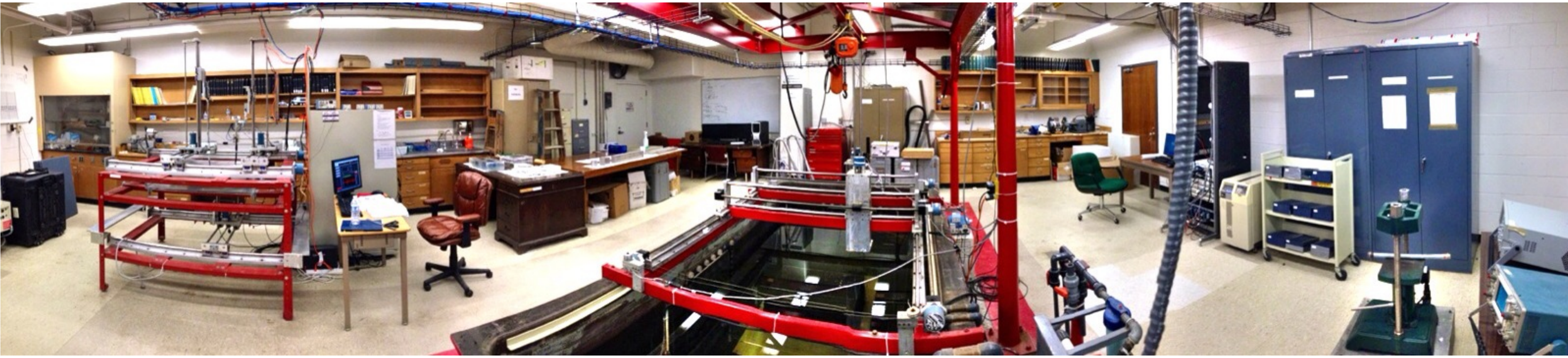
Guided waves in shallow water: A physical modeling study



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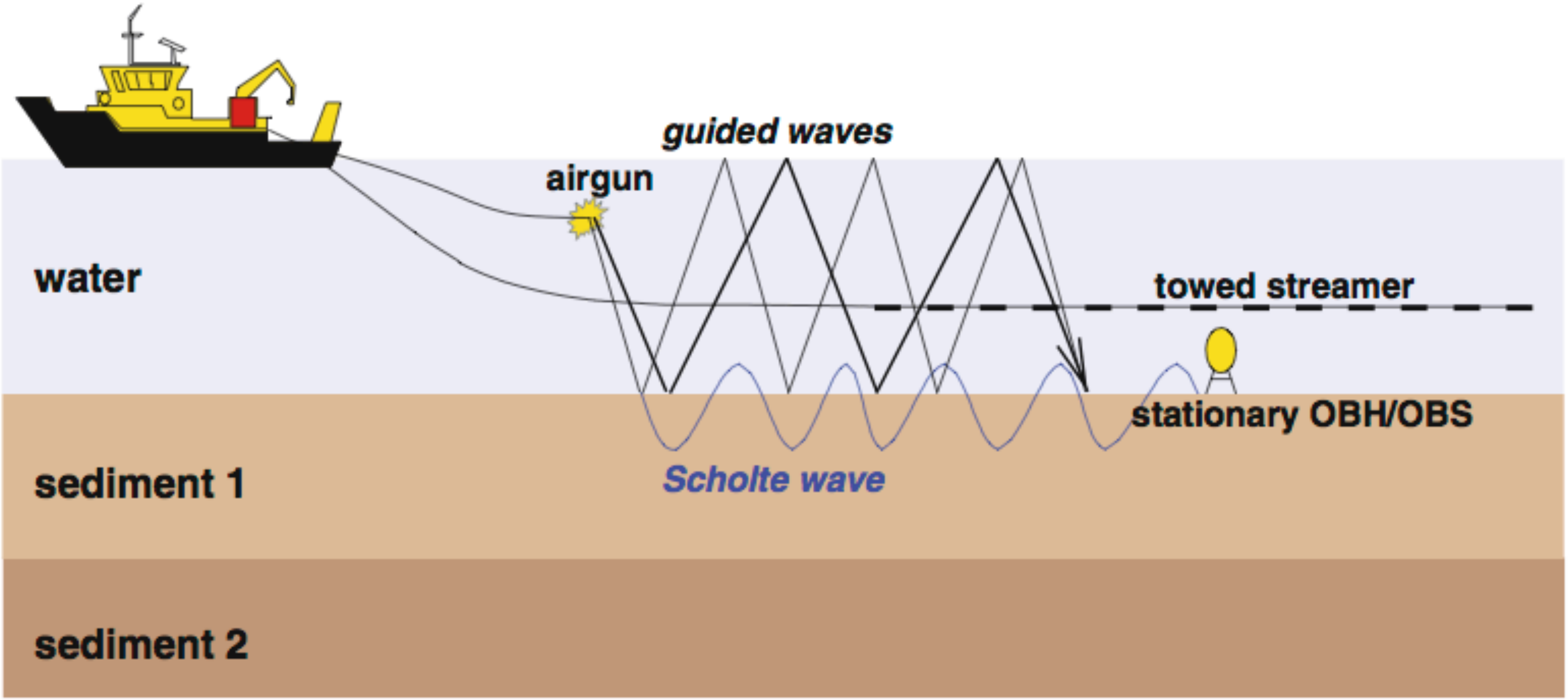
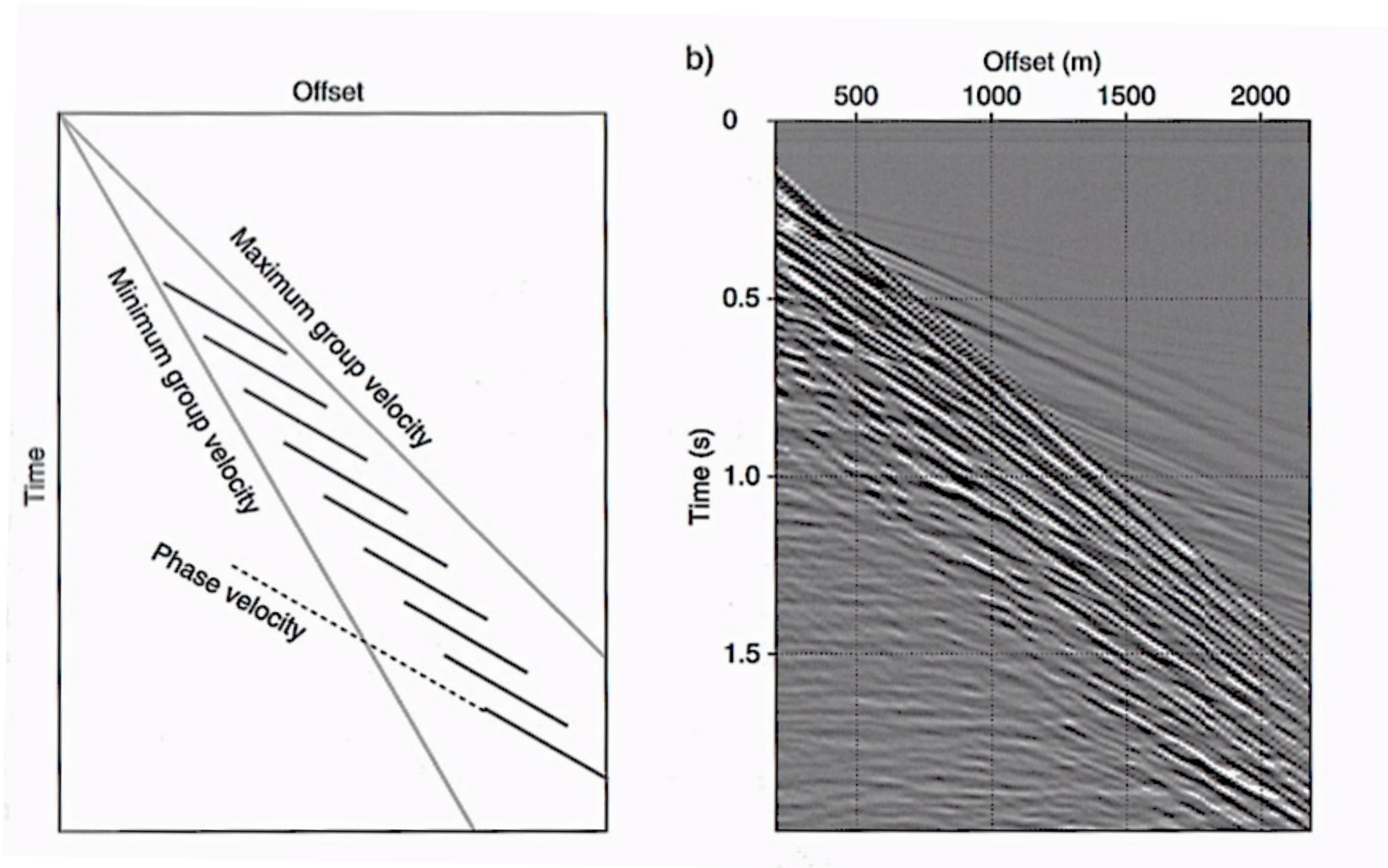
Marine seismic guided and interface waves



(Klein, 2004)

Dispersion features in shot gather



(Liner, DISC 2012)

Wavefield Solution

General form:

$$\phi = \int F(k)\,dk + \sum residues$$

continuous spectrum

diminish as 1/r^2

discrete spectrum

diminish as 1/$r^{1/2}$

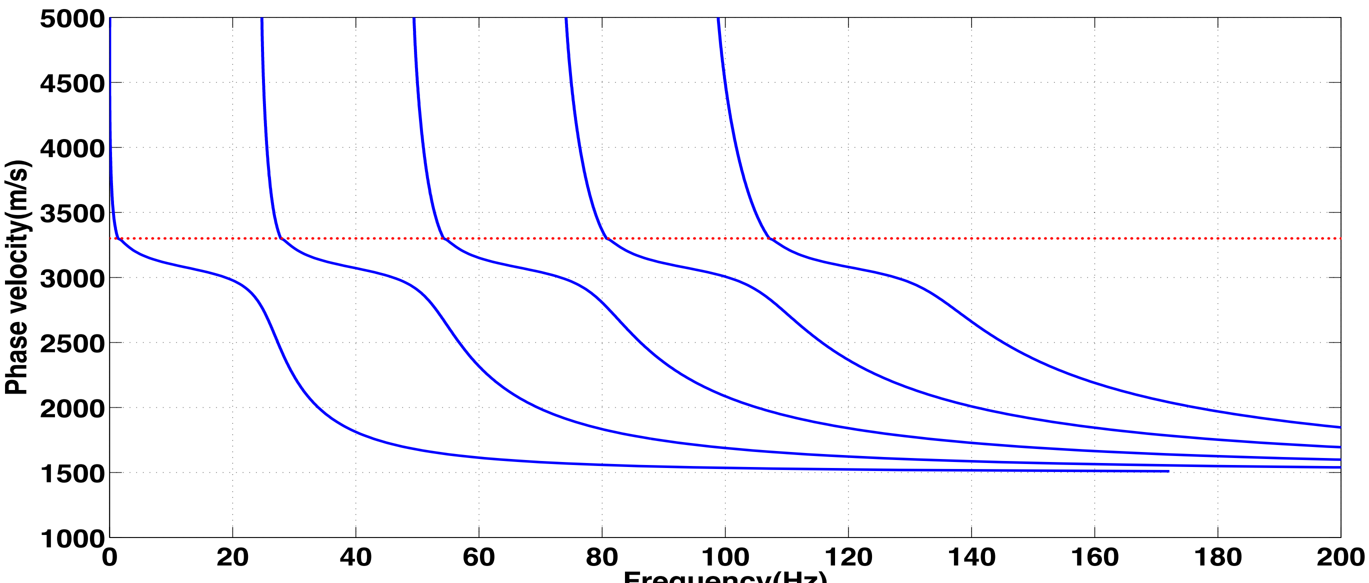
(Pekeris, 1948)

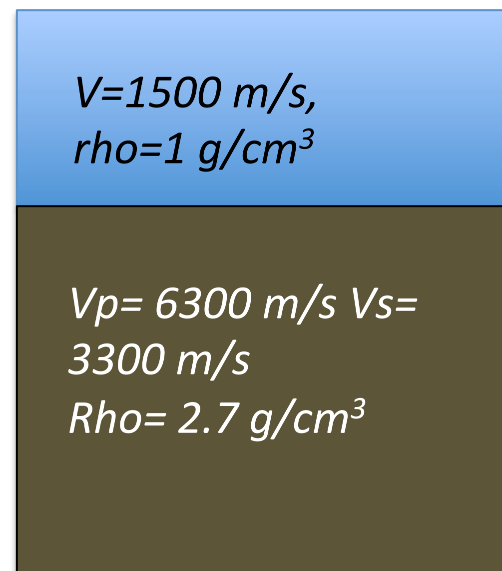
Dispersion equation:

$$\tan\left[\frac{2\pi f}{c_n} H\sqrt{c_n^2/\alpha_1^2 - 1} - (n-\frac{1}{2})\pi\right] = \frac{\rho_2}{\rho_1}\frac{\beta_2^4}{c_n^4}\frac{\sqrt{c_n^2/\alpha_1^2-1}}{\sqrt{1-c_n^2/\alpha_2^2}}\left[4\sqrt{1-c_n^2/\alpha_2^2}\sqrt{1-c_n^2/\beta_2^2} - (2-c_n^2/\beta_2^2)^2\right]$$

(Press, 1949)

f is the frequency; c_n is the phase velocity; n is the mode number; α_1, α_2 is the P-wave velocity of water and seafloor, respectively; β_2 is the shear-wave velocity of seafloor; ρ_1 and ρ_2 is the density of water and seafloor, respectively.

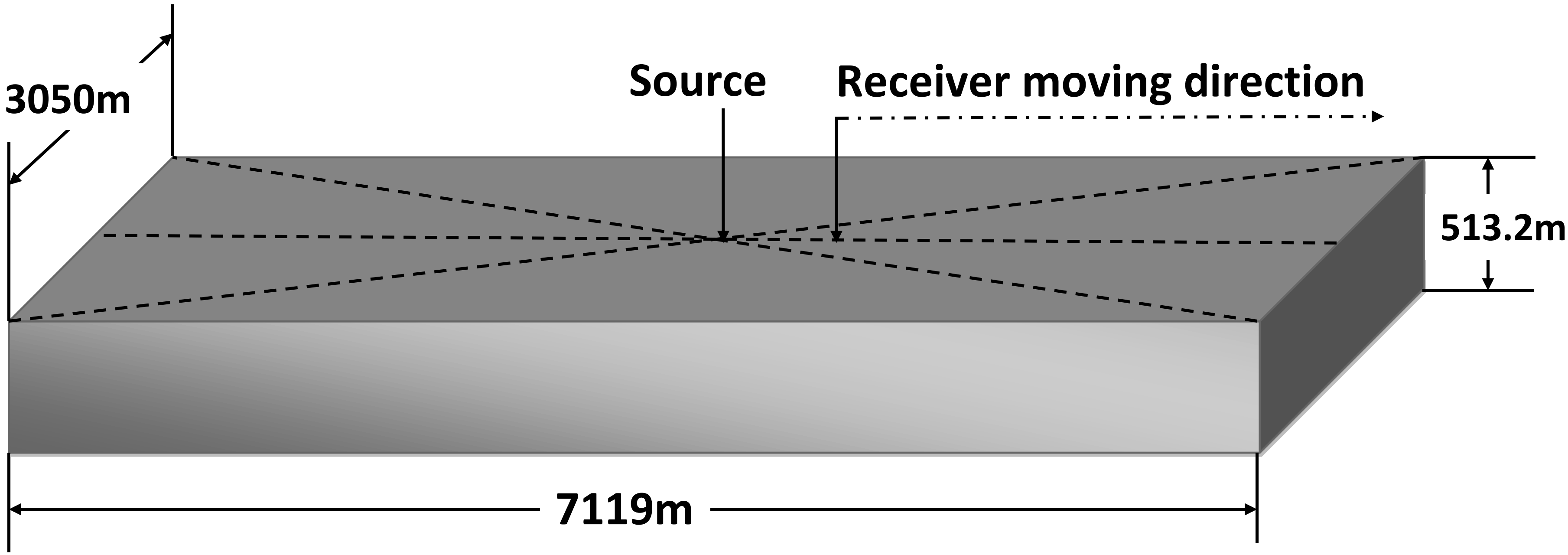




Hard Seafloor: Aluminum Block

Aluminum Block:
Vp= 6300 m/s, Vs=3300 m/s, rho=2.7 g/cm³

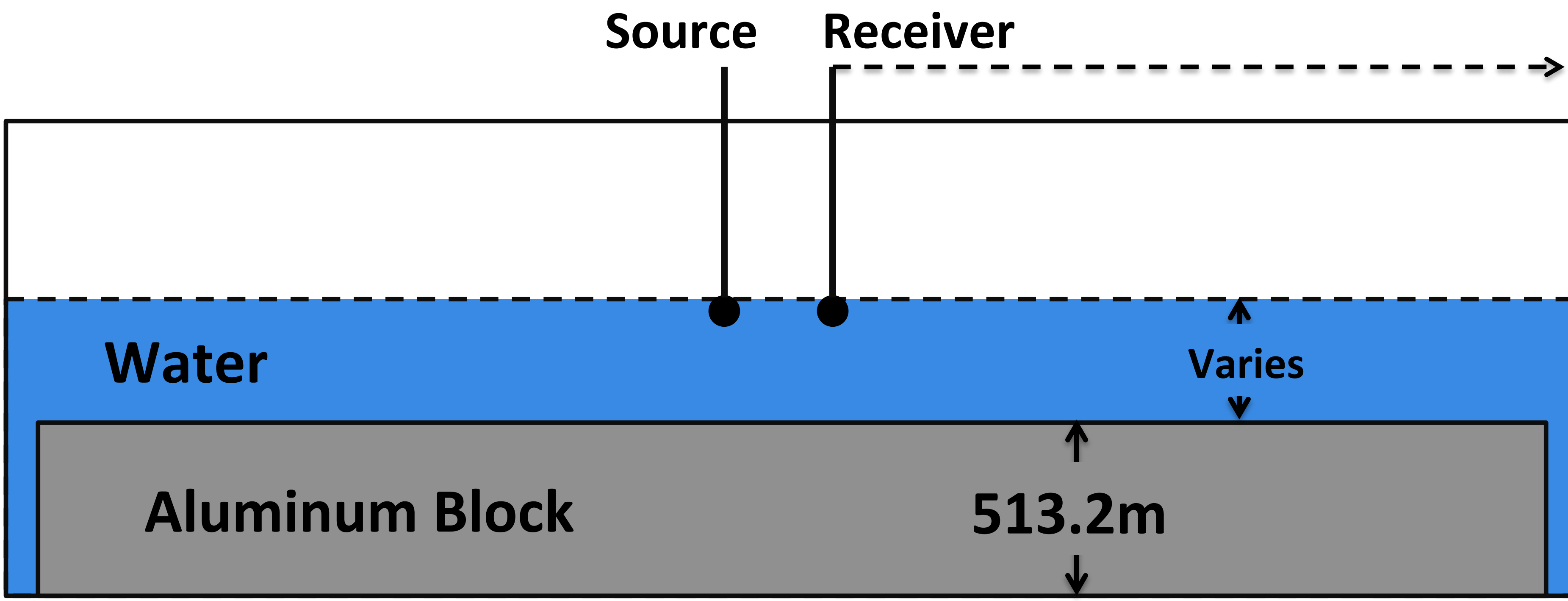
Basalt:
Vp=6300 m/s, Vs=3200 m/s, rho=*2.4 g/cm³*

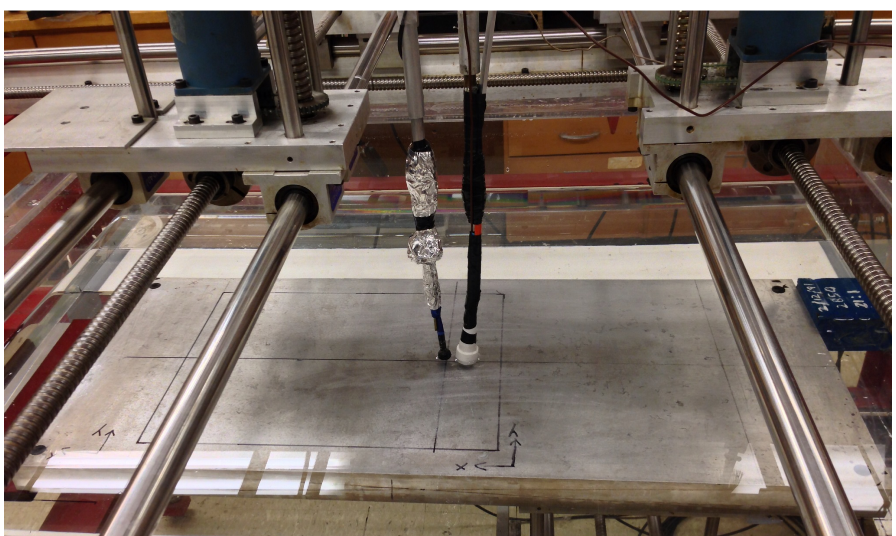


Geometry:

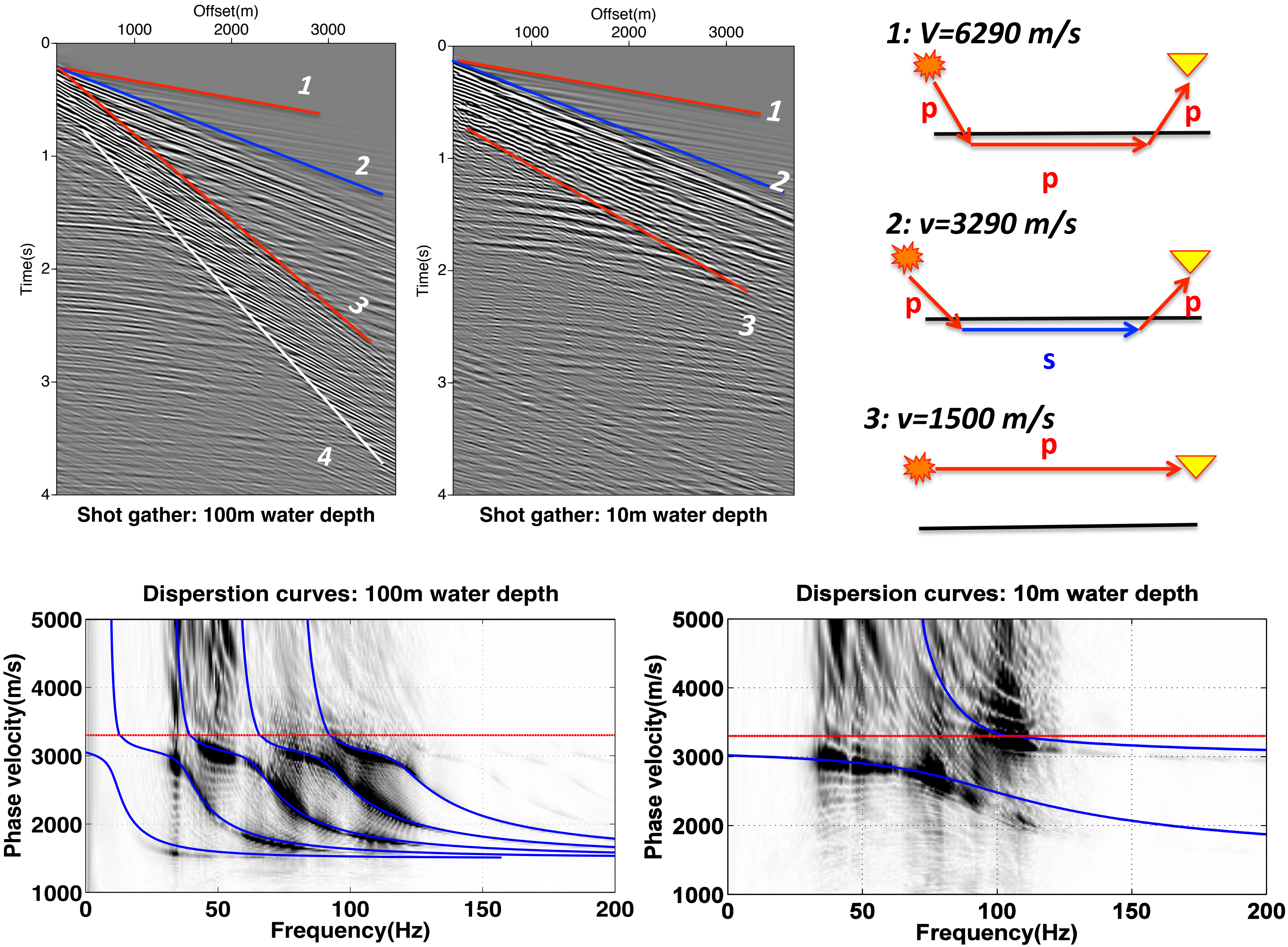
- Offset Range: 200~3500 m (2cm ~35cm);
- Near offset: 200 m (2cm);
- Far offset: 3500 m (35cm);
- Receiver interval: 10m(1mm);
- Central frequency: 30Hz.
- Scale factor: 10^4.

Varying depth

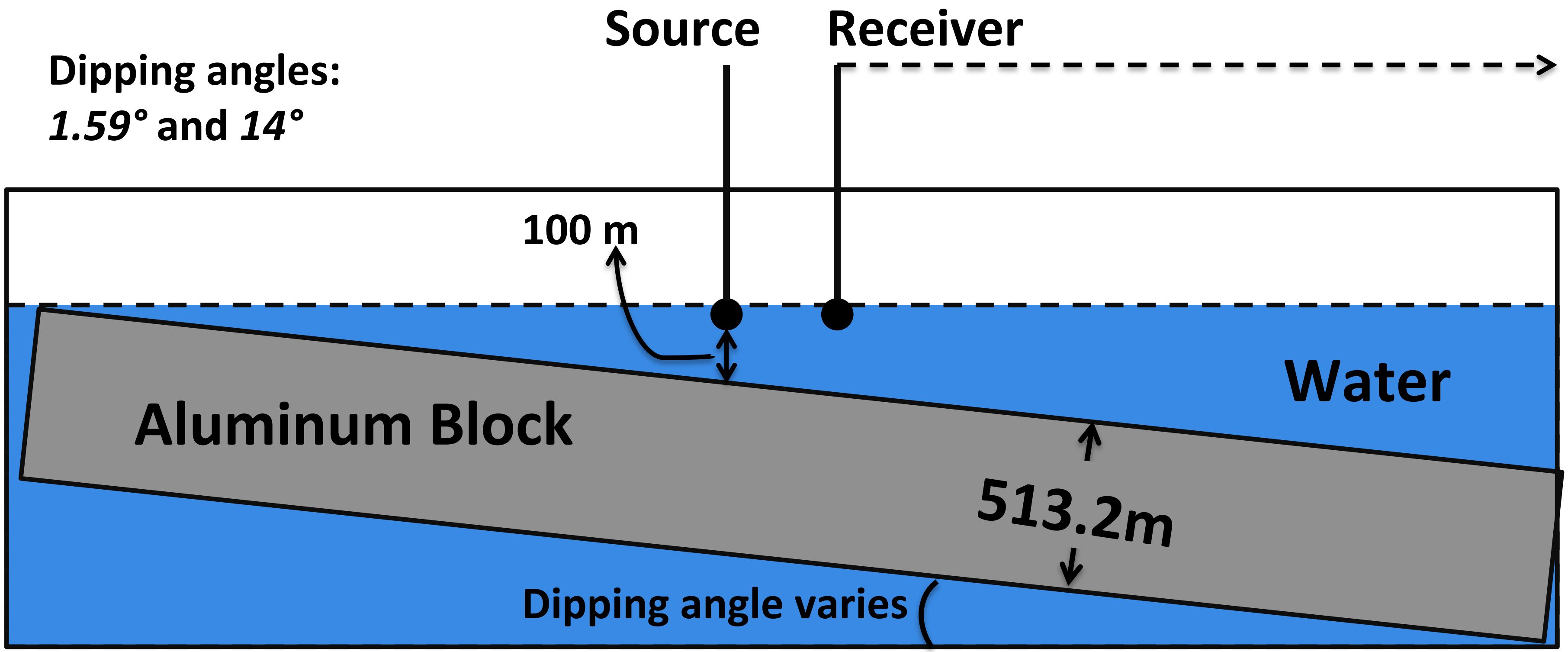


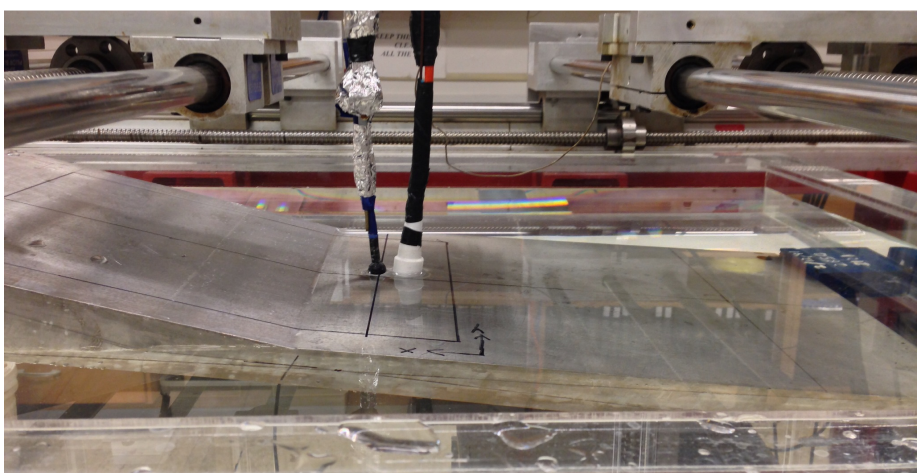


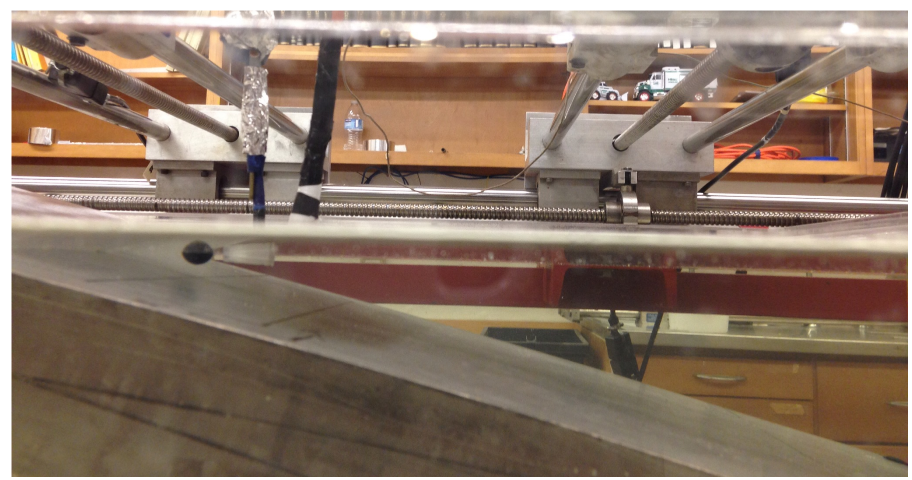
- *Flat seafloor;*
- *Varying depth: 100 m, 10 m;*

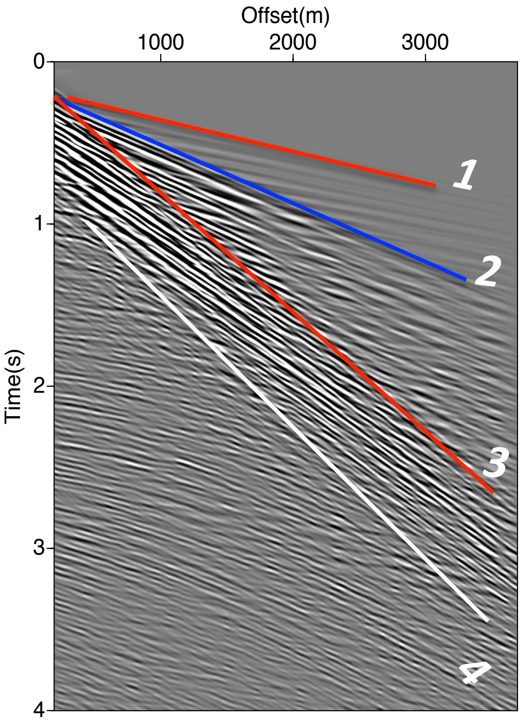

Offset(m)
1000
2000
3000
Time(s)
0
1
2
3
4
1
2
3
4
Shot gather: 100m water depth
Offset(m)
1000
2000
3000
Time(s)
0
1
2
3
4
1
2
3
Shot gather: 10m water depth
1: V=6290 m/s
p
p
p
2: v=3290 m/s
p
p
s
3: v=1500 m/s
p
Disperstion curves: 100m water depth
Phase velocity(m/s)
5000
4000
3000
2000
1000
0
50
100
150
200
Frequency(Hz)
Dispersion curves: 10m water depth
Phase velocity(m/s)
5000
4000
3000
2000
1000
0
50
100
150
200
Frequency(Hz)

Dipping seafloor

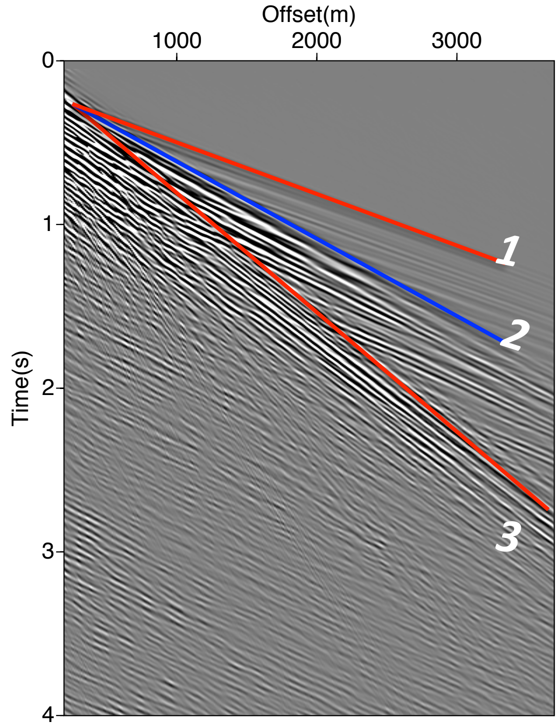




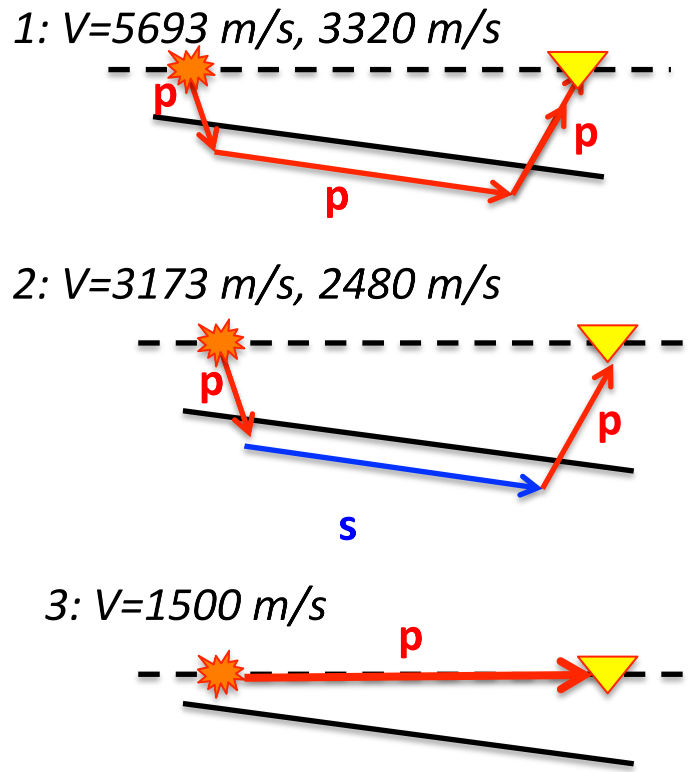




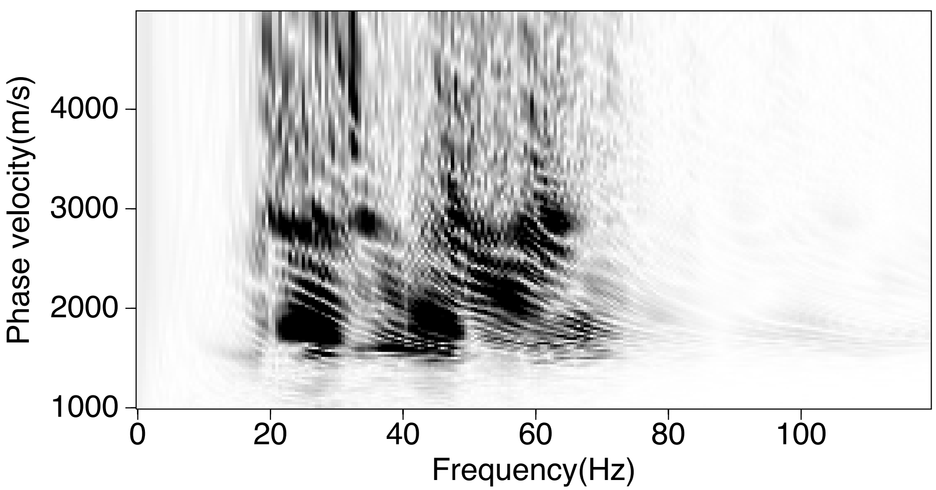
Shot gather: 1.59 degree



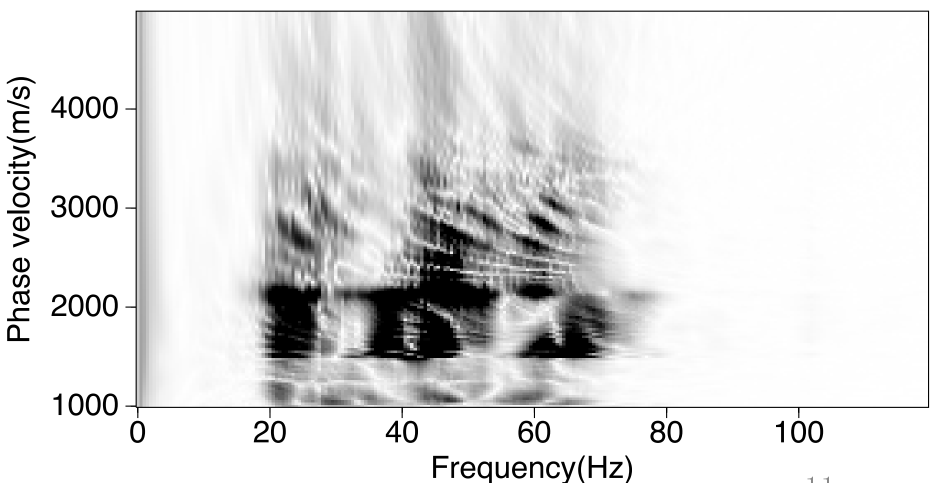
Shot gather: 14 degree



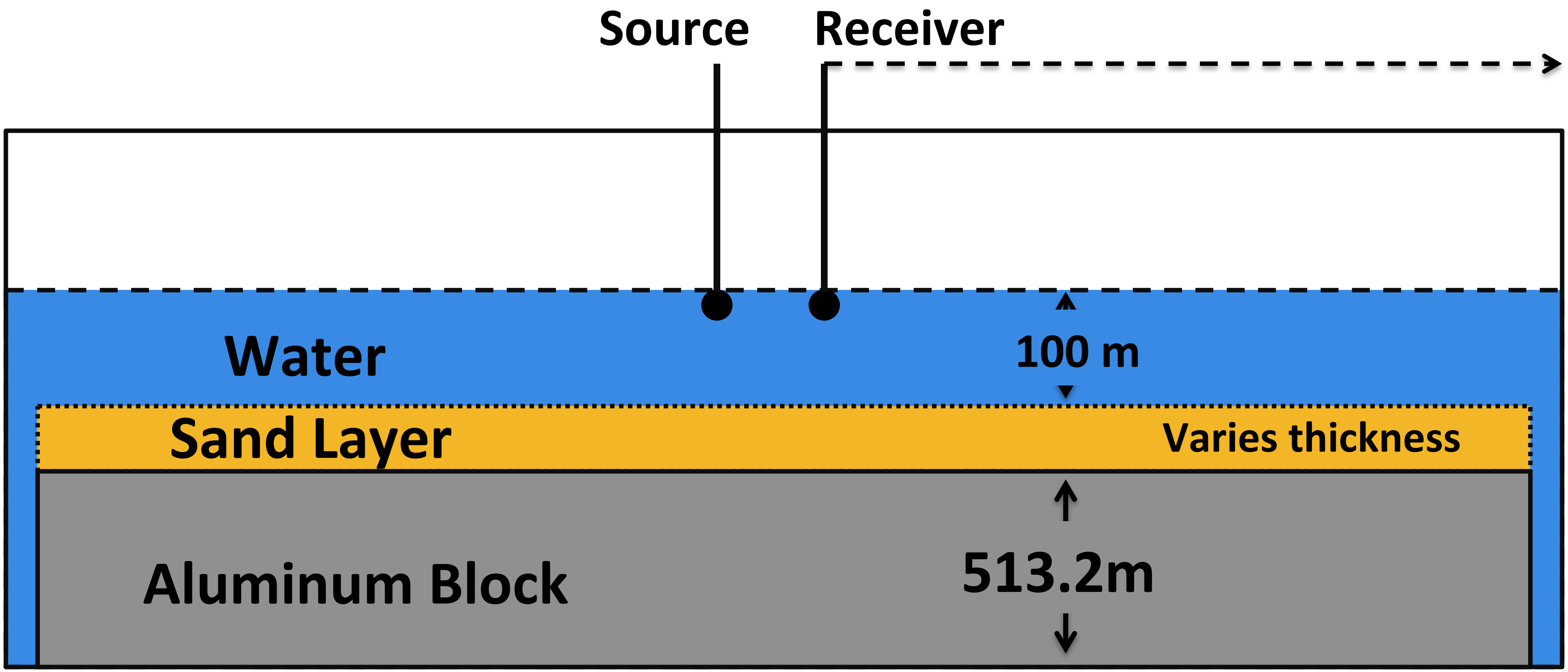
Dispersion curves: 1.59 degree dipping

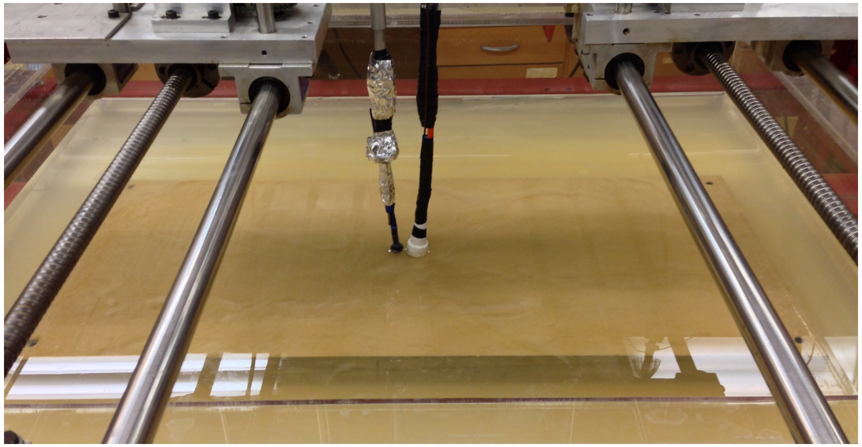


Dispersion curves: 14 degree dipping

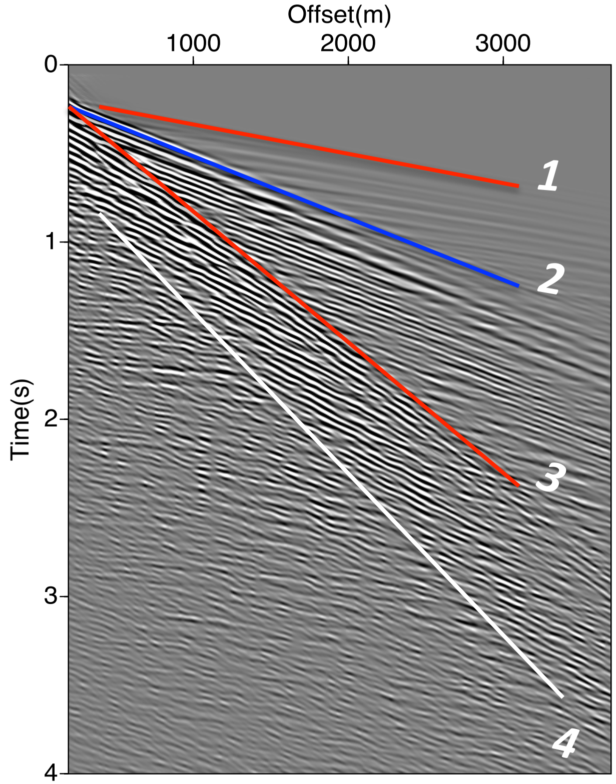


Sandy interface cover

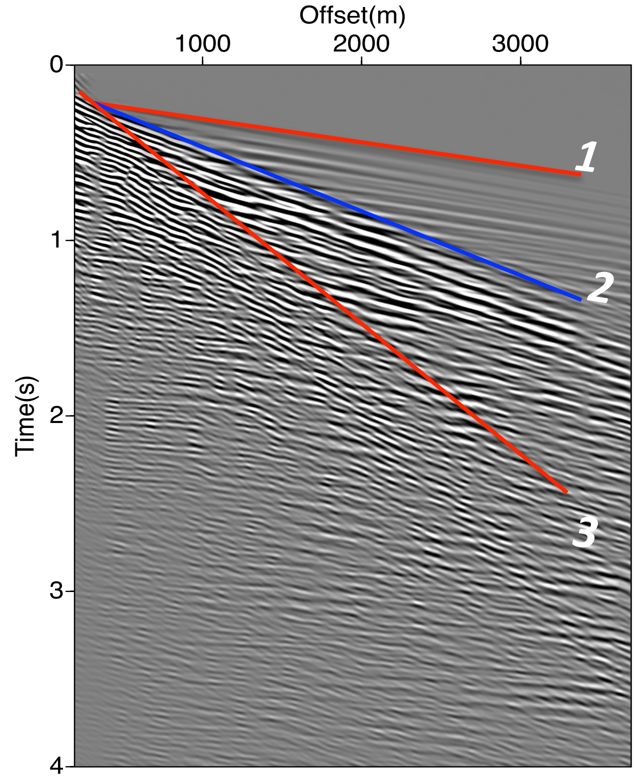




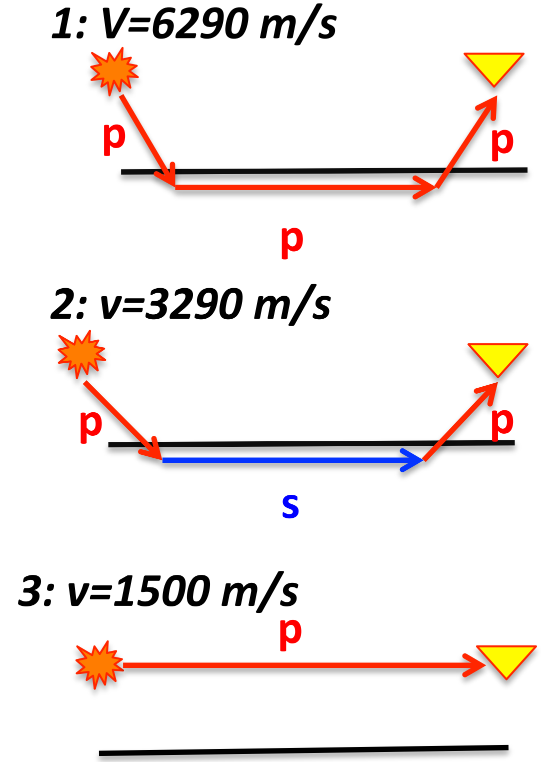
Sandy layer thicknesses:
5 m and *30 m*



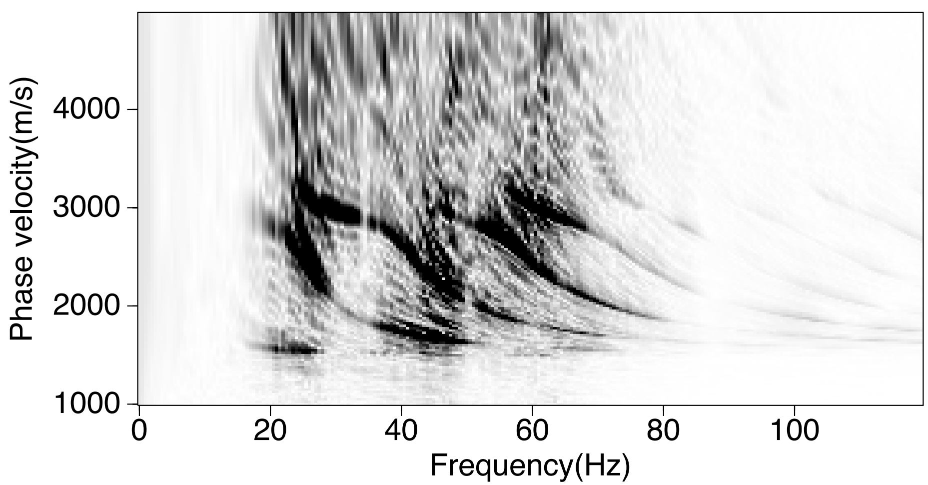
100m water depth, 5m sand layer



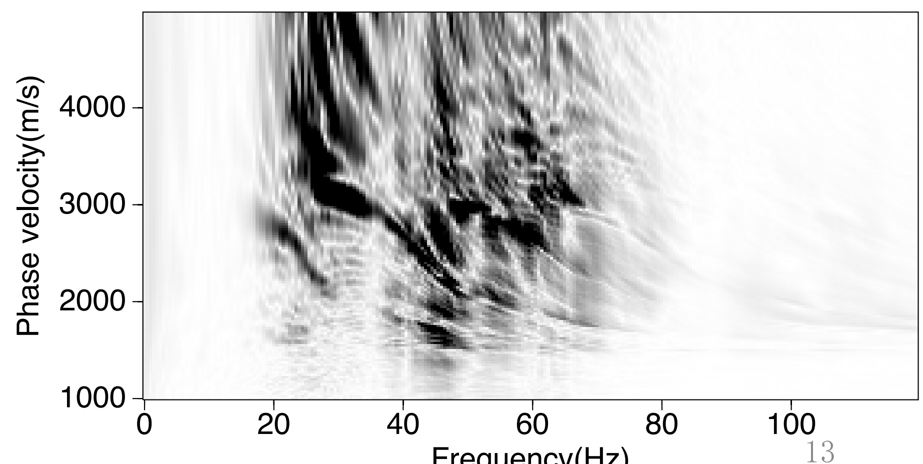
100m water depth, 30m sand layer



Dispersion curves: 5m sand layer

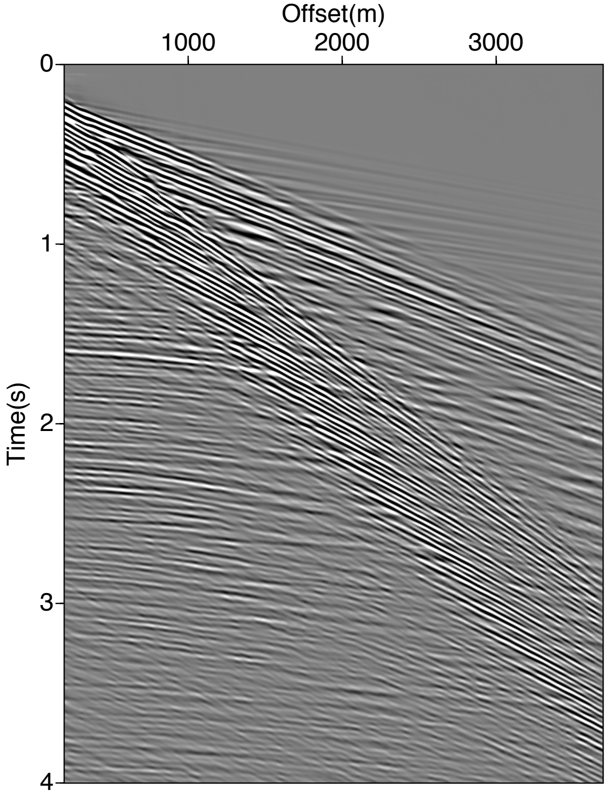


Dispersion curves: 30m sand layer

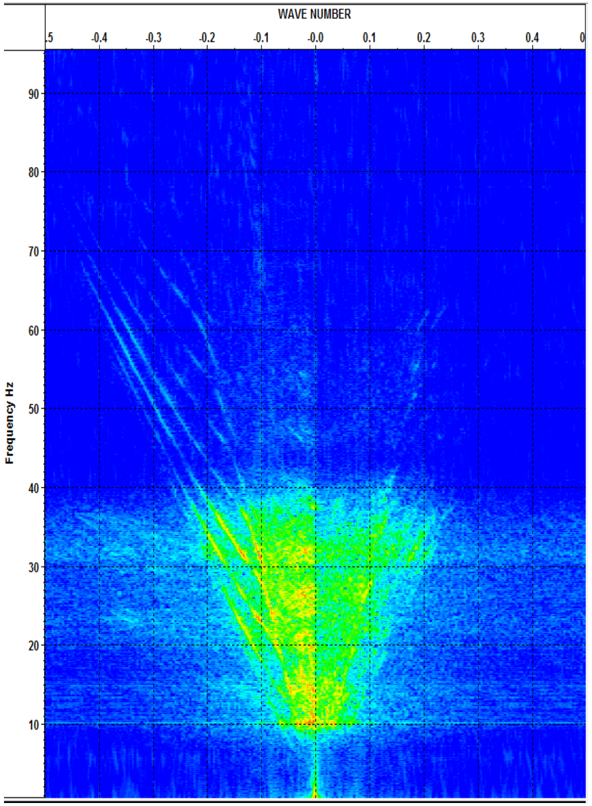


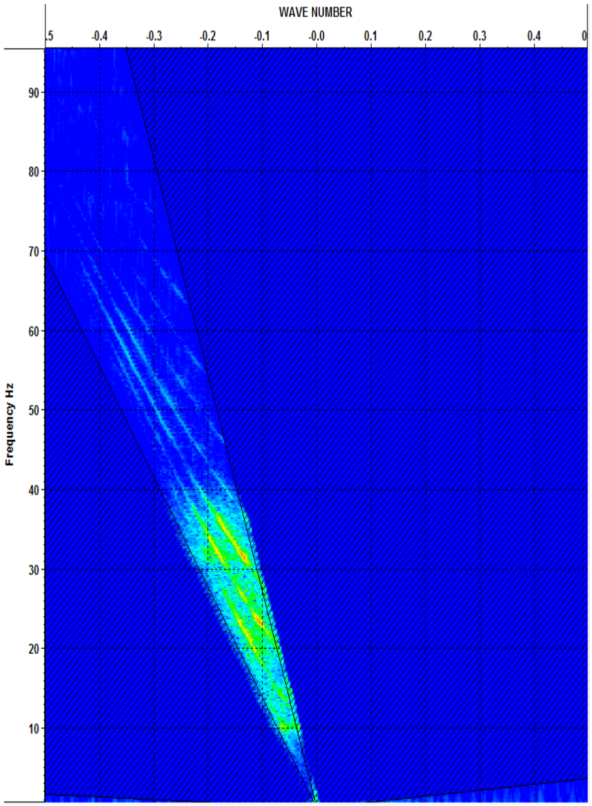
Application

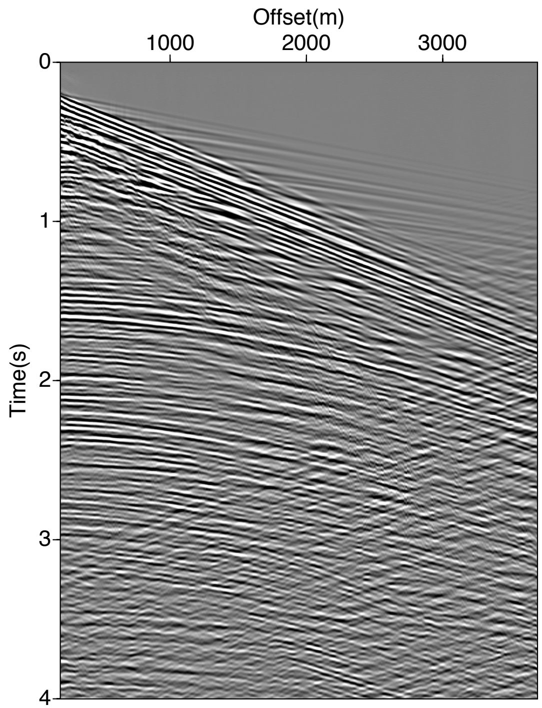
Separate body waves and guided waves



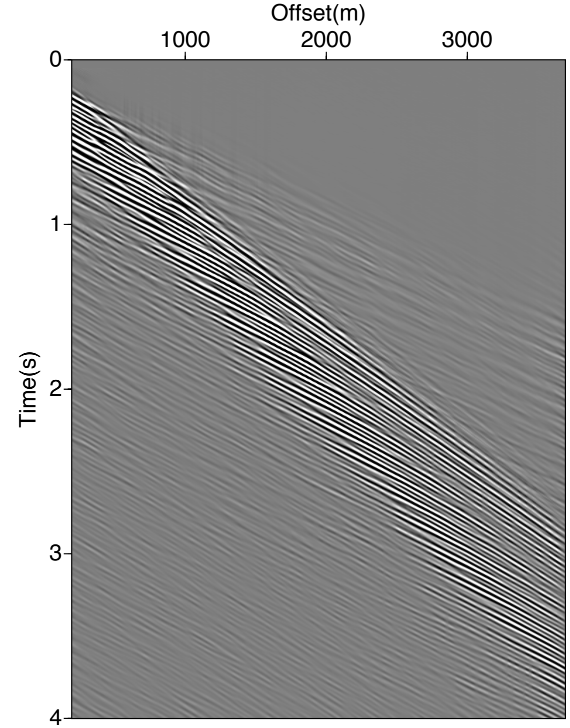
Shot gather: 100m water depth





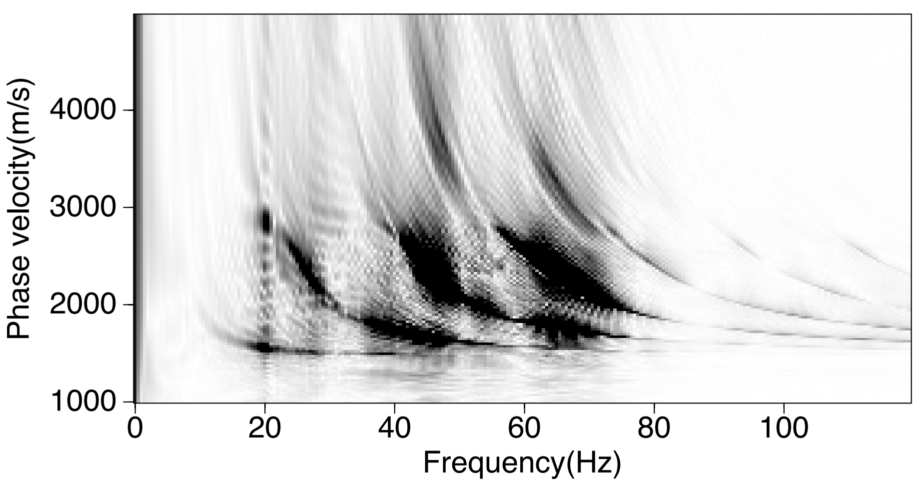


Shot gather: 100m water depth

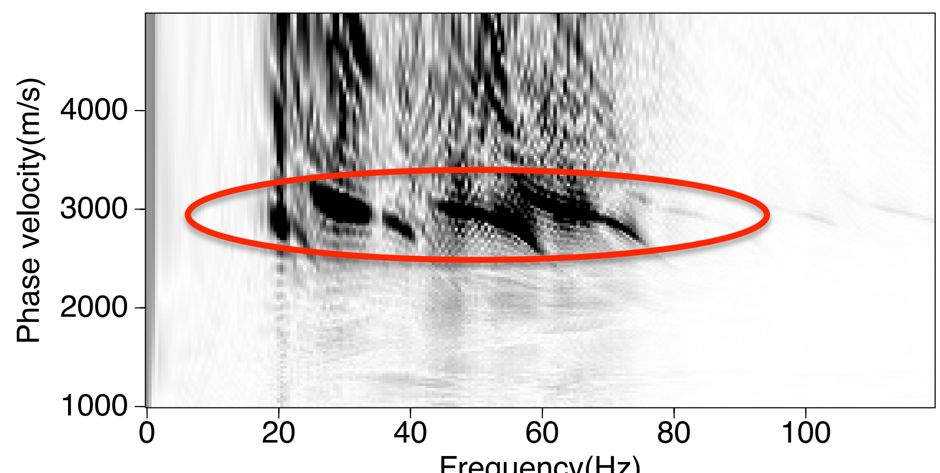


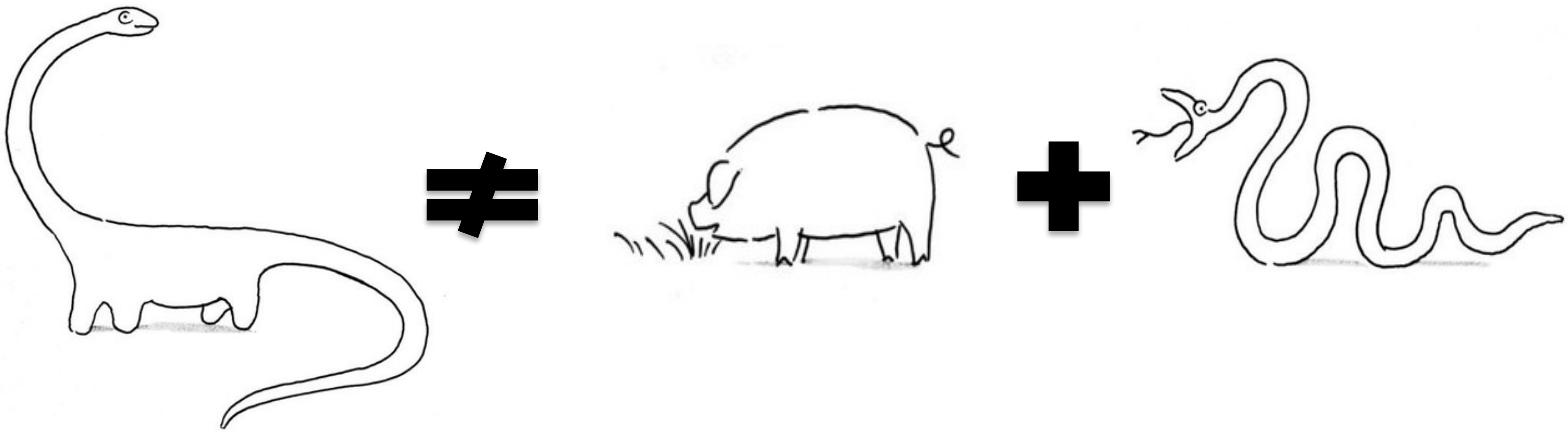
Shot gather: 100m water depth

Dispersion curves: 100m water depth



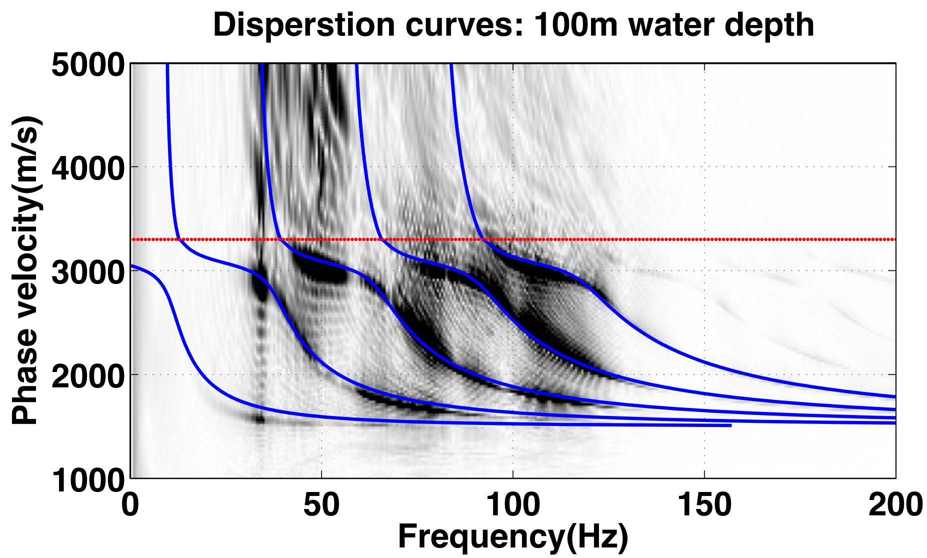
Dispersion curves: 100m water depth





Application

Transfer to *v-f* domain



Shear wave velocity picking

Shear-wave velocity profile building

Filter design

Separate dispersive waves

Conclusion

- The water depth dominates the number of normal modes;
- The properties of sedimentary layer dominate the energy distribution;
- The dipping angle of the seafloor dominates how modes couple together and bandwidth of the *v-f* spectrum.
- F-K filter cannot separate guided waves and body waves well. Filter design is necessary.

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- Dr. Robert Stewart
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Thank you