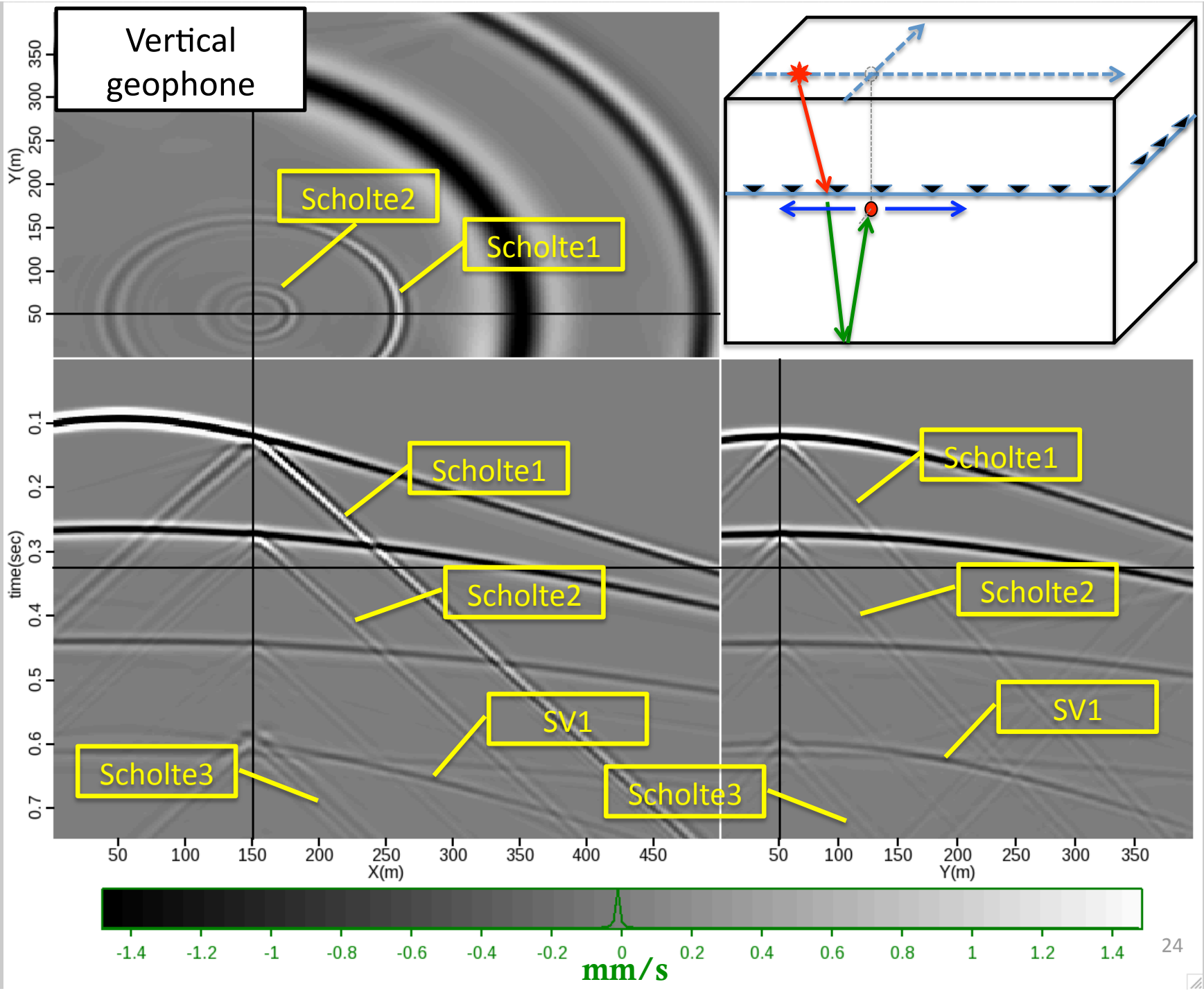

Hydrophone
Direct
P1
Direct
P1
Direct
P1
Y(m)
time(sec)
X(m)
Y(m)
bars

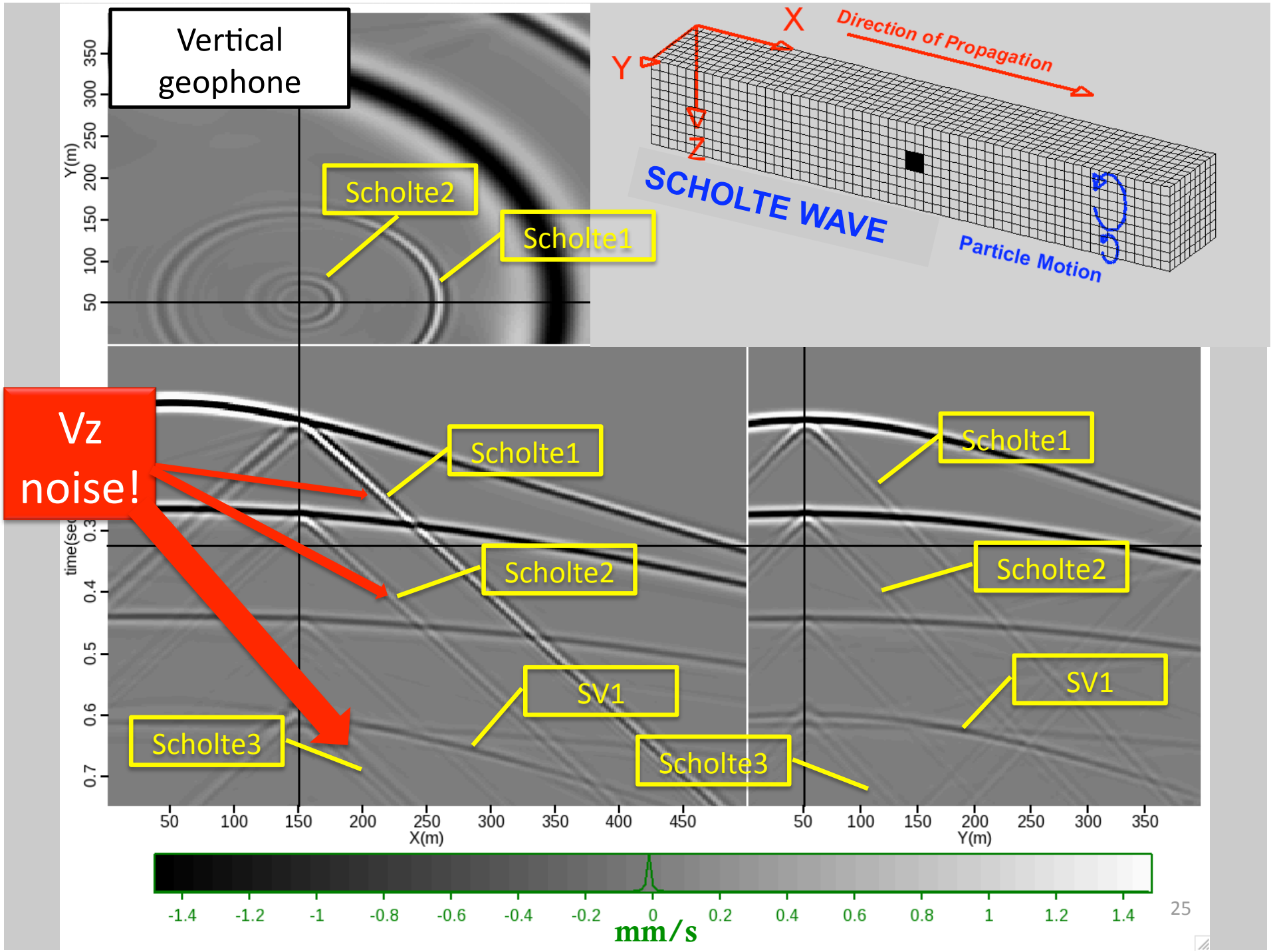

Hydrophone
Direct
P1
Direct
P1
P2
Direct
P1
Y(m)
time(sec)
X(m)
Y(m)
bars

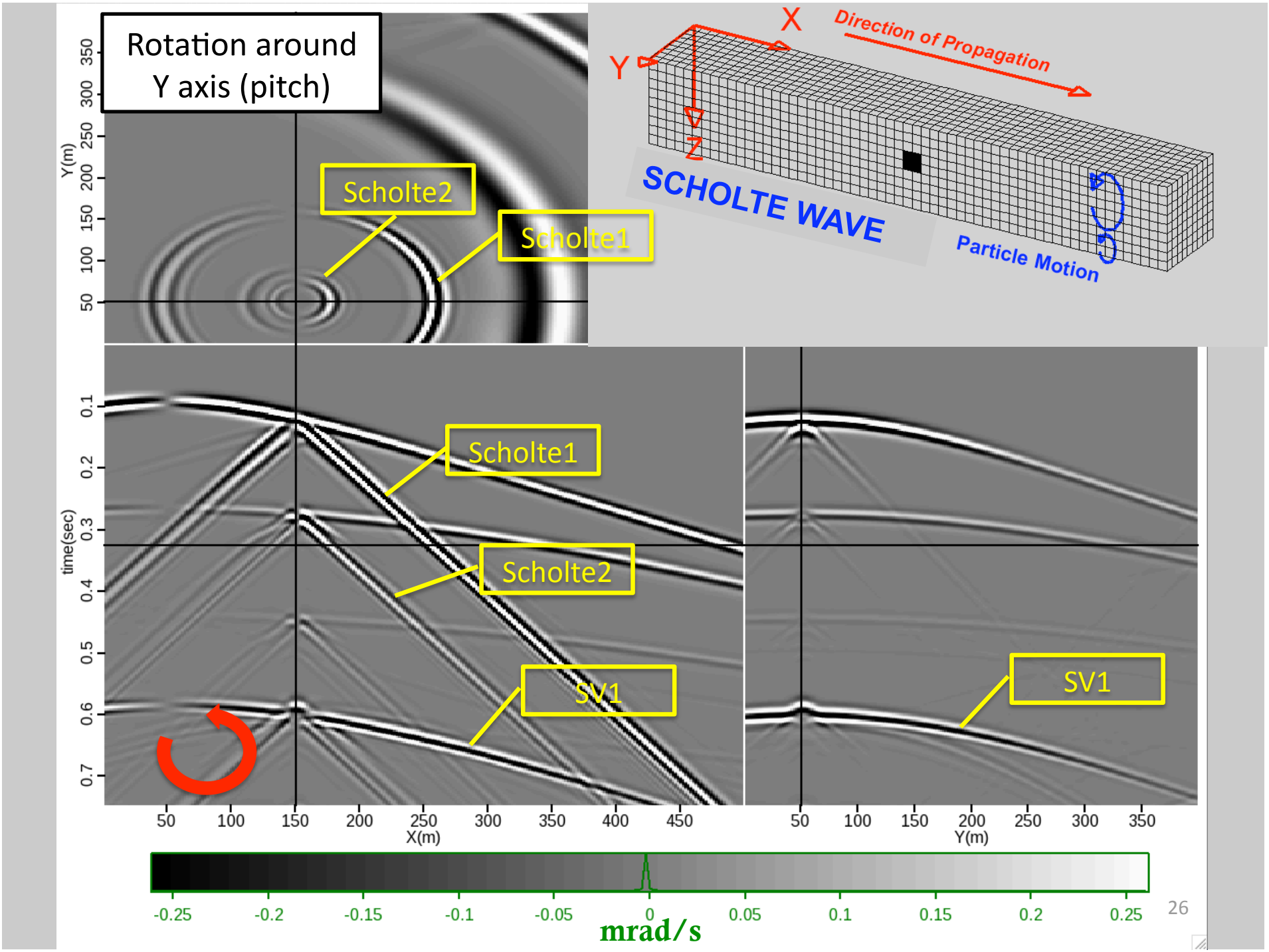

Vertical geophone
Scholte1
Scholte1
Scholte1
Y(m)
time(sec)
X(m)
Y(m)
mm/s

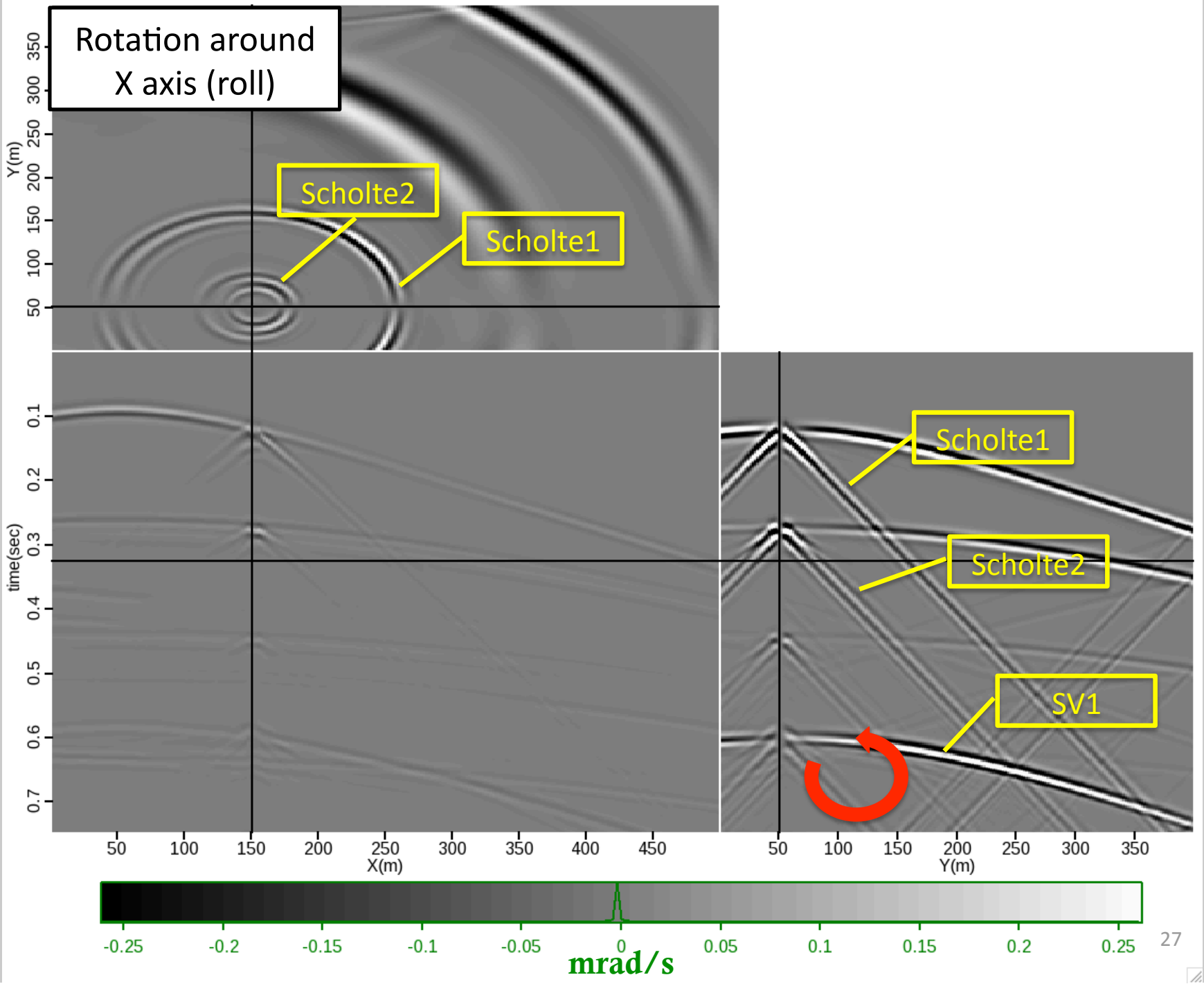

Vertical geophone
Scholte2
Scholte1
Y(m)
50
100
150
200
250
300
350
time(sec)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
X(m)
400
450
-1.4
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
mm/s

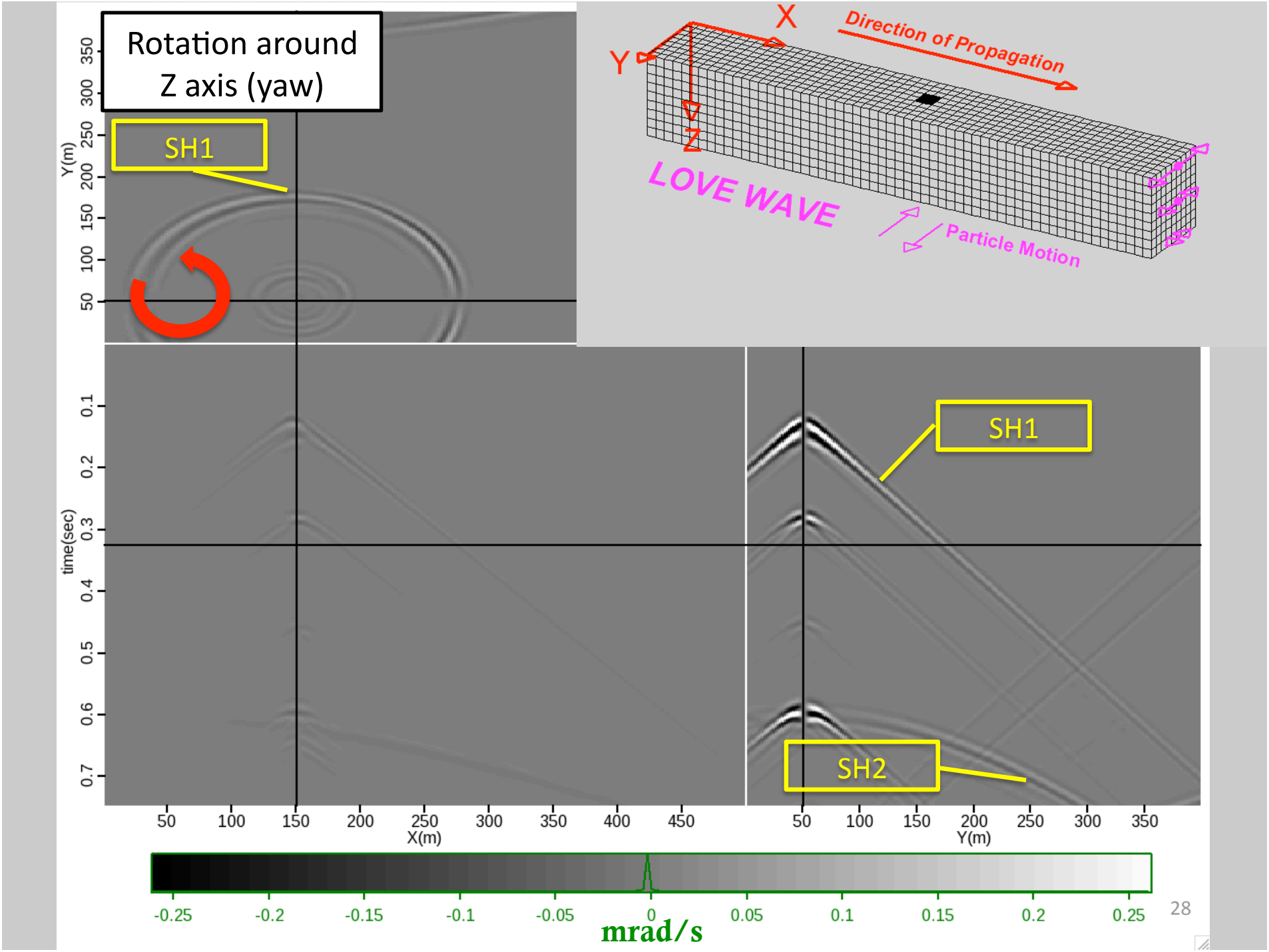

Vertical geophone
Scholte2
Scholte1
Y(m)
50
100
150
200
250
300
350
time(sec)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Scholte1
Scholte2
SV1
Scholte1
Scholte2
SV1
50
100
150
200
250
300
350
400
450
X(m)
50
100
150
200
250
300
350
Y(m)
-1.4
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
mm/s

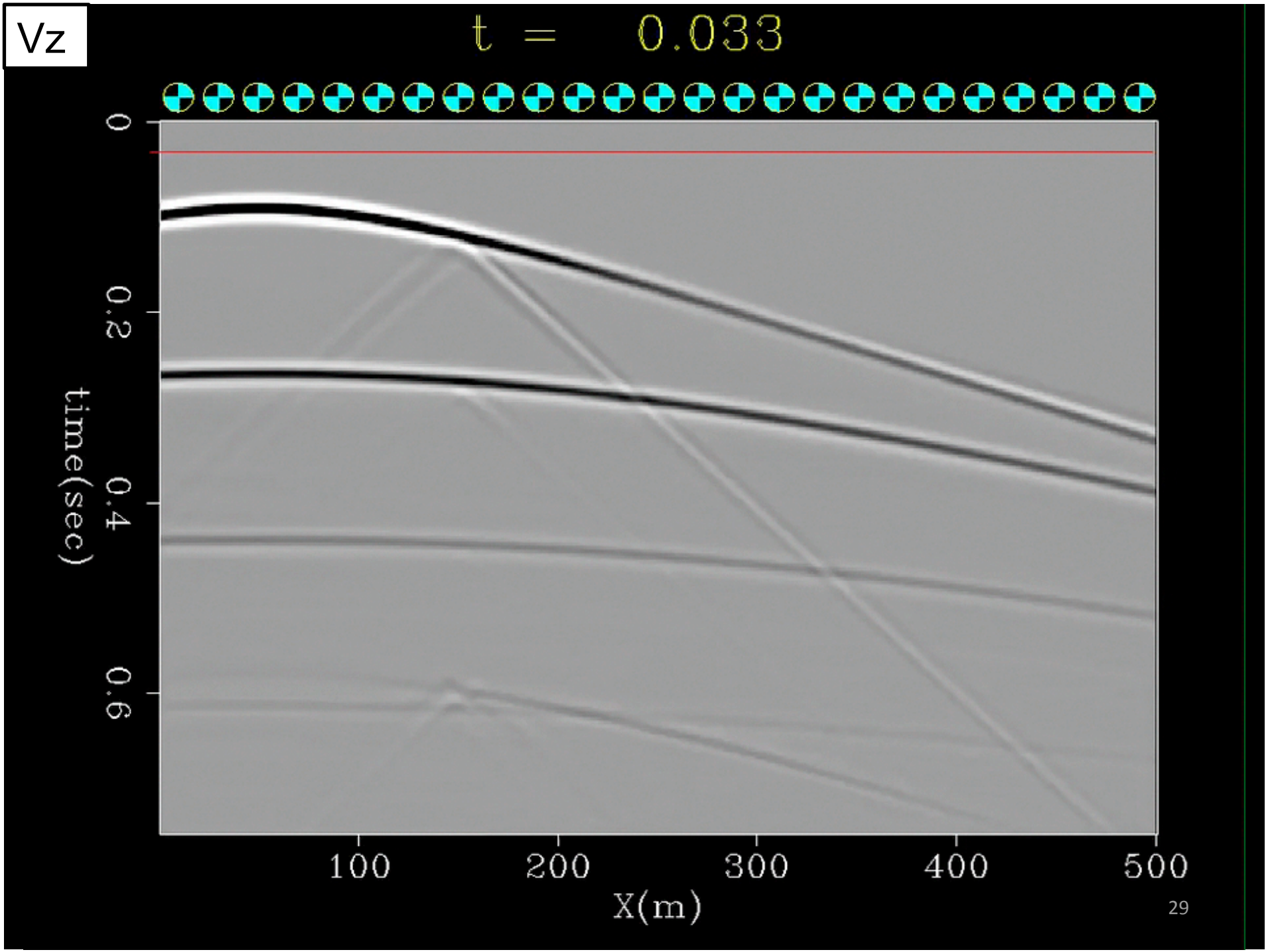

Vertical geophone
Scholte2
Scholte1
Scholte1
Scholte2
SV1
Scholte3
Scholte1
Scholte2
SV1
Scholte3
Y(m)
time(sec)
X(m)
Y(m)
mm/s


Vertical geophone
Scholte2
Scholte1
Y(m)
X
Y
Z
Direction of Propagation
SCHOLTE WAVE
Particle Motion
Vz noise!
Scholte1
Scholte2
SV1
Scholte3
Scholte1
Scholte2
SV1
Scholte3
time(sec)
X(m)
Y(m)
mm/s


Rotation around
Y axis (pitch)
Scholte2
Scholte1
Y(m)
X
Y
Z
Direction of Propagation
SCHOLTE WAVE
Particle Motion
Scholte1
Scholte2
SV1
SV1
time(sec)
X(m)
Y(m)
mrad/s


Rotation around
X axis (roll)
Scholte2
Scholte1
Y(m)
time(sec)
X(m)
Y(m)
Scholte1
Scholte2
SV1
-0.25
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
mrad/s

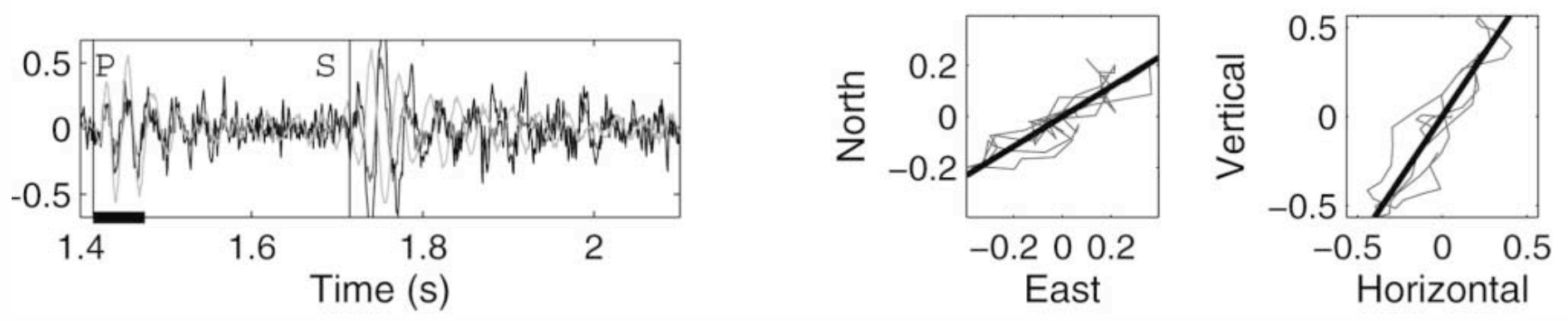

Rotation around
Z axis (yaw)
SH1
Y(m)
X
Y
Z
Direction of Propagation
LOVE WAVE
Particle Motion
time(sec)
SH1
SH2
X(m)
Y(m)
mrad/s


Vz
t = 0.033
0
0.2
0.4
0.6
time(sec)
100
200
300
400
500
X(m)

SVD of three components

De Meersman et al., 2006,
"Signal Extraction and Automated Polarization Analysis of Multicomponent Array Data."

Singular value decomposition applied to 3C geophone data



SVD of seven components

<u>Data:</u> seven-component seismogram (single trace)

$$D = \lfloor h(t), v_z(t), v_x(t), v_y(t), r_z(t), r_x(t), r_y(t) \rfloor$$

$$t \in [T_1, T_N]$$

<u>SVD:</u> $D = U \Sigma V^T$

Decompose a time-window from a 7C trace into:

- Waveform U
- Magnitude Σ
- Polarization V

SVD of seven components

<u>SVD:</u> $D = U \Sigma V^T$

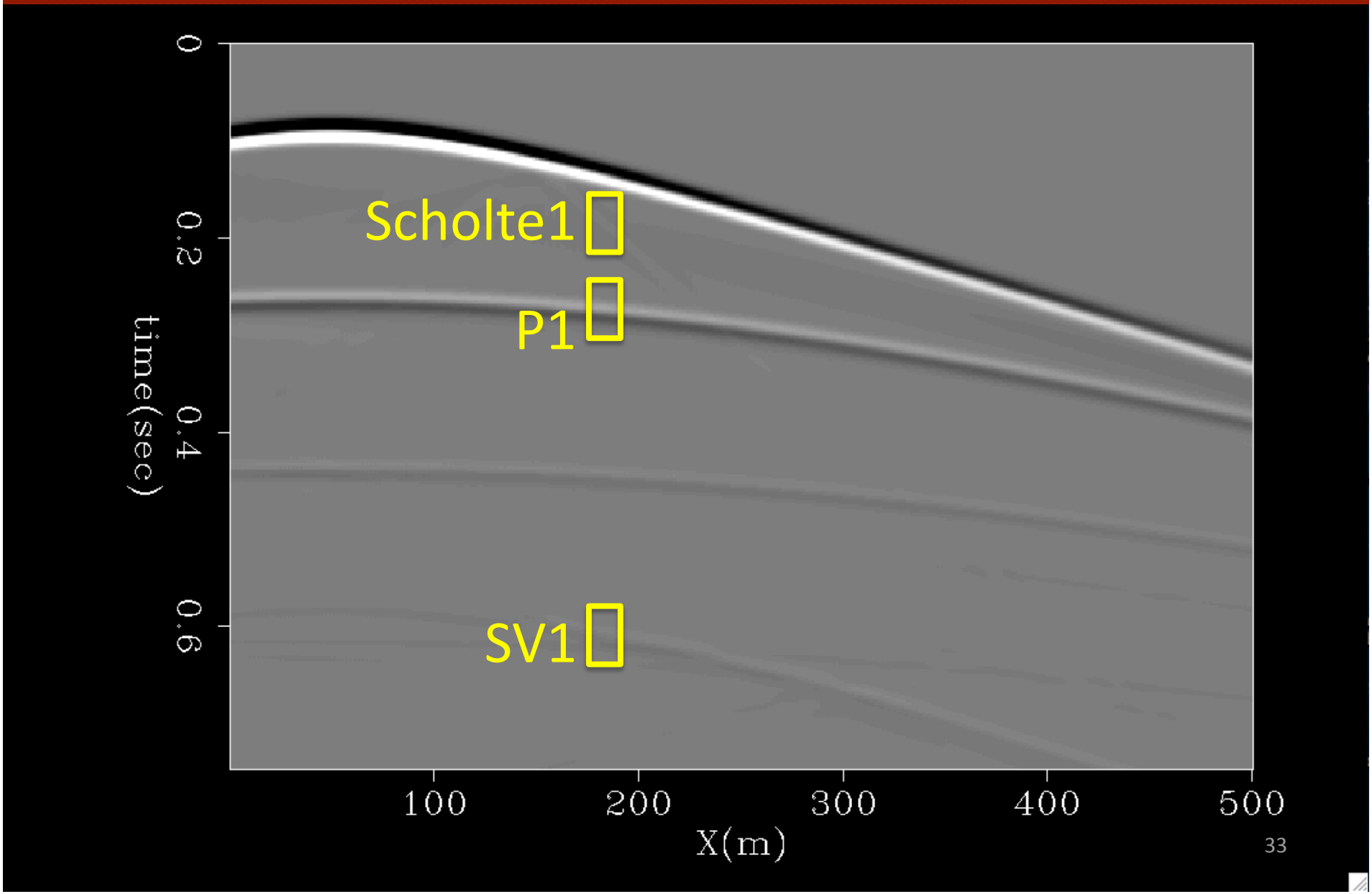
Decompose a time-window from a 7C trace into:

- Waveform U
- Magnitude Σ
- Polarization V

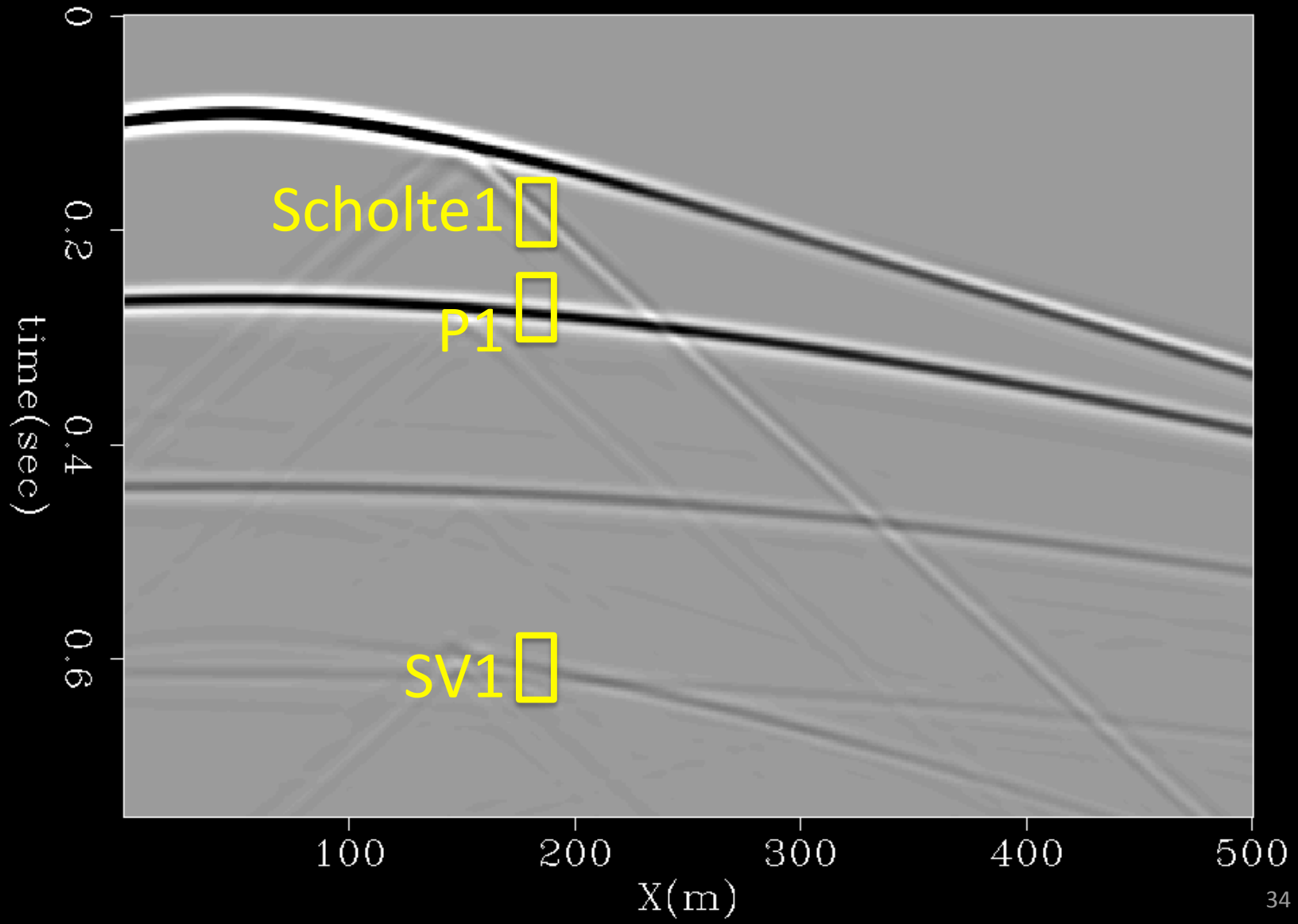
Scaled polarization vectors: $S = \Sigma V^T$

Two largest polarization vectors: $s_{j,1} = \sigma_1 v_{j,1}$ $s_{j,2} = \sigma_2 v_{j,2}$

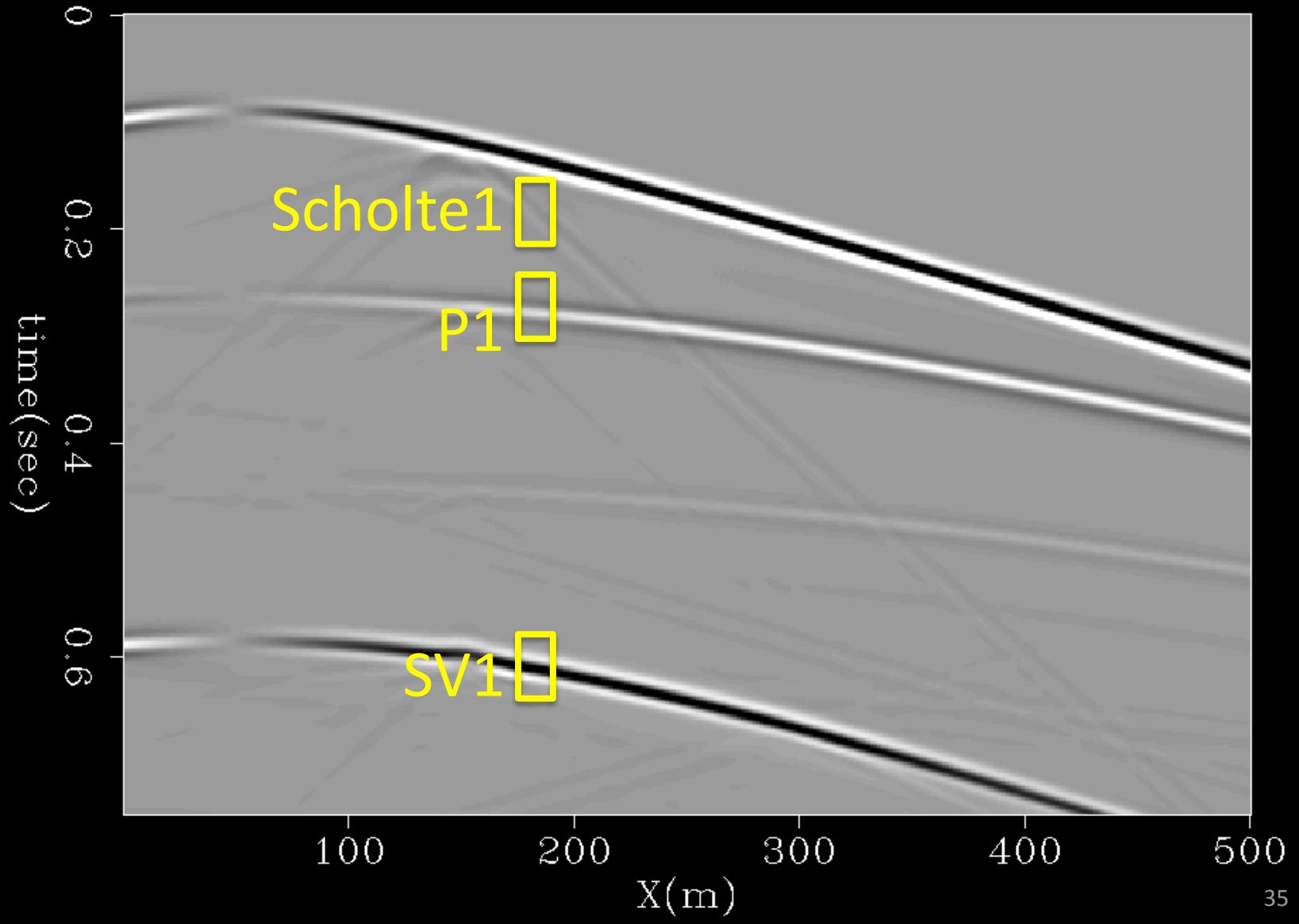
Inline hydrophone



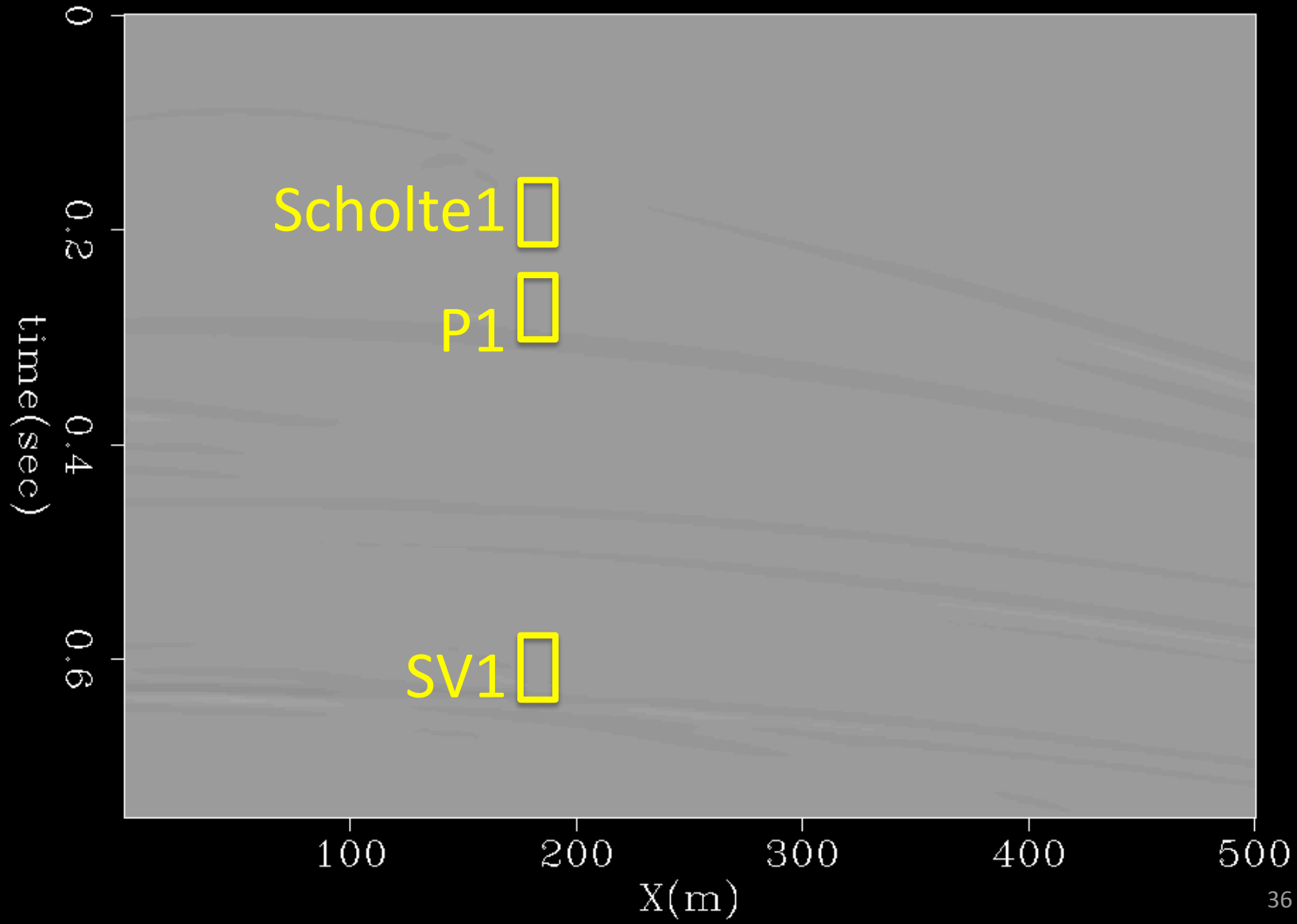
Inline vertical geophone



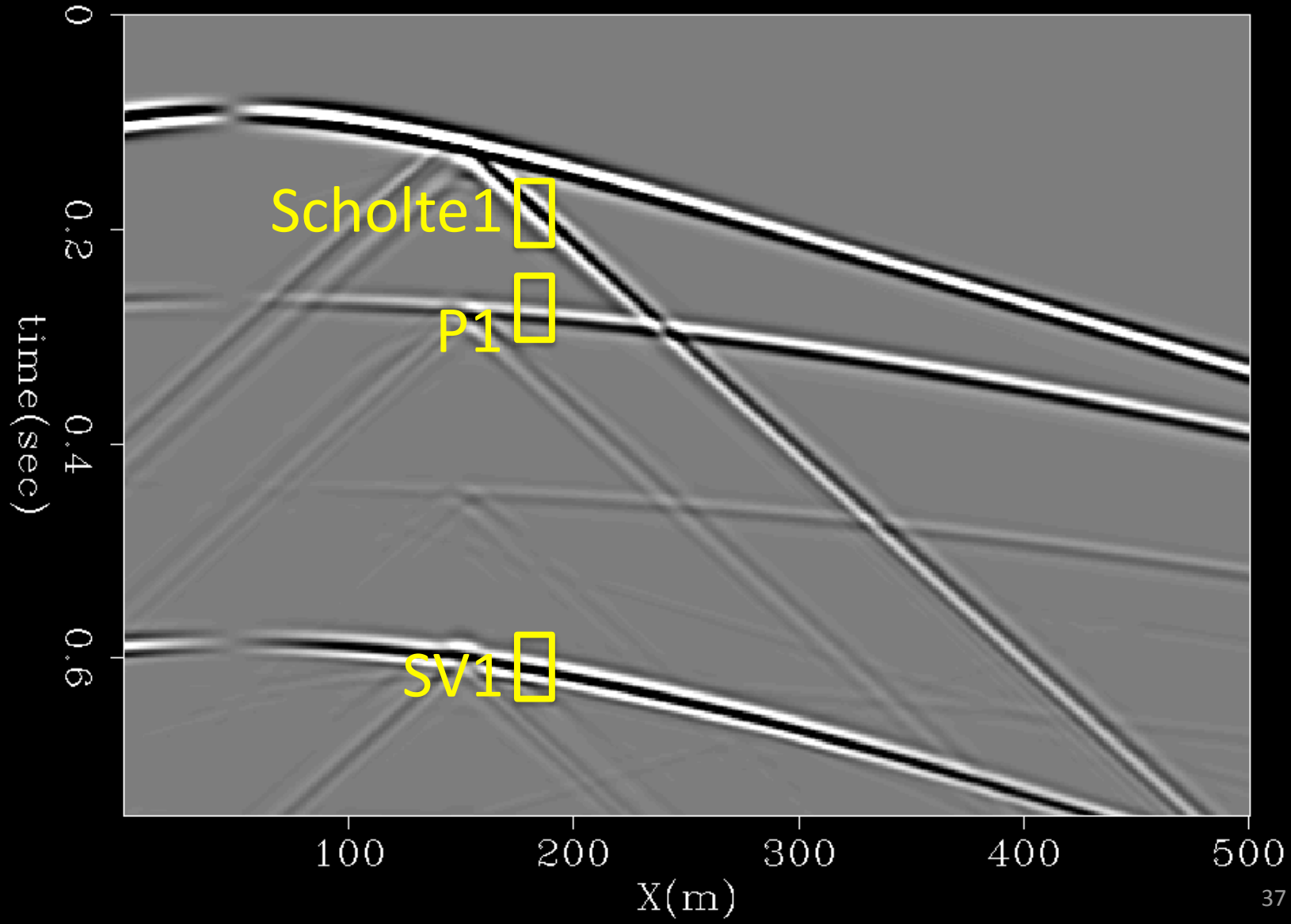
Inline horizontal ‘X’ geophone



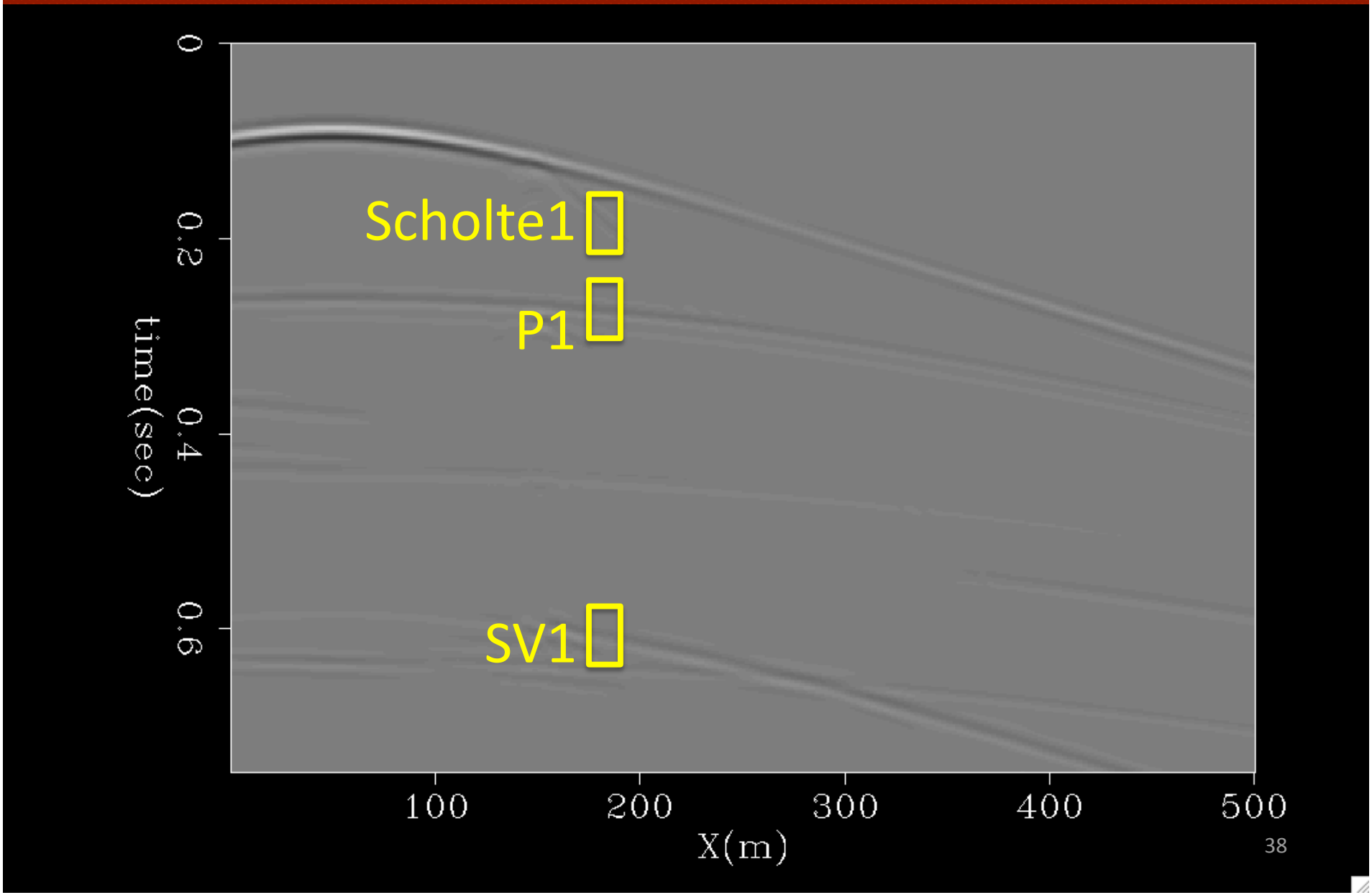
Inline horizontal ‘Y’ geophone



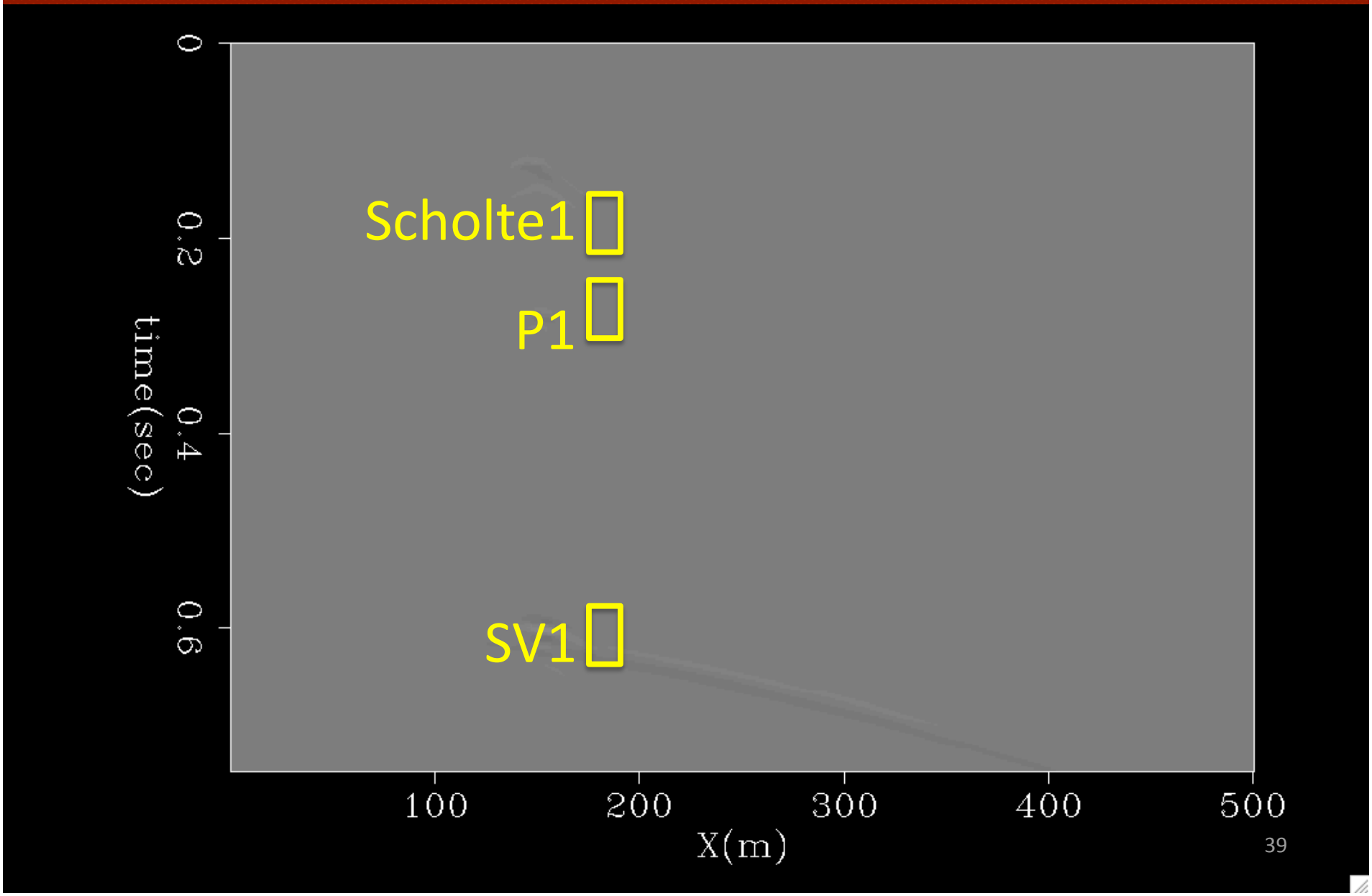
Inline pitch (rotation around Y)



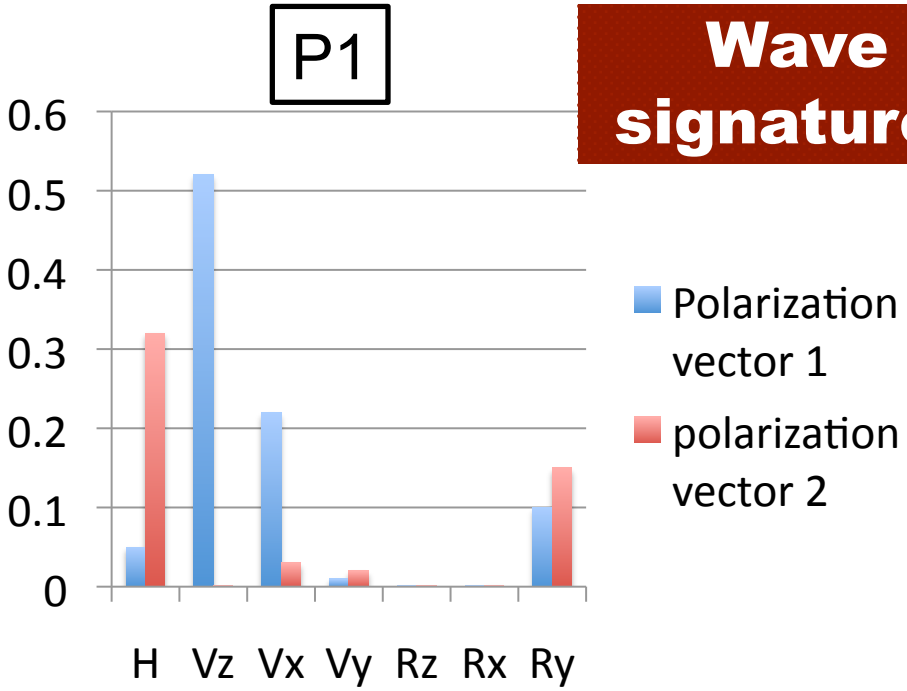
Inline roll (rotation around X)

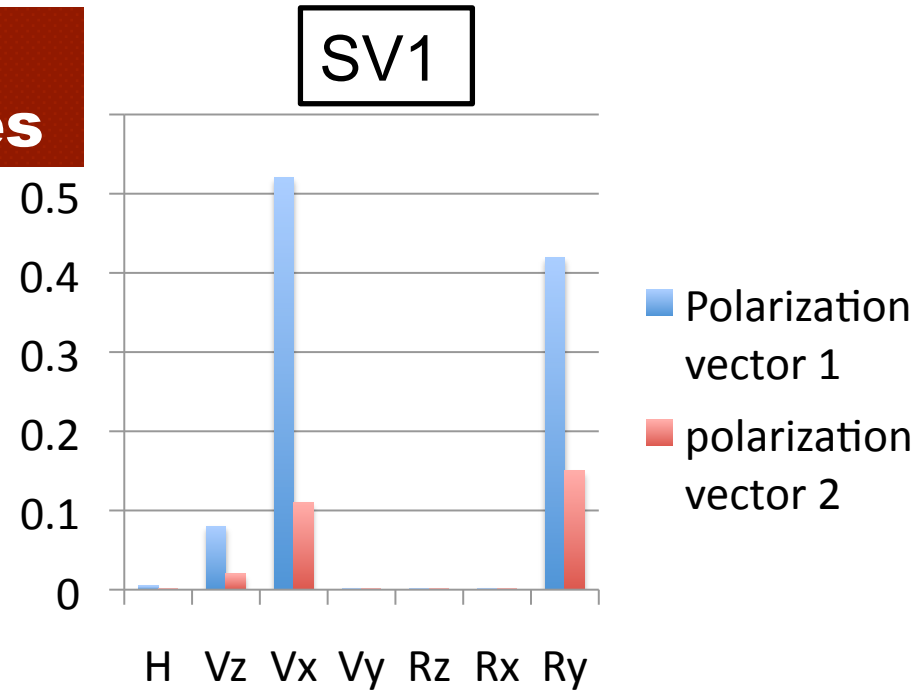


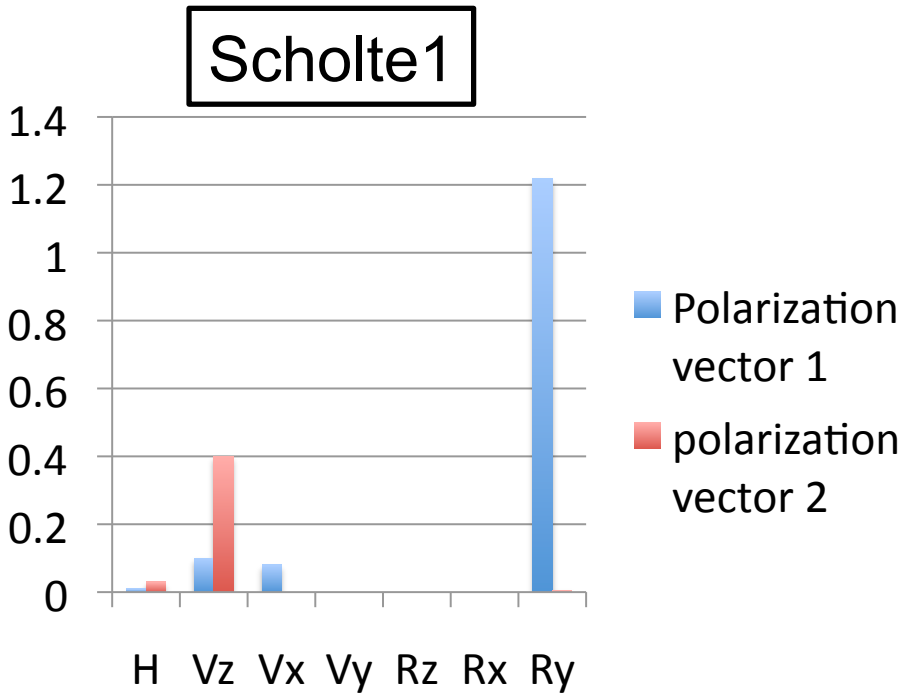
Inline yaw (rotation around Z)



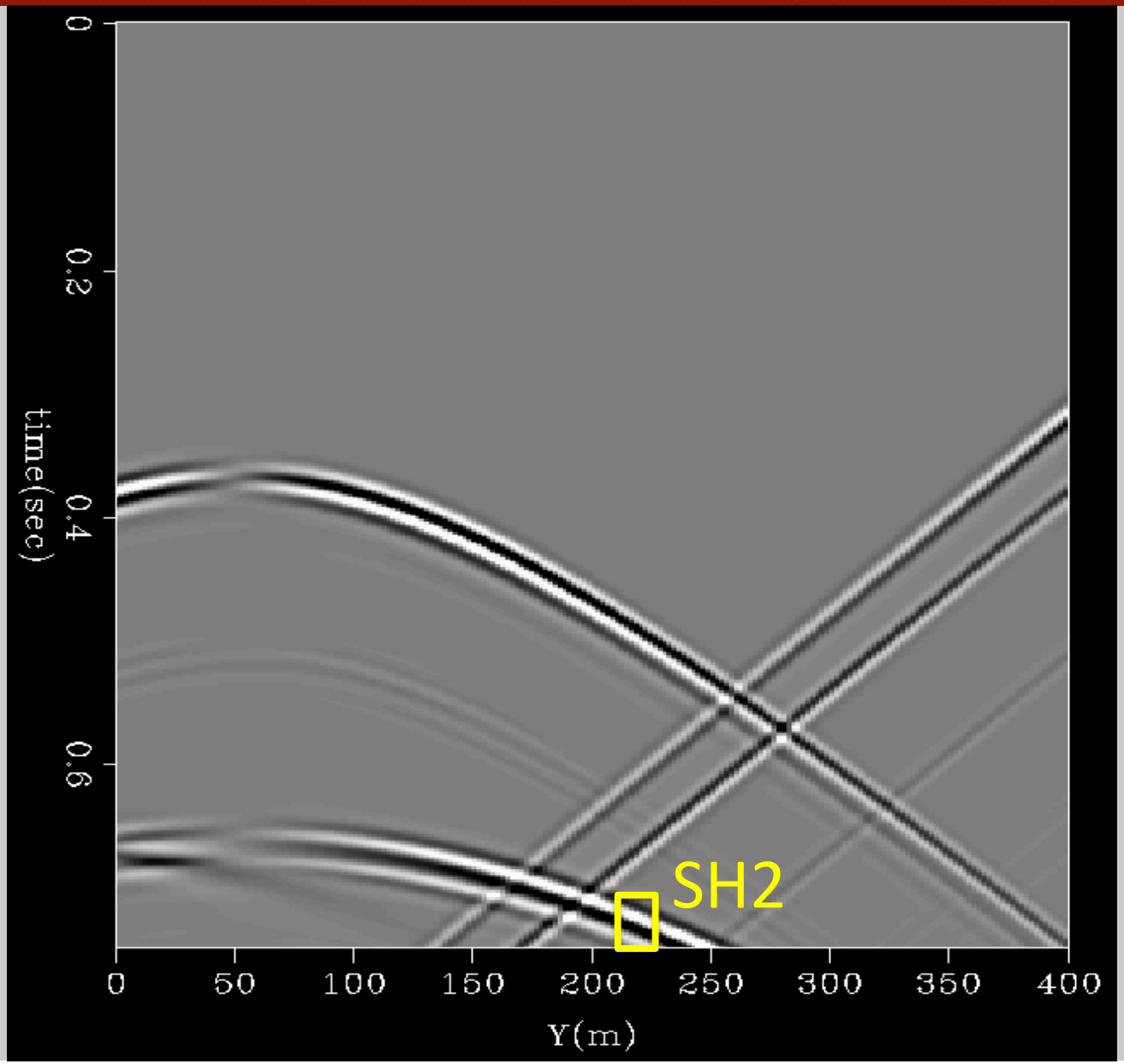
Wave signatures



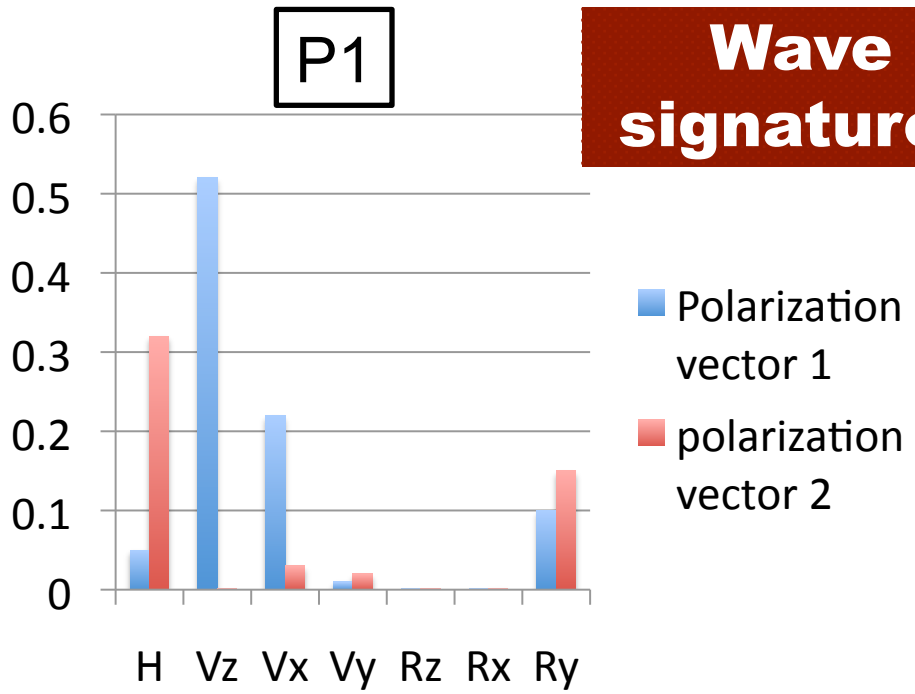


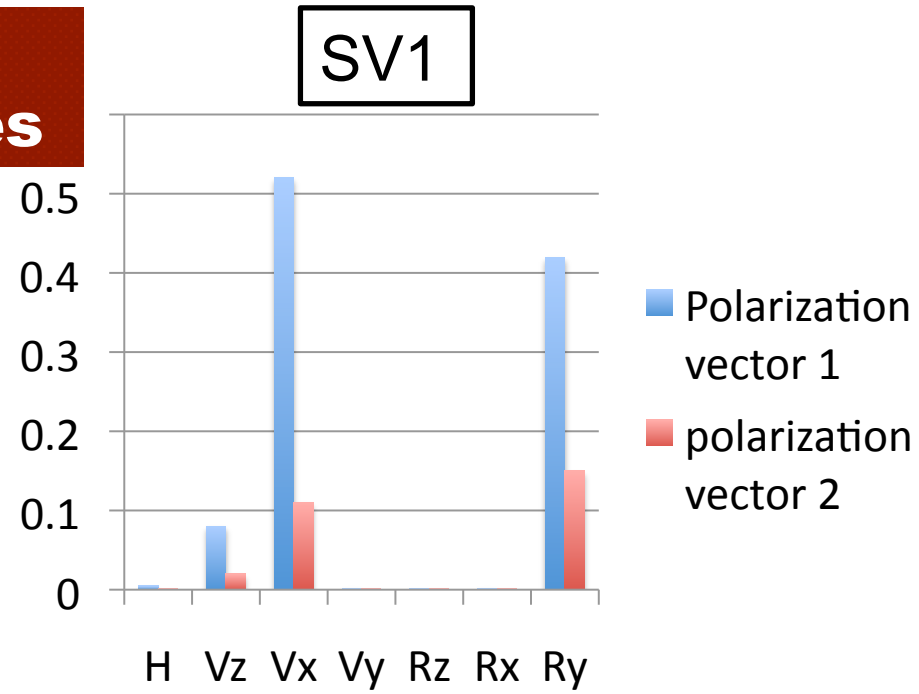


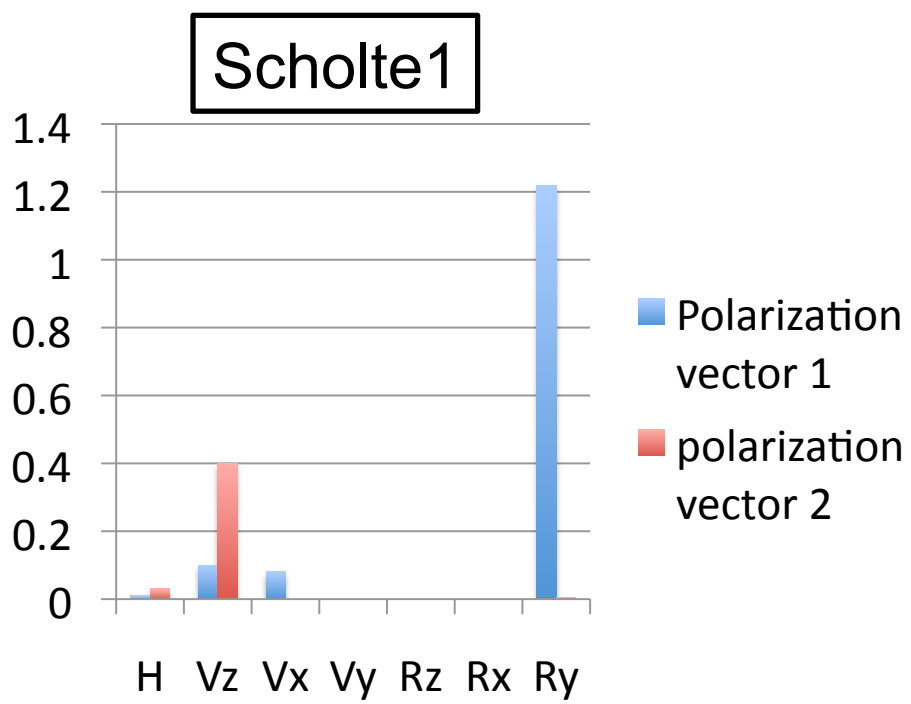
crossline yaw (rotation around Z)

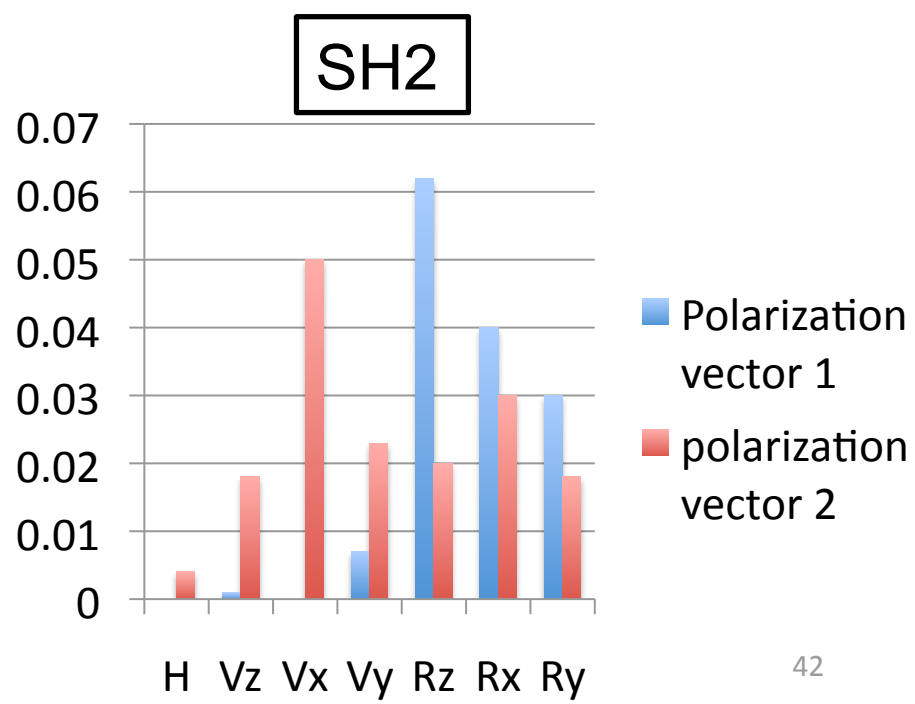


Wave signatures









Conclusions

In seven-component data:

- Different wave types have different signatures
- Body waves are distinguishable from surface waves

Vz noise

- Rotation gives us a handle on the Vz noise.
- Filtering rotations = filtering Vz noise

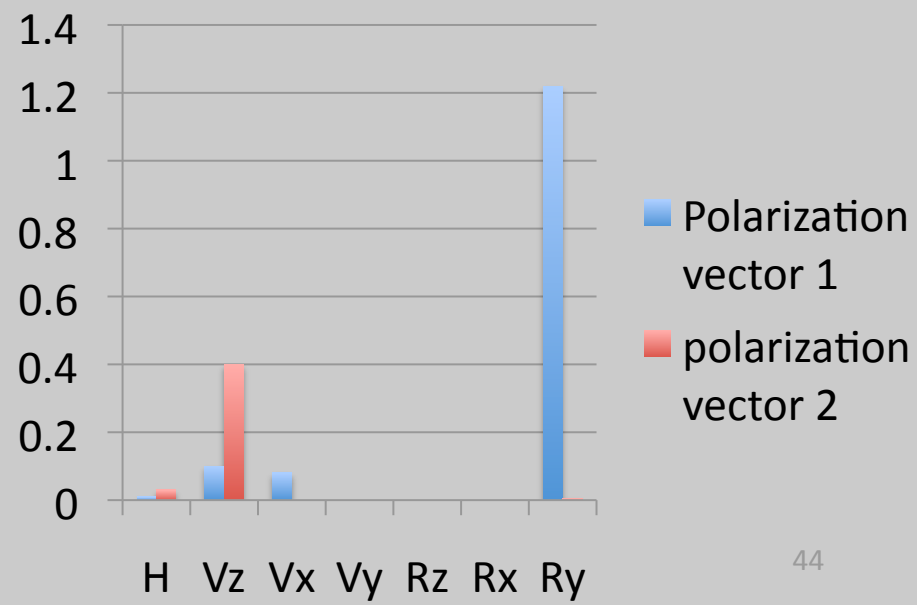
Identification → Attenuation

After SVD:

Waveform U
Magnitude Σ
Polarization V

$$D = U \Sigma V^T$$

1. Identify where the polarization is highly rotational
2. Weight down the largest singular values
3. Recompose the data



Identification → Attenuation

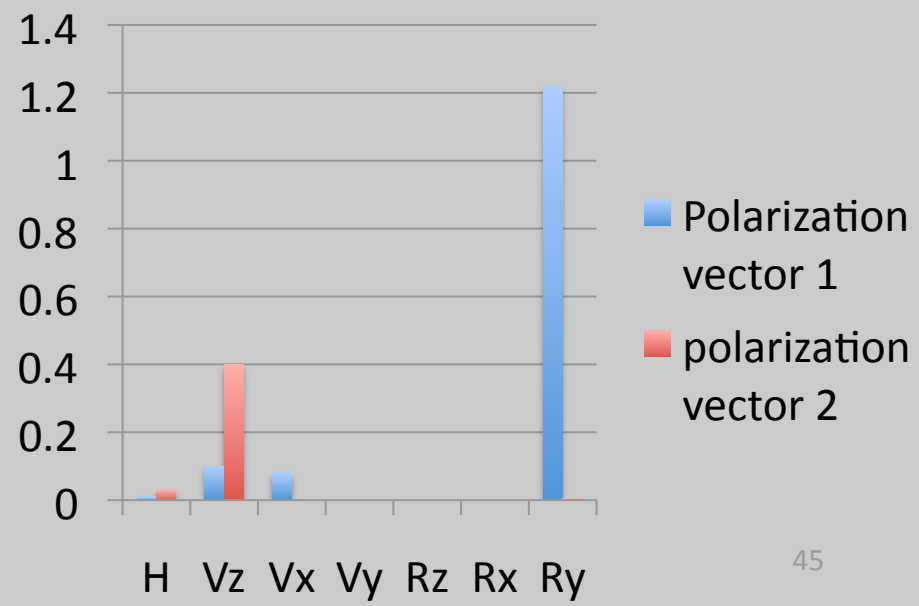
After SVD:

Waveform U
Magnitude Σ
Polarization V

$$D = U \Sigma V^T$$

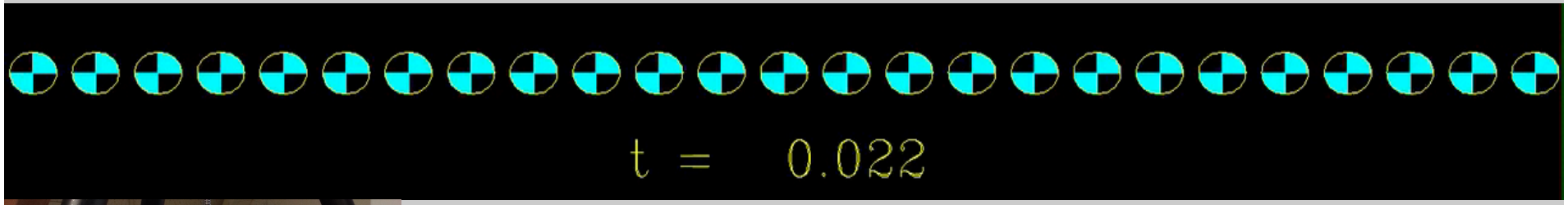
1. Identify where the polarization is highly rotational
2. Weight down the largest singular values
3. Recompose the data

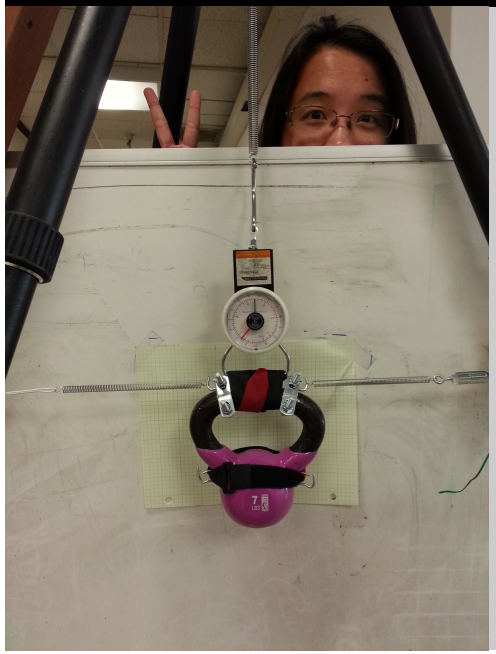
Merge into workflow that also considers moveout.



Conclusions

Please provide me with rotation data!





Thanks for your support, and your attention.

Six-component display