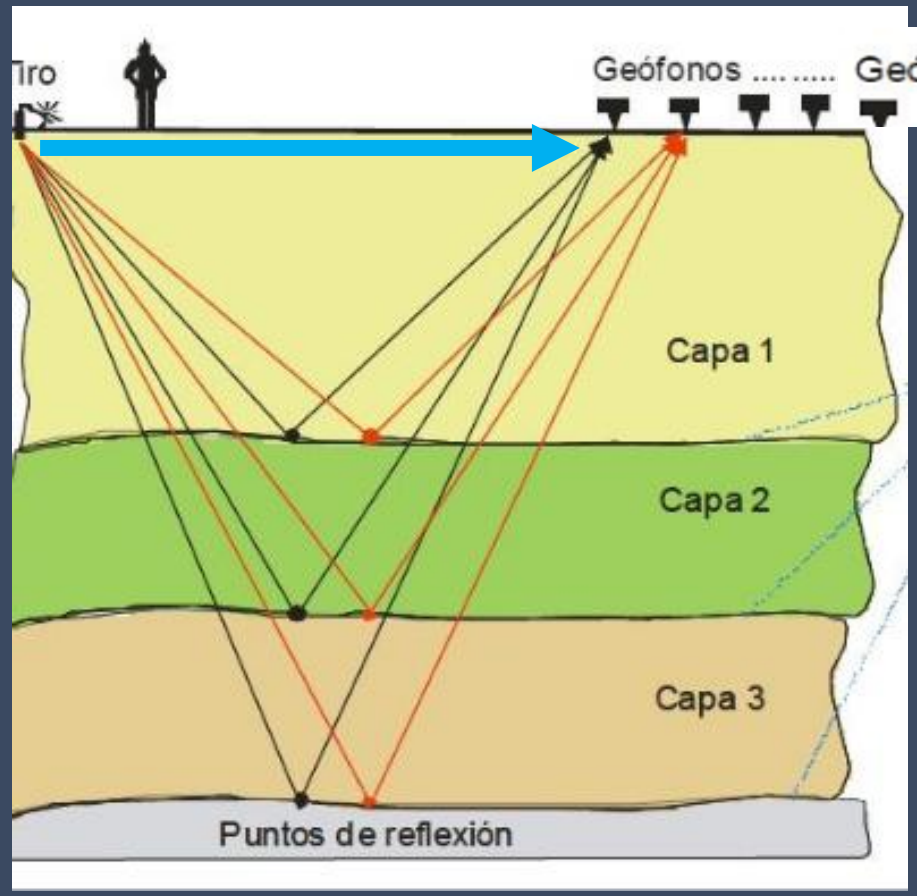
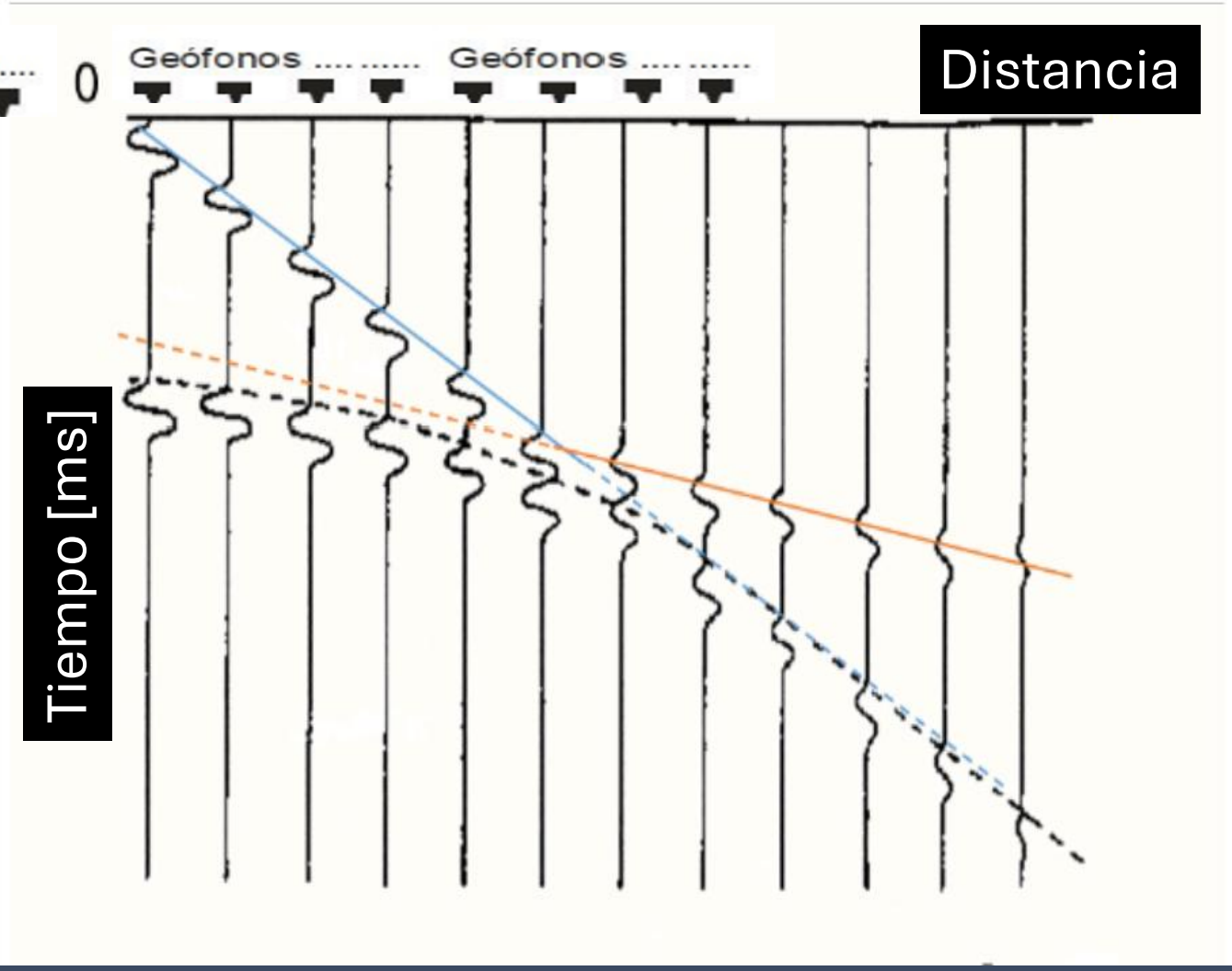
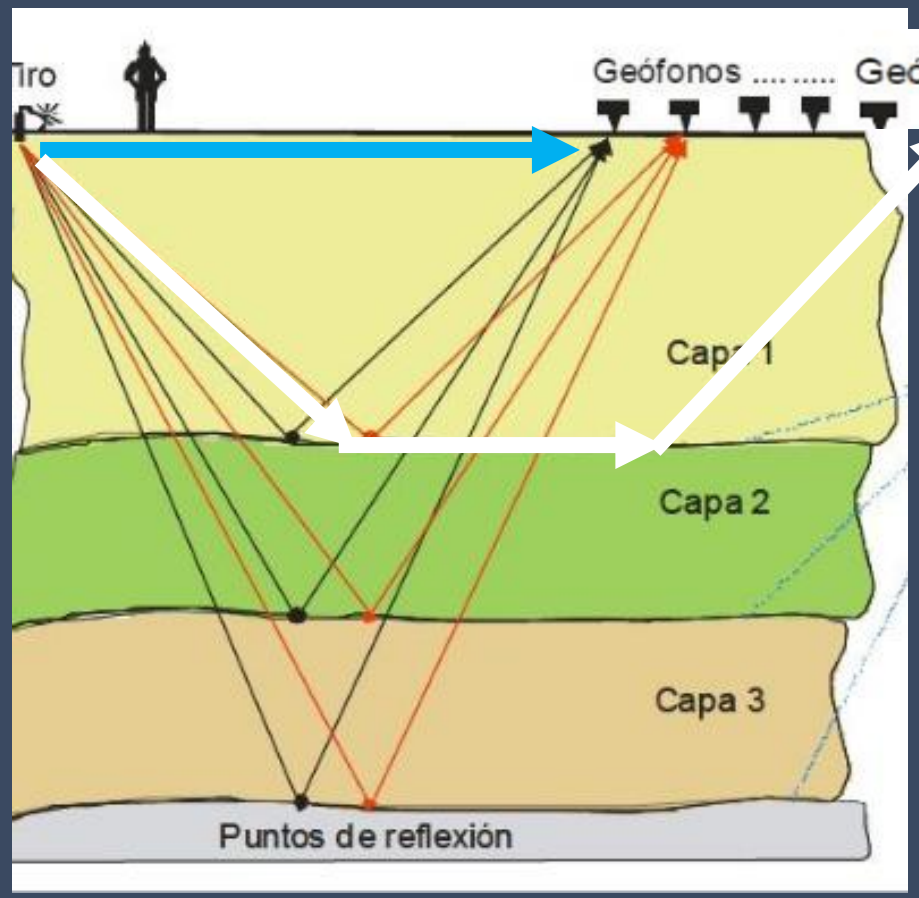
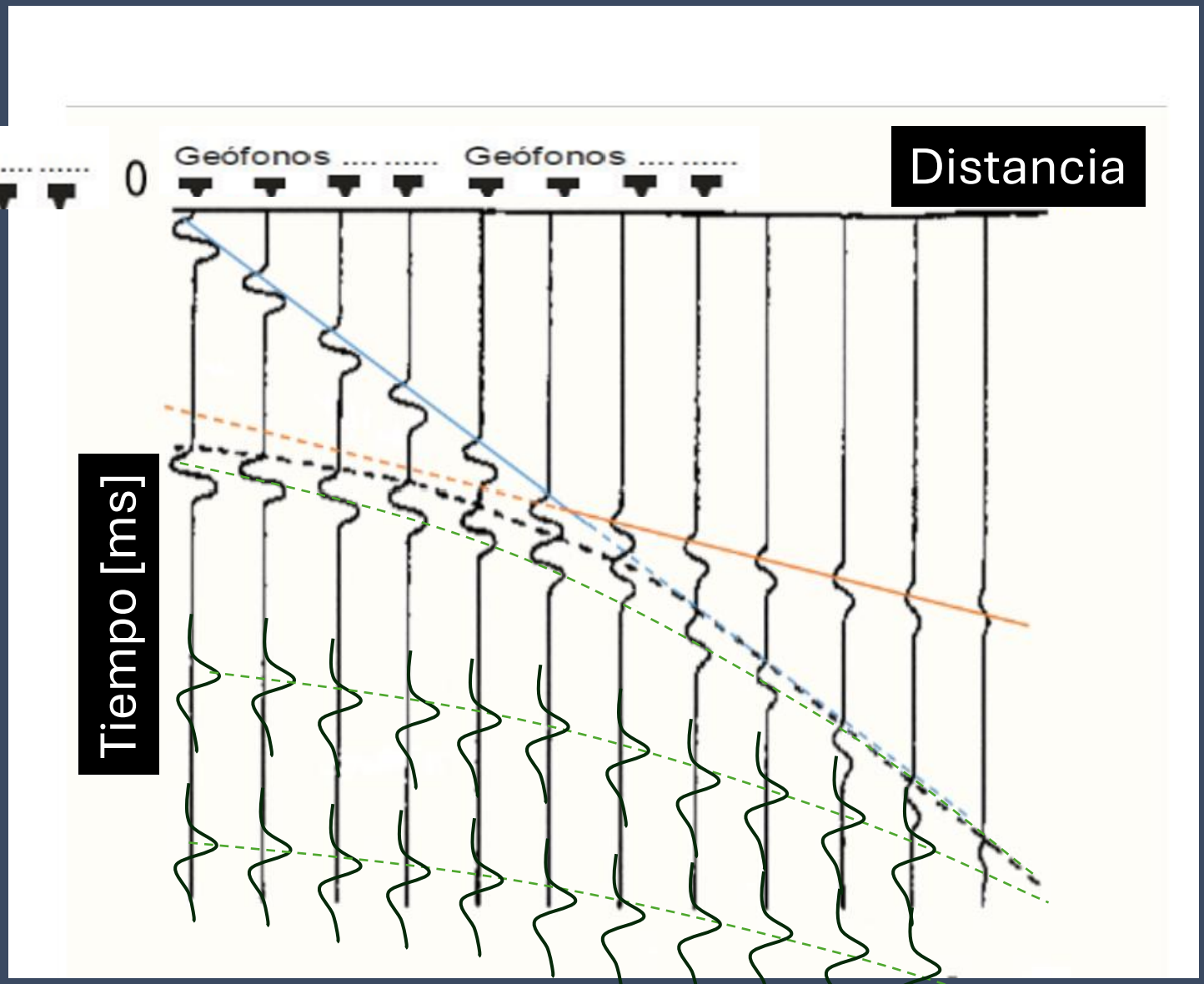
Métodos Sísmicos de Exploración

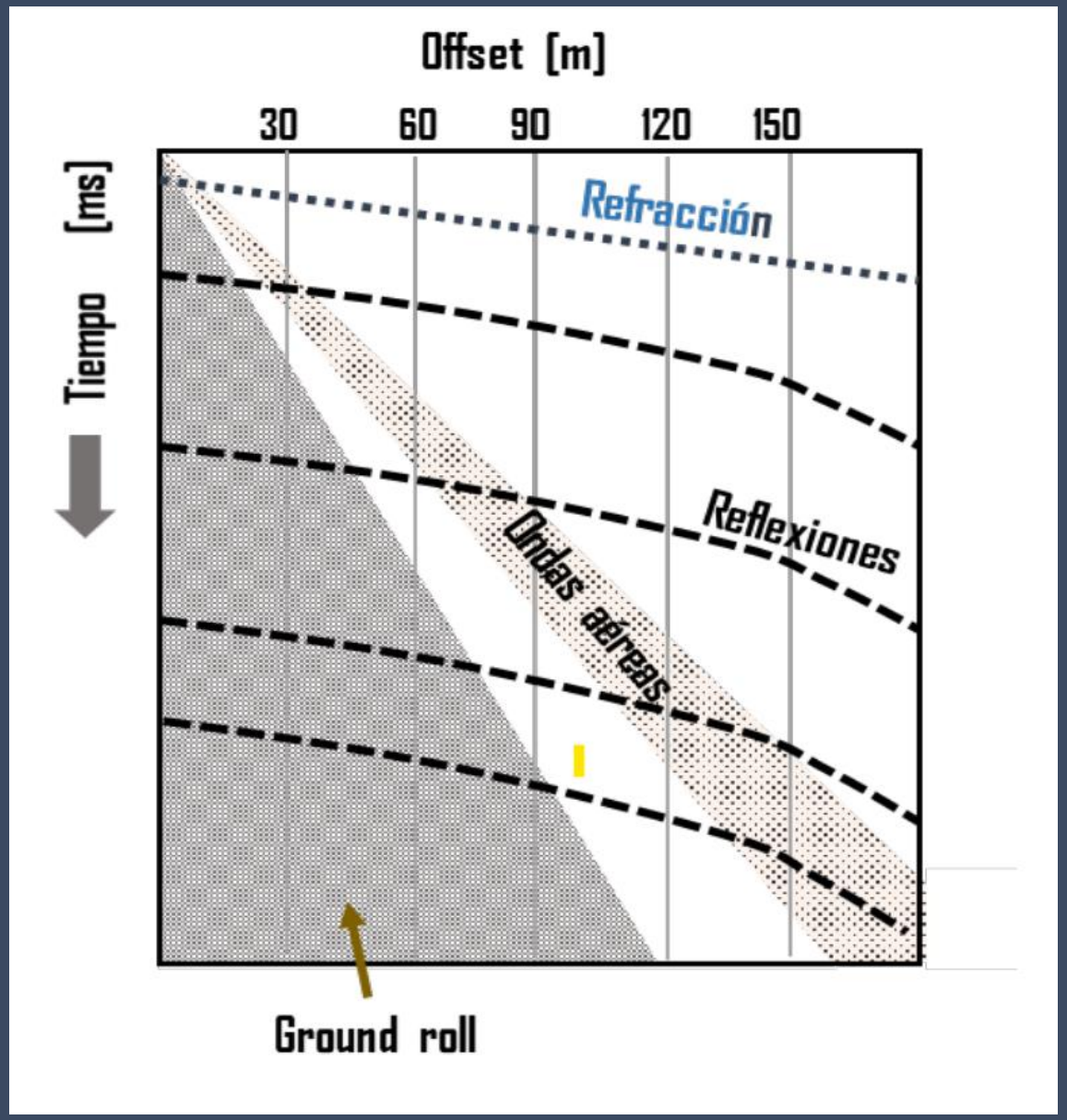
Exploración Petrolera - 2025

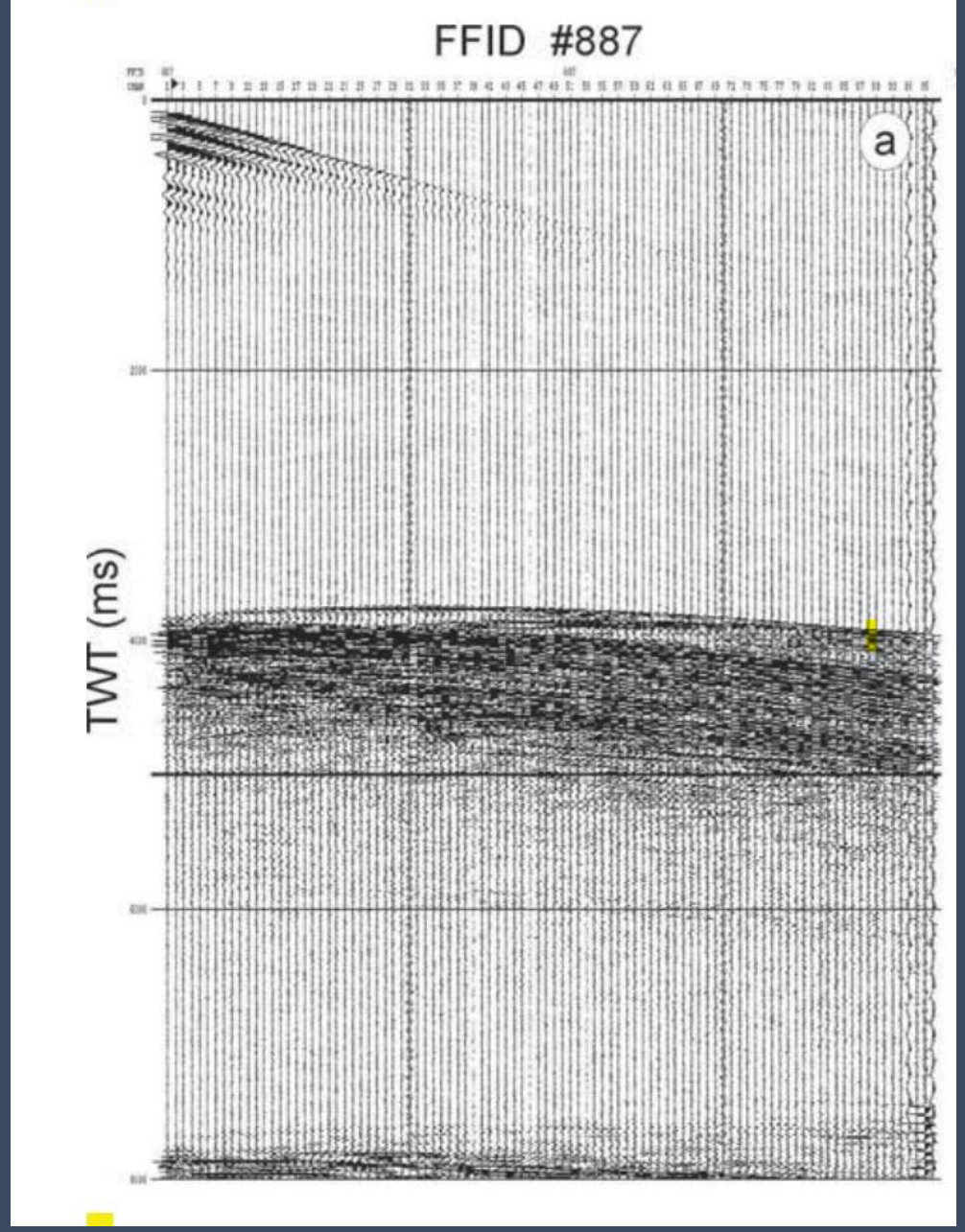

Tiro
Geófonos ..... Geófonos .....
Capa 1
Capa 2
Capa 3
Puntos de reflexión

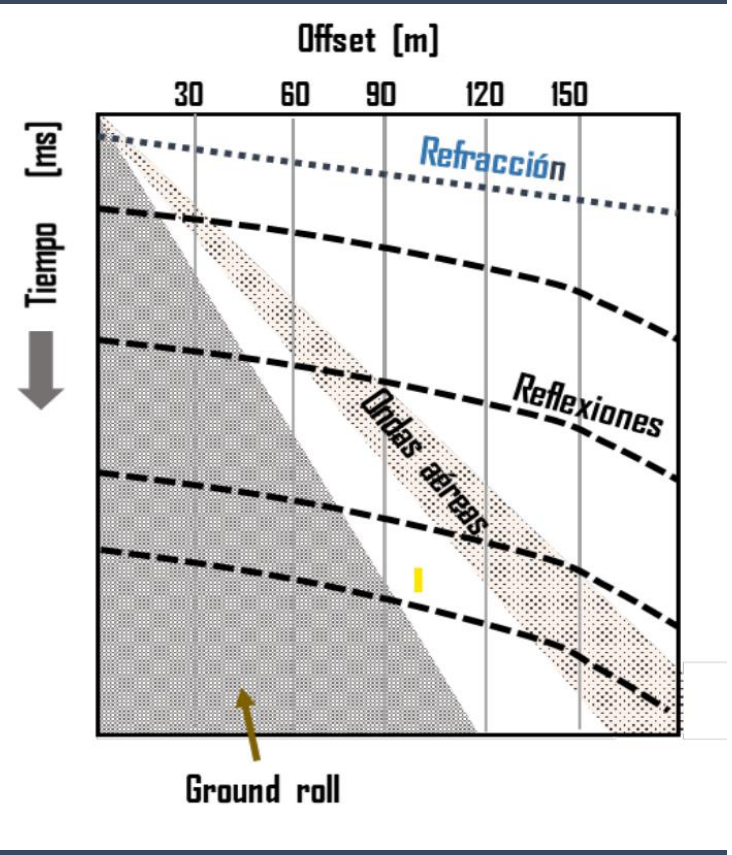

0
Geófonos ..... Geófonos .....
Distancia
Tiempo [ms]

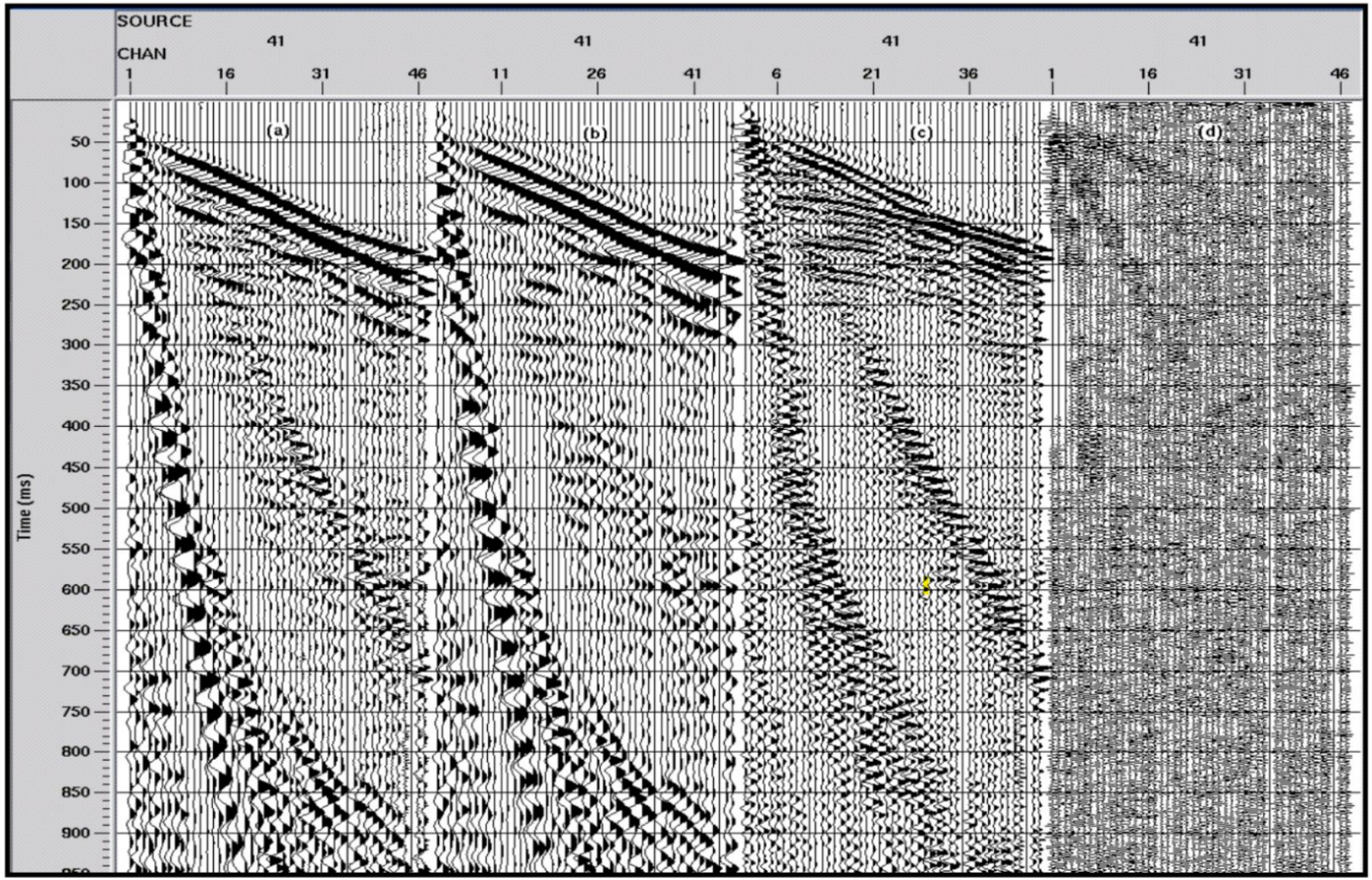

Tiro
Geófonos ..... Geófonos .....
Capa 1
Capa 2
Capa 3
Puntos de reflexión


0
Geófonos ..... Geófonos .....
Distancia
Tiempo [ms]


Offset [m]
30
60
90
120
150
Tiempo [ms]
Refracción
Reflexiones
Ondas aéreas
Ground roll

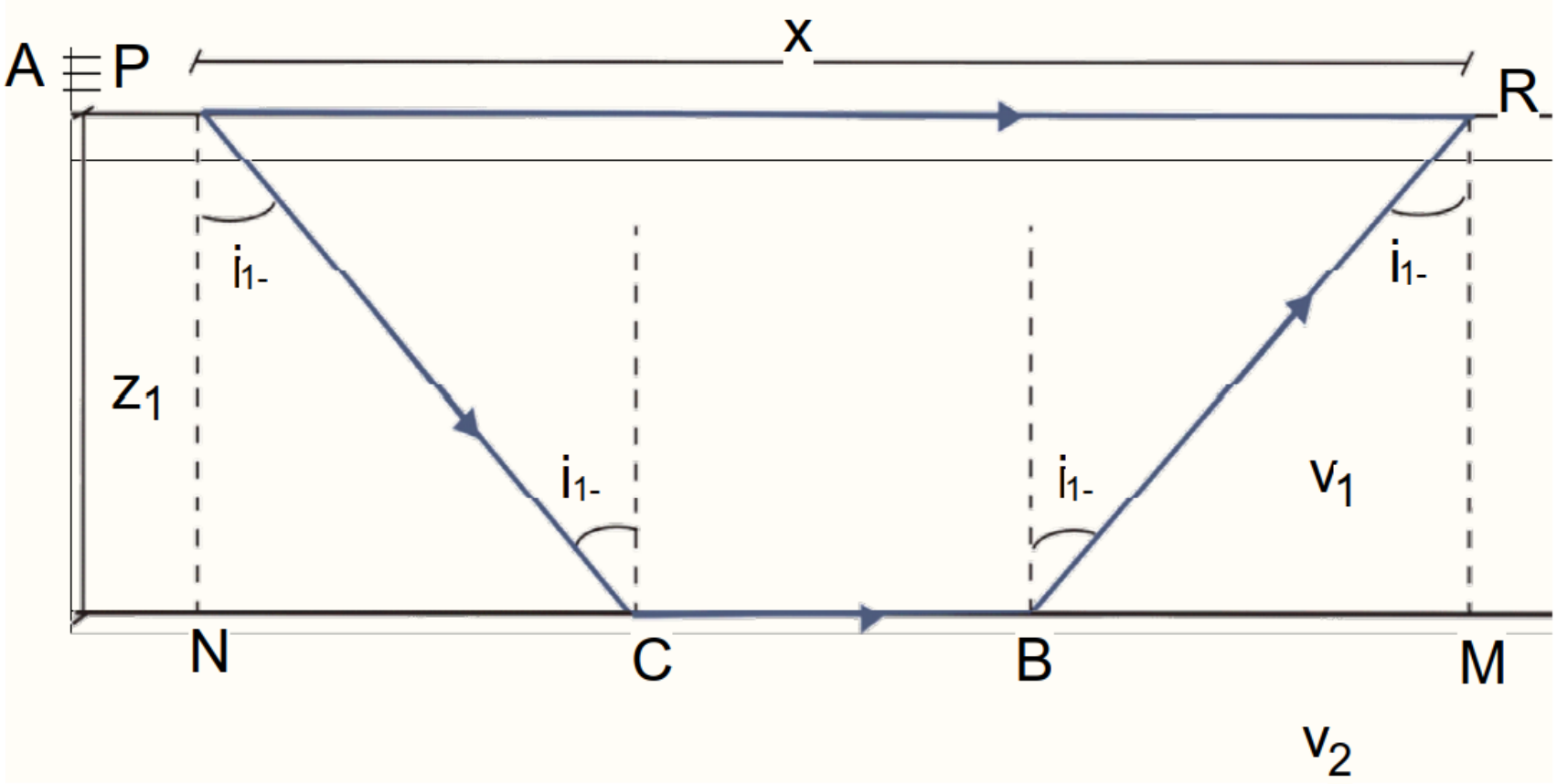

FFID #887
a
TWT (ms)


Offset [m]
30
60
90
120
150
Tiempo [ms]
Refracción
Reflexiones
Ondas aéreas
Ground roll


SOURCE
CHAN
41
1
16
31
46
11
26
6
21
36
(a)
(b)
(c)
(d)
Time (ms)
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900

(a) (b) (c) (d)

Sísmica de Refracción



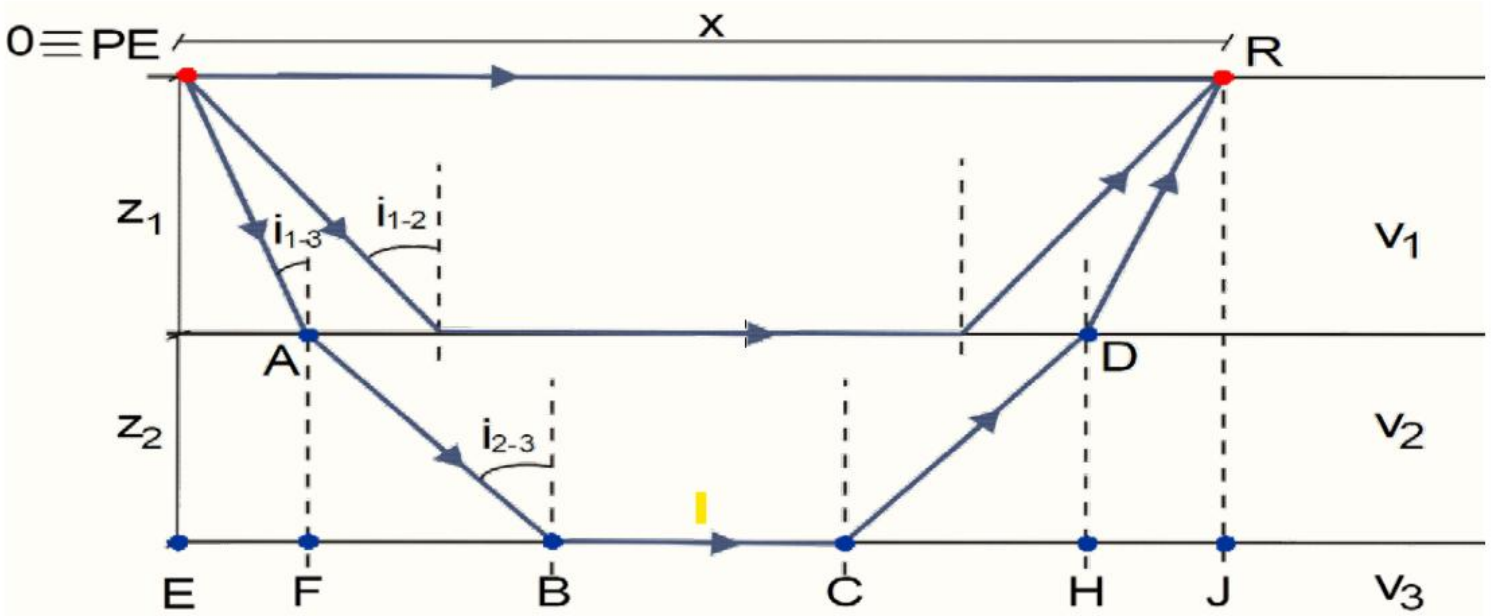
$$T_R = \frac{\overline{AC}}{v_1} + \frac{\overline{CB}}{v_2} + \frac{\overline{BR}}{v_1}$$

$$\boxed{T_2 = \frac{x}{v_2} + \theta_2,}$$

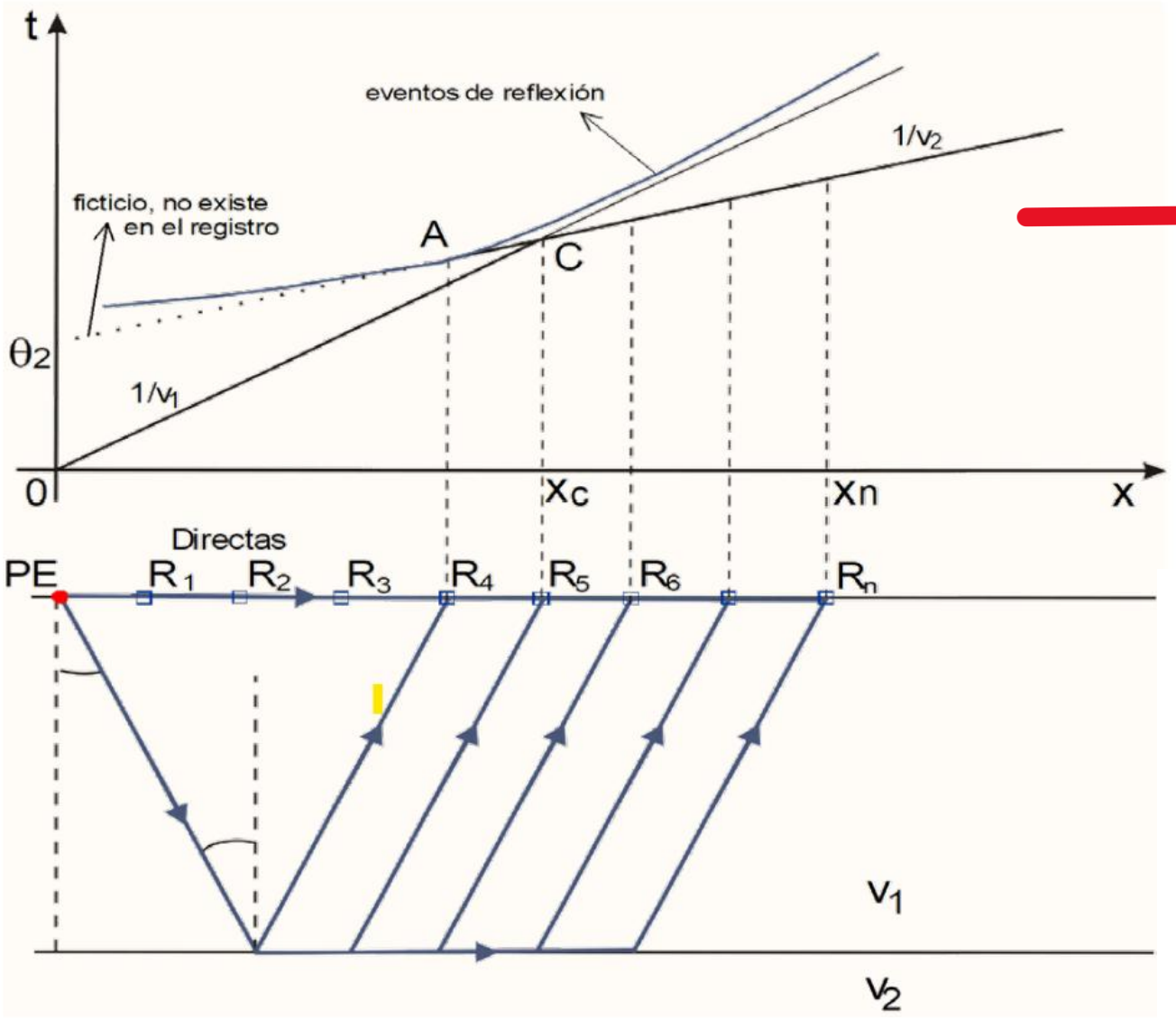
lo que representa una recta cuya pendiente es $1/v_2$ y la ordenada al origen θ_2

$t = m \cdot x + d$ (expresión matemática de una recta).

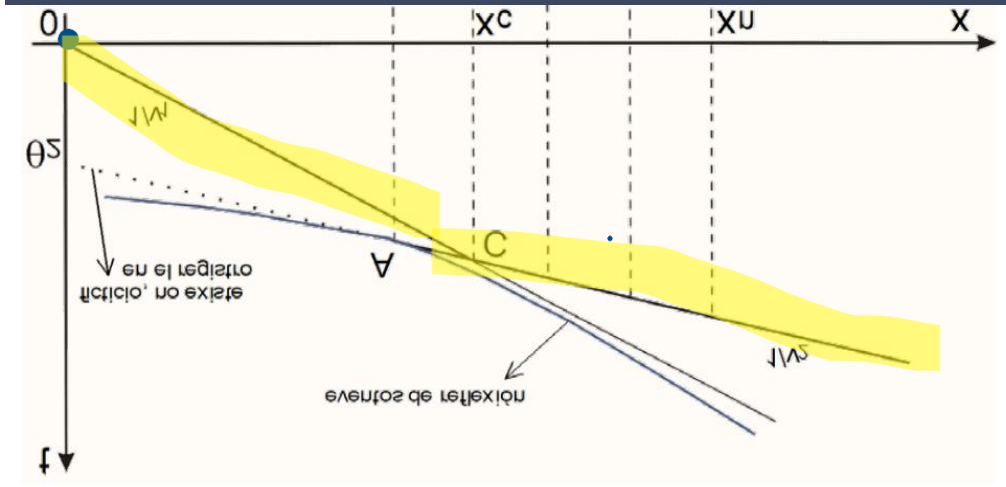
$$\boxed{\theta_2 = \frac{2 \cdot z_1}{v_1} \cdot \cos(i_{1-2}),}$$

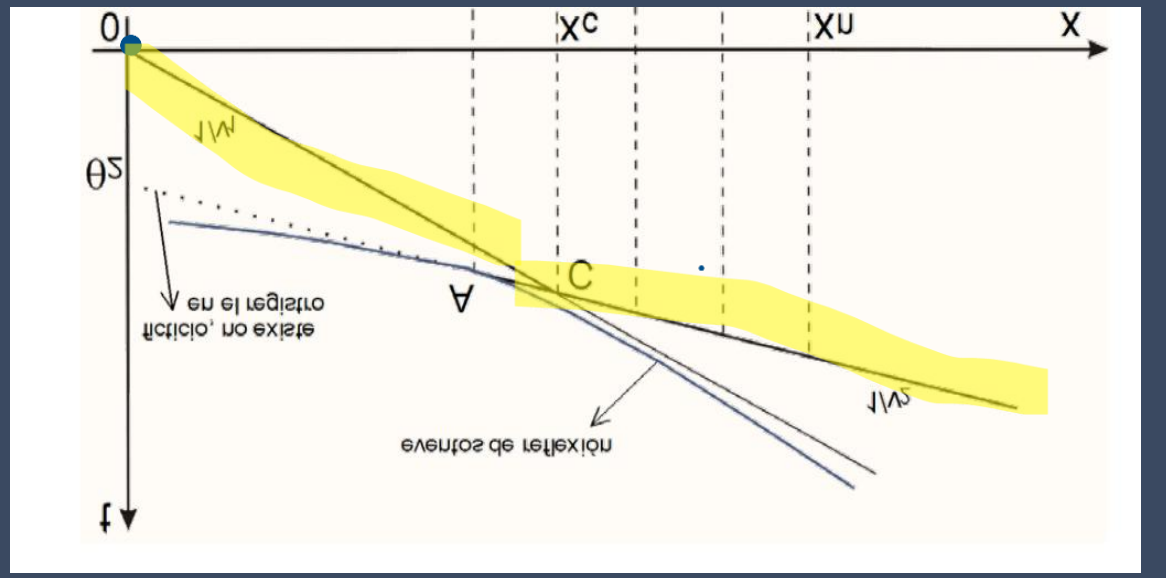


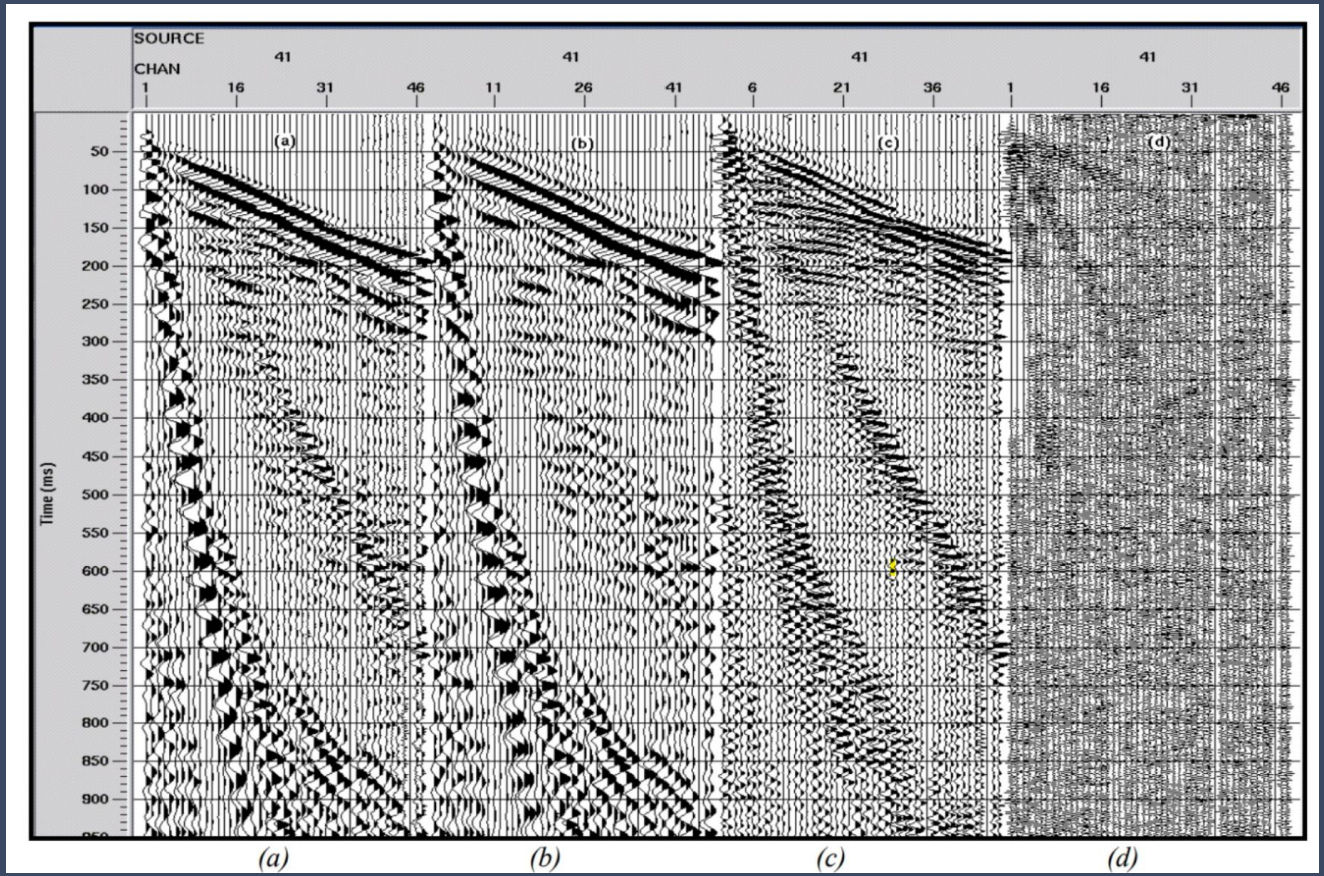
$$T_3 = \frac{x}{v_3} + \underbrace{\frac{2 \cdot z_1}{v_1} \cdot \cos(i_{1-3})}_{\theta_1} + \underbrace{\frac{2 \cdot z_2}{v_2} \cdot \cos(i_{2-3})}_{\theta_2},$$


t
eventos de reflexión
1/v2
ficticio, no existe
en el registro
A
C
θ2
1/v1
0
xc
xn
x
Directas
PE
R1
R2
R3
R4
R5
R6
Rn
v1
v2

Dromocrona


t
eventos de reflexión
1/v2
ficticio, no existe
en el registro
A
C
θ2
1/v1
0
xc
xn
x


t
0
x
x_n
x_c
θ_c
v_1
v_2
C
A
eventos de reflexión
fricicio, no existe
en el registro


SOURCE
CHAN
41
1
16
31
46
11
26
6
21
36
Time (ms)
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
(a)
(b)
(c)
(d)

¿Por qué dos?

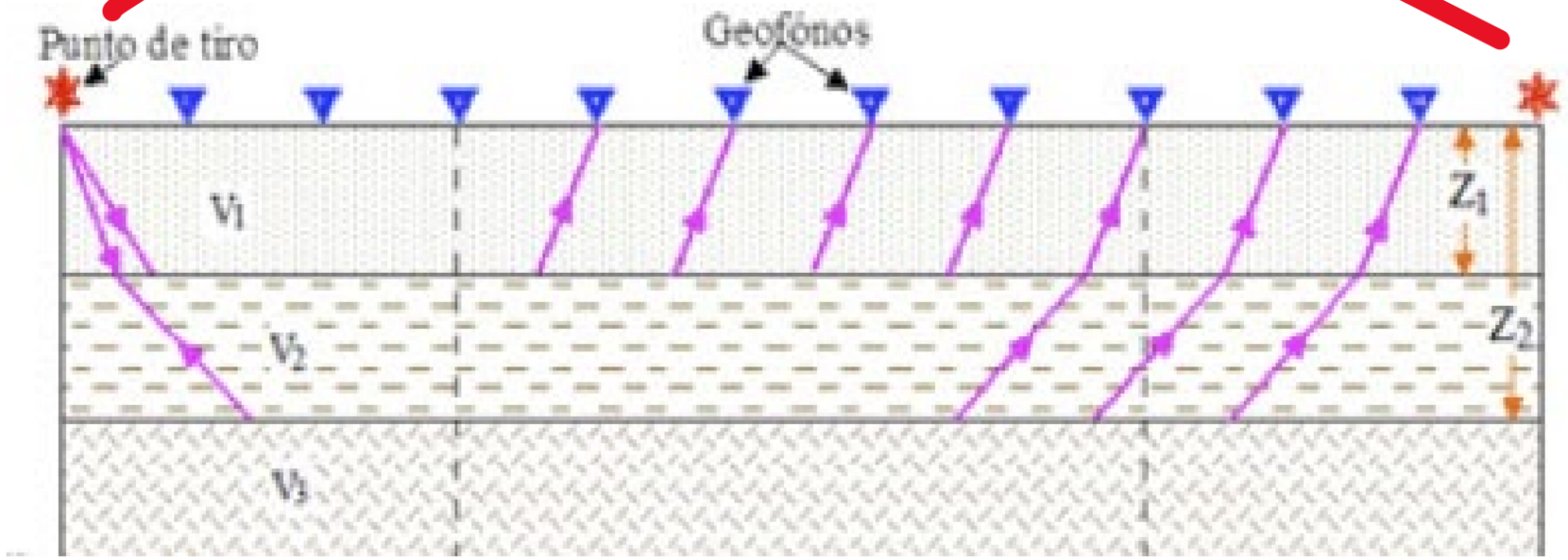
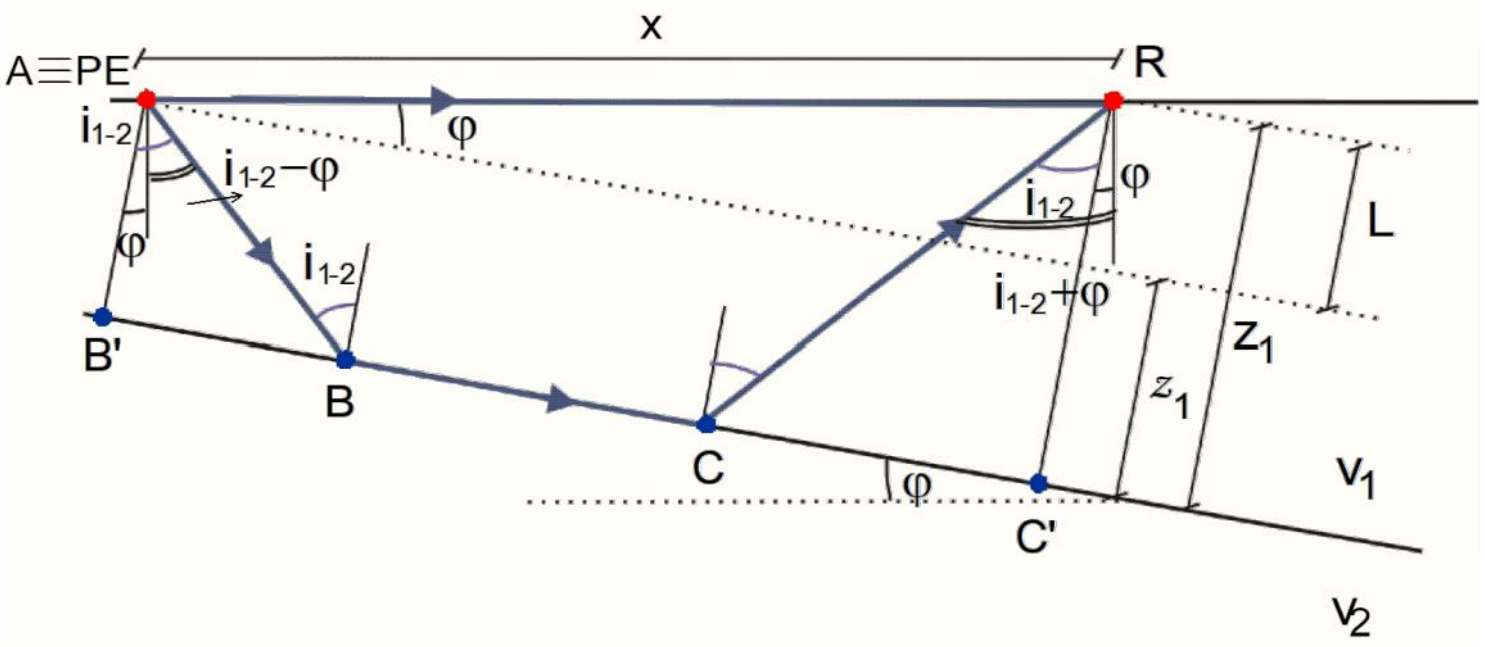


Figura N° 8: Arreglo de refracción asimétrico, con la ubicación del punto de tiro del perfil y del contraperfil. Distribución de receptores. Fuente de Imágenes: Modificado de Sheriff et al., 1991.



$$T_{2b} = \frac{2 \cdot z_1}{v_1} \cdot \cos(i_{1-2}) + \frac{x}{v_1} \cdot \text{sen}(i_{1-2} + \varphi)$$, llamando velocidad aparente de bajada a: $$\boxed{v_{2b} = \frac{v_1}{\text{sen}(i_{1-2} + \varphi)}}$$

este término es θ_{2b}

$$T_{2s} = \frac{2 \cdot z_1}{v_1} \cdot \cos(i_{1-2}) + \frac{x}{v_1} \cdot \text{sen}(i_{1-2} - \varphi)$$, llamando velocidad aparente de subida a: $$\boxed{v_{2s} = \frac{v_1}{\text{sen}(i_{1-2} - \varphi)}}$$

este término es θ_{2s}

$$v_{2b} = \frac{v_1}{\text{sen}(i_{1-2} + \varphi)} < v_{2Real} = \frac{v_1}{\text{sen}(i_{1-2})} < v_{2s} = \frac{v_1}{\text{sen}(i_{1-2} - \varphi)}$$

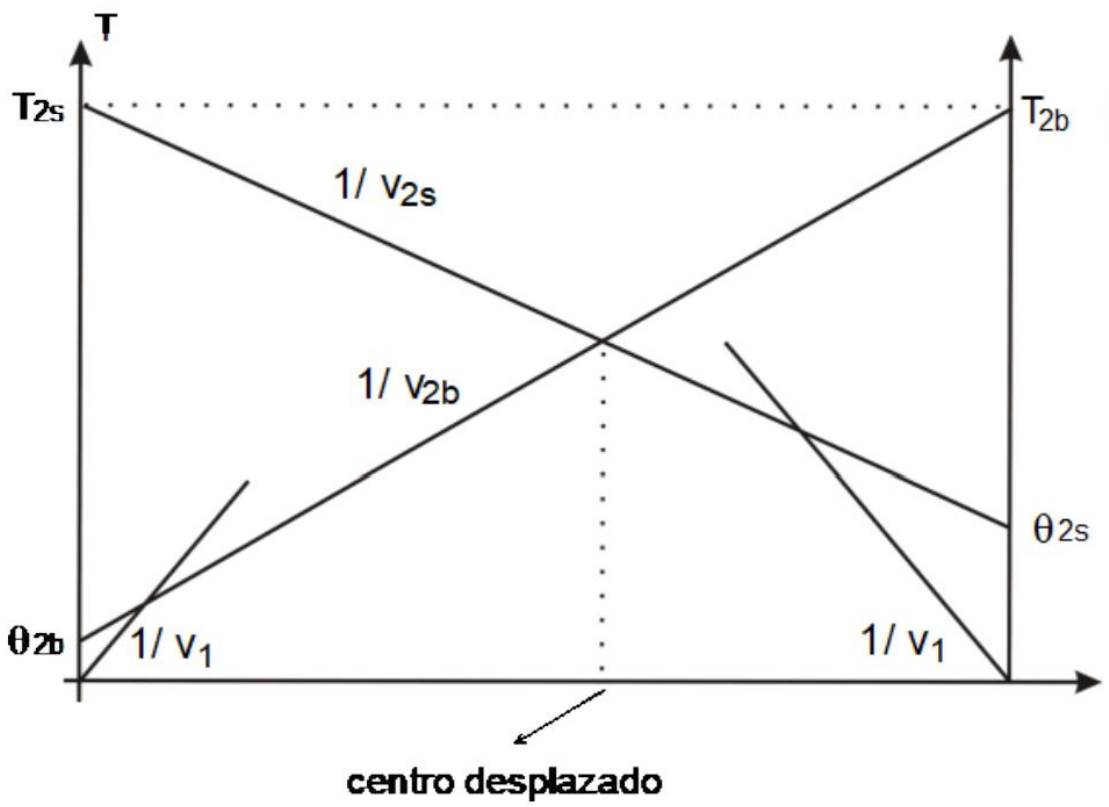
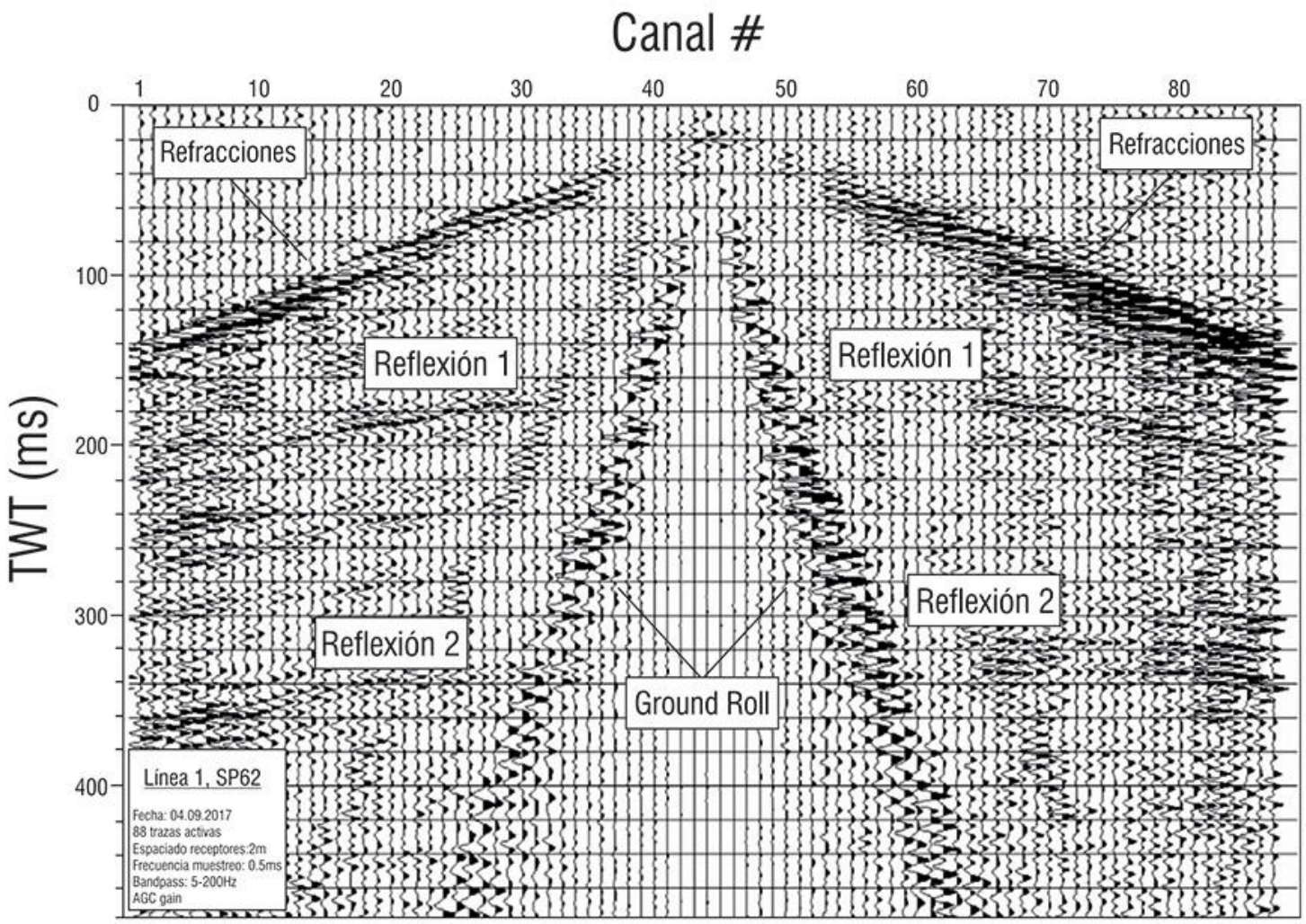


Figura N°13: Dromocrona del Perfil y contraperfil para un sistema de 1 capa inclinada.

$$v_{2b} = \frac{v_1}{sen(i_{1-2} + \varphi)} < v_{2Real} = \frac{v_1}{sen(i_{1-2})} < v_{2s} = \frac{v_1}{sen(i_{1-2} - \varphi)}$$

Sísmica de Reflexión


Canal #
1
10
20
30
40
50
60
70
80
0
100
200
300
400
TWT (ms)
Refracciones
Refracciones
Reflexión 1
Reflexión 1
Reflexión 2
Reflexión 2
Ground Roll
Línea 1, SP62
Fecha: 04.09.2017
88 trazas activas
Espaciado receptores:2m
Frecuencia muestreo: 0.5ms
Bandpass: 5-200Hz
AGC gain

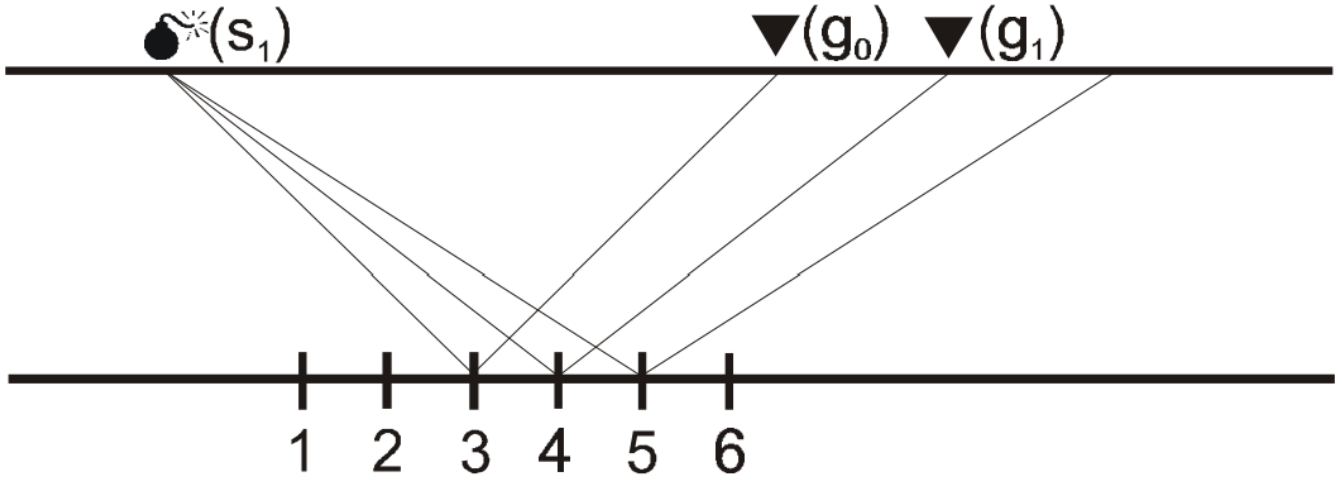
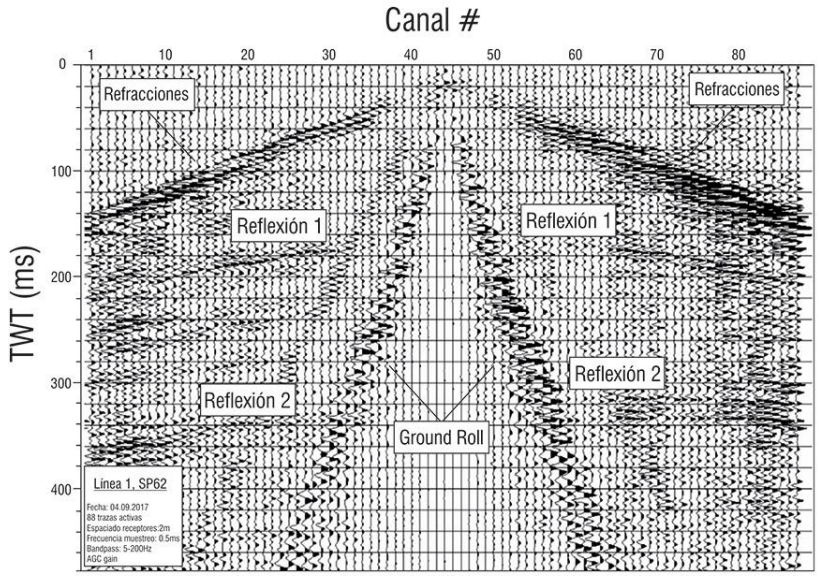


Figura b



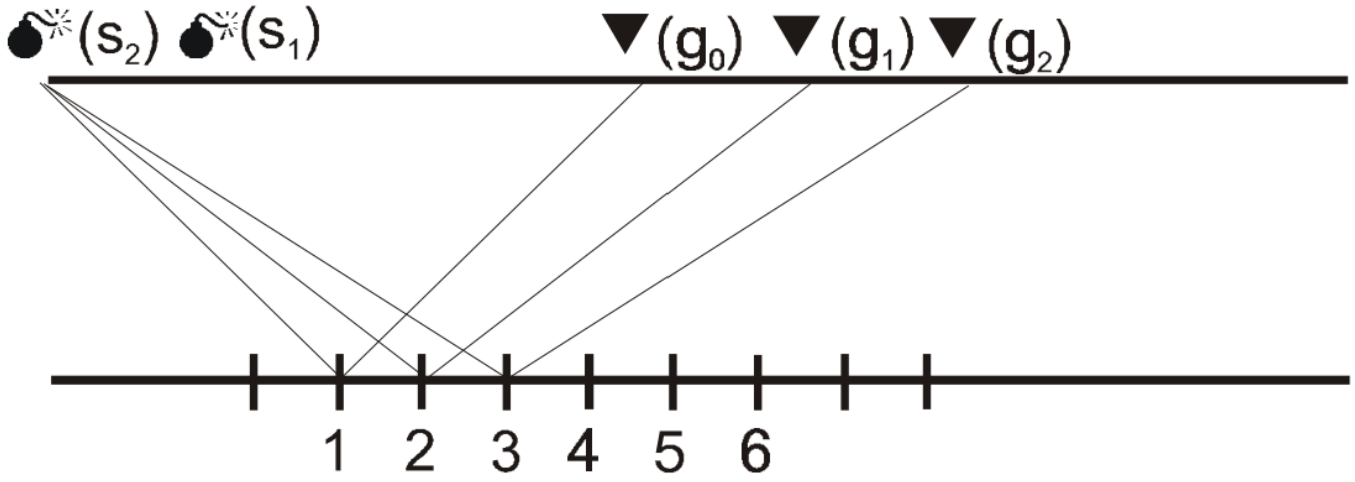
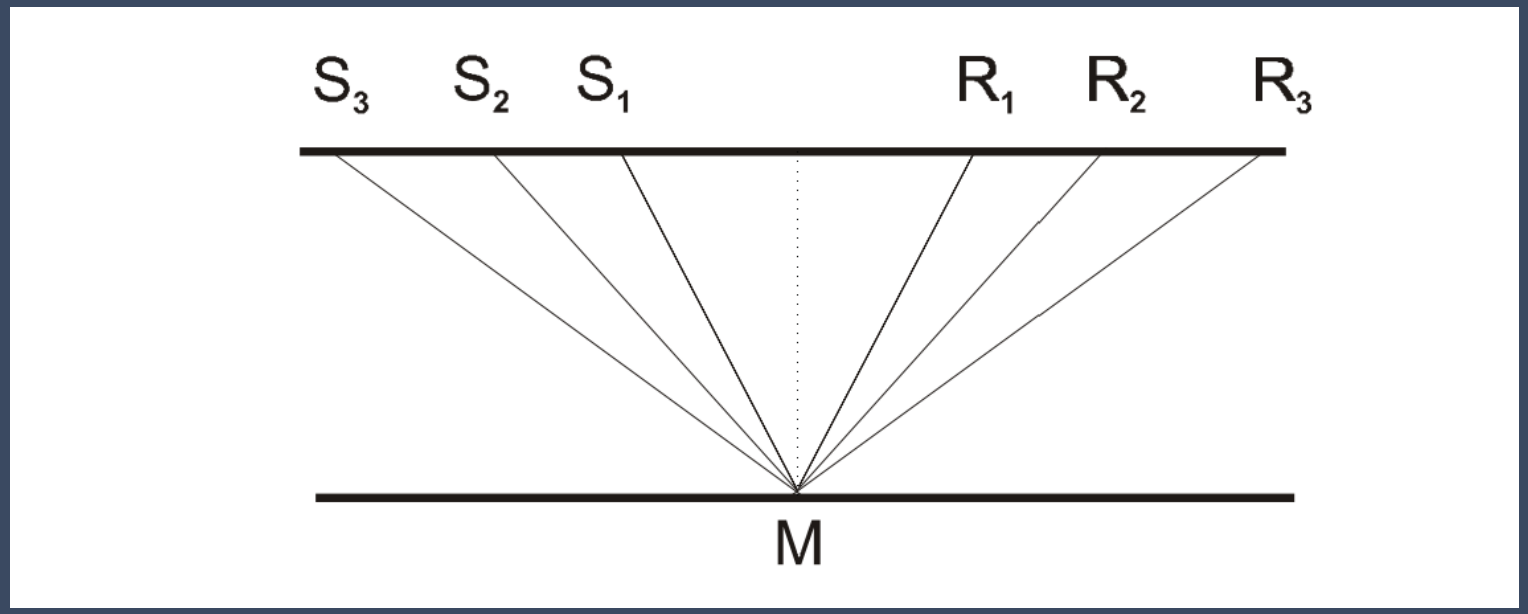
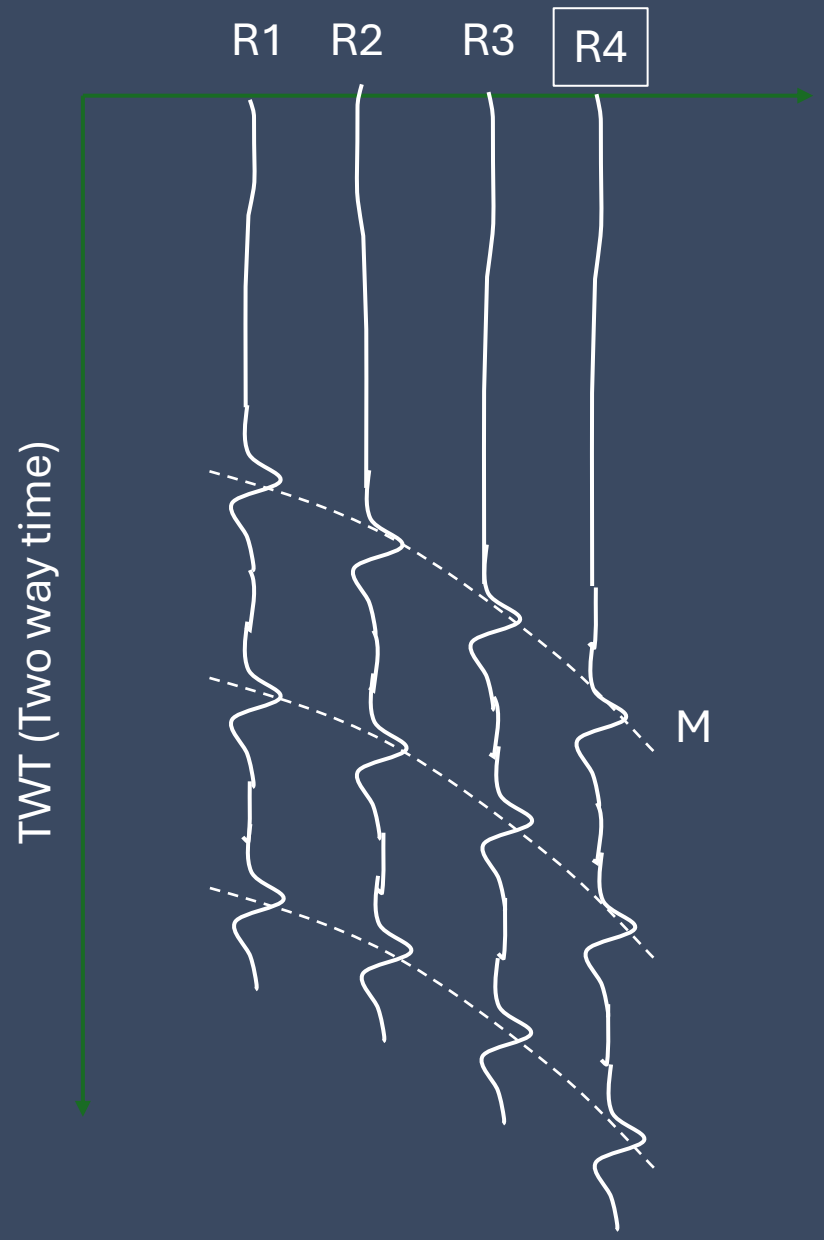


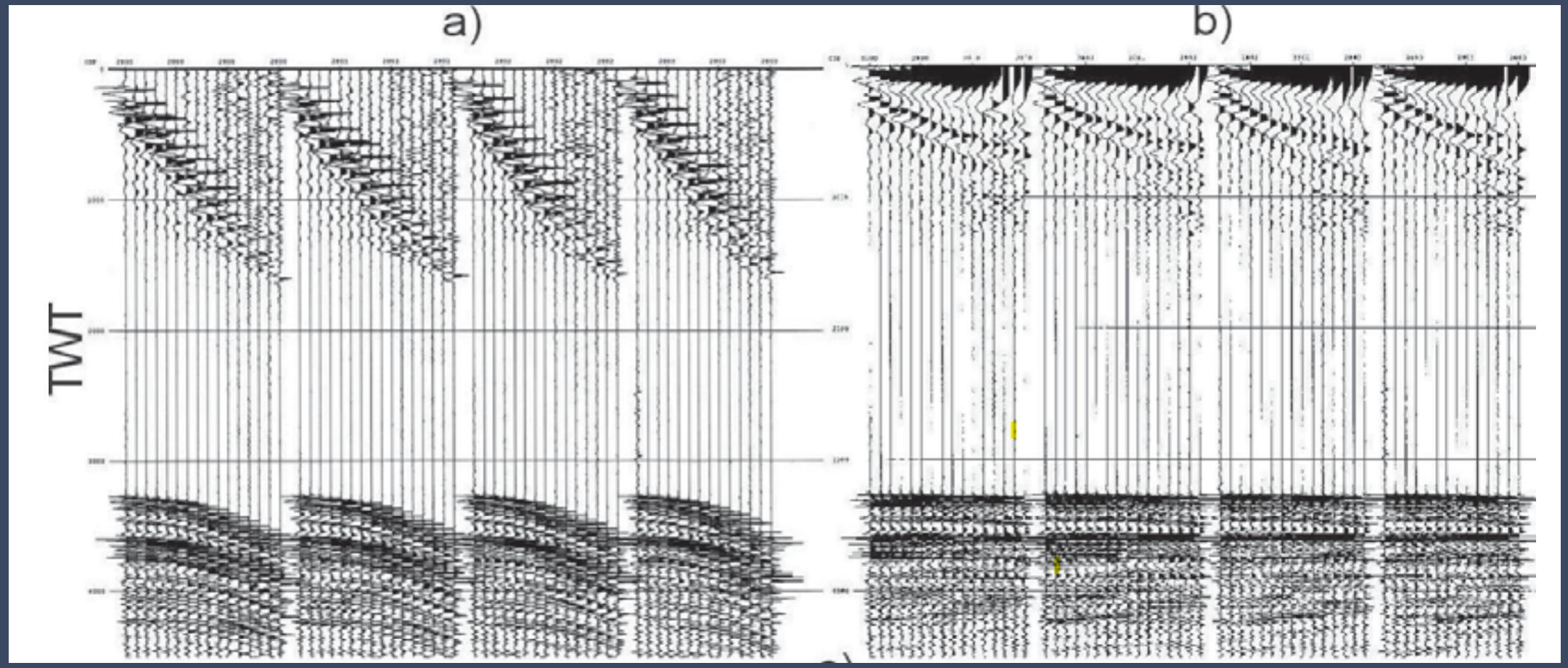
Figura c





$$t^2(x) = t^2(0) + \frac{x^2}{v^2}$$

Correcciones NMO (Normal Move Out) y Stacking



Convolución - Deconvolución

$Z_1 = \rho_1 . v_1$

$Z_2 = \rho_2 . v_2$

$Z_n = \rho_n . v_n$

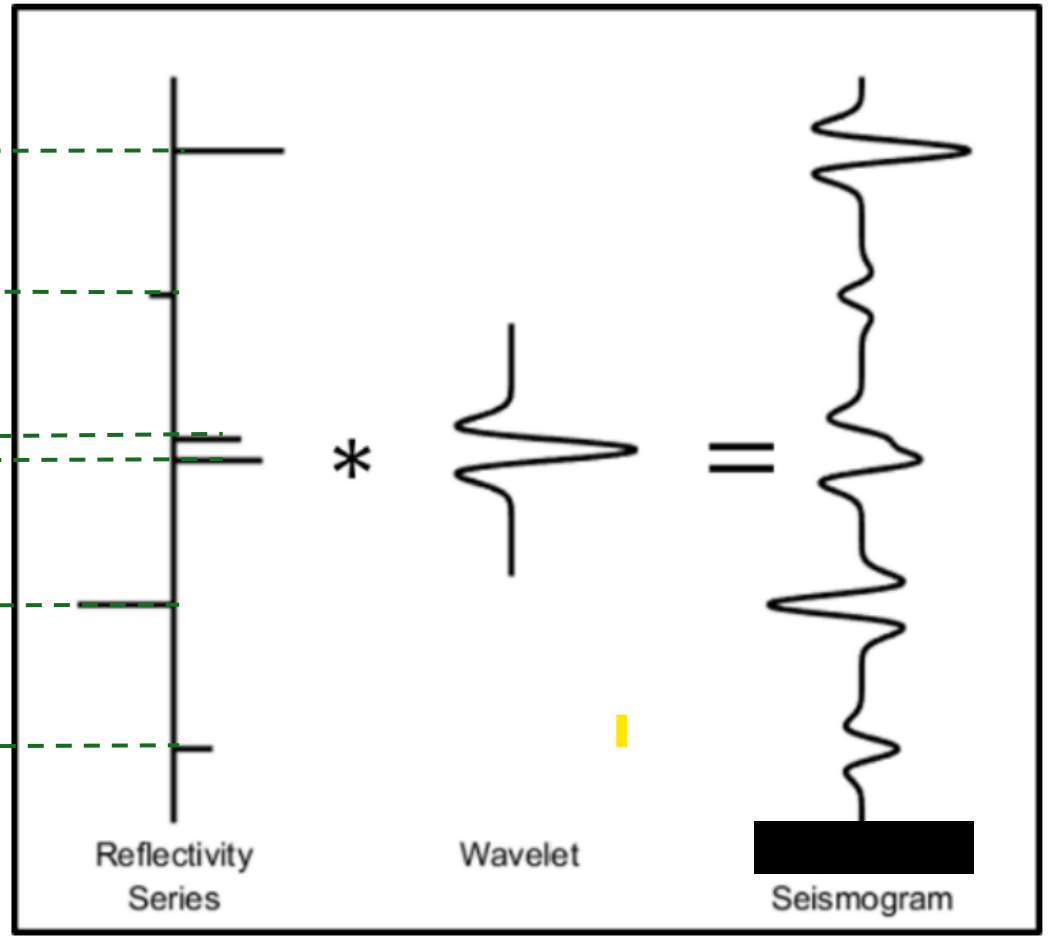


Figure 1. Synthetic seismogram modeling based on Eq. 1.

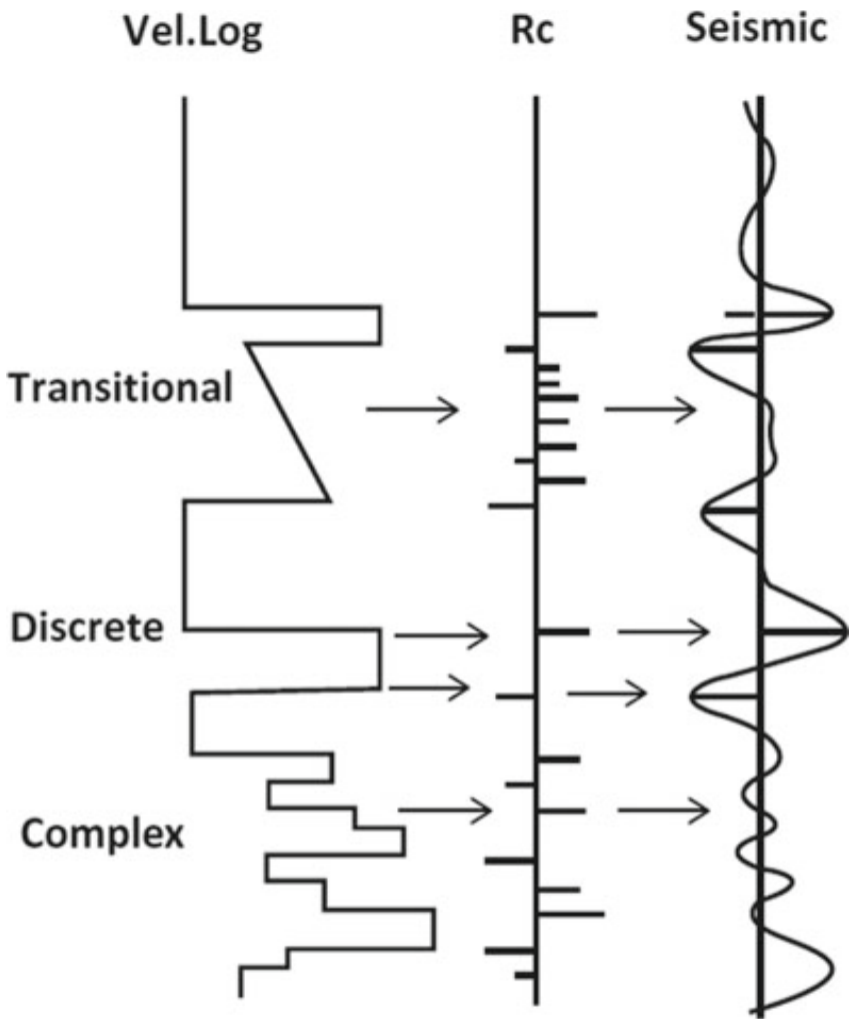


Fig. 10 Schematic showing the different types of reflectors. A 'discrete' reflector causes top and bottom reflections, resolvable with distinctive polarity and exact arrival time. The 'transitional' and 'complex' reflectors are composite events of several closely spaced beds with uncertain signage of polarity and delayed arrival time

Resolución Vertical

Resolución: capacidad de separar dos rasgos distintos en tiempo (profundidad) y distancia lateral (Nanda, 2021).

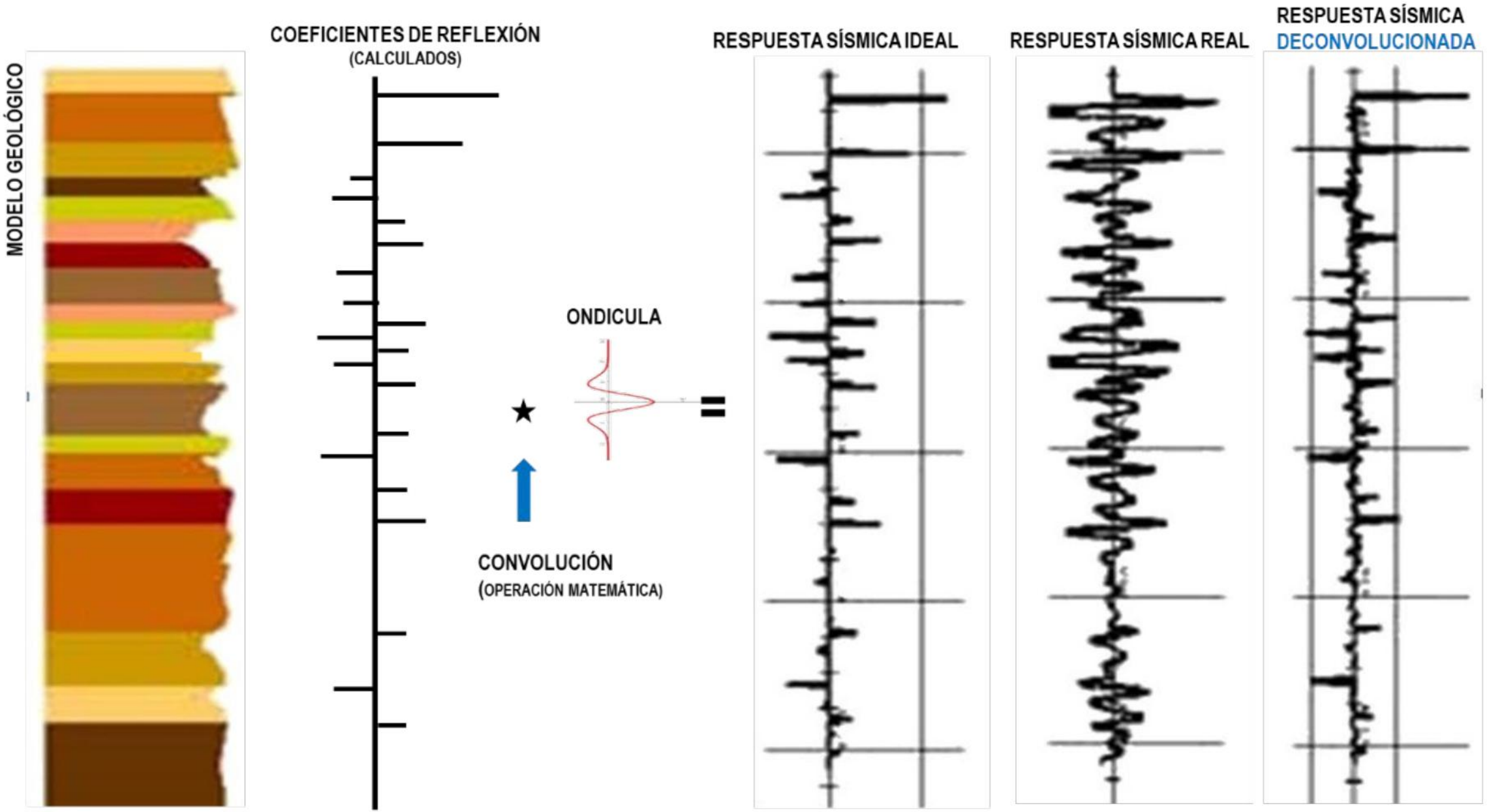


Figura N° 18: esquema del proceso de convolución de la ondicula con el modelo geológico, dando

Resolución vertical

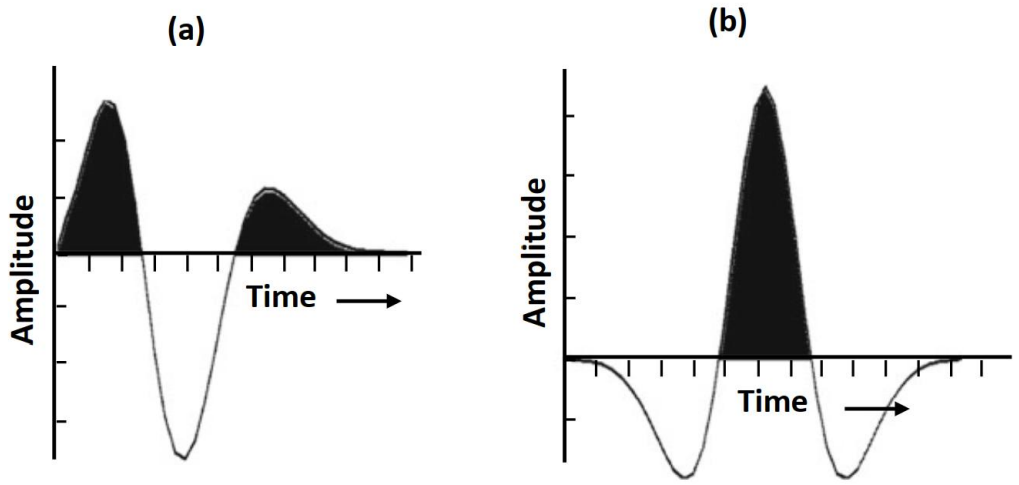
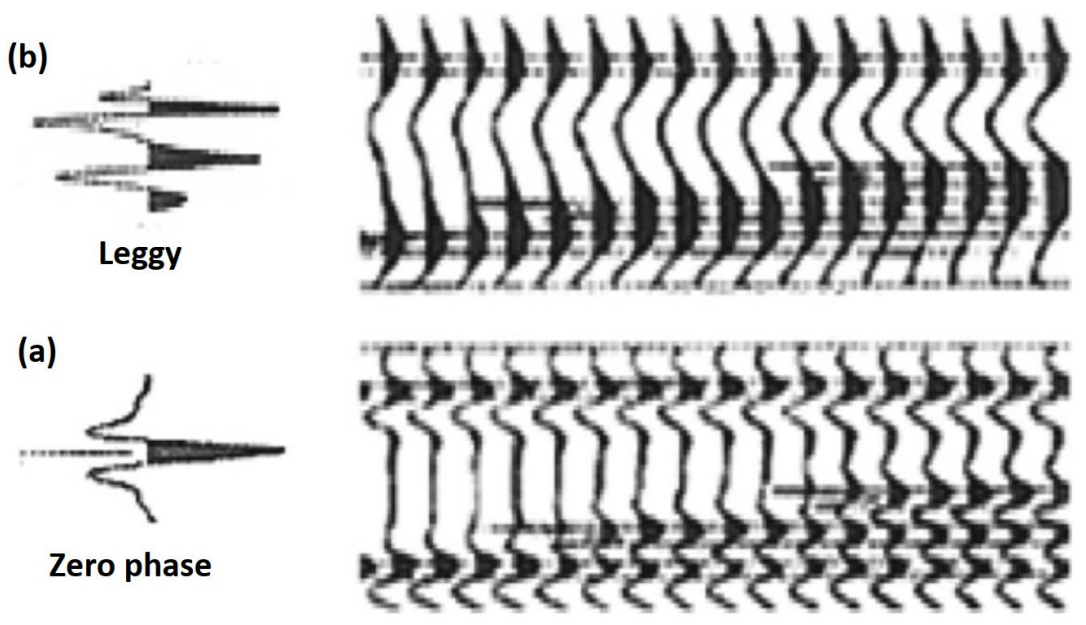


Fig. 2 Showing types of seismic source wavelet types (**a**) minimum phase wavelet, generated by dynamite on land and air-gun in offshore and (**b**) zero phase wavelet generated by Vibroseis in land data acquisition. Zero phase wavelet is symmetrical with even side lobes and the amplitude maxima occurs at time corresponding to exact depth of the strata without time delay. Note the minimum phase wavelet (**a**) is asymmetrical with energy loaded in front and the maxima occurs at a delayed time



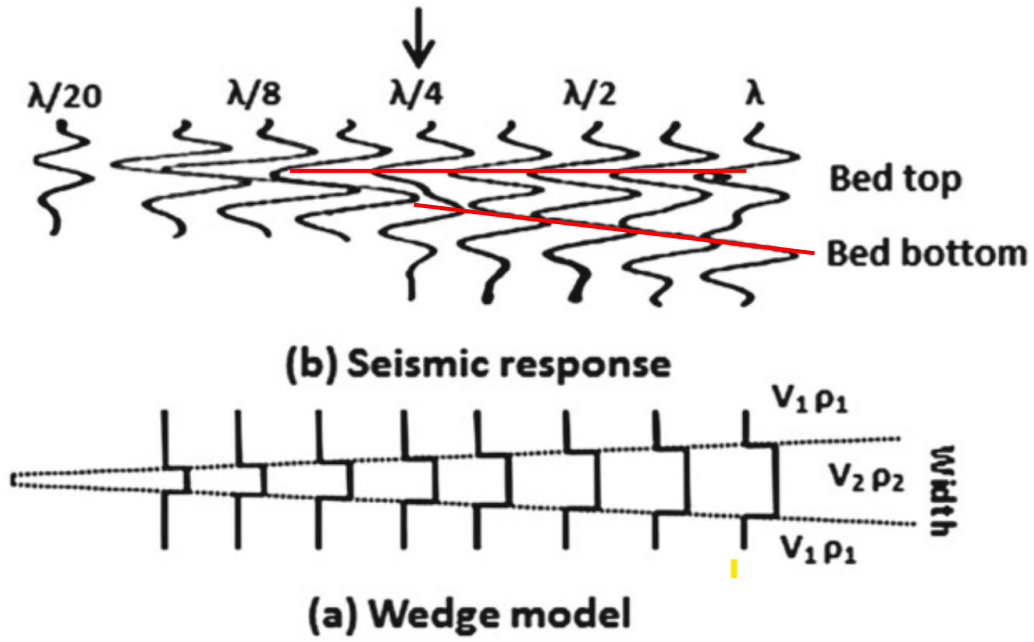


Fig. 4 Schematic illustrating Widess wedge model for vertical resolution limits. (**a**) The Widess wedge model and (**b**) seismic response for varying bed thickness. For a bed thickness greater or equal to the wave length (λ), the top and bottom reflections are clearly resolvable and are so till quarter wave length (λ/4). For beds thinner than λ/4 the top and bottom reflections are not distinct (arrow marked), limiting the vertical resolution to quarter wave length (after Widess 1973)

$$\lambda = \frac{v}{f}$$

velocidad

Frecuencia
10Hz – 70Hz

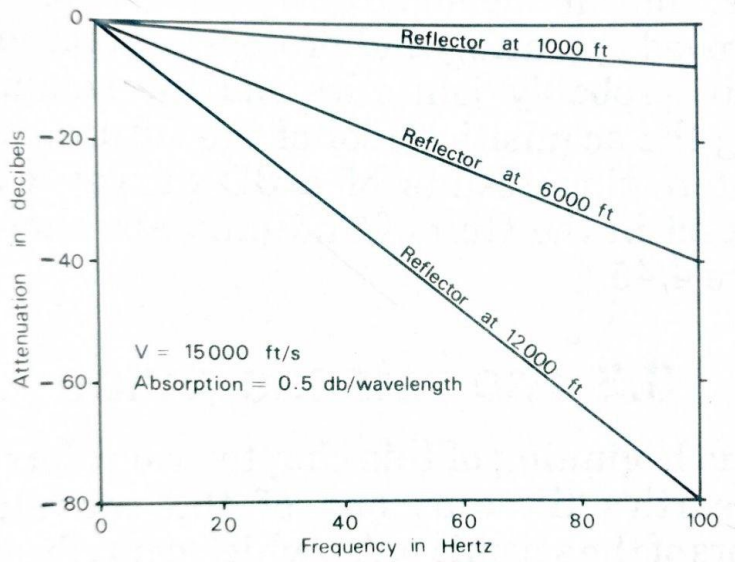


Figure 3/12 The effect of absorption in reducing seismic bandwidth with depth of a reflector. High frequencies are severely attenuated in the spectrum of deep reflections (after Evenden *et al.*, 1971).

λ = 2000 m/s ÷ 40 Hz = 50 metros

Velocidad promedio en sedimentos

Resolución horizontal

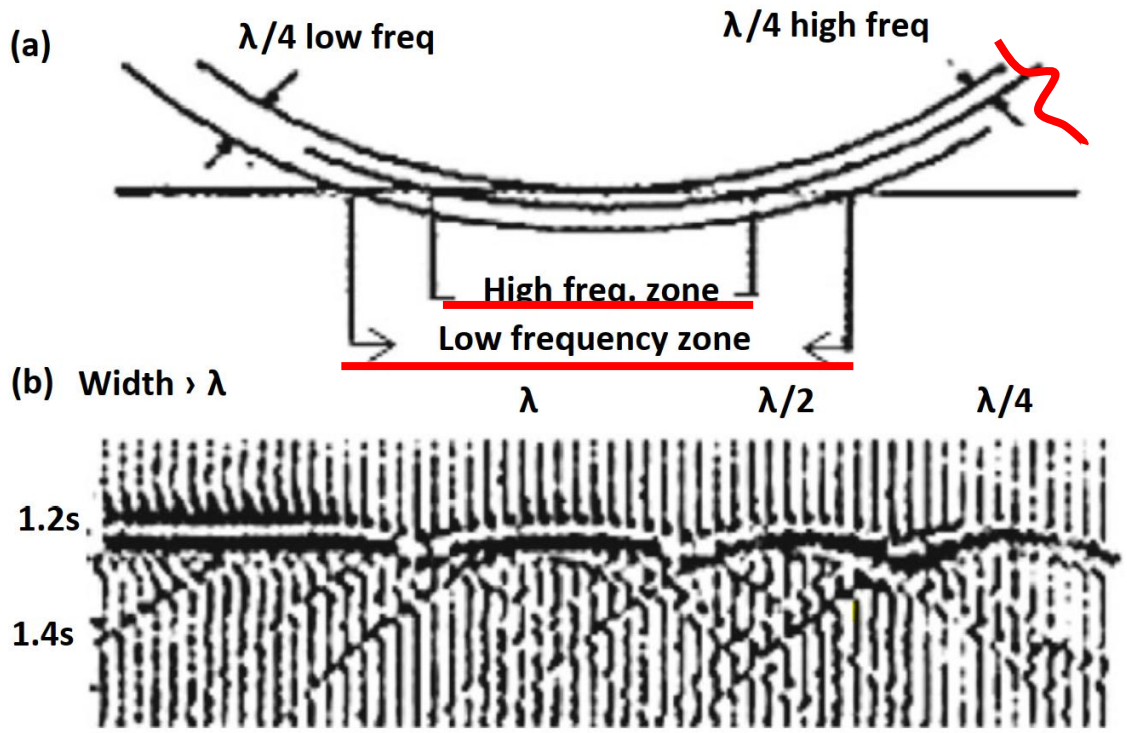
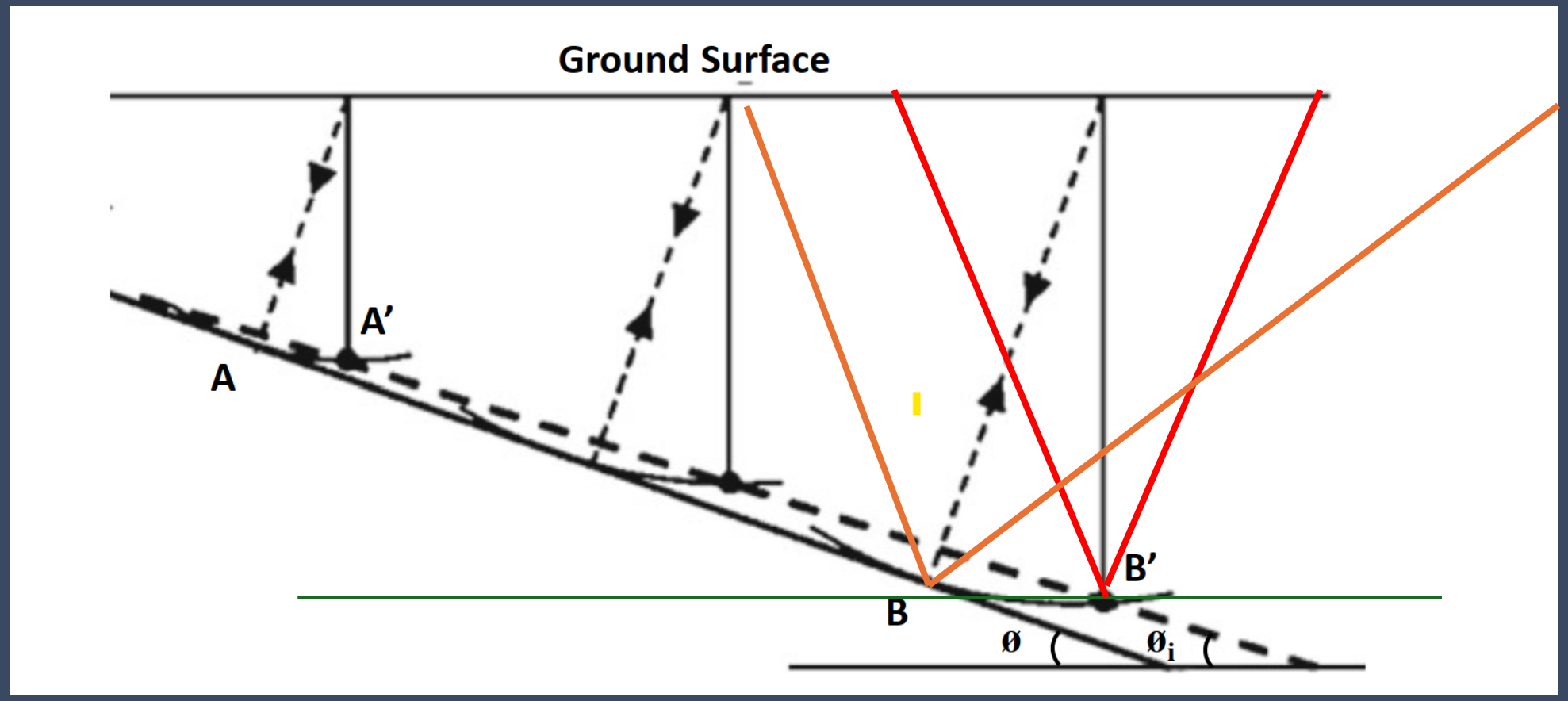
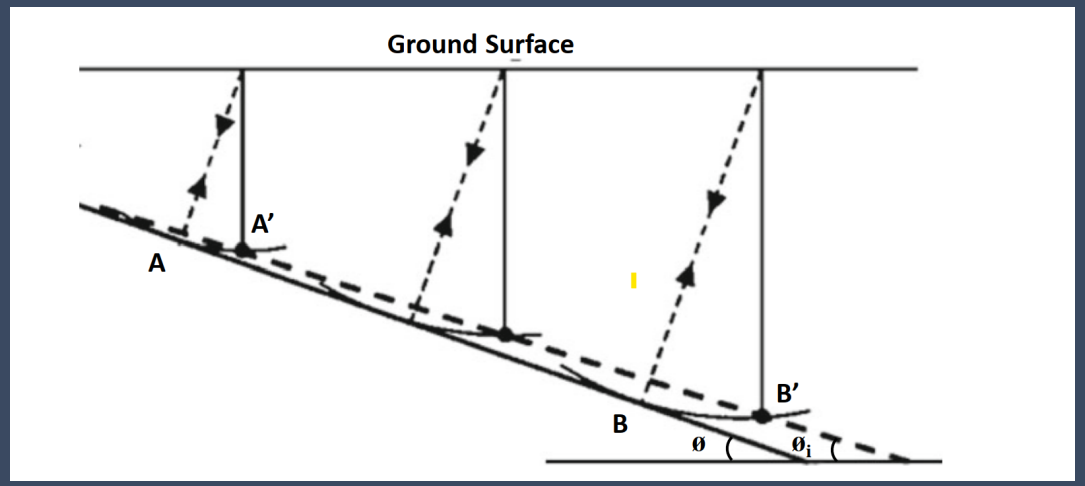


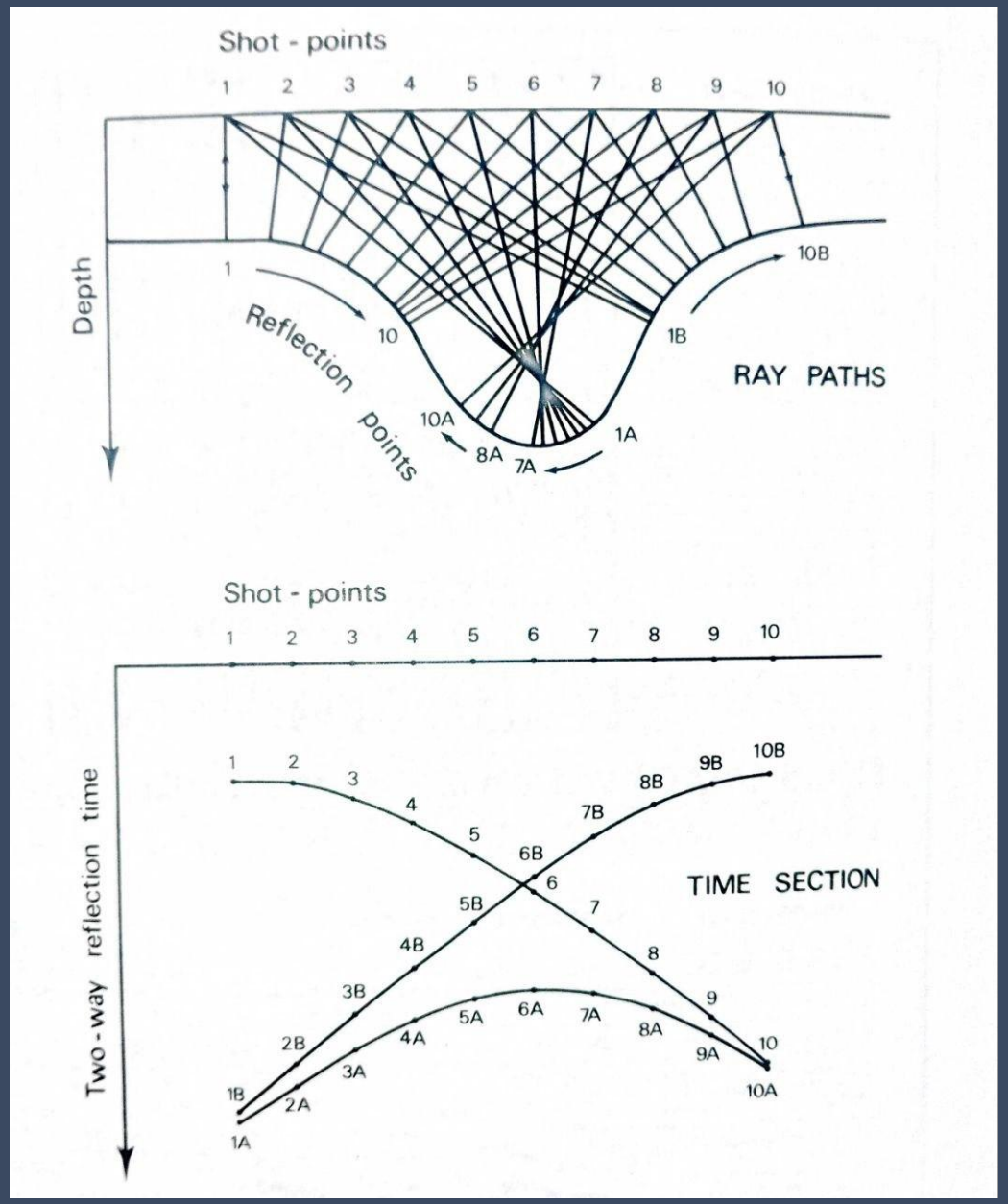
Fig. 5 Schematic illustrating phenomenon of reflection and the Fresnel's zone. (**a**) Spherical wave front incident on plane surface forms contact zones of different widths for each of the frequencies in the bandwidth. However, the contact area for the dominant frequency mainly influences creating reflection events and is known as the (first) Fresnel zone and is a measure of lateral resolution. Smaller the zone-width better is the resolution. The width of Fresnel zone at a depth is dependent on frequency, being larger for low frequency than for high frequency. (**b**) Synthetic reflection events computed with variable source wavelength. Notice the start of deterioration in reflection at λ/4, which sets this as the limit of spatial resolution (after Meckel and Nath 1977)

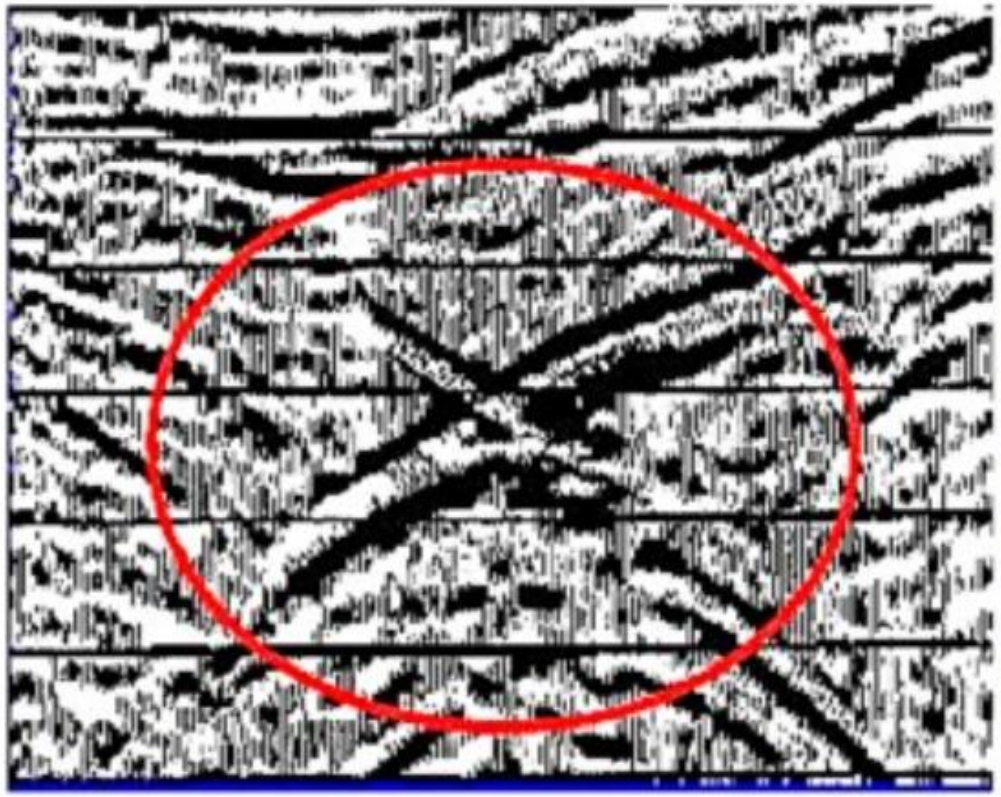
$$R \approx \sqrt{\lambda \cdot \frac{z}{2}}$$

Migración

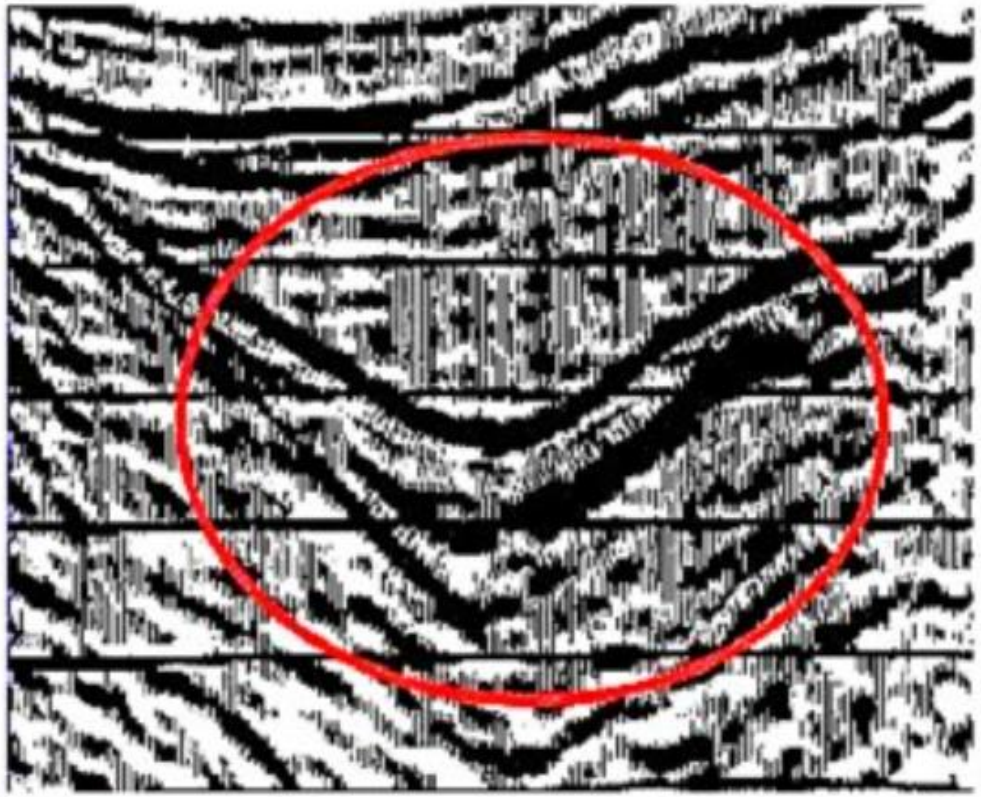



Ground Surface
A'
A
B'
B
ø
øi

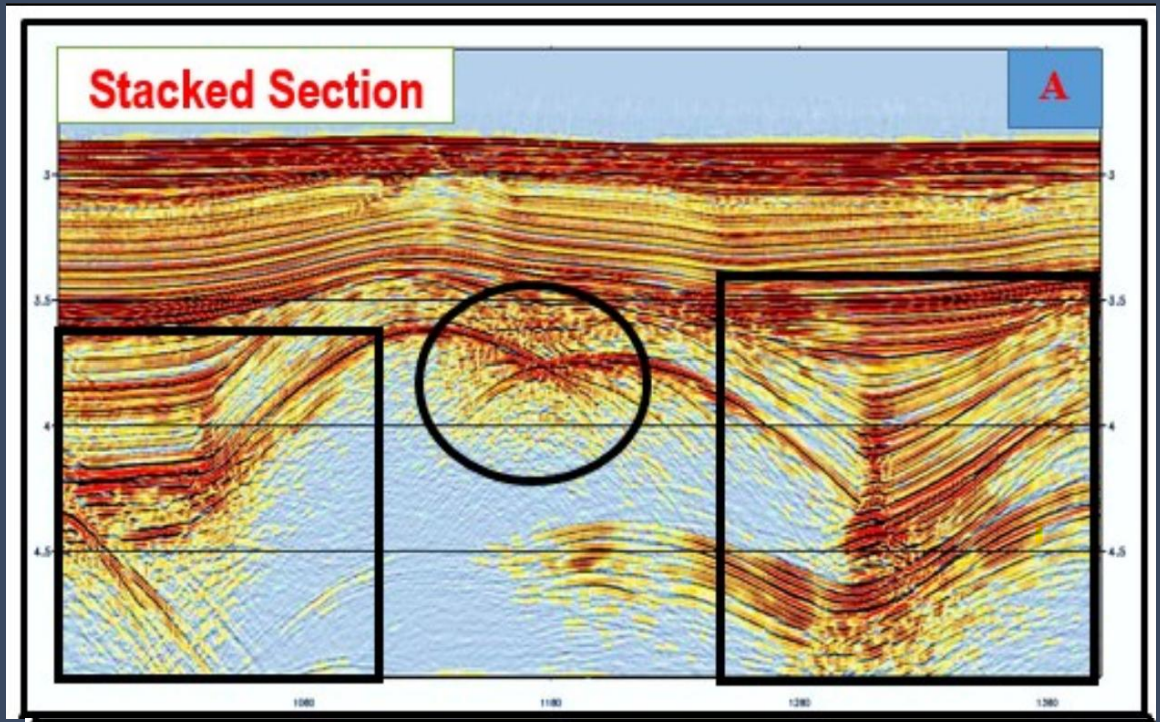

Shot - points
1 2 3 4 5 6 7 8 9 10
Depth
Reflection points
RAY PATHS
10B
1B
1A
10A
8A
7A
Shot - points
1 2 3 4 5 6 7 8 9 10
Two-way reflection time
TIME SECTION
1B
2B
3B
4B
5B
6B
7B
8B
9B
10B
1A
2A
3A
4A
5A
6A
7A
8A
9A
10A



A



B


Stacked Section
A
3
3.5
4
4.5

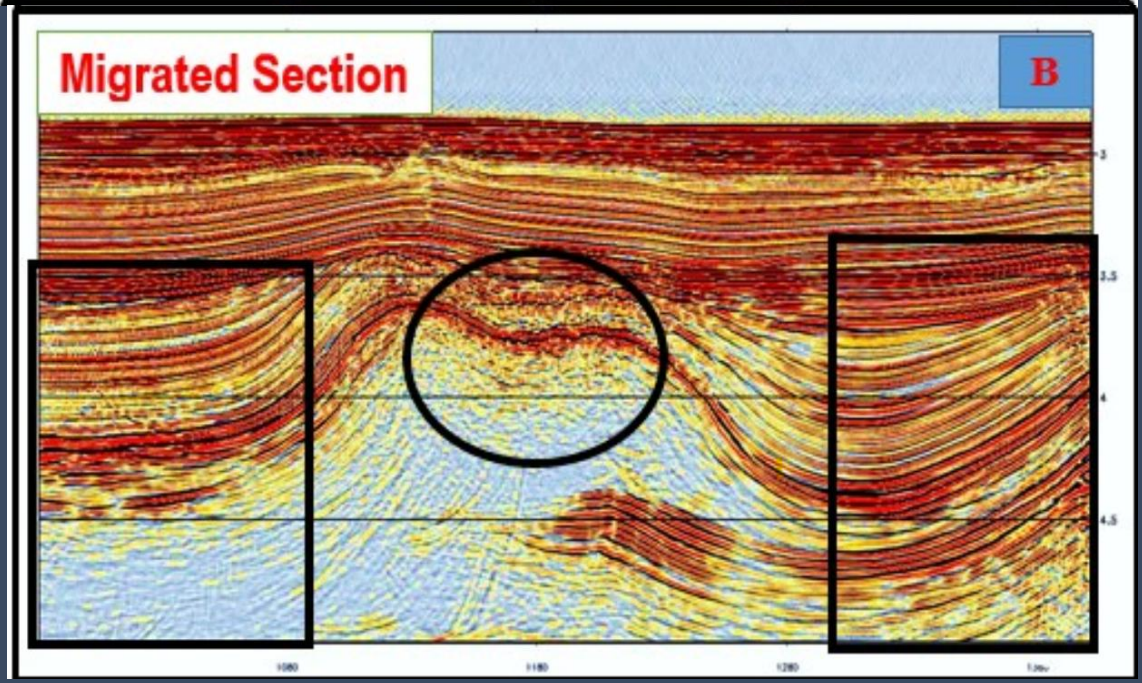
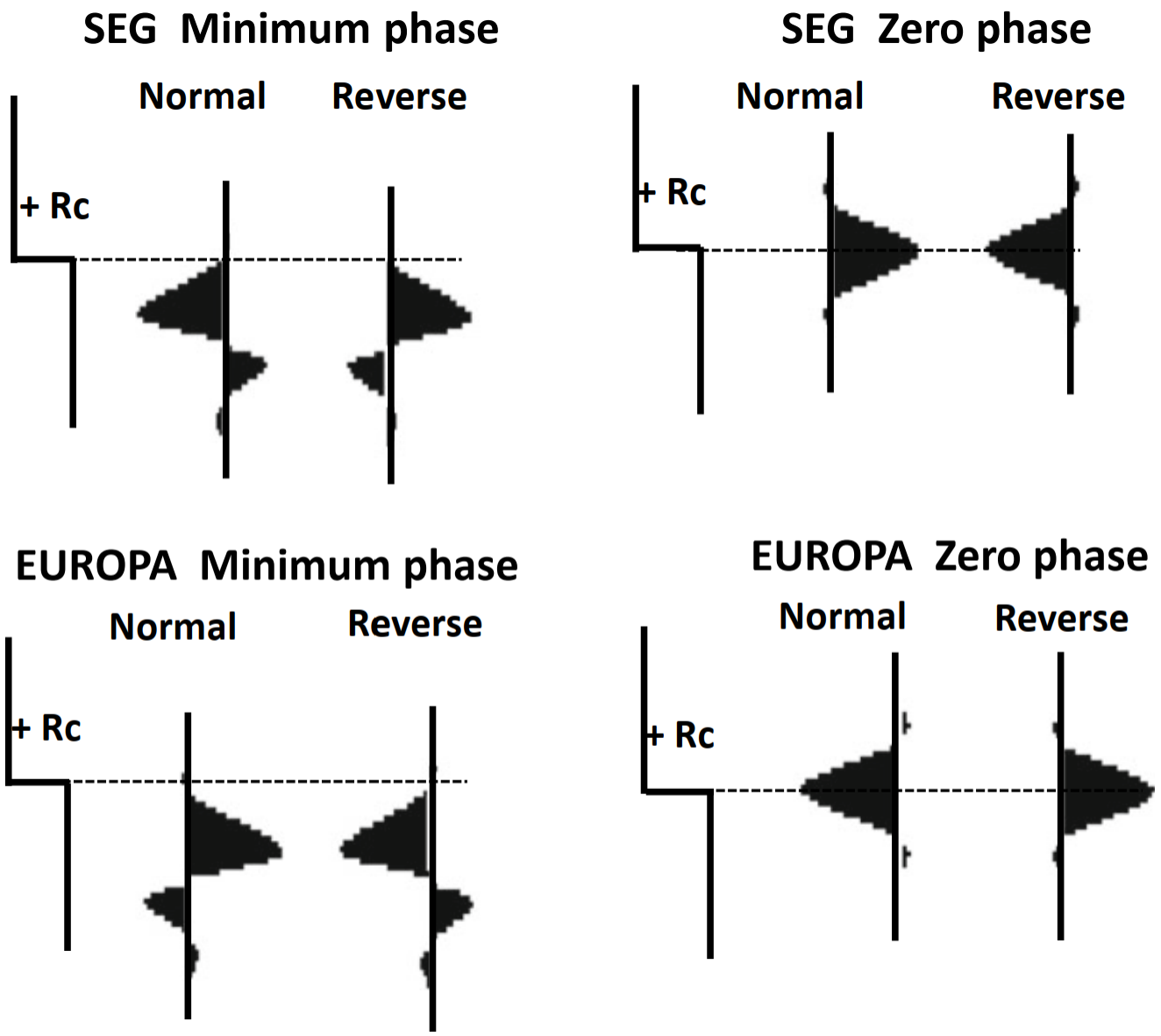

Migrated Section
B
3
3.5
4
4.5

Fig. 12 Display of different polarity conventions for minimum and zero phase source wavelets in SEG and Europa, Normal and Reverse. Note the opposite polarity conventions for minimum and zero phase wavelets in both SEG and Europa. The Europa convention is opposite to corresponding SEG convention



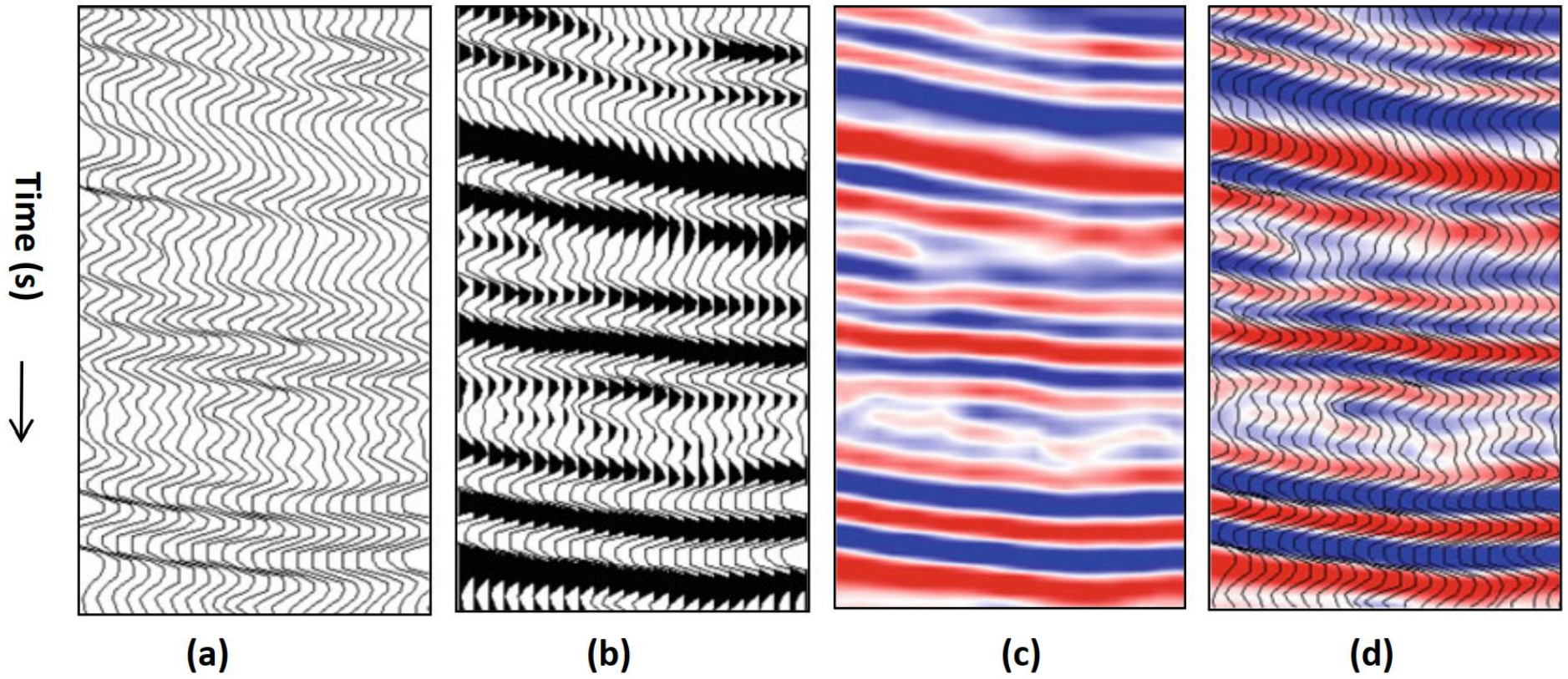


Fig. 16 Seismic segments showing types of display modes. (**a**) wiggle, (**b**) wiggle and variable area, (**c**) variable density, (**d**) combination of wiggle and variable density. Note the lateral changes in wave form seen clearly in wiggle and variable area mode (**b**) but not so clear in (**c**). Lateral variability in wave forms provide valuable geologic information

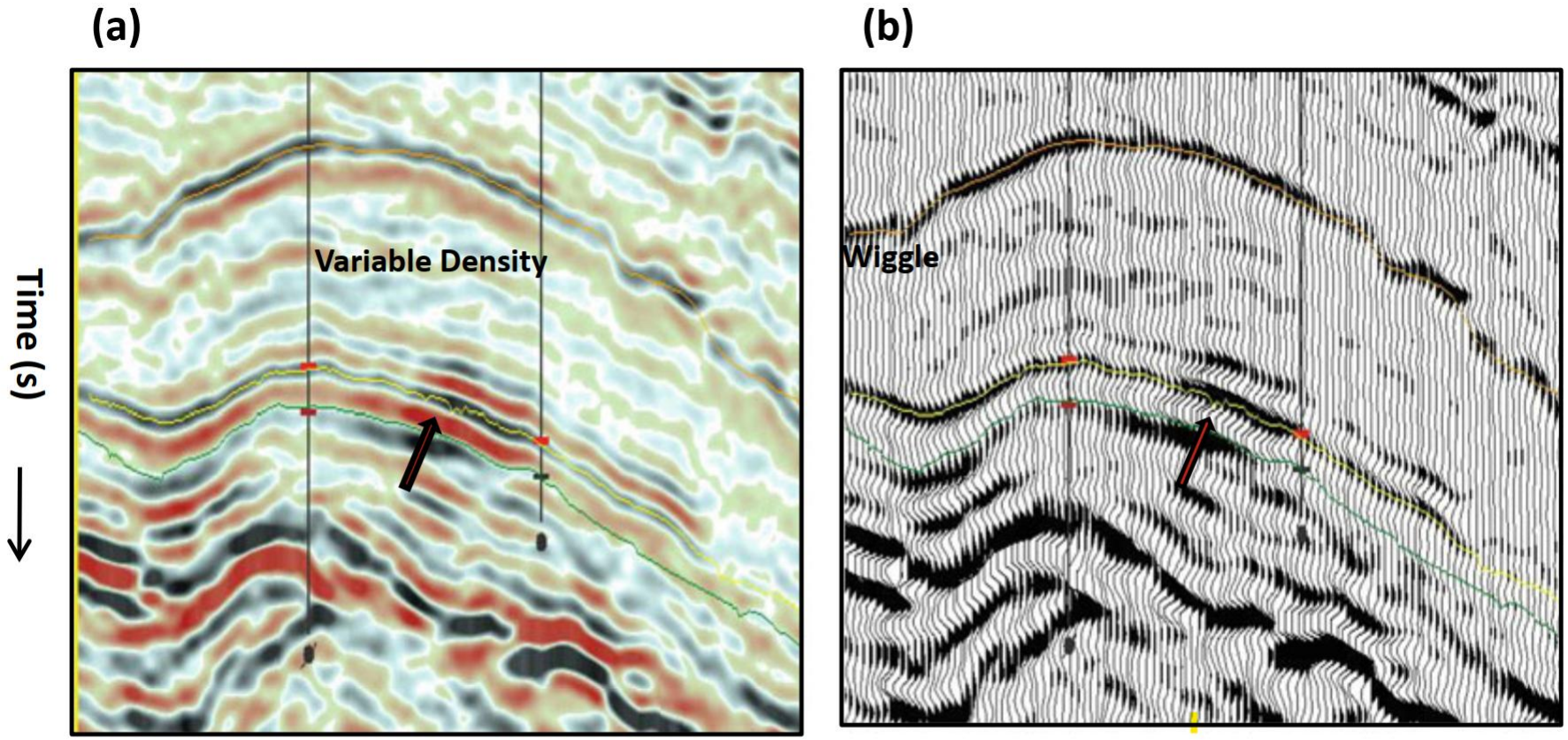


Fig. 17 Seismic image in display modes showing comparison of (**a**) variable density and (**b**) Wiggle with variable area modes. Reflection standouts and continuity are seen better in the variable density, but does not show the changes in wave form and misses the important geologic information they carry. Wiggle and VA mode shows clearly the variations (the trough marked by arrow) and help proper correlation based on reflection character and also offer geologic information from the lateral change of wave forms (image: courtesy, Hardy Energy, India)

Sísmica 3D

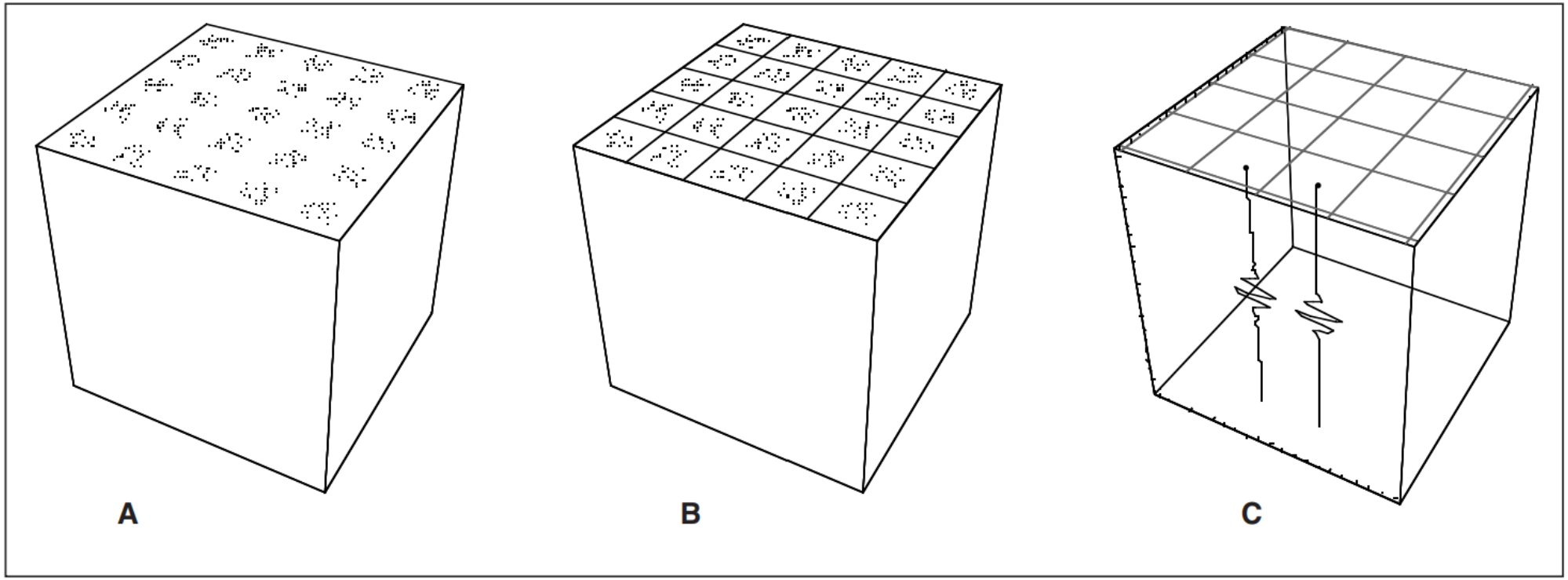


Figure 12–4. From Liner, 1999; courtesy PennWell.

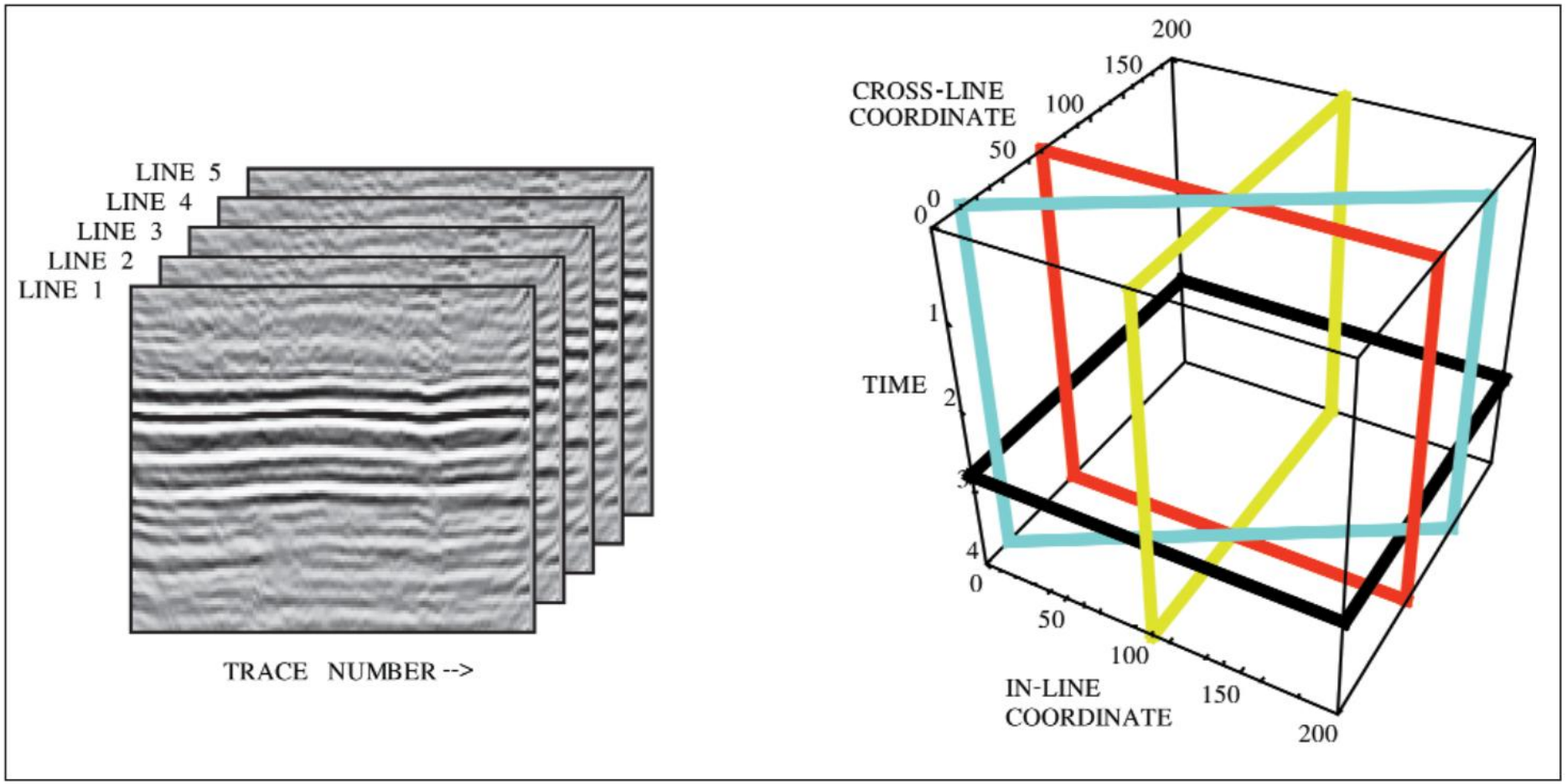


Figure 12–5. From Liner, 1999; courtesy PennWell.

Sísmica de Pozo VSP (Vertical Seismic Profile)

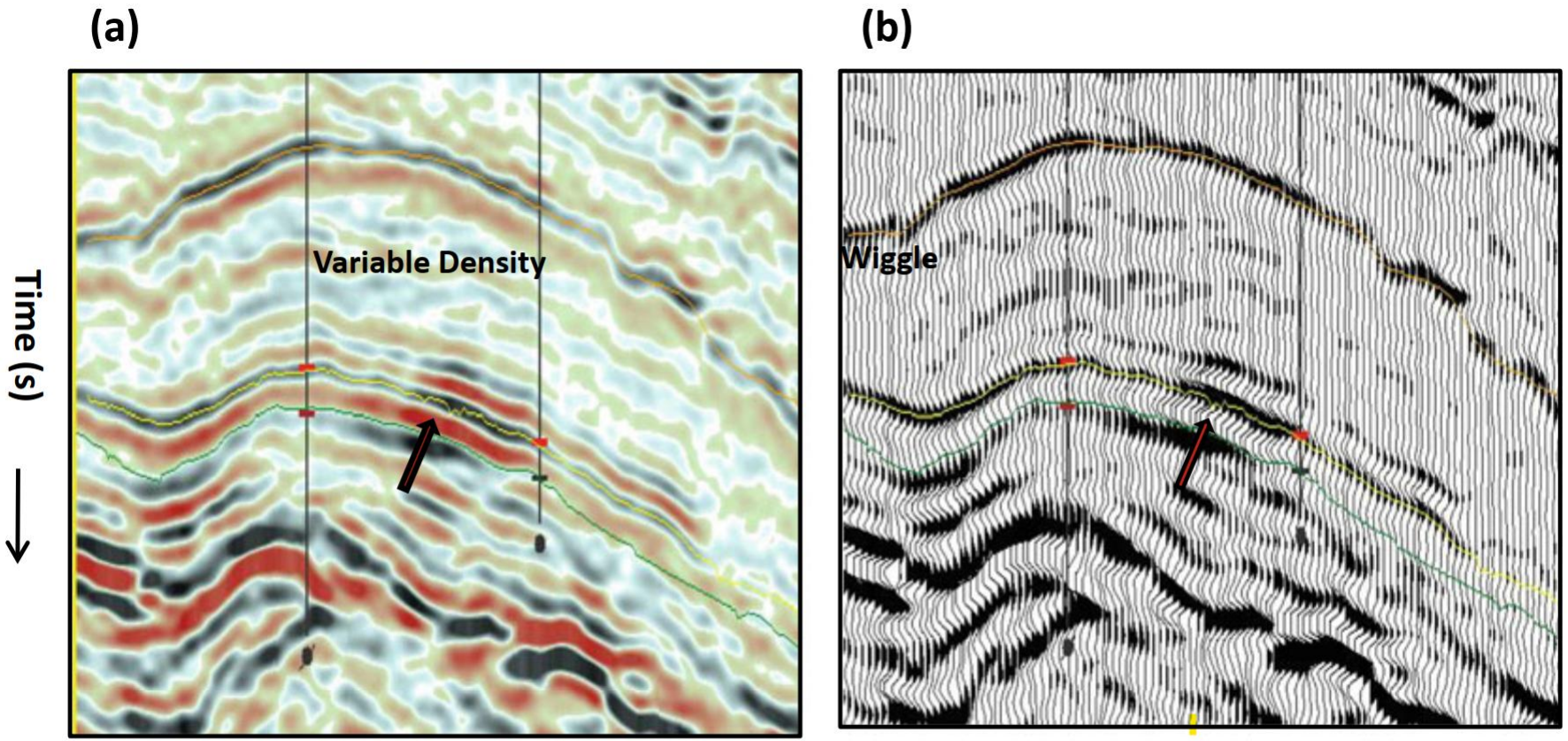


Fig. 17 Seismic image in display modes showing comparison of (**a**) variable density and (**b**) Wiggle with variable area modes. Reflection standouts and continuity are seen better in the variable density, but does not show the changes in wave form and misses the important geologic information they carry. Wiggle and VA mode shows clearly the variations (the trough marked by arrow) and help proper correlation based on reflection character and also offer geologic information from the lateral change of wave forms (image: courtesy, Hardy Energy, India)

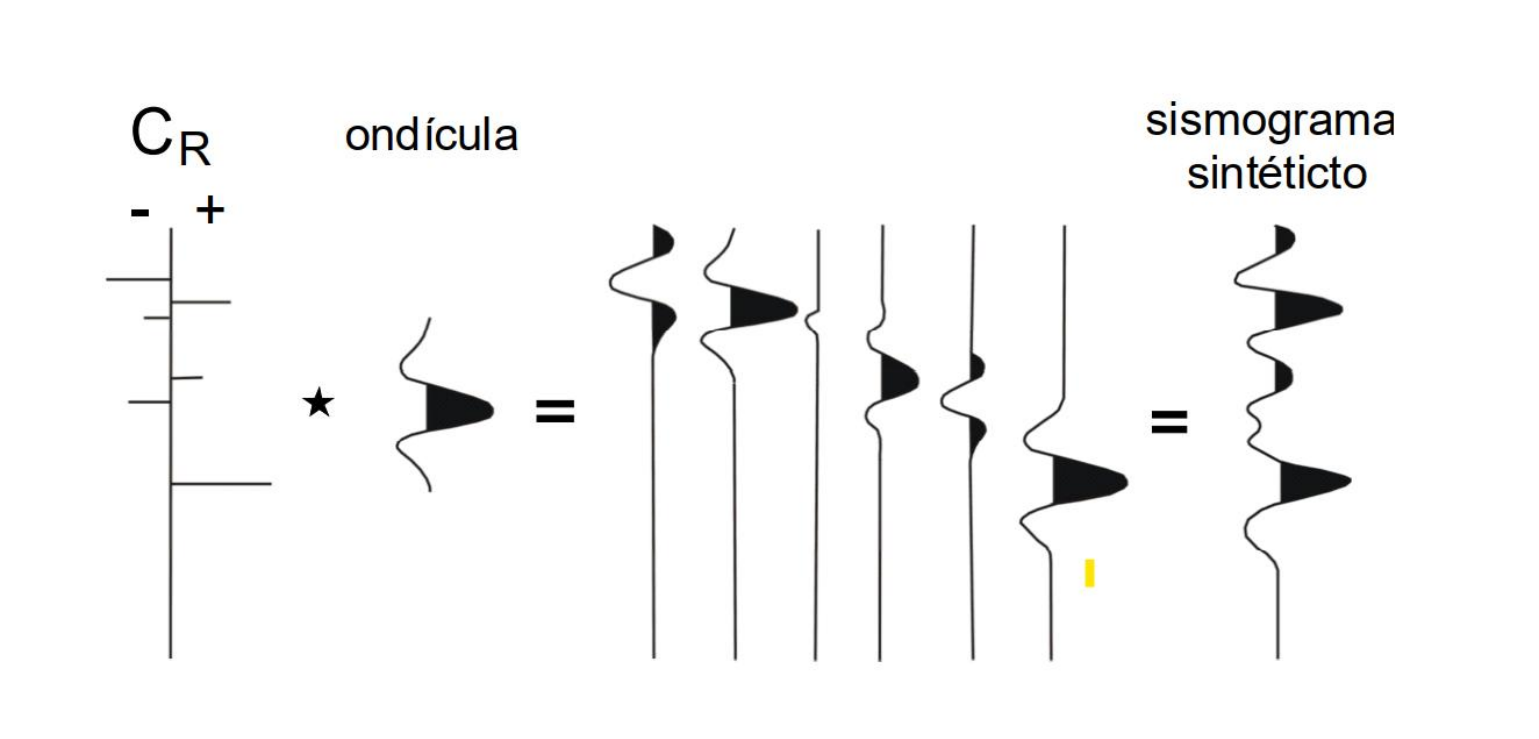
Sismograma sintético

$$CR = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

$$Z_i = \rho_i \cdot v_i$$

Perfil de densidad

Perfil Sónico



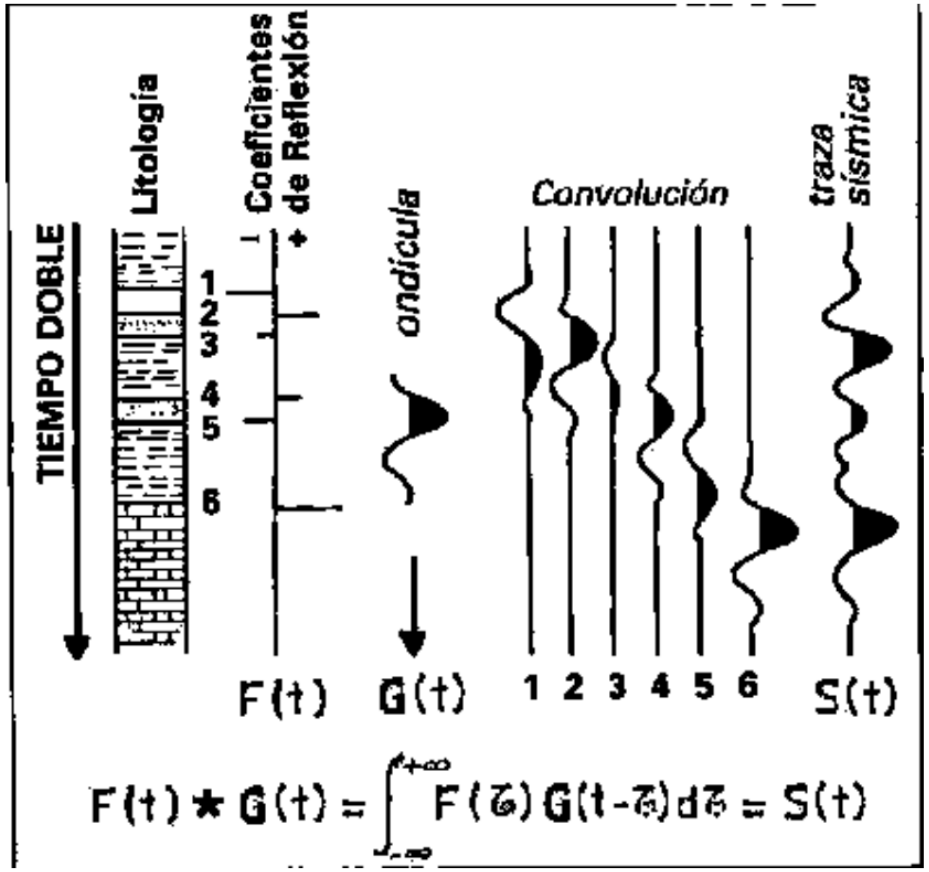
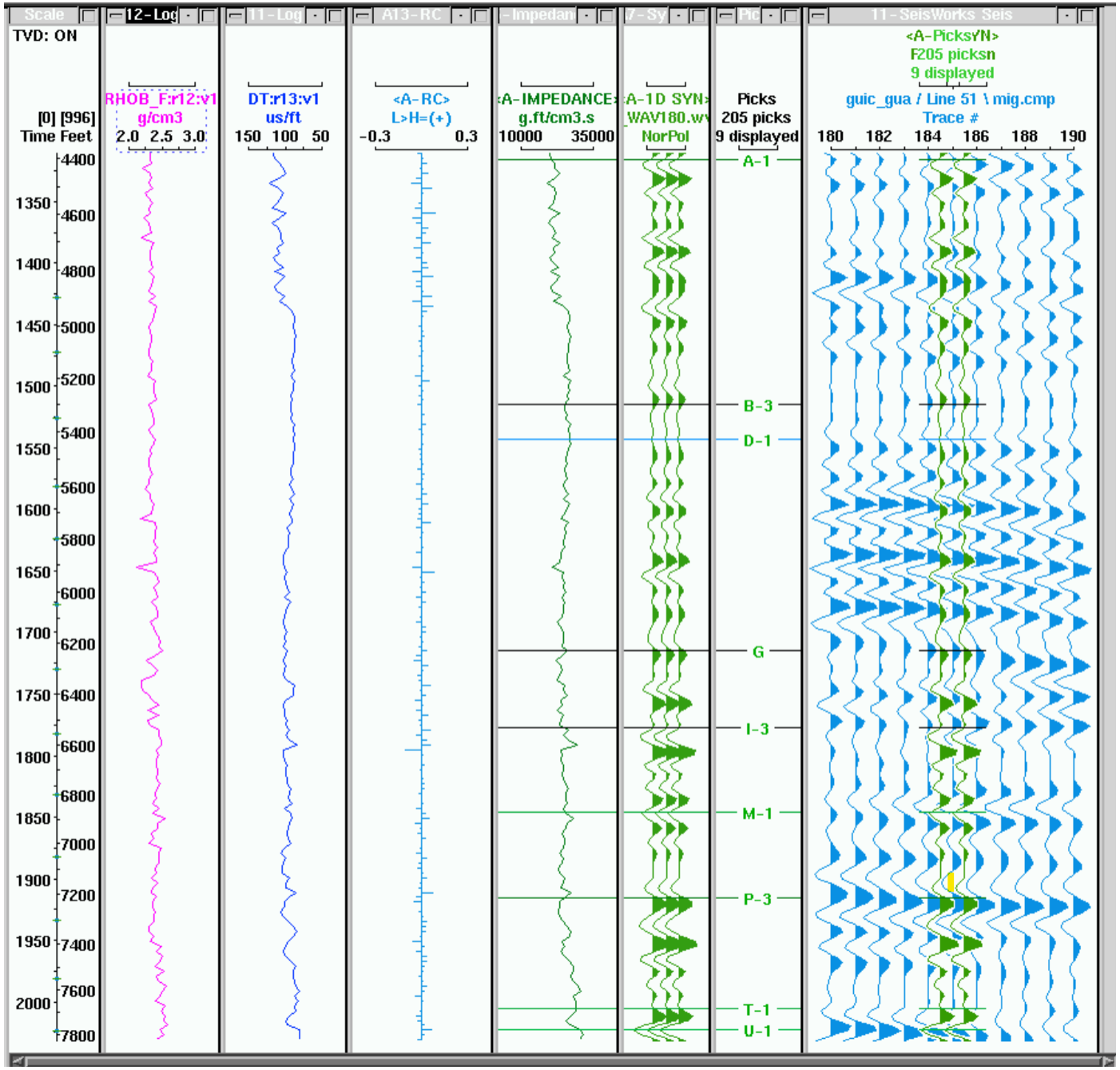
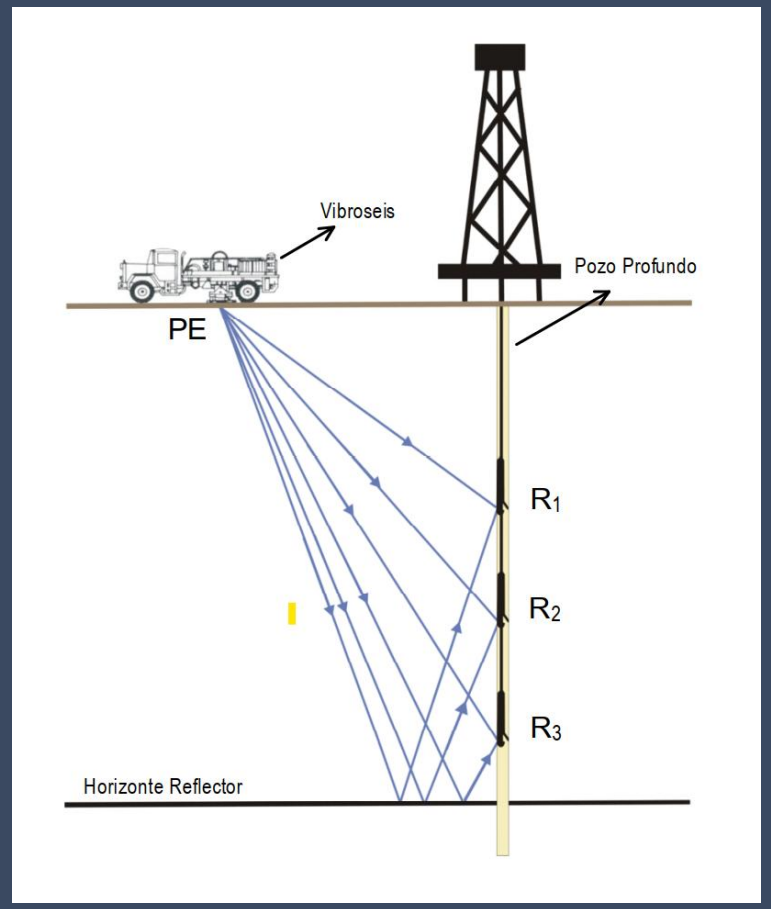
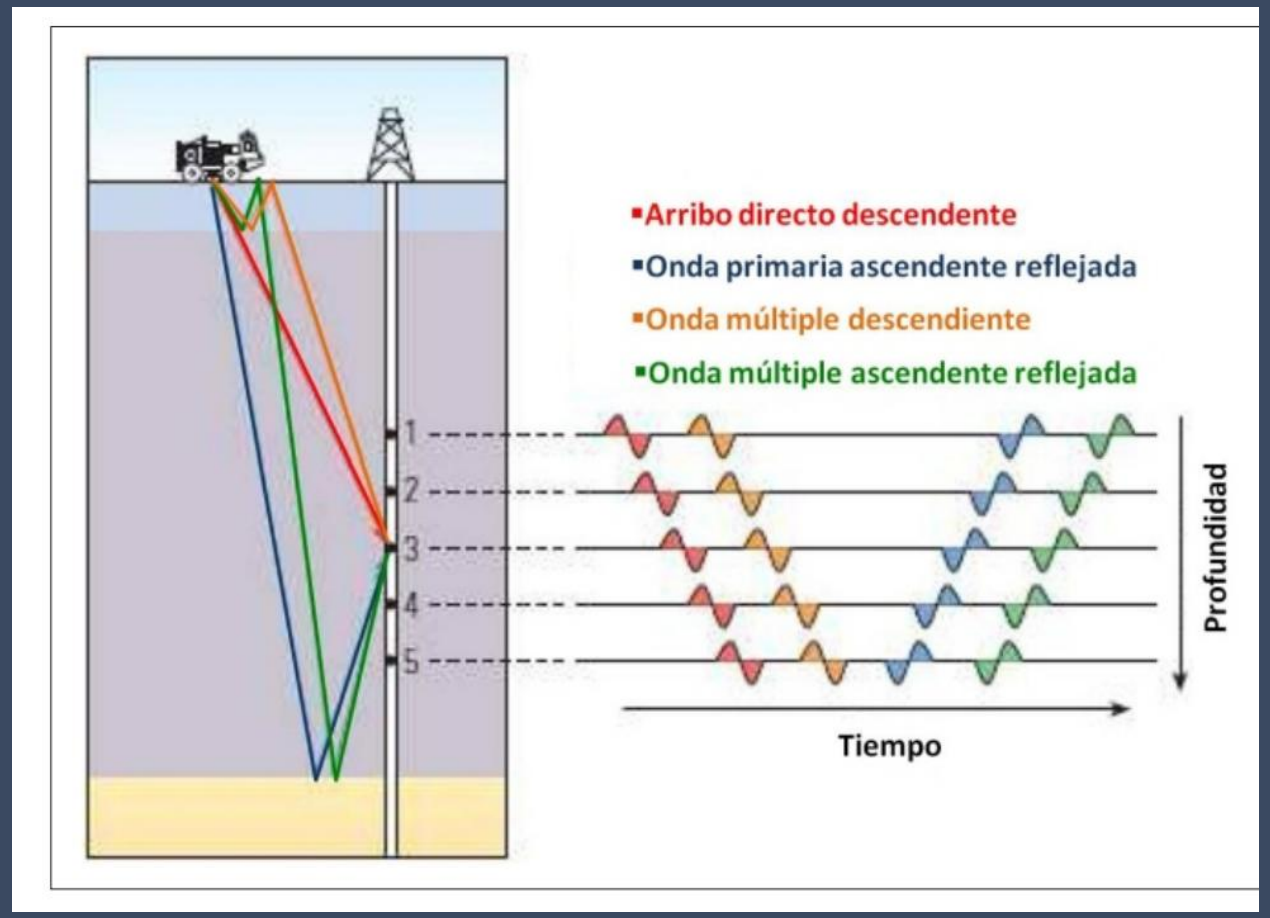


Figura 14: Operación matemática de convolución; modelo de traza sísmica, (Chelotti *et al*, 2010).


Scale
TVD: ON
[0] [996]
Time Feet
12-Log
RHOB_F:r12:v1
g/cm3
2.0 2.5 3.0
11-Log
DT:r13:v1
us/ft
150 100 50
A13-RC
<A-RC>
L>H=(+)
-0.3 0.3
-Impedan
<A-IMPEDANCE>
g.ft/cm3.s
10000 35000
7-Sy
<A-1D SYN>
WAV180.wv
NorPol
Pic
Picks
205 picks
9 displayed
11-SeisWorks Seis
<A-PicksYN>
F205 picksn
9 displayed
guic_gua / Line 51 \ mig.cmp
Trace #
180 182 184 186 188 190
4400
4600
4800
5000
5200
5400
5600
5800
6000
6200
6400
6600
6800
7000
7200
7400
7600
7800
1350
1400
1450
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
A-1
B-3
D-1
G
I-3
M-1
P-3
T-1
U-1

VSP


Vibroseis
Pozo Profundo
PE
R1
R2
R3
Horizonte Reflector


Arribo directo descendente
Onda primaria ascendente reflejada
Onda múltiple descendiente
Onda múltiple ascendente reflejada
1
2
3
4
5
Profundidad
Tiempo

- ***Checkshot***
- ***VSP Cero Offset (ZVSP)***
- ***VSP Offset (OVSP)***
- ***VSP Walkaway***

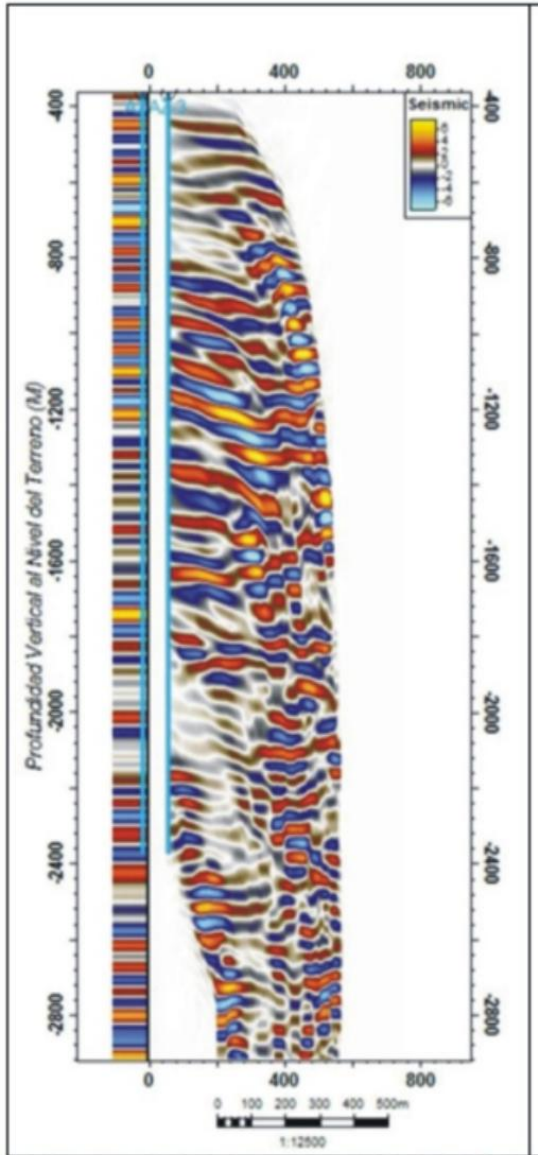


Figura 4.4.1.-Imagen 1D (ZVSP) y 2D (OVSP) (Tomada de Parga-

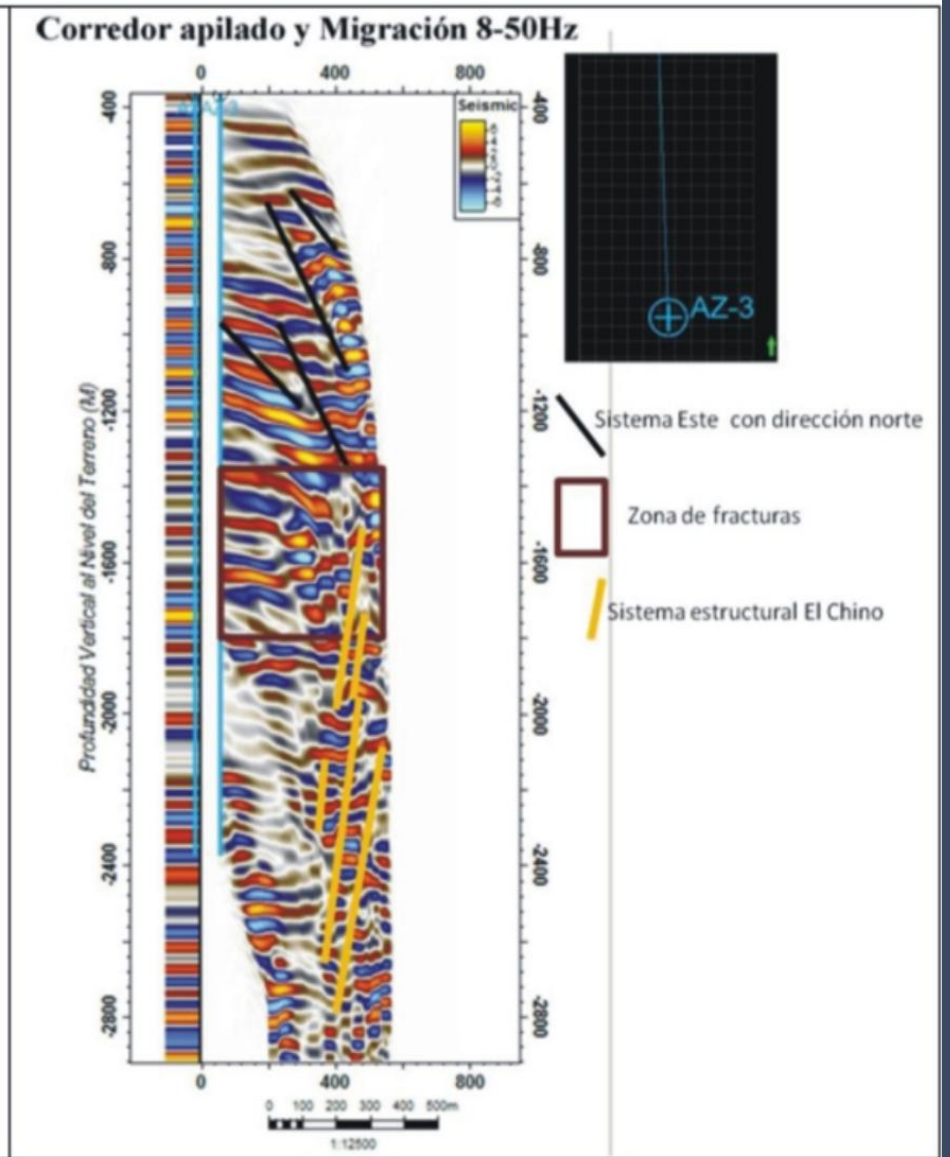
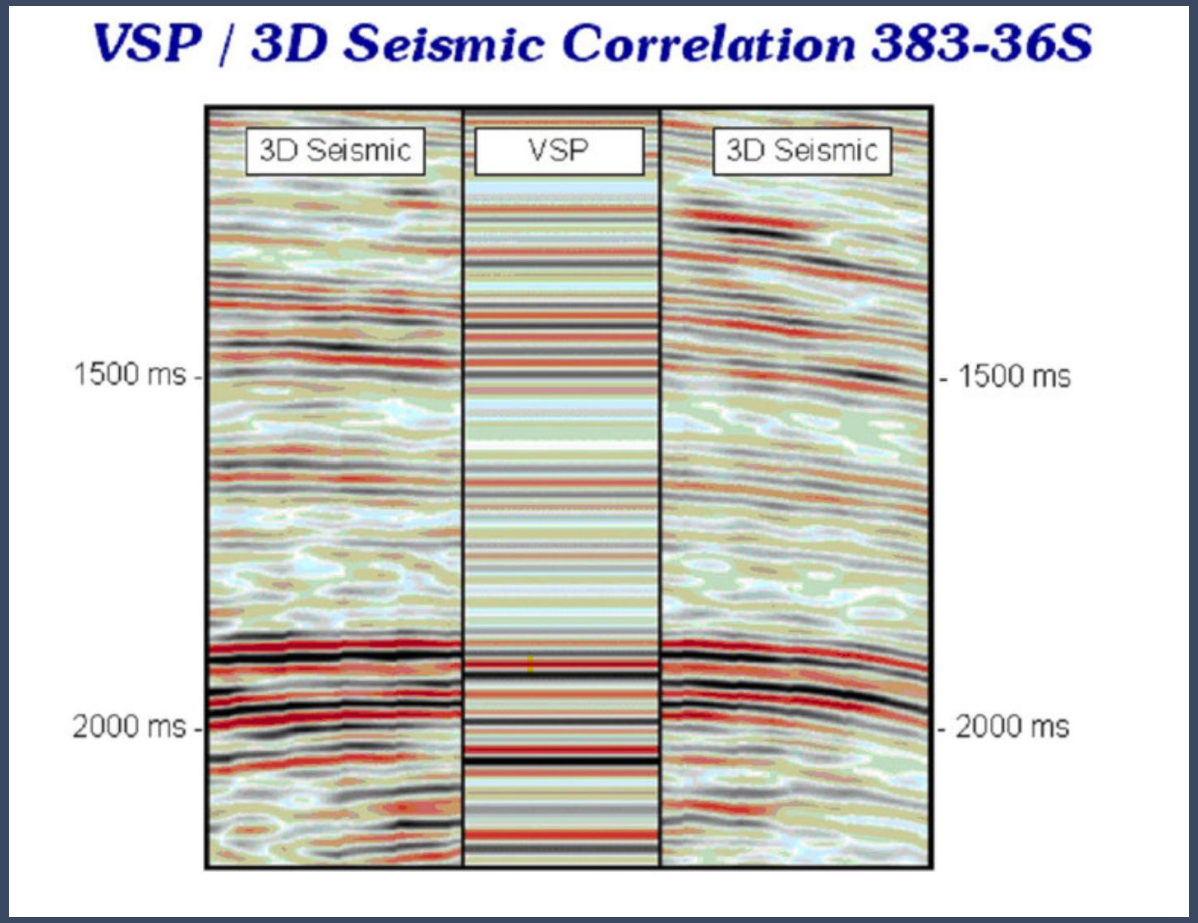
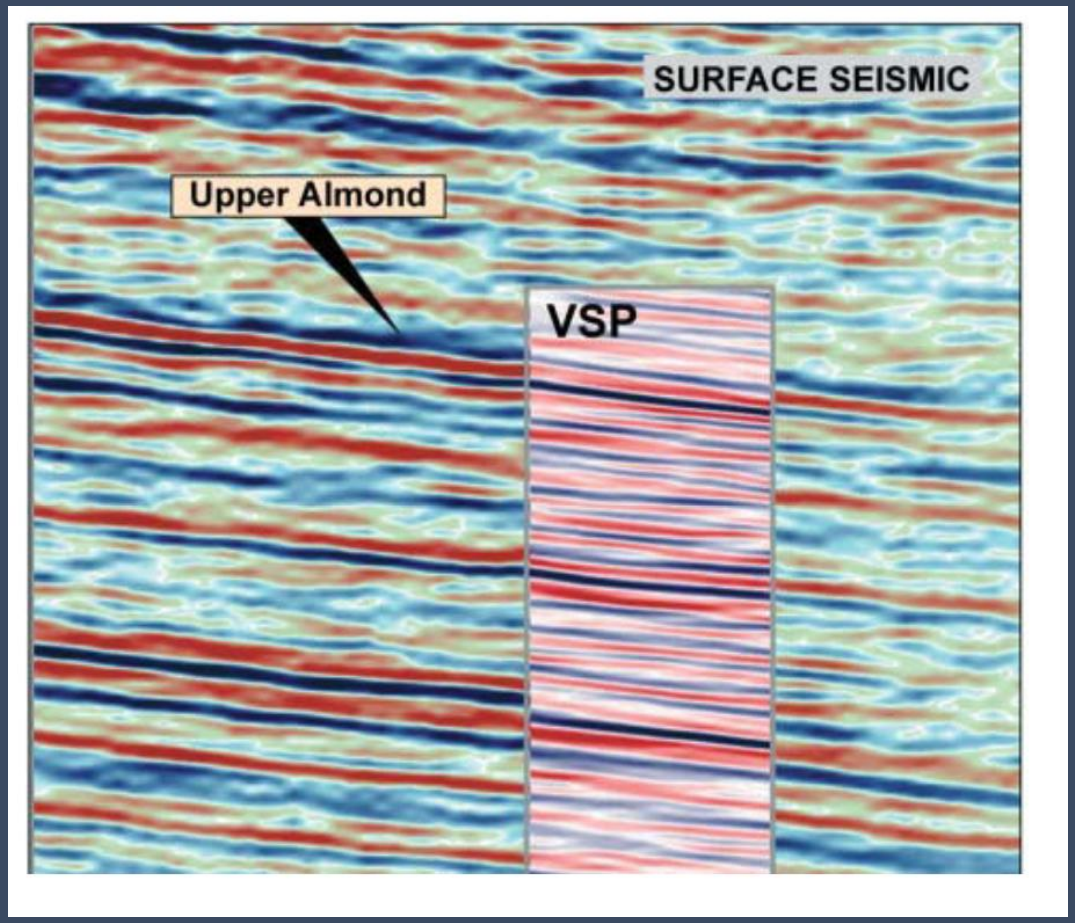


Figura 4.4.2.-Interpretación del registro OVSP.


VSP / 3D Seismic Correlation 383-36S
3D Seismic
VSP
3D Seismic
1500 ms
1500 ms
2000 ms
2000 ms


SURFACE SEISMIC
Upper Almond
VSP