The mushy seafloor problem: observations and questions

T. Dahm, SPICE workshop
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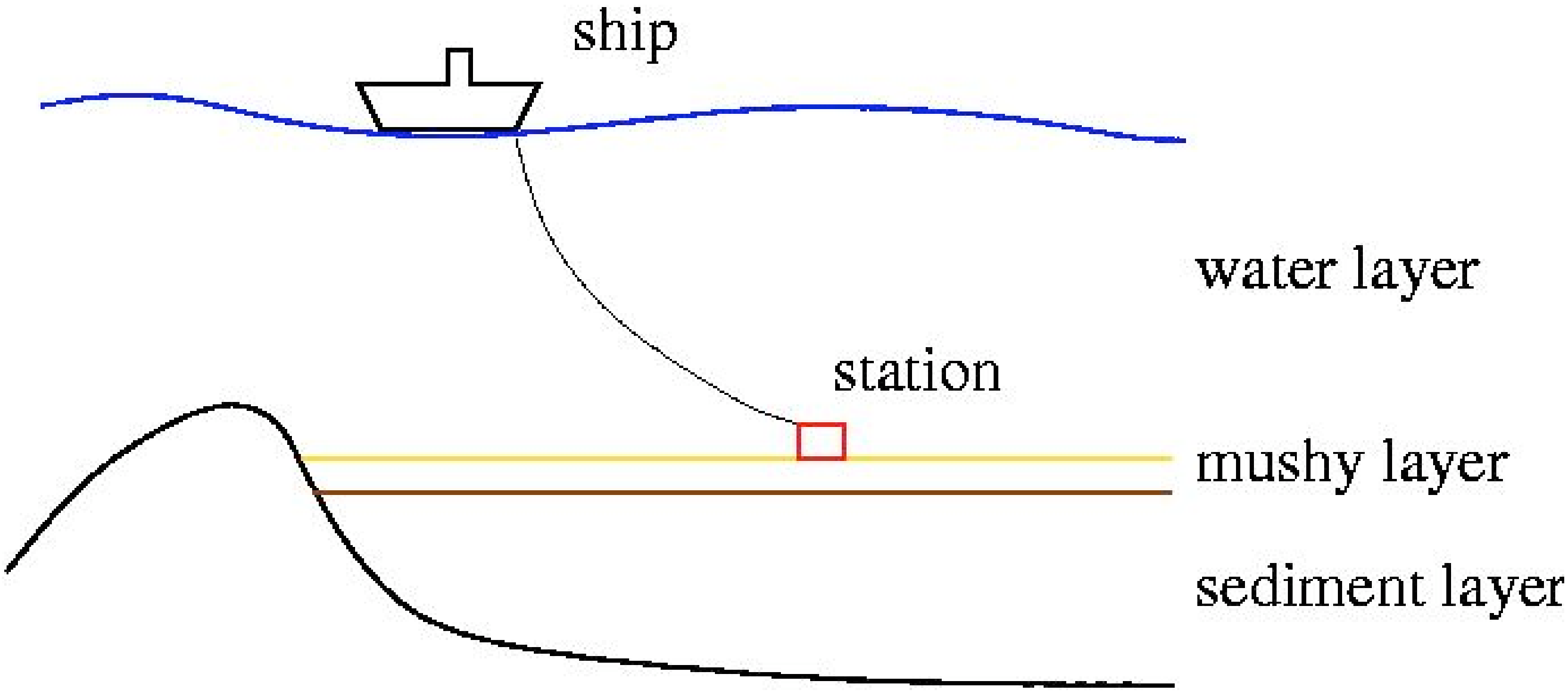
Content

1. Introduction
2. Problems:
    1. Deployment & stations
    2. The water layer
    3. The sediment and mushy layer
    4. Noise & tilt
3. Open questions

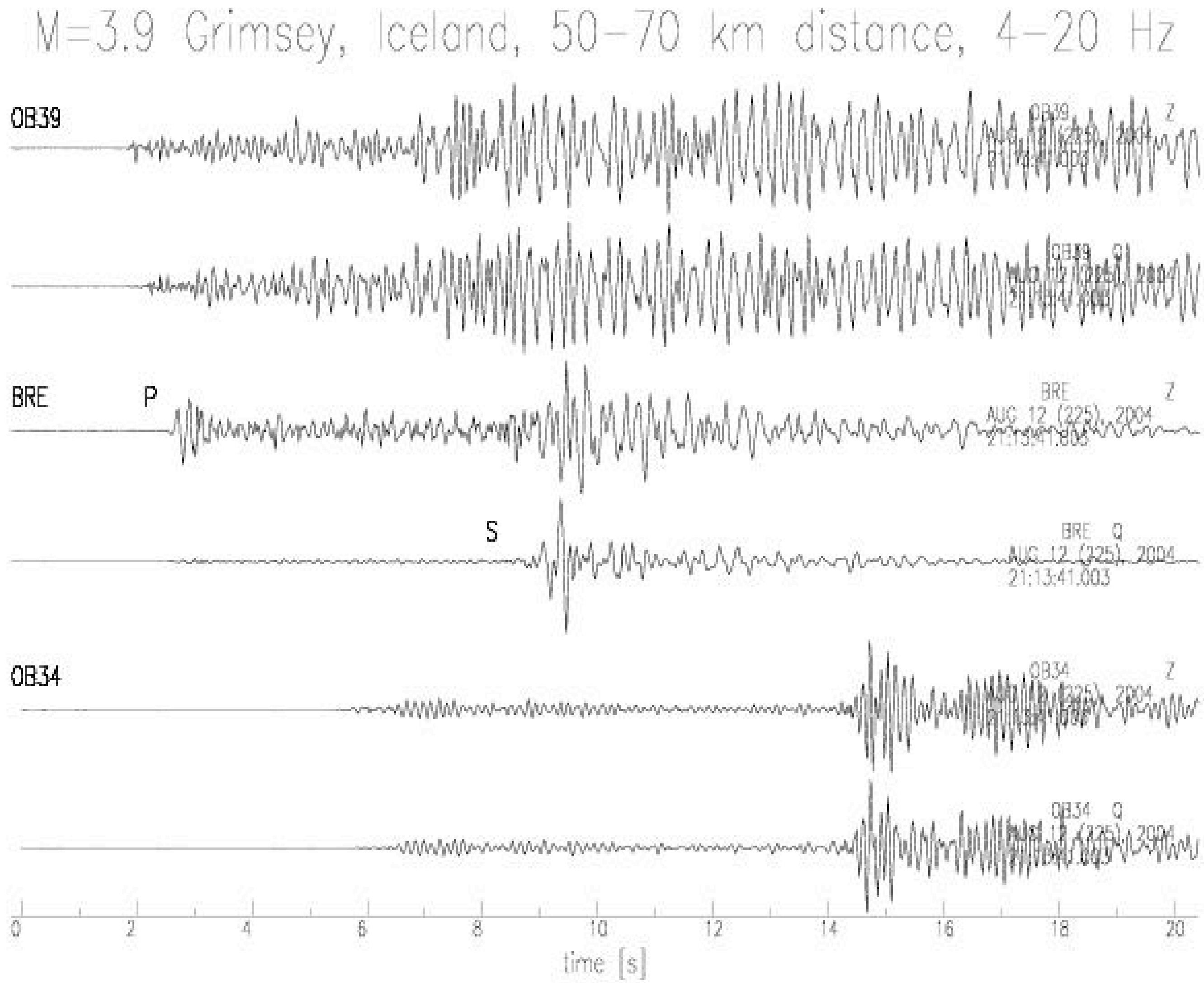
Need for sea-floor seismic data

- Prospecting natural resources like gas or oil and monitoring field production
- Estimating natural hazard by seismic methods, e.g. slope instabilities, volcanism, earthquakes
- Filling large gaps for passive seismological observations

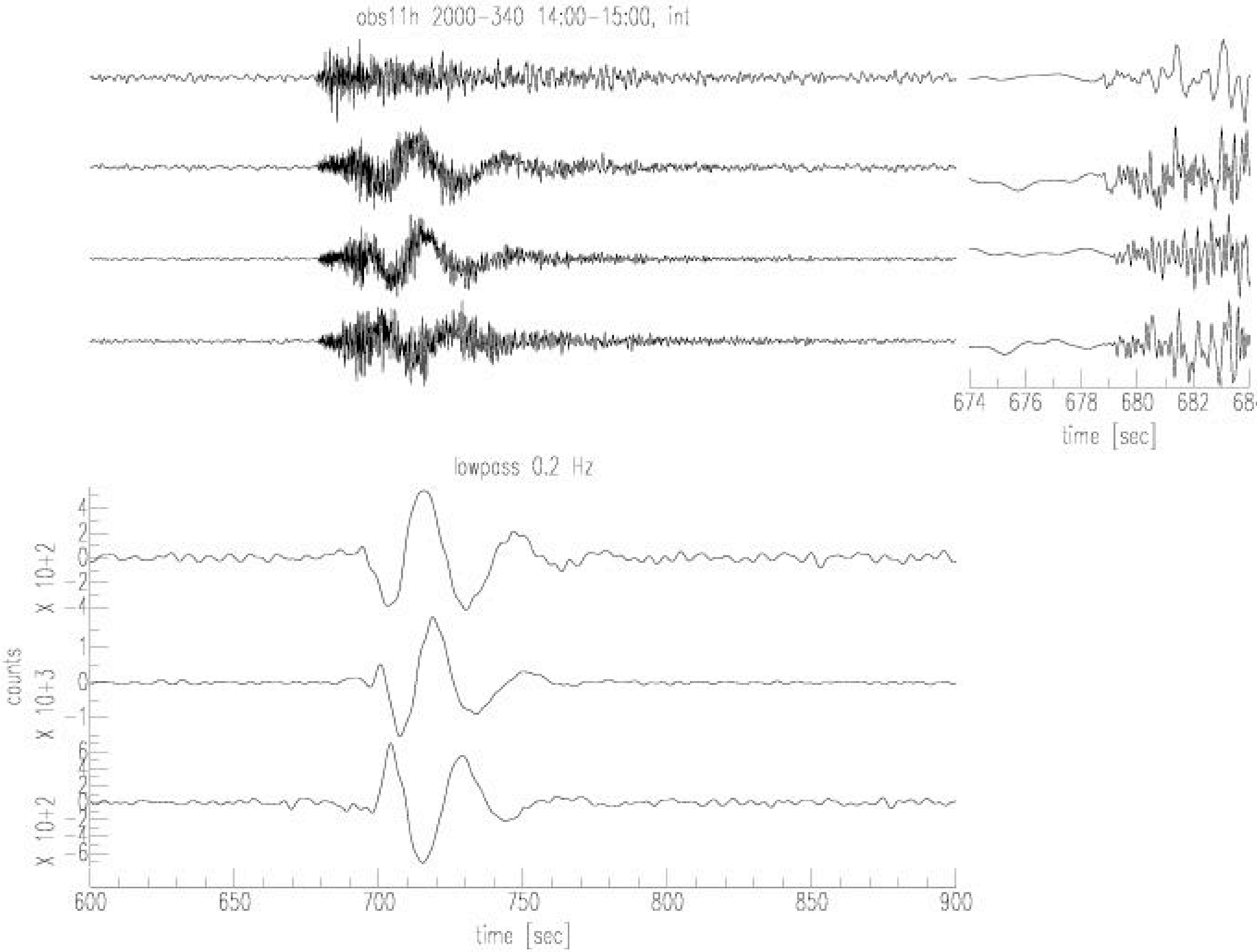
The sea-floor problem



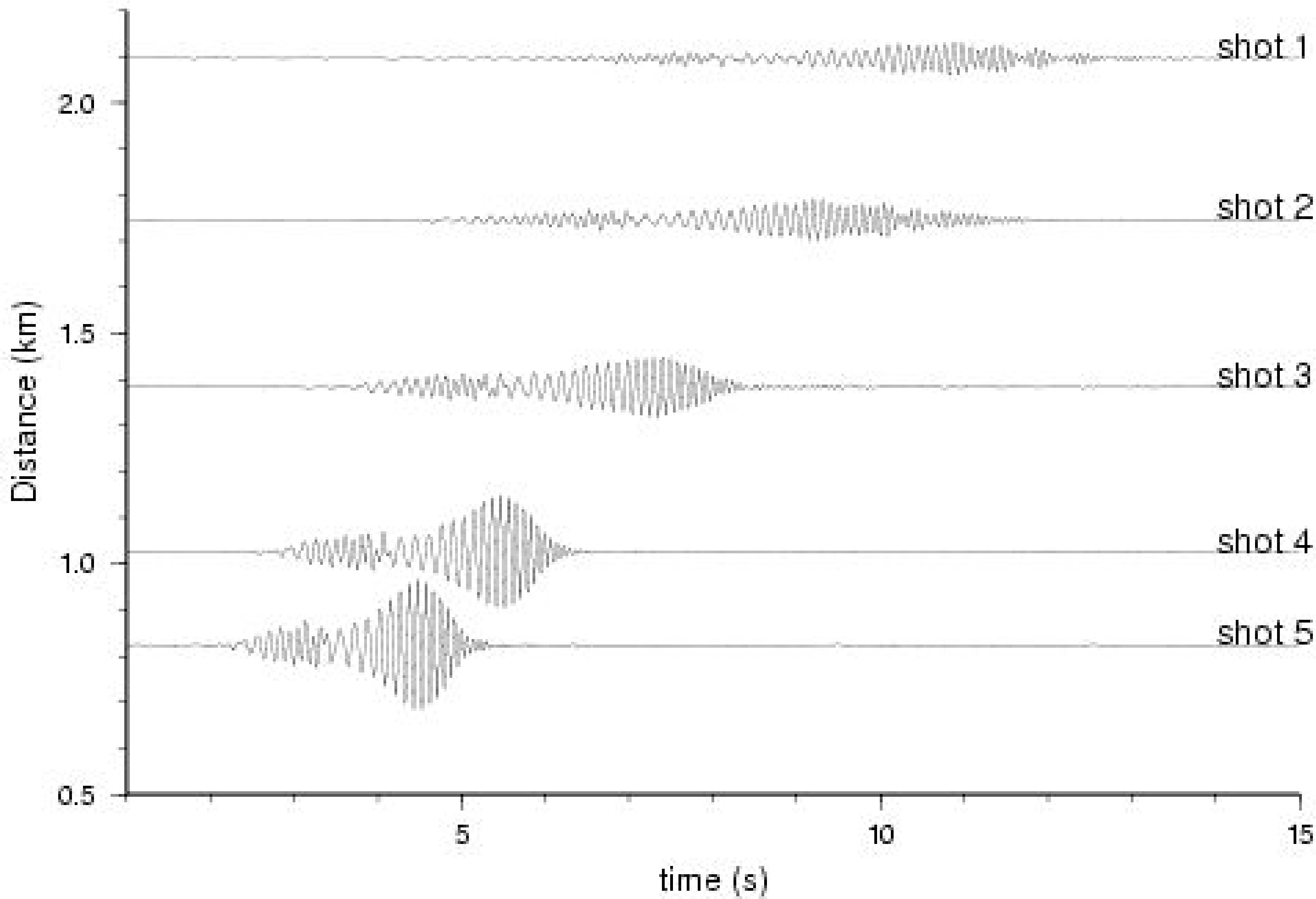
Seismogram example: local earthquake and short period sensors



Local earthquake, Tyrrhenian sea, wide band sensor (0.03-15 Hz)



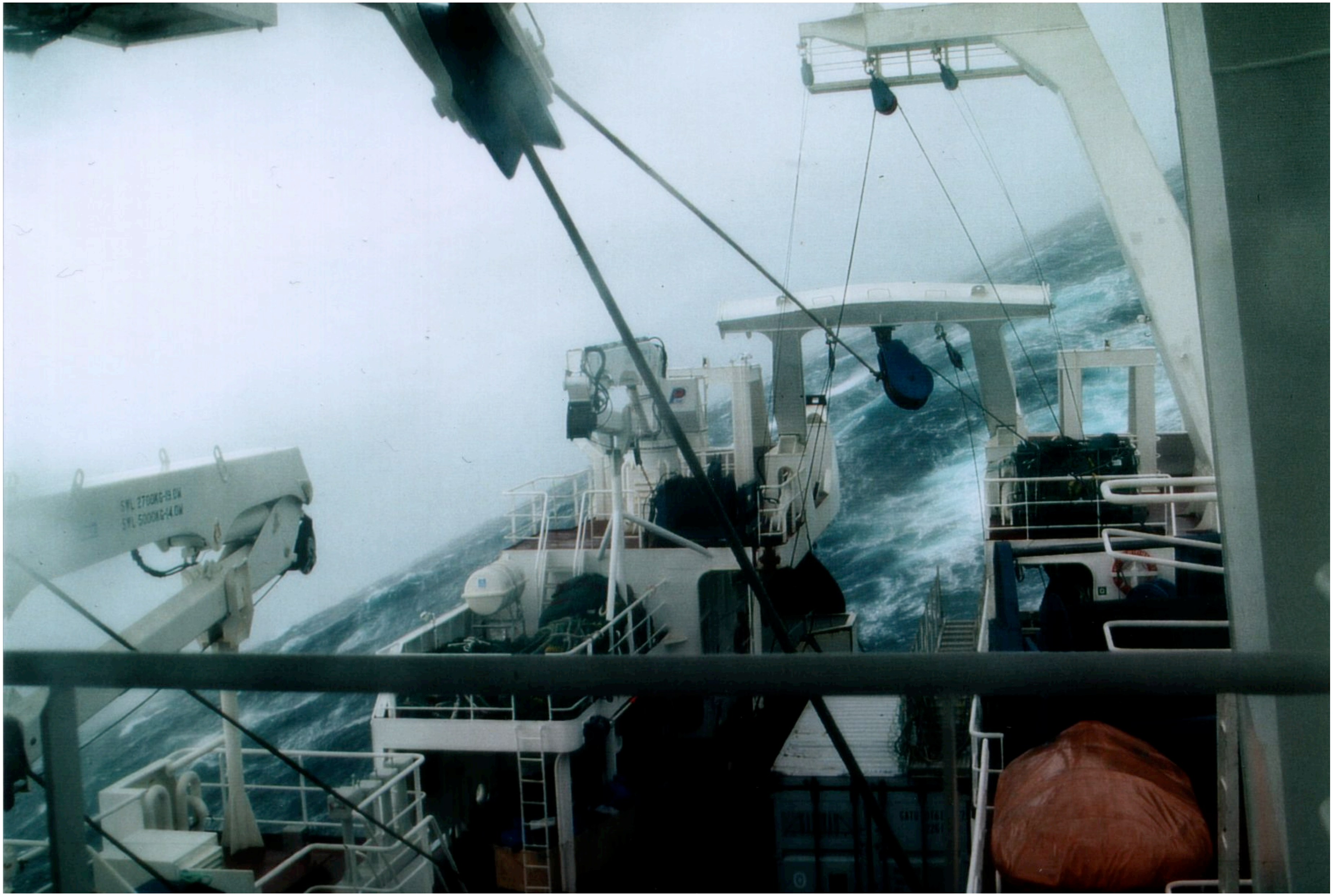
Implosive source, indian ocean, 4.5 Hz sensor, (SR=1000 Hz)



Problem 1: deployment

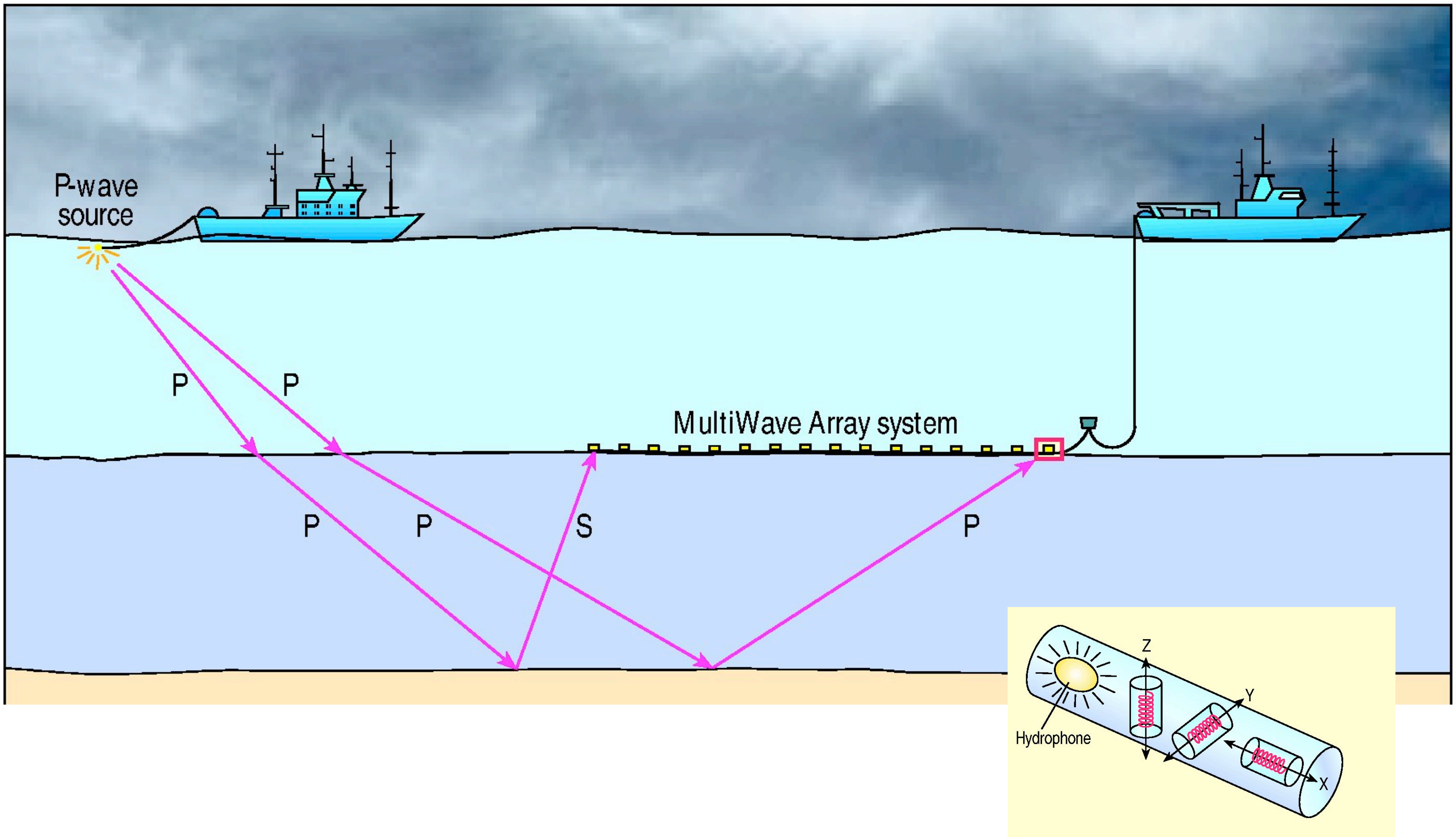
- Ship
- Sensors and sensor gimbaling
- Deployment and coupling

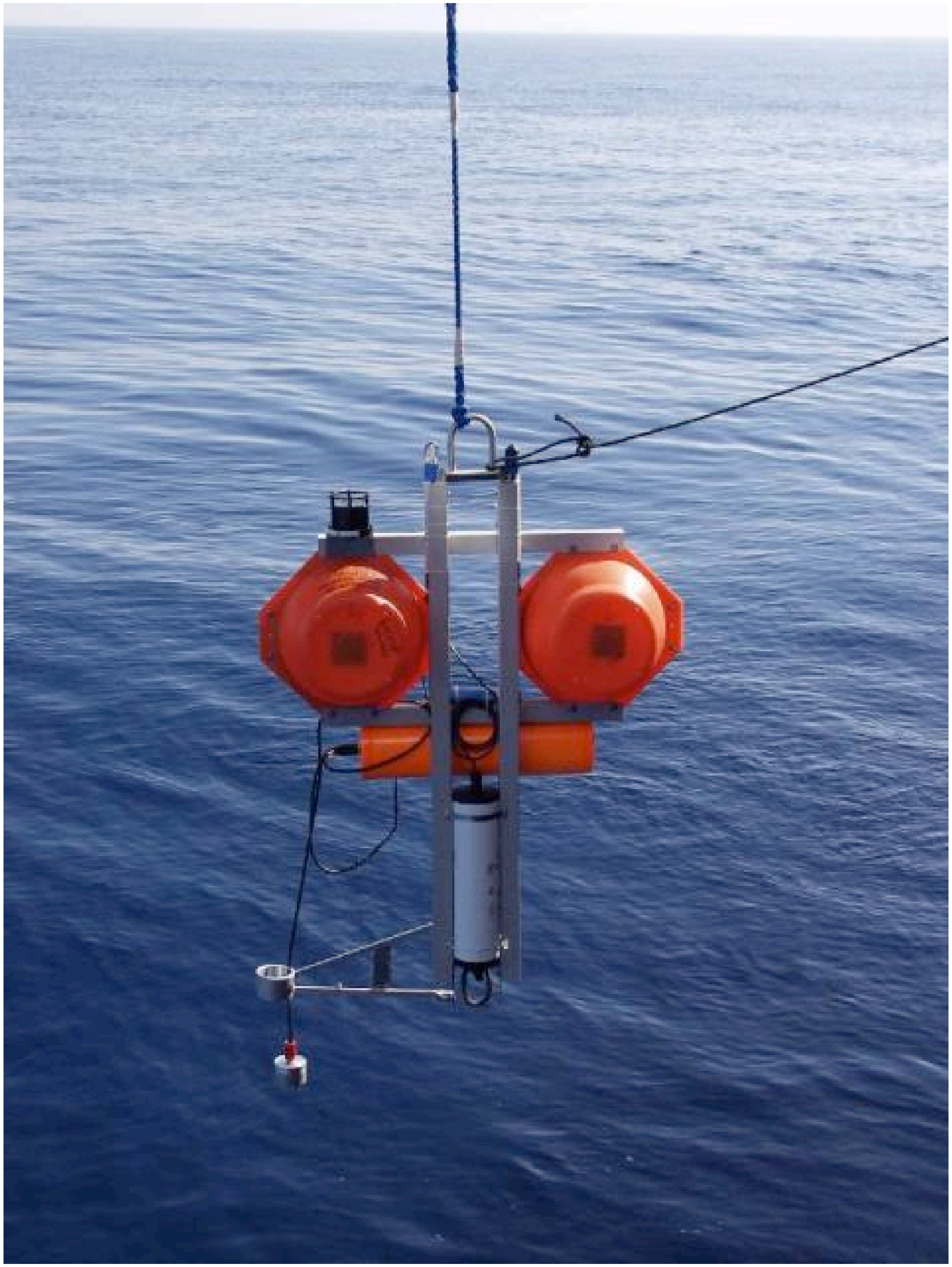

planeterde
POLARSTERN



Arni Fridriksson , Tjörnes Fracture Zone Iceland 2004

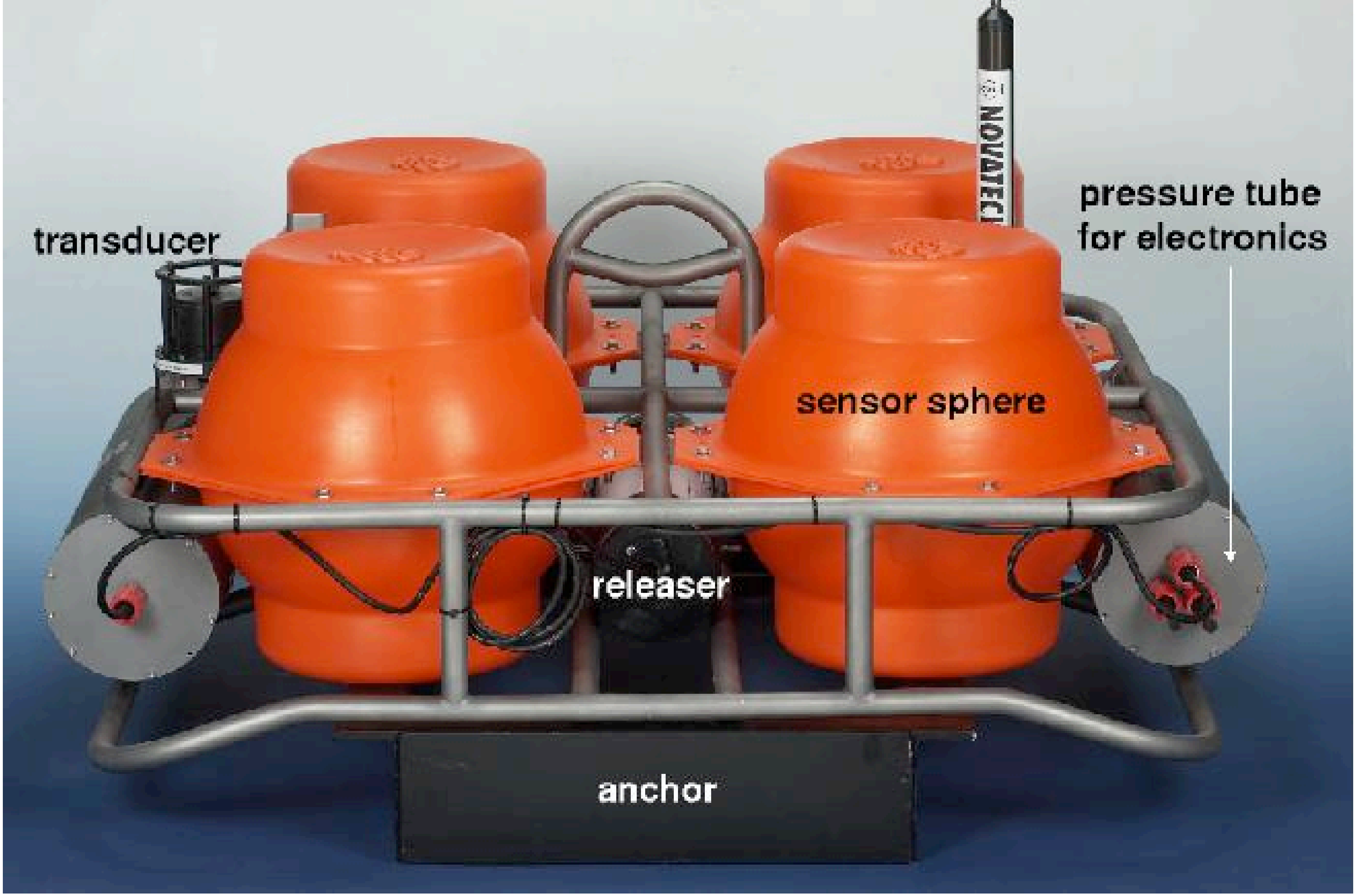
4C ocean bottom cables





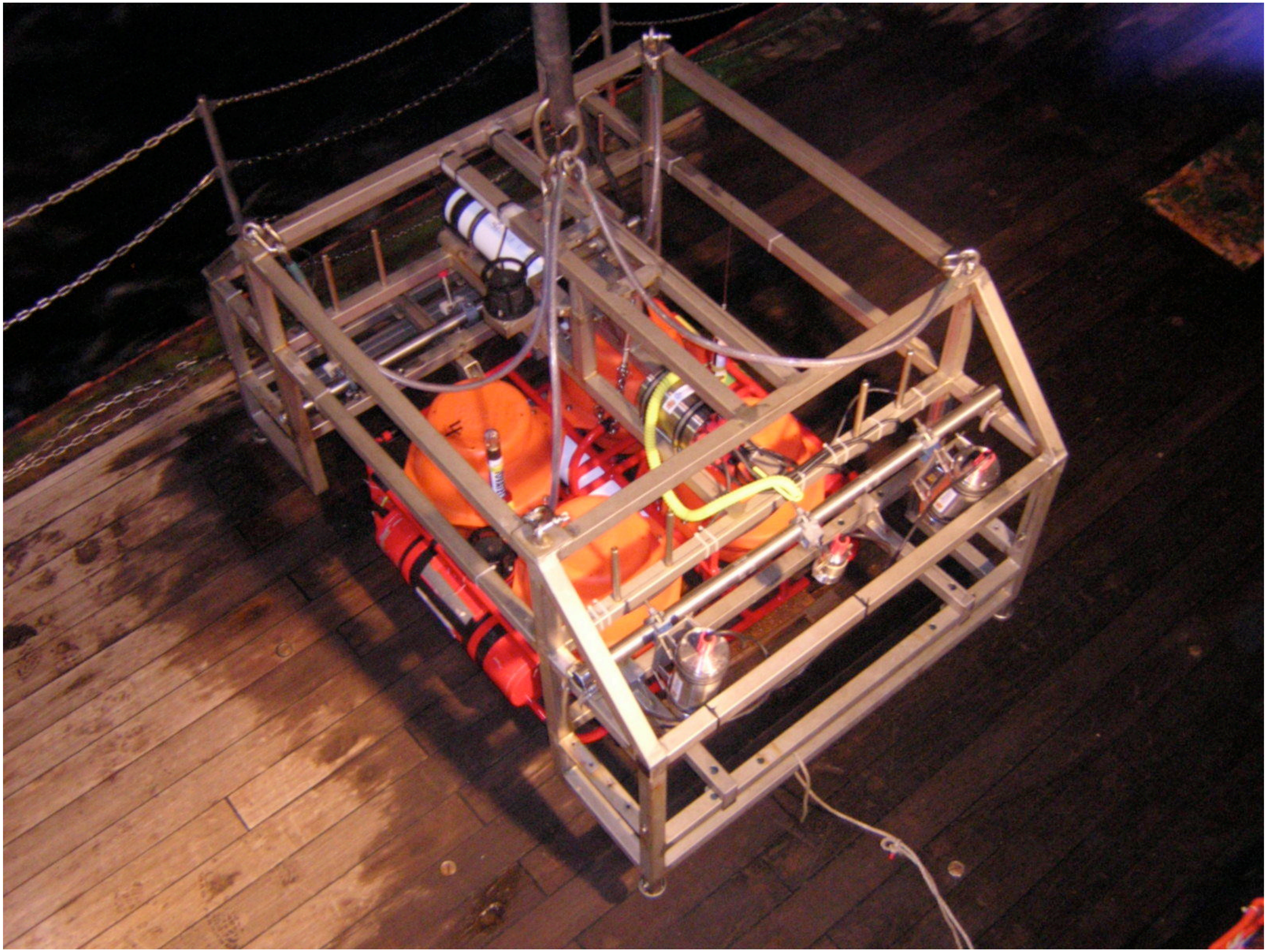
Hydrophone &
short period geophone
(Hamburg University)

Wide-band seismic station (Hamburg University)



wide-band seismic station (IfM-Geomar)

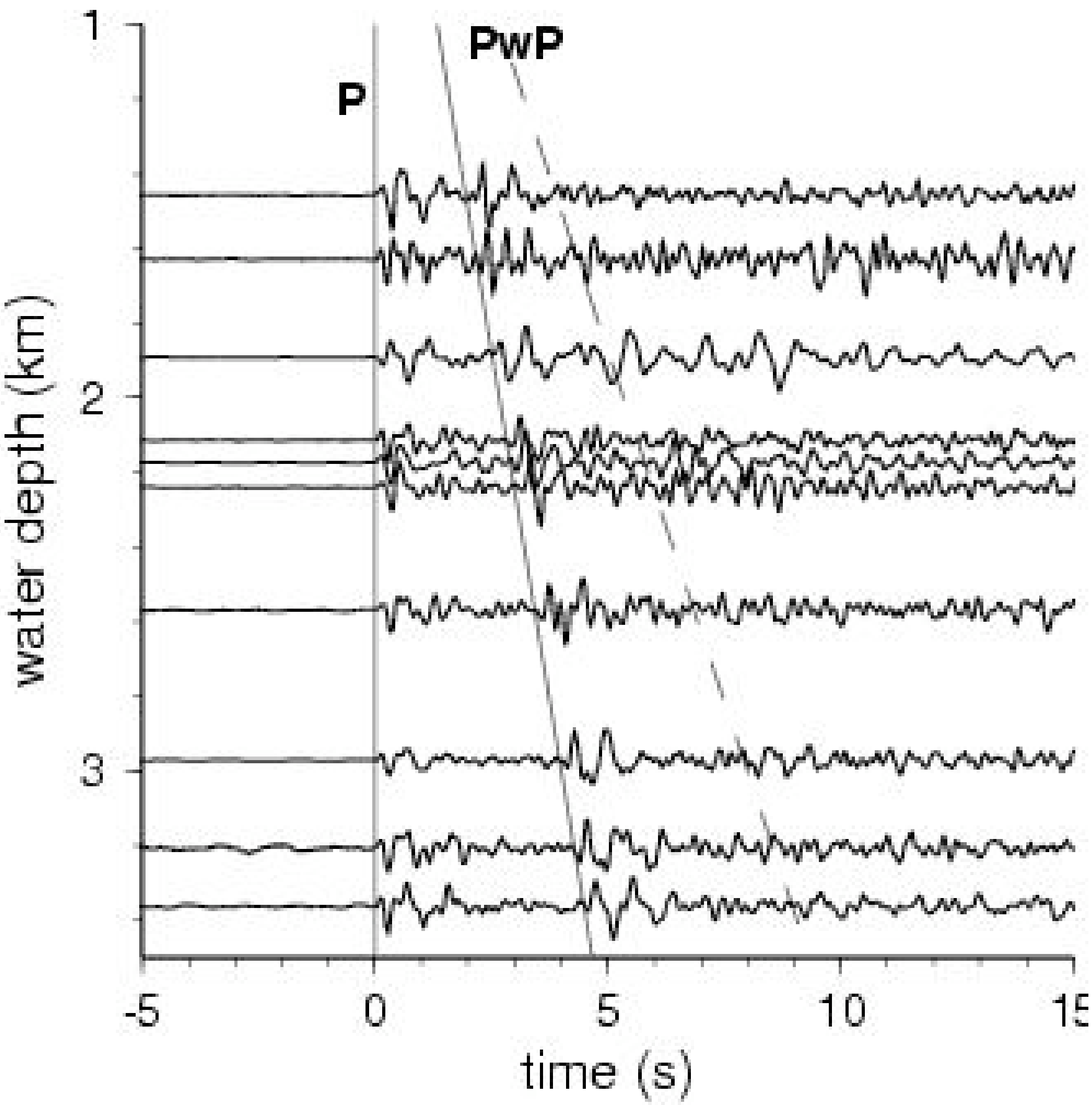
OBS deployment frame



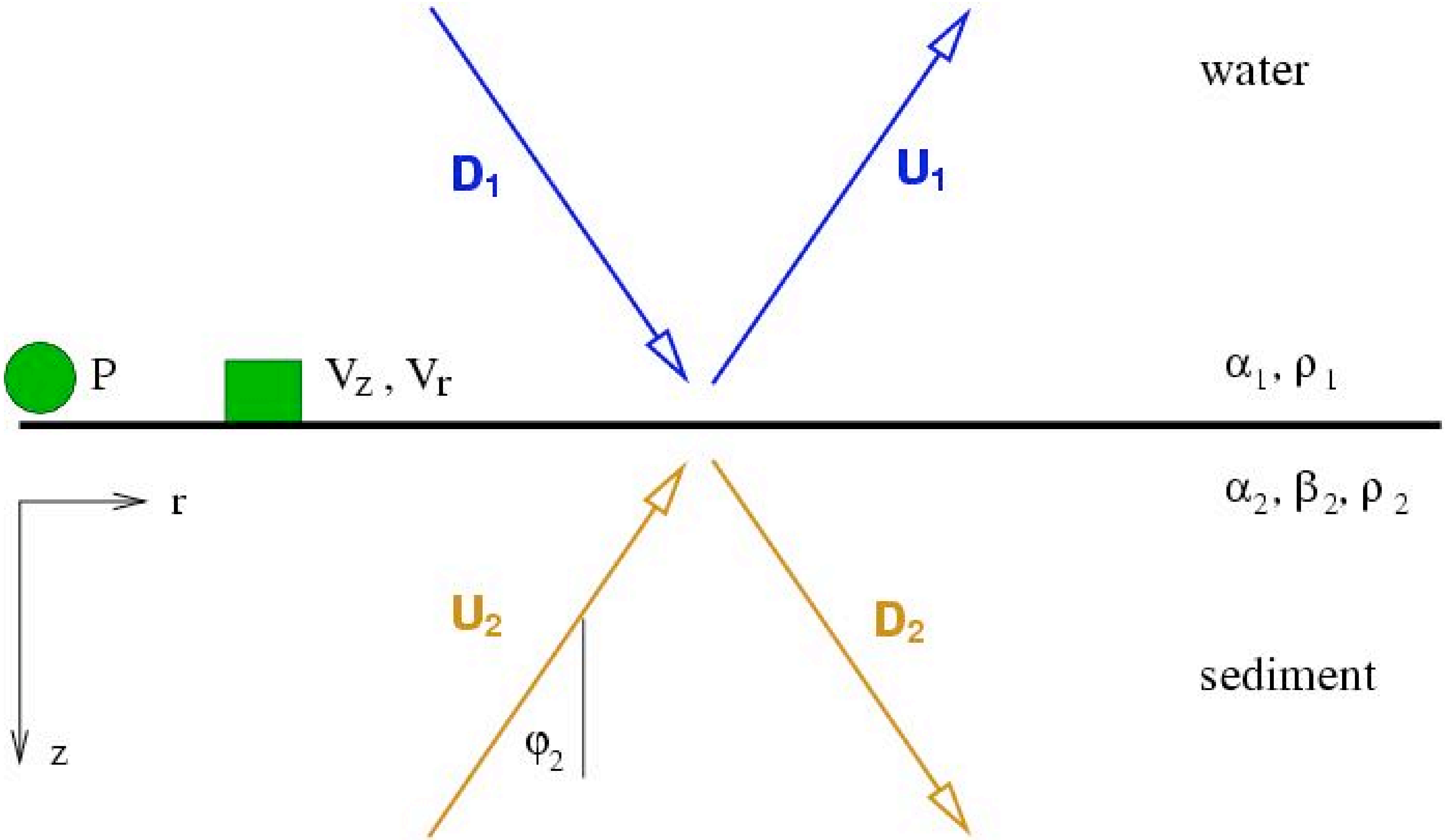
Problem 2: the water layer

- Water layer multiples
- Waveform decomposition to attenuate multiples
- Potential applications for receiver functions and travel-time residuals

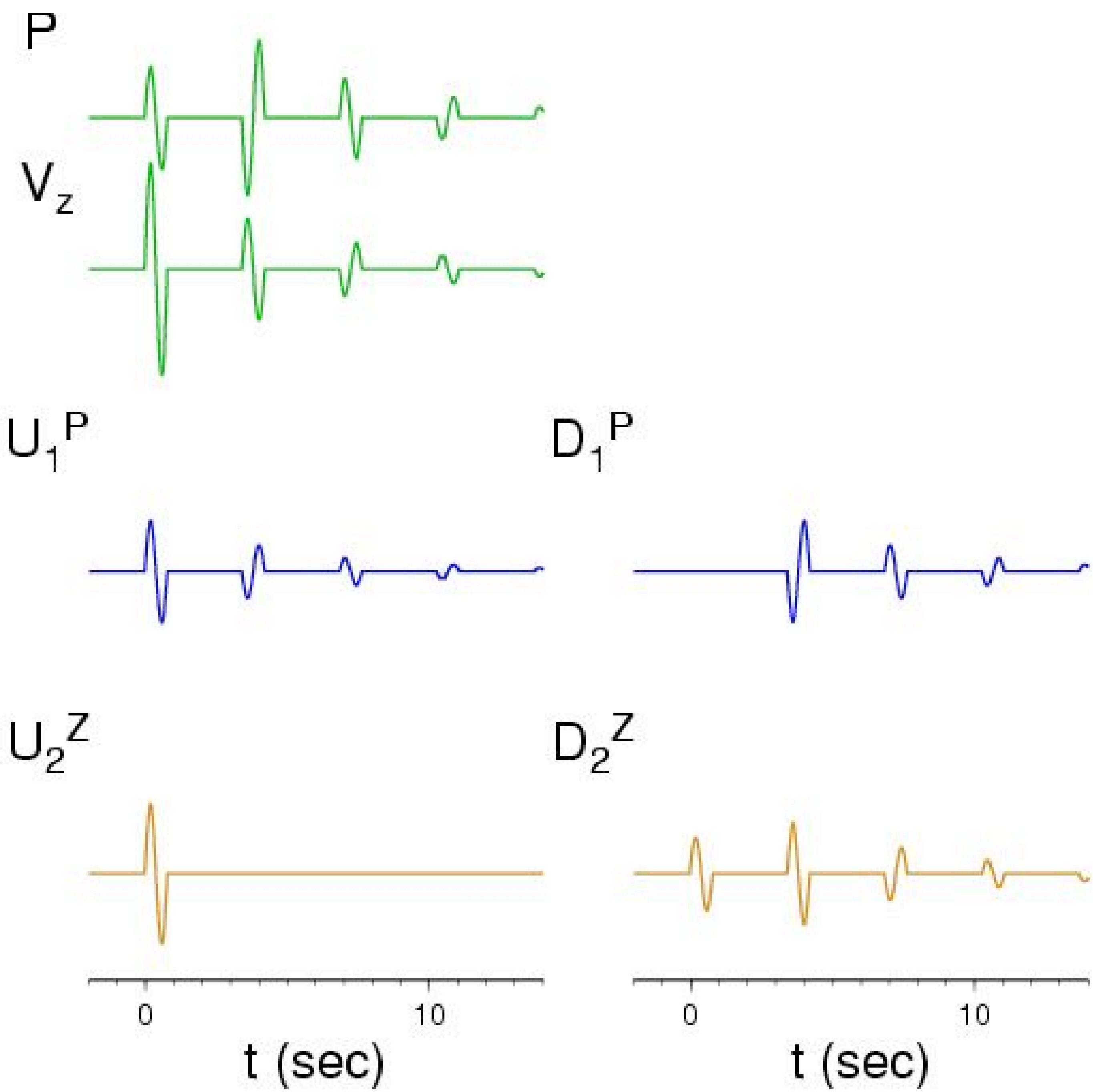
Deep local earthquake, Tyrrhenian Sea, Ml=4



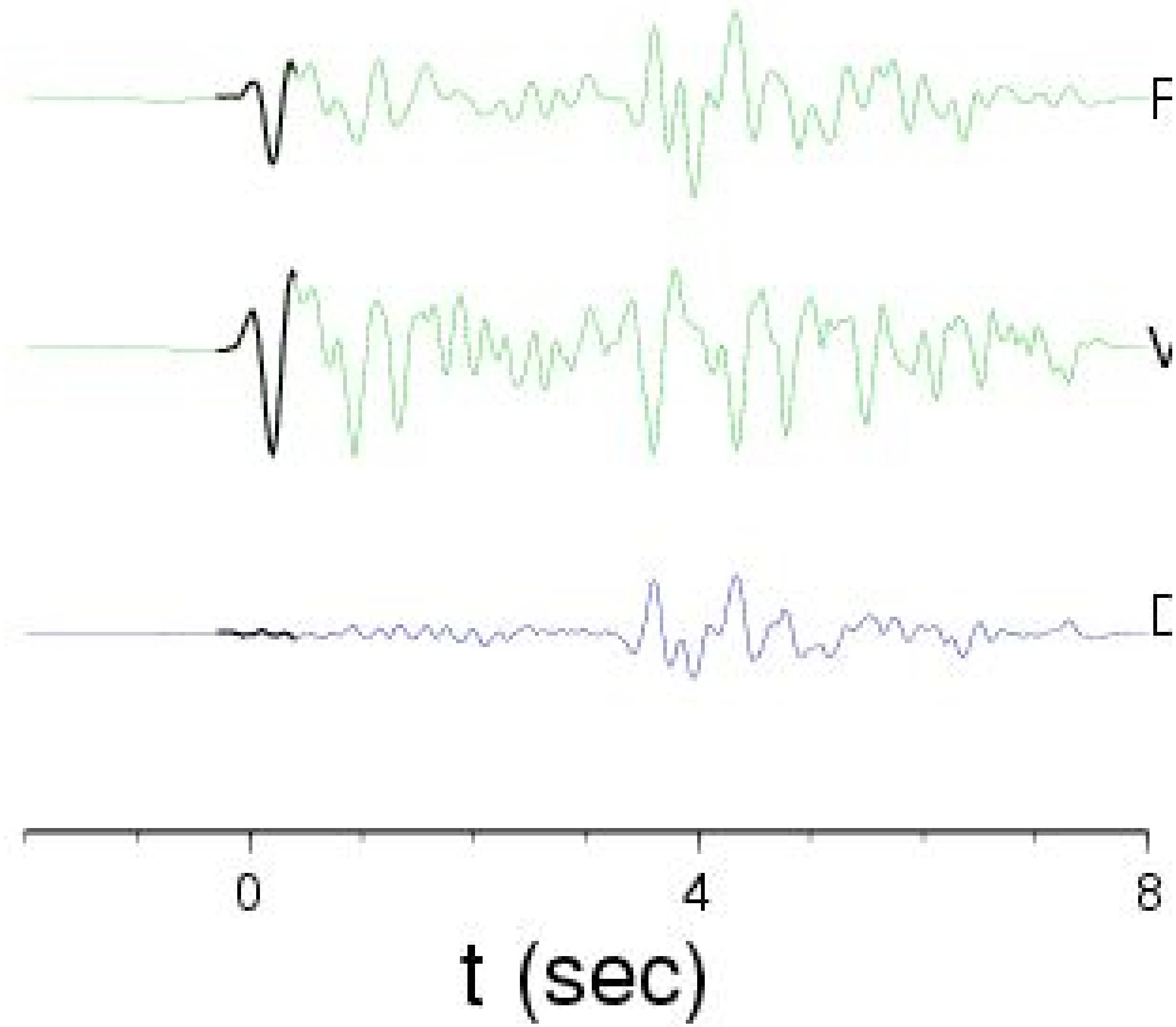
Waveform decomposition from 4C measurments



e.g. Amundson & Reitan (Geophysics, 1995), Thorwart & Dahm (GJI, 2005)



P
V_z
U_1^P
D_1^P
U_2^Z
D_2^Z
0
10
t (sec)
0
10
t (sec)

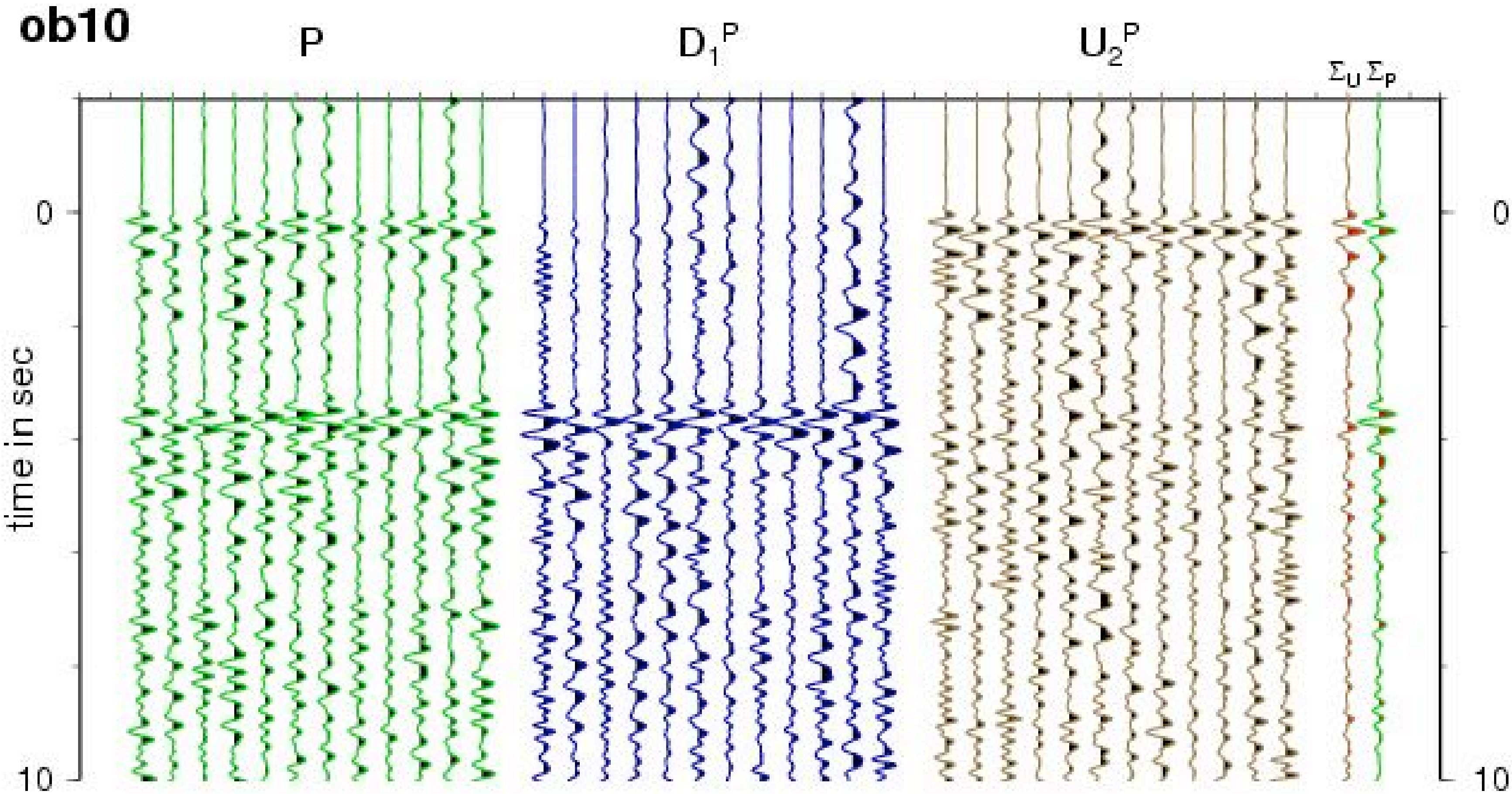


P

Z

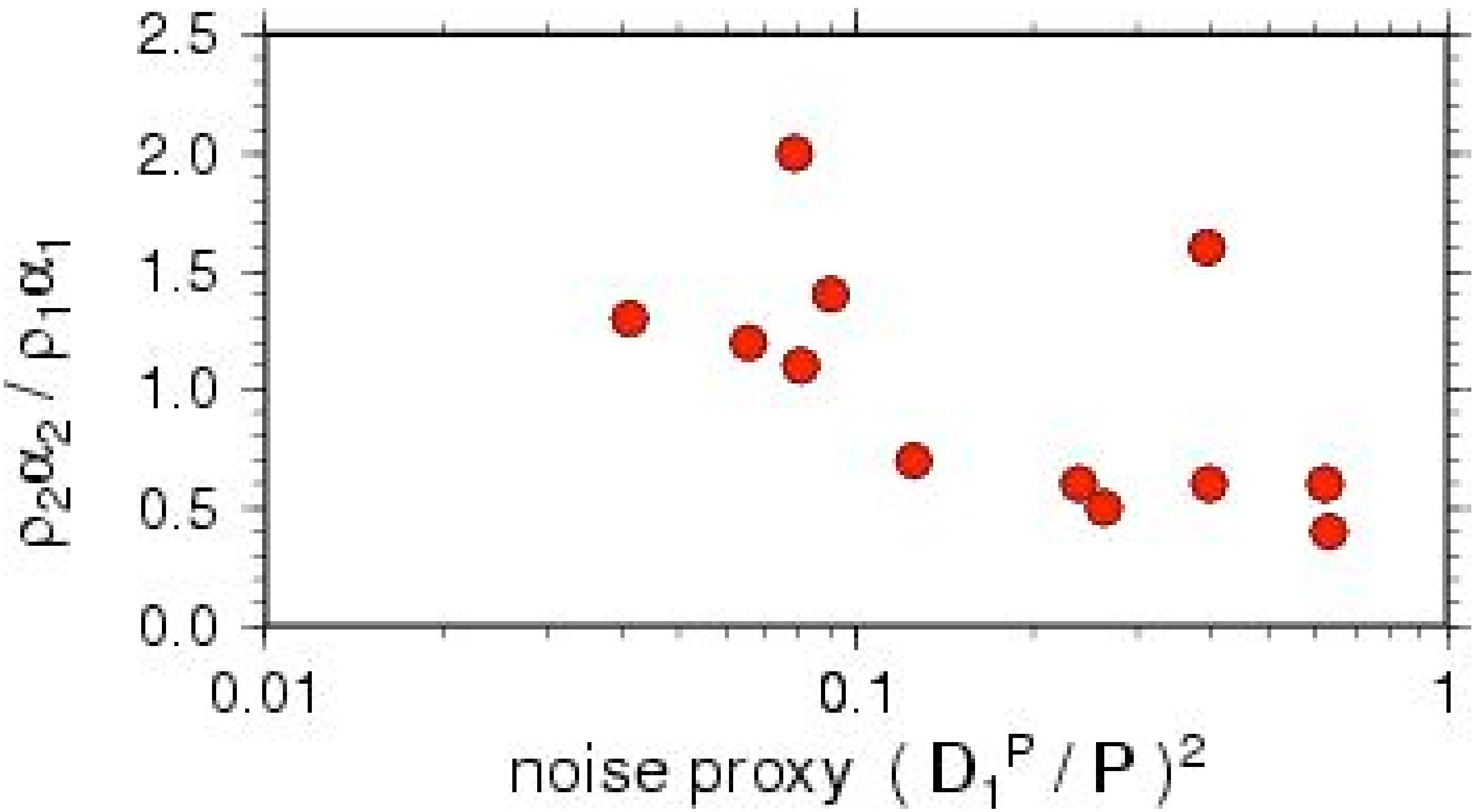
downgoing
in water

Thorwart & Dahm (GJI, 2005)

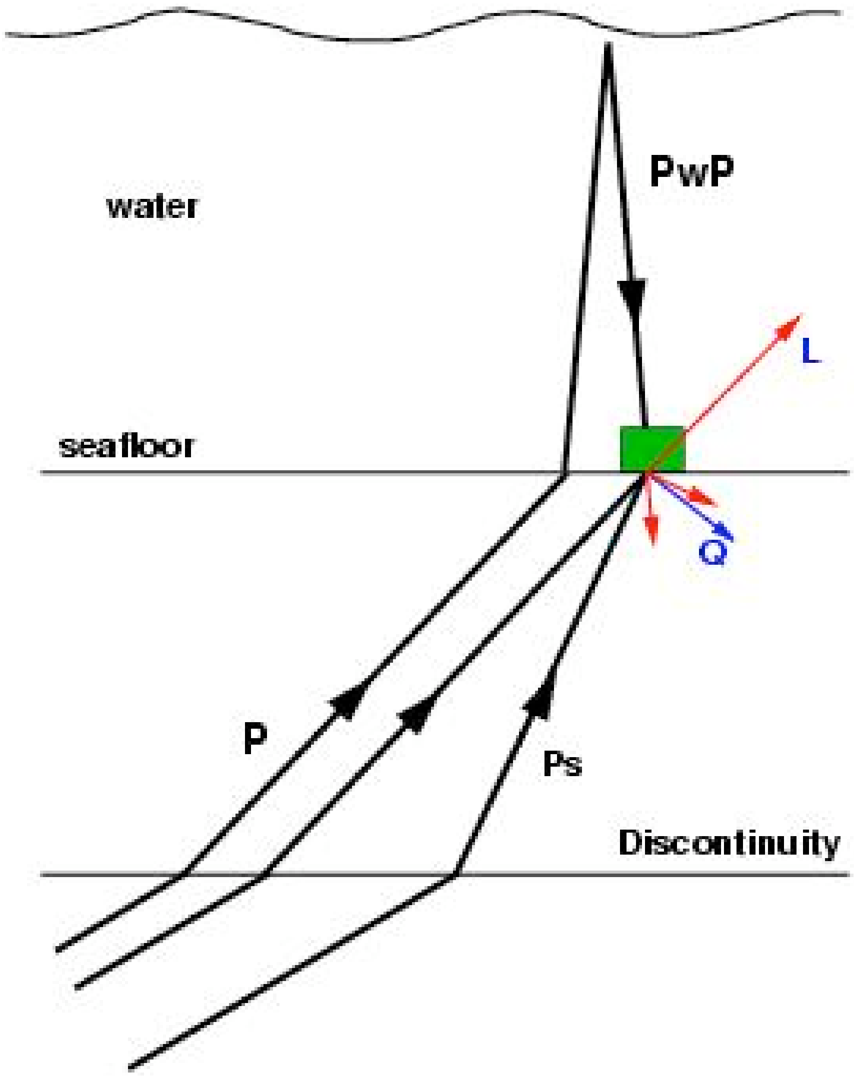


original down water up sediment

P-wave impedance contrast

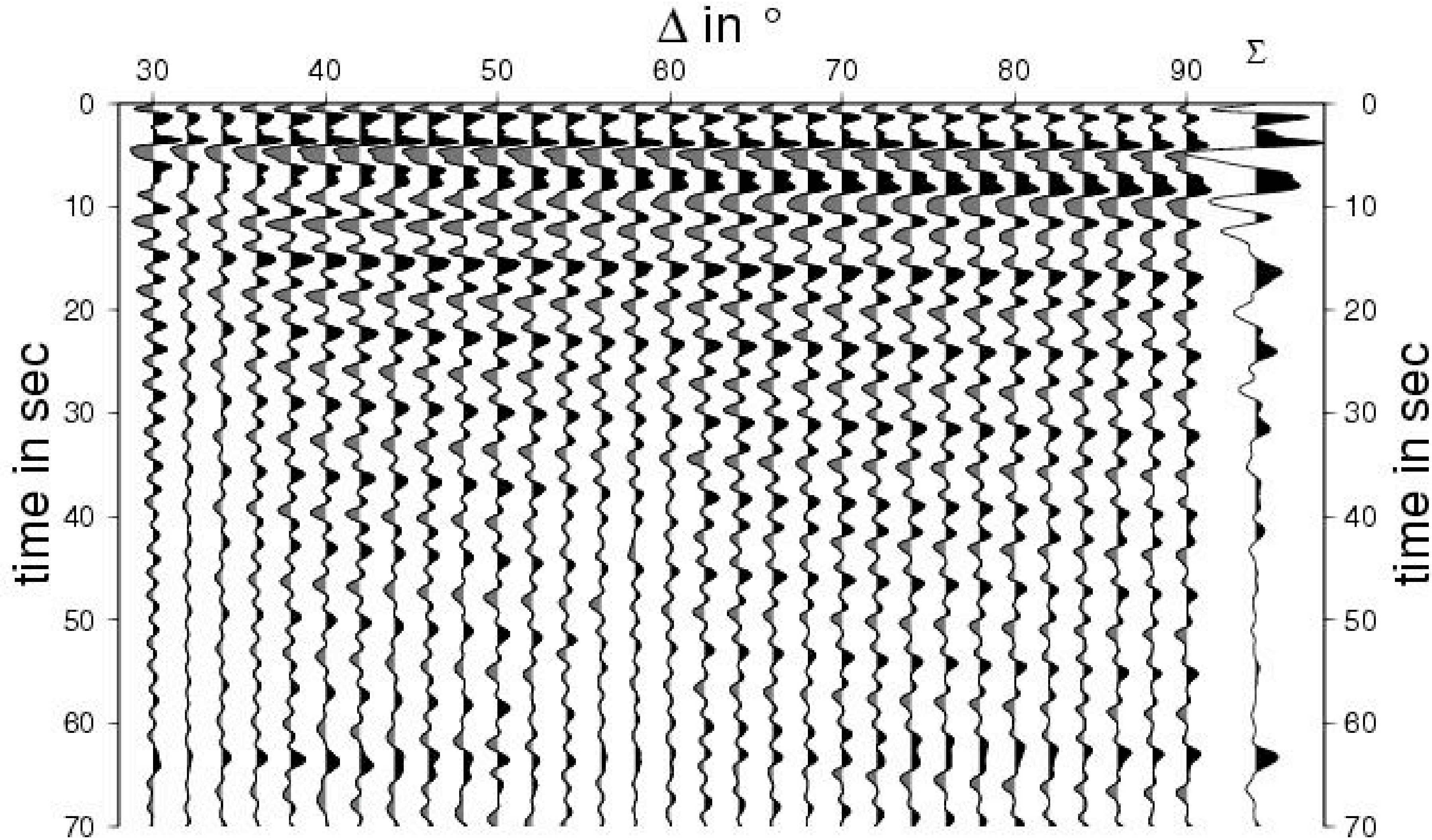


Receiver functions with OBS

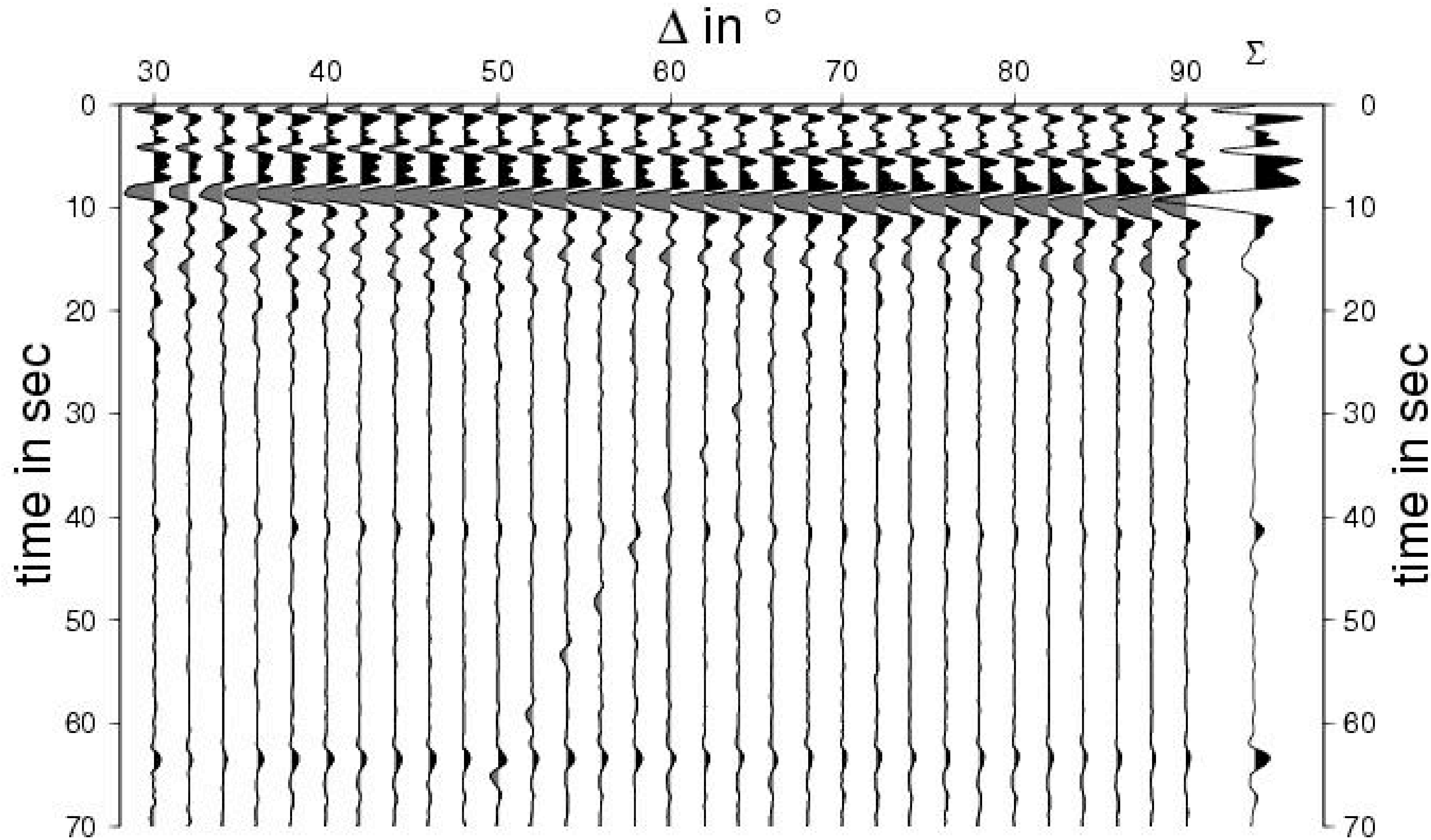


PwP multiples have a large component on in the Q-direction

Synthetic receiver functions

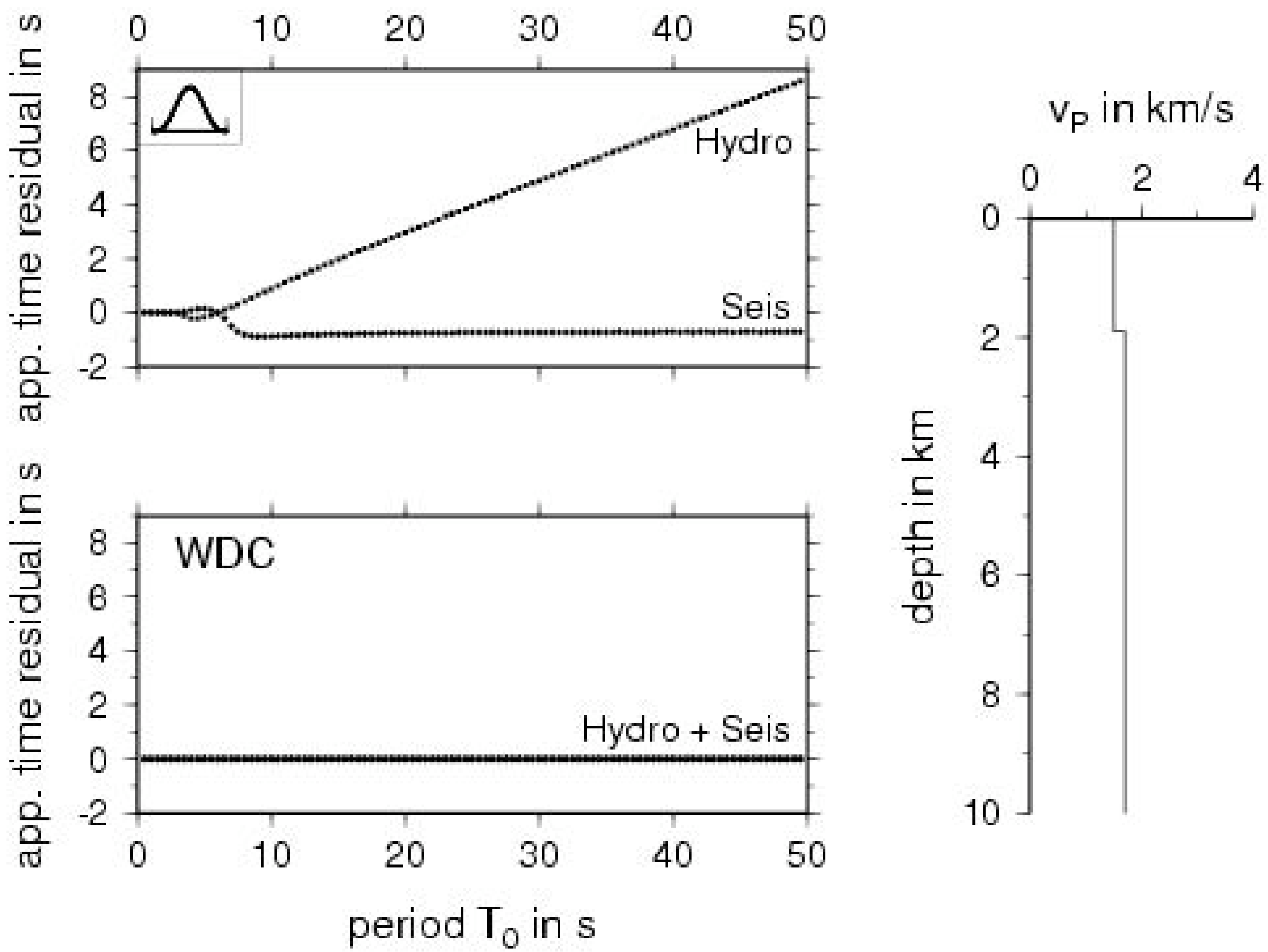


Receiver functions after WF decomposition

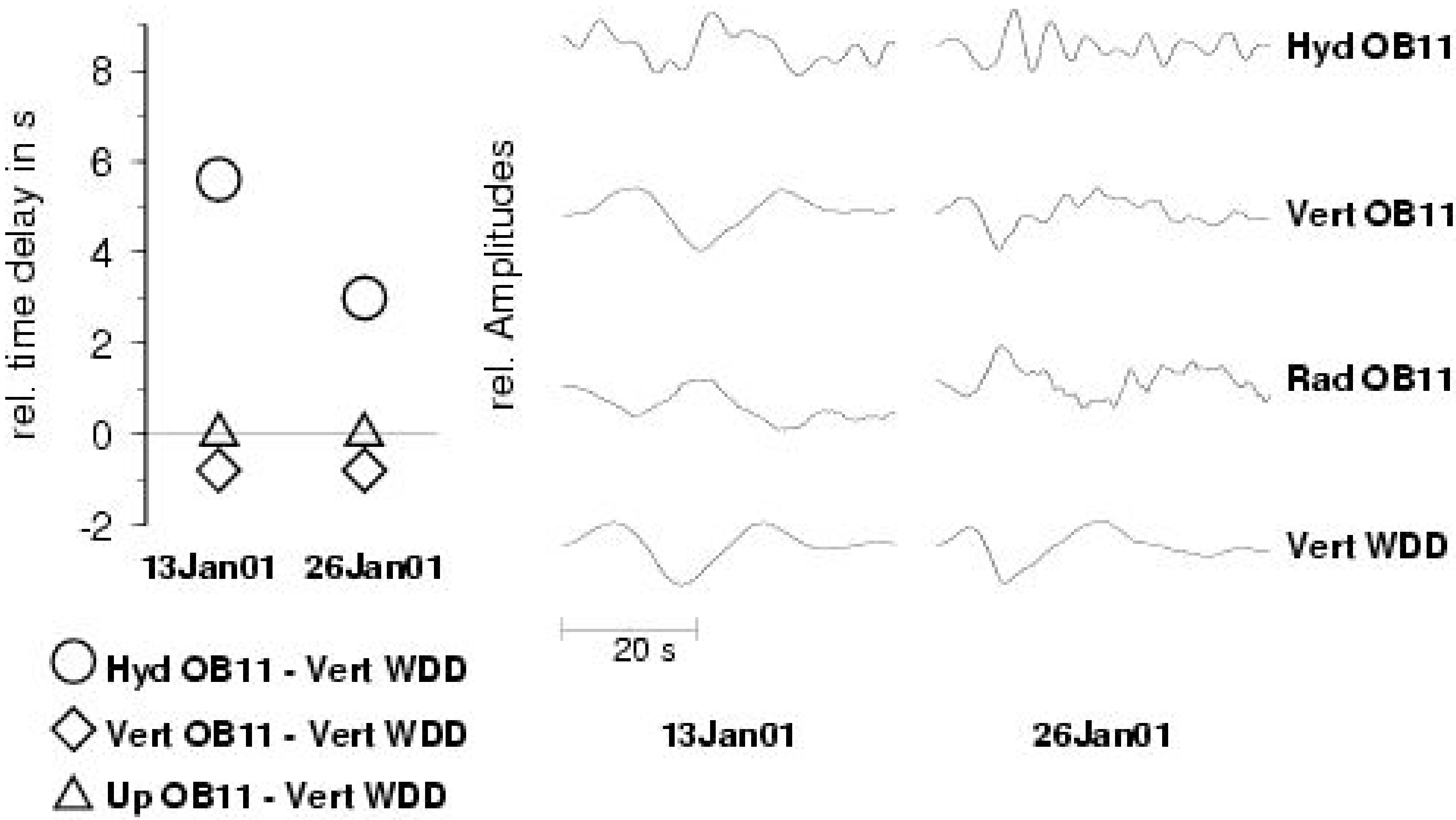


Problem of travel time residuals

Predicted apparent time delays



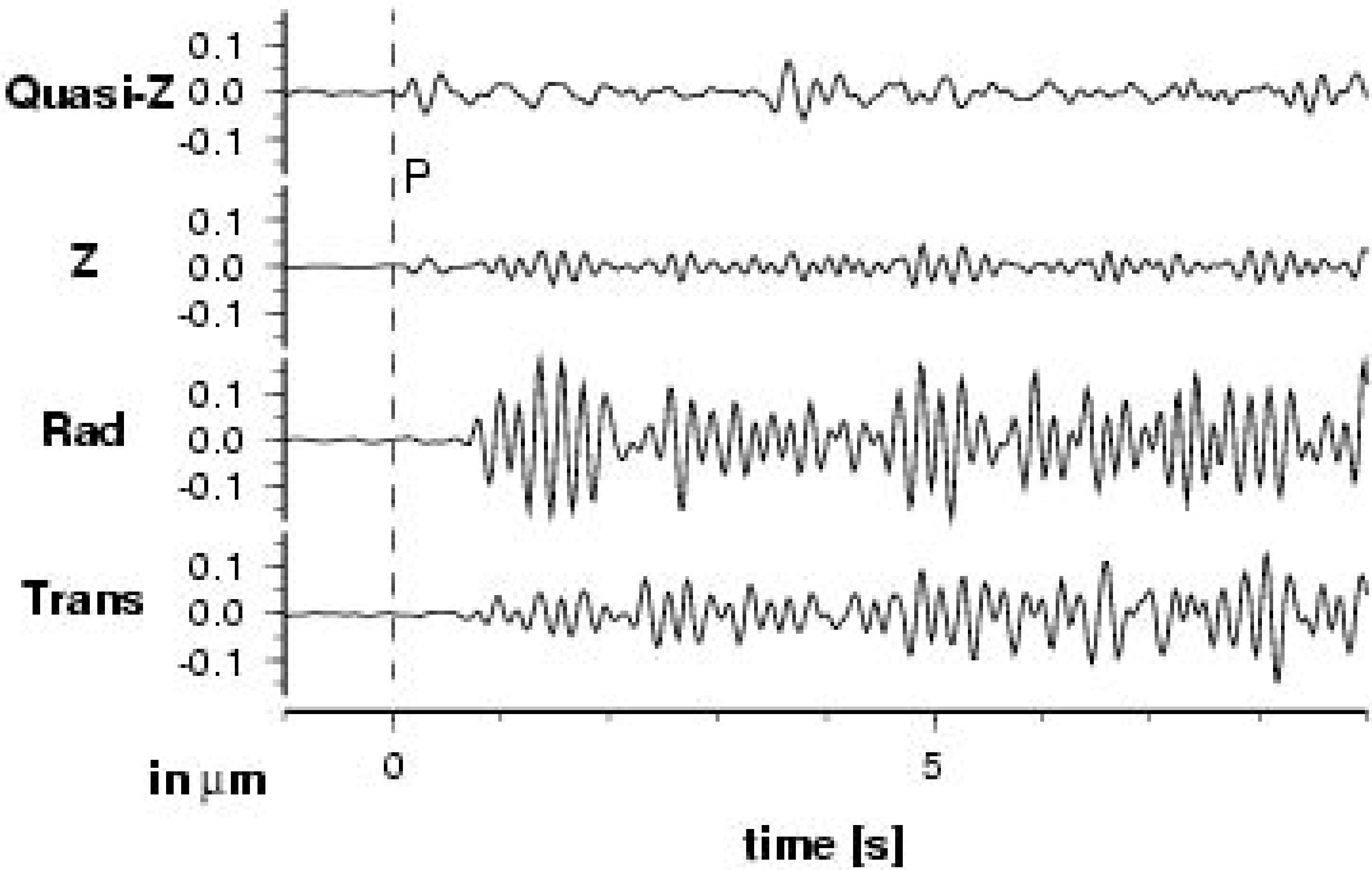
Observed residuals



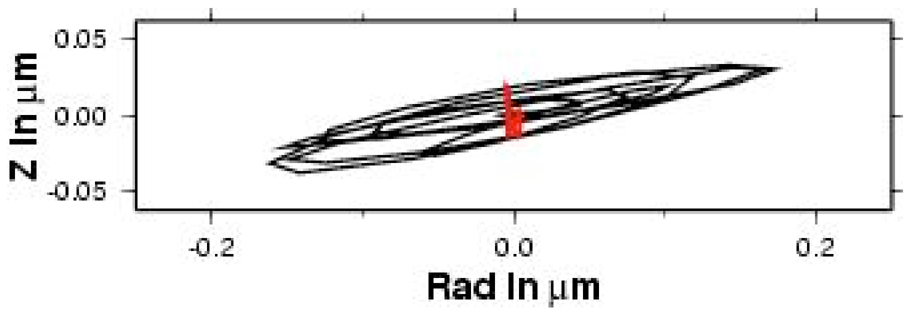
Problem 3:
the mushy and sediment layer

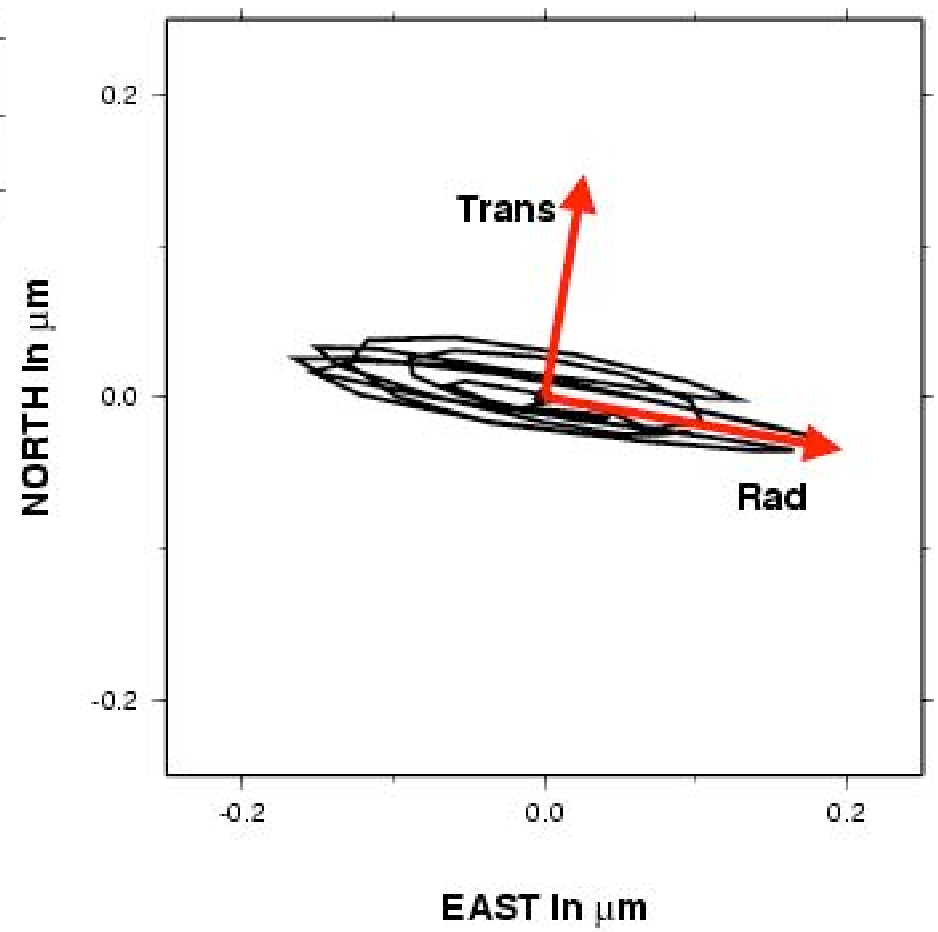
- Ringing and resonances
- Interface waves

Characteristics of ringing phases

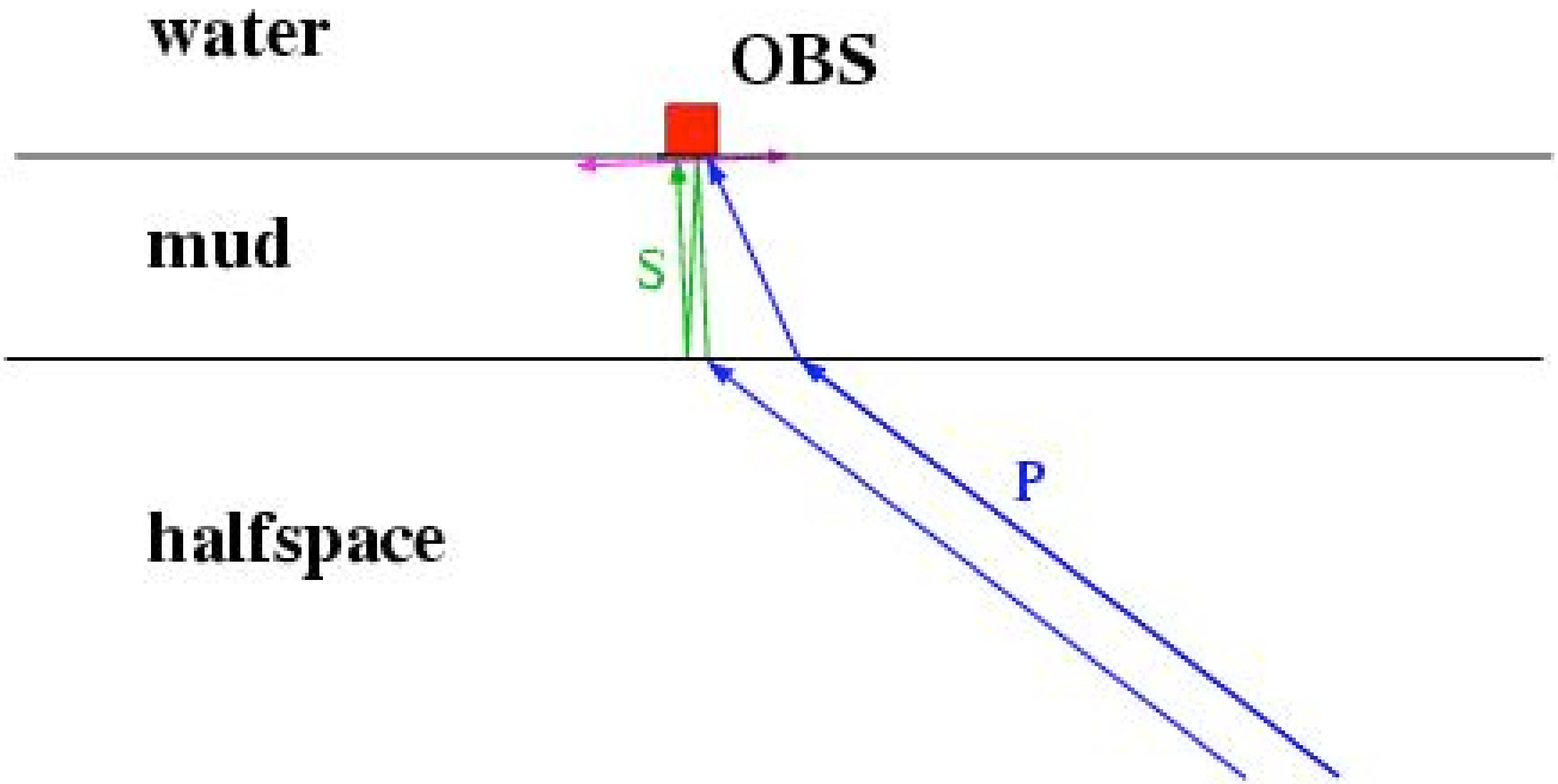


Polarisation of ringing phases

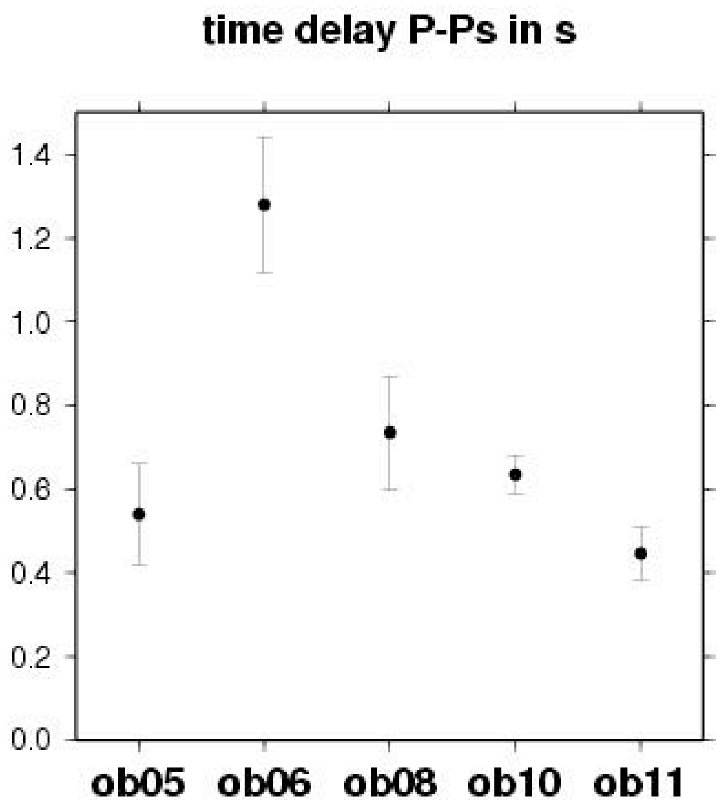


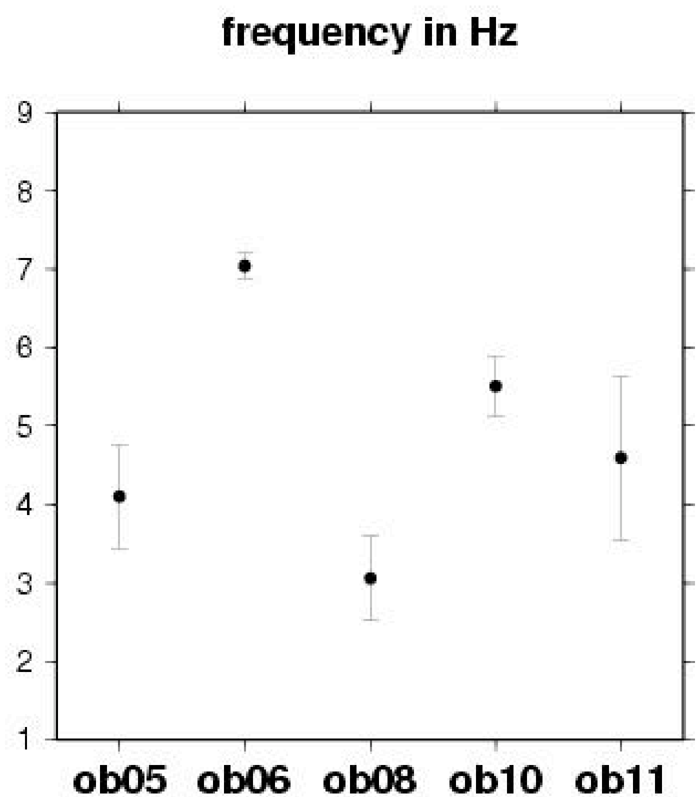


simple model

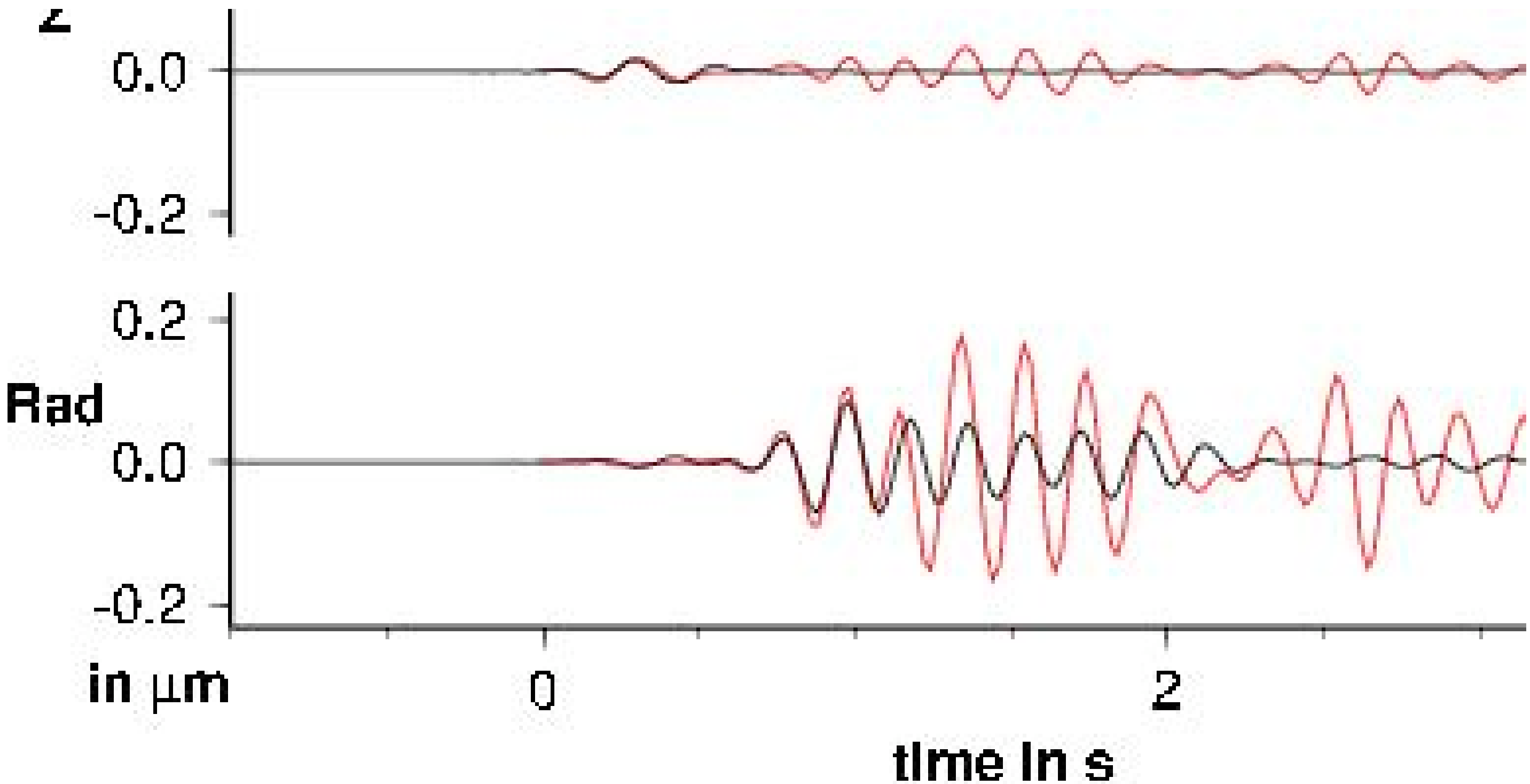


Time delay and resonance frequency

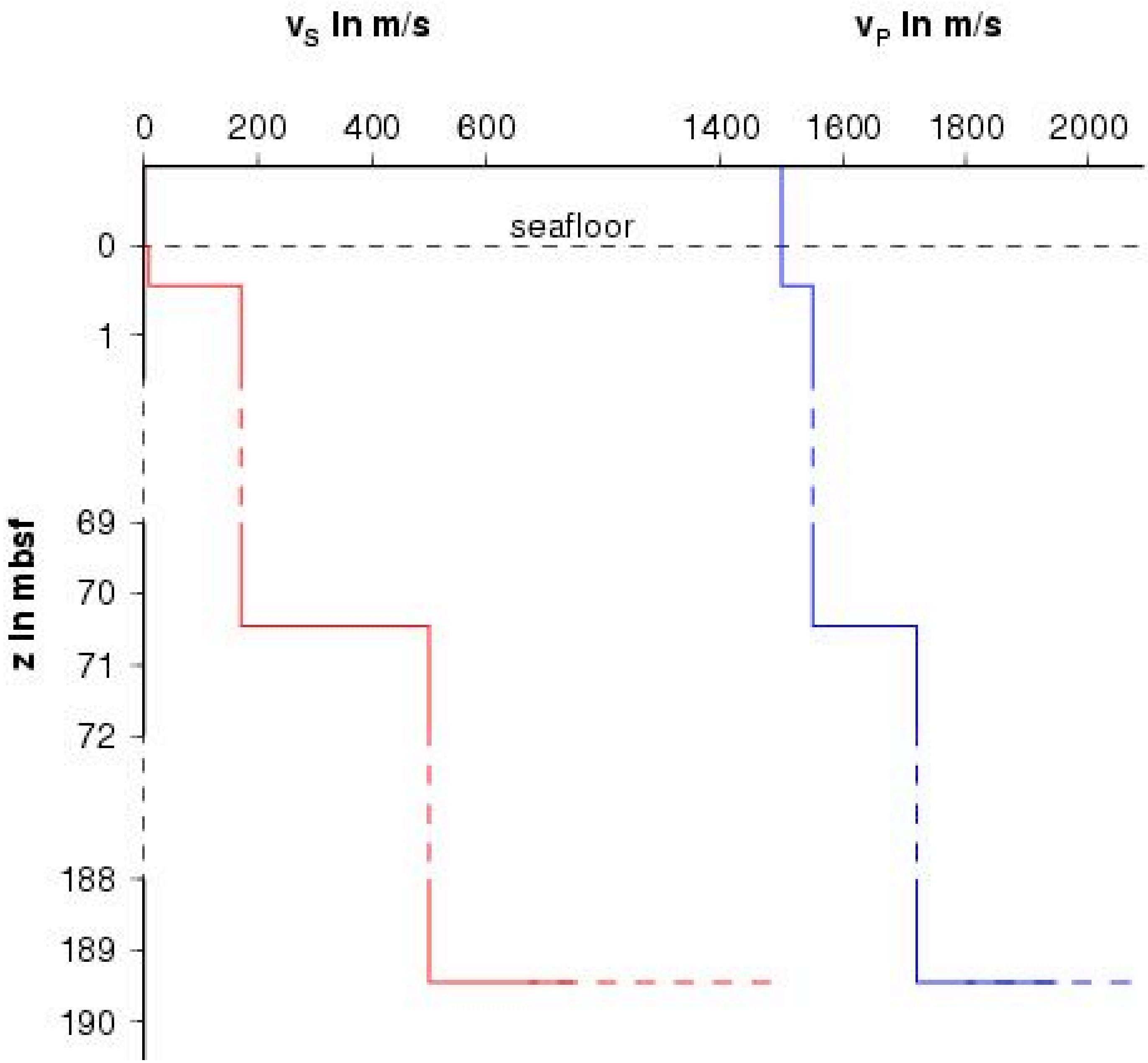




Monte Carlo modeling: best fit

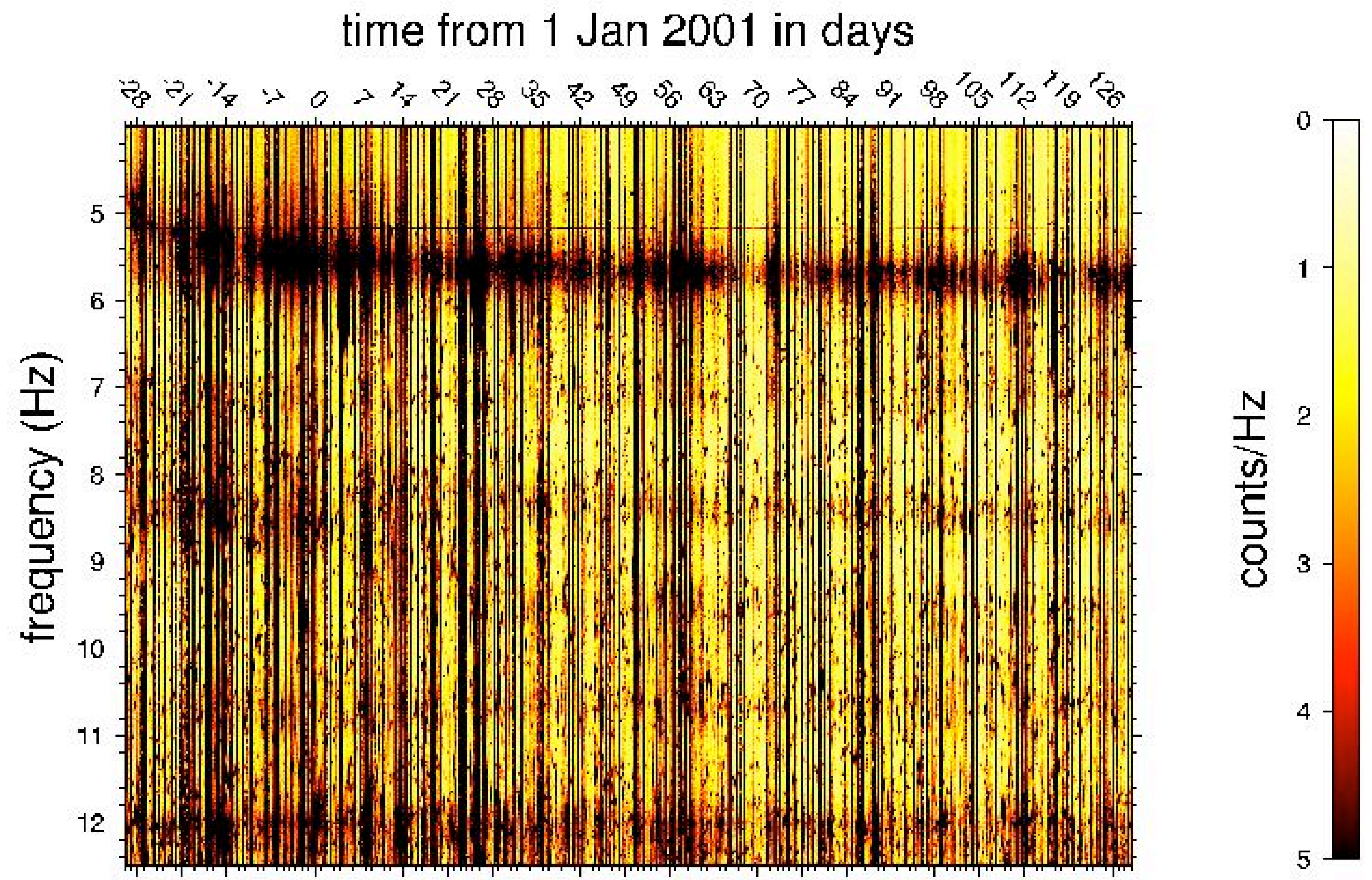


M. Thorwart, PhD thesis 2005



v_S in m/s
v_P in m/s
0
200
400
600
1400
1600
1800
2000
seafloor
0
1
69
70
71
72
188
189
190
z in mbsf

Spectrogram over 6 month (TySea): the shift in the resonance peak of the ringing phase indicates compaction of about 5 cm



Applications

- Estimation of sensor orientation
- Estimation of S-wave velocity
- Finding static time delays for S-waves

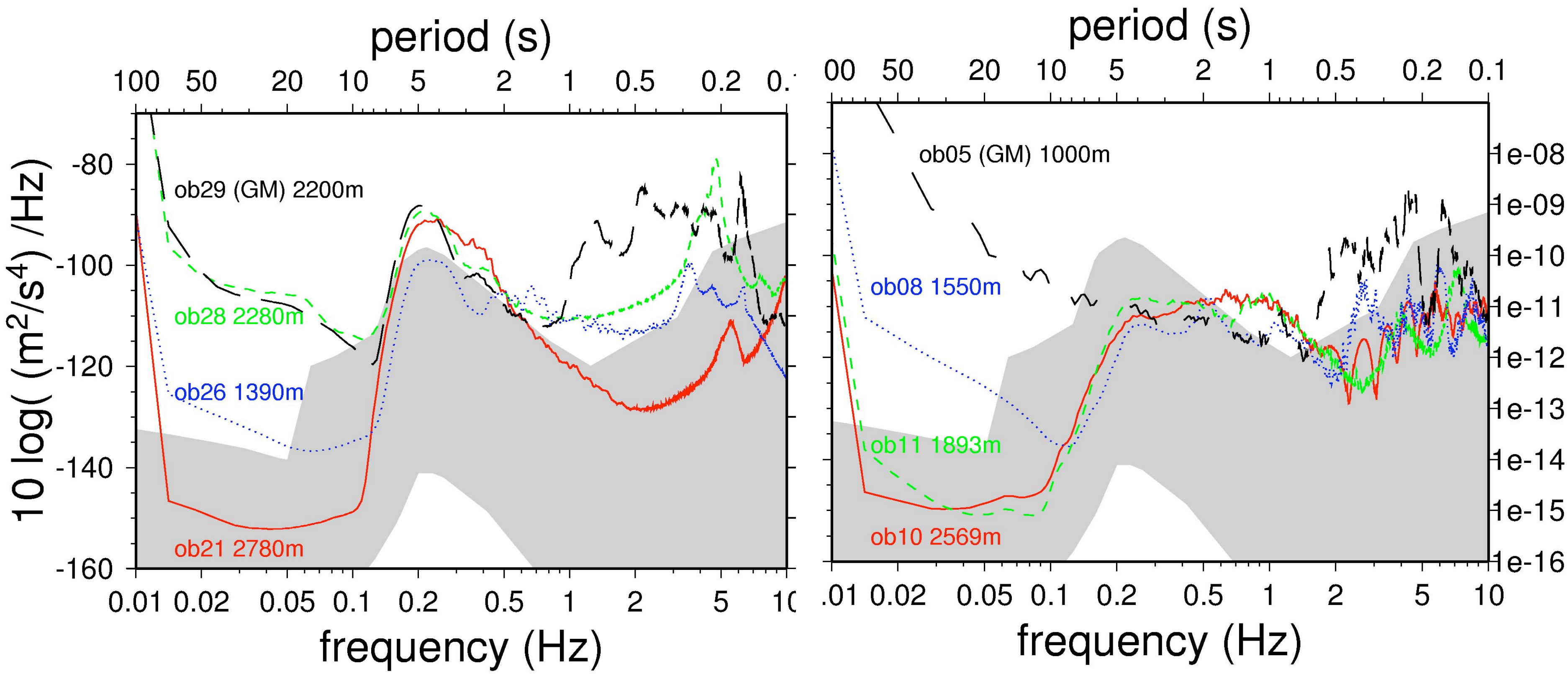
Scholte waves

See poster from Nhi Nguyen this afternoon !

Problem 4: noise

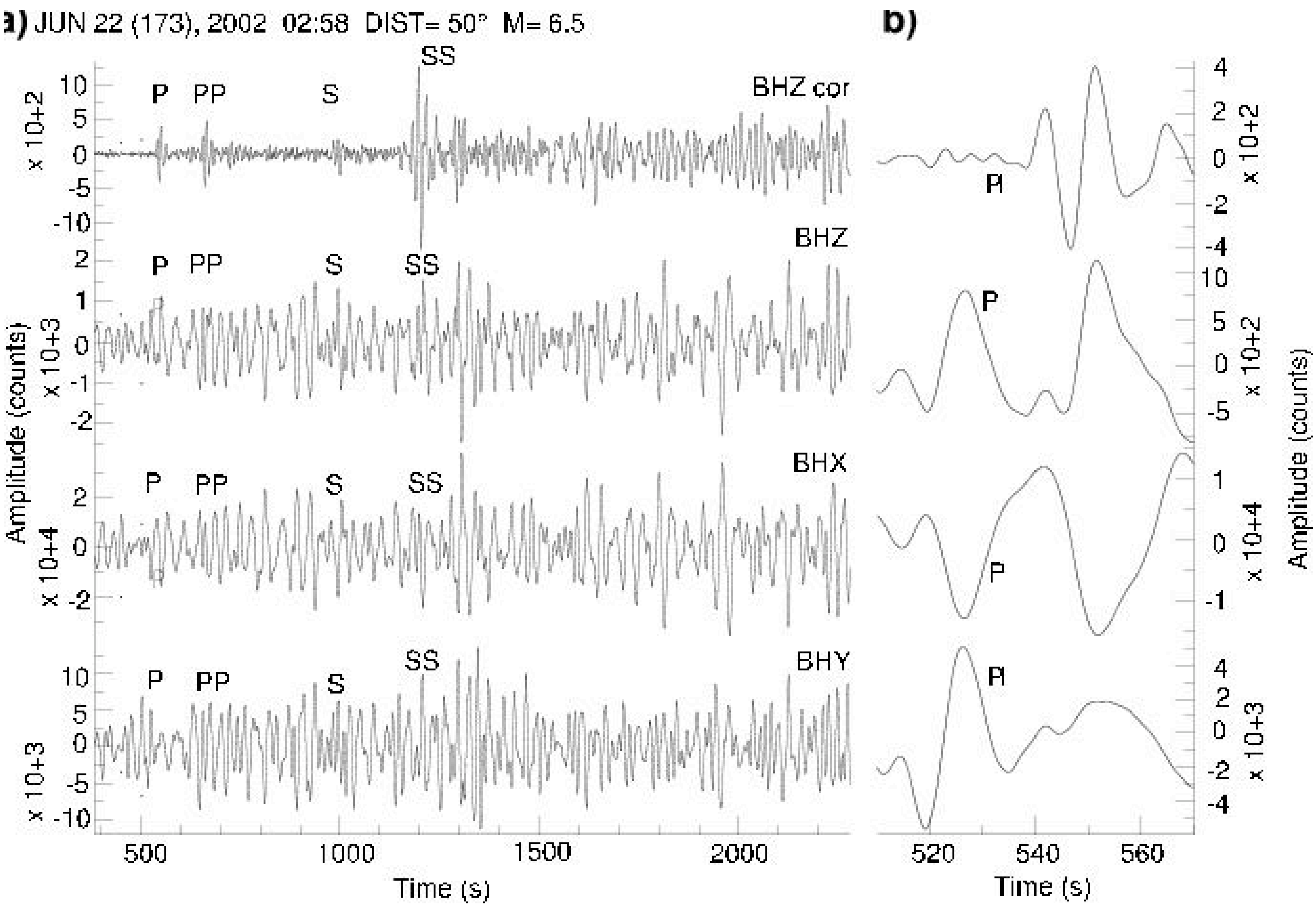
- High frequency noise (>1 Hz)
- Microseismic noise (0.1-1 Hz)
- Low frequency noise and tilt (< 0.1Hz)

PSD noise in the North Atlantic and Tyrrhenian Sea



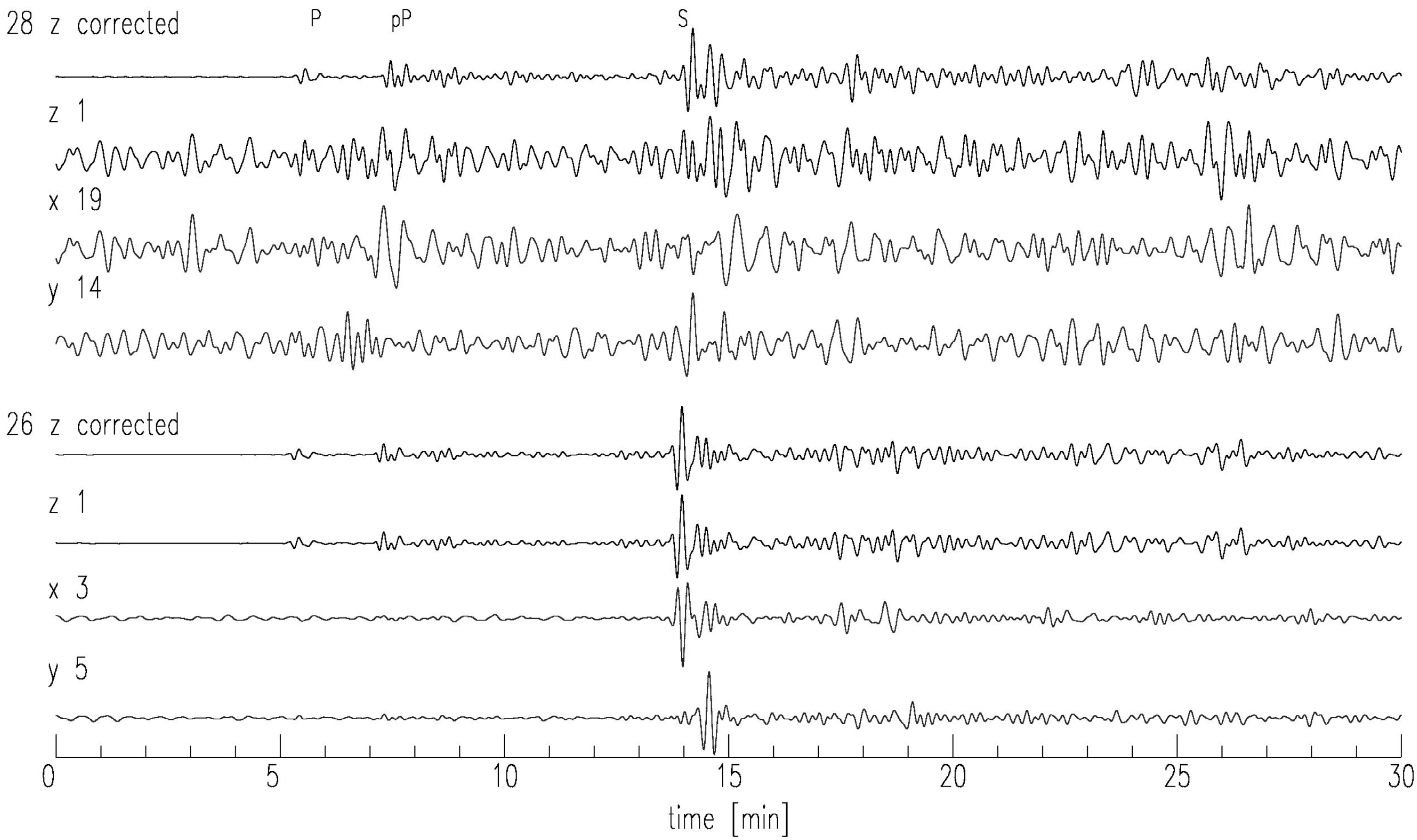
Note: the poor station for f < 0.1 Hz can be improved to the noise level of high fidelity stations (e.g. ob21,10)when tilt-induced noise is removed!

Removal of tilt-induced noise



Dahm, Tilmann, Morgan (BSSA, 2005, in press)

Removal of tilt induced noise



Method by Crawford & Webb

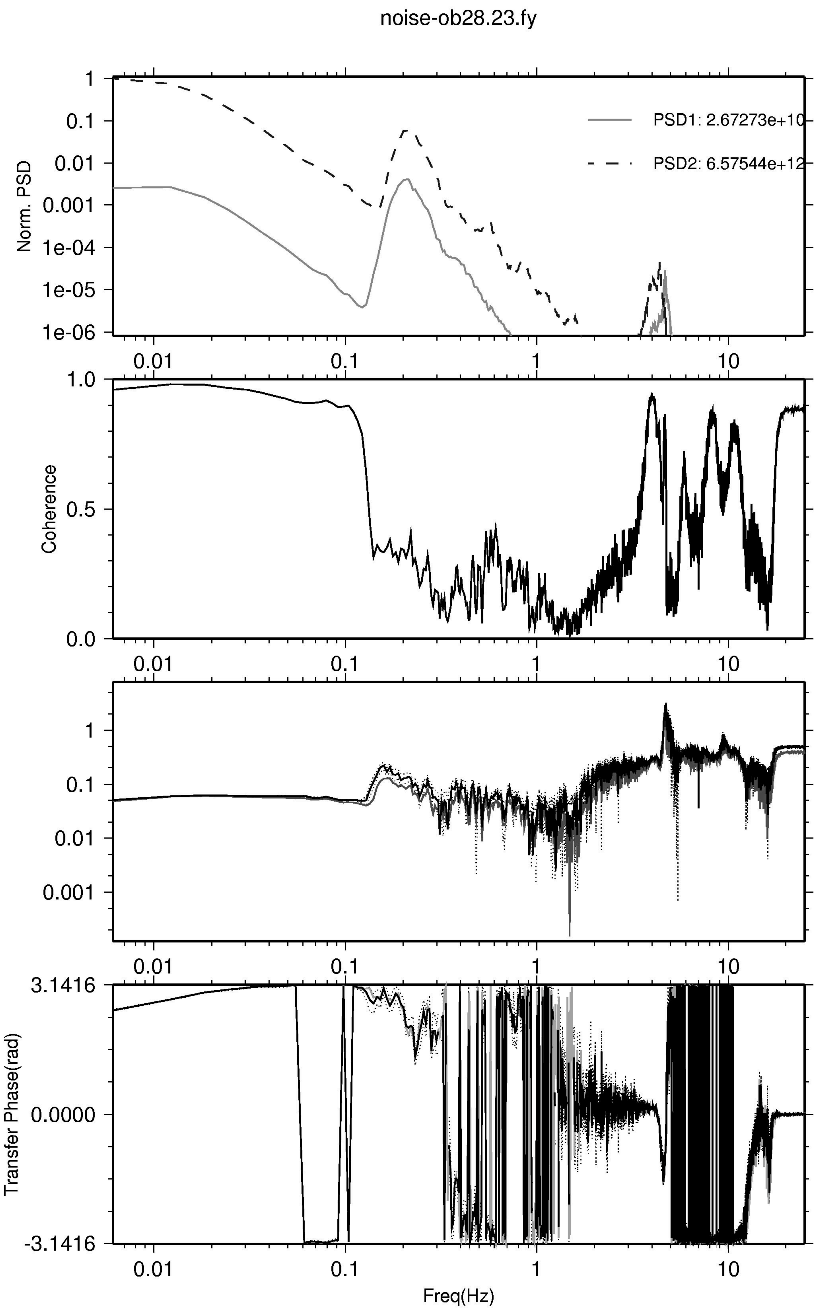
(Crawford & Webb (2000) BSSA 90, 952-963)

Noise below 0.1 Hz on horizontal recordings is typically 2 orders of magnitude larger than on verticals. It is generated by transient tilt.

A high coherence between noise on the vertical and horizontal components indicates a poorly leveled station (static tilt).

The tilt noise signal on the vertical is removed by subtracting the cross-over signal predicted from the horizontal recordings.

Example of transfer function estimation



PSD of Z and X component

Coherency

Amplitude of transfer function

Phase of transfer function

Dahm, Tilmann, Morgan (BSSA,2005)

Estimated static tilt from noise

Tyrrhenian Sea

ob05	ob06	0b08	ob10	0b11
0.3	(34)	2.1	1.2	1.3

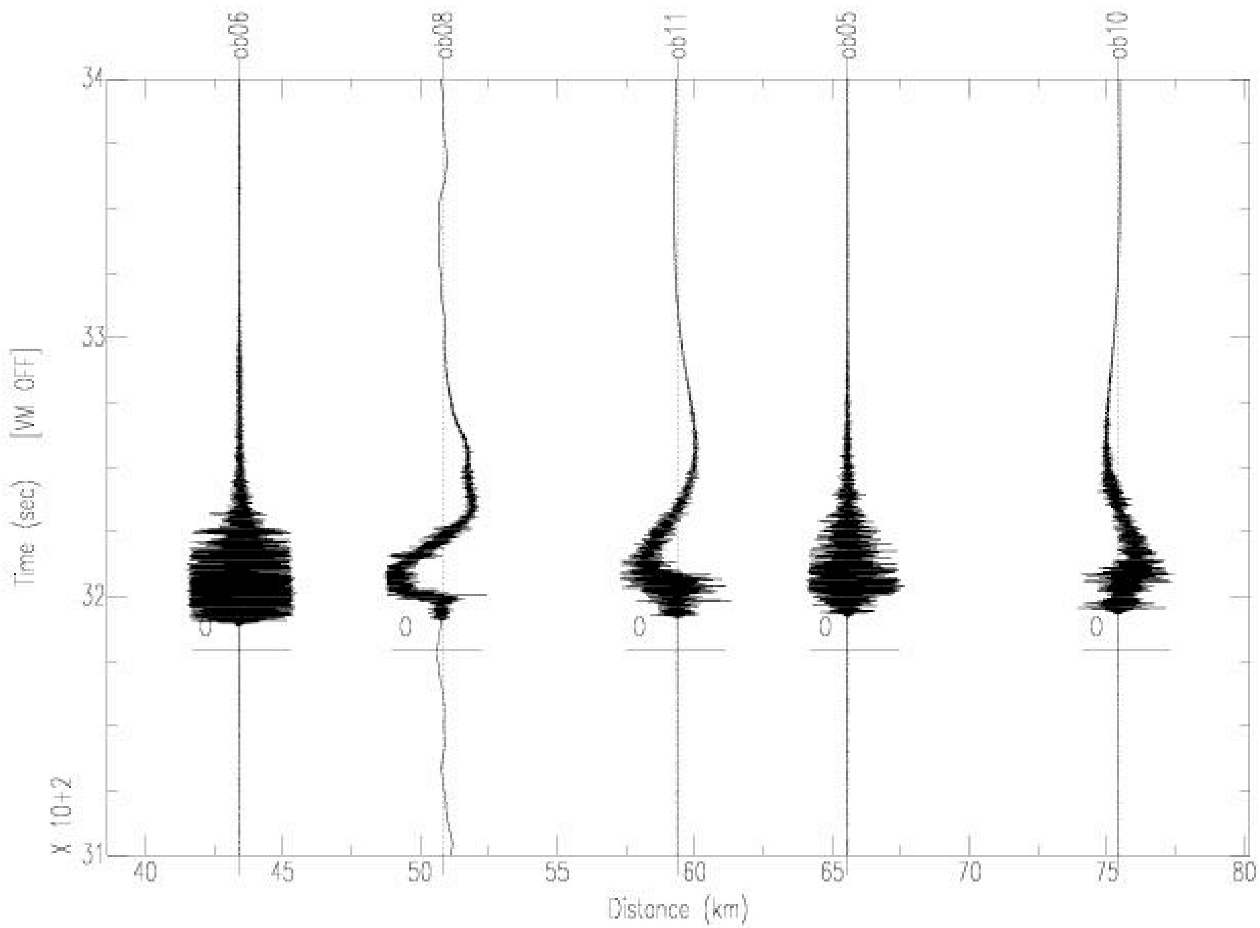
North Atlantic

ob21	ob23	ob26	ob28	ob29
0.3	0.7	0.8	7.1	1.9

3. Open questions

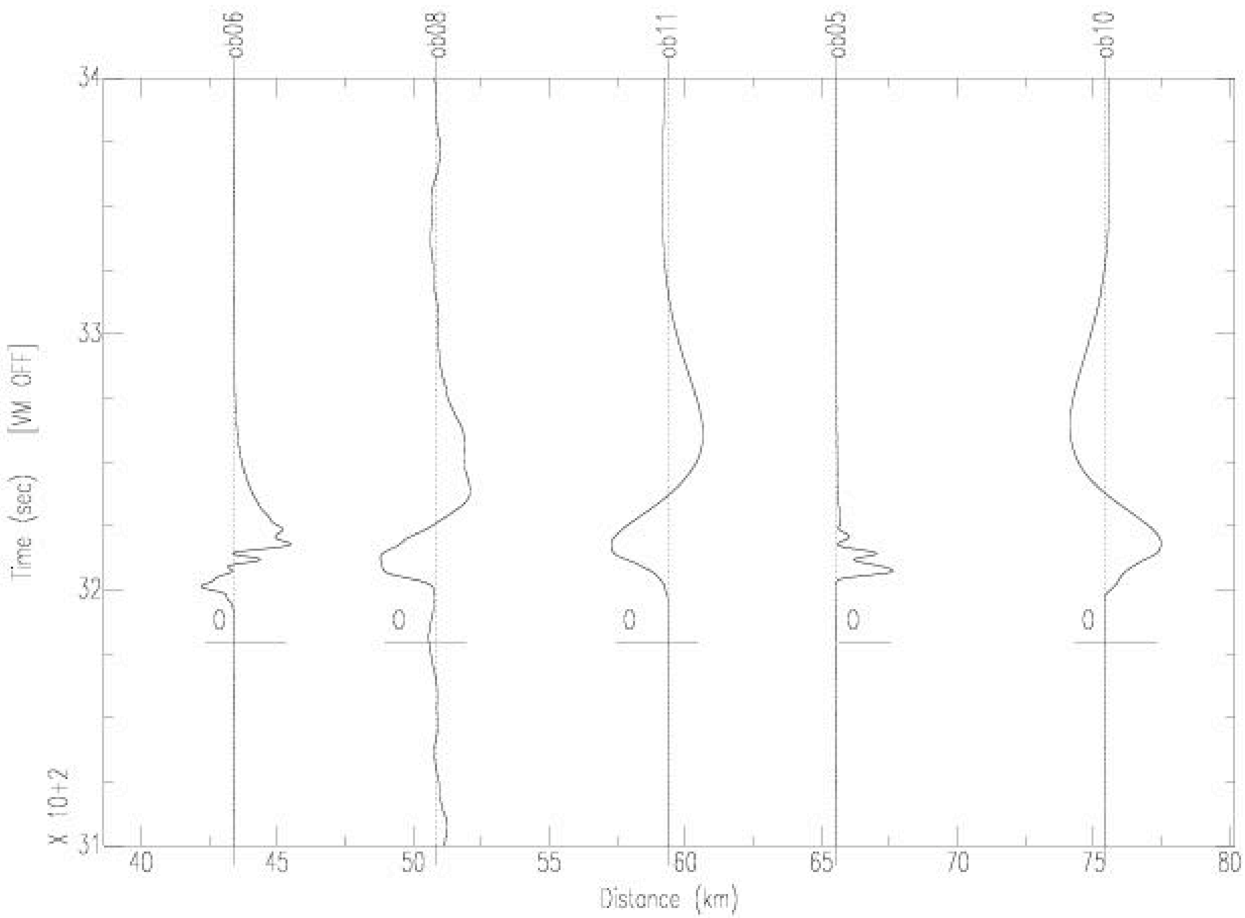
1. Scholte waves - what is the role of:
   1. Porosity
   2. Anisotropy
   3. Topography
   4. Presence of gas
2. Origin of strong “leaky phases” in Tyrrhenian Sea?
3. What is the role of non-geometric waves ?
4. Should we consider gravity for mushy layer modeling?

What are these waves ? Pl?

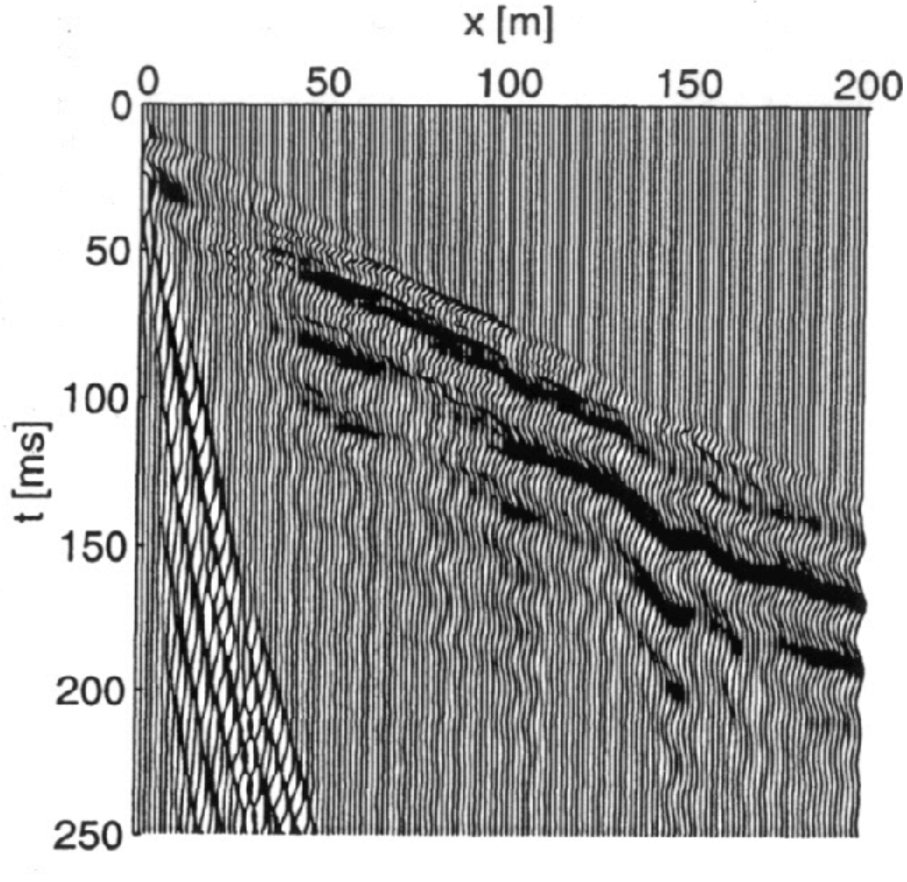


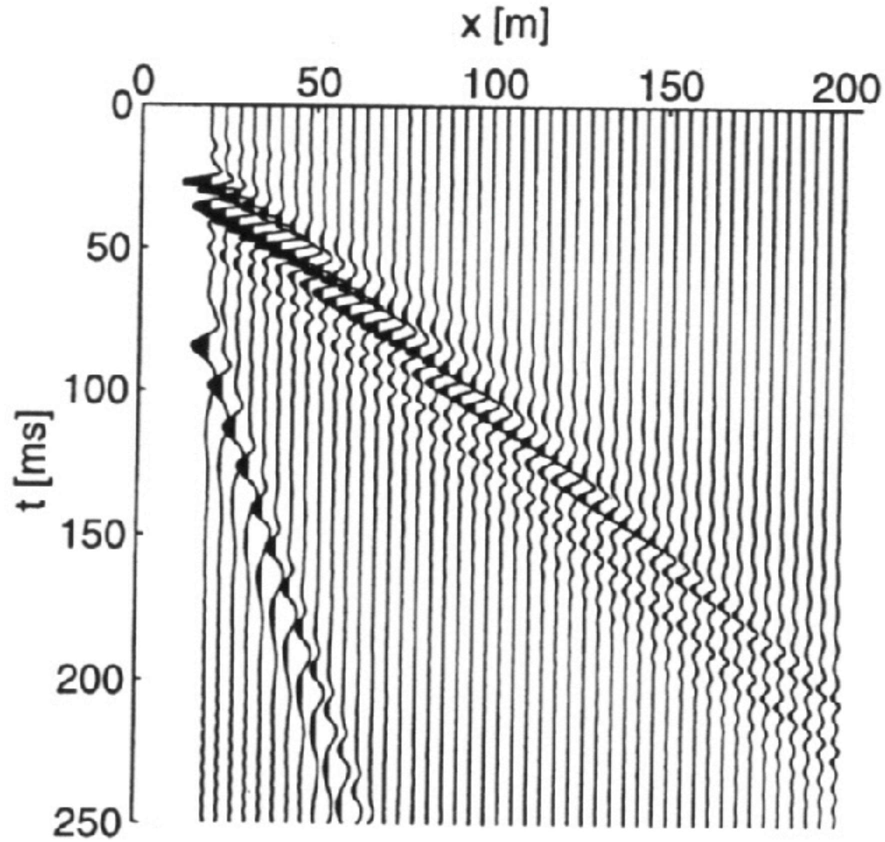
raw data recordsection: ob05 and ob06 are ‘short period’ sensors

Low-pas filtered (0.1 Hz)



P-wave leaky modes in mud. Are they expected in mushy layer?

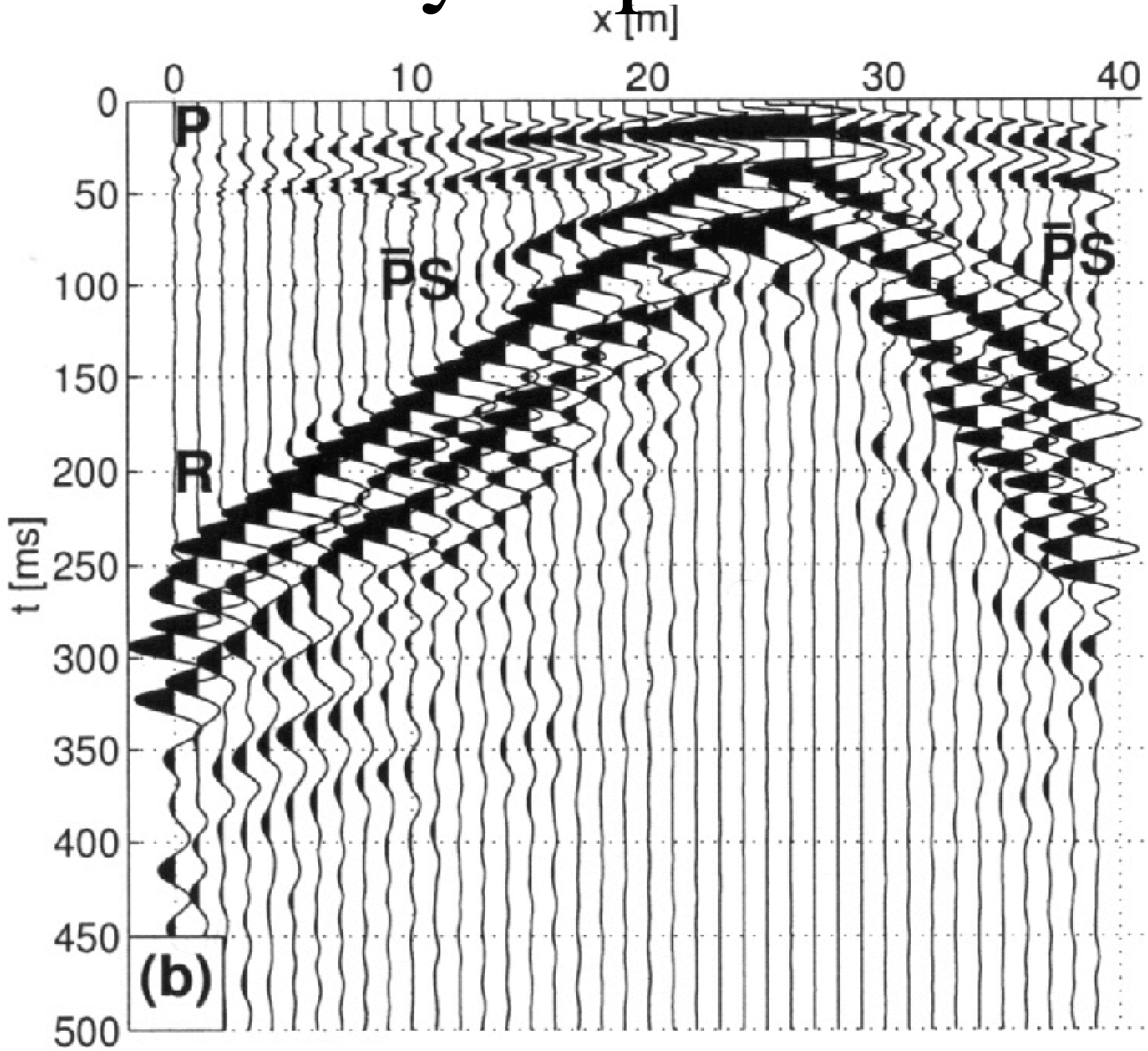




P leaky modes are faster than Rayleigh waves

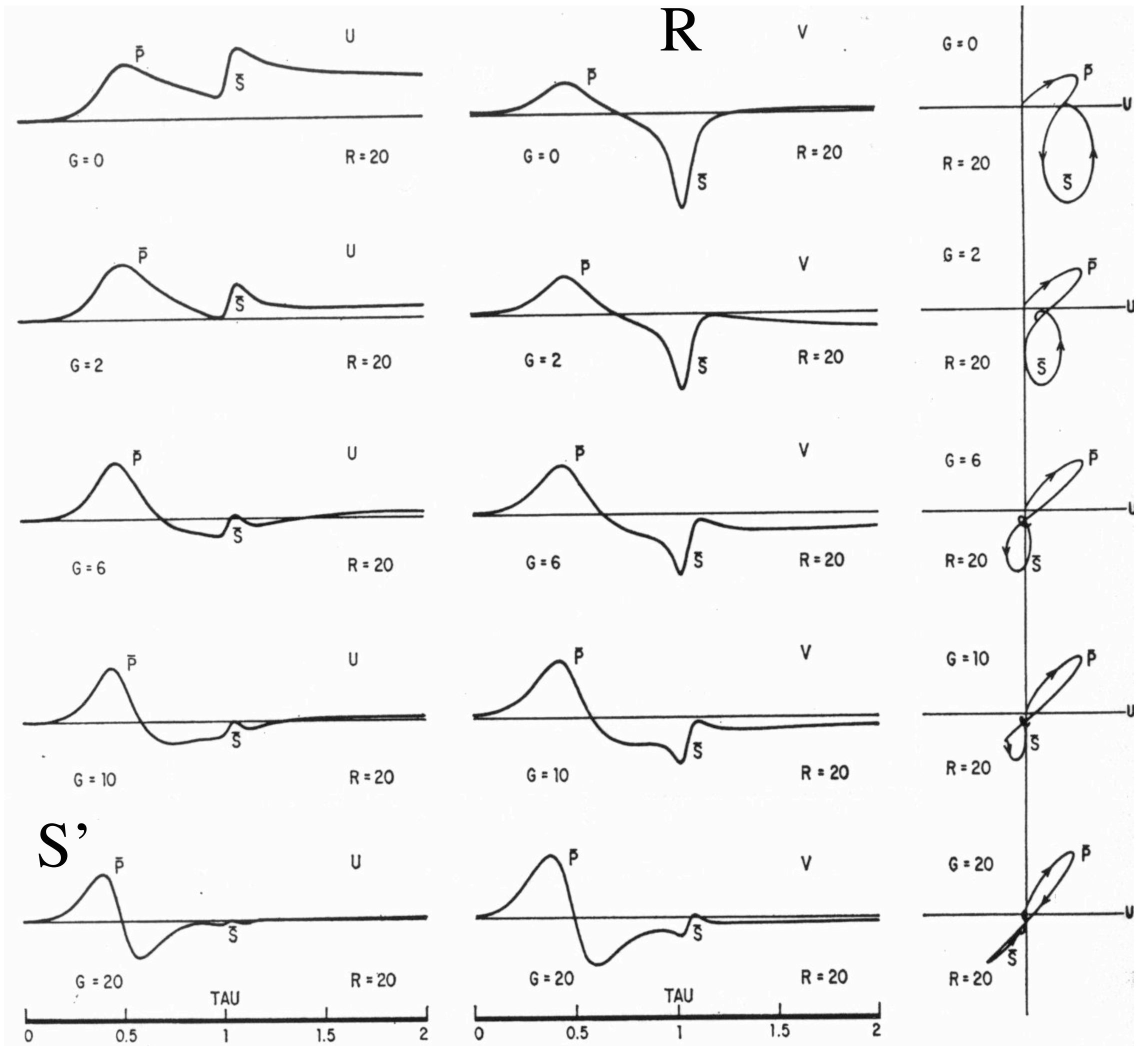
Roth, Holliger & Green (GRL,1998)

Non-geometric PS-phase in mud.
Are they important at seafloor?



Roth & Holliger
(GJI, 2000)

Influence of gravity on leaky mode Rayleigh waves (Gilbert, 1970)



normal Poisson ratio

high Poisson ´ratio

Summary

- Improvement of deployment techniques is needed
- Water layer multiples can be attenuated by waveform decomposition (4C data needed). Technique has other potential applications
- Mushy layer introduces ringing and unknown signals
- LP noise on Z can be attenuated when stations were poorly leveled