Reflection seismic 1
script

Filters

- Temporal Fourier ($t \Rightarrow f$) transformation
- Spatial Fourier ($x \Rightarrow k_x$) transformation applications

$\Rightarrow$ f-k_x transformation

- Radon (τ-p_x) transformation
  - Linear Radon transform
  - Parabolic Radon transform

Transformation domains

1-D-Transformation

t domain ⟷ **f domain**

Time domain — Frequency domain

Fourier transformation

2-D-Transformation

t-x domain ⟷ **f-k_x domain**

Time-Place — Frequency-Wavenumber

2-D-Fourier

t-x domain ⟷ **τ-p_x domain**

Time-Place — (Intercept - slowness)

τ-p-Transformation

Temporal Fourier transformation

Fourier Transformation:

$$G(f) = \int_{-\infty}^{\infty} g(t) e^{-i2\pi ft} dt$$

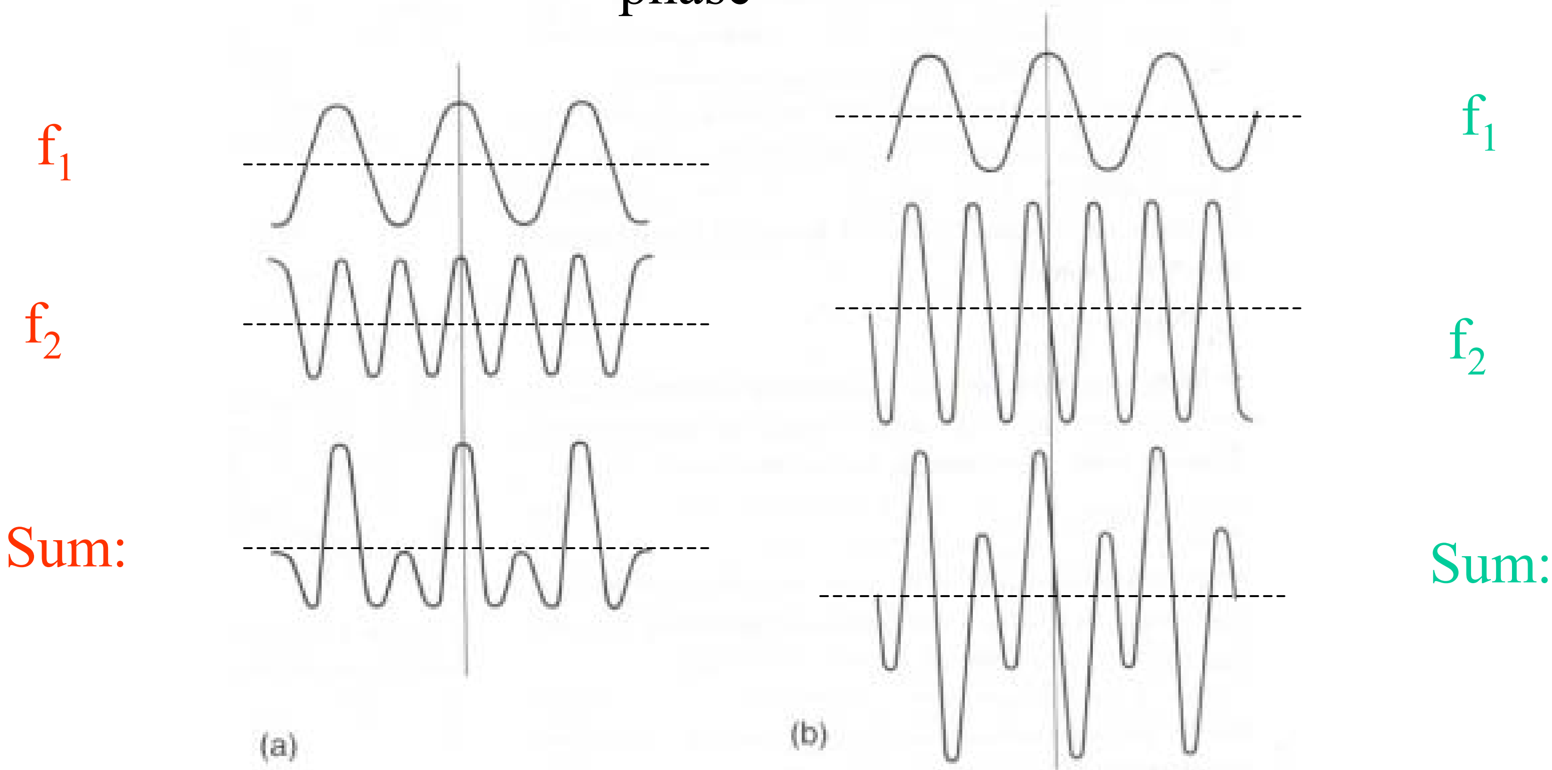
Inverse Fourier Transformation:

$$g(t) = \int_{-\infty}^{\infty} G(f) e^{i2\pi ft} df$$

Sampling will preserve all frequencies up to the Nyquist frequency:

$f_N = 1/(2\,\Delta t)$

- frequency
- amplitude
- phase



Spatial Fourier transformation

Fourier Transformation:

$$G(k_x, f) = \int_{-\infty}^{\infty} g(x, f)\, e^{i2\pi k_x x}\, dx$$

Inverse Fourier Transformation:

$$g(x, f) = \int_{-\infty}^{\infty} G(k_x, f)\, e^{-i2\pi k_x x}\, dk$$

Spatial Fourier transformation is discussed for one horizontal (x) direction, but can be carried out in the two horizontal directions.

Temporal versus Spatial Fourier transformation

Temporal Fourier transformation

Sampling interval Δt
sampling rate (sampling frequency) $1/\Delta t$
Sampling will preserve all frequencies up to the Nyquist frequency:
$f_N=1/(2\ \Delta t)$

Spatial Fourier transformation

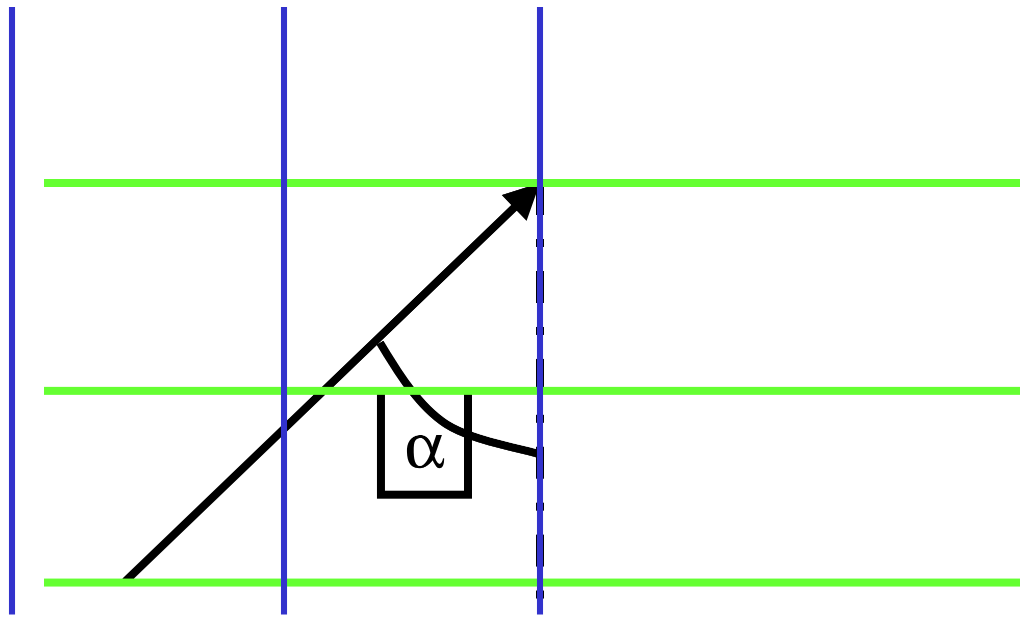
Spatial sampling interval Δx
Spatial sampling rate (sampling frequency) $1/\Delta x$
Sampling will preserve all frequencies up to the Nyquist frequency:
$k_N=1/(2\ \Delta x)$

Apparent velocity:

The phase velocity which a wavefront appears to have along a line of geophones

$$V_{app} = v$$

$$\lambda_{app} = \frac{v}{f}$$



$$V_{app} = \infty$$

$$\lambda_{app} = \infty$$

Apparent velocity: $$V_{app} = \frac{V}{\sin\alpha}$$

Apparent wavelength: $$\lambda_{app} = \frac{V_{app}}{f}$$

Apparent wavenumber k_{app}

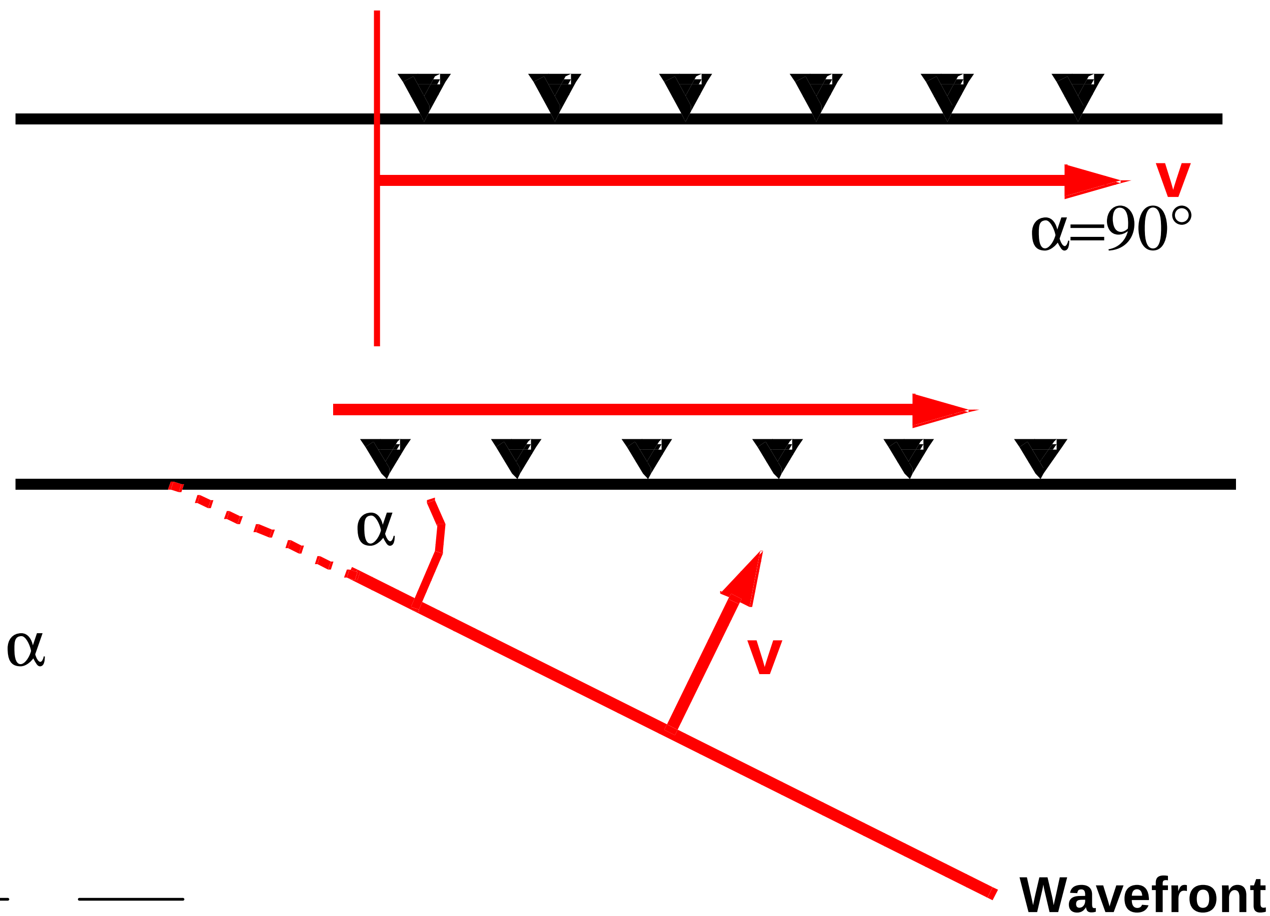
⇒**Number of waves per unit distance perpendicular to a wavefront**

Horizontal Wave

$v_{app} = v$

Incoming Wave

$v_{app} = v / \sin \alpha$



app

app *app*

Spatial sampling criterion

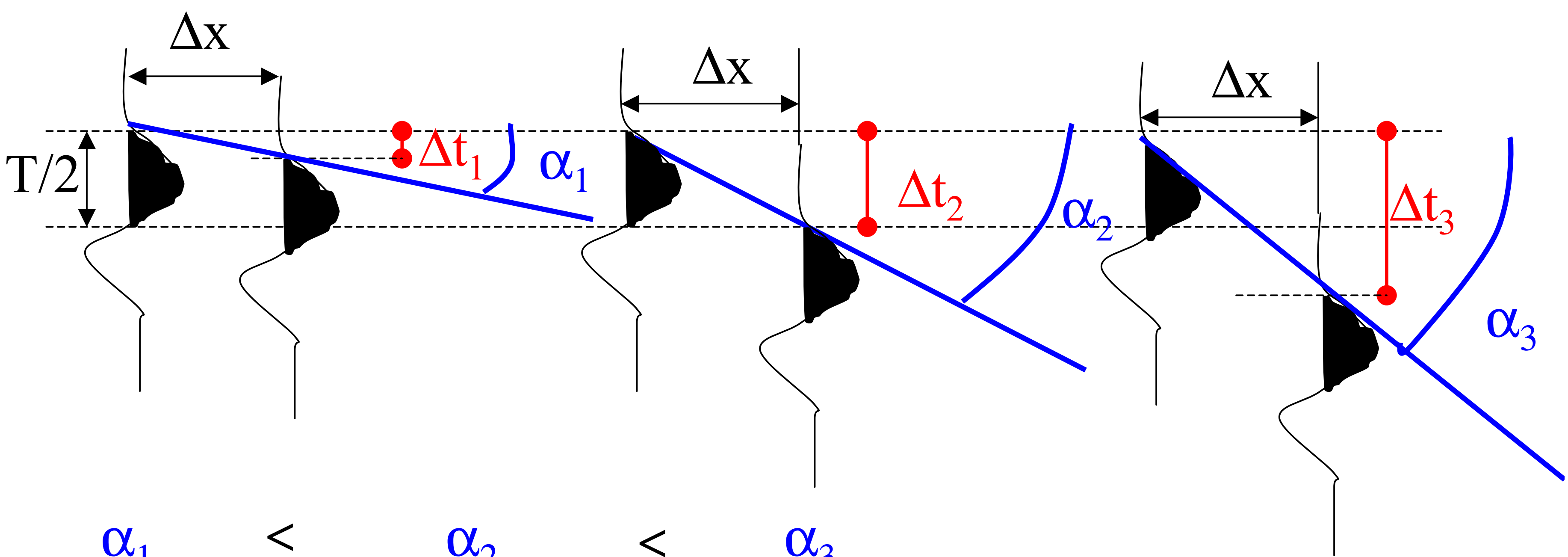
From a practical point of view, subsequent measurements must be carried out in such a way that events on separate traces can be correlated as coming from the same horizon or reflection point in the subsurface (Yilmaz, 1987)

For a given frequency component, the time delay between subsequent measurements can be at most half the period (T/2) of that frequency component to enable a correlation of two measured reflections as coming from the same horizon

Max time delay: $$\Delta t = \frac{\Delta x}{v_{app}^{\min}} < \frac{T^{\min}}{2} = \frac{1}{2 f^{\max}}$$

Two spatial samples for one apparent wavelength

Spatial sampling criterion



$\alpha_1 < \alpha_2 < \alpha_3$

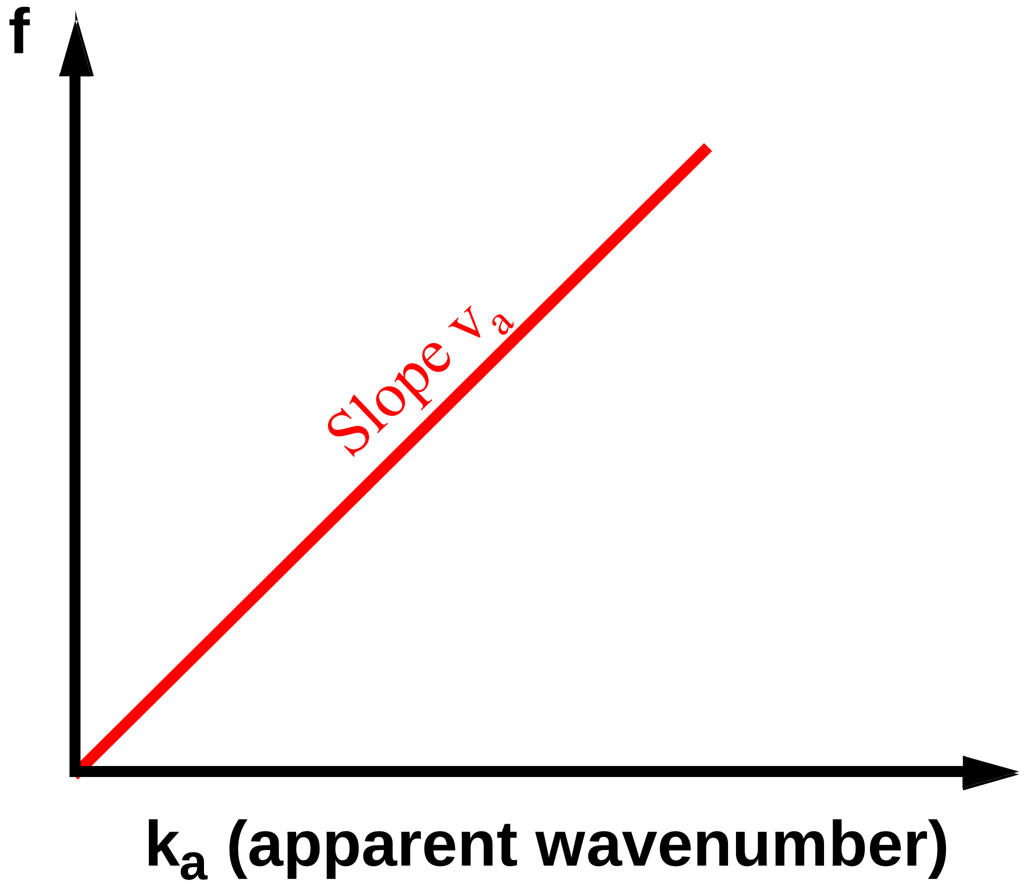
$v_{app1}^{\min} > v_{app2}^{\min} > v_{app3}^{\min}$

$$v_{app} = \frac{v}{\sin\alpha}$$

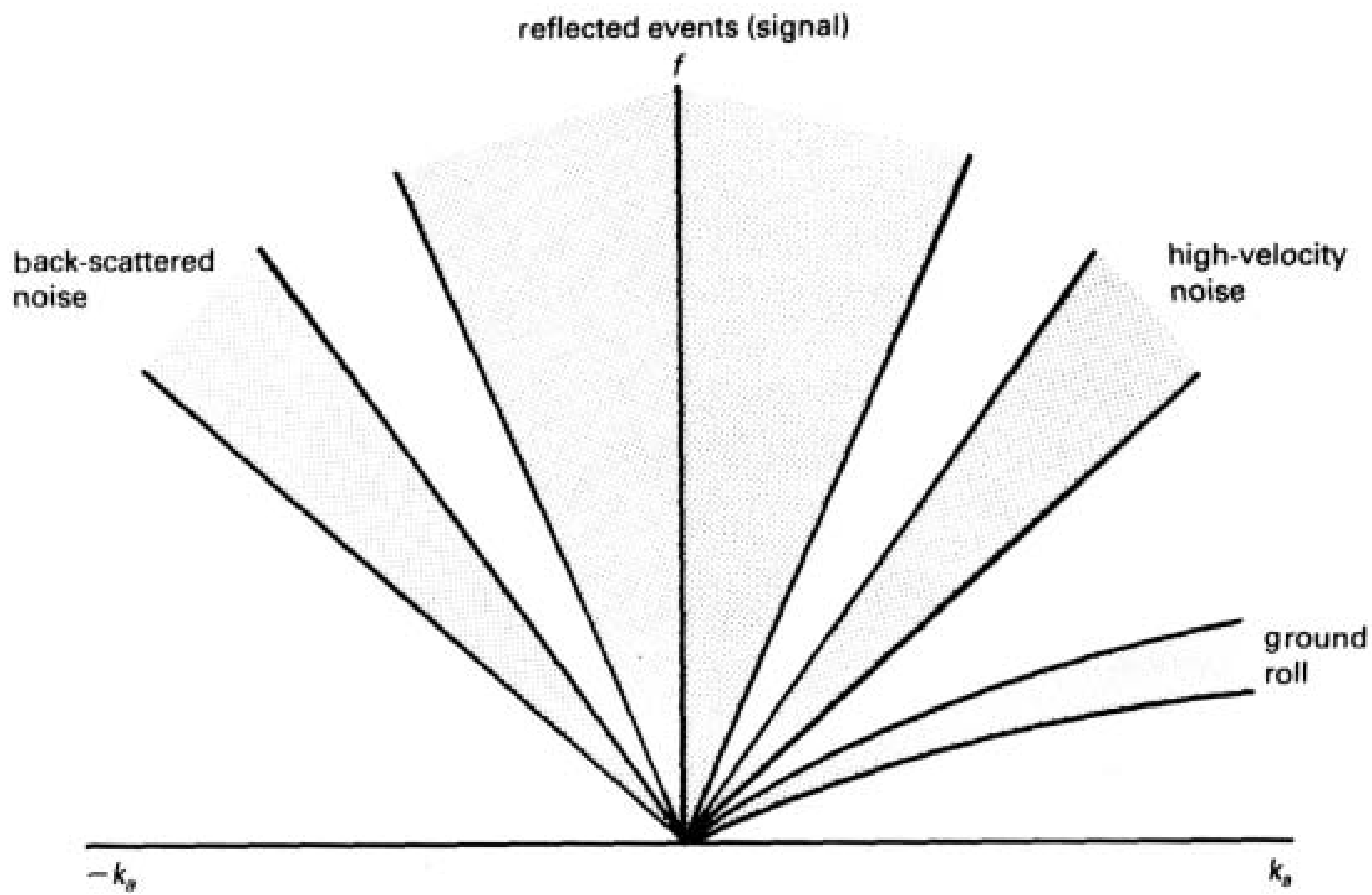
$$\Delta t = \frac{\Delta x}{v_{app}^{\min}}$$

$\Delta t_1 < \frac{T^{\min}}{2} \qquad \Delta t_2 = \frac{T^{\min}}{2} \qquad \Delta t_3 > \frac{T^{\min}}{2}$

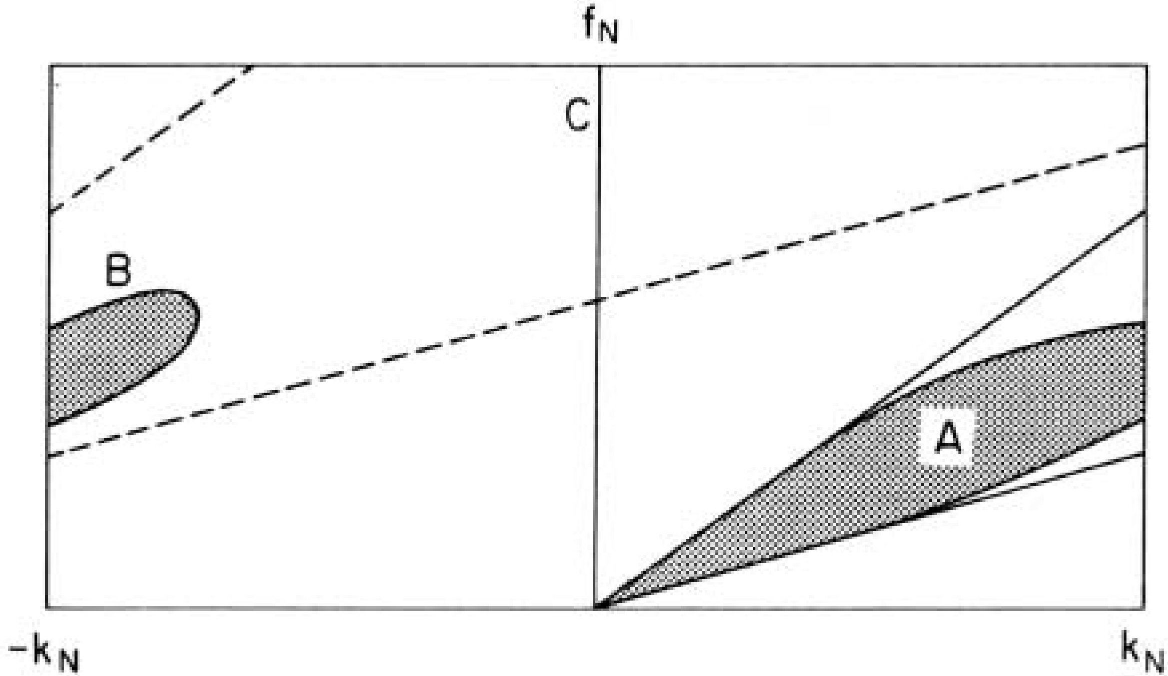
f-k-Spectrum



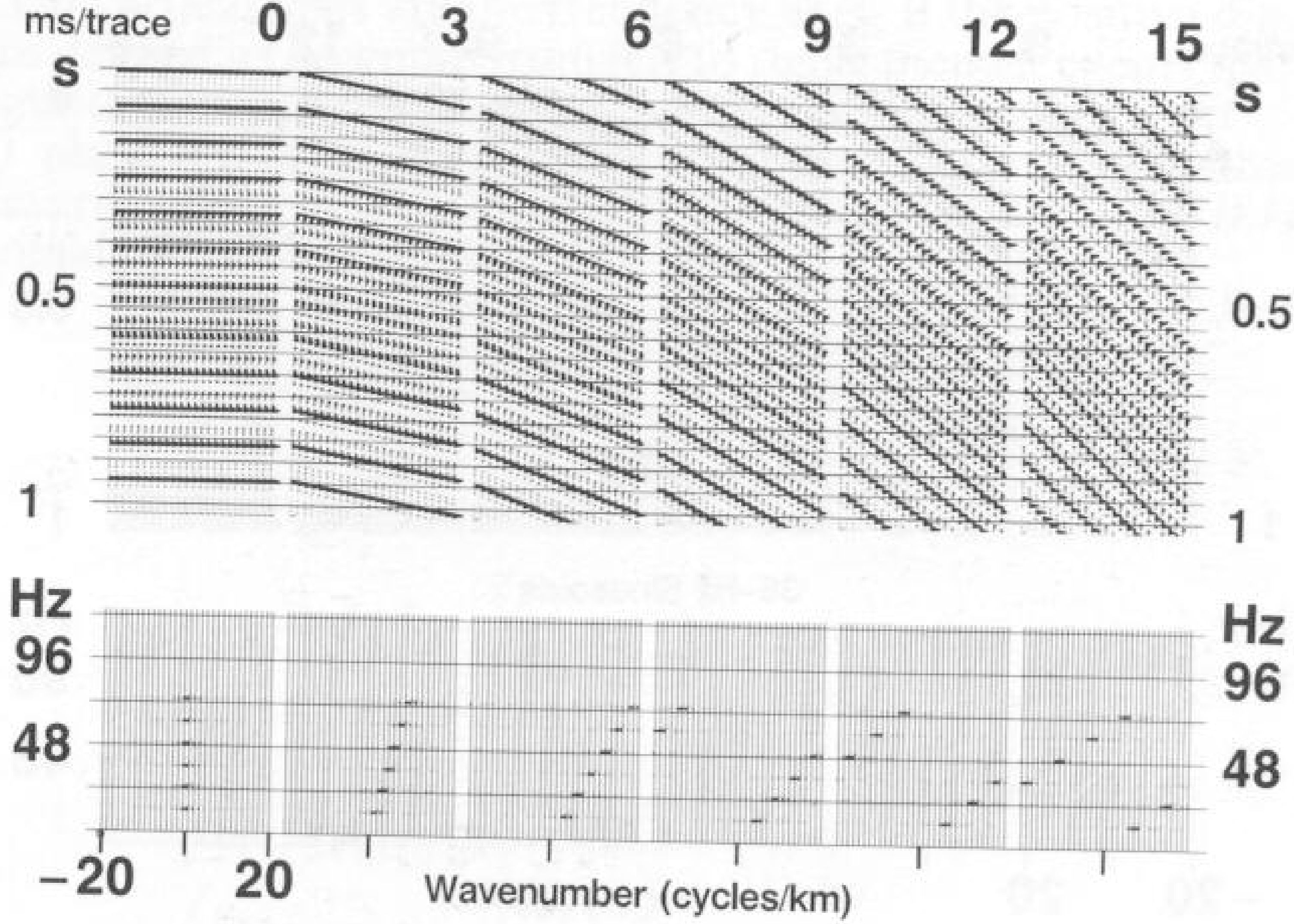
$f = v_a k_a$


reflected events (signal)
f
back-scattered noise
high-velocity noise
ground roll
$-k_a$
k_a

Aliasing

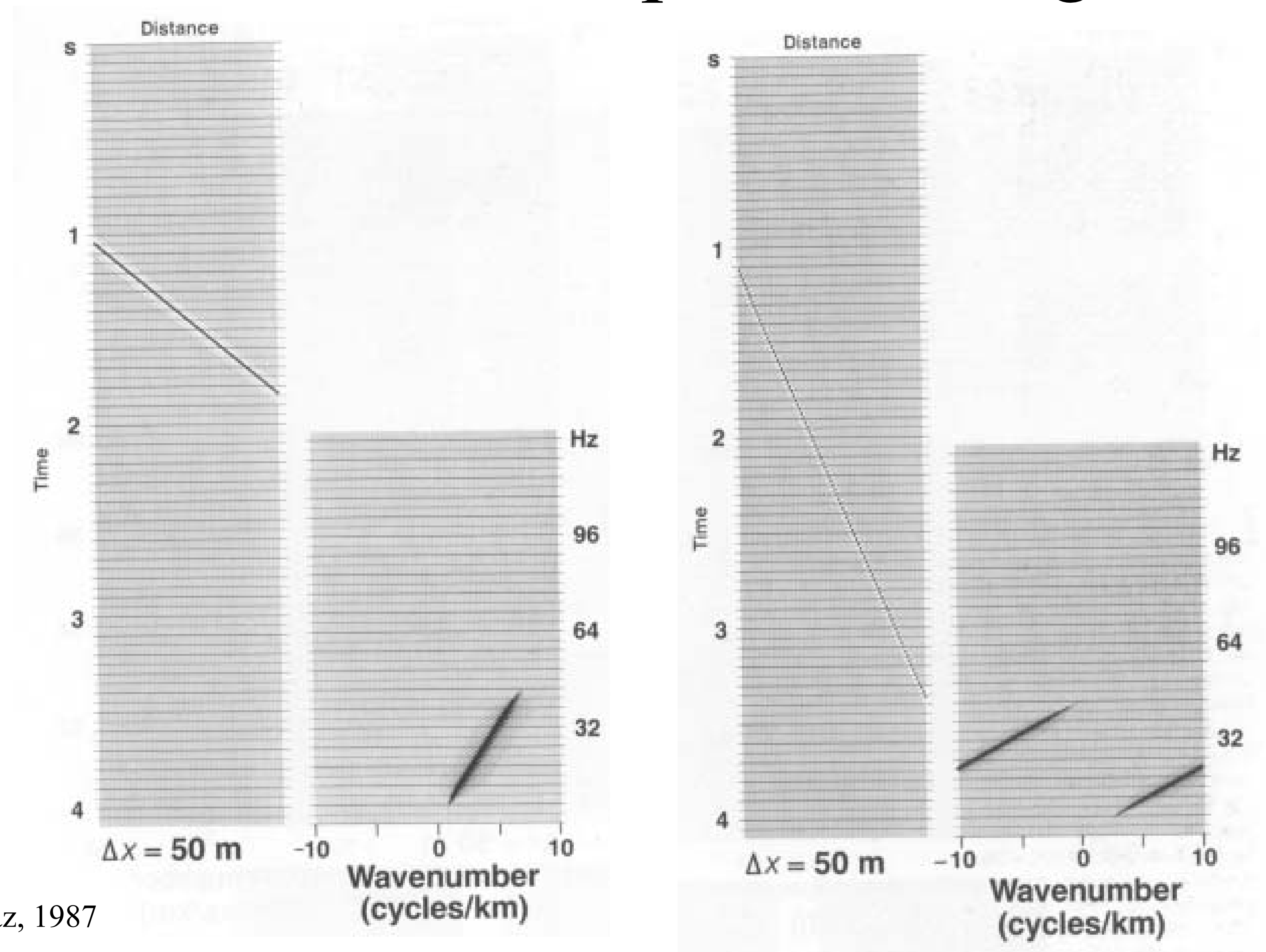


Influence of frequency on aliasing



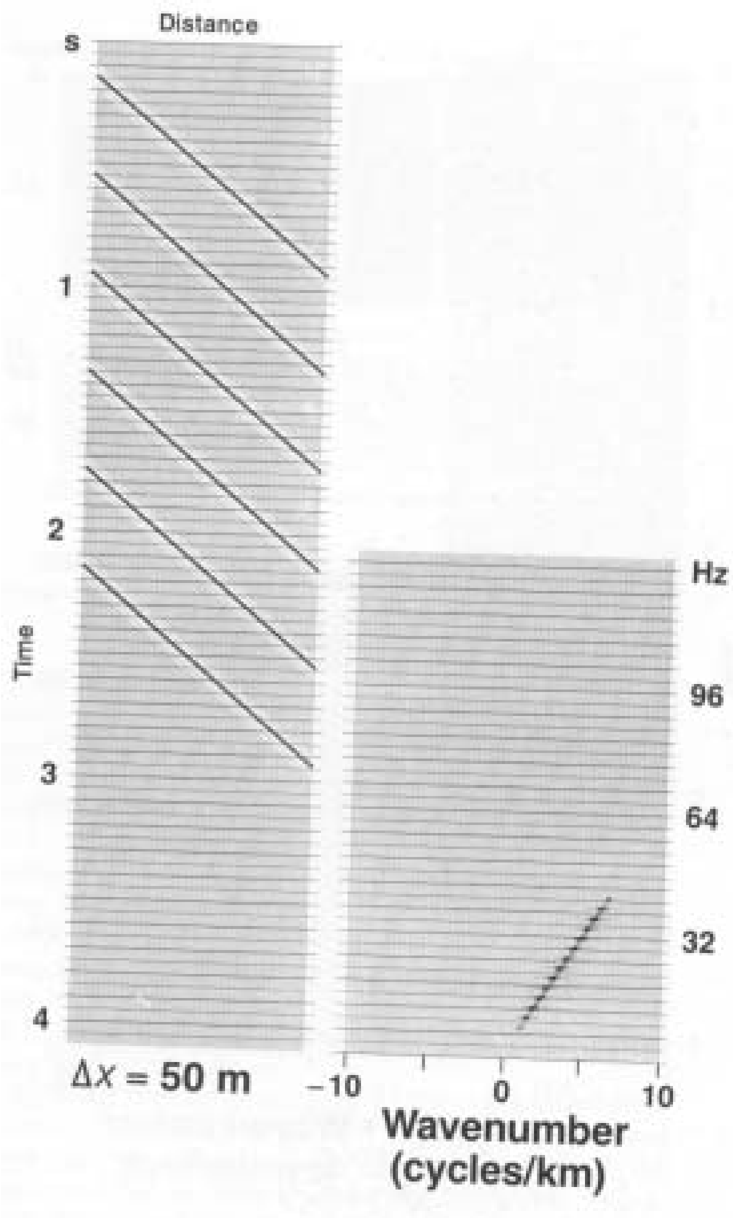
Yilmaz, 1987

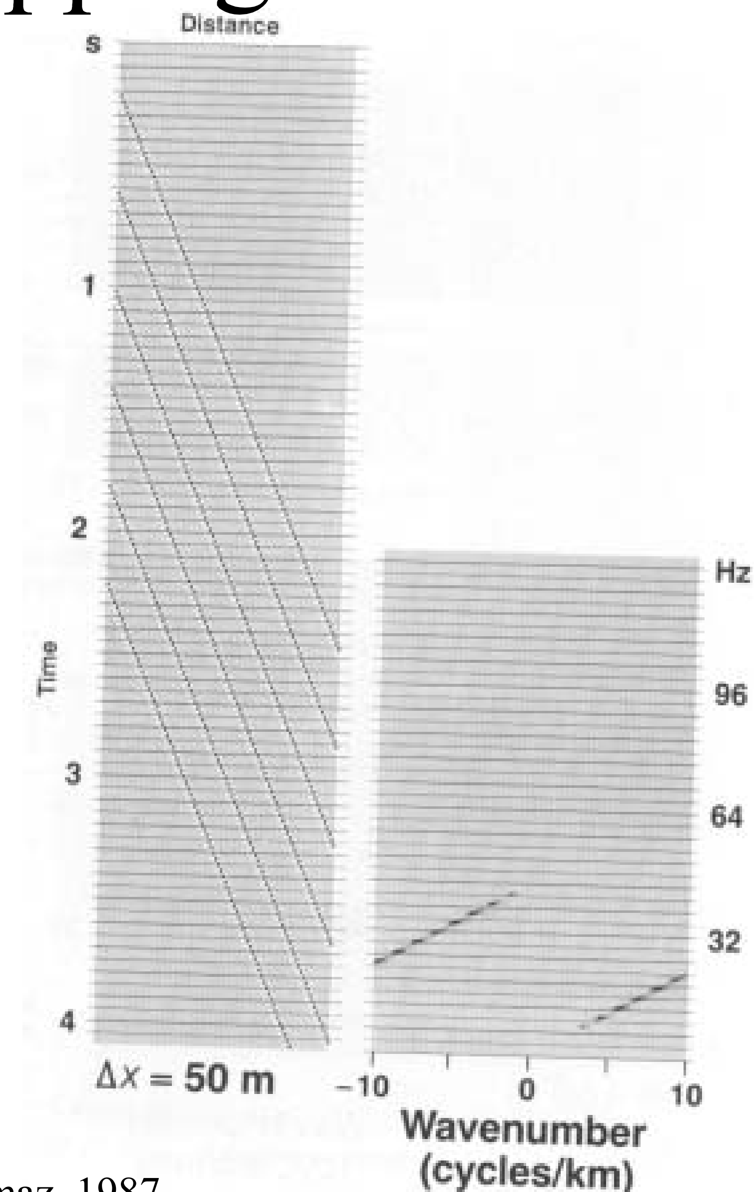
Influence of dip on aliasing



Yilmaz, 1987

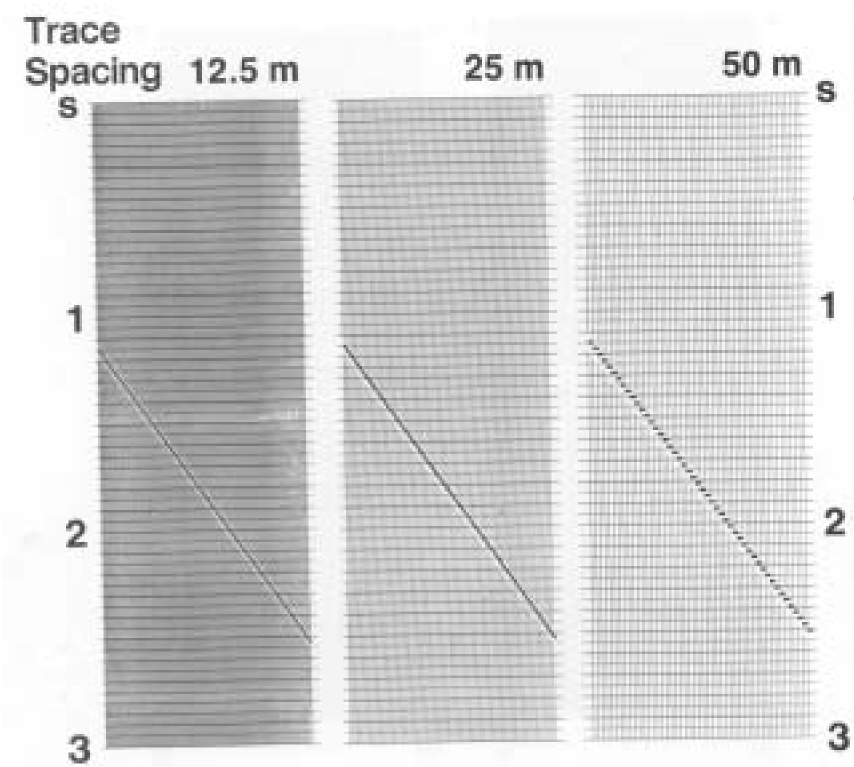
Summation of dipping events

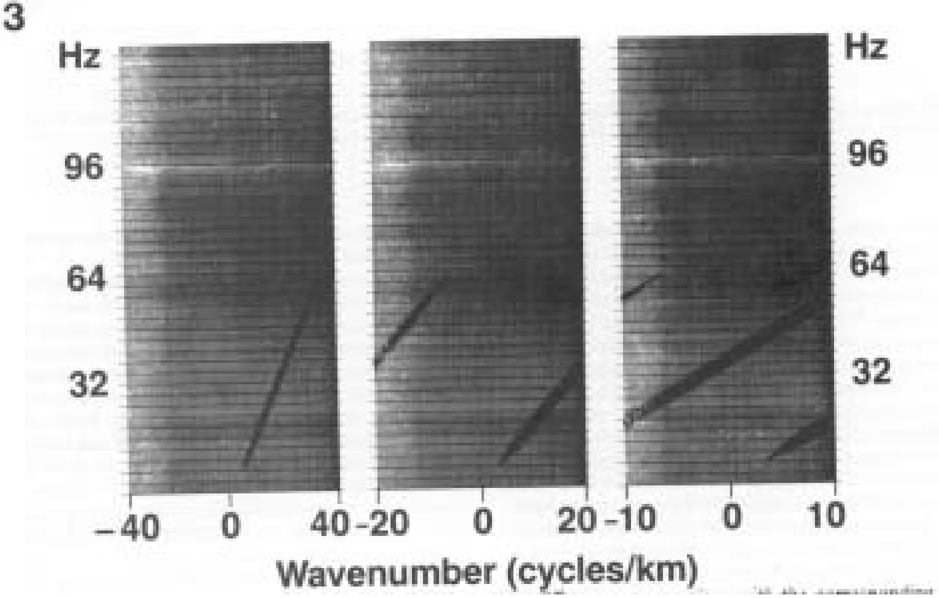




Yilmaz, 1987

Influence of spacing on aliasing

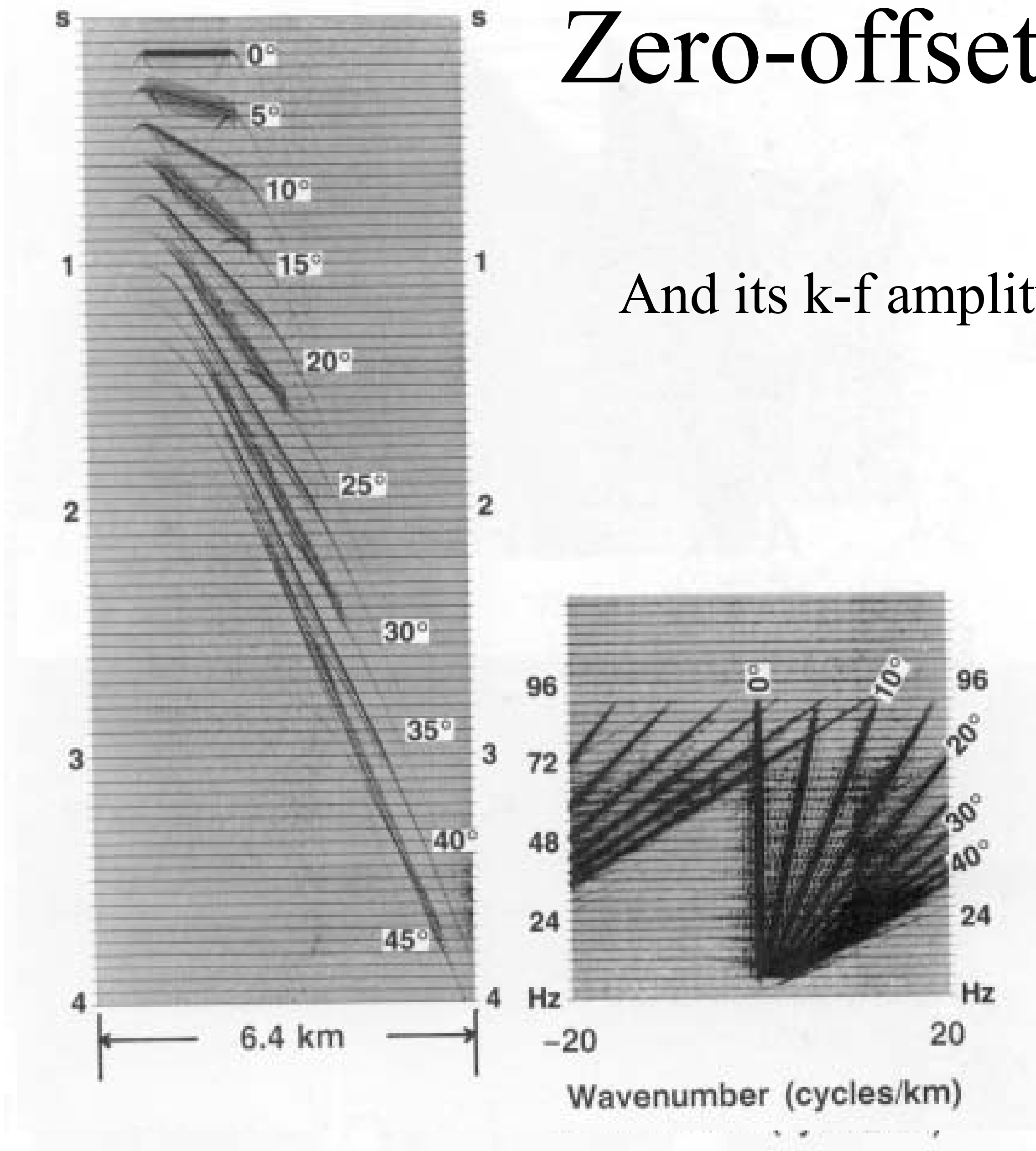




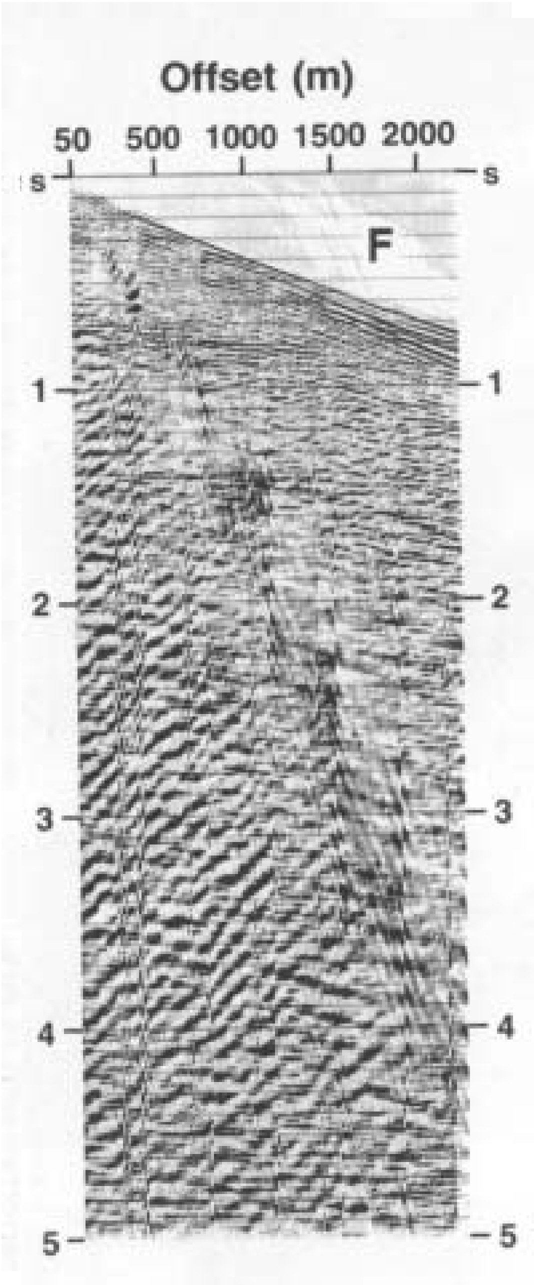
Yilmaz, 1987

Zero-offset section

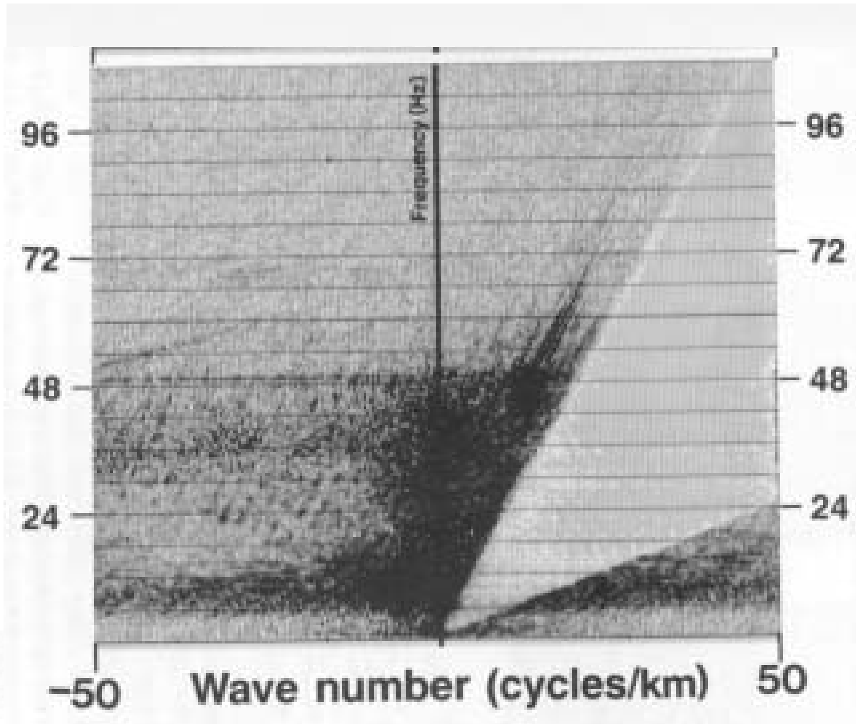
And its k-f amplitude spectrum



Yilmaz, 1987

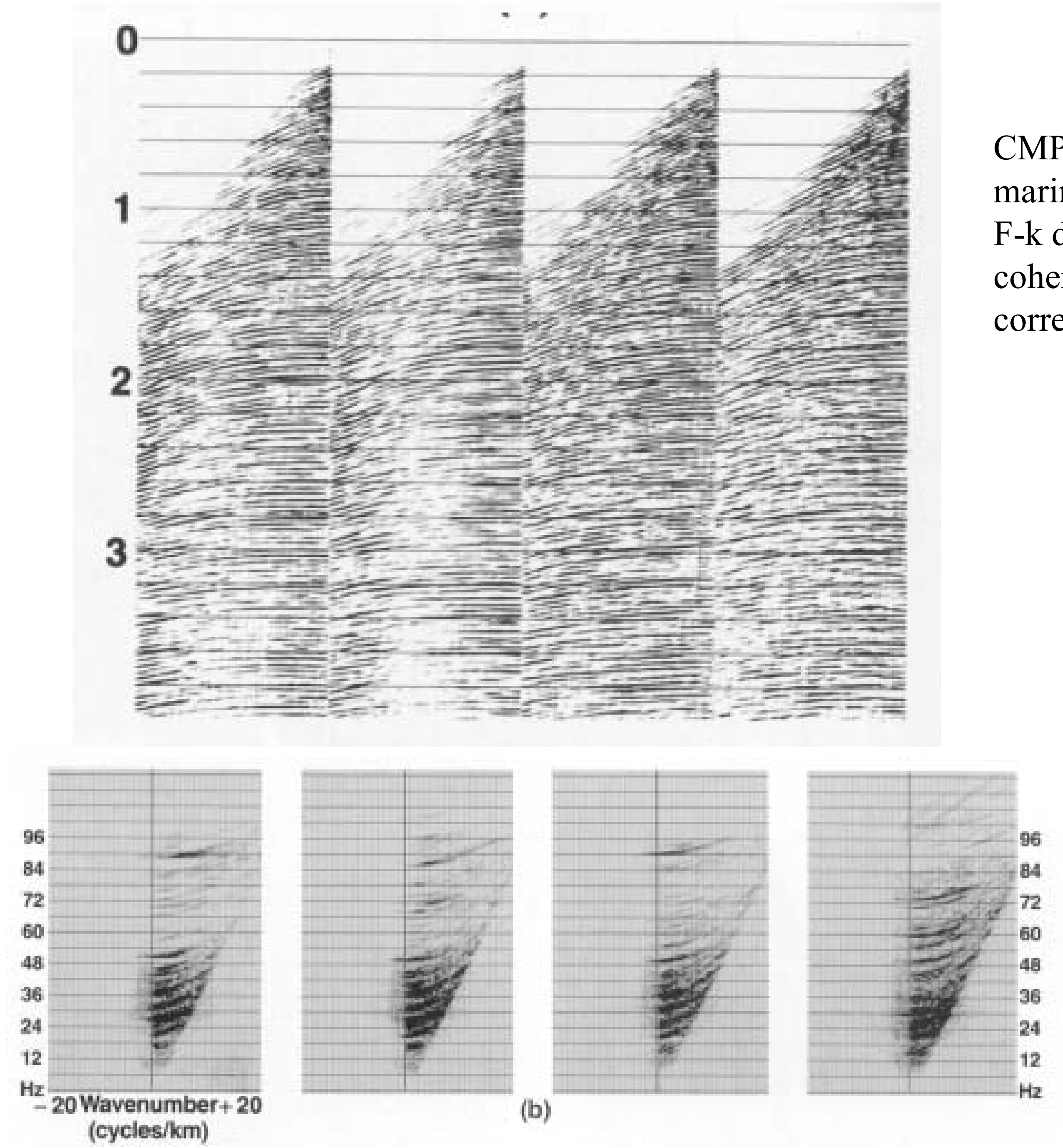


Composite walk-away noise test



Rejection ground roll energy

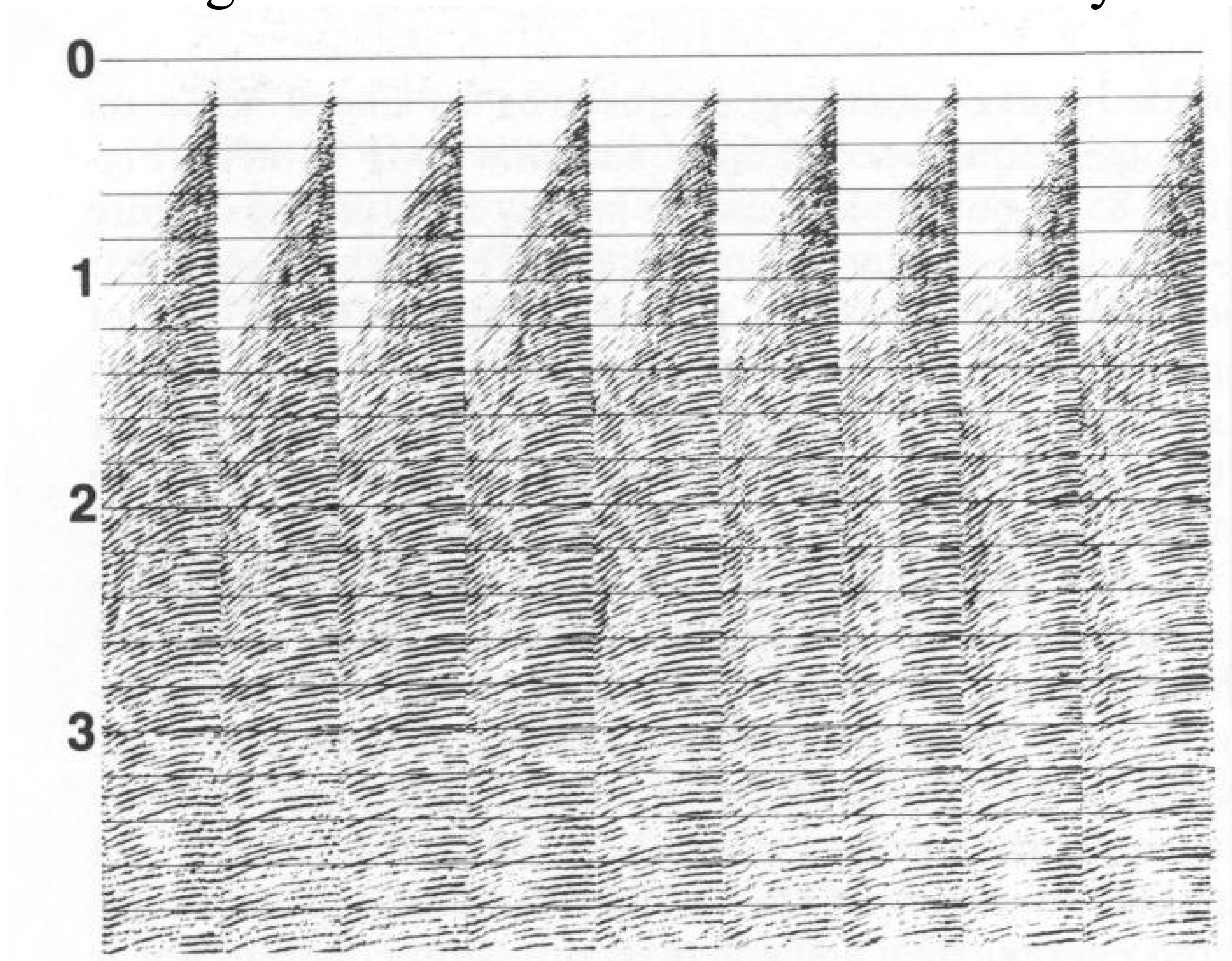
Yilmaz, 1987



CMP gathers from a shallow marine survey before and after F-k dip filtering to remove coherent noise with corresponding f-k spectra

Yilmaz, 1987

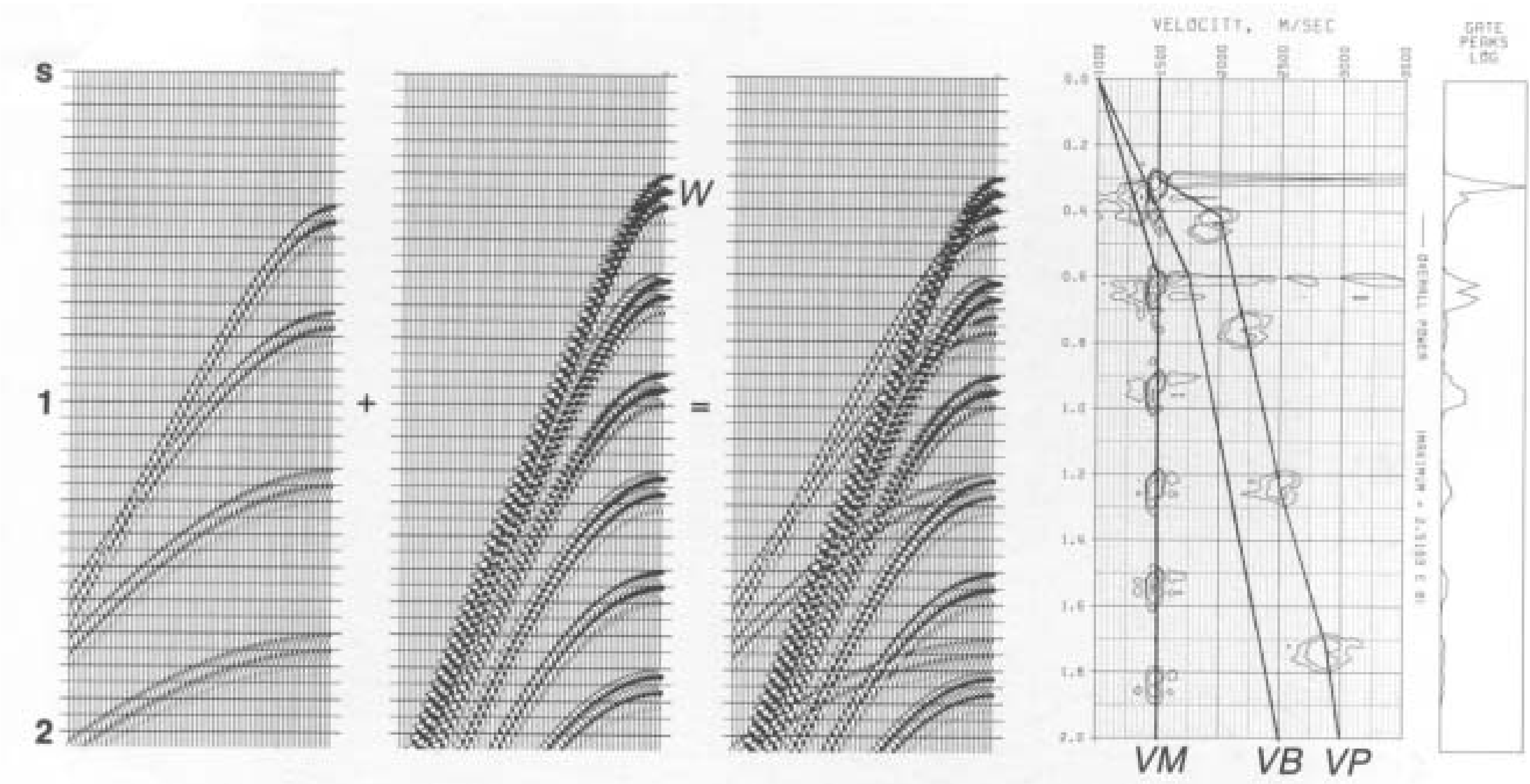
CMP gathers from a shallow marine survey



Before and after f-k dip filtering to remove coherent linear noise

Yilmaz, 1987

Synthetic CMP gathers containing multiples

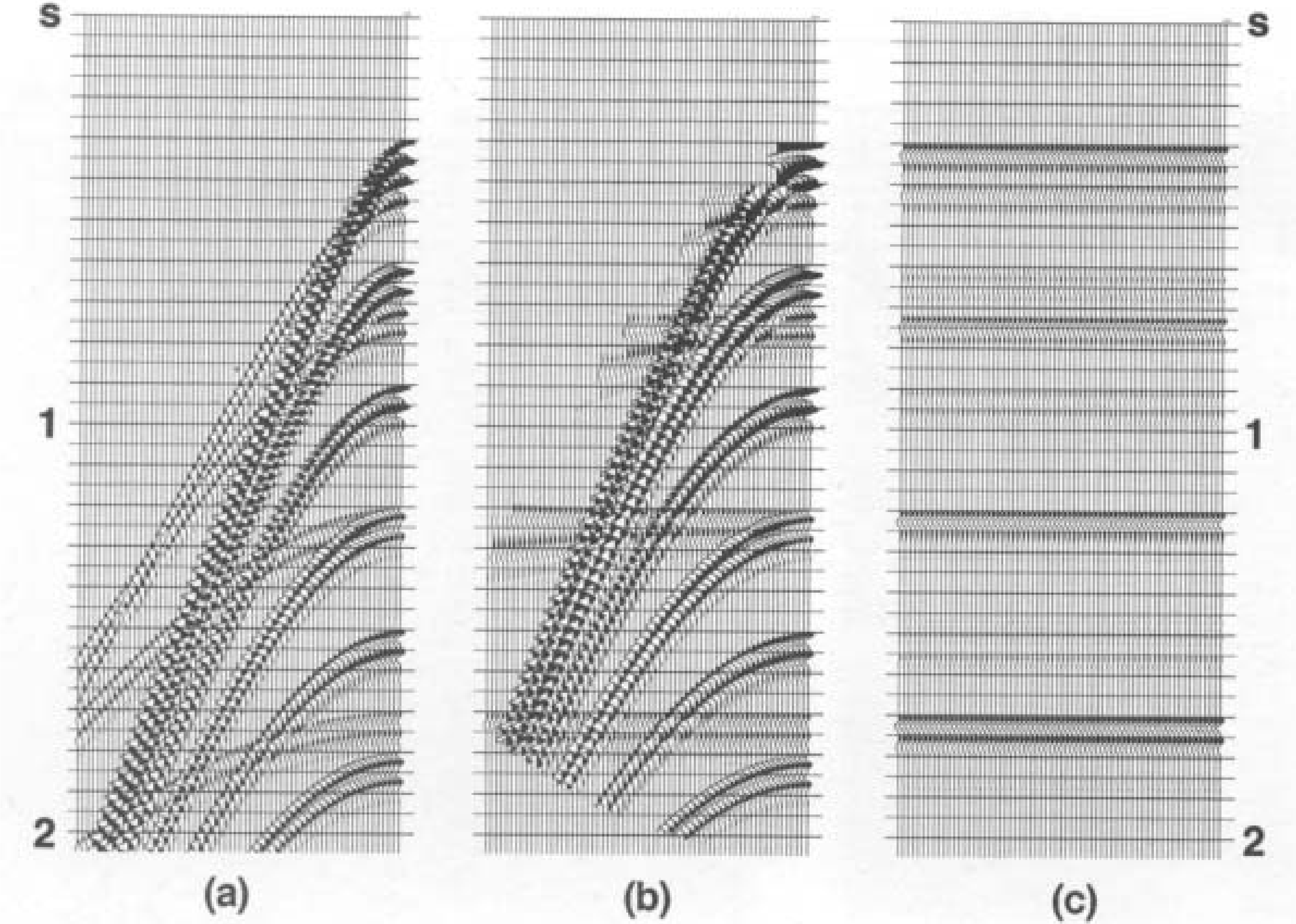


primaries + Water-bottom multiples = ↑

VM velocity multiples
VP velocity primaries

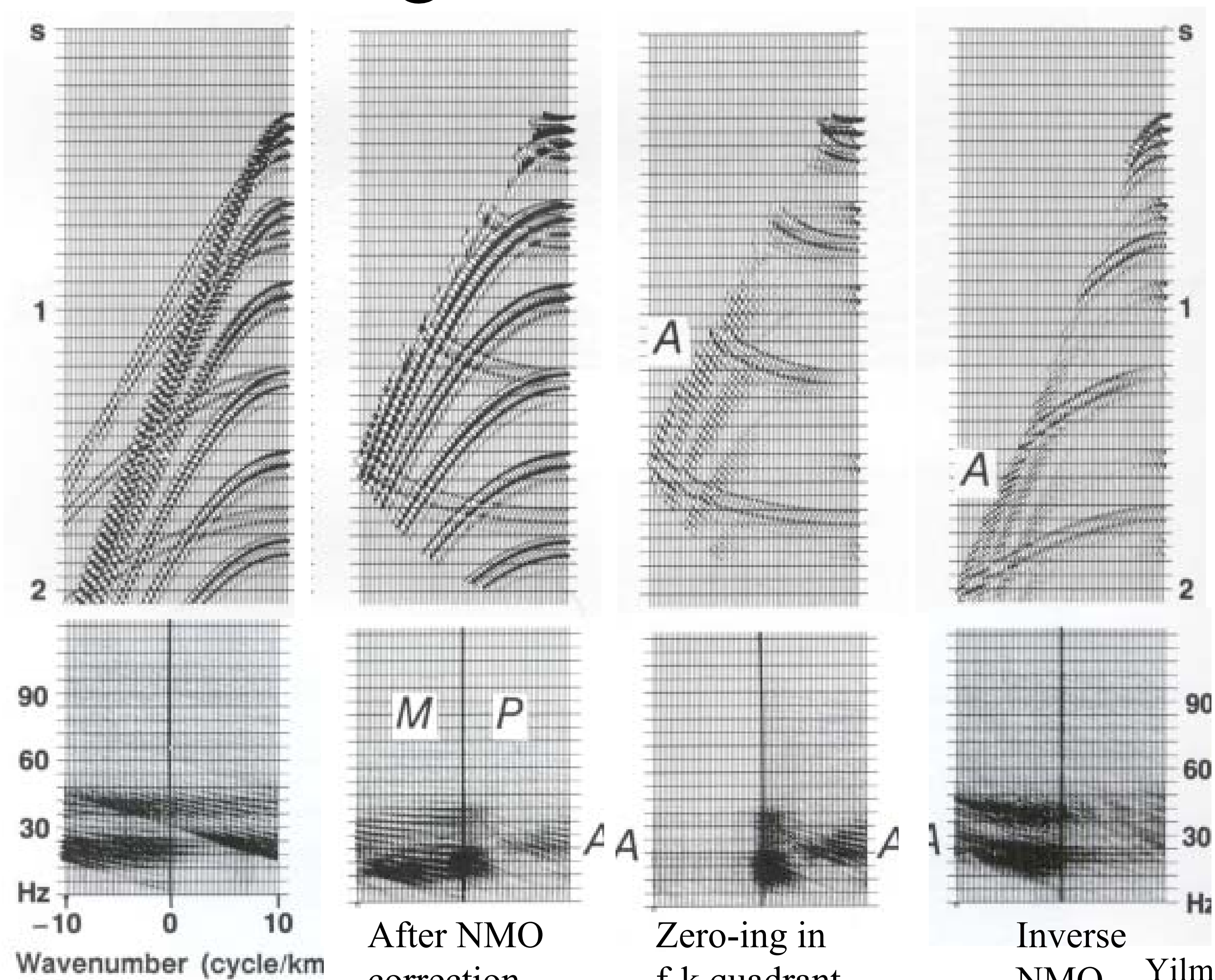
Yilmaz, 1987

NMO correction using primary velocity function



Yilmaz, 1987

Zeroing in the f-k domain



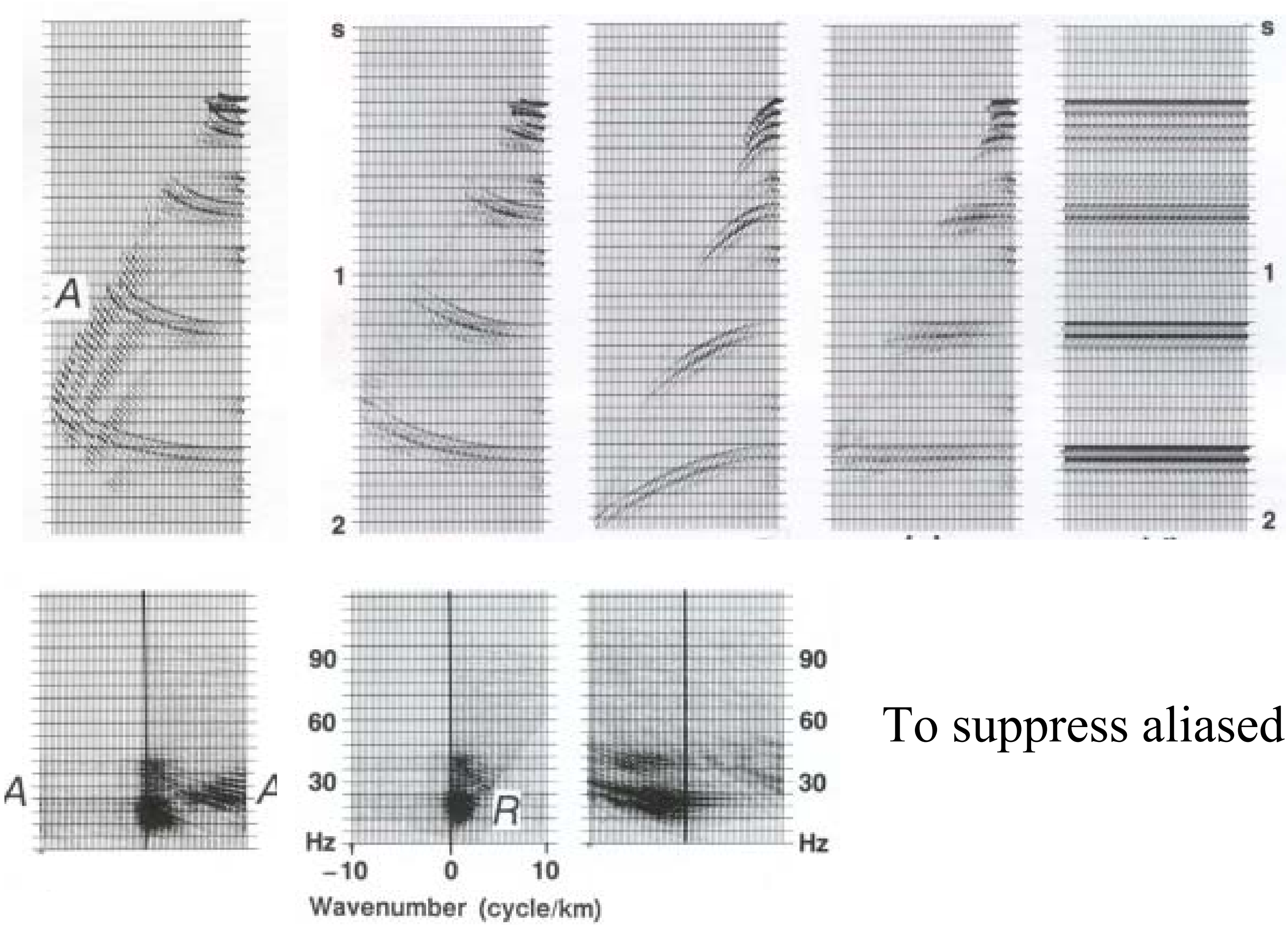
After NMO correction

Zero-ing in f-k quadrant

Inverse NMO

Yilmaz, 1987

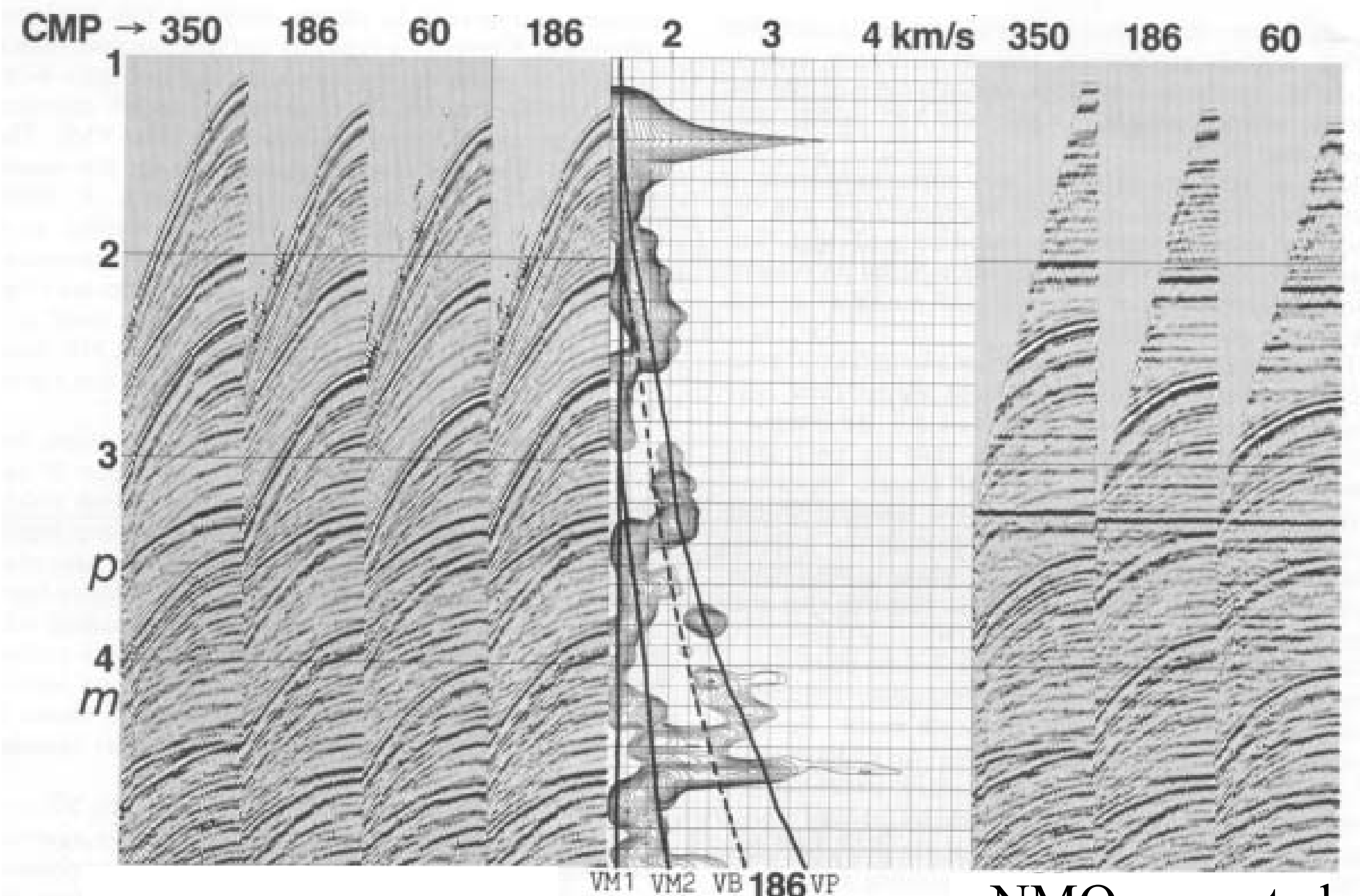
Zero-ing in f-k domain



To suppress aliased energy

Yilmaz, 1987

CMP gathers with strong multiples

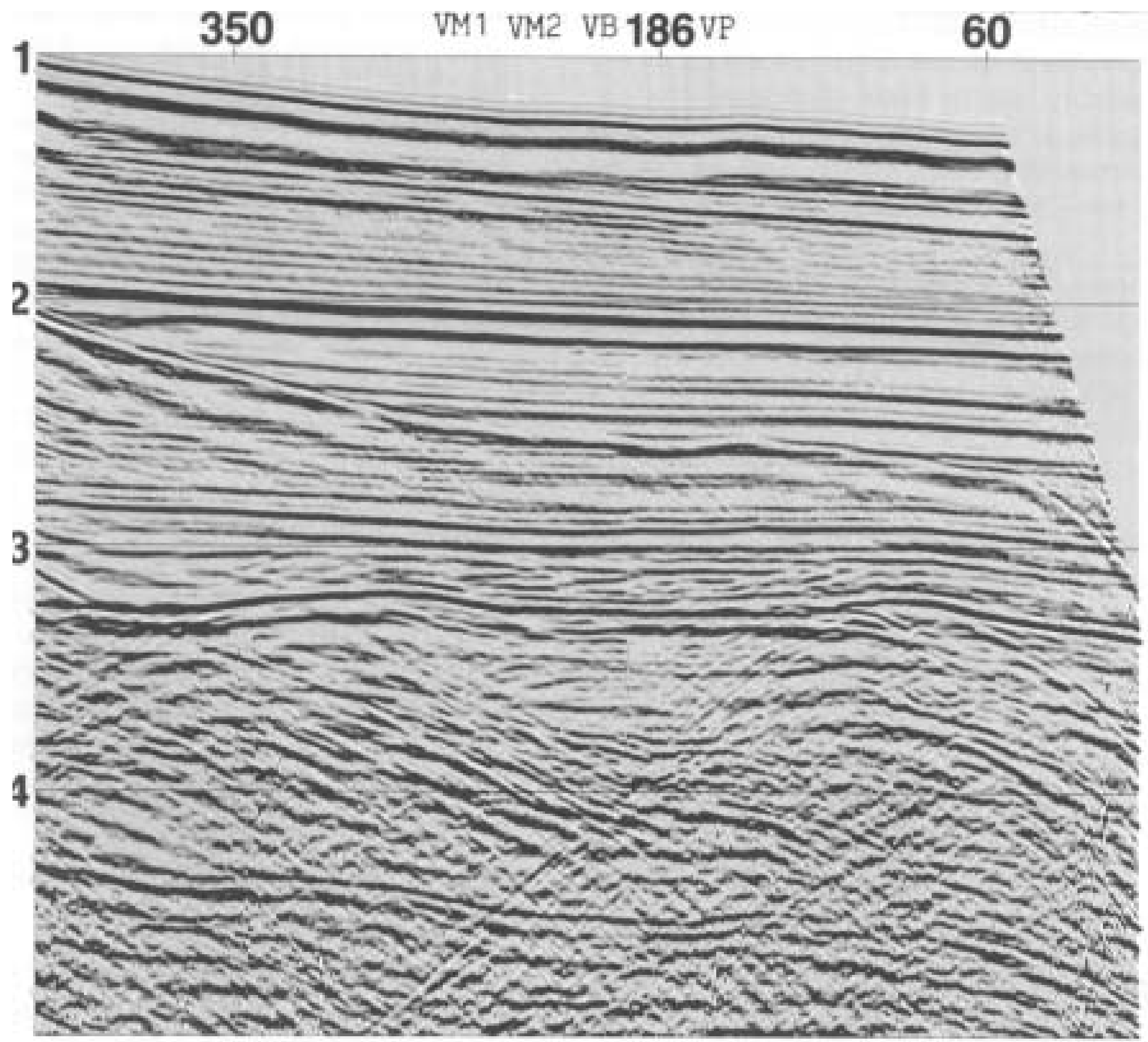


VM1= slow (water-bottom) multiples
VM2= fast (peg-leg) multiples

NMO corrected data
using primary velocities

Yilmaz, 1987

CMP stack using former gathers



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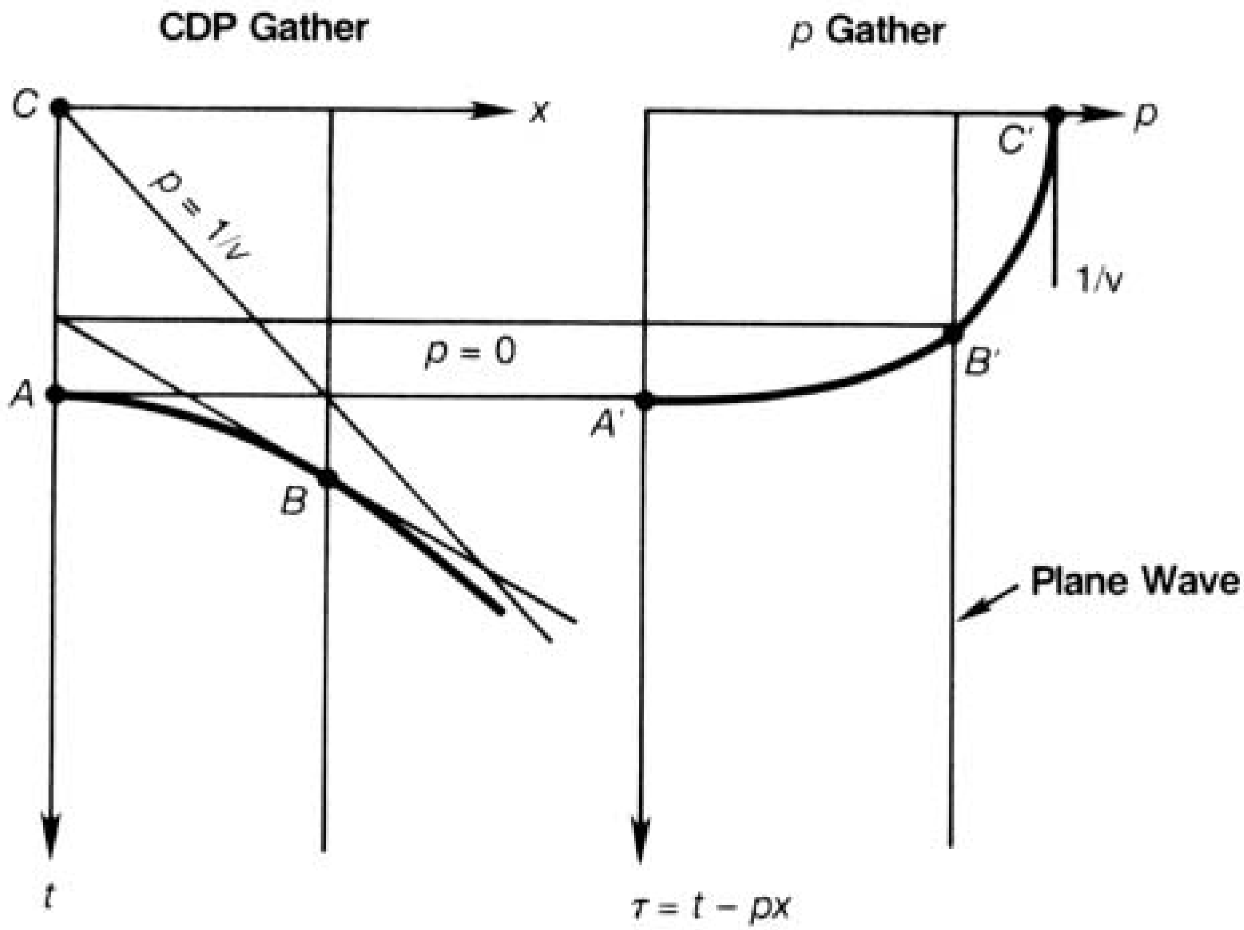
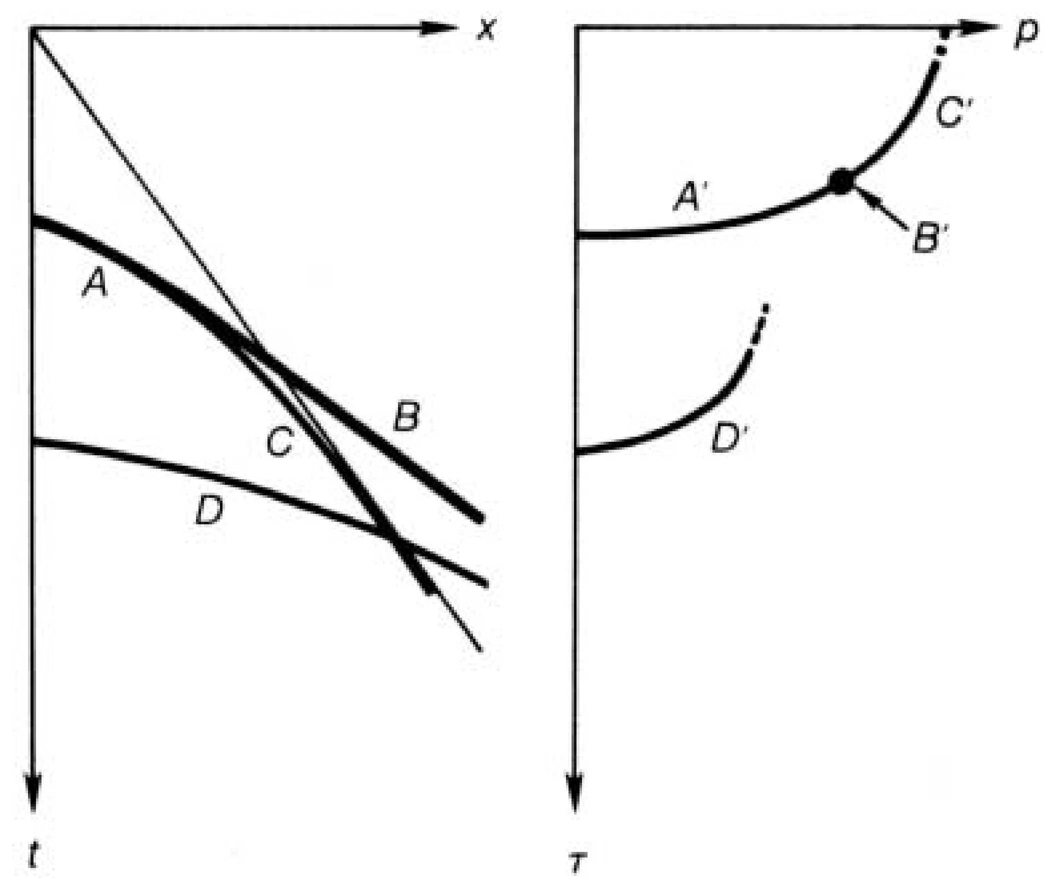
Use of radon transformation

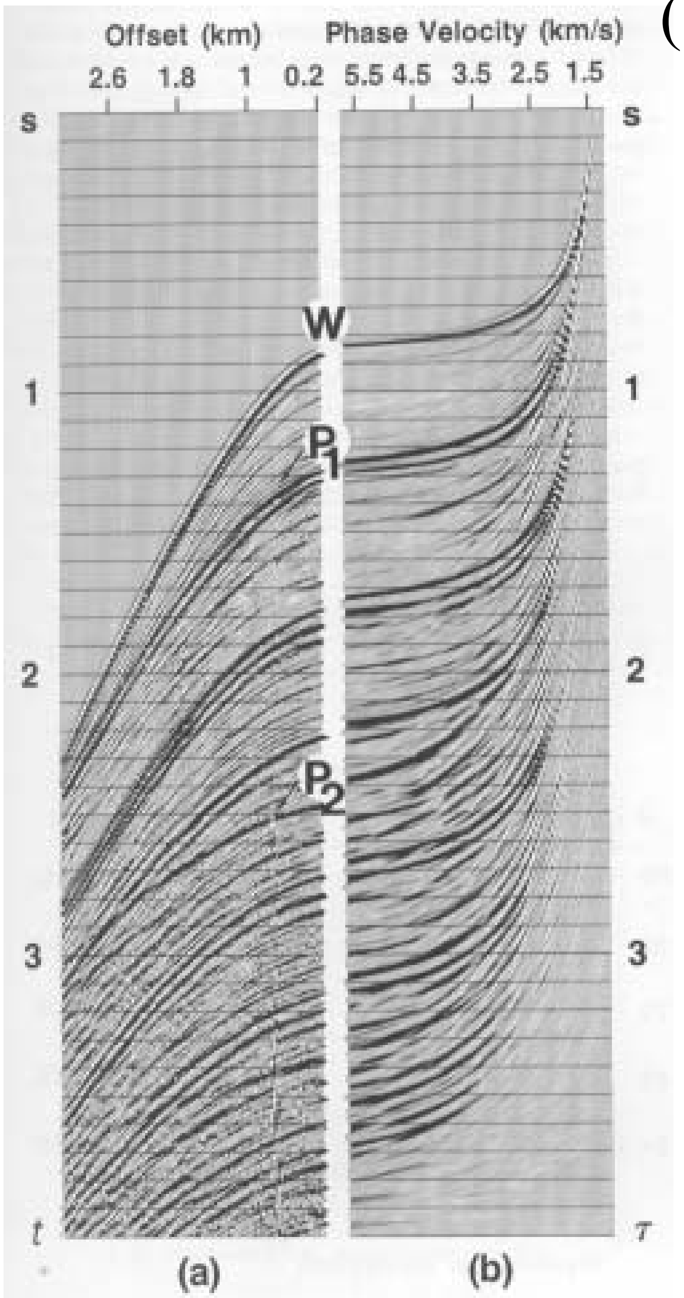
- Velocity filter
- Suppression of multiples
- Interpolation of traces
- Analysis of guided waves

Hyperbola maps onto an ellipse



τ-p transformation for various arrivals



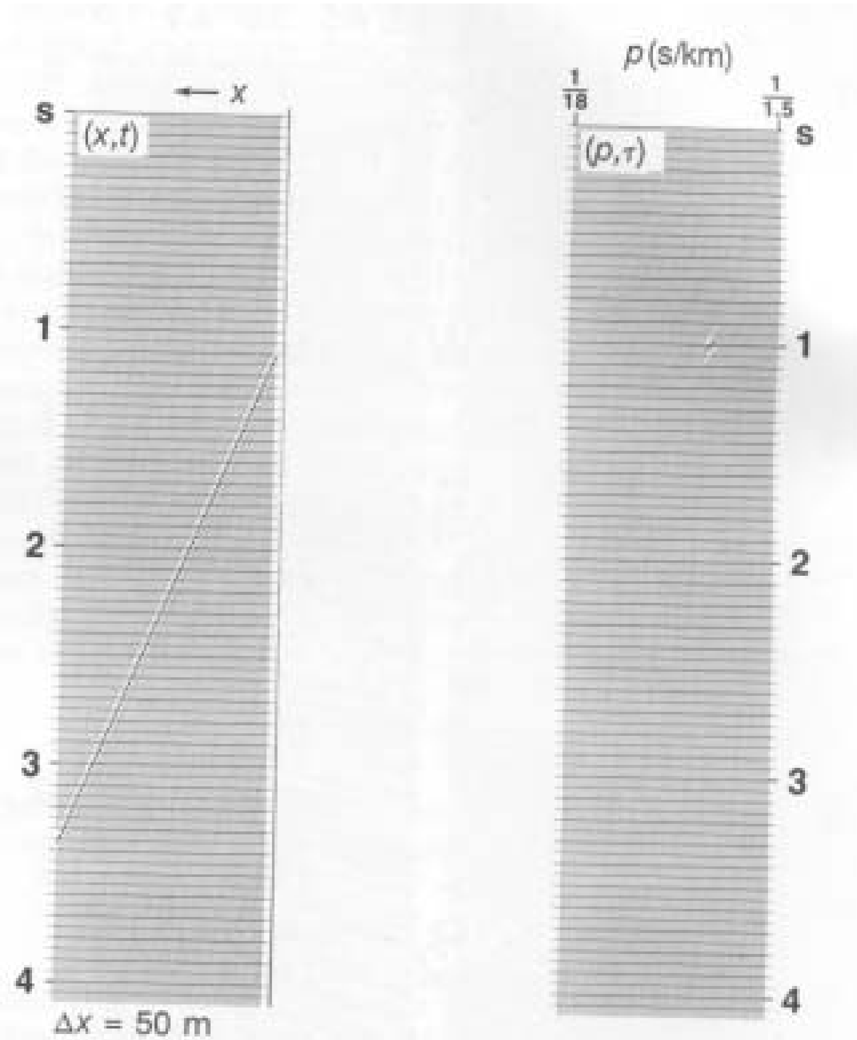


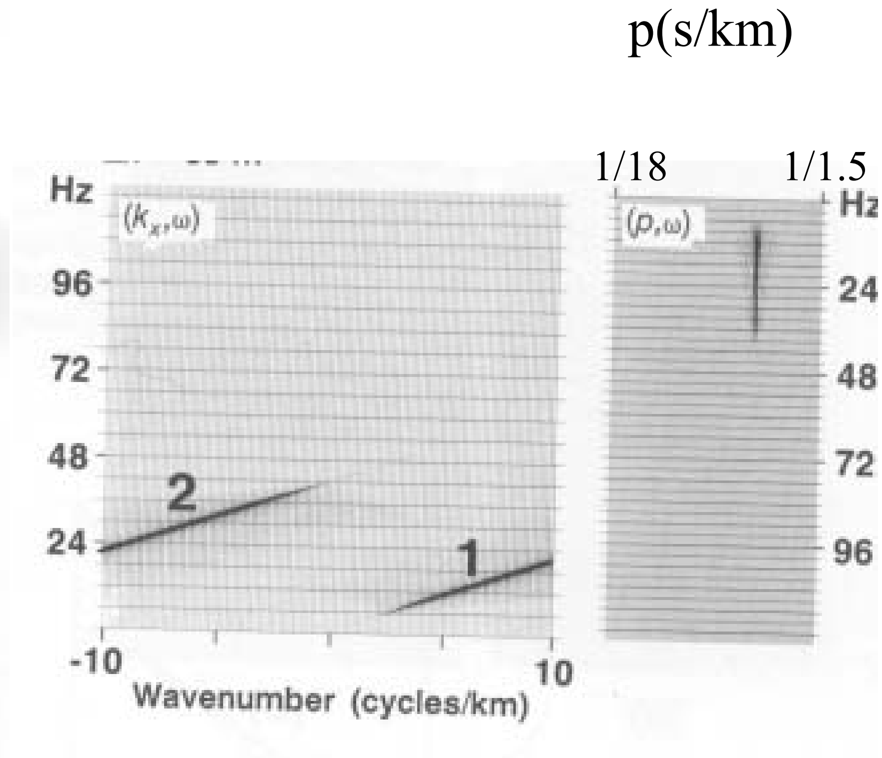
(1/p)

P1 and P2 are primaries
W is water bottom which
results in multiples

Yilmaz, 1987

Dipping event in different domains



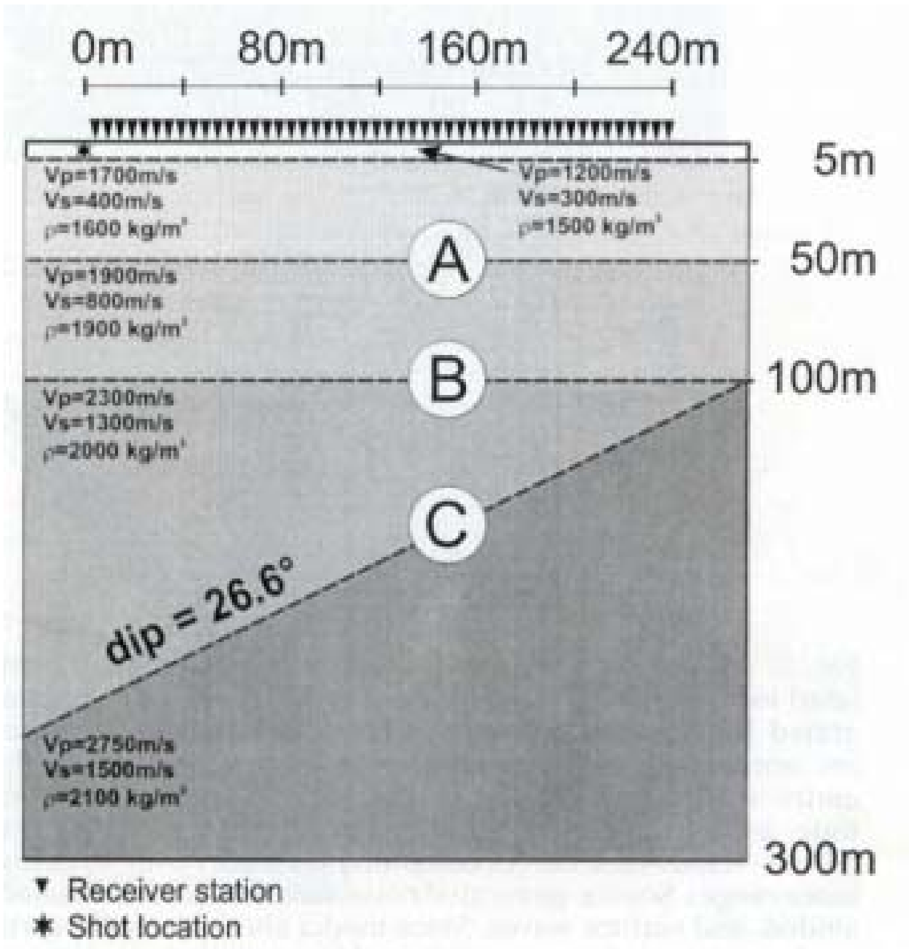


Yilmaz, 1987

Reducing source-generated noise in shallow seismic data using linear and hyperbolic τ–p transformations

Roman Spitzer,
Frank Nitsche and
Alan G. Green

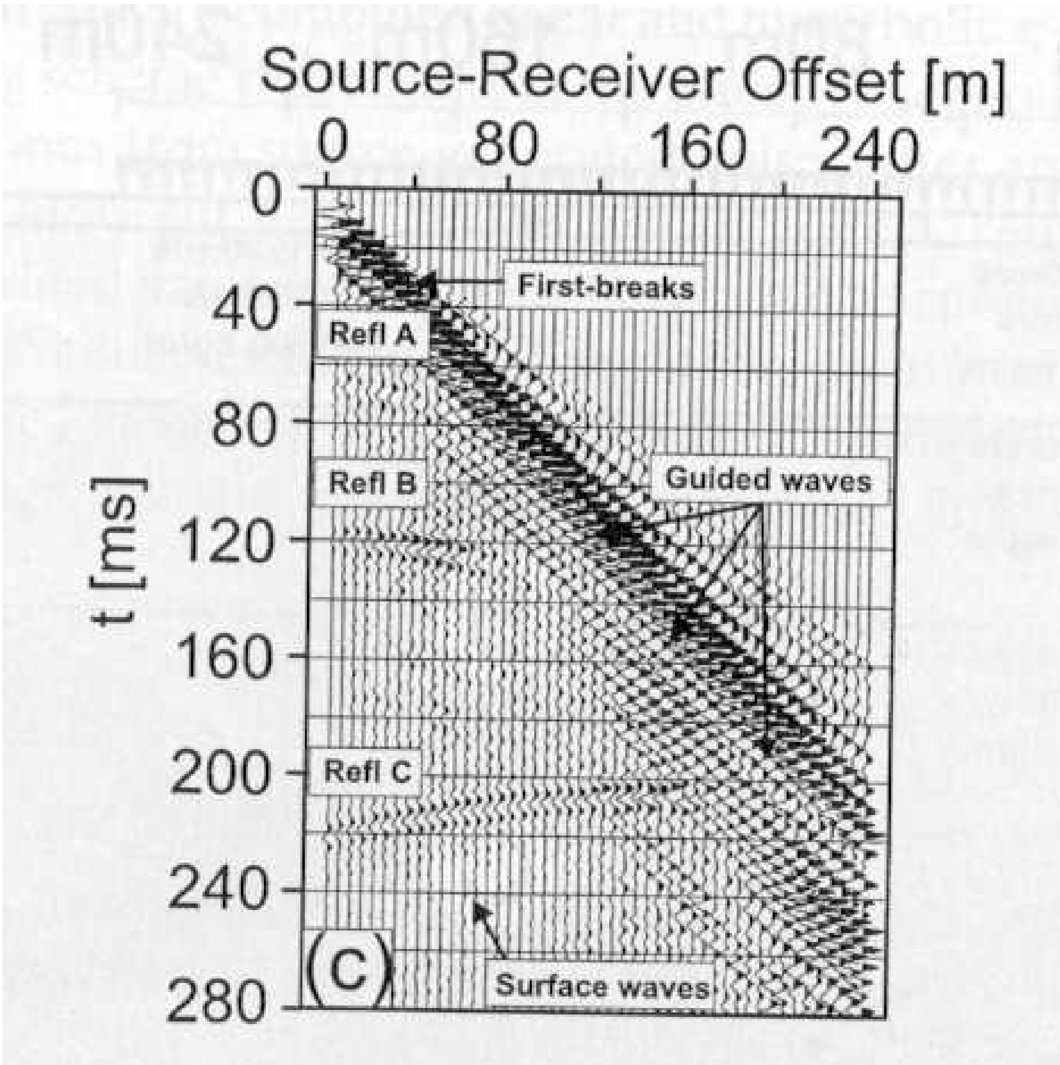
2-D velocity model



48 receivers
5 m. interval

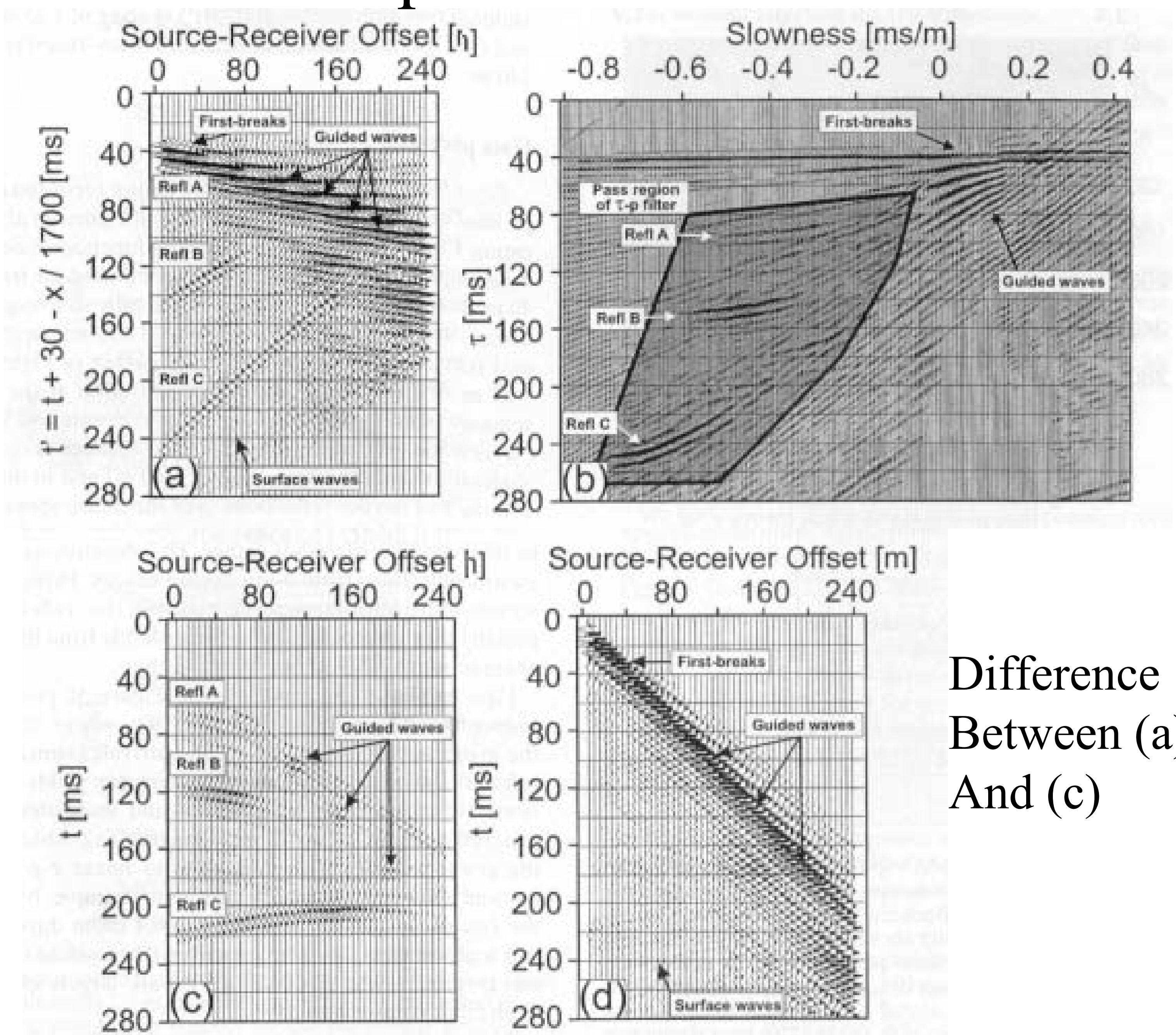
Source location:
5 m from first geophone
3m depth

Shot gather



(a) Raw shot gather
(b) Time and offset varying gain
(c) Spectral balancing (80-250 Hz)

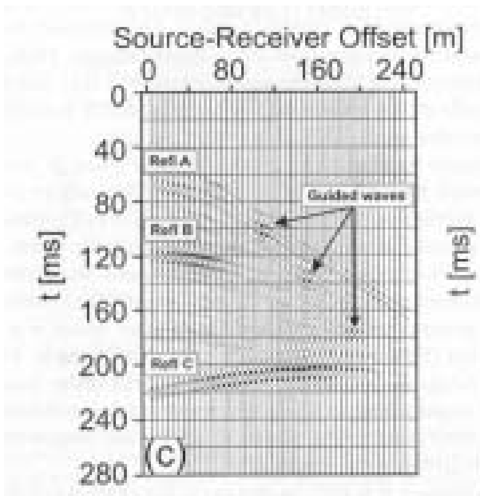
Linear τ-p transformation



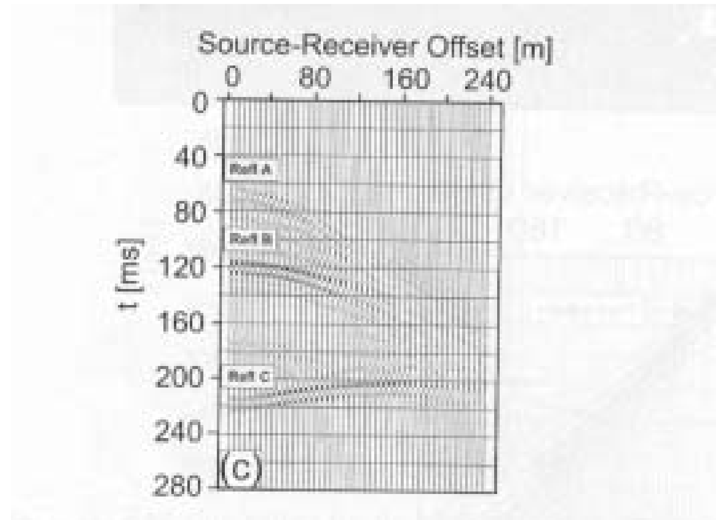
Result of filtering

Difference Between (a) And (c)

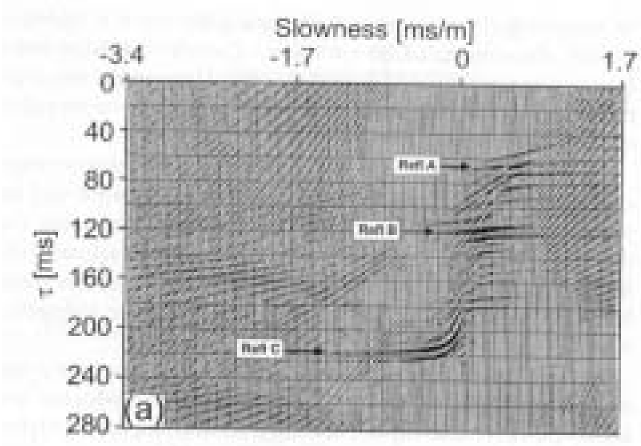
Hyperbolic τ-p transformation



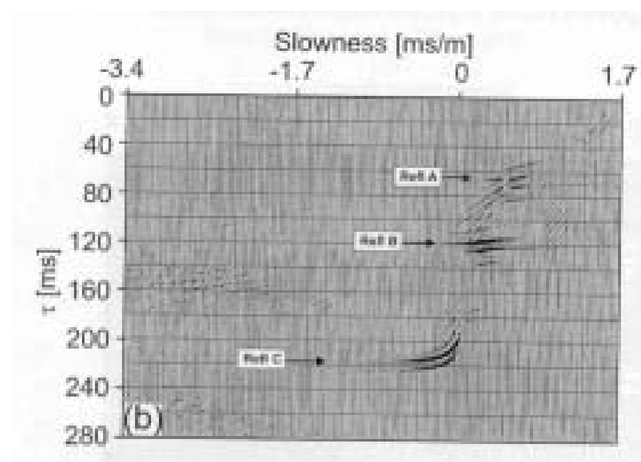
Hyperbolic τ-p transformation



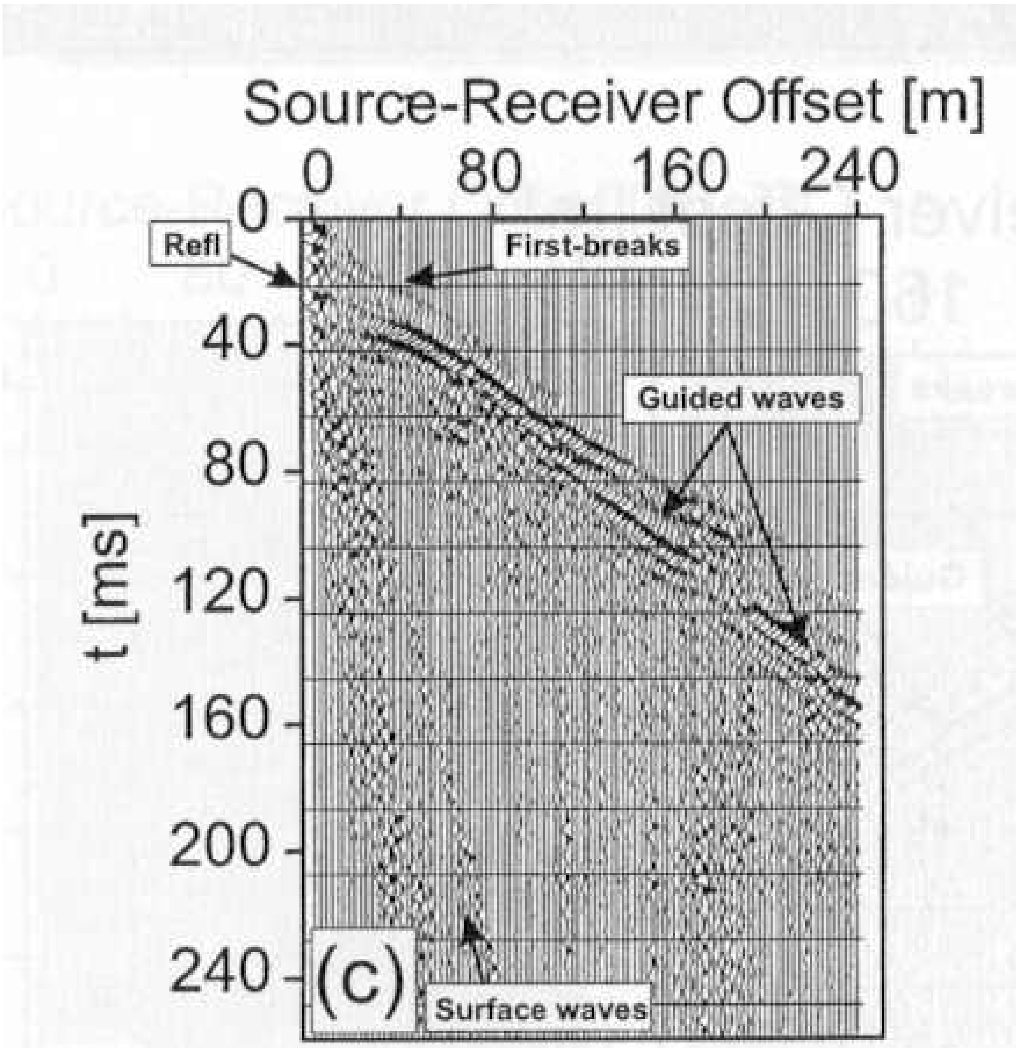
Inverse hyperbolic τ-p transformation



Amplitude of each sample is squared

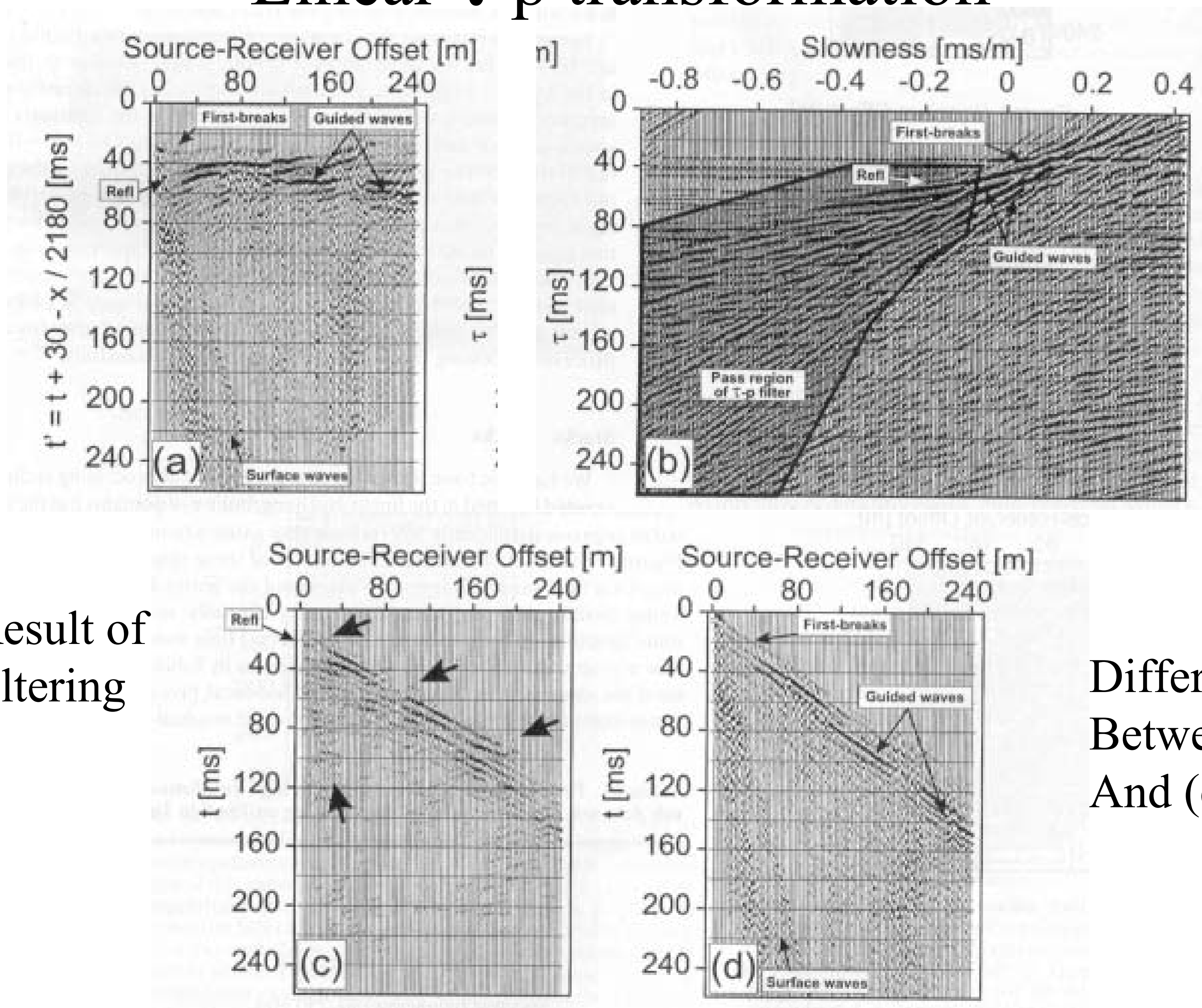


Shot gather along a high-resolution seismic line in northern Switzerland



(a) Raw shot gather
(b) Time and offset varying gain
(c) Spectral balancing (80-250 Hz)

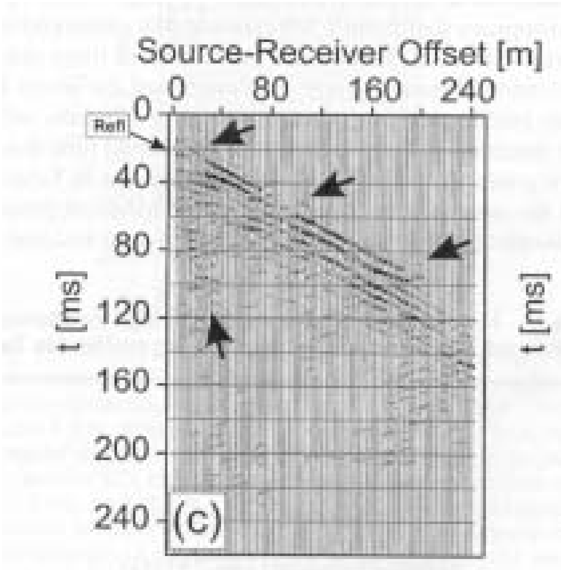
Linear τ-p transformation



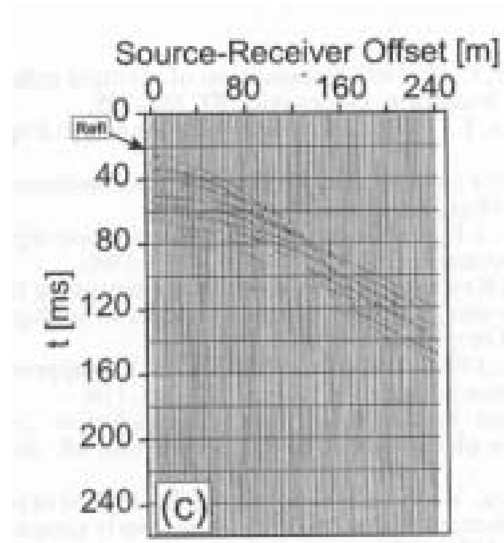
Result of filtering

Difference Between (c) And (c)

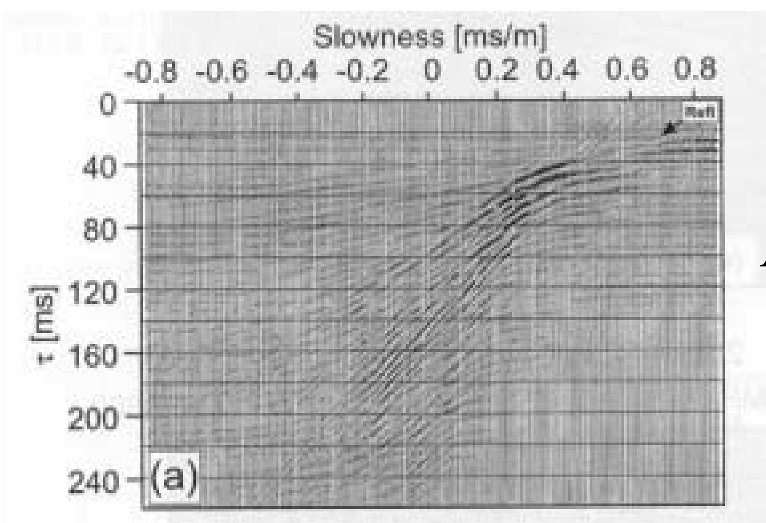
Hyperbolic τ-p transformation



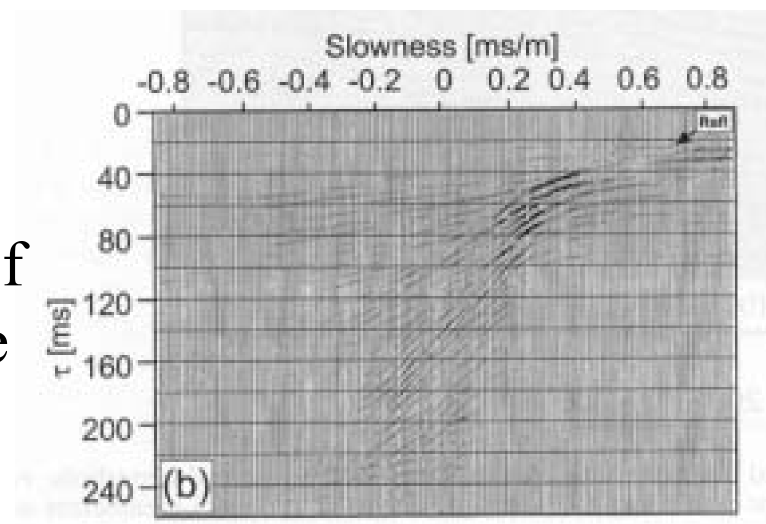
Hyperbolic τ-p transformation



Inverse hyperbolic τ-p transformation

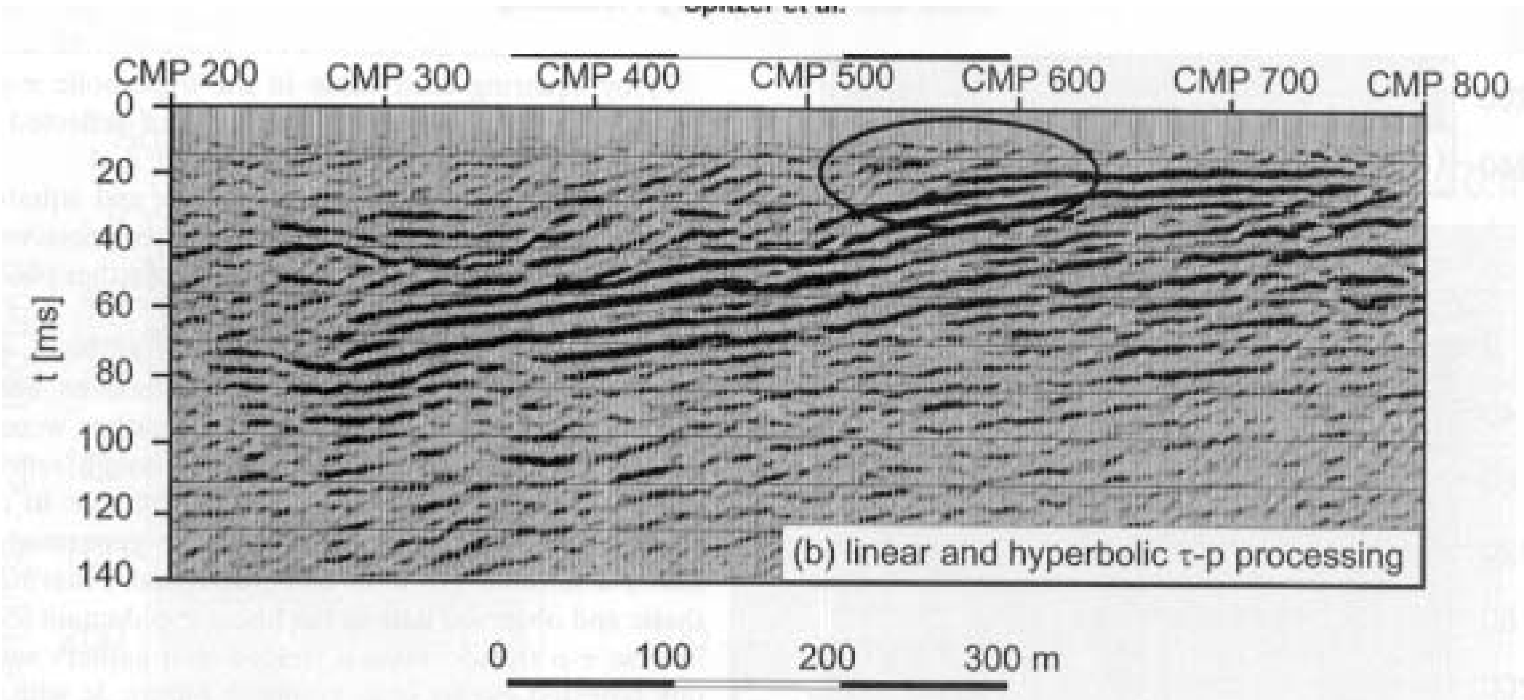


Amplitude of each sample is squared



Stacked sections

Processing:
- CMP sorting
- NMO corrections
- NMO stretch mute
- Stacking



Reflections were found to extend to shallower depths and more continuous