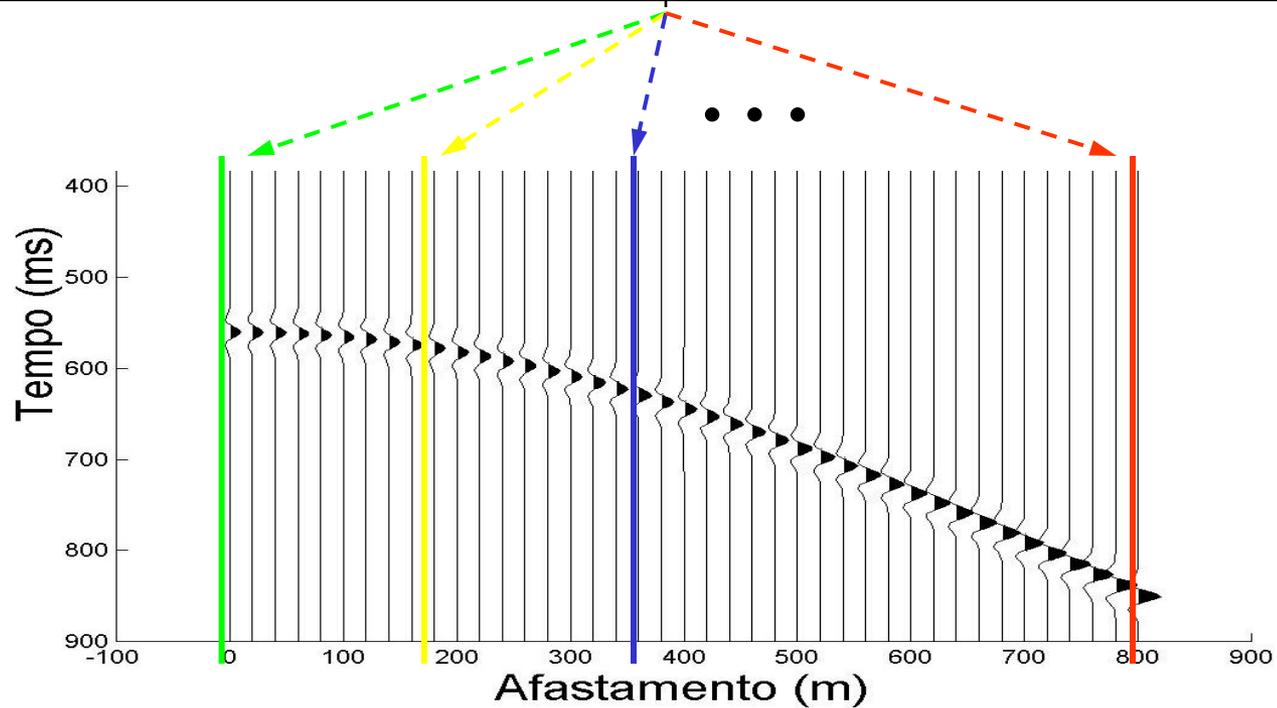
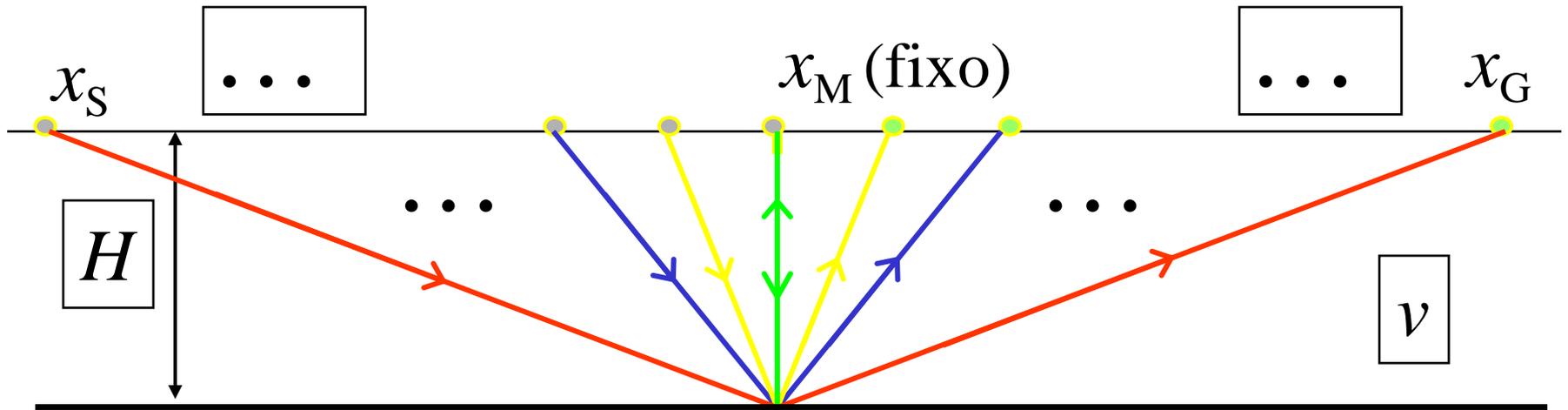
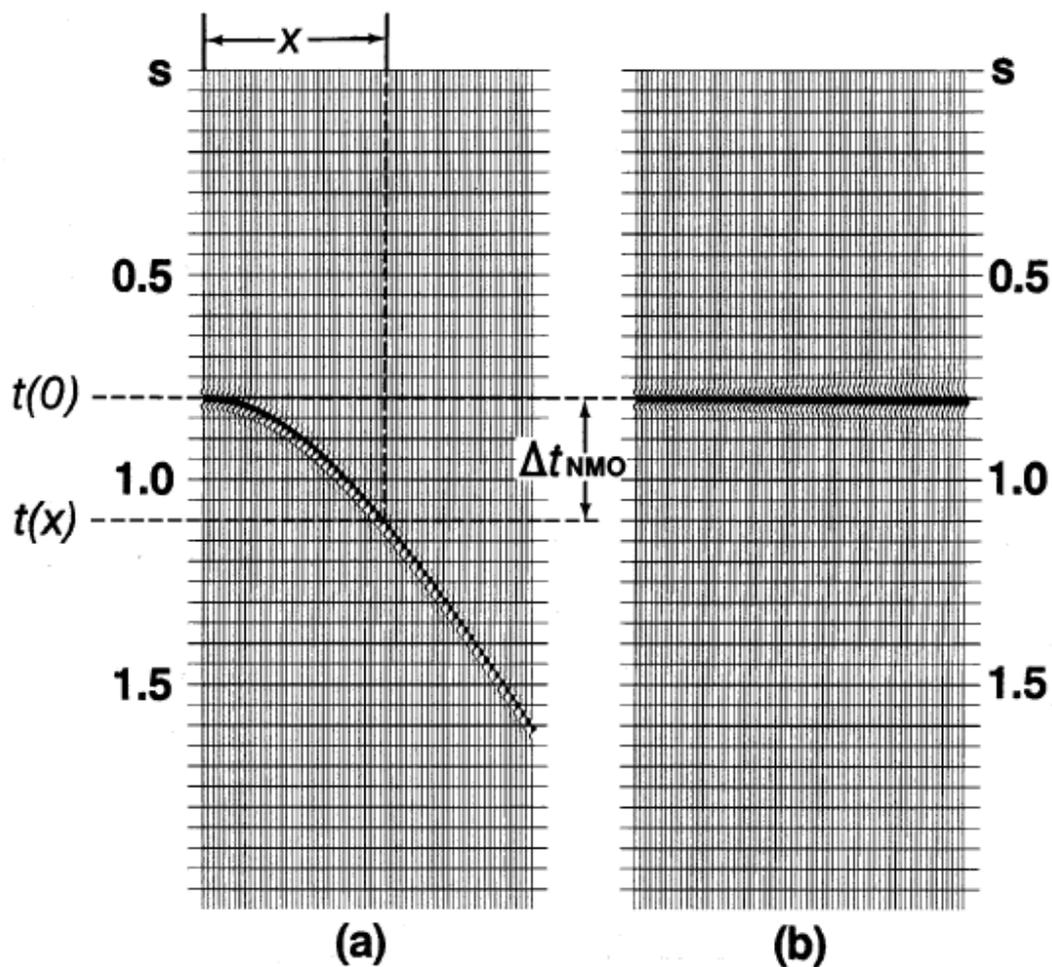


$$t_x^2 = t_0^2 + \frac{x^2}{v^2}$$

Conjunto CMP



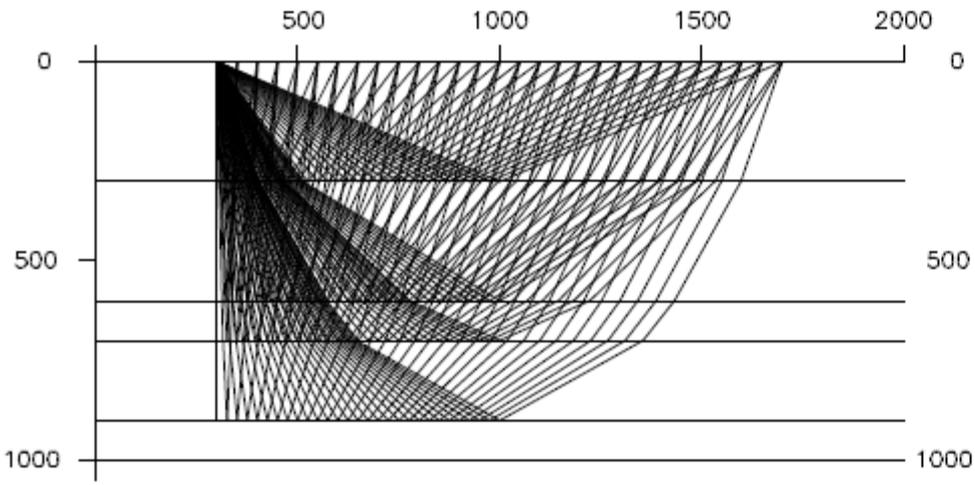


$$\Delta t_{NMO} = t_x - t_0$$

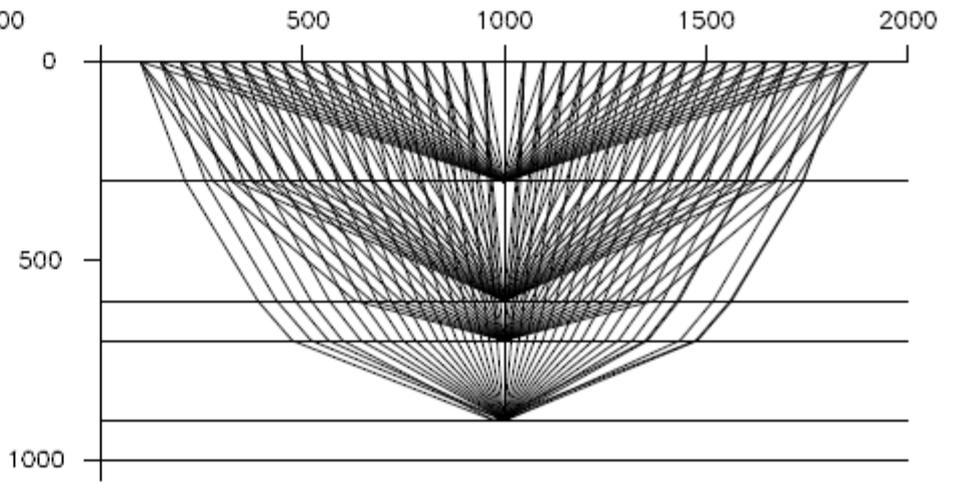
$$t_x^2 = t_0^2 + \frac{x^2}{v^2}$$

$$\Delta t_{NMO} = t_0 \left[\sqrt{1 + \left(\frac{x}{v_{NMO} t_0} \right)^2} - 1 \right]$$

FIG. 3.1-3. NMO correction (equation 3-2a) involves mapping nonzero-offset traveltime t onto zero-offset traveltime t_0 . (a) Before and (b) after NMO correction.

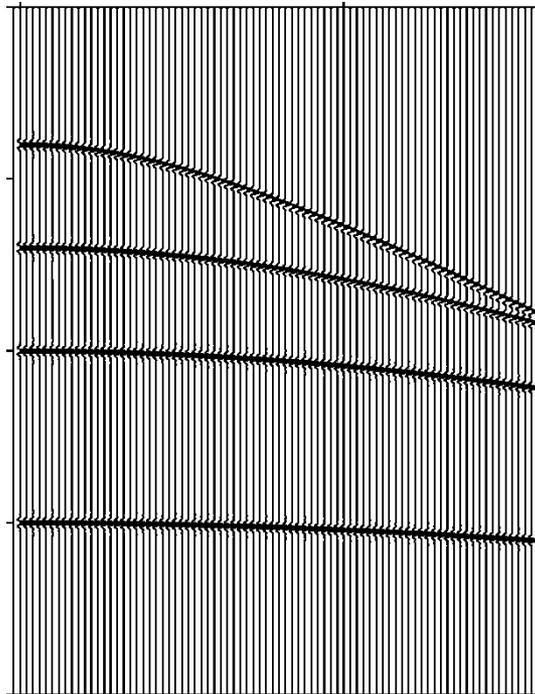


shotflat



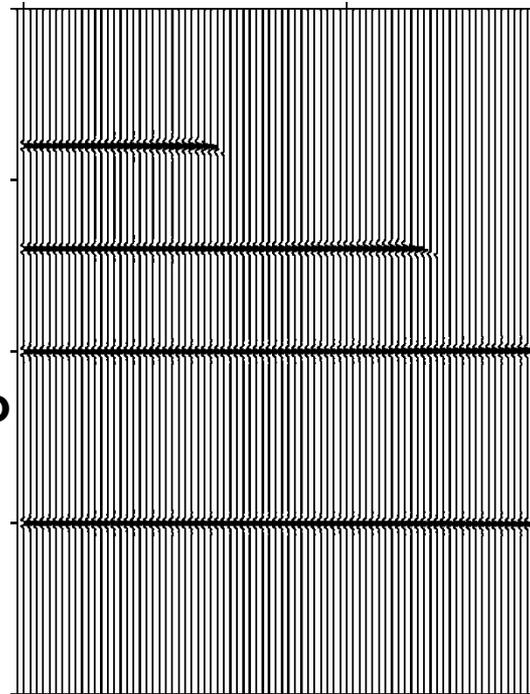
cmpflat

Objetivo da análise de velocidades



Hipérbole de reflexão

→
correção
NMO



horizontalizadas

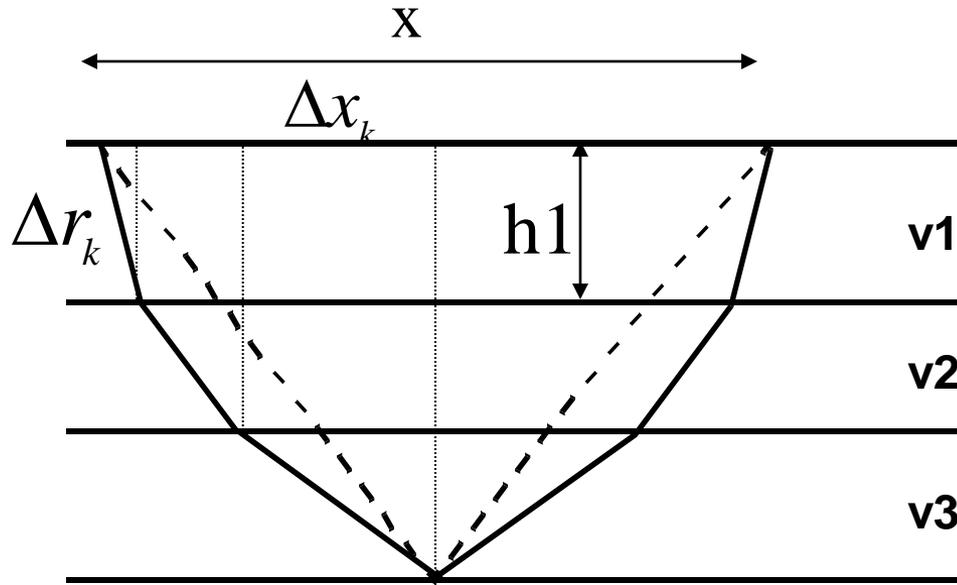
→



empilhamento

(NMO = Normal Moveout)

Diversas camadas horizontalizadas



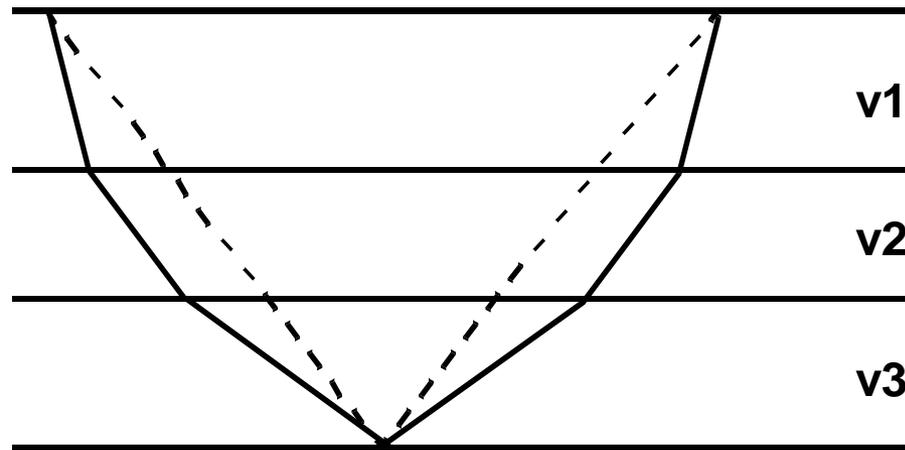
Considerando $x > 0$ e refrações nas interfaces

$$t_{(x,n)} = 2 \sum_{k=1}^n \frac{\Delta r_k}{V_k} = 2 \sum_{k=1}^n \frac{(\Delta x_k^2 + h_k^2)^{1/2}}{V_k}$$

$$x = 2 \sum_{k=1}^n \Delta x_k$$

$$\Delta x_k = ?$$

Diversas camadas horizontalizadas



$$t_{(x,n)}^2 = c_1 + c_2 x^2 + c_3 x^4 + \dots + c_j x^{2j-2} + \dots$$

onde os coeficientes $c_1=(t_0)^2$, $c_2=1/(V_{\text{RMS}})^2$ e c_3, c_4, \dots funções que dependem da espessura (h_1, h_2, \dots, h_n) e velocidade de cada camada (v_1, v_2, v_n)

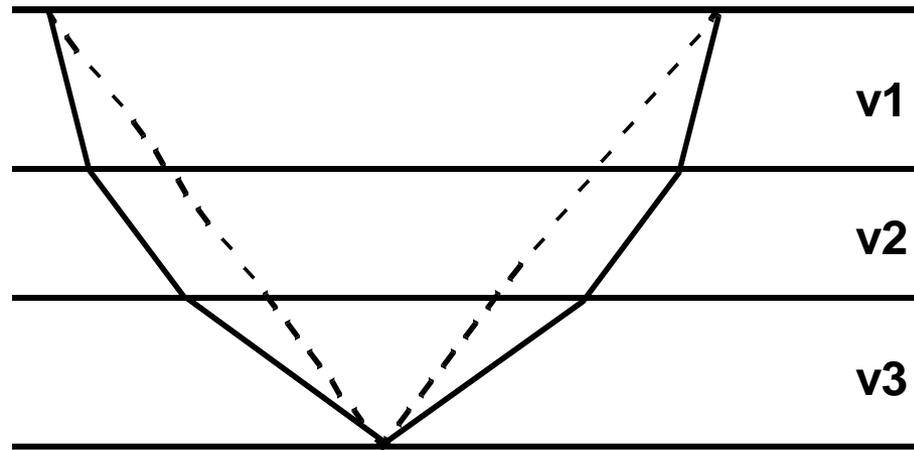
$$t_{(x,n)}^2 = c_1 + c_2 x^2 + c_3 x^4 + \dots + c_j x^{2j-2} + \dots$$

Para distâncias $x_n \sim h_n$ os 2 primeiros termos da expressão anterior permitem a precisão necessária para os propósitos da sísmica de exploração

$$t_{(x,n)}^2 = c_1 + c_2 x^2$$

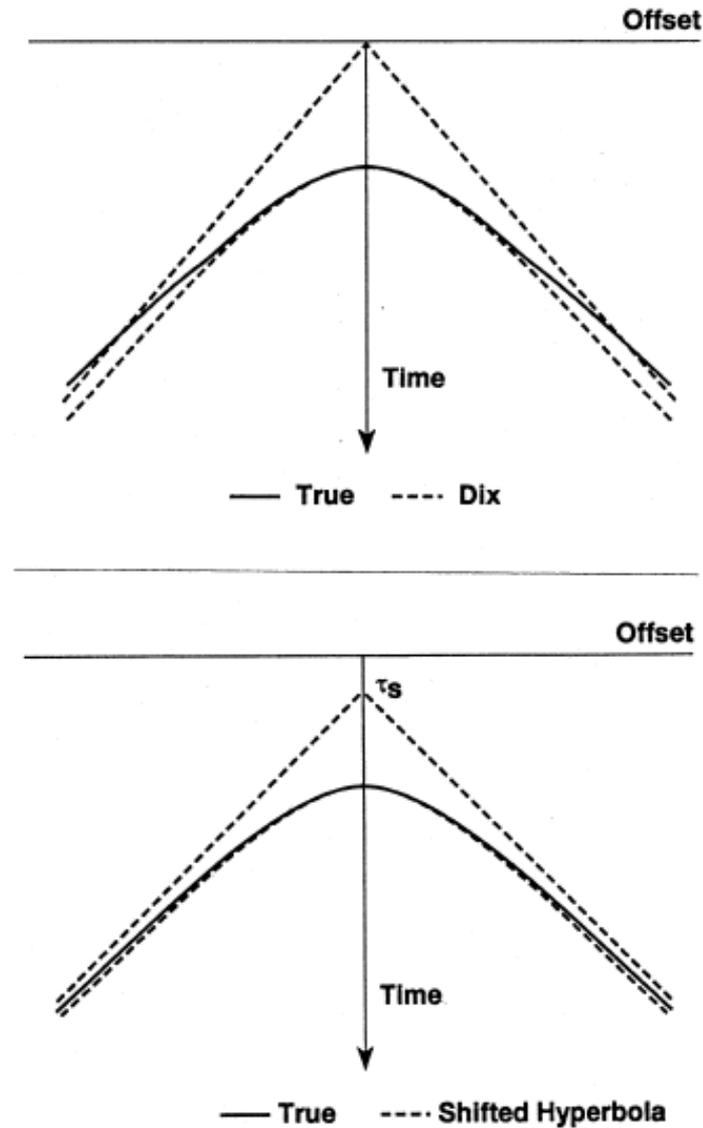
$$c_1 = (t_0)^2 \quad c_2 = 1/(V_{\text{RMS}})^2$$

Diversas camadas horizontalizadas



$$t_x^2 = t_0^2 + \frac{x^2}{v_{rms}^2}$$

$$V_{rms}^2 = \frac{\sum_{i=1}^n v_i^2 t_i}{\sum_{i=1}^n t_i}$$



Yilmaz – Seismic data analysis

FIG. C-1. Traveltime trajectories based on (top) the hyperbolic equation (C-23) and (bottom) the time-shifted hyperbolic equation (C-14). Compare with the true traveltime trajectory associated with a layered model (Castle, 1994).

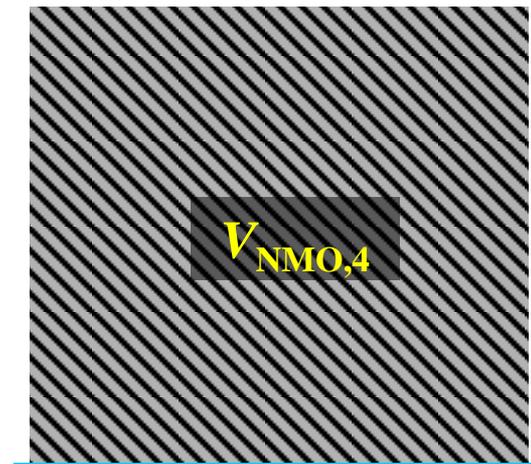
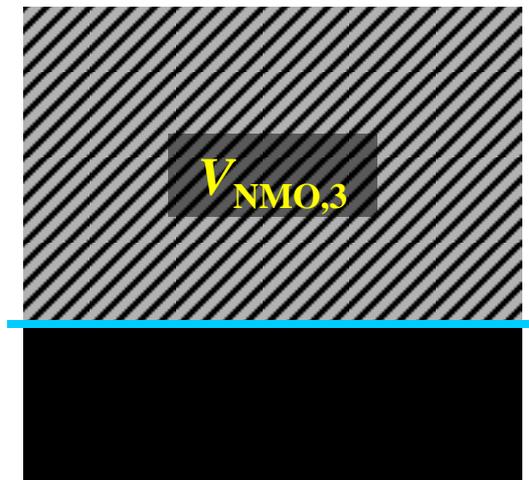
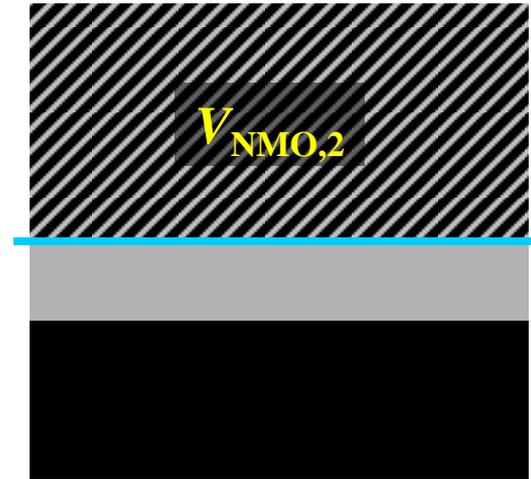
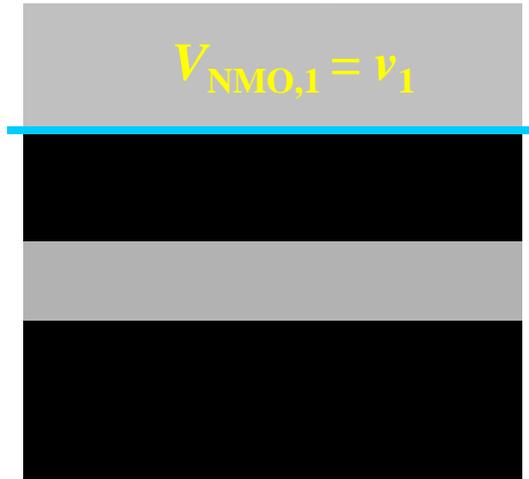
Correção NMO - multicamadas

Para meios estratificados, a velocidade NMO representa a velocidade do pacote de estratos acima da interface sísmica considerada (refletor)



$$t_x^2 = t_0^2 + \frac{x^2}{v_{rms}^2}$$

Correção NMO - multicamadas



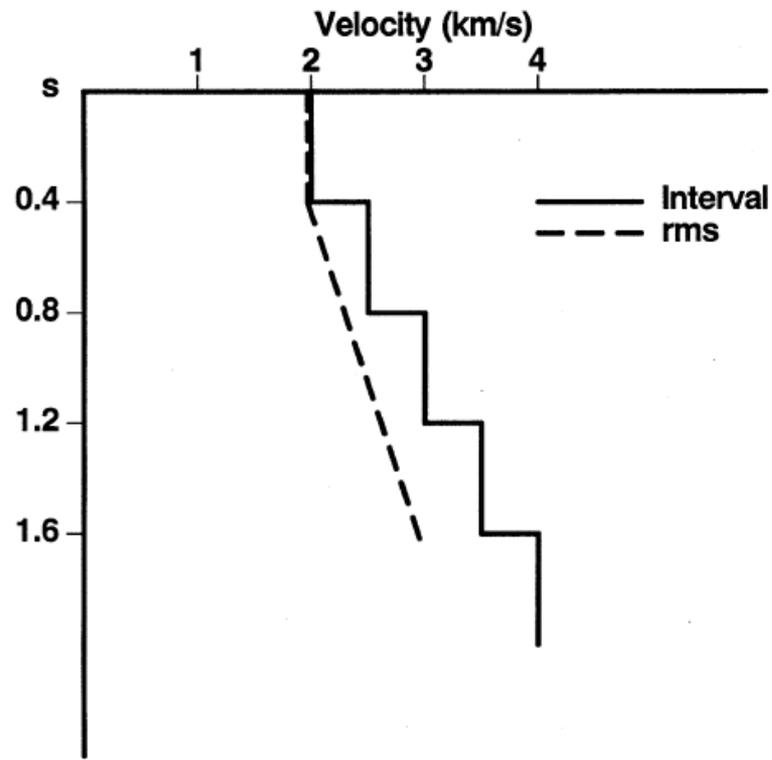


FIG. 3.1-8. A hypothetical velocity function used in generating the synthetic CMP gather in Figure 3.1-7a.

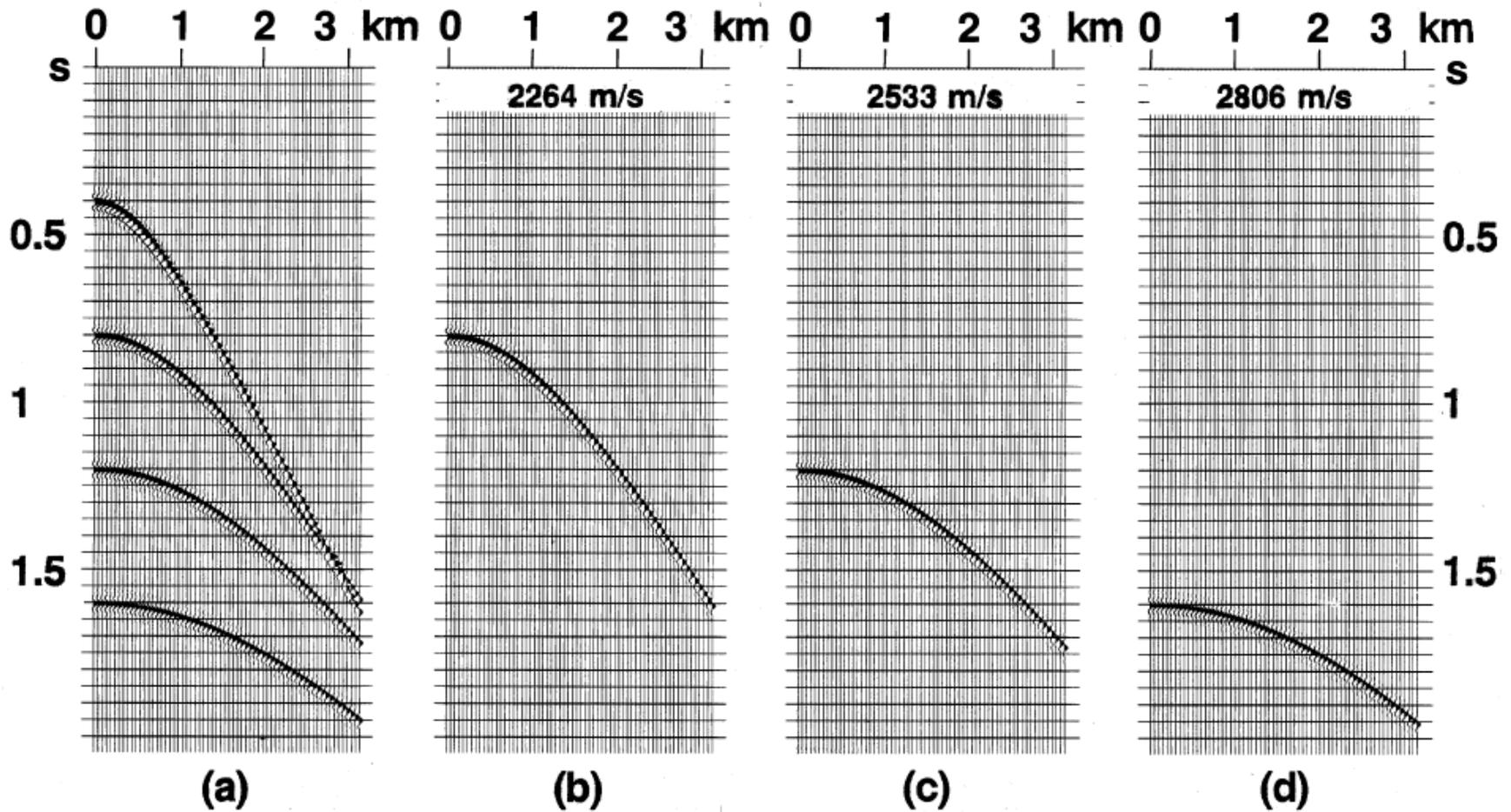


FIG. 3.1-7. (a) A synthetic CMP gather derived from the velocity function depicted in Figure 3.1-8; (b), (c), and (d) are CMP gathers derived from the rms velocities (indicated at the top of each gather) associated with the second, third, and fourth reflectors from the top. The traveltimes in (a) were derived using the raypath integral equations for a horizontally layered earth model.

$$t_x^2 = t_0^2 + \frac{x^2}{v_{rms}^2} + C_2 x^4$$

Sugestão Yilmaz

$$1) \quad t^2 = t_0^2 + \frac{x^2}{v^2} \longrightarrow v_{rms}(t_0)$$

$$2) \quad t^2 = t_0^2 + \frac{x^2}{v_{rms}^2} + C_2 x^4 \longrightarrow C_2(t_0)$$

$$3) \quad t^2 = t_0^2 + \frac{x^2}{v_{rms}^2} + C_2 x^4 \longrightarrow v_{rms}(t_0)$$

Castle, R. J., 1994, [A theory of normal moveout: Geophysics](#), **59**, 983-999.

$$t = t_0 \left(1 - \frac{1}{S}\right) + \sqrt{\left(\frac{t_0}{S}\right)^2 + \frac{x^2}{S v_{rms}^2}} \quad S=1 \longrightarrow t^2 = t_0^2 + \frac{x^2}{v_{rms}^2}$$

$$1) \quad S=1 \quad v_{rms}(t_0)$$

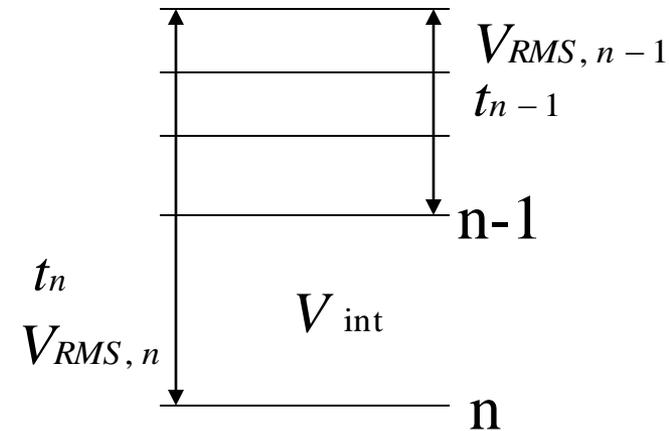
$$2) \quad t = t_0 \left(1 - \frac{1}{S}\right) + \sqrt{\left(\frac{t_0}{S}\right)^2 + \frac{x^2}{S v_{rms}^2}} \longrightarrow S(t_0)$$

$$3) \quad t = t_0 \left(1 - \frac{1}{S}\right) + \sqrt{\left(\frac{t_0}{S}\right)^2 + \frac{x^2}{S v_{rms}^2}} \longrightarrow v_{rms}(t_0)$$

Fórmula de Dix

Conversão da v_{rms} em velocidade intervalar

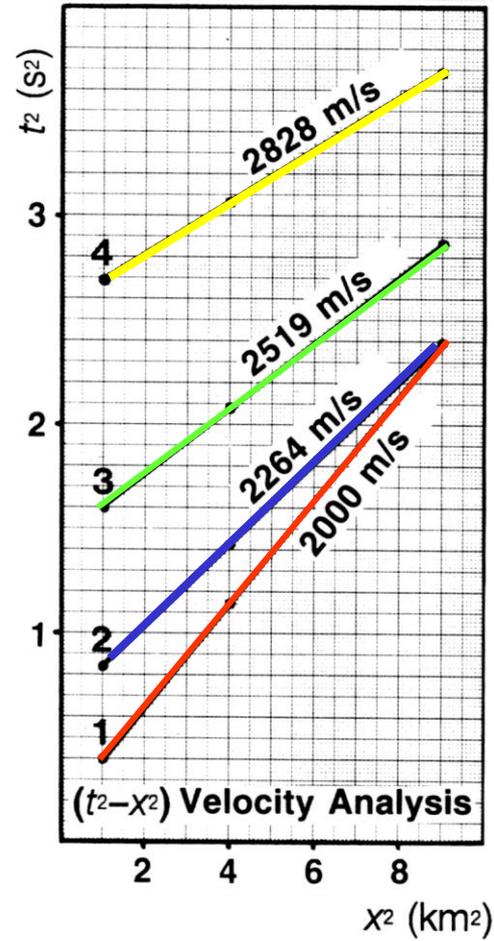
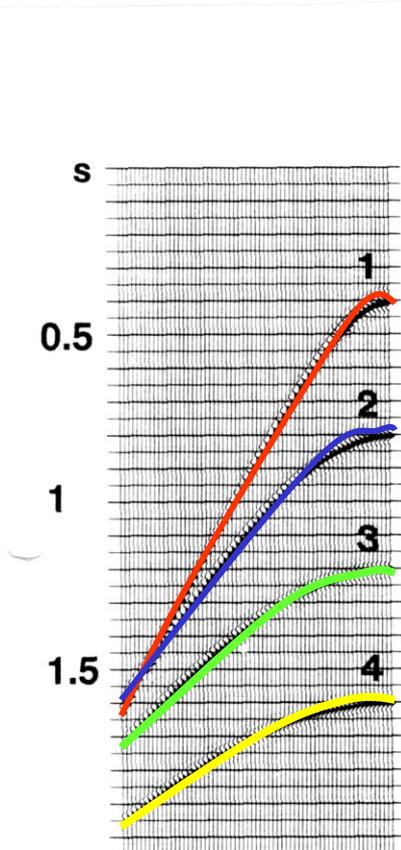
$$V_{int} = \sqrt{\left[\frac{(V_{RMS,n})^2 t_n - (V_{RMS,n-1})^2 t_{n-1}}{t_n - t_{n-1}} \right]}$$



Métodos para análise de velocidades

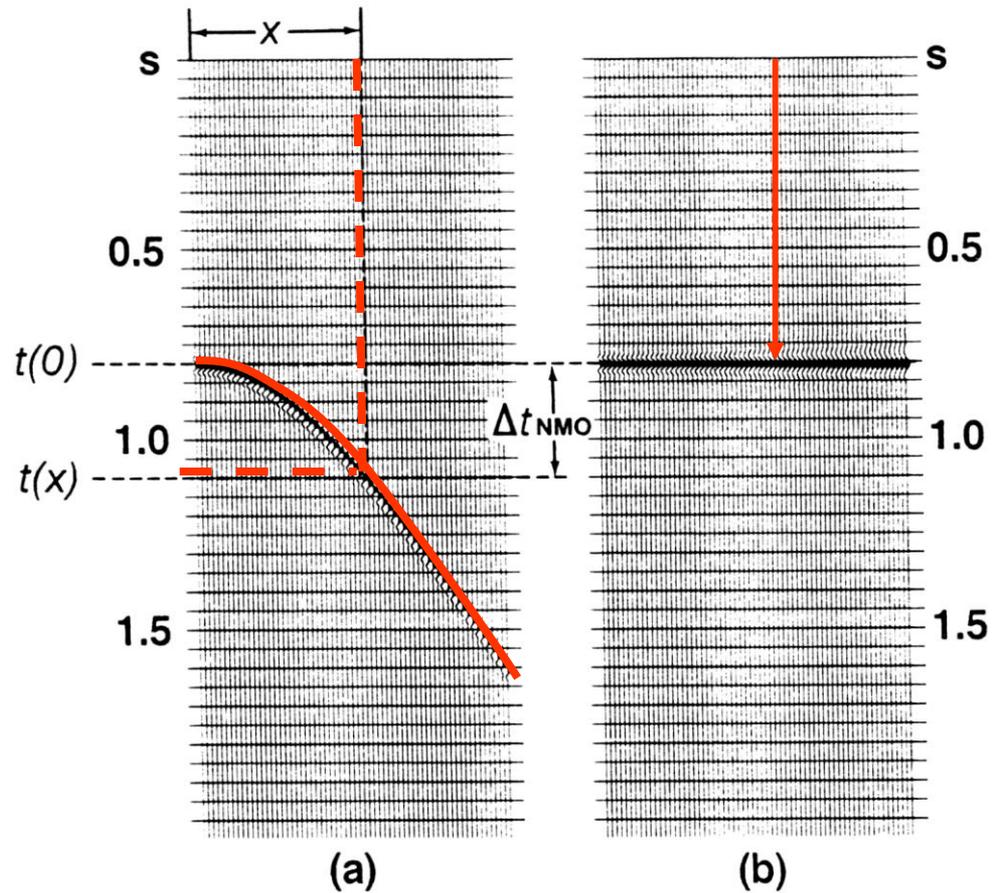
- **Análise x^2-t^2**
- **Métodos que usam a correção NMO:**
 - **CVP - constant velocity panels**
 - **CVS - constant velocity stacks**
- **Análise do espectro de velocidades (semblance)**

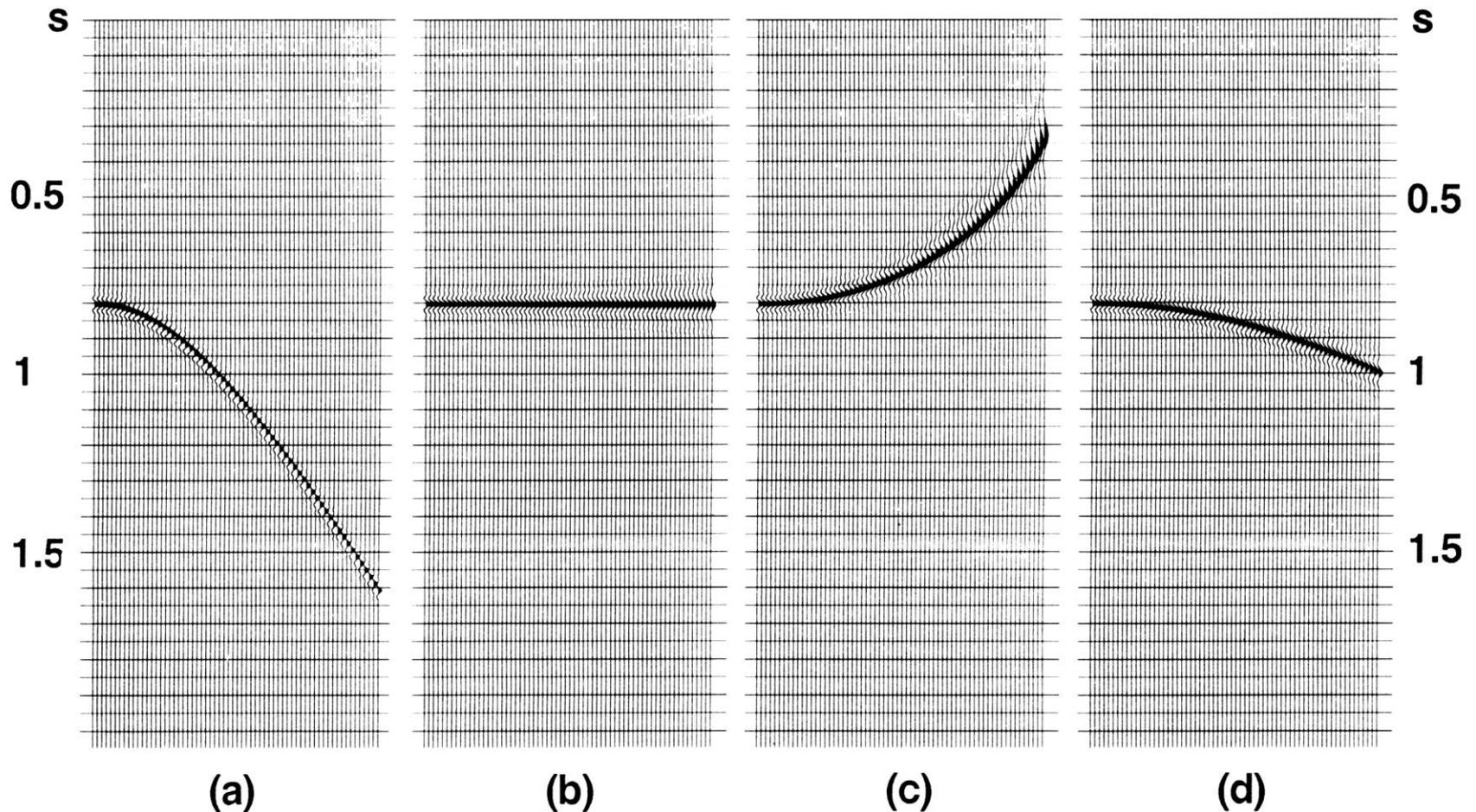
Análise x^2-t^2



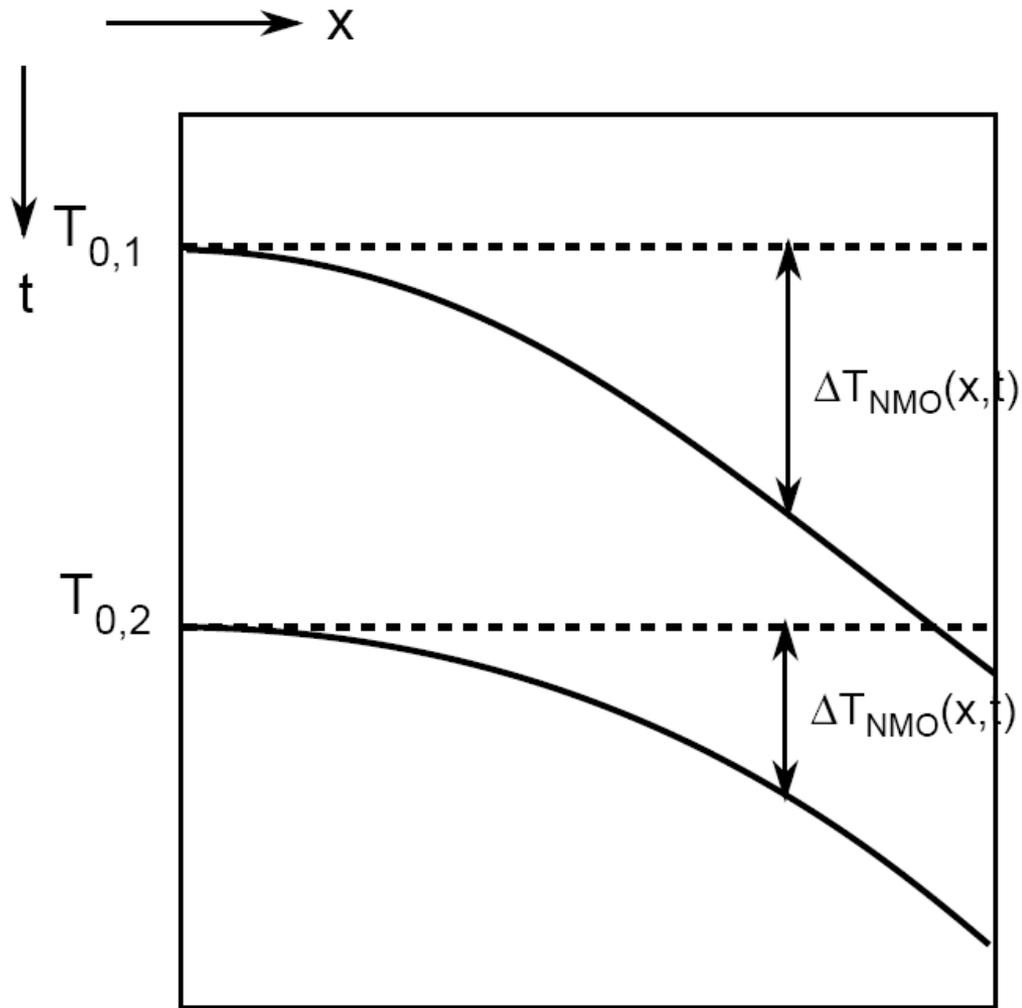
$$t^2 = t_0^2 + \frac{x^2}{v_{stack}^2}$$

Métodos que usam a correção NMO





- (a) Reflexão não corrigida
- (b) Corrigida com velocidade correta
- (c) Velocidade muito baixa
- (d) Velocidade muito alta



$$\Delta t_{NMO} = t_0 \left[\sqrt{1 + \left(\frac{x}{v_{NMO} t_0} \right)^2} - 1 \right]$$

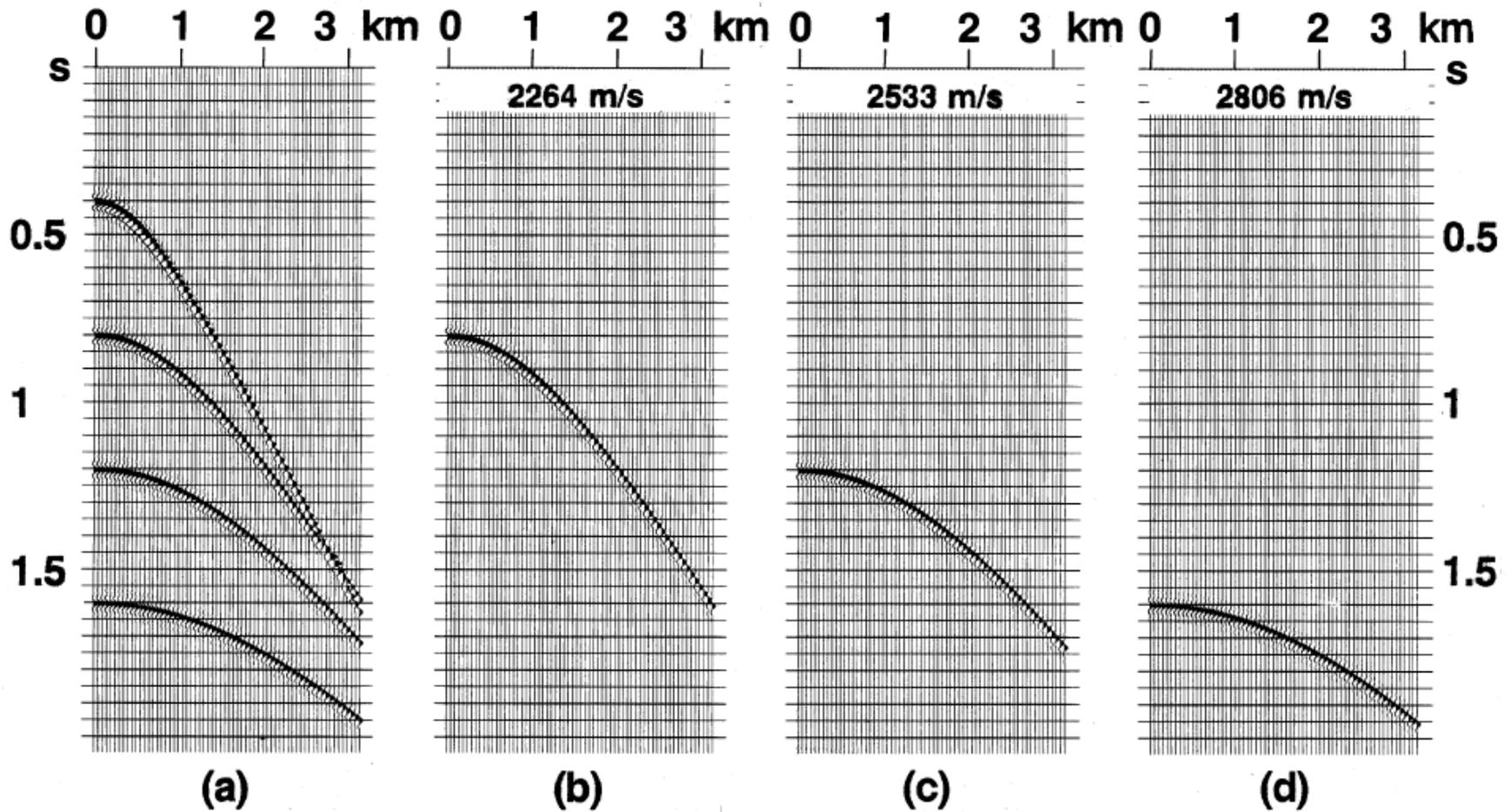
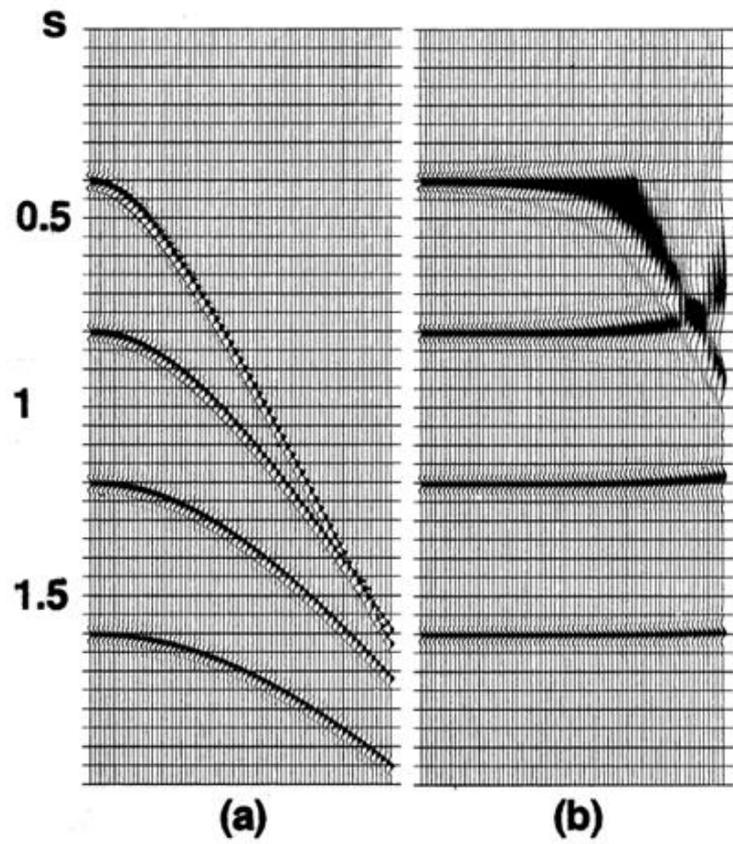
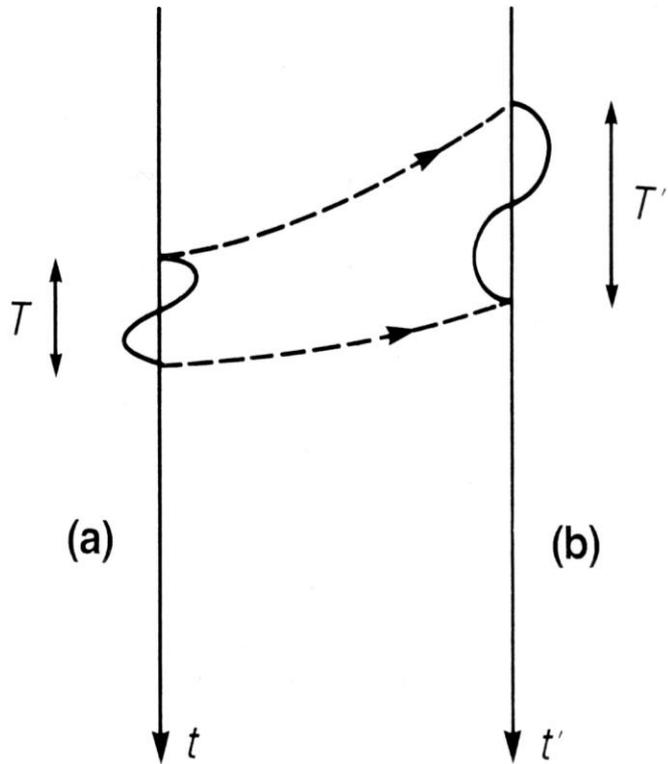


FIG. 3.1-7. (a) A synthetic CMP gather derived from the velocity function depicted in Figure 3.1-8; (b), (c), and (d) are CMP gathers derived from the rms velocities (indicated at the top of each gather) associated with the second, third, and fourth reflectors from the top. The traveltimes in (a) were derived using the raypath integral equations for a horizontally layered earth model.



Yilmaz – Seismic data analysis

Stretching (estiramento)



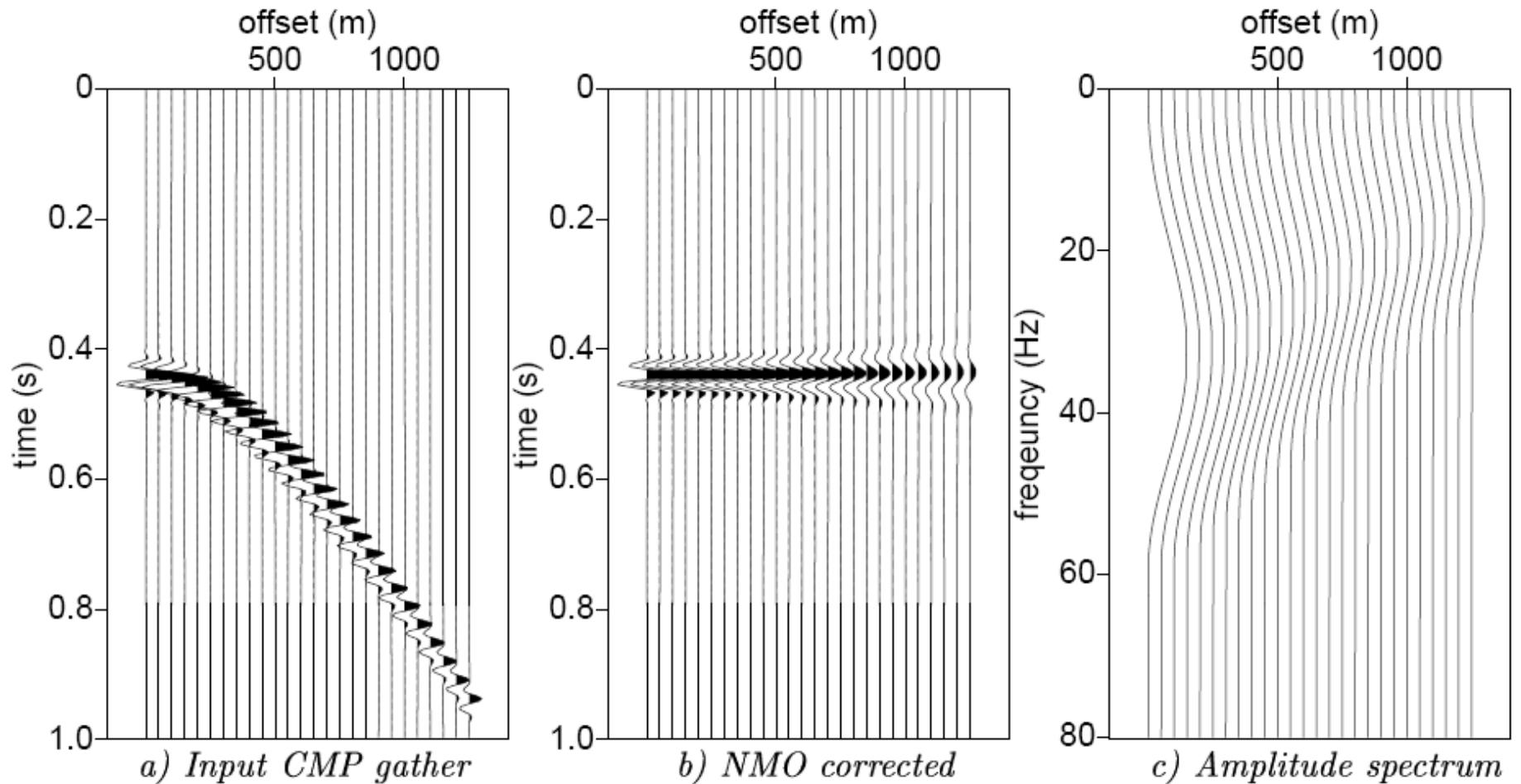
$$\Delta t_{NMO} = t(x) - t(0)$$

$$t(0) = \left(t^2(x) - \frac{x^2}{V^2} \right)^{1/2}$$

$$\Delta t_{NMO(1)} = t(x) - \left(t^2(x) - \frac{x^2}{V^2} \right)^{1/2}$$

$$\Delta t_{NMO(2)} = t(x) + dt - \left((t(x) + dt)^2 - \frac{x^2}{V^2} \right)^{1/2}$$

Stretching (estiramento)



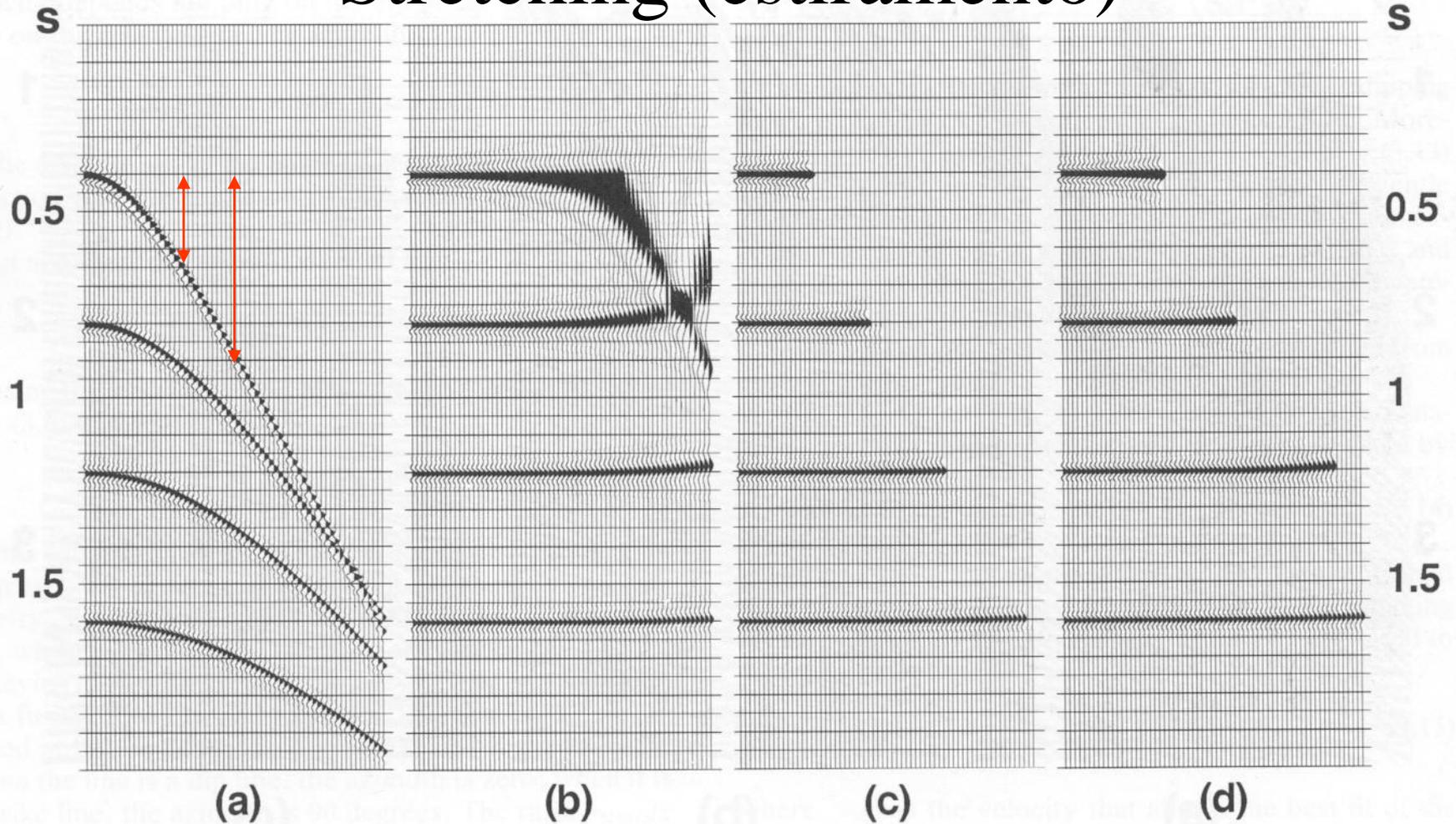
Stretching (estiramento)

$$\frac{\Delta f}{f} = \frac{\Delta t_{NMO}}{t_0};$$

Table 3-2. NMO stretching.

t_0, s	$v_{NMO}, m/s$	% $\Delta f/f$ for $x = 1000$ m	% $\Delta f/f$ for $x = 2000$ m
0.25	2000	123	312
0.5	2500	28	89
1	3000	5	20
2	3500	1	4
4	4000	0.2	0.8

Stretching (estiramento)

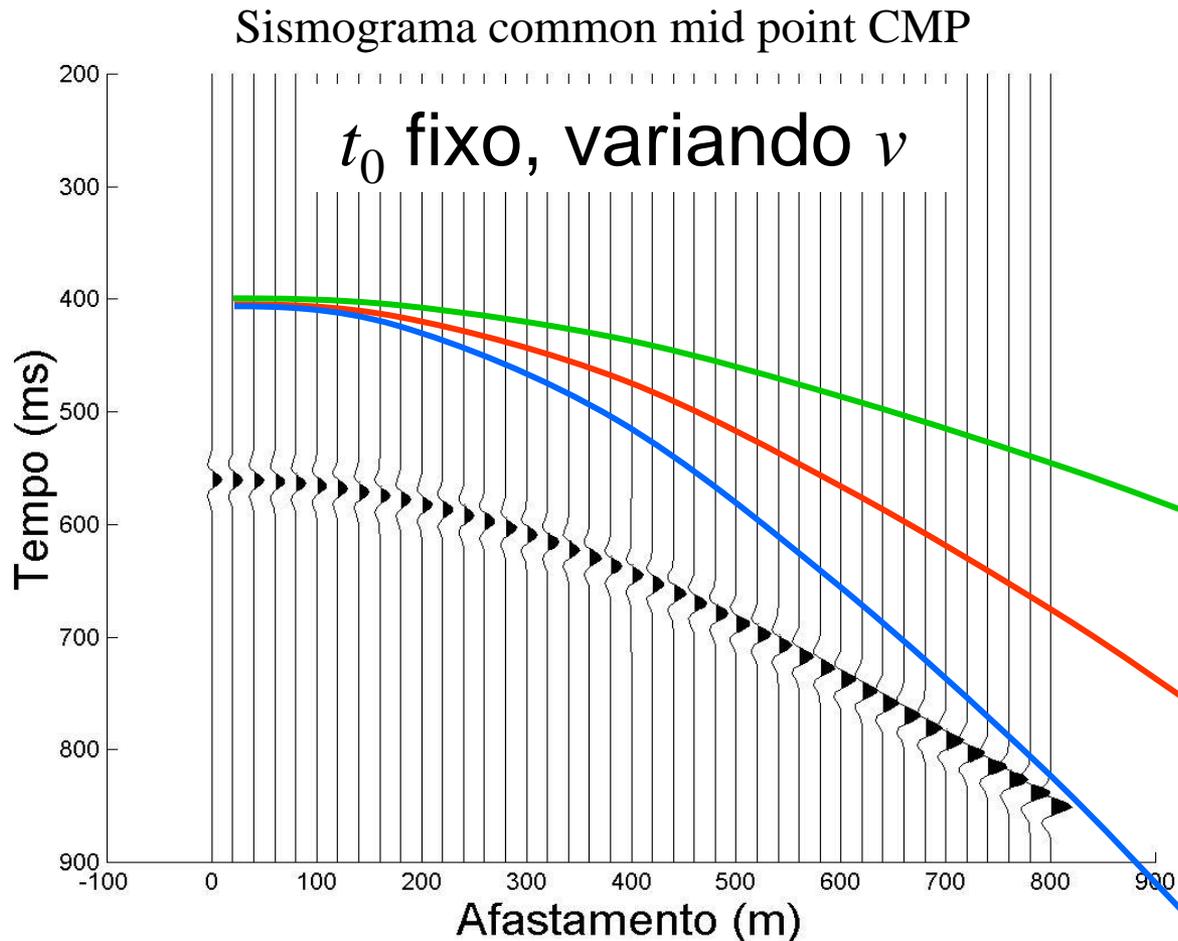


$$\frac{\Delta t_{\text{NMO}}}{T_0} = \frac{\Delta f}{f_{\text{dom}}},$$

50%

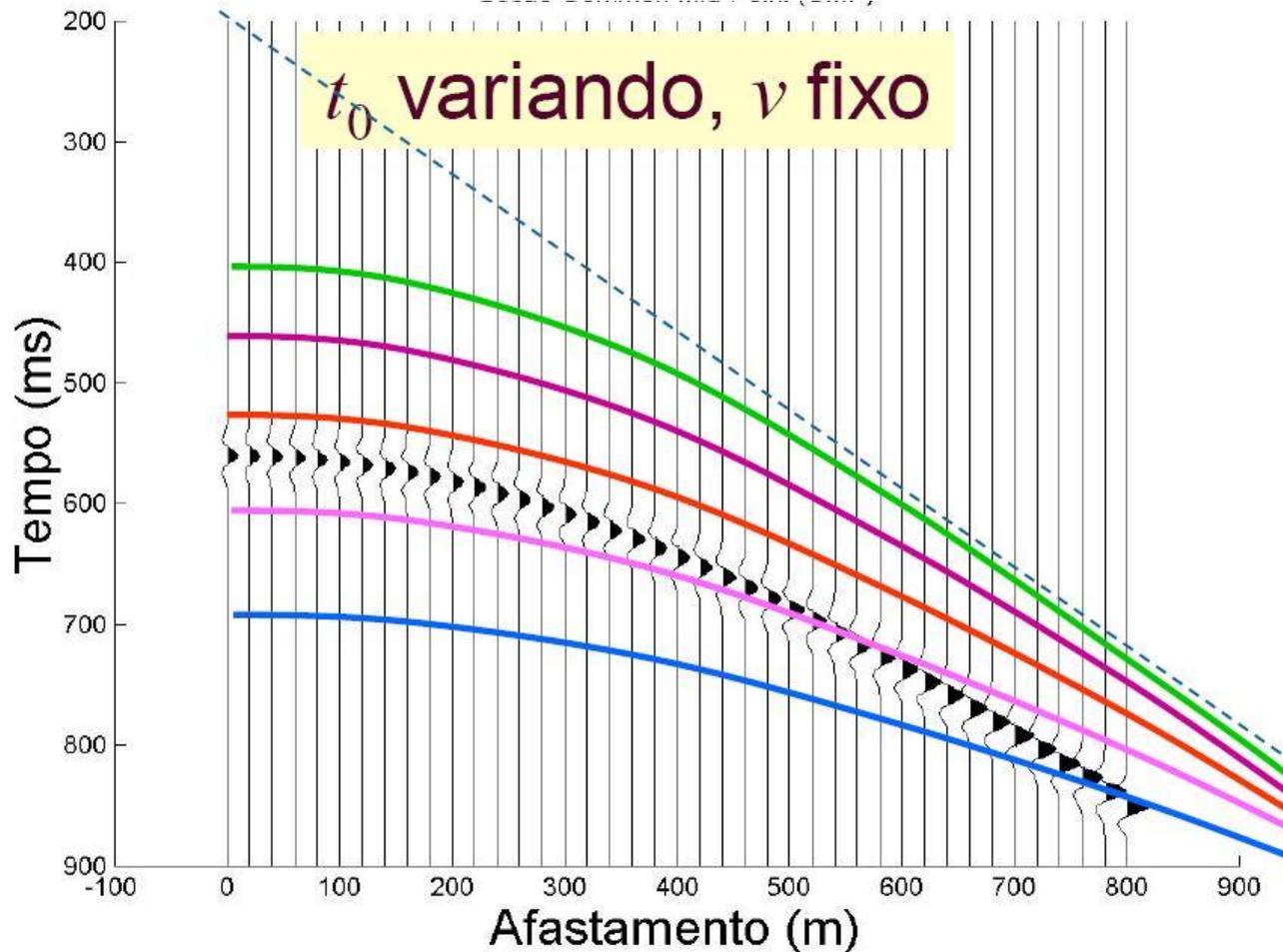
100%

Tempo de trânsito (CMP)

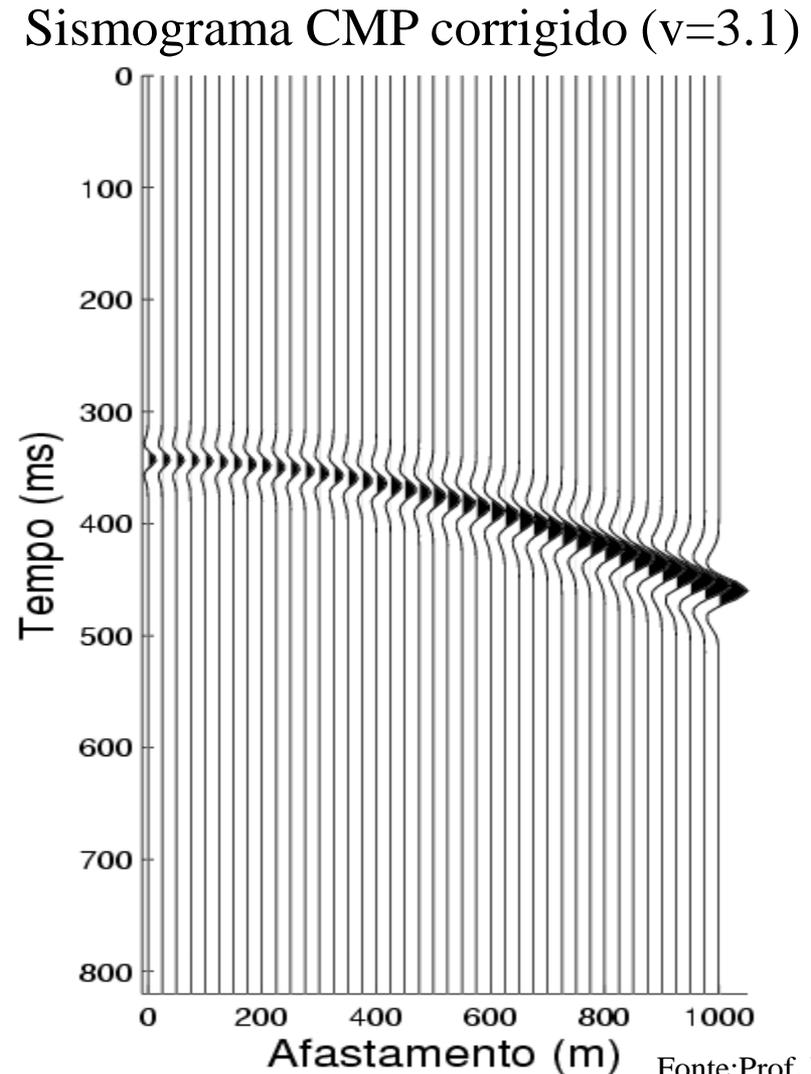
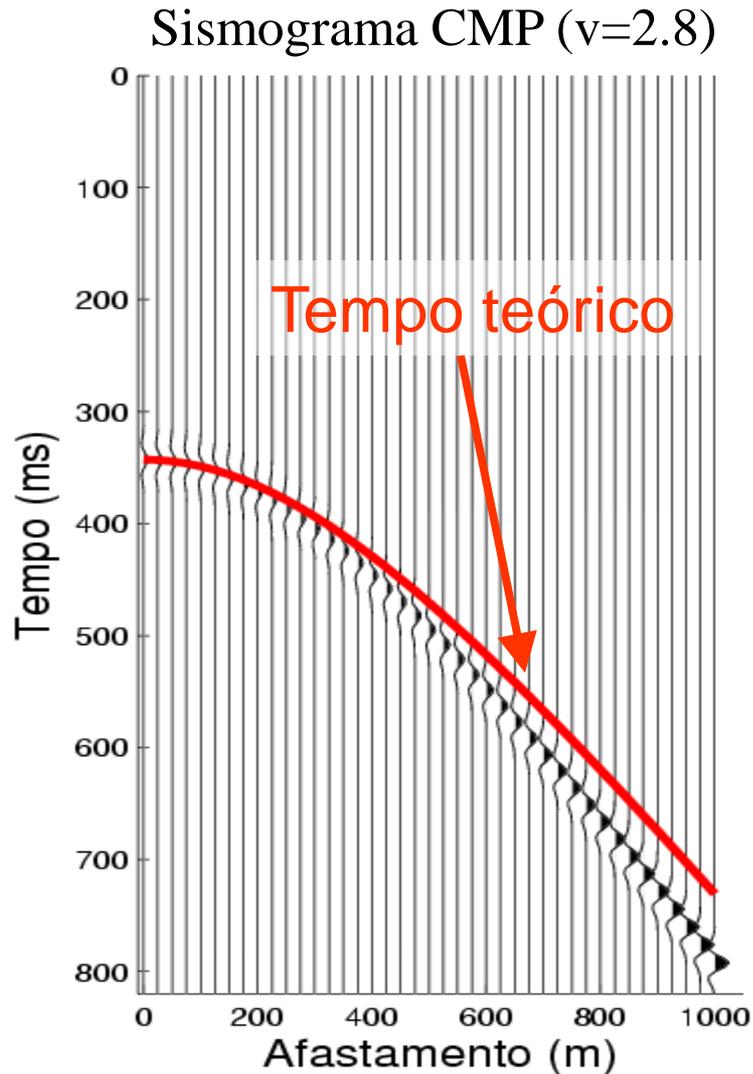


Tempo de trânsito (CMP)

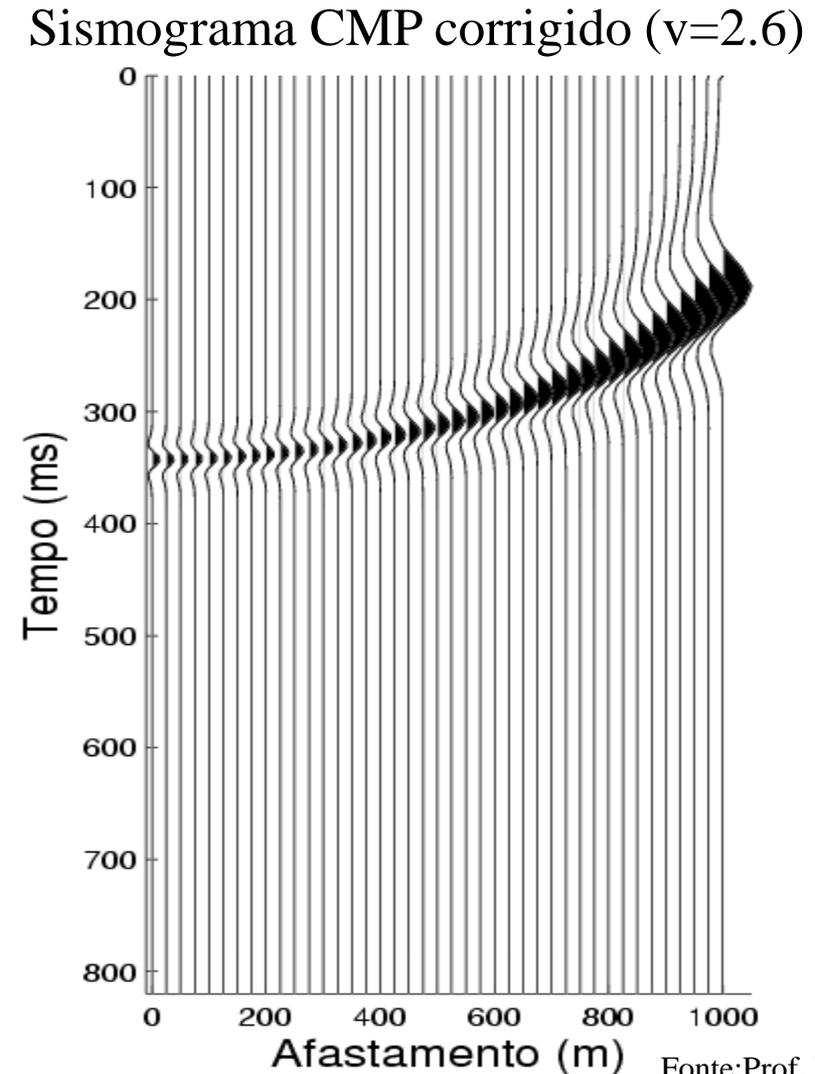
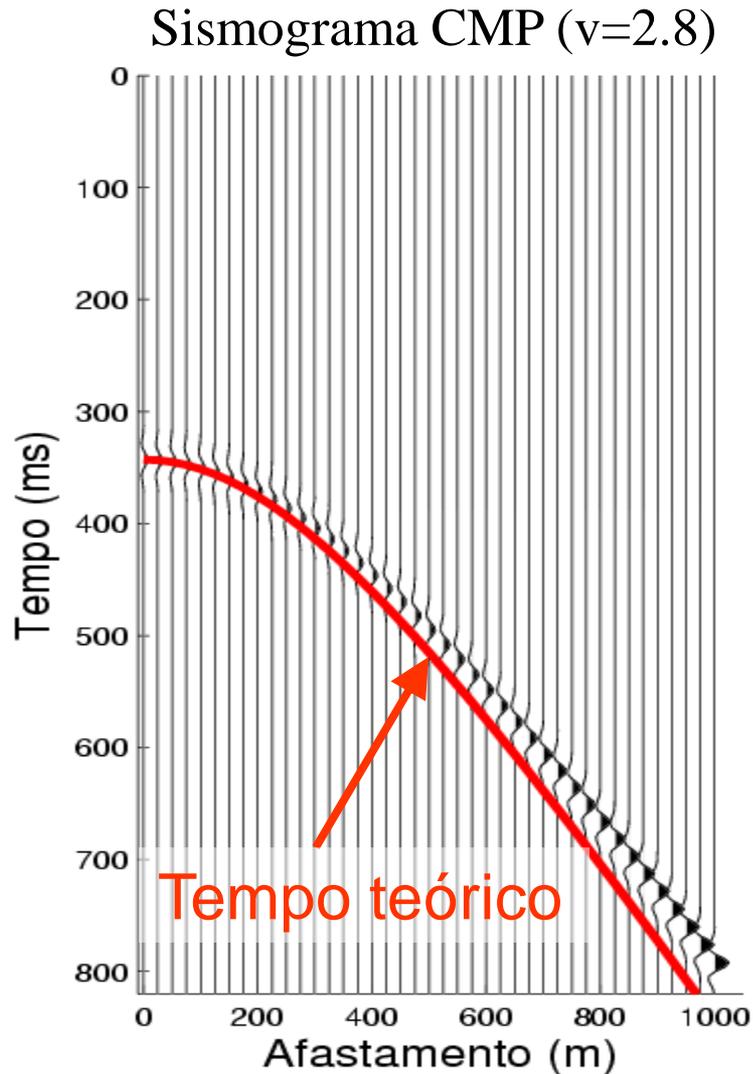
Sismograma common mid point CMP

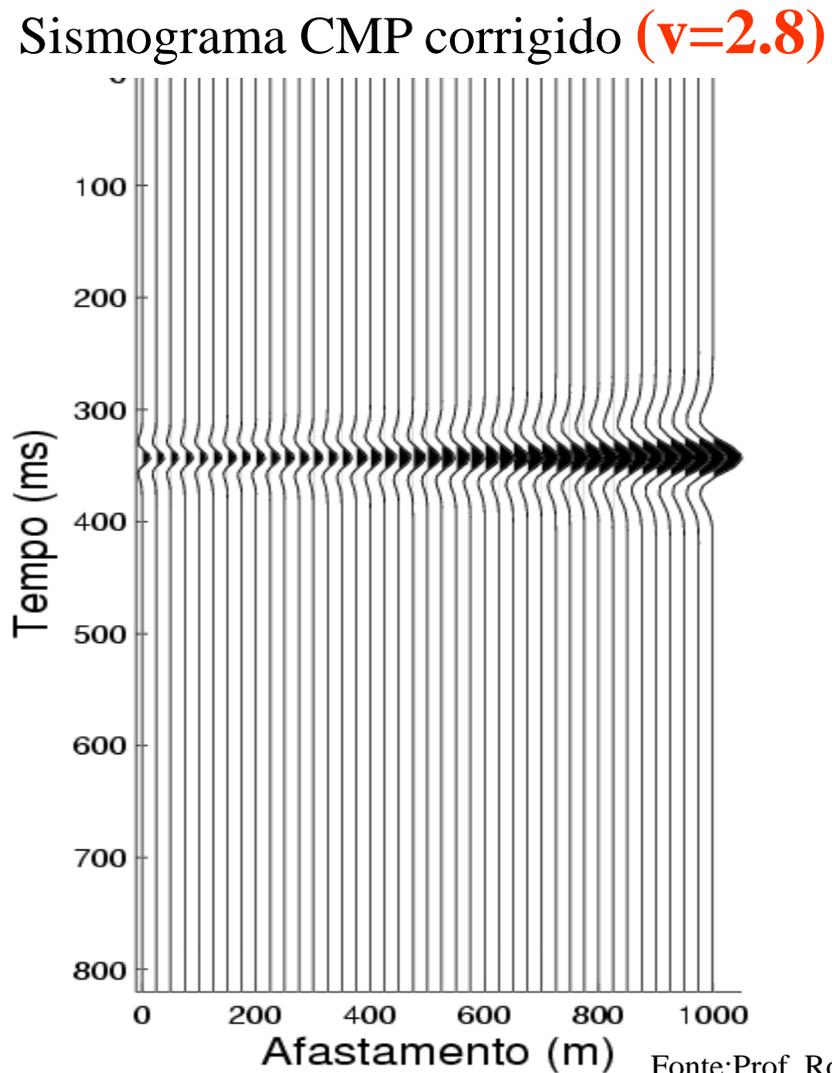
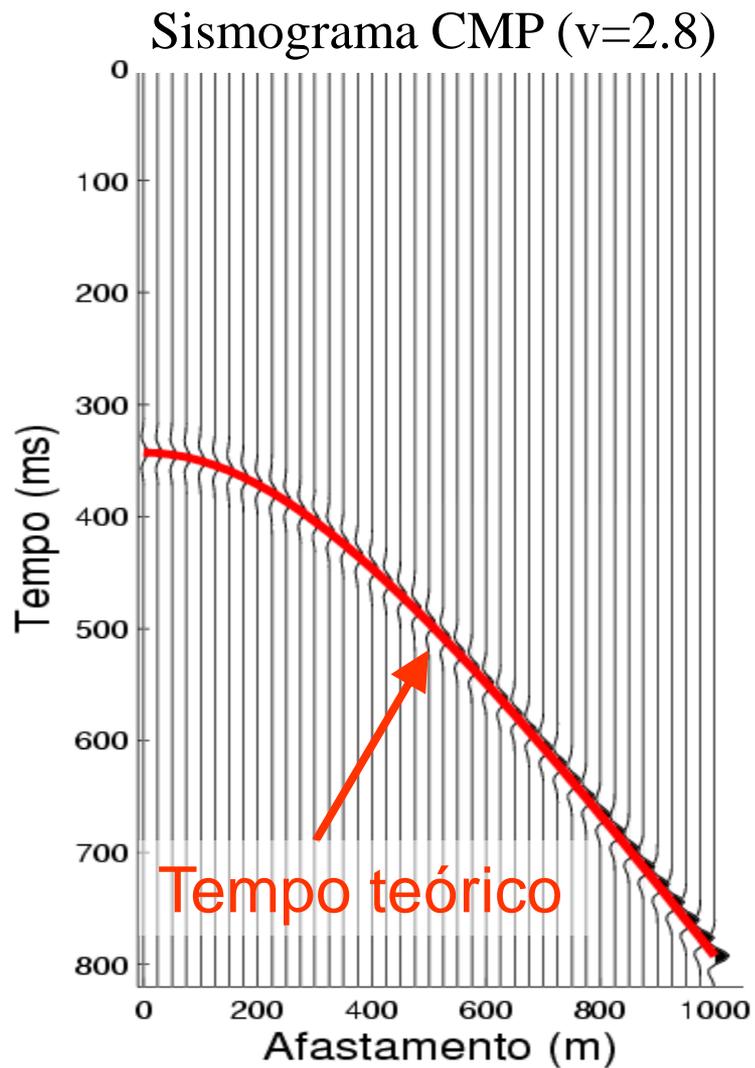


Correção NMO



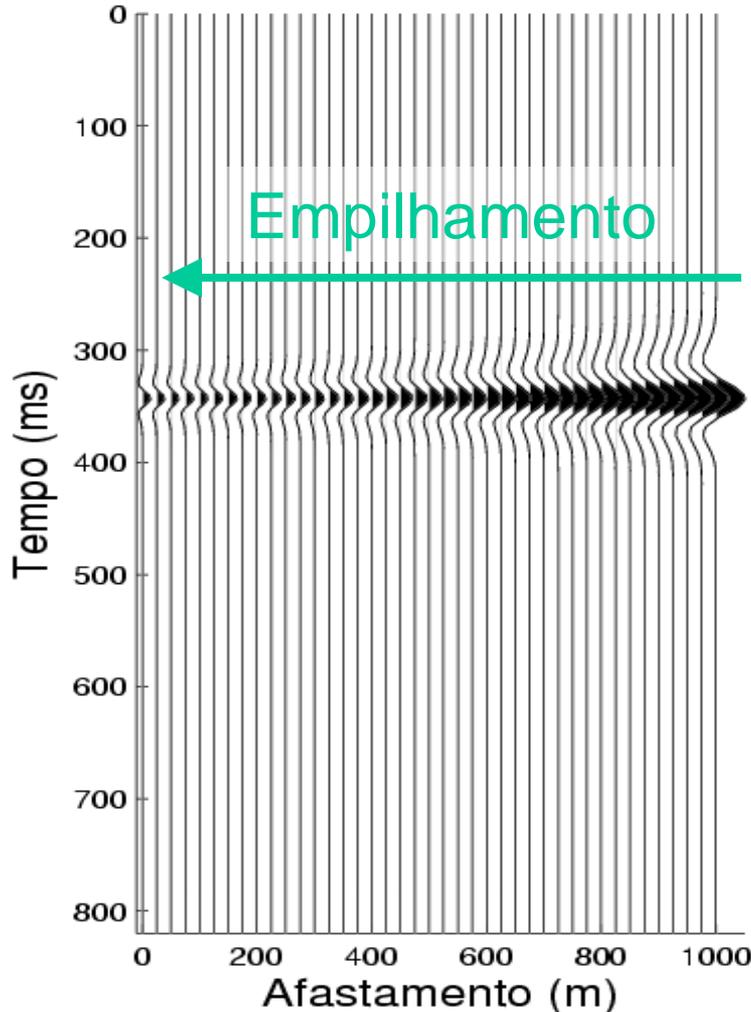
Correção NMO





Empilhamento NMO

Sismograma CMP corrigido ($v=2.8$)



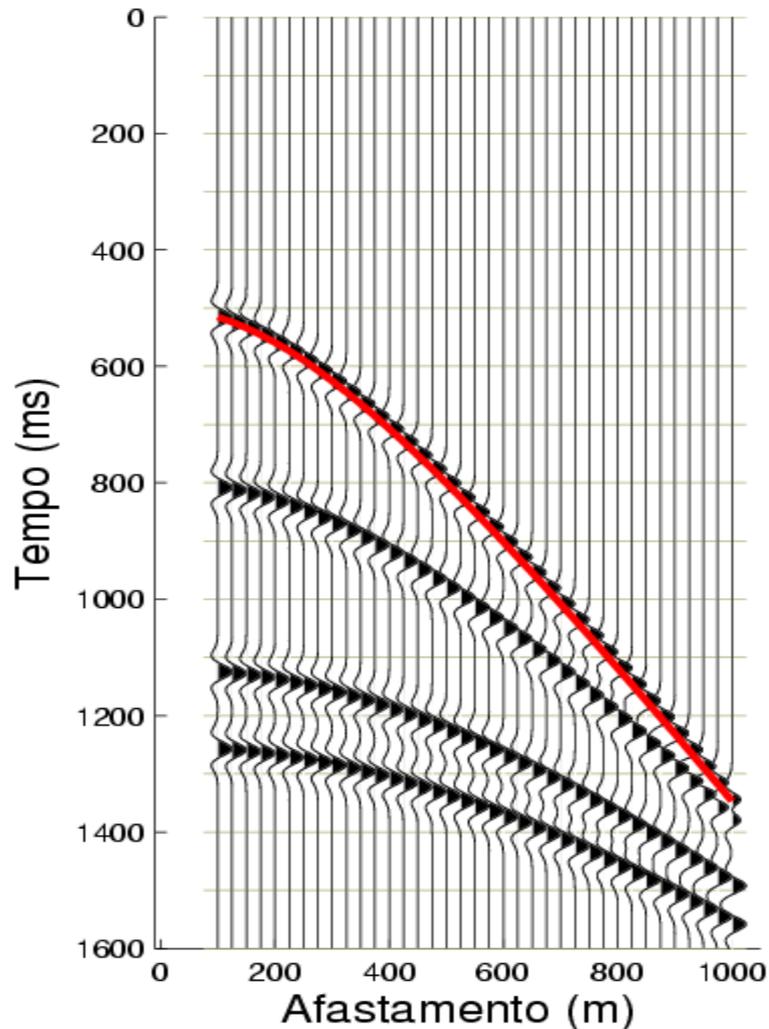
Empilhamento

Após a correção NMO todos estes traços podem ser somados, dando origem a um traço

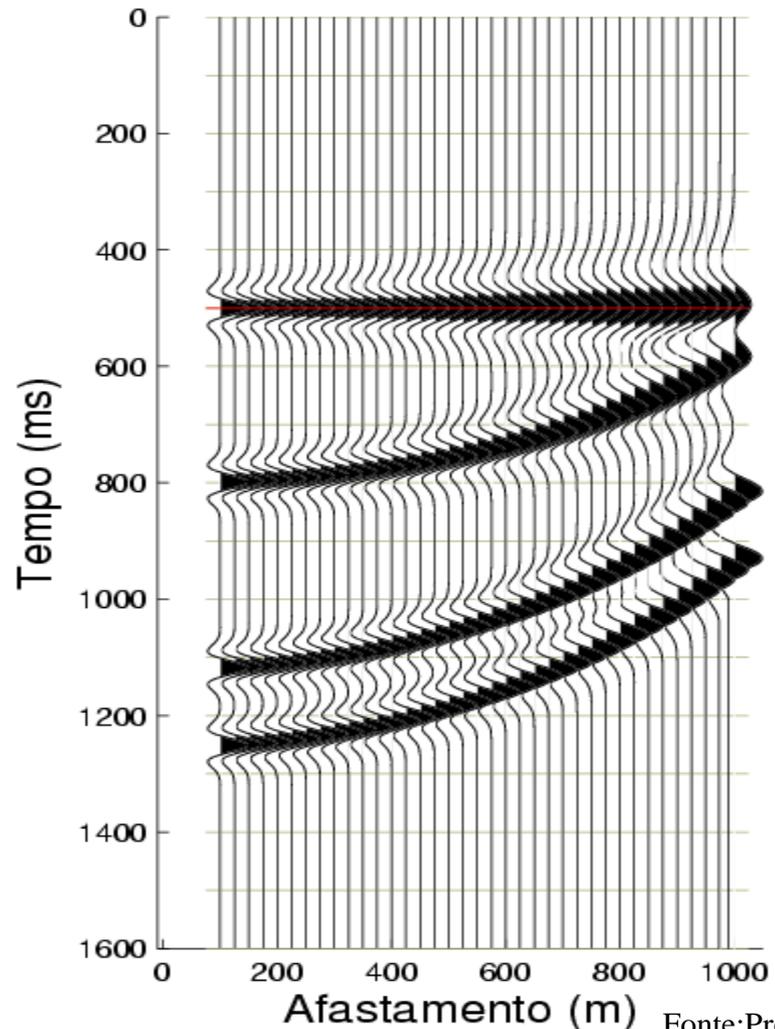
Cada conjunto CMP dá origem a um traço empilhado

Correção NMO - multicamadas

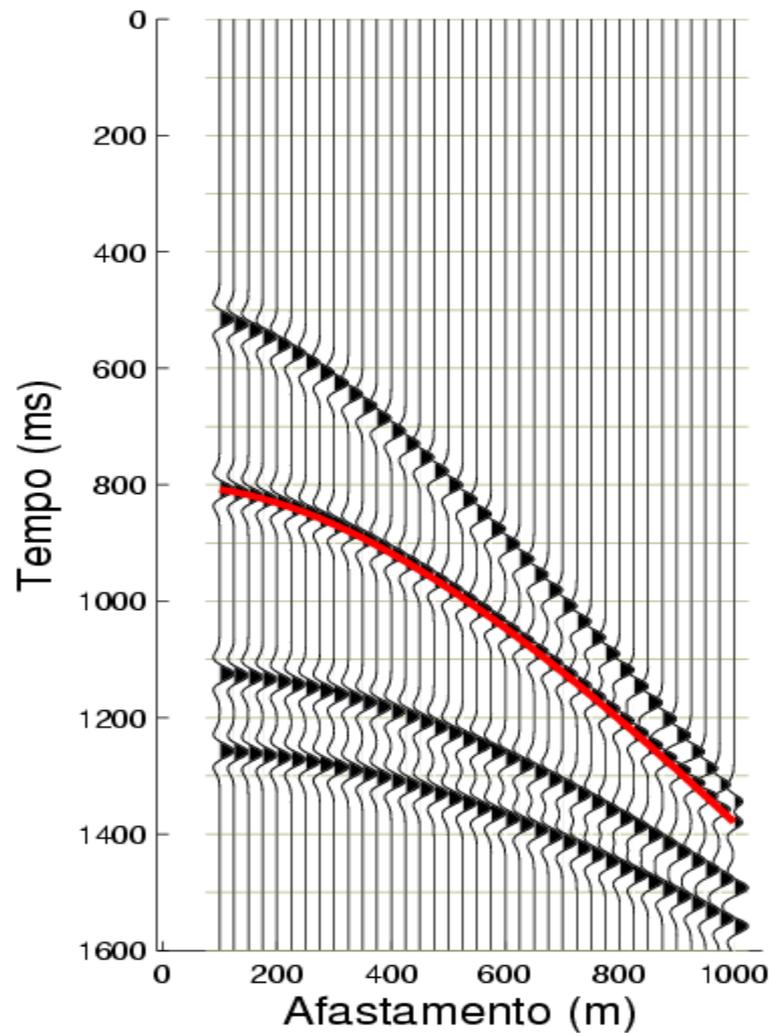
Sismograma CMP (v=2.8)



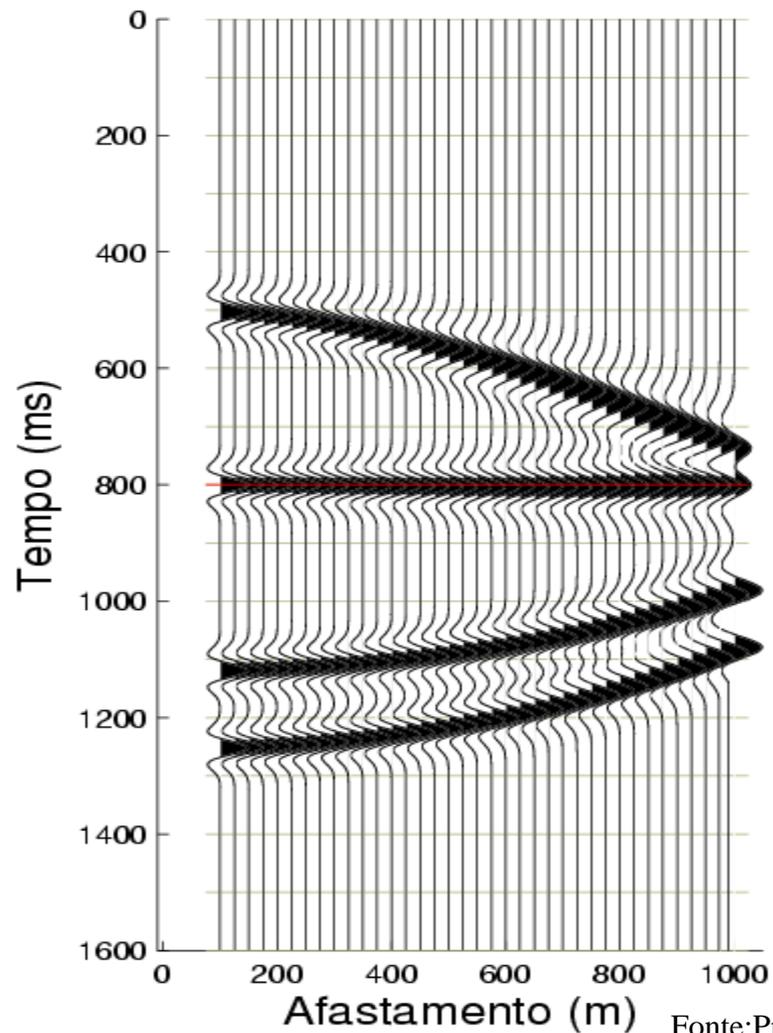
Sismograma CMP corrigido (v=1.6)



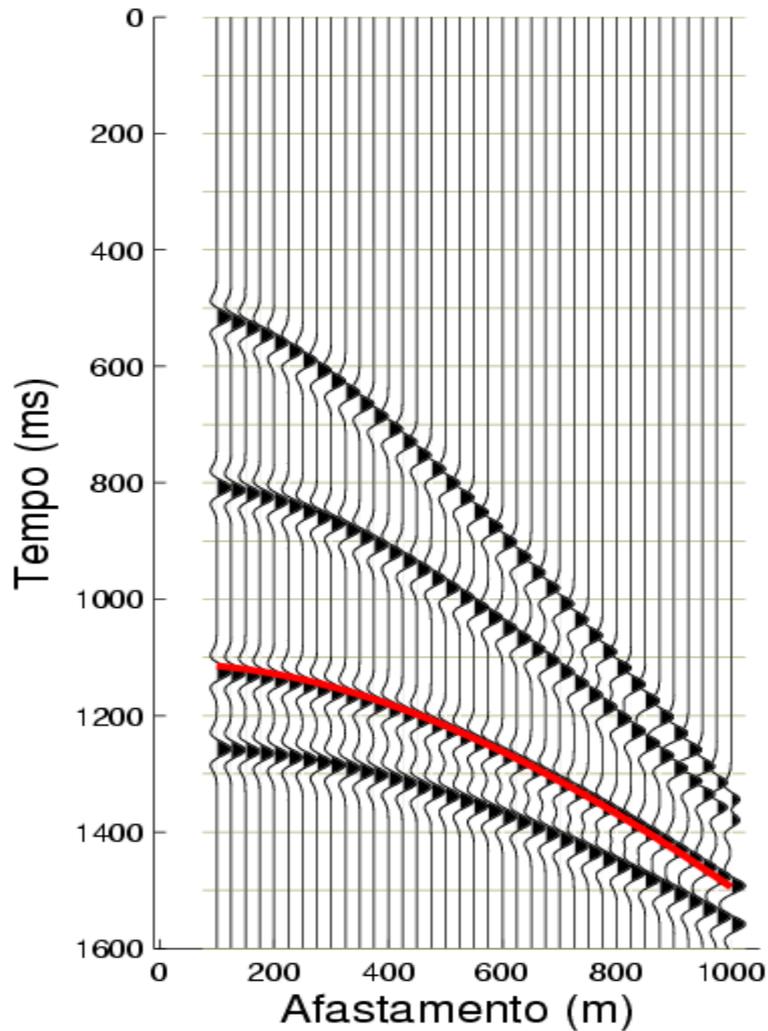
Sismograma CMP ($v=2.8$)



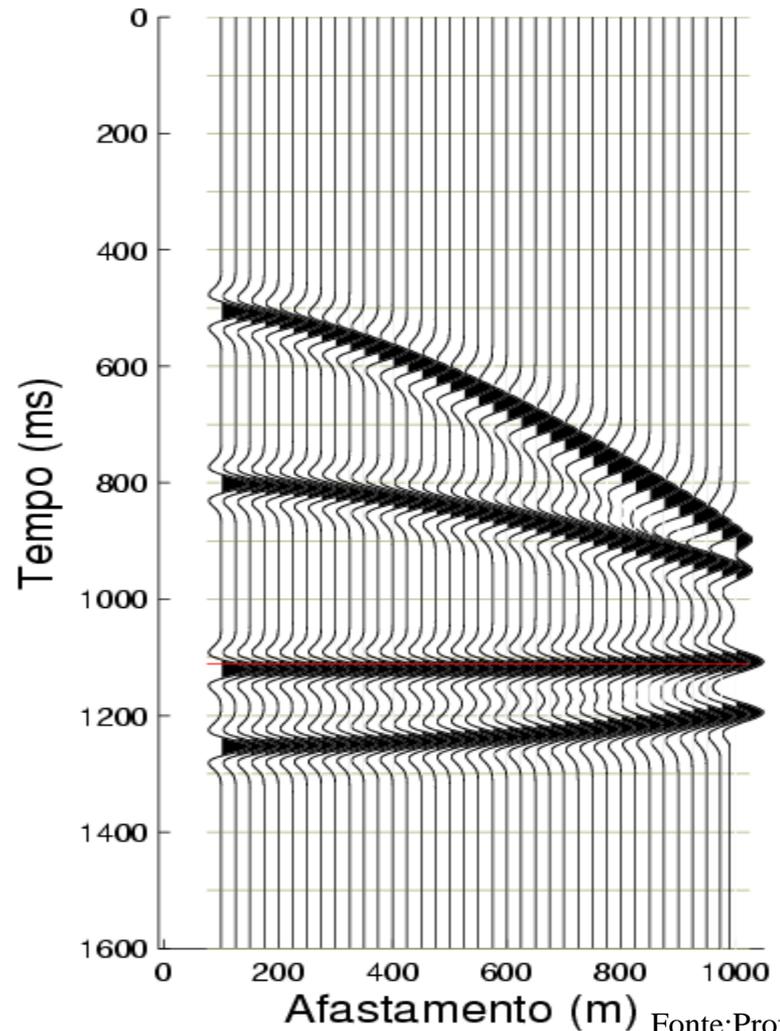
Sismograma CMP corrigido ($v=1.78$)



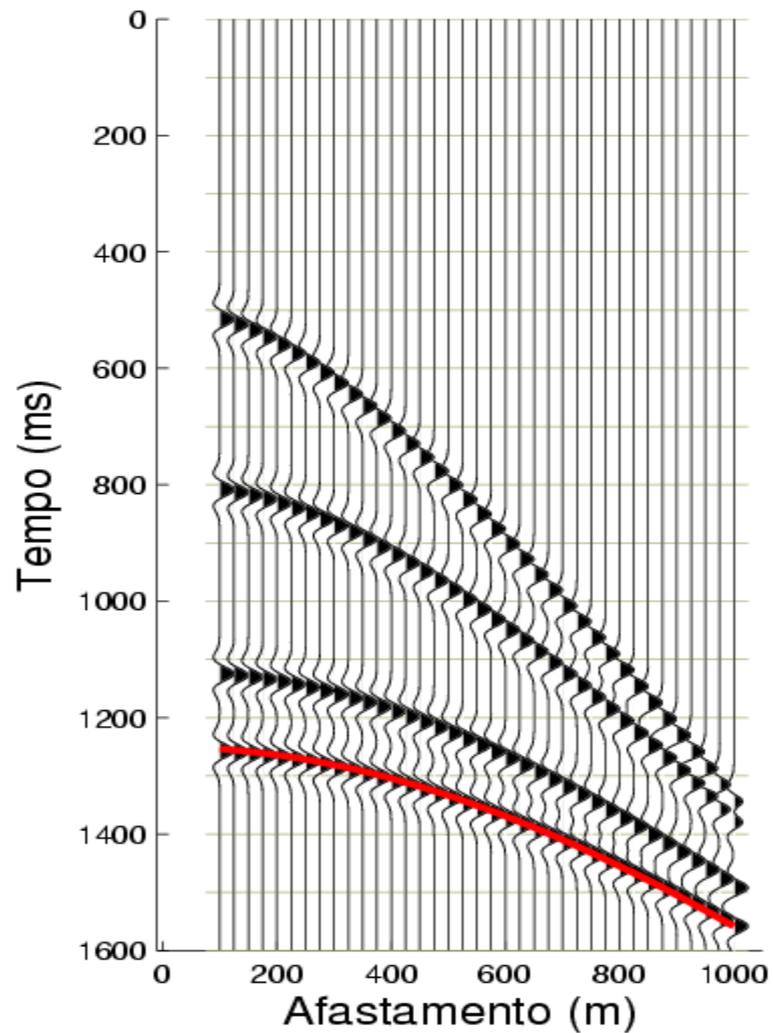
Sismograma CMP (v=2.8)



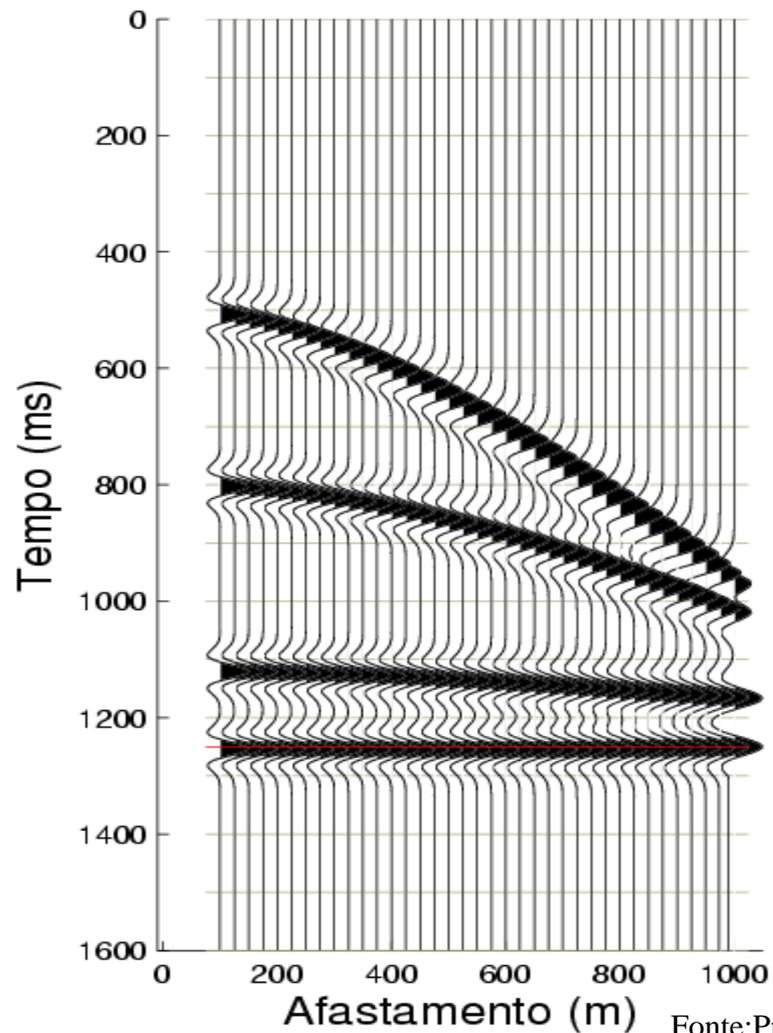
Sismograma CMP corrigido (v=2.0)



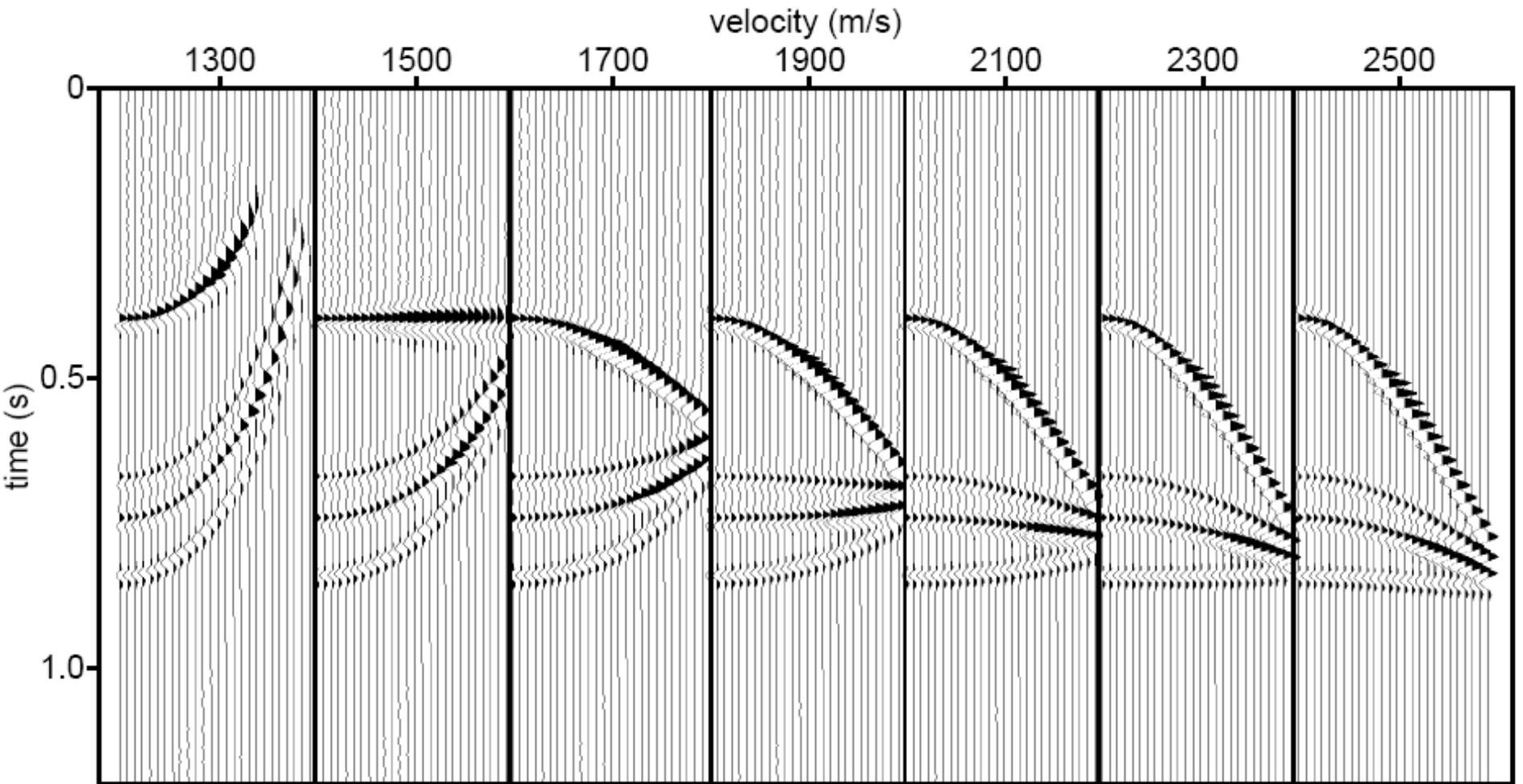
Sismograma CMP ($v=2.8$)



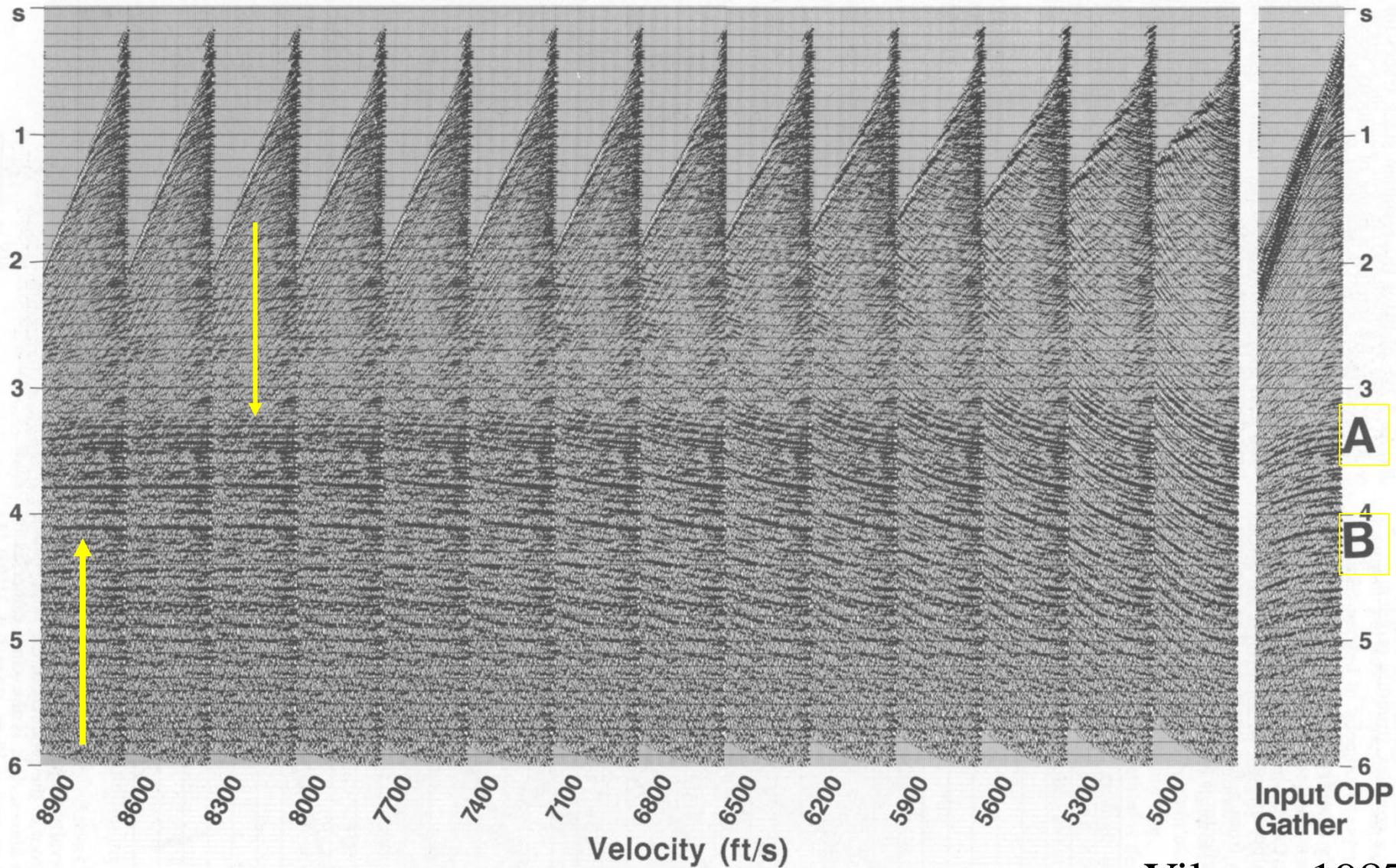
Sismograma CMP corrigido ($v=2.15$)



Panel NMO



Panel CVP (1)



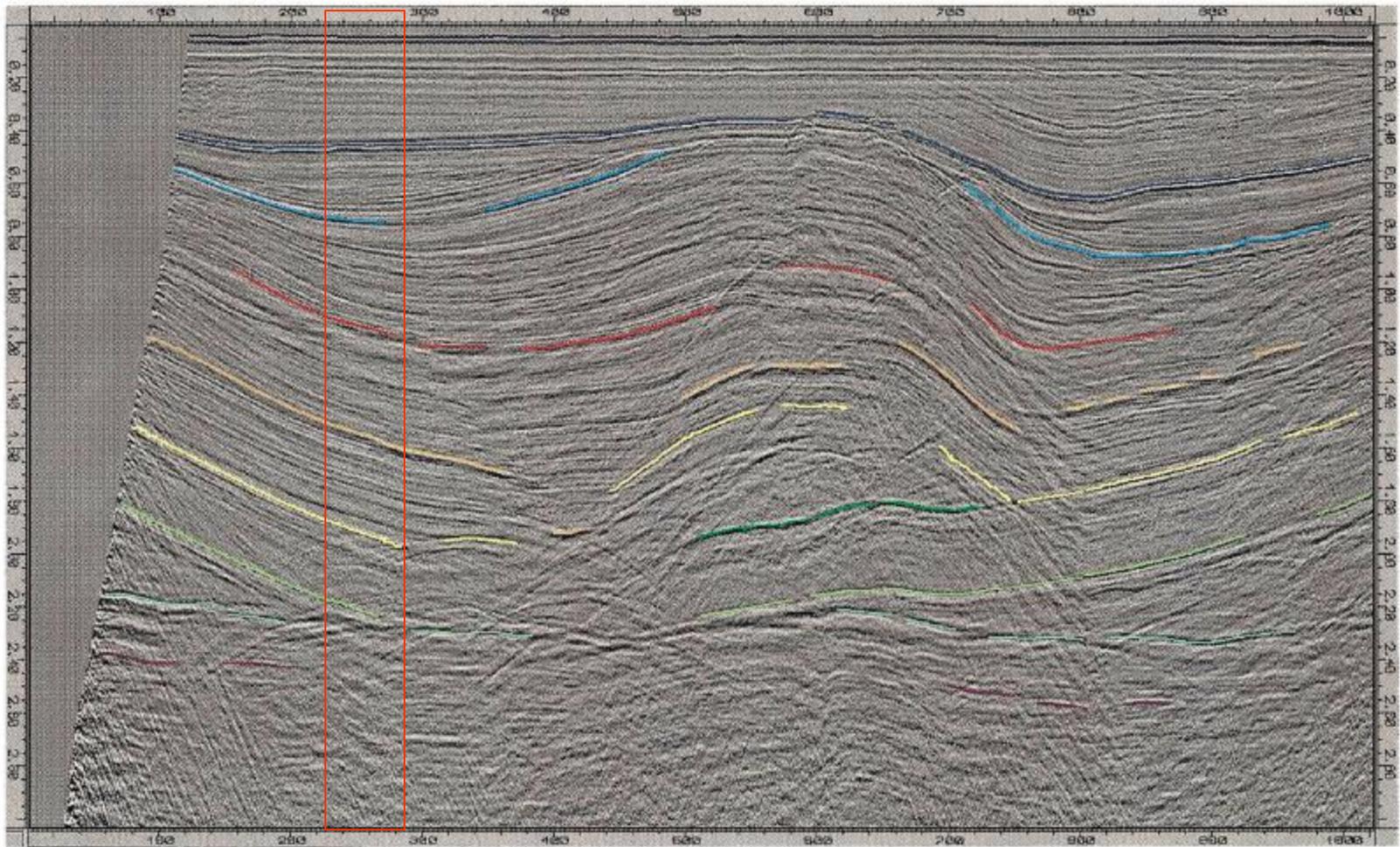
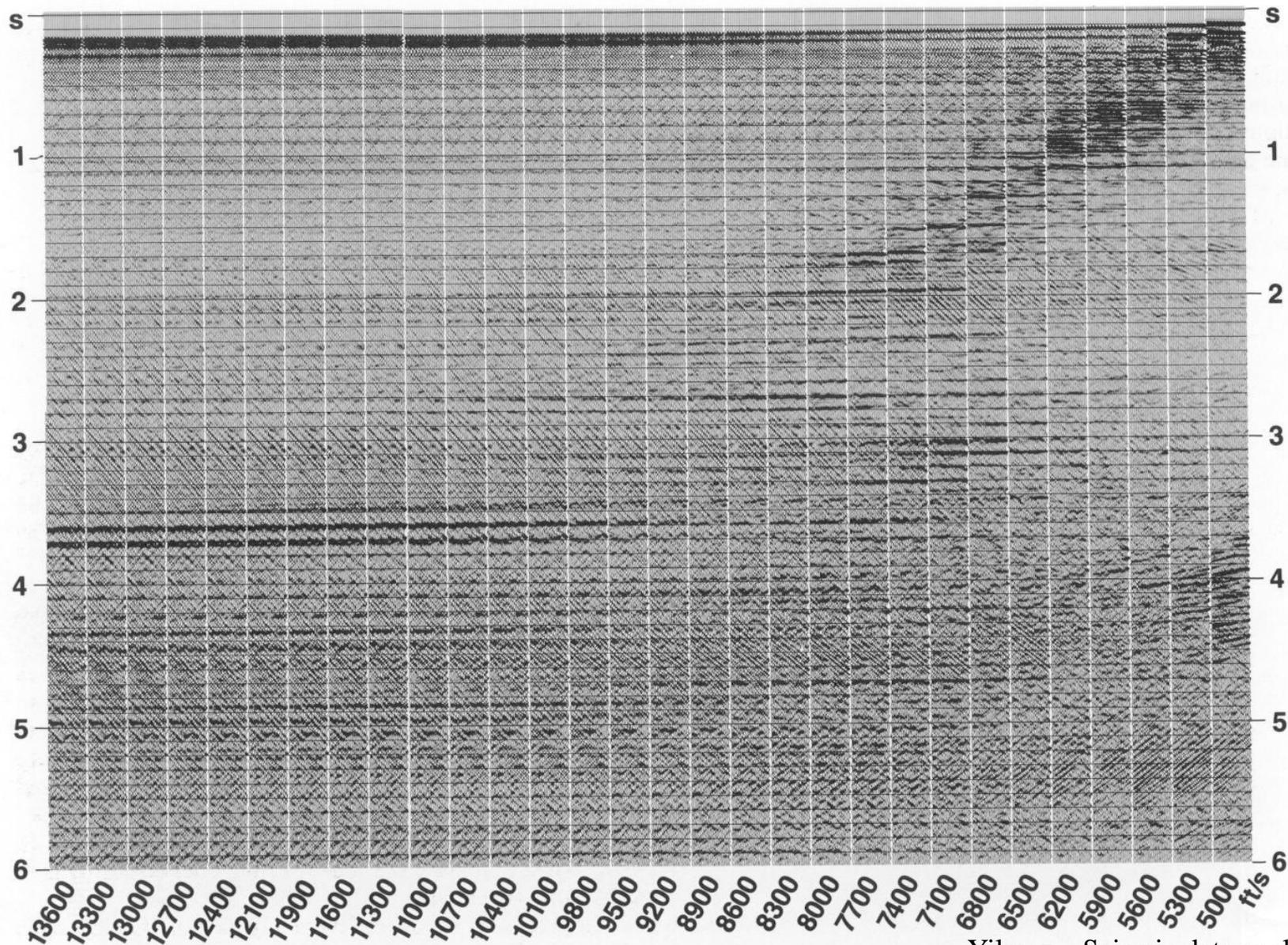
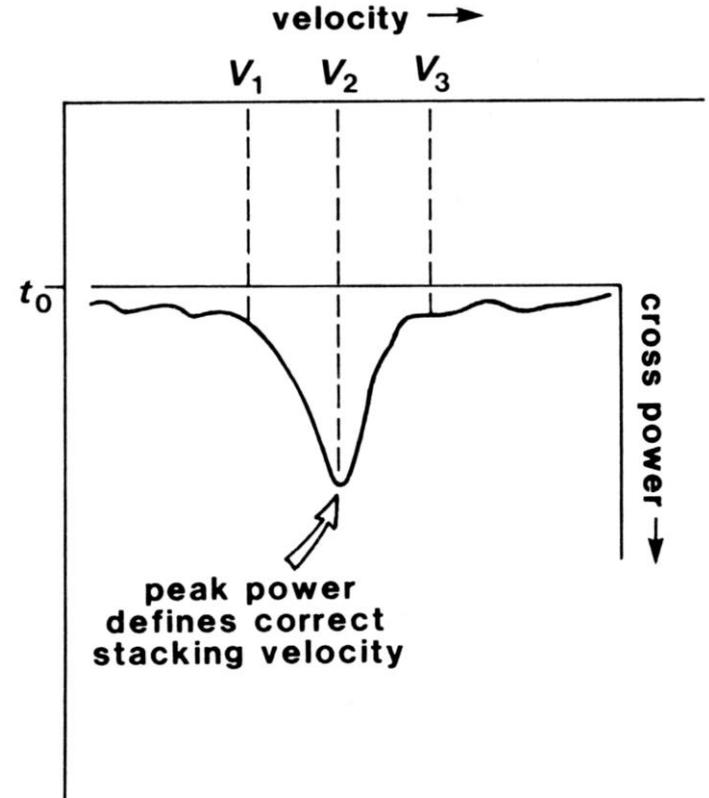
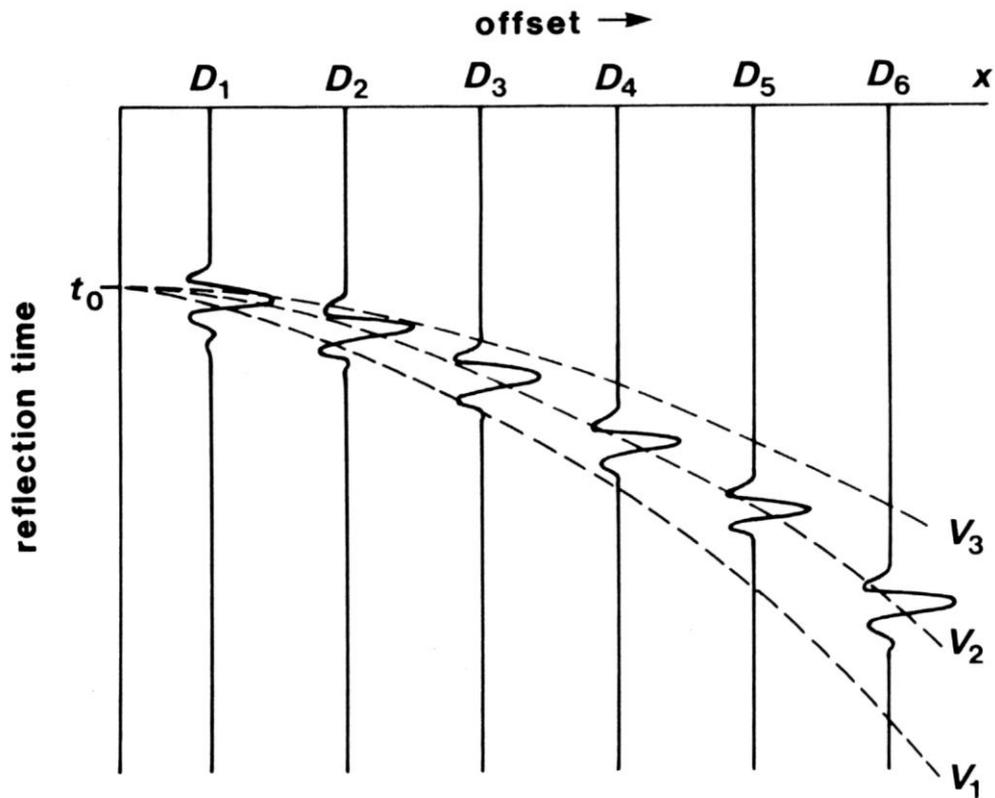


FIG. 3.2-35. A CMP-stacked section with interpreted time horizon segments associated with geological markers.

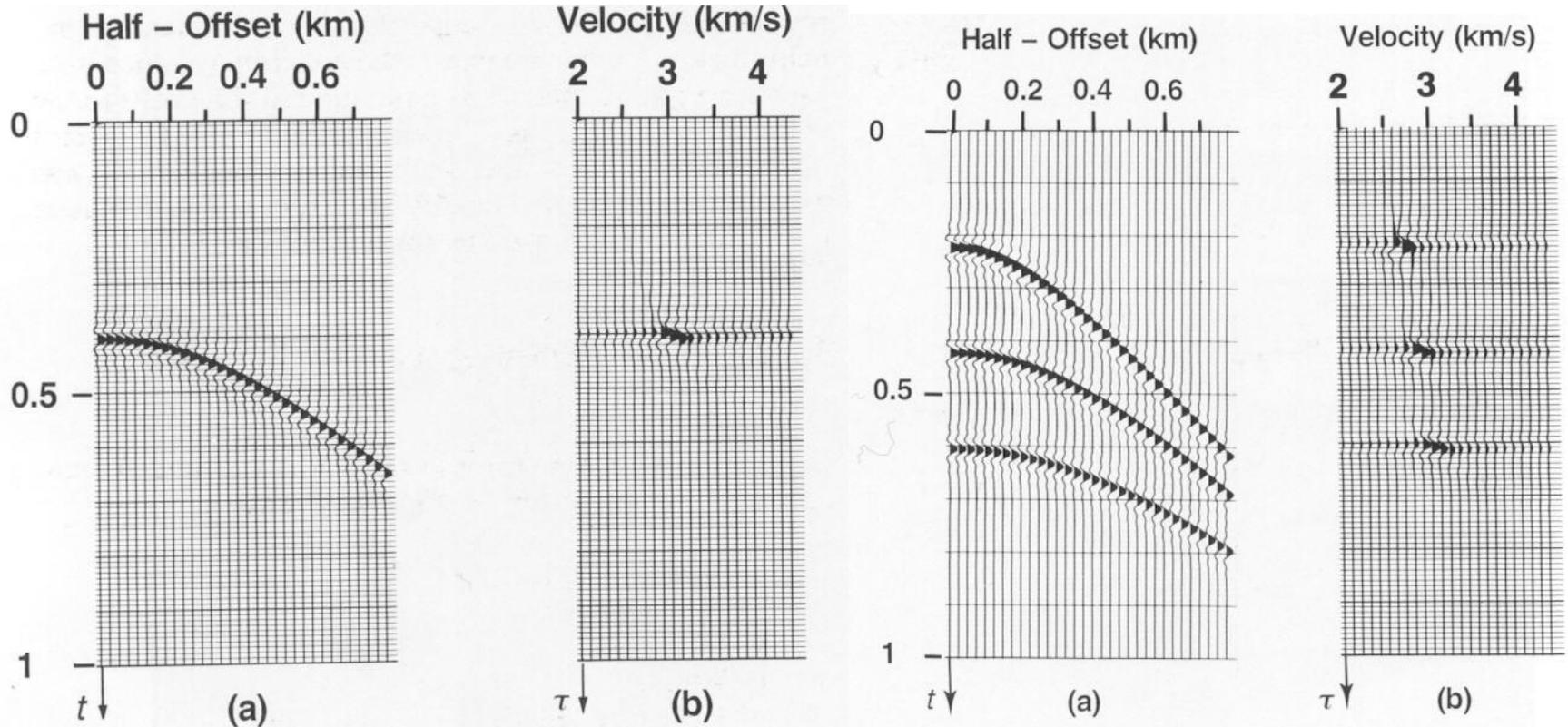
Painel CVS (empilhado) de 24 conjuntos CMP



Velocidade de empilhamento



Espectro de velocidades

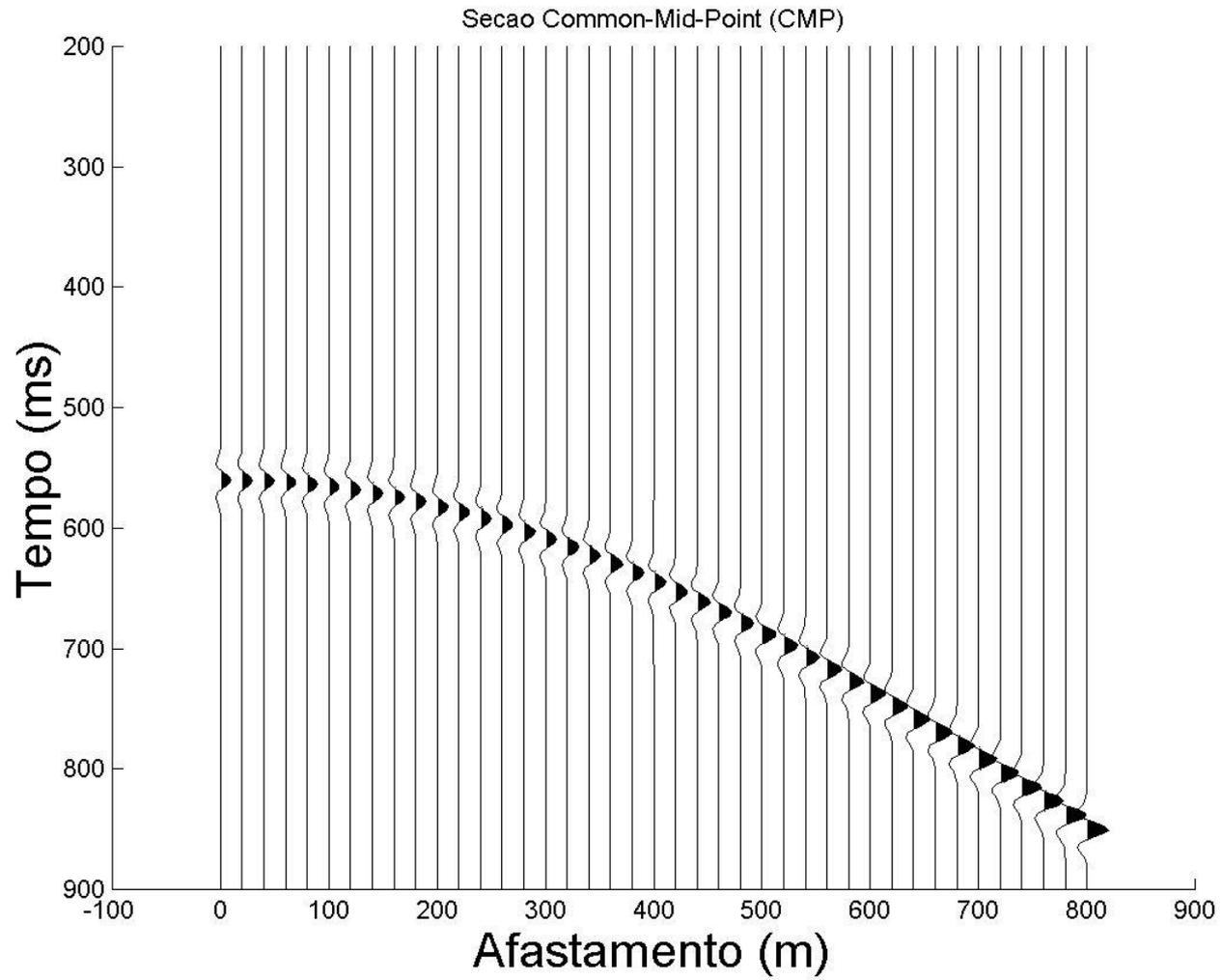


Método para calcular o espectro de velocidades

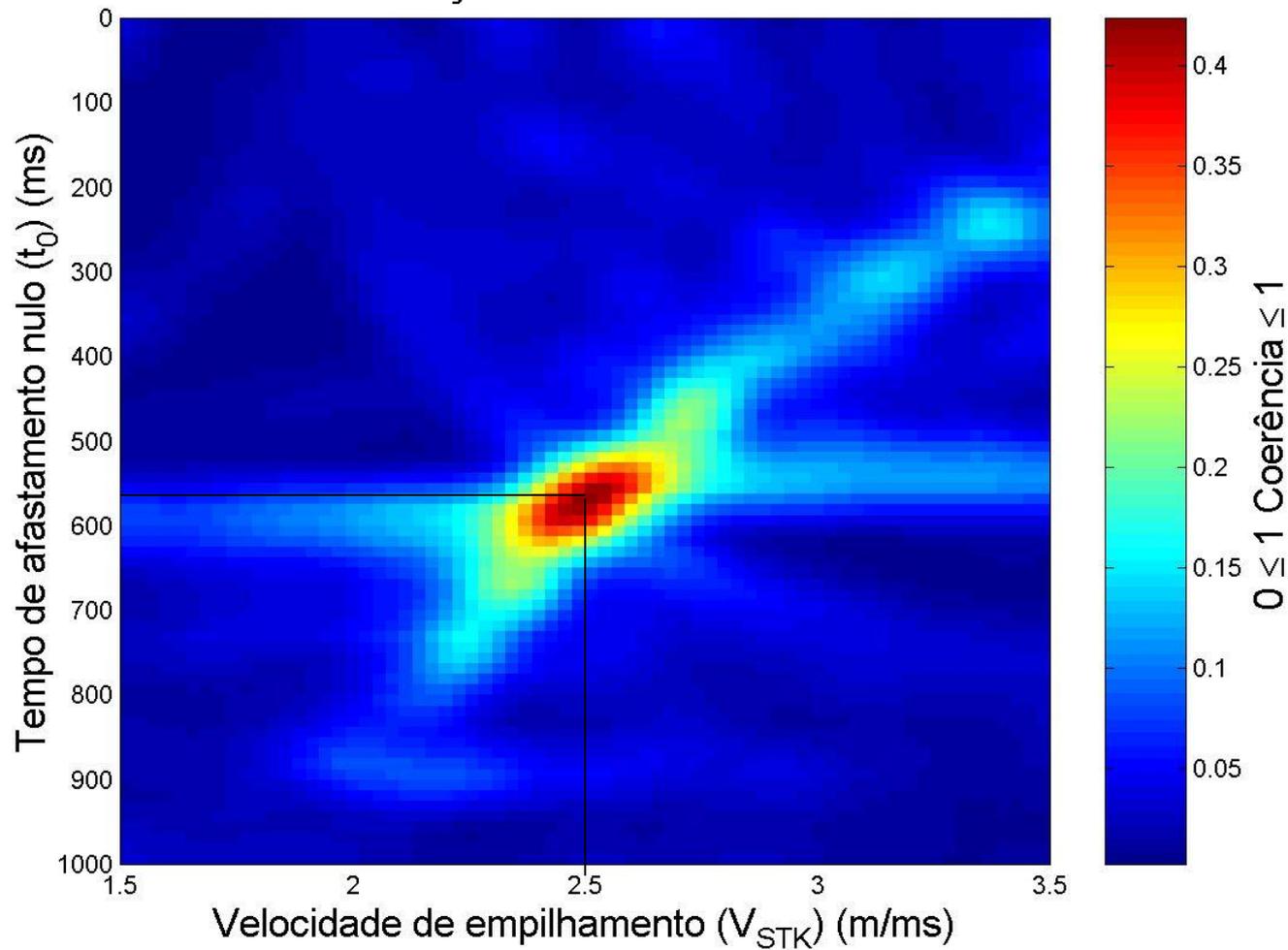
Semblance

$$\frac{1}{n} \frac{\sum_t \left(\sum_i w_{i,t} \right)^2}{\sum_t \sum_i w_{i,t}^2} = \frac{1}{n} \frac{\sum_t s_t^2}{\sum_t \sum_i w_{i,t}^2}$$

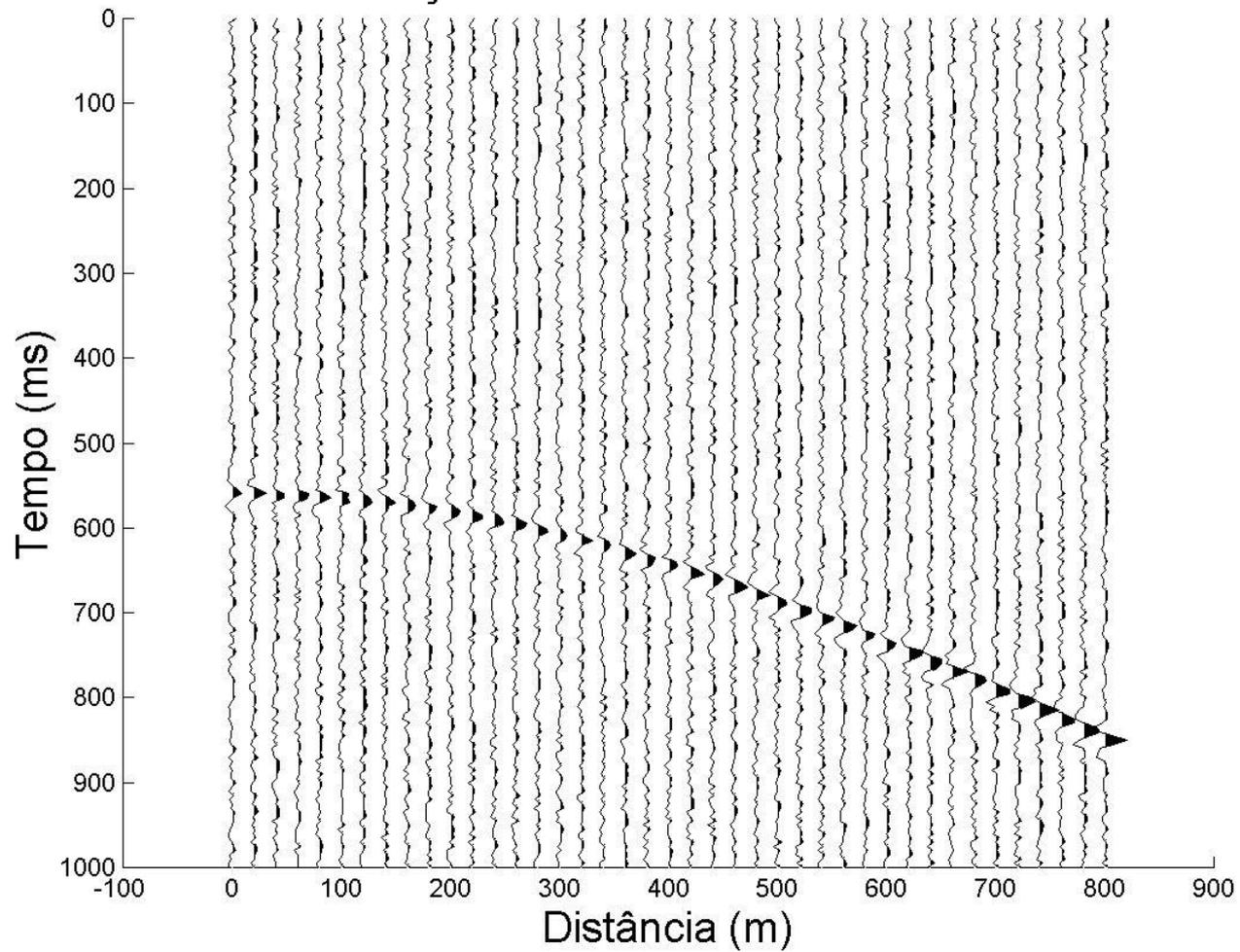
$w_{i,t}$ valor para o traço i , tempo t



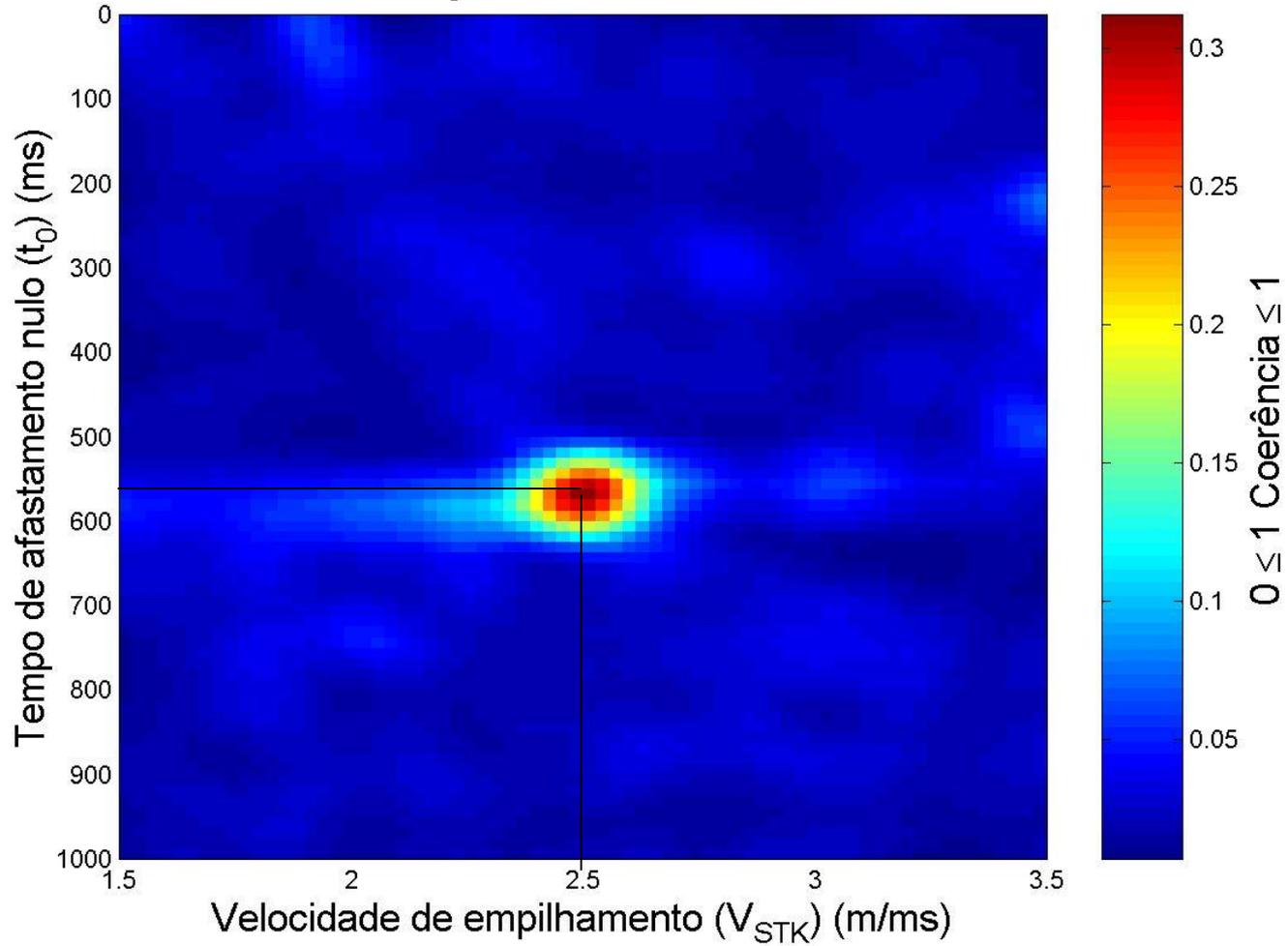
Seção de coerência



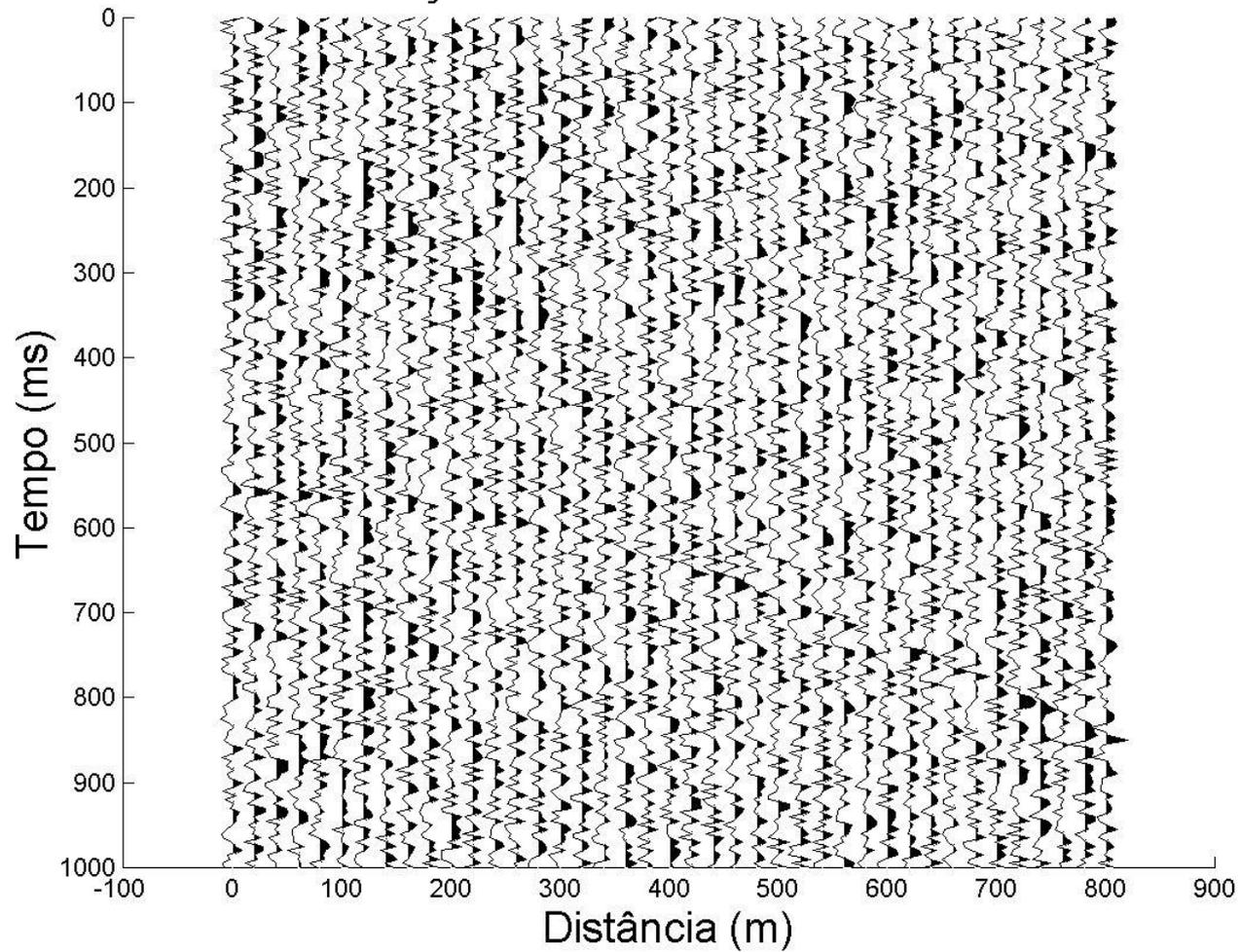
Seção CMP com 20% de ruído



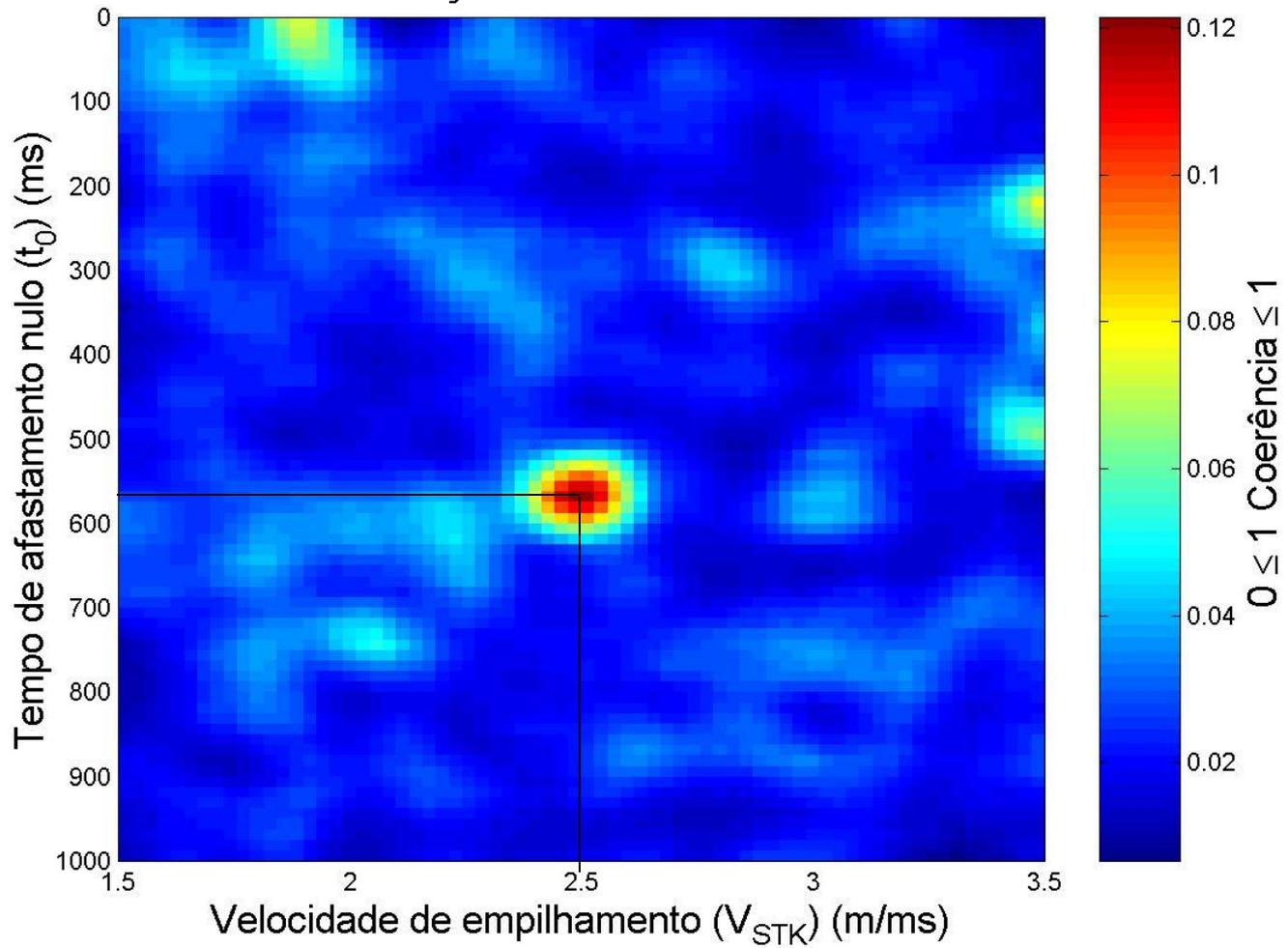
Seção de coerência



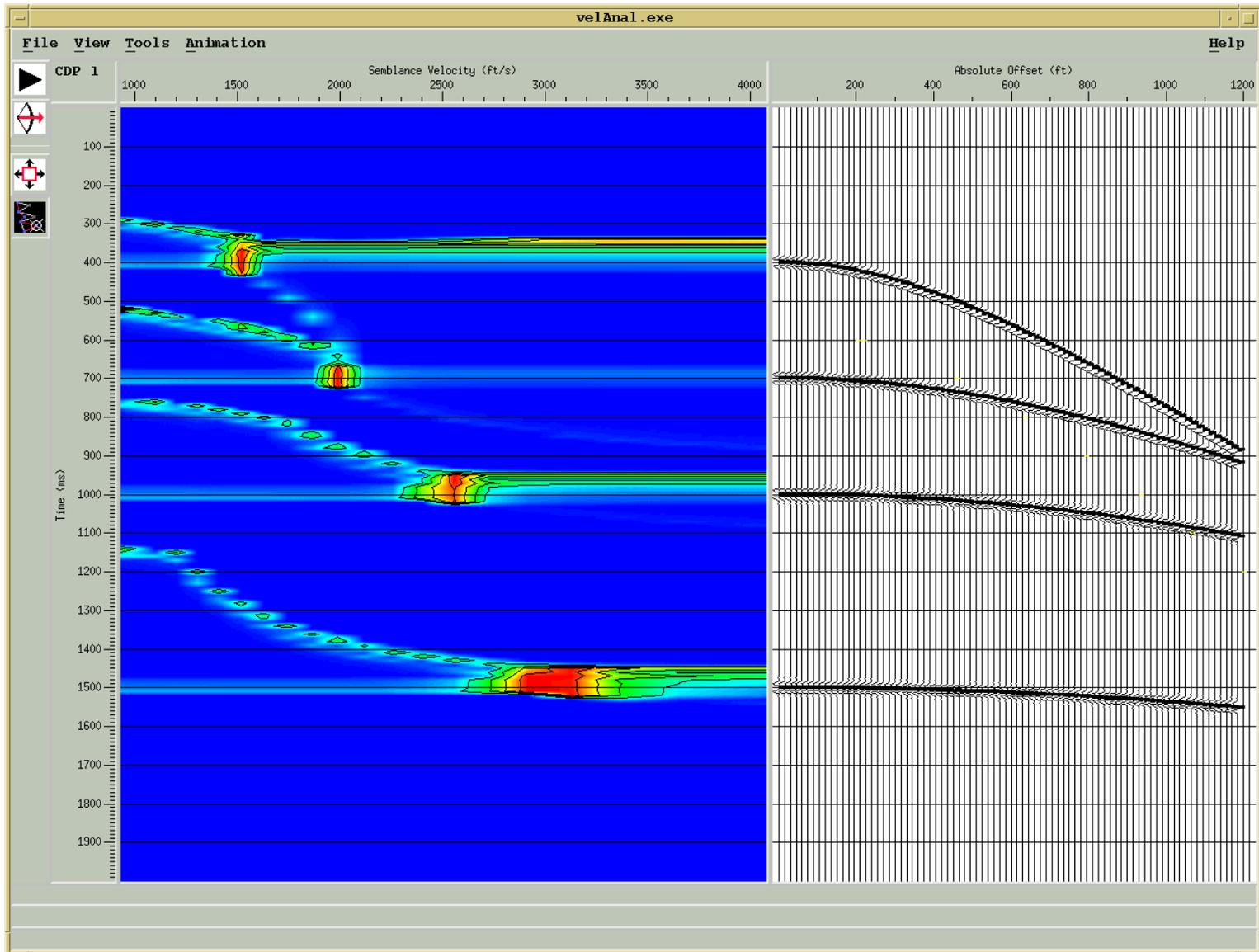
Seção CMP com 90% de ruído

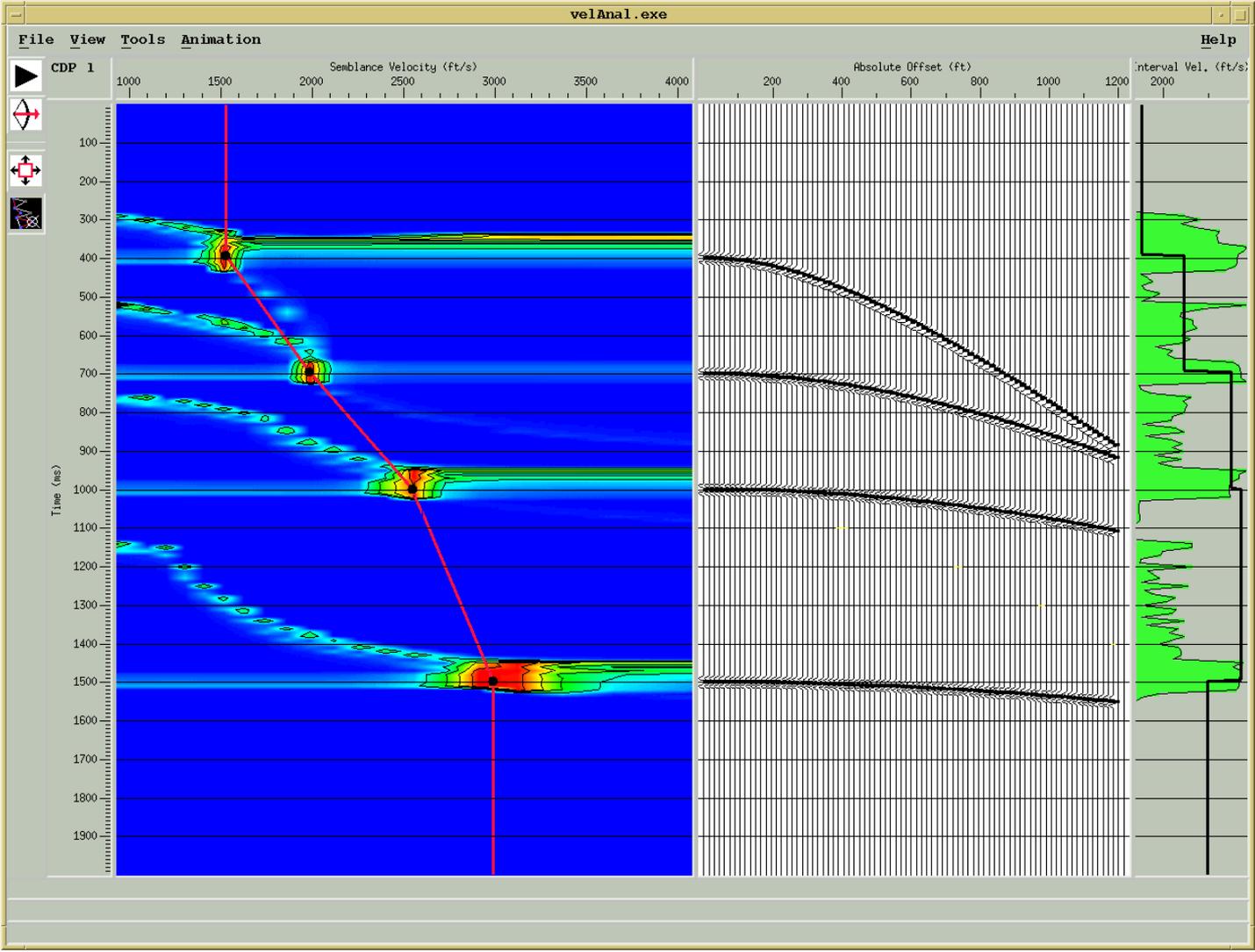


Seção de coerência

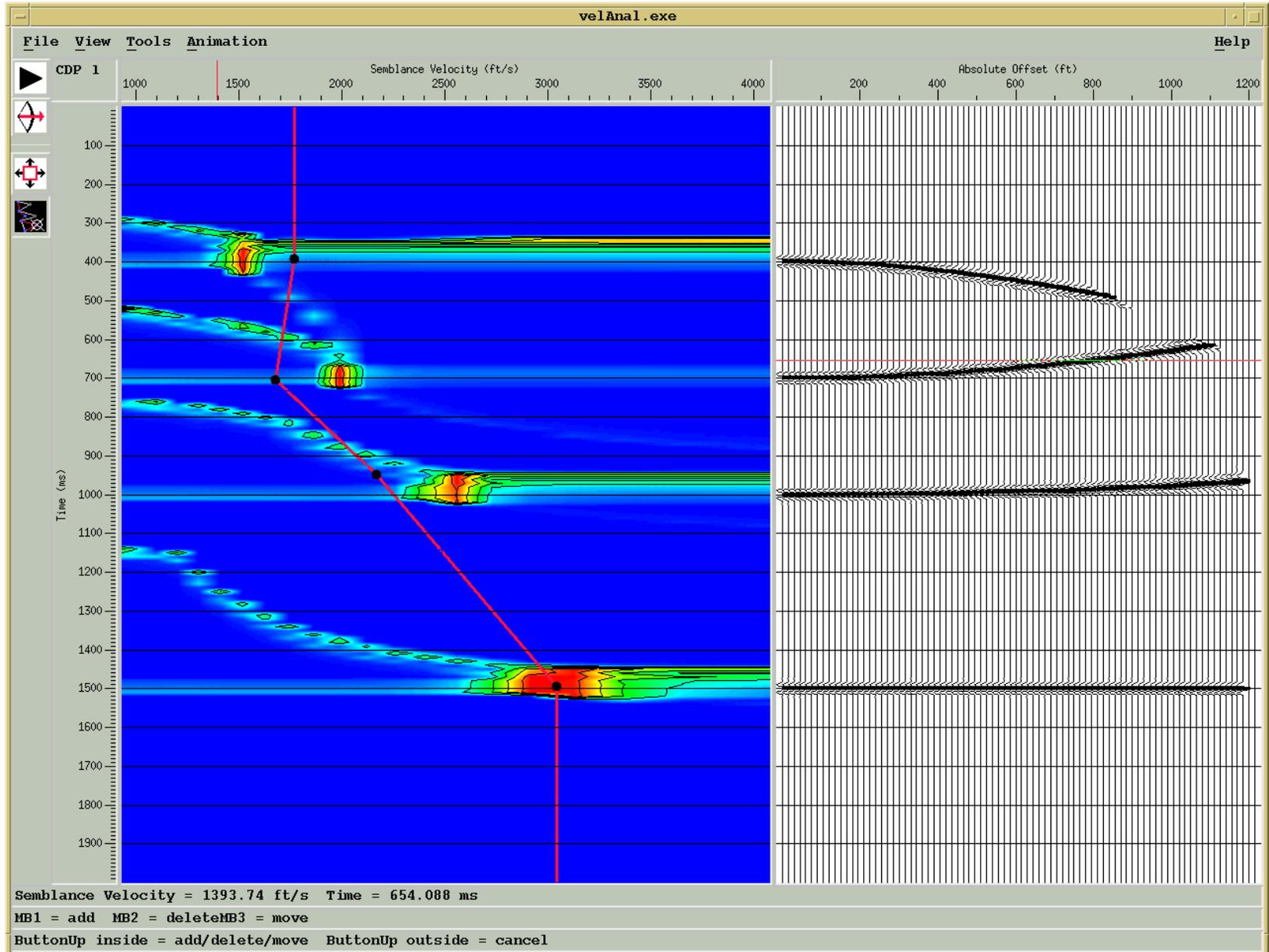


Semblance

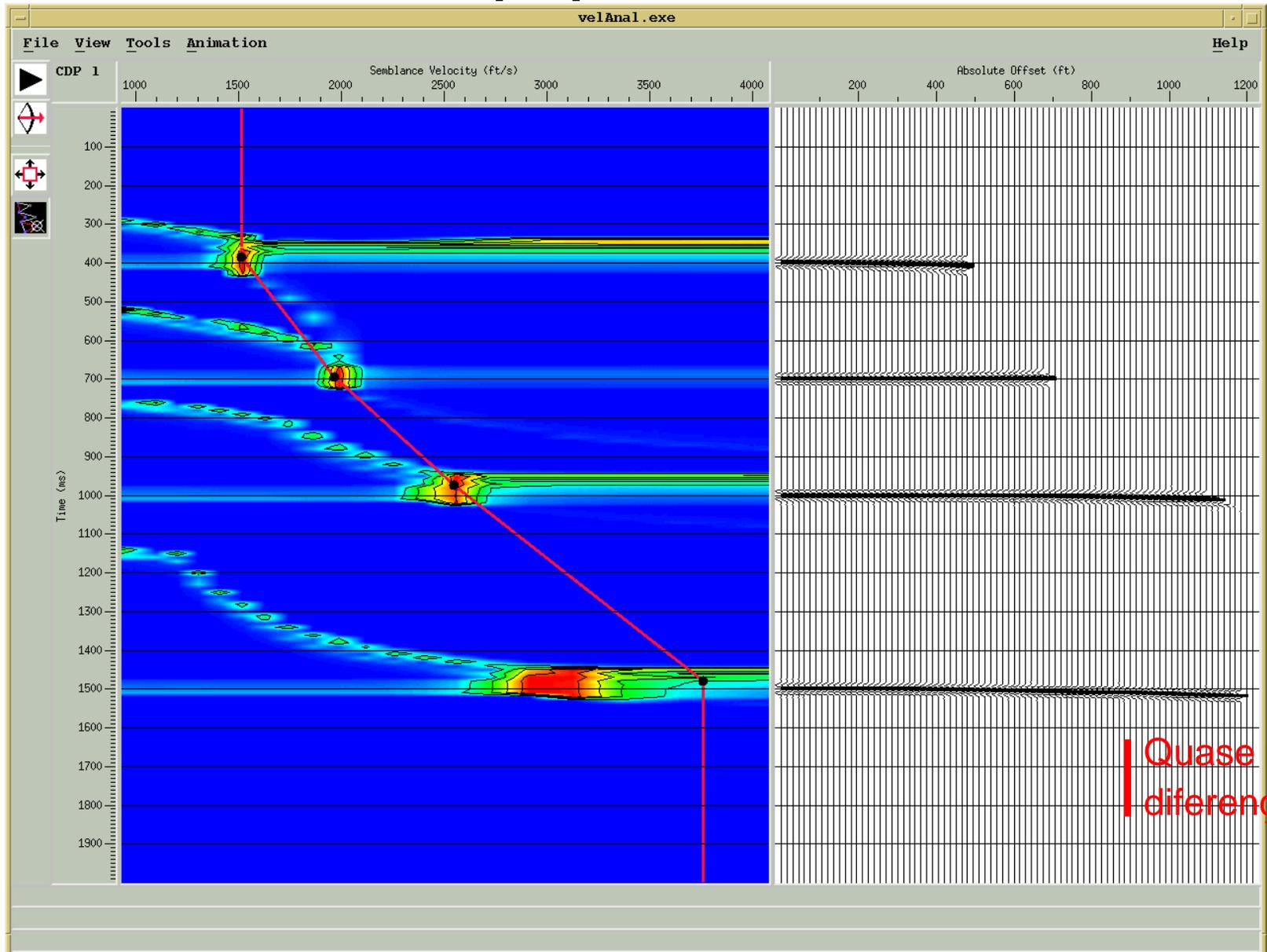




Resultado usando velocidades incorrectas



Erros para altas velocidades e tempos de trajetórias pequenos



Fatores que afetam as estimativas das velocidades

- Profundidade dos refletores
- Move-out da reflexão
- Comprimento do arranjo
- Relação S/R