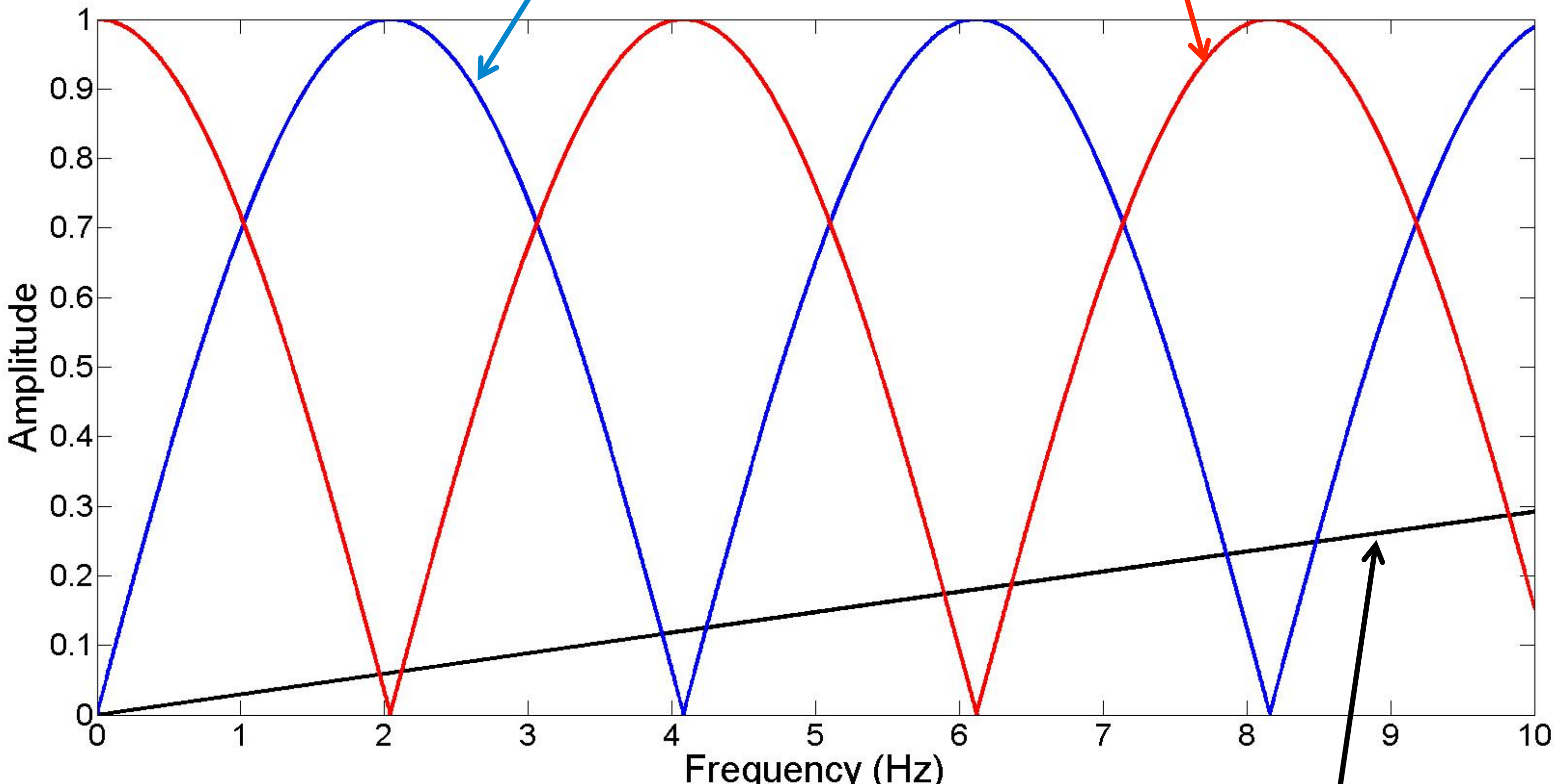
Using geophone components to obtain ultralow frequency seismic signals at long offsets

Landrø, Haavik & Amundsen

(SEG 2014)

Receiver ghost spectra for hydrophone and geophone

$$G_h = \left|\sin\left(\frac{2\pi fz\cos\theta}{c}\right)\right| \qquad G_g = \left|\cos\left(\frac{2\pi fz\cos\theta}{c}\right)\right|$$

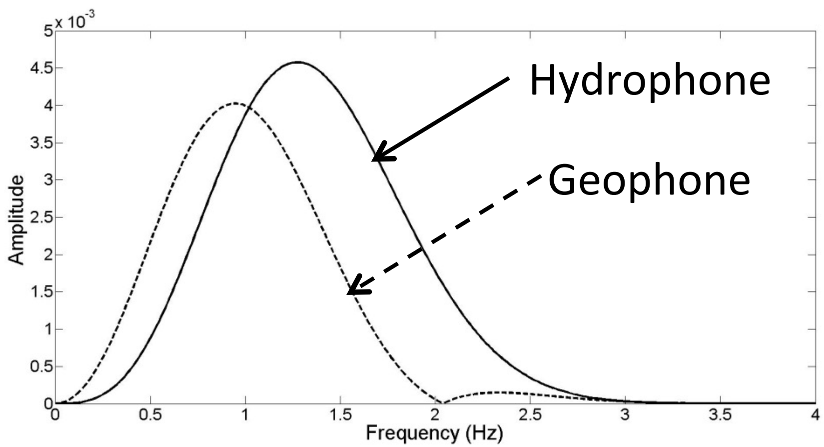


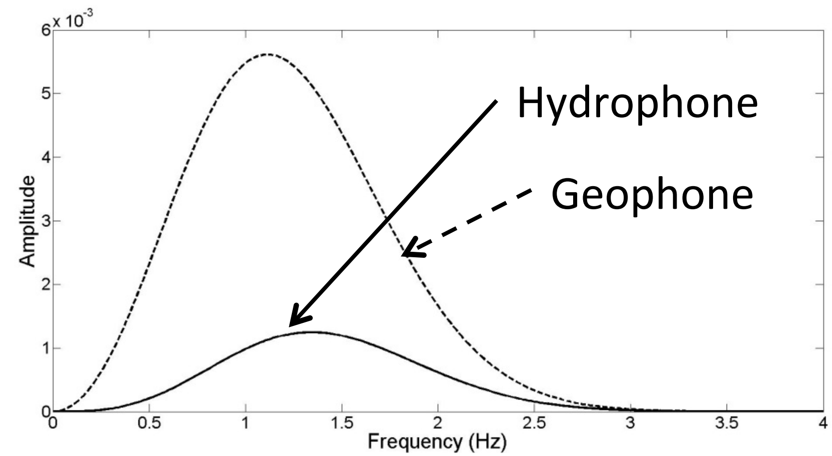
Incidence angle = 45 degrees

Source ghost

Source: Landrø, Haavik and Amundsen, SEG 2014

Modeled effect of instrument + source + receiver ghost + low frequency source spectrum





Source depth: 10 m
Receiver depth: 260 m
Angle: 45 degrees

Source depth: 10 m
Receiver depth: 60 m
Angle: 45 degrees

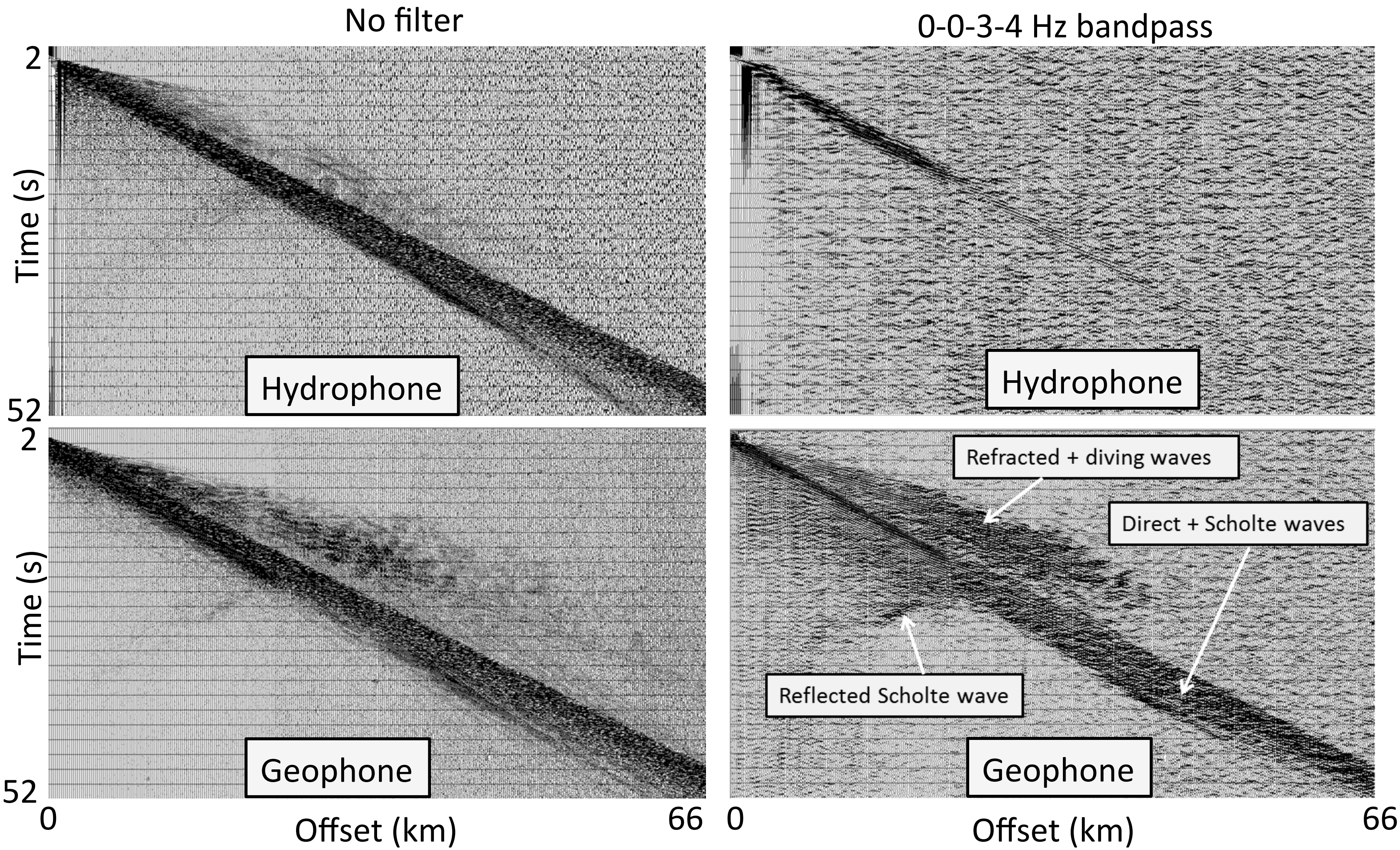
$$H(f) = \frac{f^2 / f_0^2}{1 - f^2 / f_0^2 + 2jkf / f_0}$$

← Transfer Function

Geophone has a better ultra-low frequency response, especially for shallow receiver depths

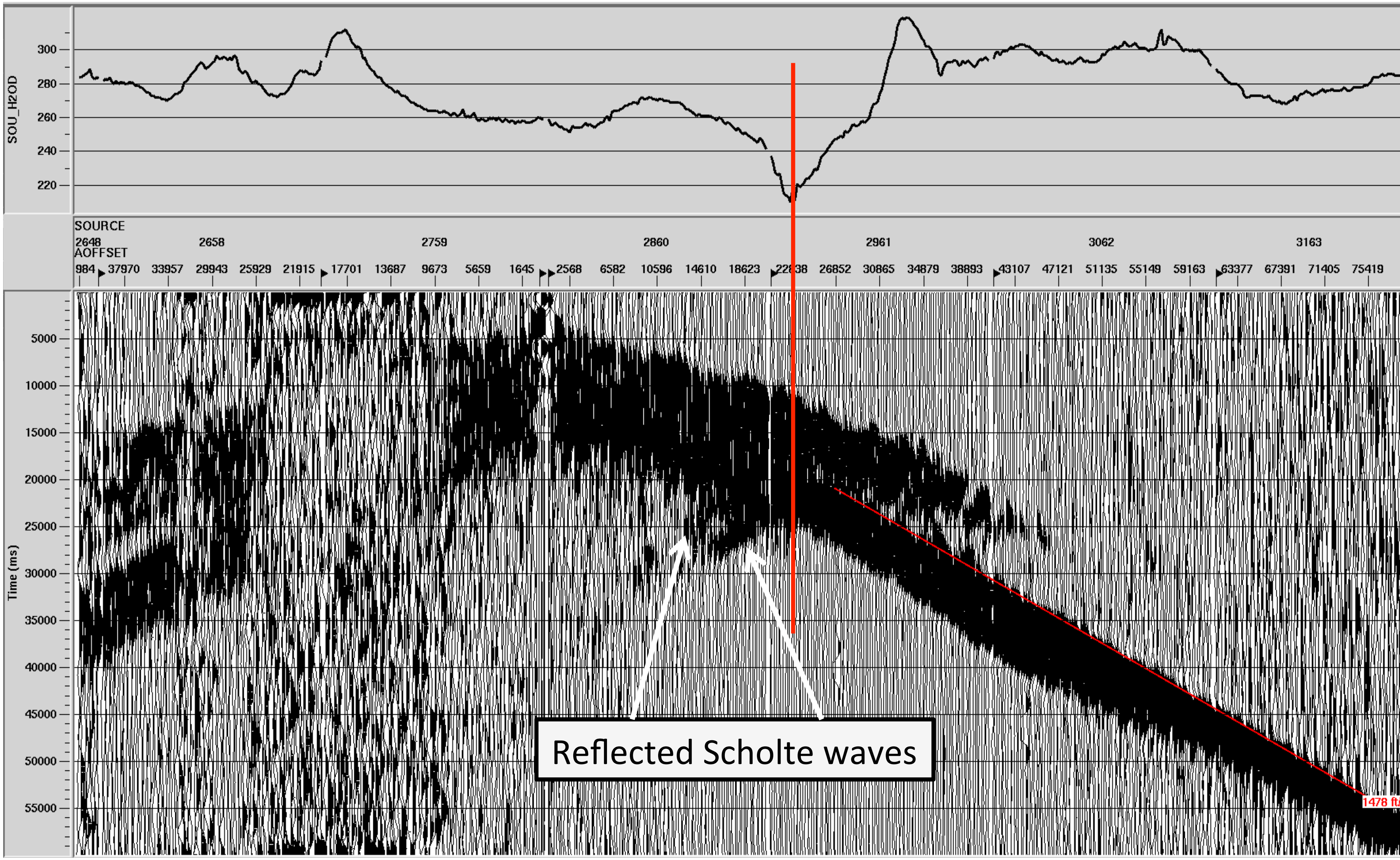
Source: Landrø, Haavik and Amundsen, SEG 2014

Geophone data has more energy at low frequencies

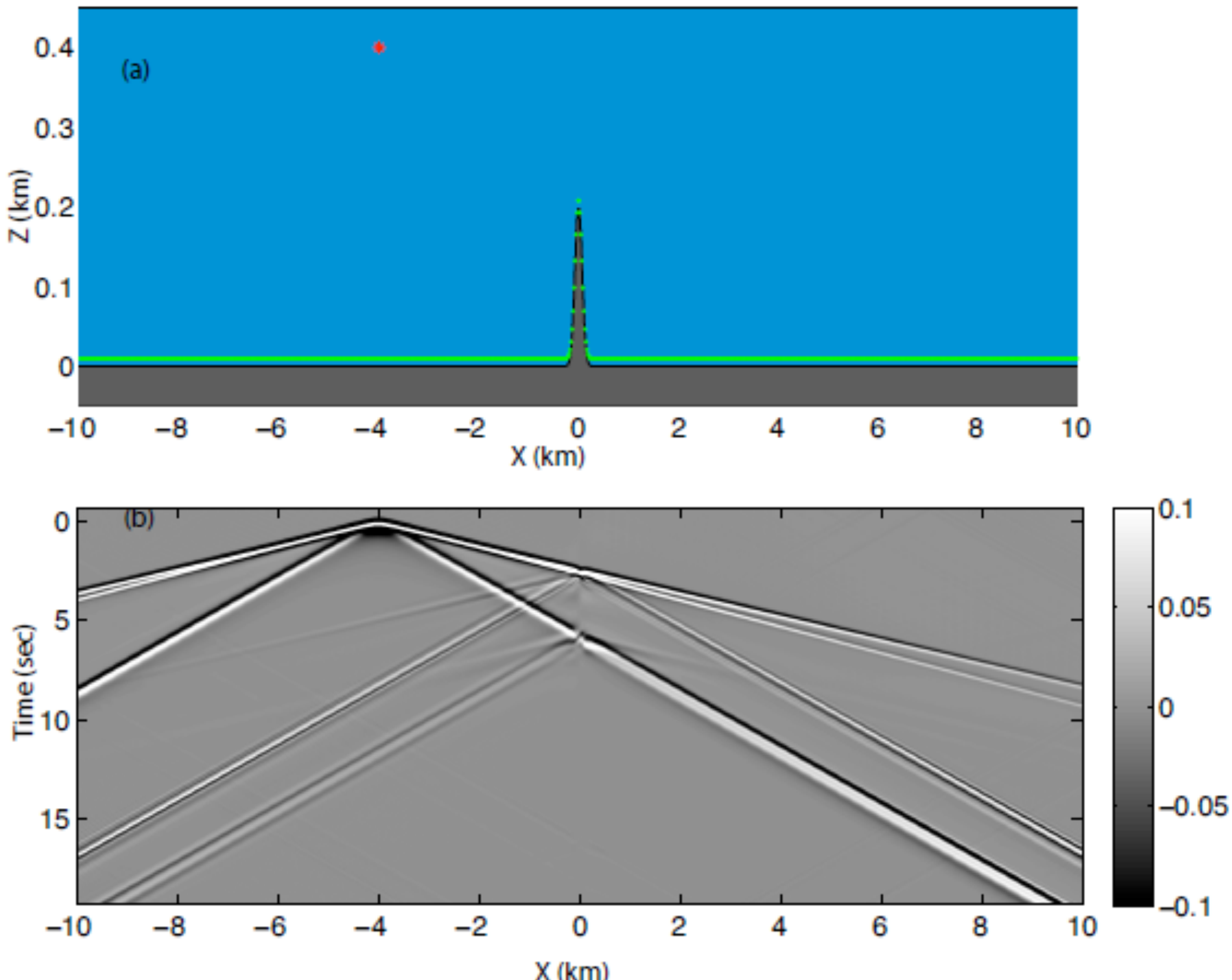


Source: Landrø, Haavik and Amundsen, SEG 2014

The two reflected Scholte-waves caused by bump at seabed

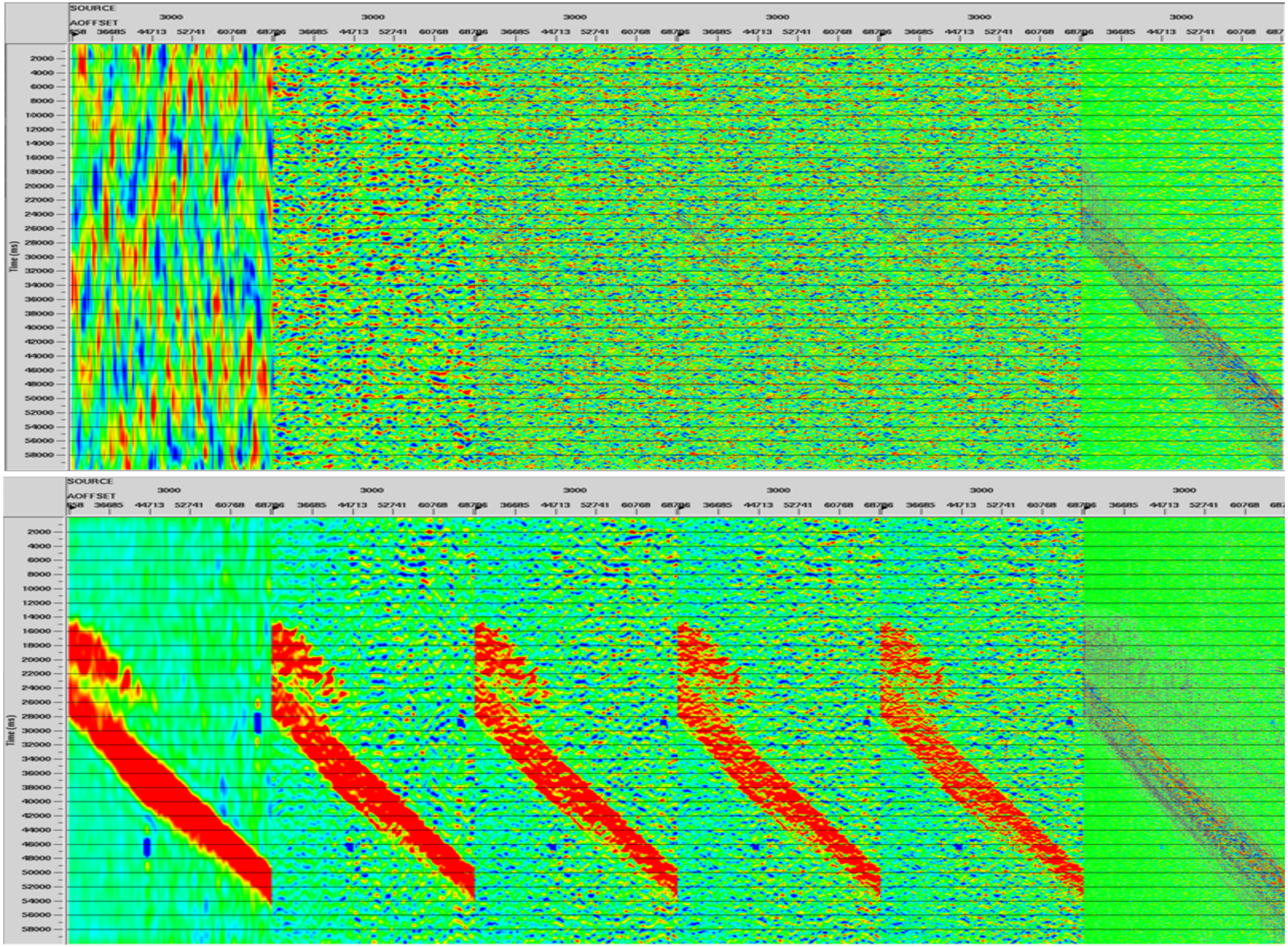


Scholte waves generated by seafloor topography



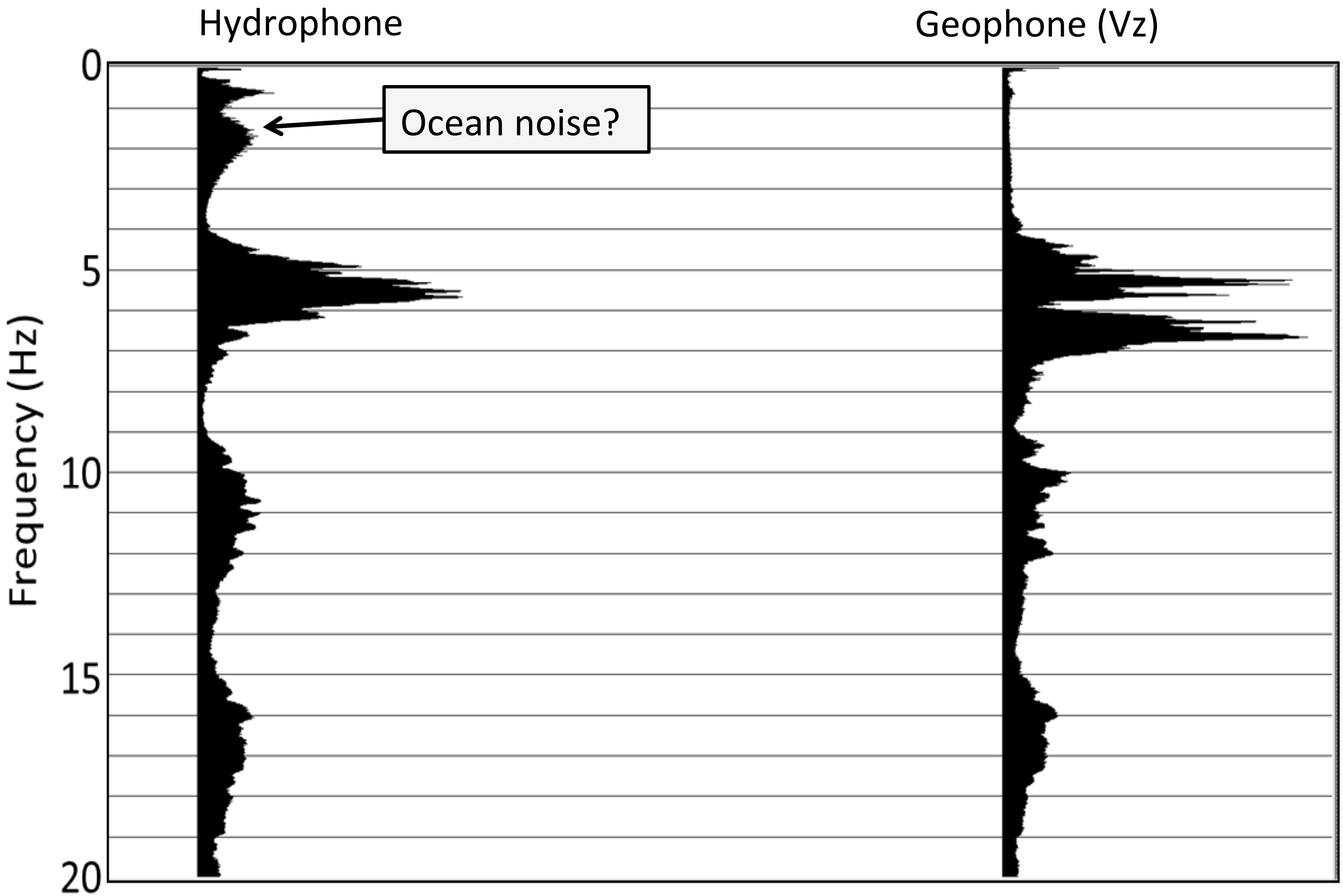
Zheng et al., 2013

Including gradually more frequencies into the data from left to right: 0-0-0.25-0.3 Hz; 0-0-1-2 Hz; 0-0-2-3 Hz; 0-0-3-4 Hz; 0-0-4-5 Hz and 0-0-30-40 Hz. Offset range is from 28 to 68 km, and time interval from 0 to 60 seconds. Hydrophone (top) and Vz (bottom).



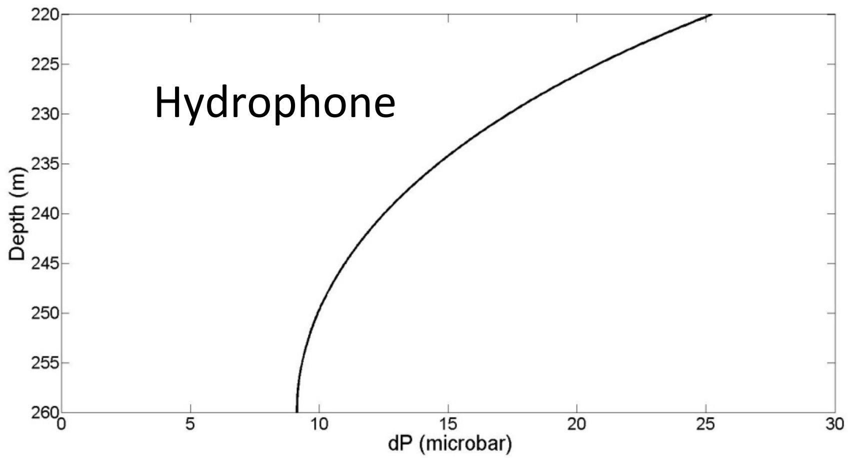
Source: Landrø, Haavik and Amundsen, SEG 2014

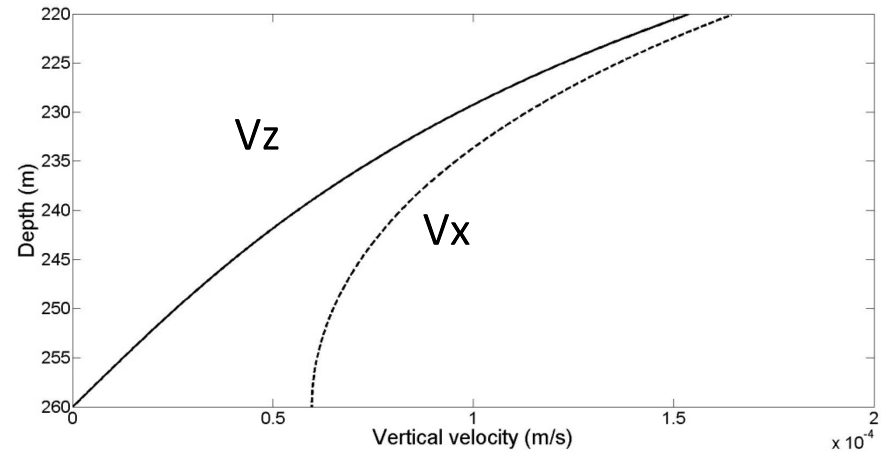
Amplitude spectra comparison



Source: Landrø, Haavik and Amundsen, SEG 2014

Modeled noise level generated by a 150 m long wave (5 m wave height and 0.1 Hz)

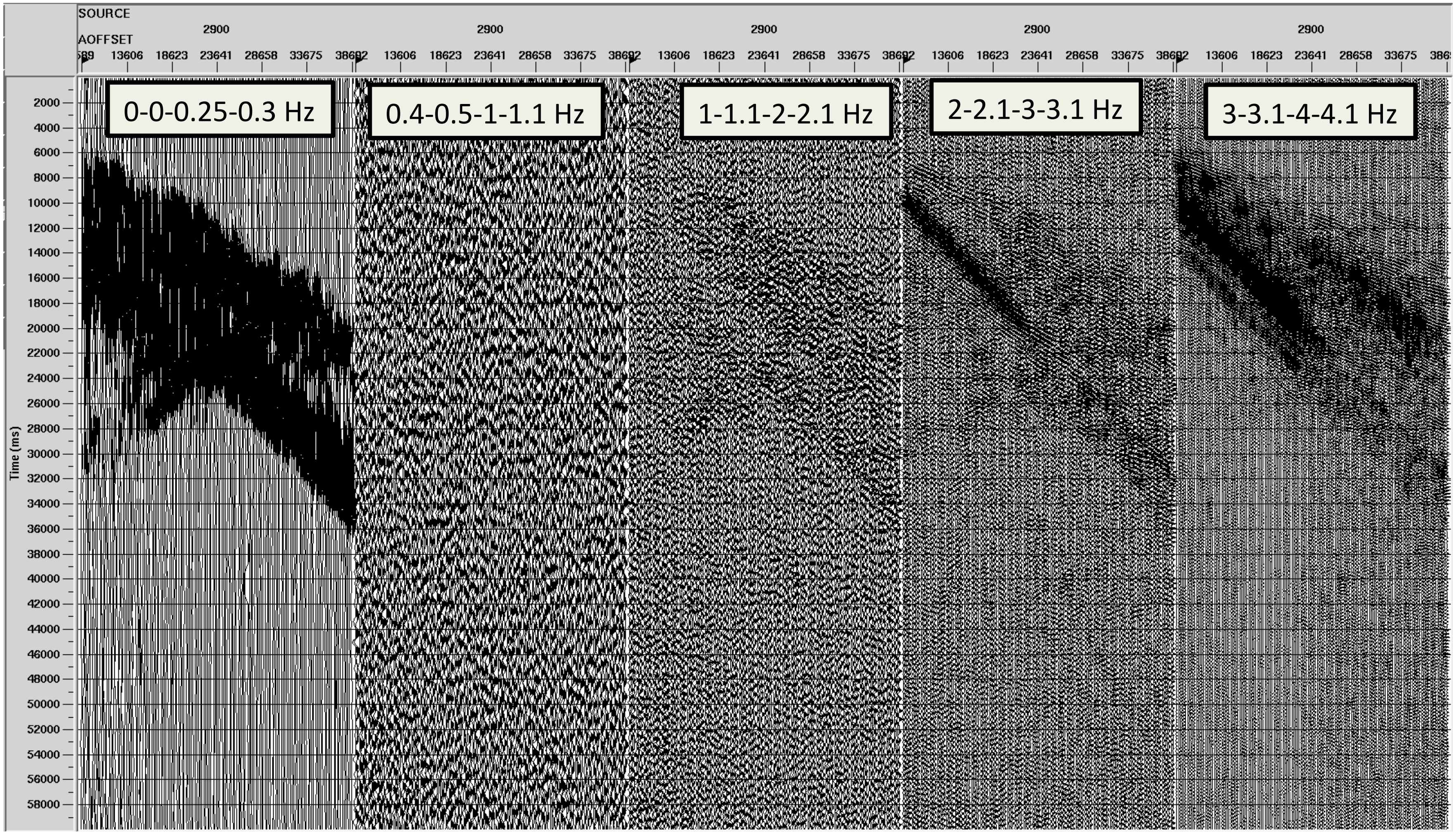




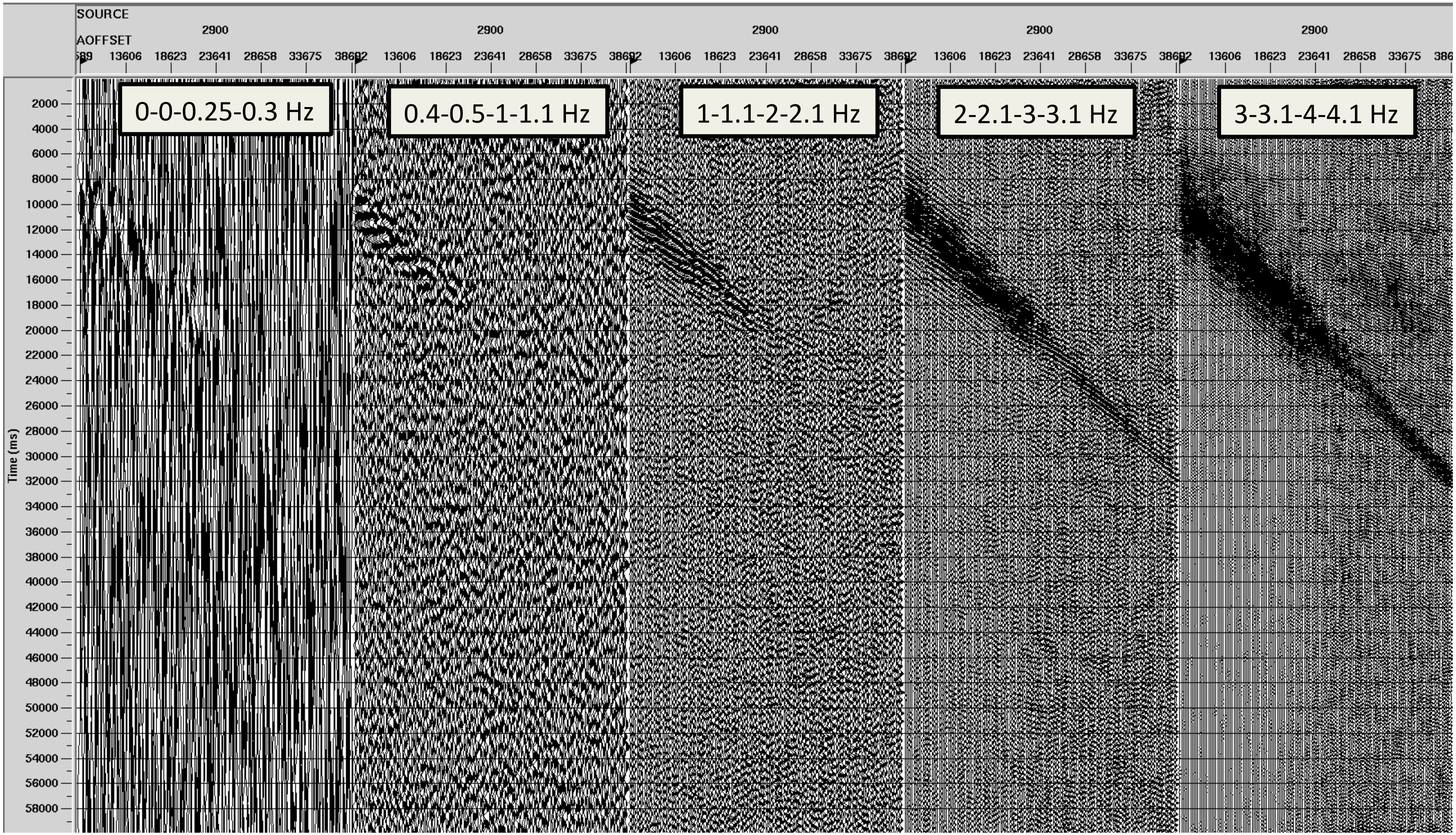
Vz is zero at the seabed

Source: Landrø, Haavik and Amundsen, SEG 2014

The strong signal at 0.1 Hz and the gradual build up from 2-4 Hz for the Vz-component

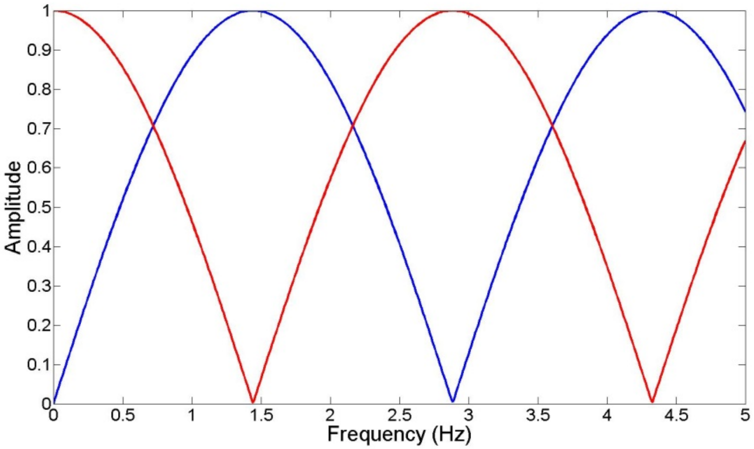


Same for the hydrophone recording

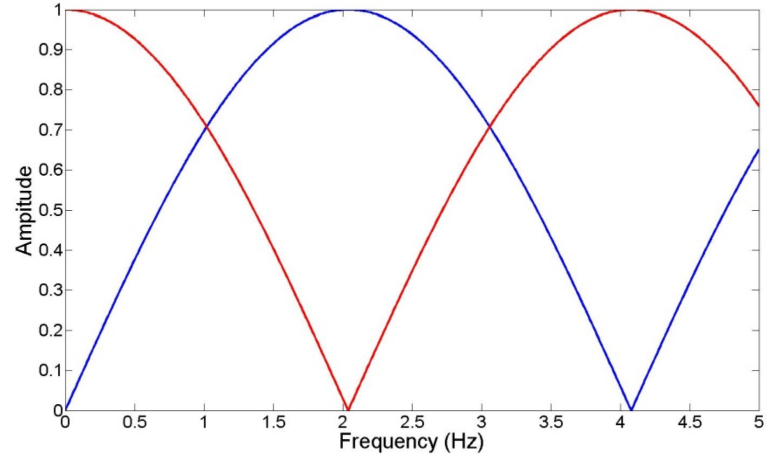


Complementarity between hydrophone and geophone

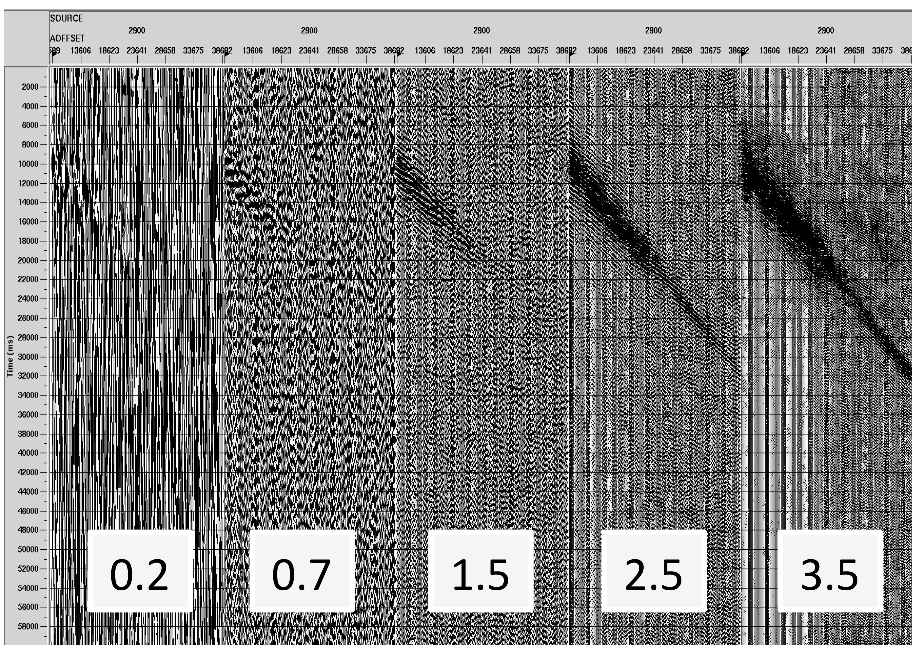
$\theta = 0$



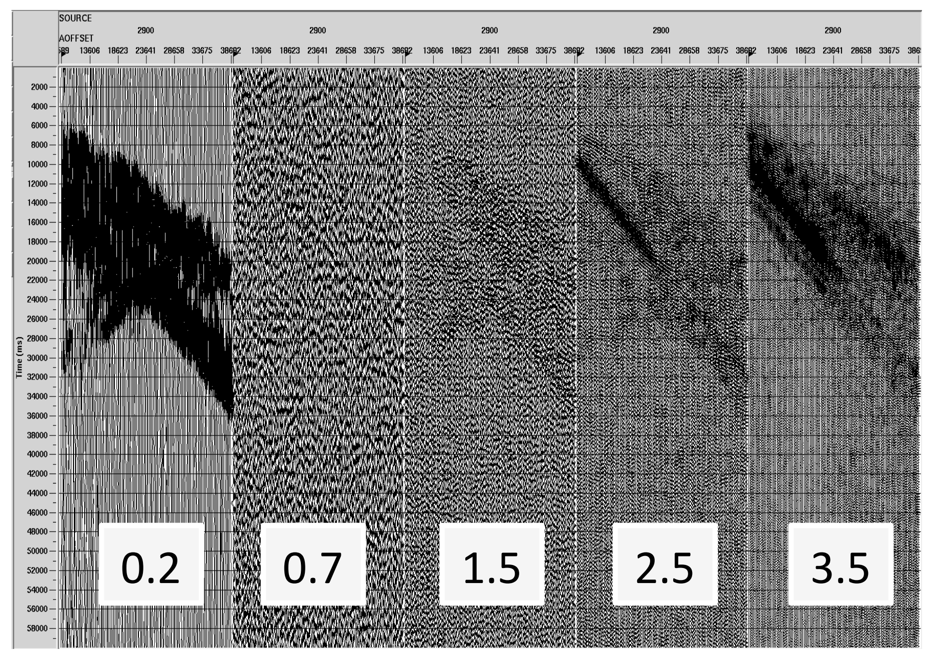
$\theta = 45$



Hydrophone



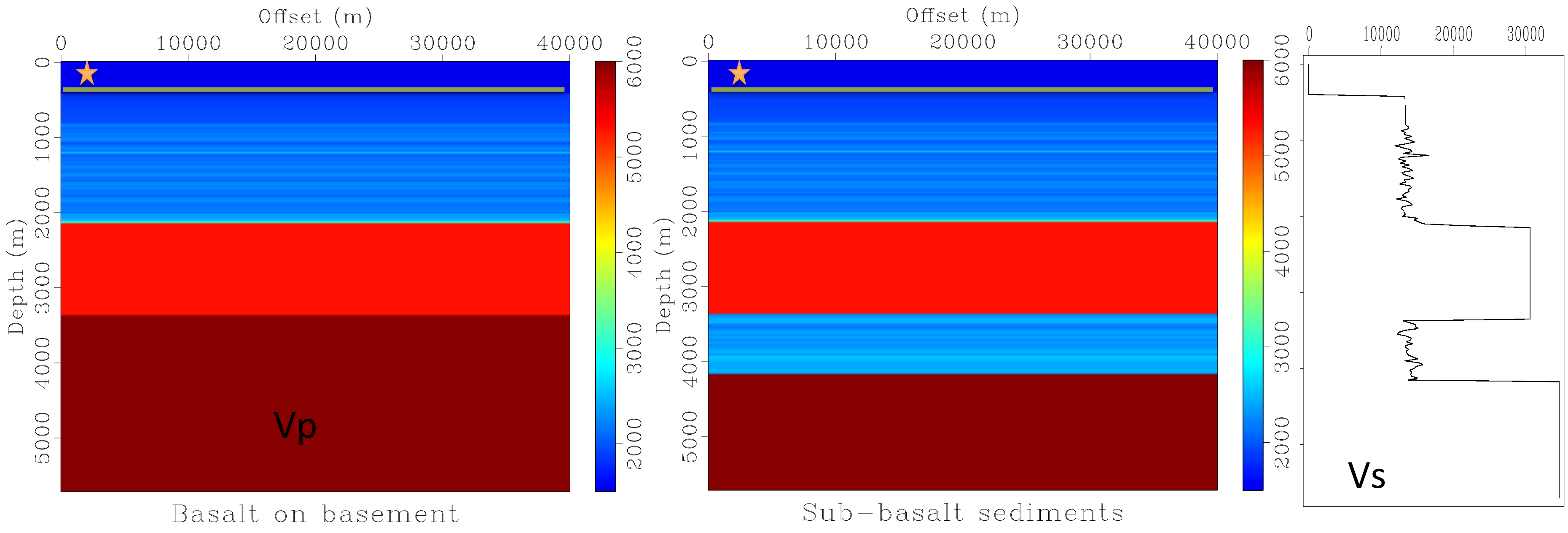
Geophone (Vz)



Applications of Ultralow frequency energy

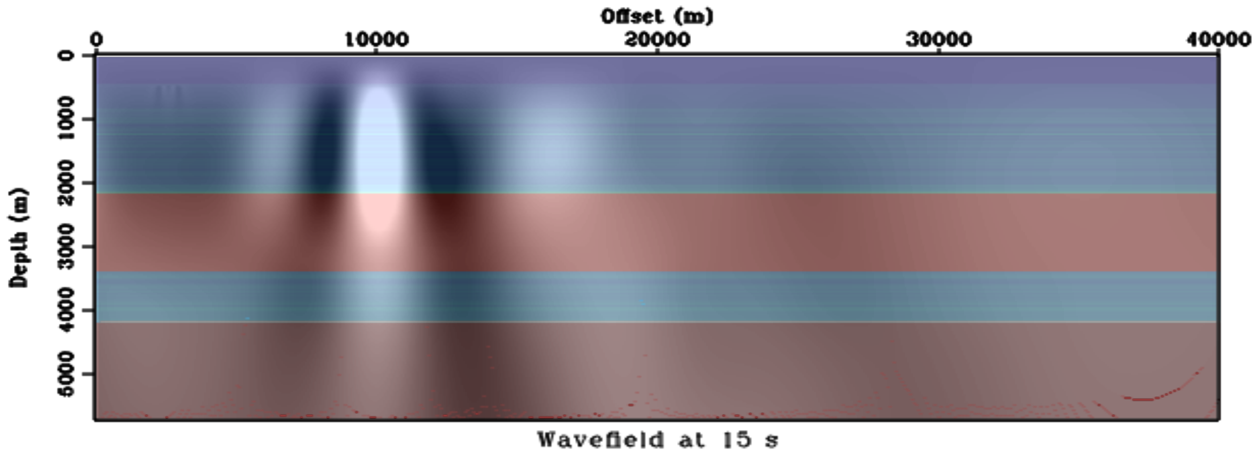
- FWI of refractions, reflections and diving waves

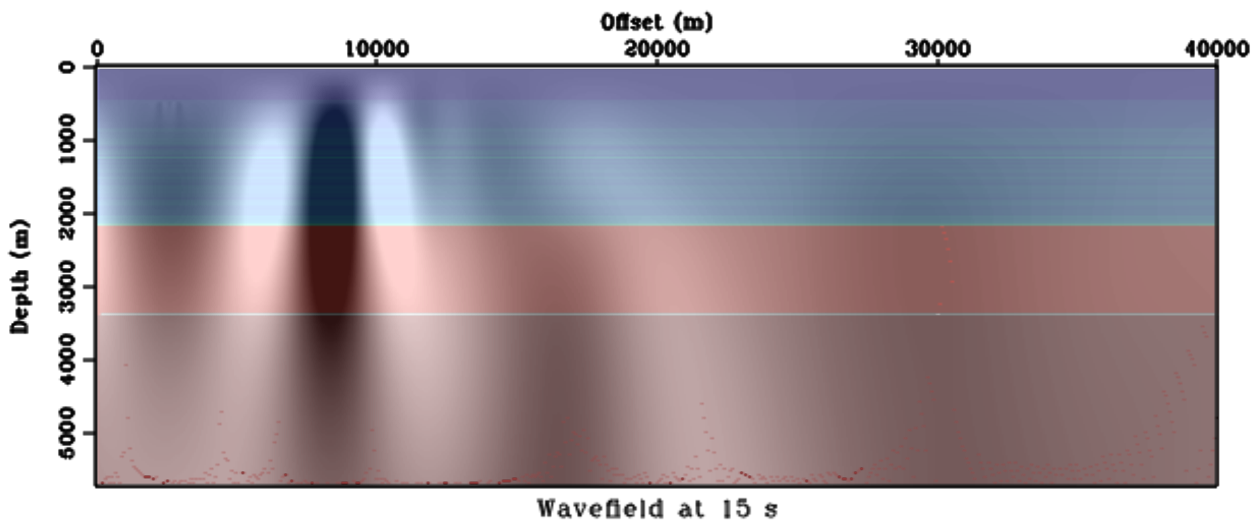
- Obtaining S-wave velocities from Scholte waves
- Demonstrate the presence of sediments below basalt



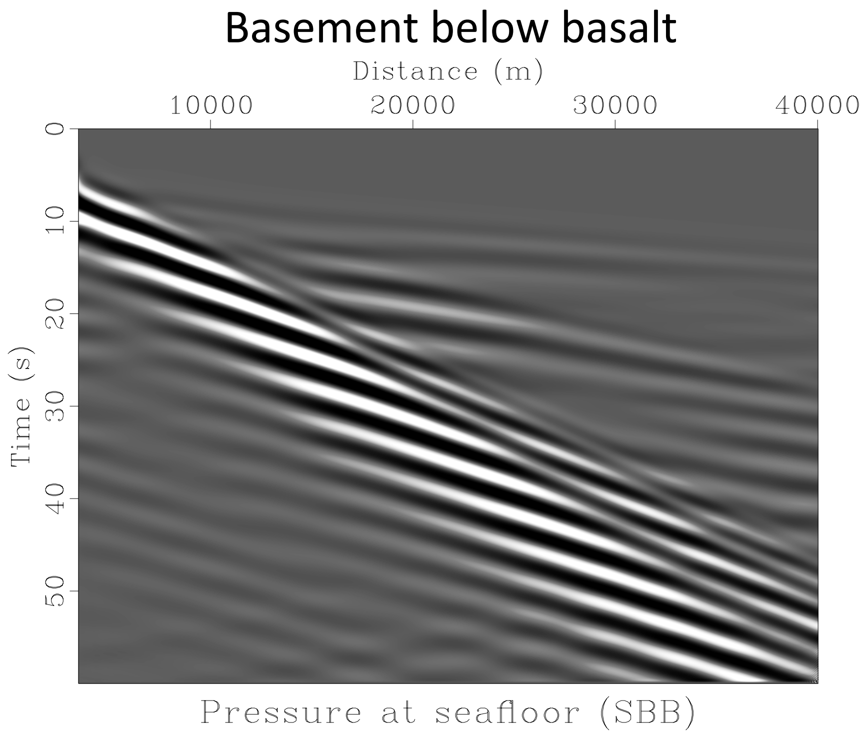
NB! Vertical Exaggeration ~10

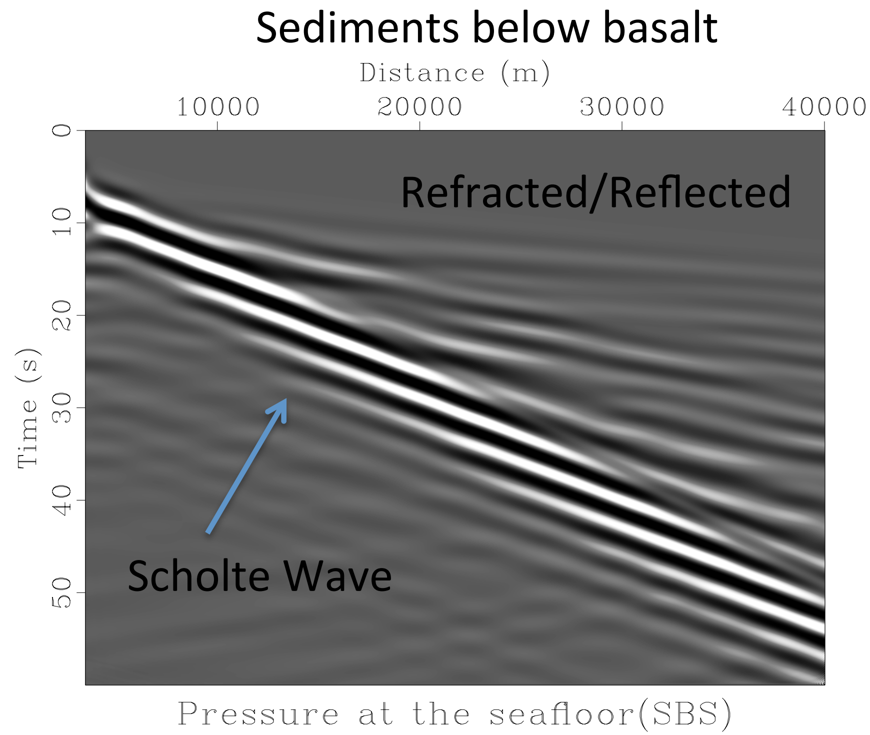
Wavefield at 15 s





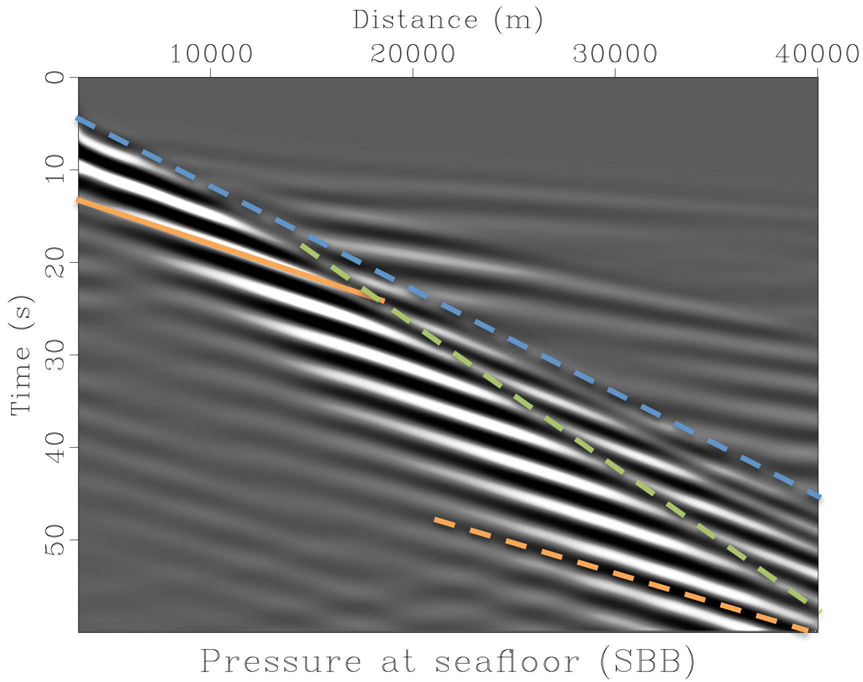
Wavefield extracted at the seafloor





Wavefield extracted at tha seafloor

Basement below basalt

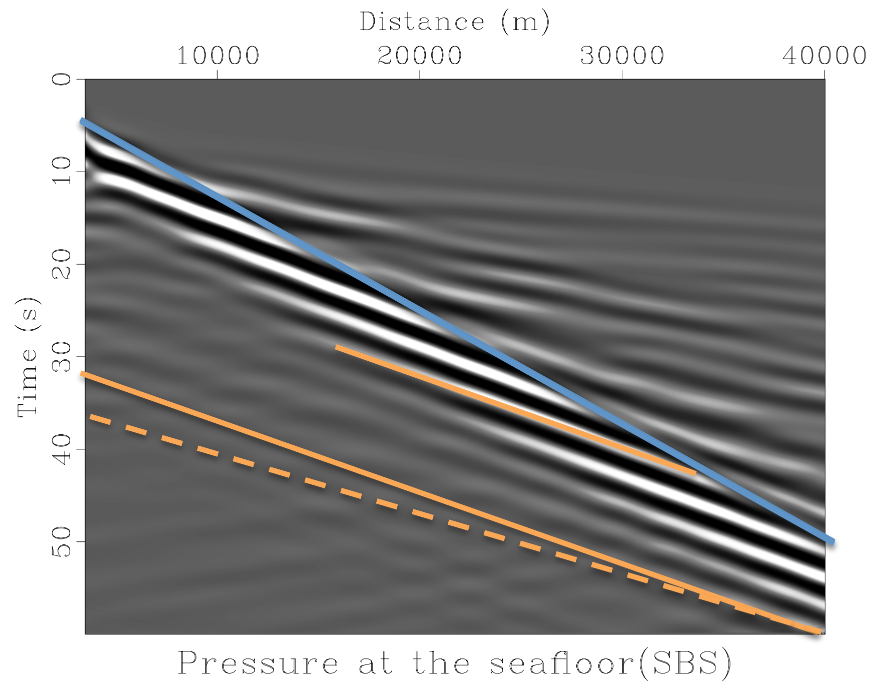


- - - Phase velocity = 1522 m/s

- - - Group velocity = 890 m/s

- - - Other mode (?) = 663 m/s

Sediments below basalt

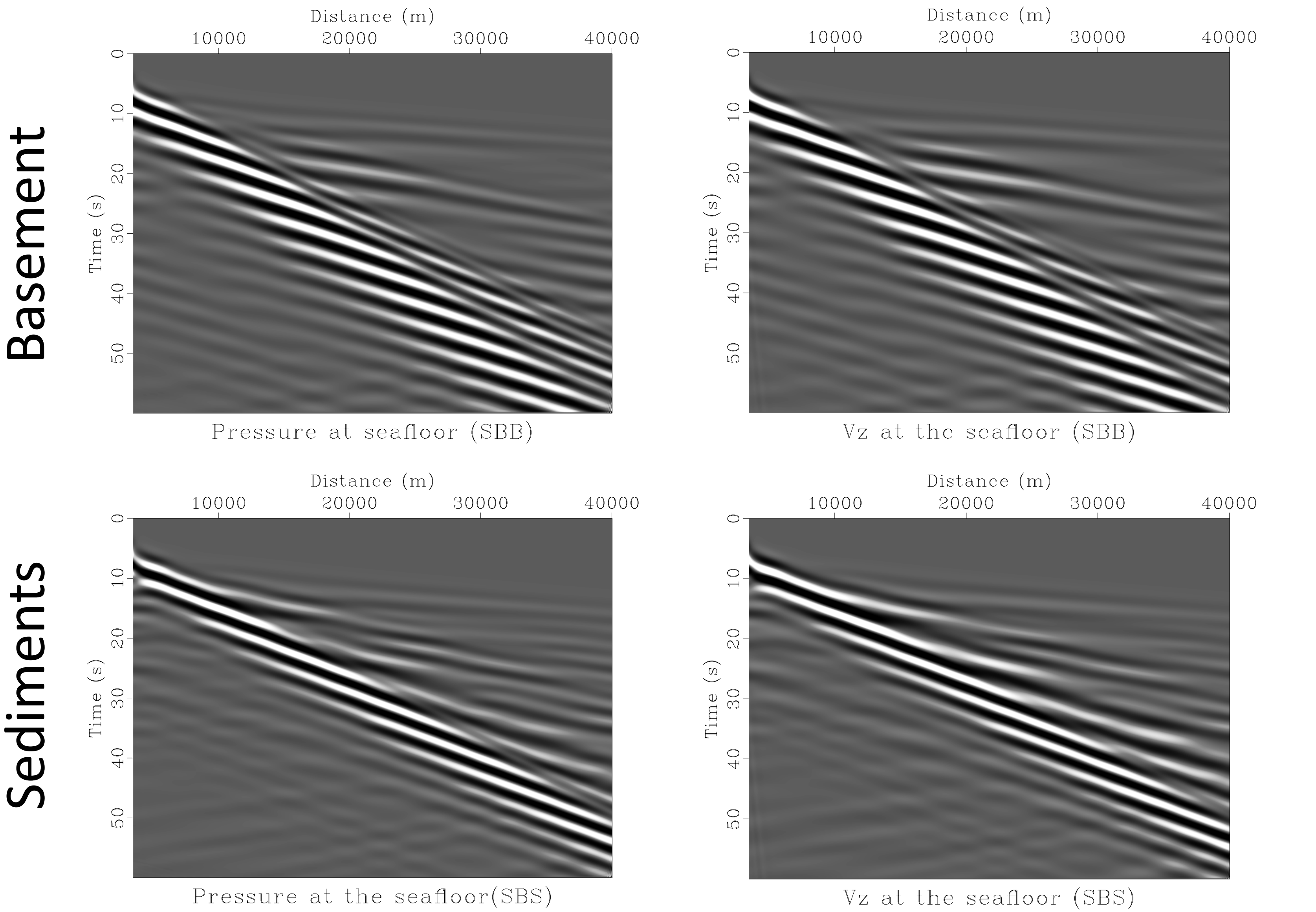


— Phase velocity = 1258 m/s

— Group velocity = 811 m/s

The Scholte wave velocity are influenced by sediments below basalt!

Pressure and Vz extracted at seafloor



We find that the ultralow frequency response of the vertical geophone component is superior compared to the hydrophone signal at long offsets.

To enhance the low frequency content of seismic data we suggest three major focal points:

- Use large air guns that create big bubbles and preferentially shallow source depths.
- Use the geophone recordings to obtain ultralow frequencies, since there is no ghost notch at zero Hertz for geophone data.
- Improve the low frequency response of the geophones.

We think that the ultralow frequency seismic signal can be used for many applications, for example FWI and Scholte wave velocity inversion/attribute.

Source: Landrø, Haavik and Amundsen, SEG 2014

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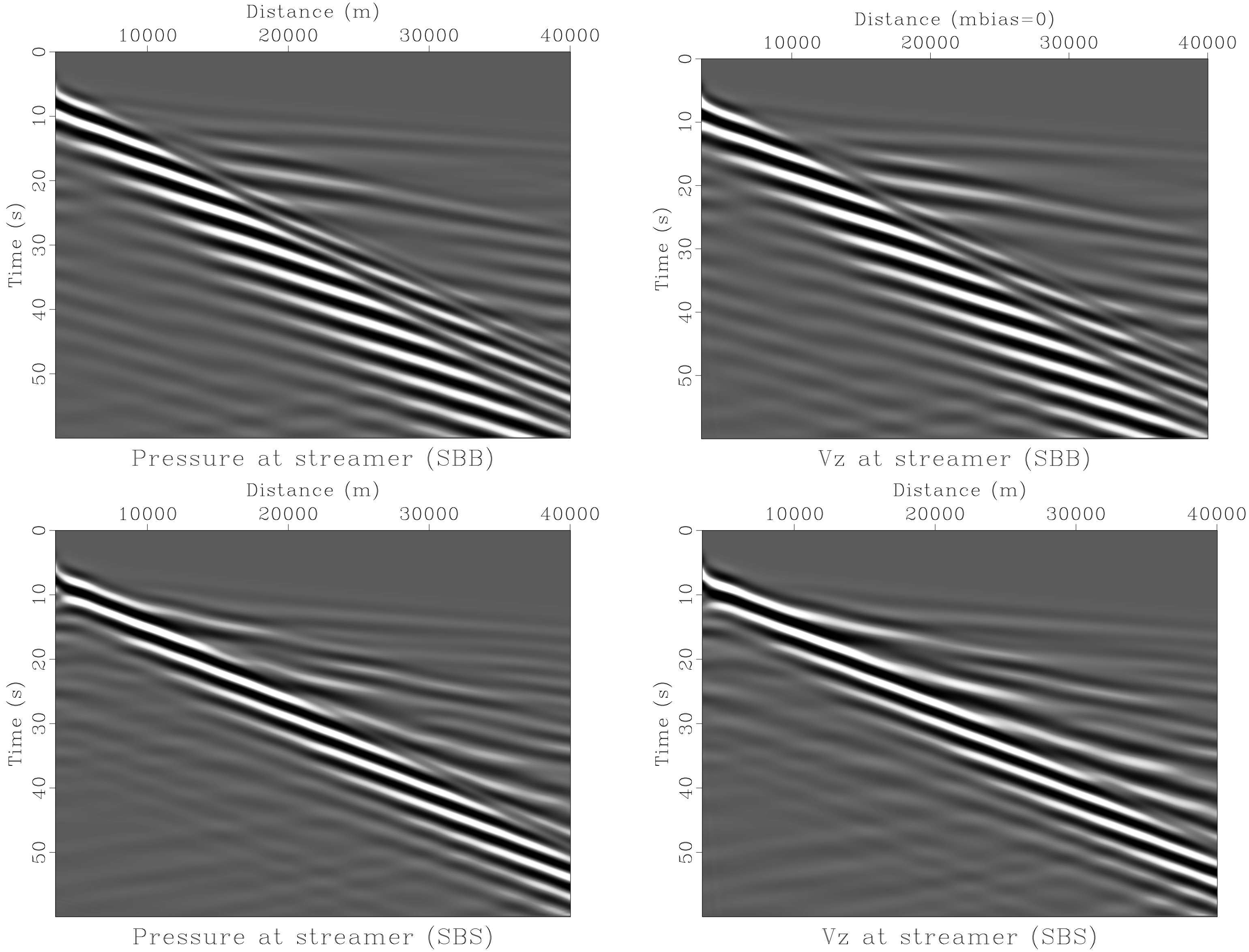
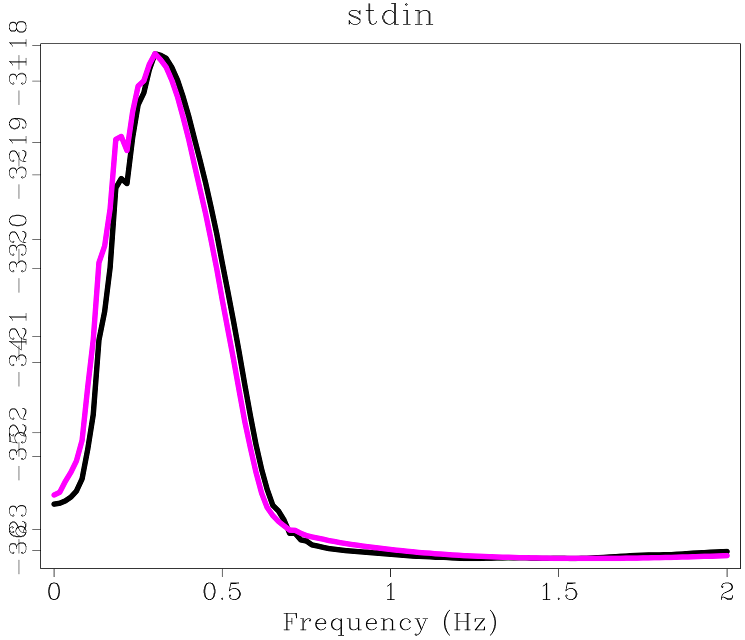
Wavefield recorded at 50 m



Sediments



Basement