# Overview of Broadband Seismic

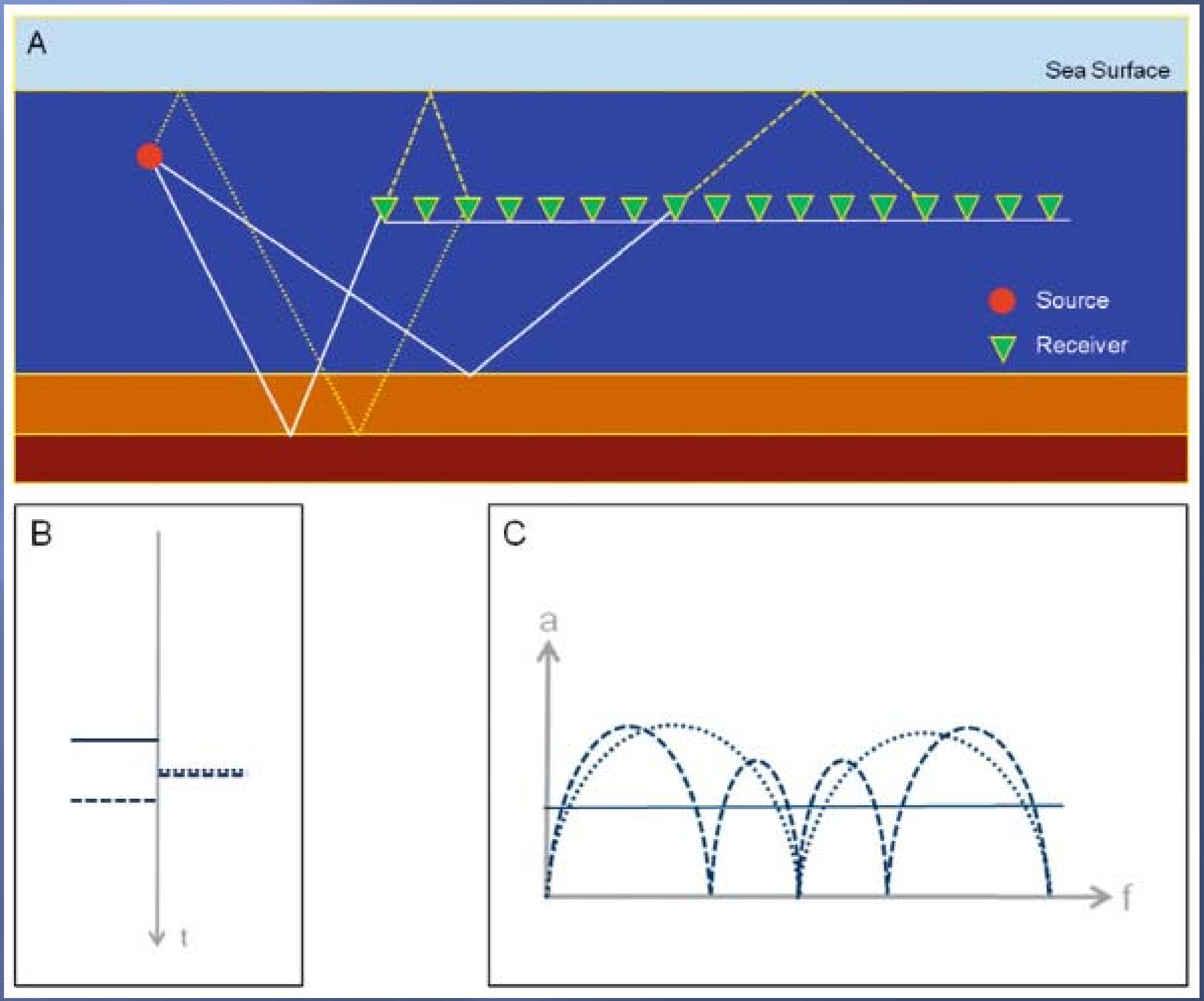
*Rocky Roden*

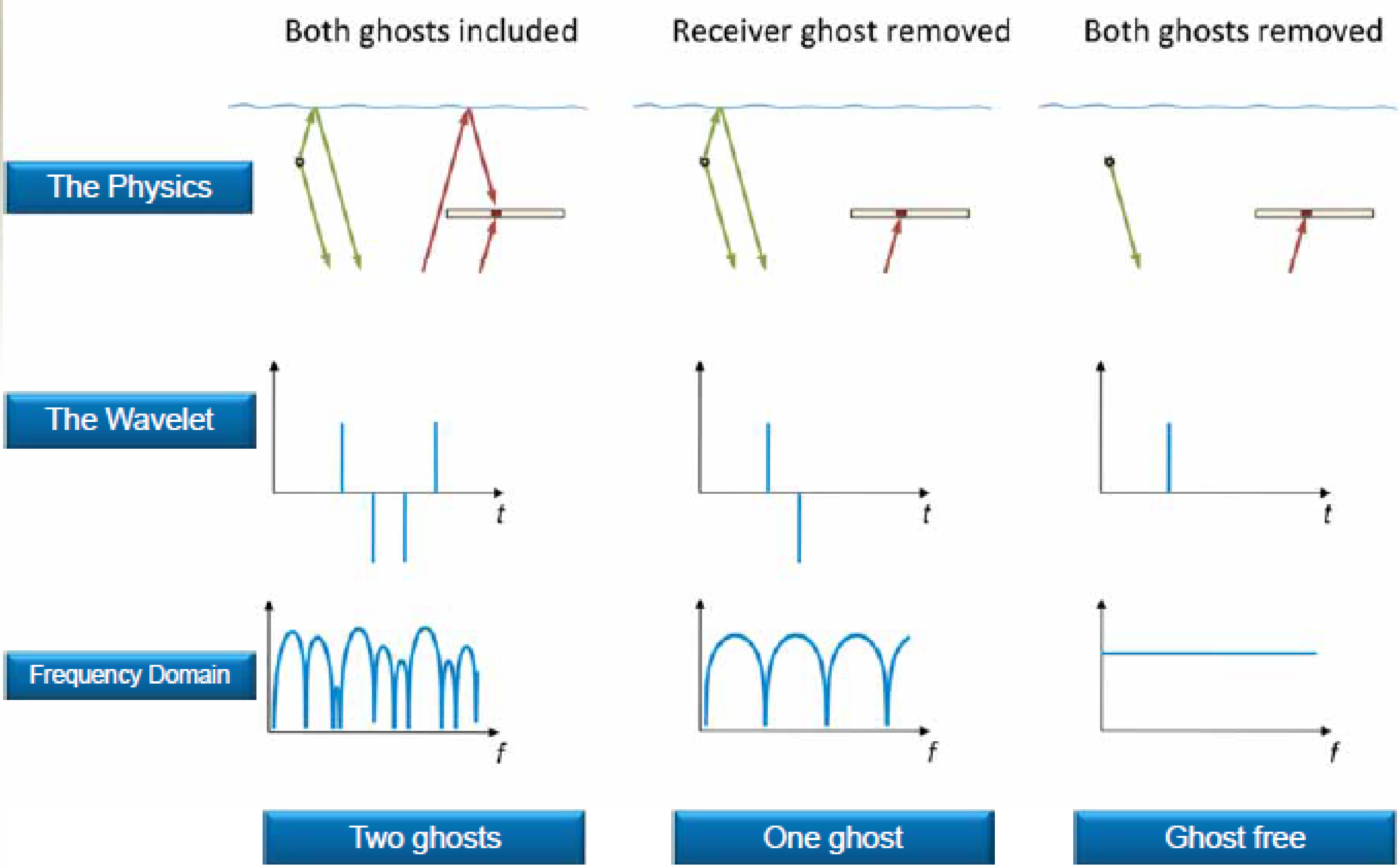
*September 2013*

**<u>Broadband Seismic Data</u>** – A term used to describe a broader range of frequencies in seismic data than has conventionally been acquired, both at the low and high end of the frequency spectrum.

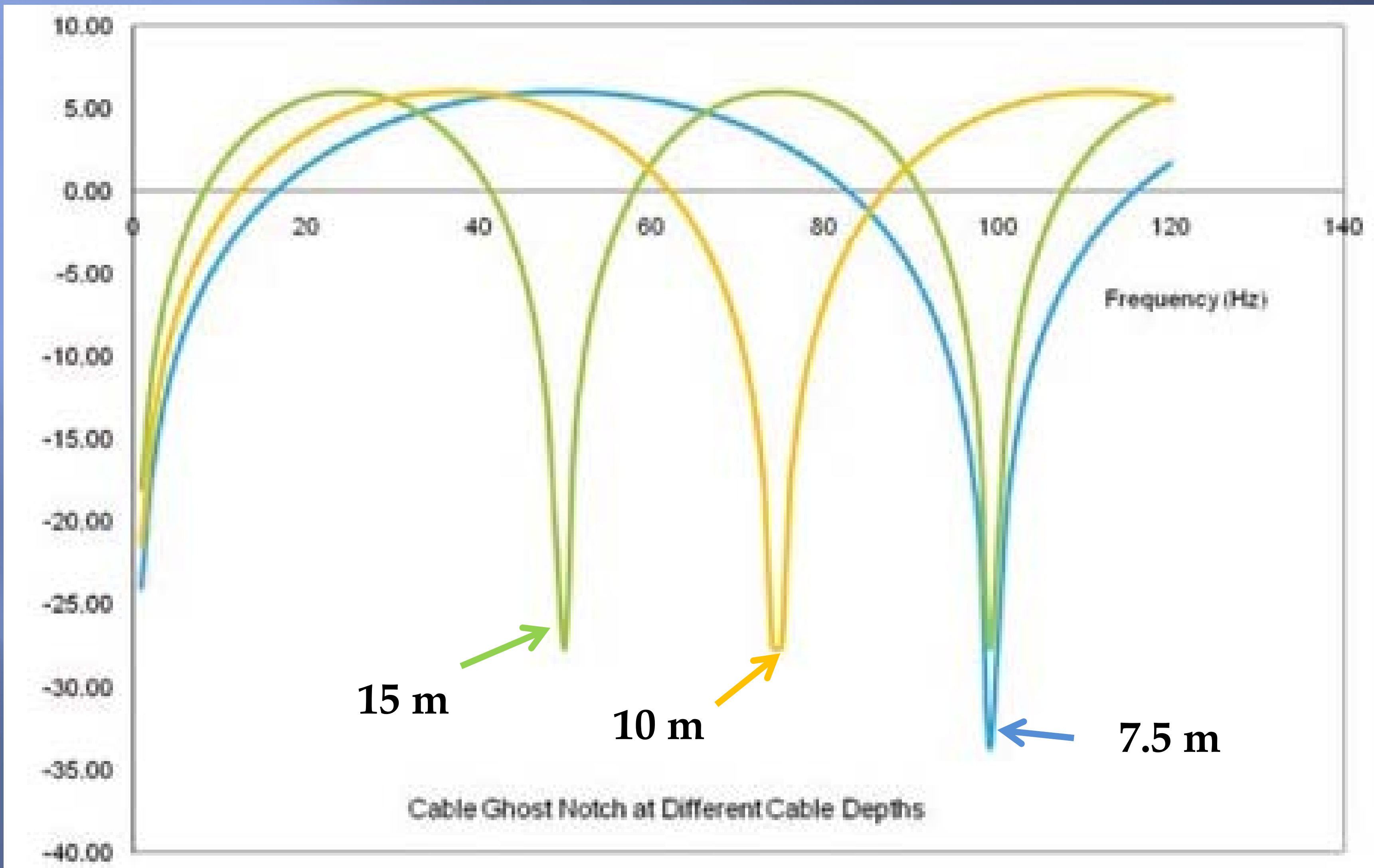
***Over the last 5 years, this broadband seismic data term has evolved as a result of seismic contractors having developed techniques in acquisition and processing to specifically address the <u>sea surface ghost effects.</u>***

*The ghost is the reflection from the sea surface that interferes constructively or destructively with the primary reflections reducing the seismic bandwidth at the low and high ends of the spectrum.*




Both ghosts included
Receiver ghost removed
Both ghosts removed
The Physics
The Wavelet
Frequency Domain
t
t
t
f
f
f
Two ghosts
One ghost
Ghost free

*Towing streamers shallow favors the higher frequencies at the expense of attenuating the low frequencies and increasing noise, while towing streamers deep favors the lower frequencies at the expense of attenuating frequencies in the seismic bandwidth.*




Soubaras and Dowle, 2010

**Several of the acquisition technologies that have evolved over the last 5 years were tried in the 80's with limited success due to:**

- *Inadequate processing algorithms*
- *Deficiencies in marine acquisition technology*
- *Lack of streamer control in horizontal and vertical planes*
- *Reduced accuracy in receiver positioning along streamers*

# Broadband Seismic Solutions by Contractor

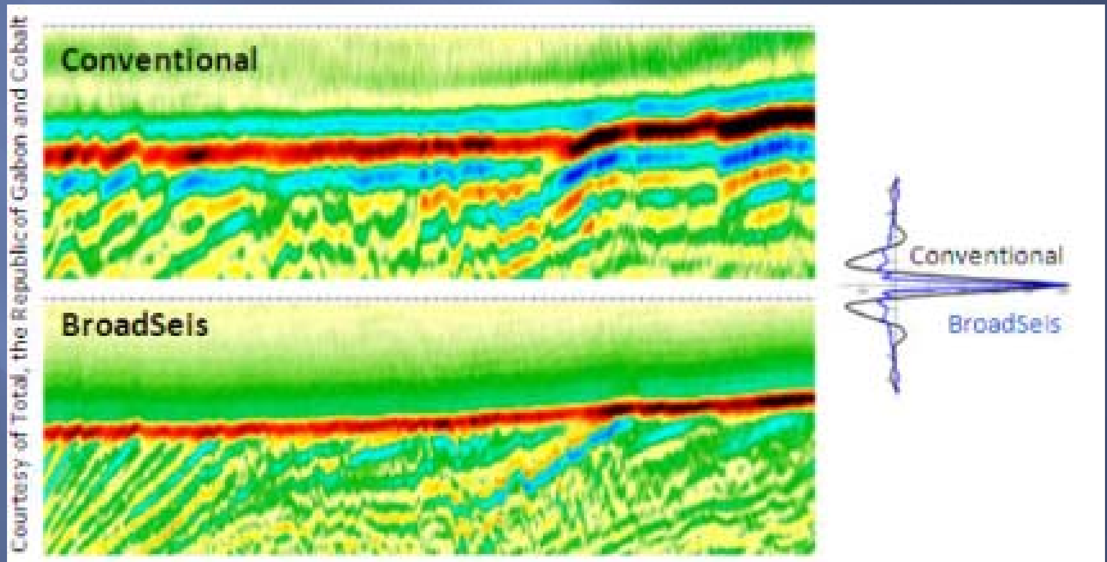
*CGG*
*PGS*
*WesternGeco*
*TGS*
*Ion (GXT)*
*Others?*

CGG

**BroadSeis** – *Incorporates variable receiver depths along a streamer (slant streamer)*

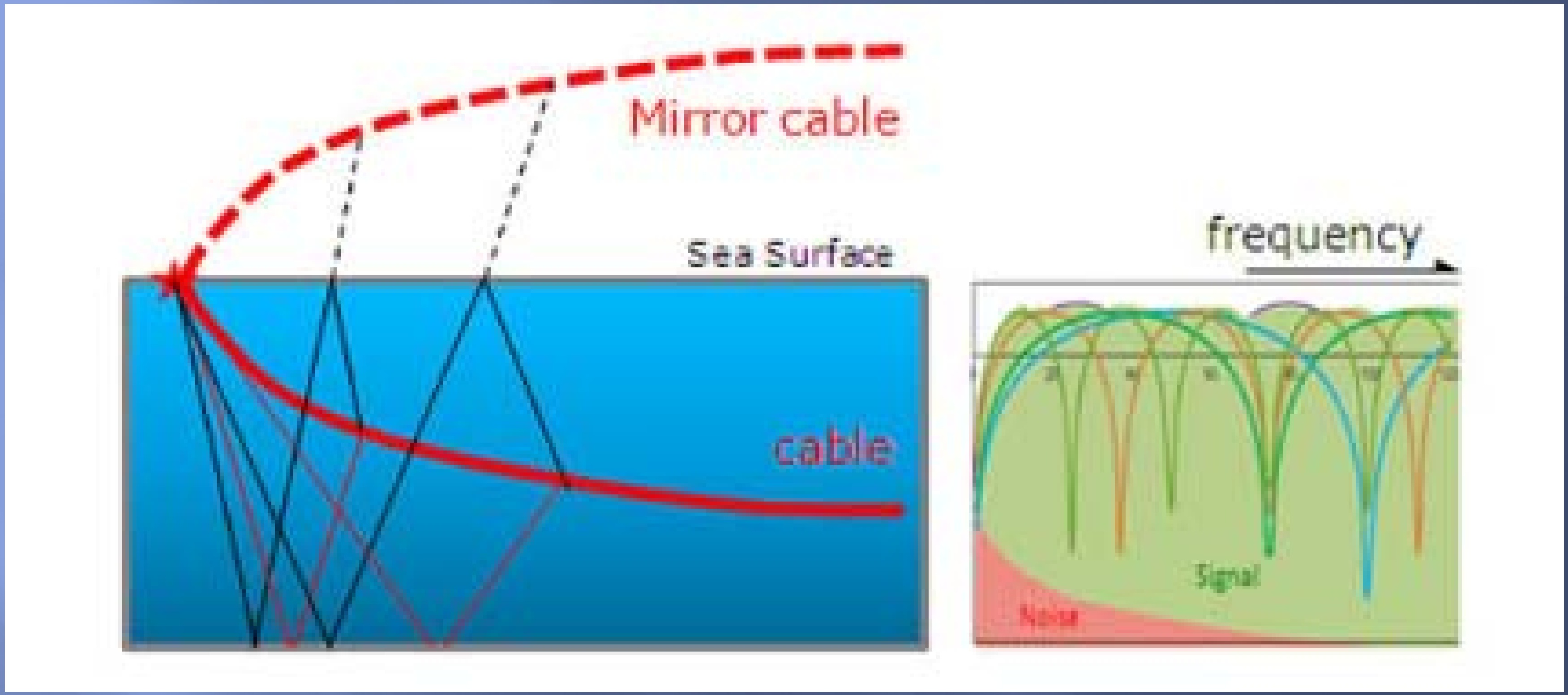
*Uses solid streamers that have low noise performance characteristics and can be towed at greater depths than industry norms.*

*Can record data down to 2.5 Hz.*



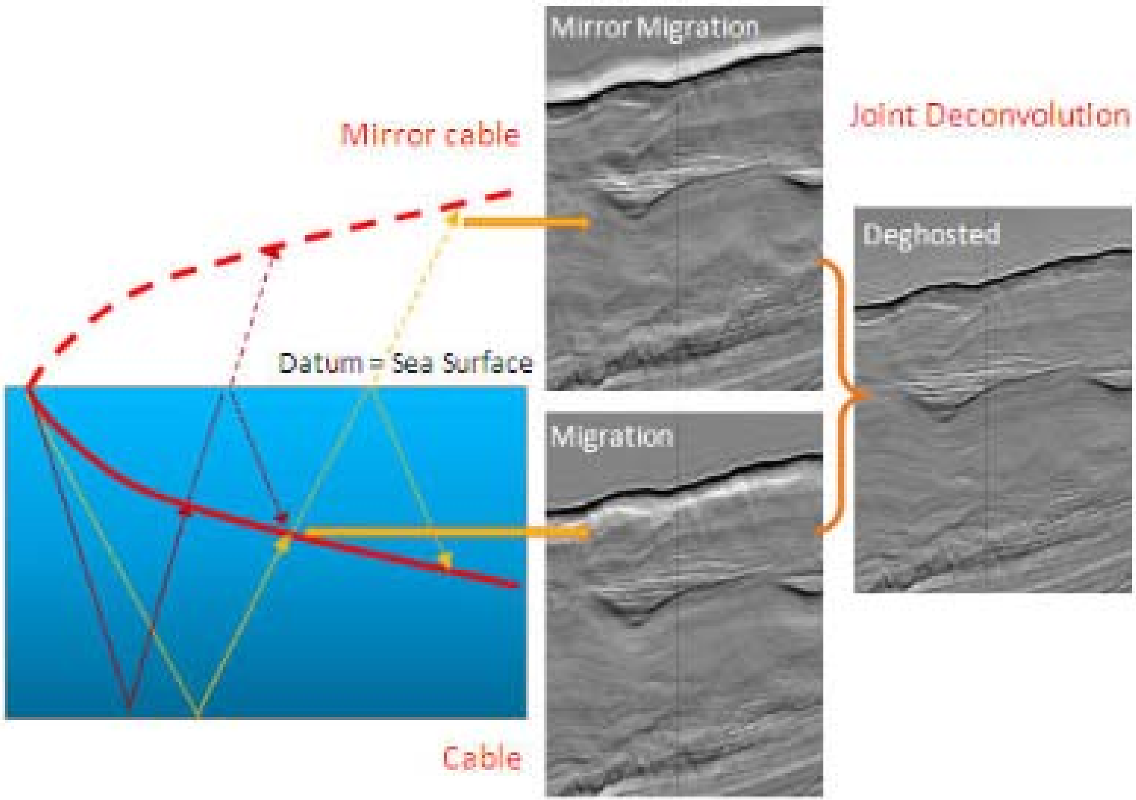

The lack of sidelobes provided by the low frequencies in a broadband wavelet redumake it possible to resolve a huge amount of detail, thanks to the lack of confusion caused by interference – in this case allowing dipping sediments to be traced right up to the water bottom.

CGG




*BroadSeis data are "detuned", as the receivers vary in depth their ghost notches vary in frequency and cancel when the different offsets are stacked together*

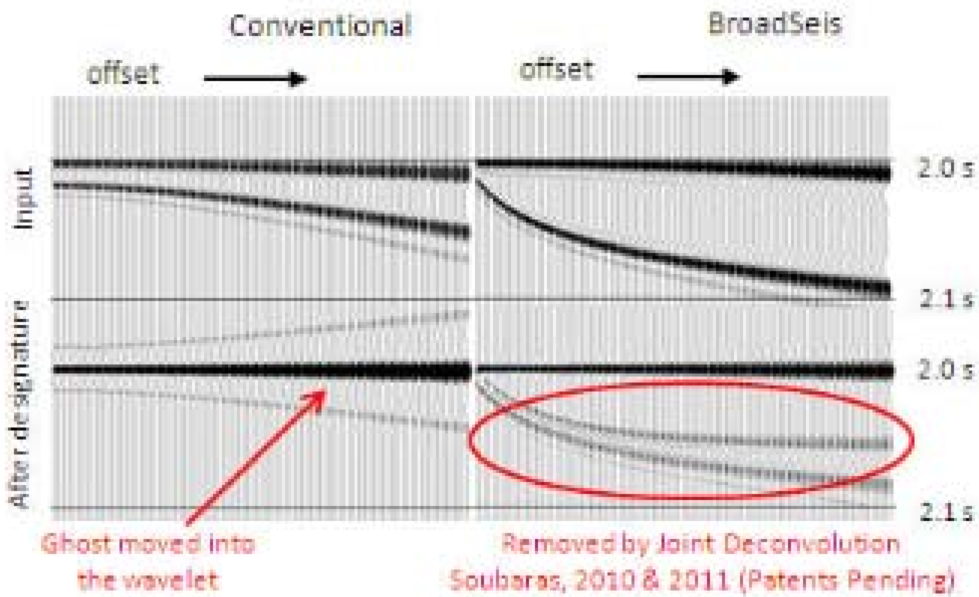
CGG




*Regular migration enhances the primary reflections, mirror migration enhances the ghost reflections*

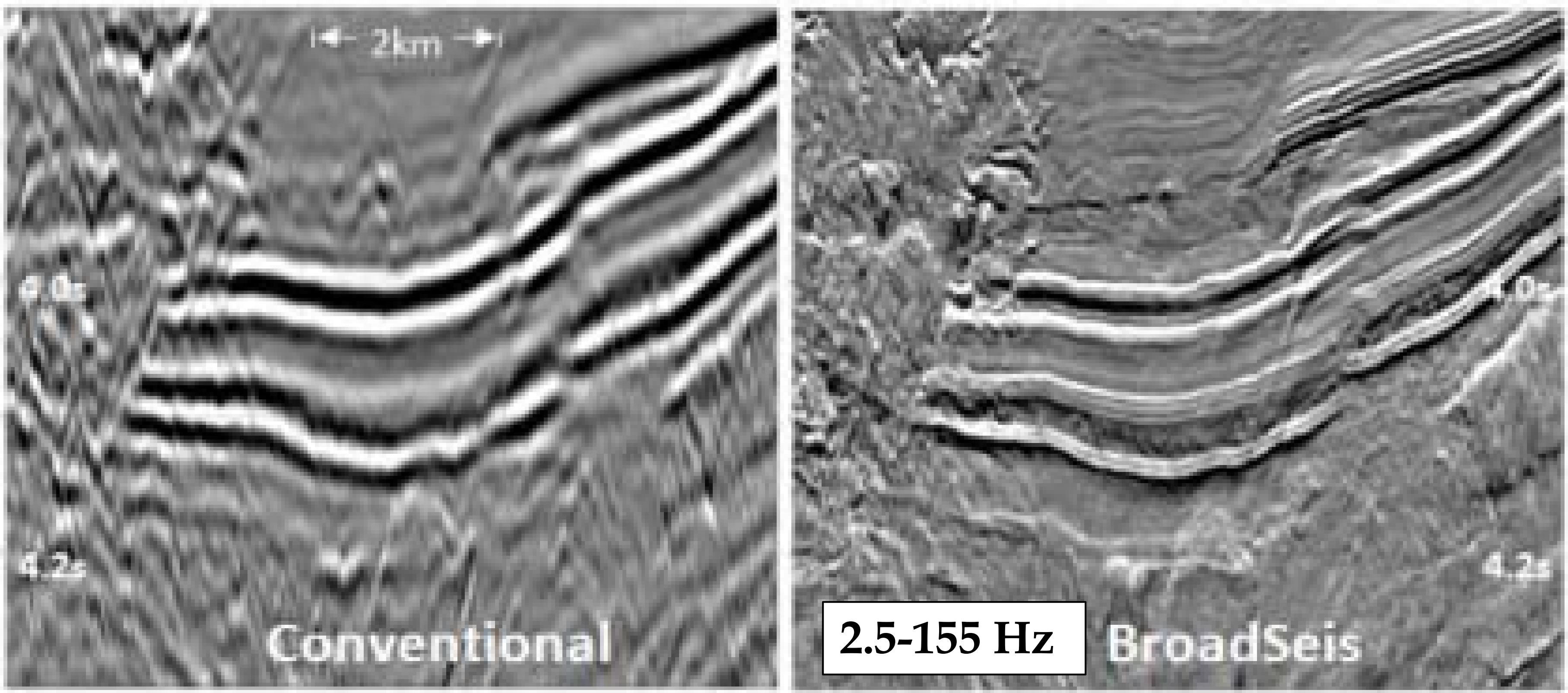
*Joint Deconvolution combines the conventional and the mirror migration to deghost the data*

*Ghost is separated from the source wavelet and can be removed*



CGG

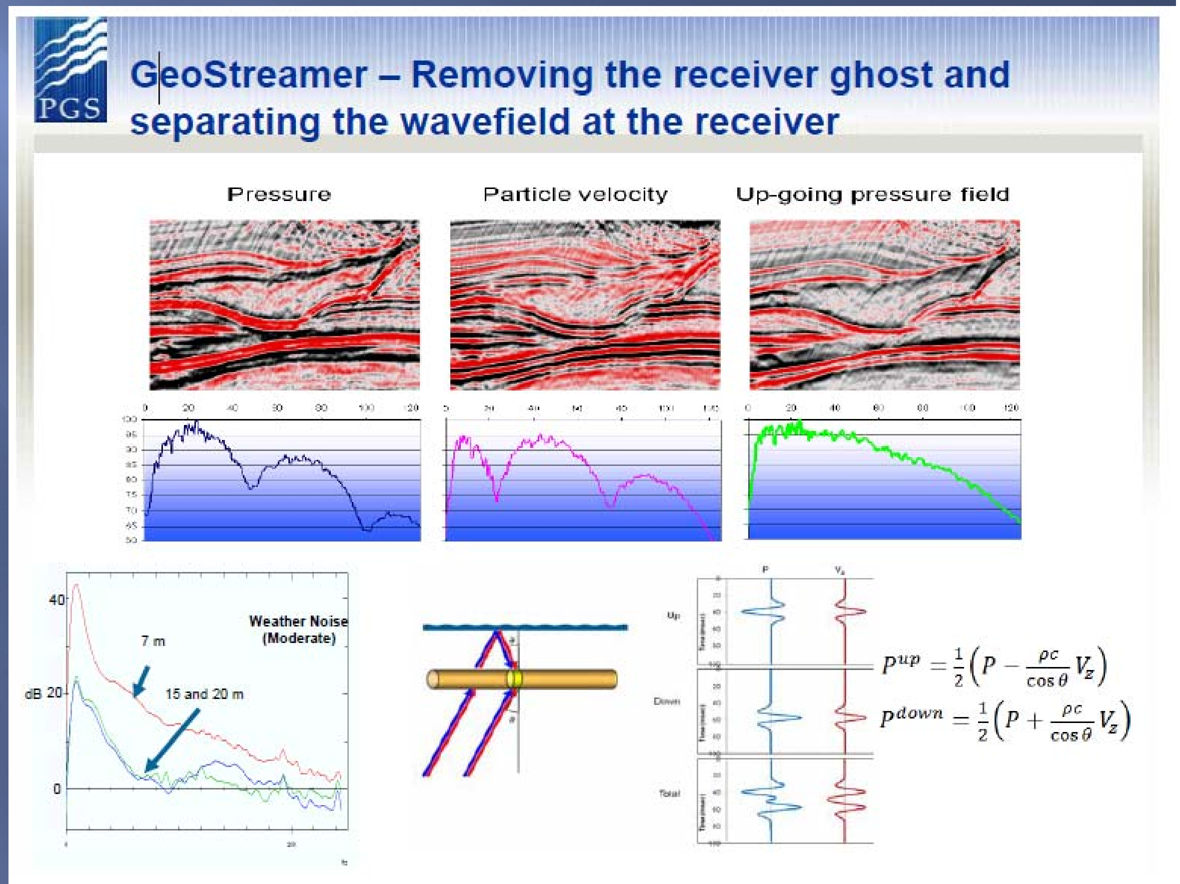
*The variable streamer depth and subsequent diversity of the streamer ghost notches, can be tuned for different targets. Surveys can be designed according to water depth, target depth, and velocity profile of the area.*



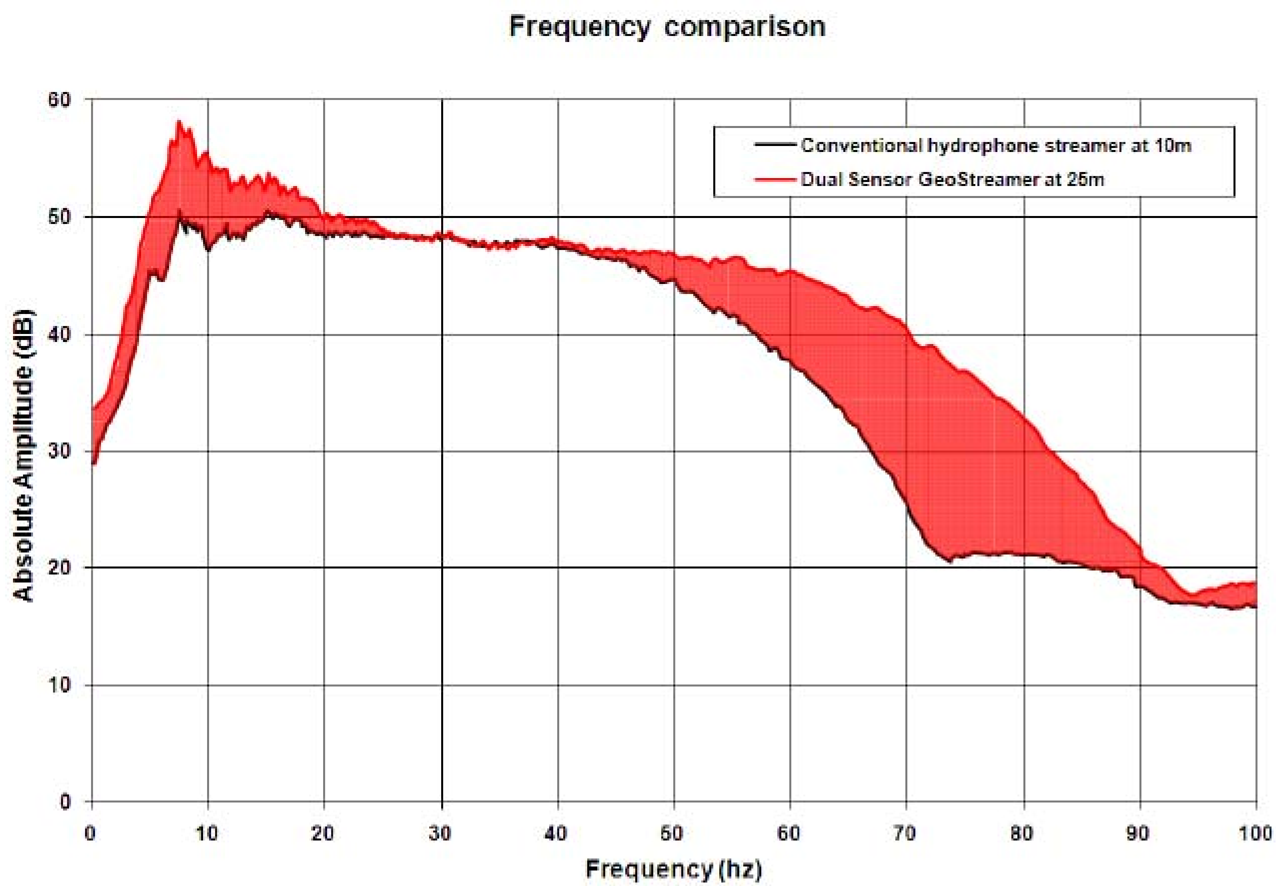
# **GeoStreamer** – *Dual sensor streamer with a pressure and vertical particle velocity sensors.*

*This configuration allows the receiver ghost to be removed by separating the up- and down-going wavefields.*

*Facilitates towing the streamer deeper (15m) increasing the seismic acquisition weather window.*

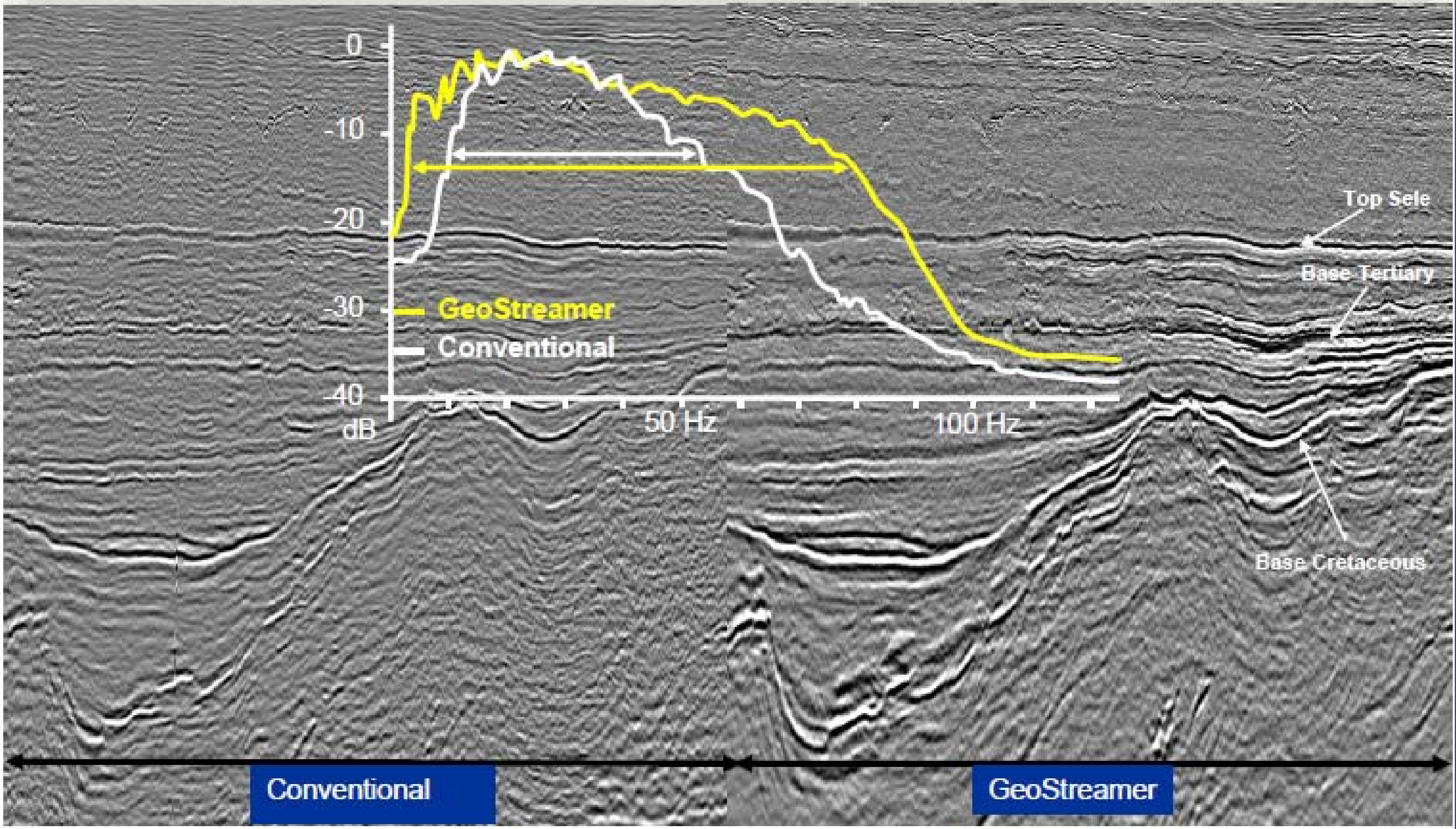


# Amplitude spectrum comparison 10m vs. 25m



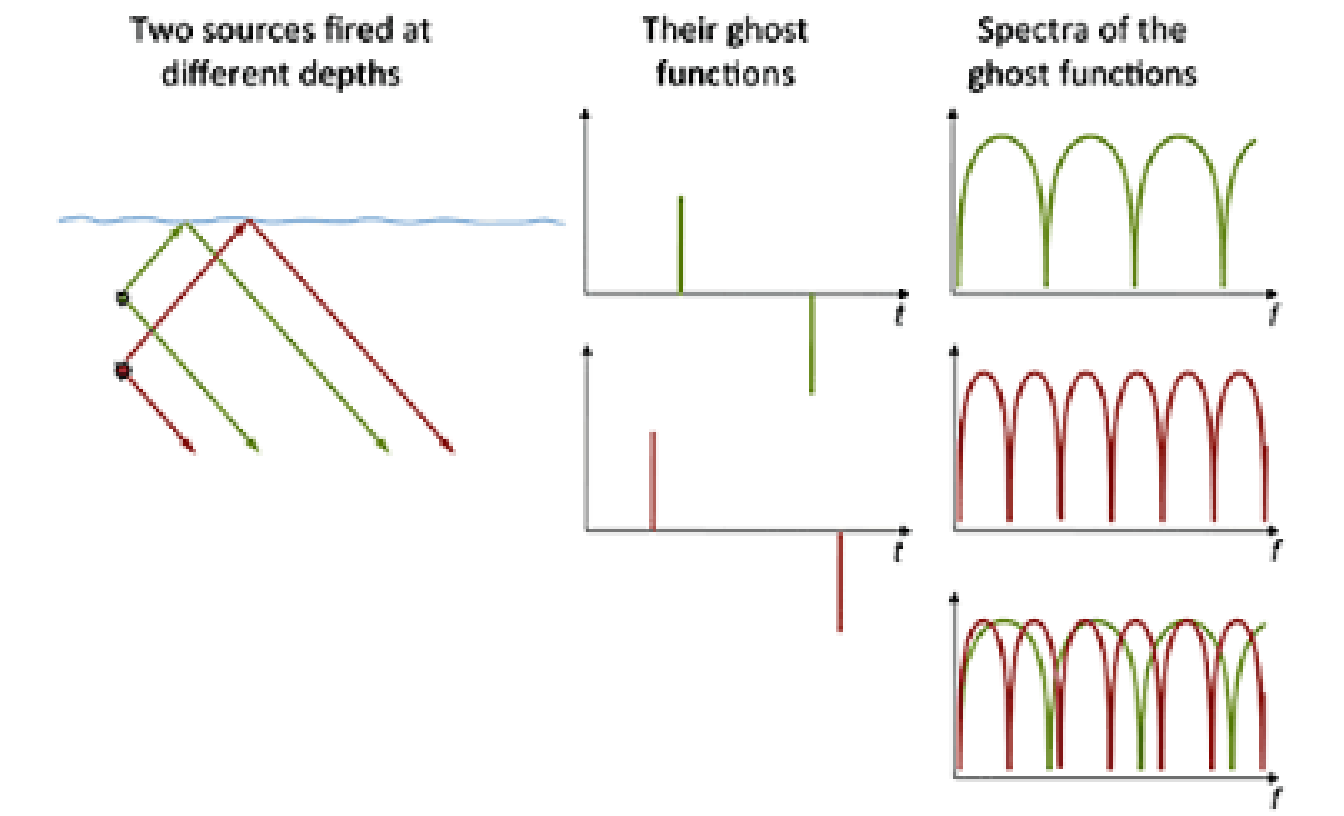
PGS

# Seismic comparison Conventional versus GeoStreamer



PGS

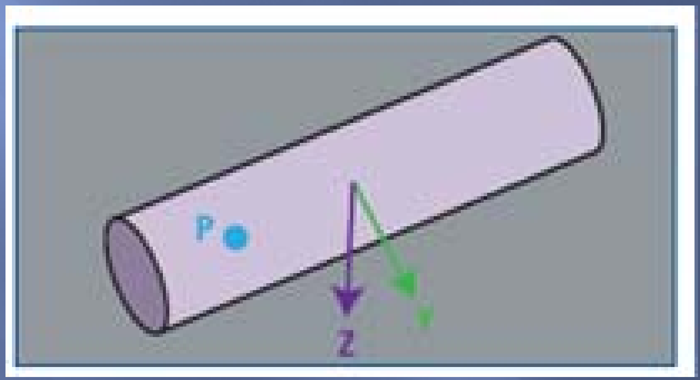
**GeoSource** – *Time and depth distributed source using sub-sources operating at specific depths and time delays.*




*Schematic illustration of the principle behind GeoSource. Sub-sources fired at different depths yield source wavelets with different delays between the primary event and the source ghost event (centre column). These wavelets have complementary amplitude spectra (right column).*

WesternGeco

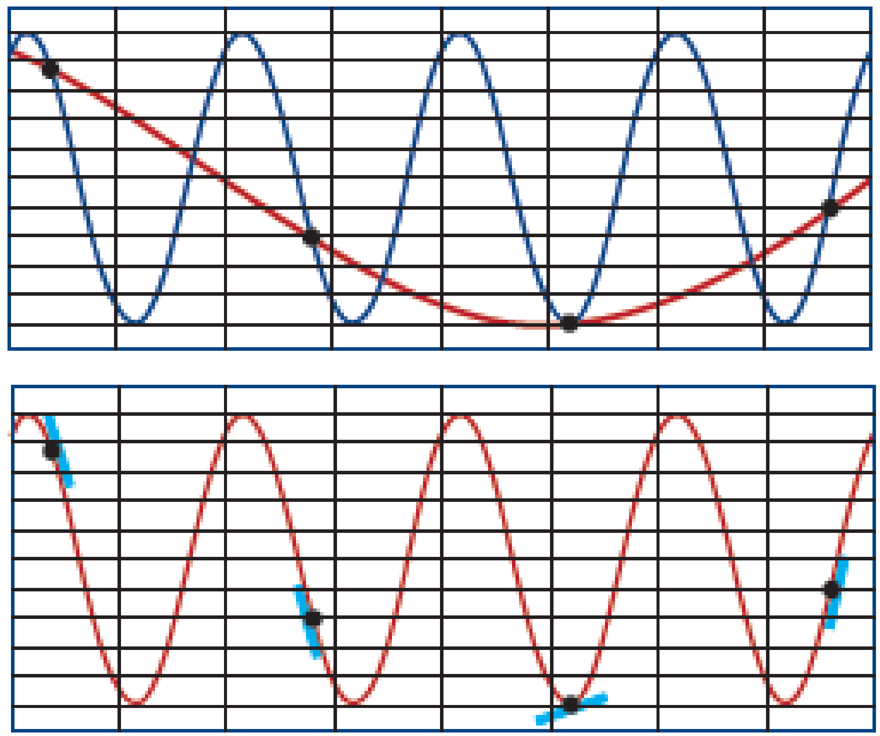
**Isometric 3D (Nessie-6)** *– A streamer design that combines measurements of wavefield pressure and gradient-vertically and crossline.*




*Uses point-receiver hydrophones with calibrated multi-component, MEMS accelerometers, that measure the full-particle acceleration, due to the upgoing and downgoing seismic wavefield.*

WesternGeco

*Direct measurement of the vertical and crossline gradient enables unaliased reconstruction of the pressure wavefield between the streamers.*



Measurement of crossline gradients enables unaliased reconstruction of the seismic wavefield between streamers. The blue waveform represents the actual signal, and the red waveform, the reconstructed signal. The figures contrast reconstructed signal with pressure-only measurements (top) versus pressure + gradients (bottom).

WesternGeco

*Prestack Slant Streamer deghosting – Perform deghosting in the prestack stage of processing to take advantage of the closely spaced (3.125 m) point-receiver sampling in their latest generation streamers.*

*Over/Under Streamers – Employ shallow streamers for medium to high frequencies and deeper streamers for low frequencies.*

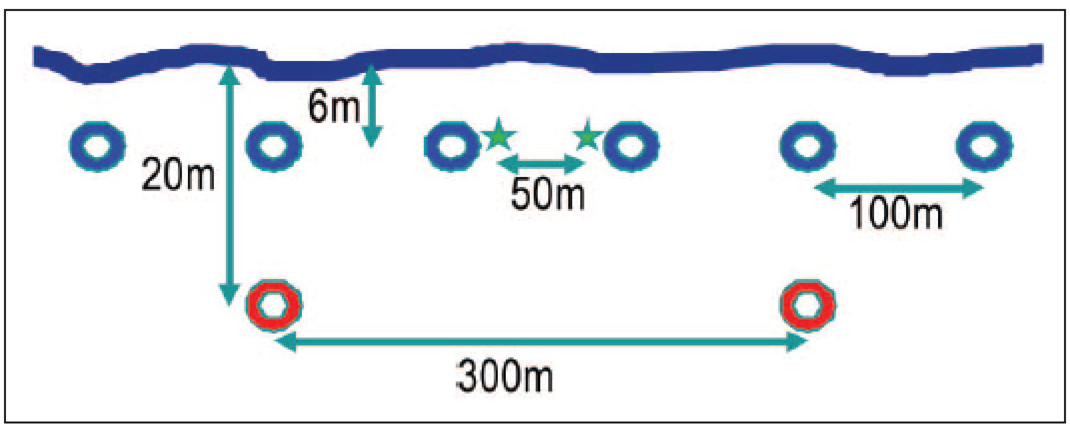
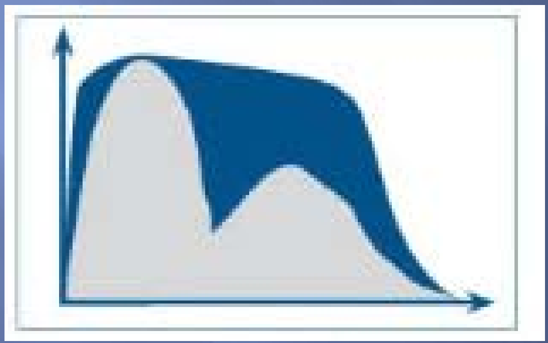


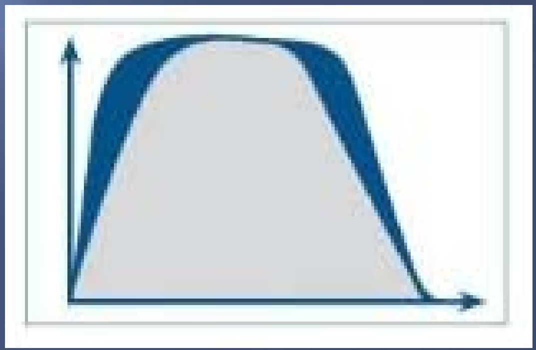

**Figure 4.** *Example of sparse over/under acquisition geometry. Note that the upper spread is towed very shallow, for example 6 m, and only a small number of streamers, in this example only two, are towed at depth.*

TGS

**Clari-Fi** – *Three step processing process applied to any type of acquired seismic data.*

*1. Clari-Fi Totus – In the prestack domain broadens spectrum through first notch and beyond by using a multi-dimensional deconvolution approach specifically to address source/receiver ghosts.*
*Clari-Fi Amplio – Broadens spectrum using deterministic shaping operators that are computed on the source wavelets.*

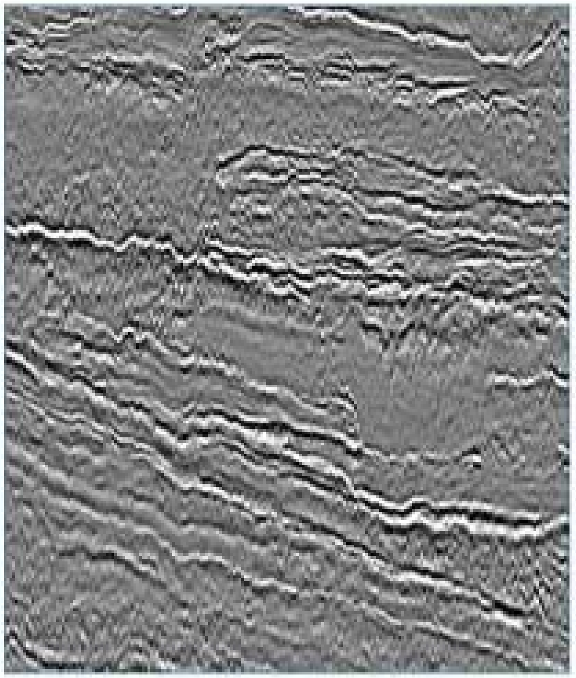




*2. Effectively solve for Earth's attenuation – Effective Q*

*3. Multi-domain noise attenuation*

TGS



Kirchhoff pre-stack time migration of data before Clari-Fi Totus (data from Gulf of Mexico)

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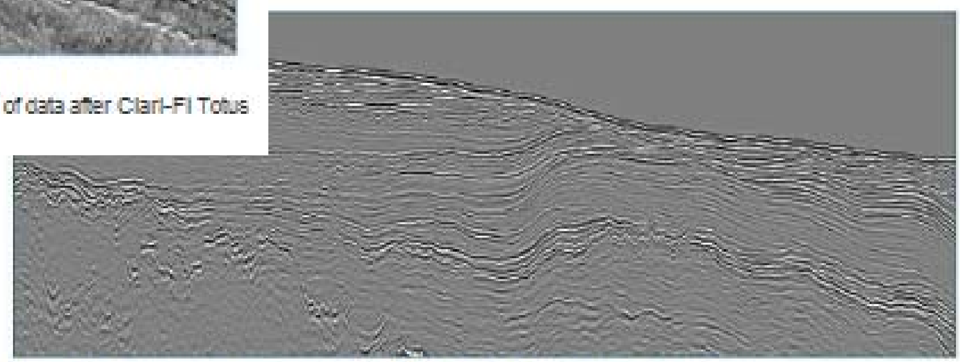
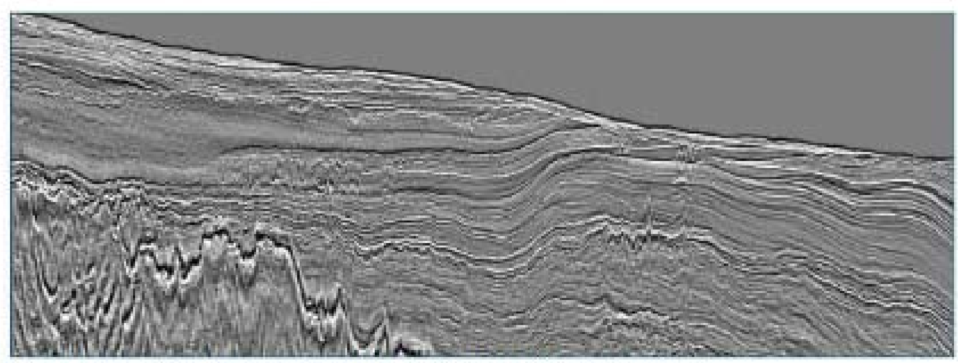


Kirchhoff pre-stack time migration of data before Clari-Fi Amplio (data from West of Shetlands)



Kirchhoff pre-stack time migration of data after Clari-Fi Amplio (data from West of Shetlands)

## ION (GXT)

**WiBand** – *Processing for any acquisition configuration that applies a suite of nonlinear optimization techniques that design an infinite impulse response operator to invert the effects of the ghosts. Also produces approximation techniques to extend the method to handle the angle variability of the time delay between the primary and ghost.*

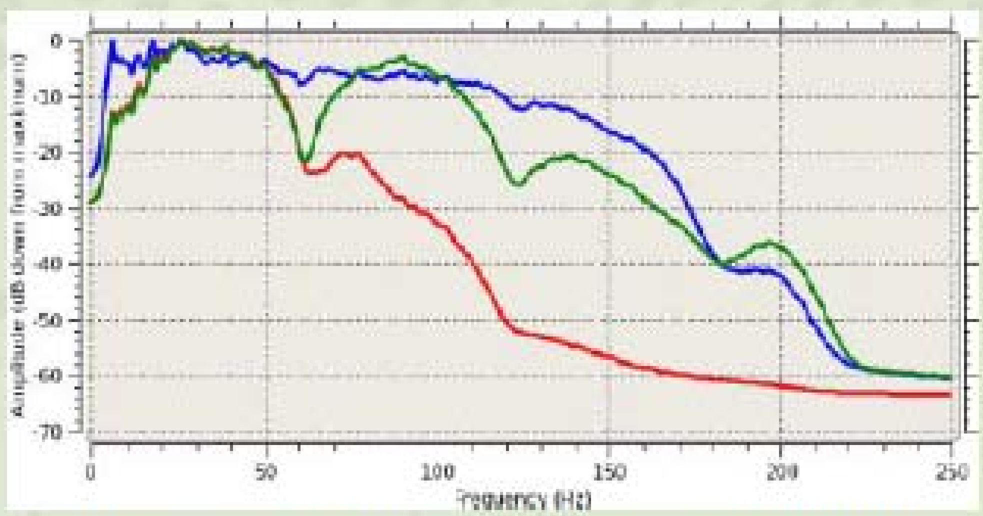



Fig. 1 Spectra: Raw deep tow data (green); after high-cut filter (red), after WiBand (blue).

# ION (GXT)

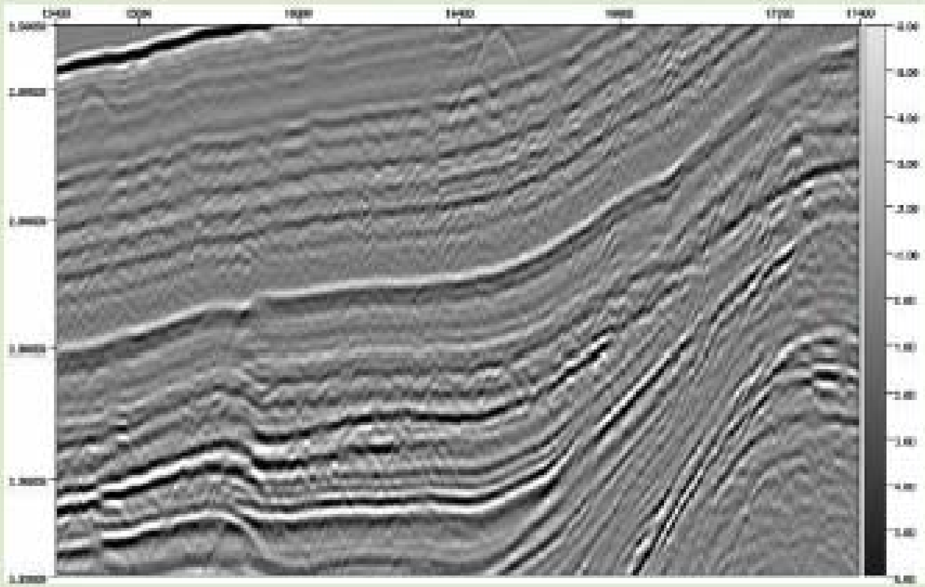


Fig. 2 Deep tow data after conventional processing.

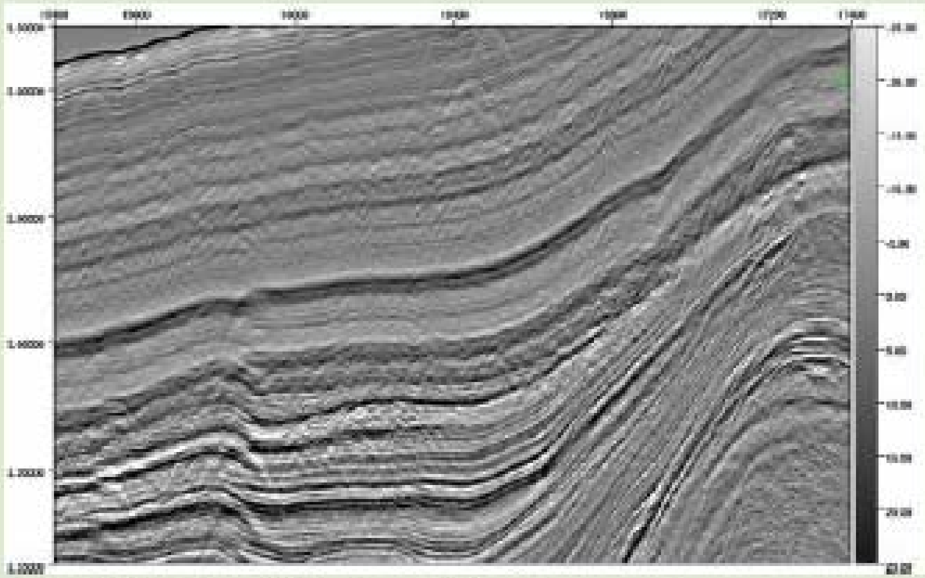


Fig. 3 Deep tow data after WiBand processing.

# Other Companies with announced broadband solutions

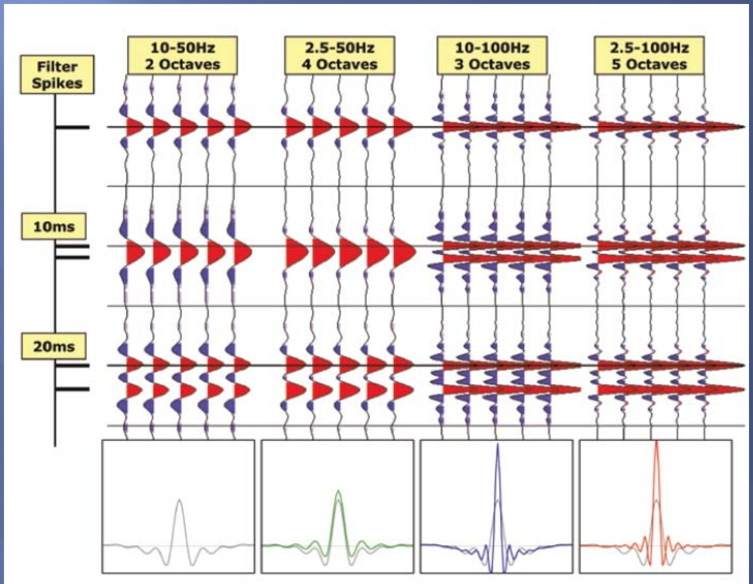
**Polarcus –** ***<u>RightBand</u>–over/under streamer acquisition (Ion processing)***

**Dolphin –** ***<u>SHarp</u>-combination acquisition and processing***

# Broadband Seismic Implications for Interpretation

*Broadband spectrum increases vertical resolution at the high end*

*Low frequencies improve interpretation by minimizing wavelet sidelobe effects*




*Low frequency trends can be added for inversion*

*More accurate elastic properties derivation*

*How does broadband data change rock physics modeling results?*