



UNIVERSIDADE FEDERAL DO PARÁ
INSTITUTO DE GEOCIÊNCIAS
PROGRAMA DE PÓS-GRADUAÇÃO EM GEOFÍSICA
QUALIFICAÇÃO DE DOUTORADO

Inversão do modelo de velocidades no domínio ERC utilizando as aproximações de tempo de trânsito SRC não hiperbólico

Autor: Rodolfo André Cardoso Neves

Orientador: Prof.Dr. João Carlos Cruz

Inversão do modelo de velocidades no domínio ERC utilizando as aproximações de tempo de trânsito SRC não hiperbólico

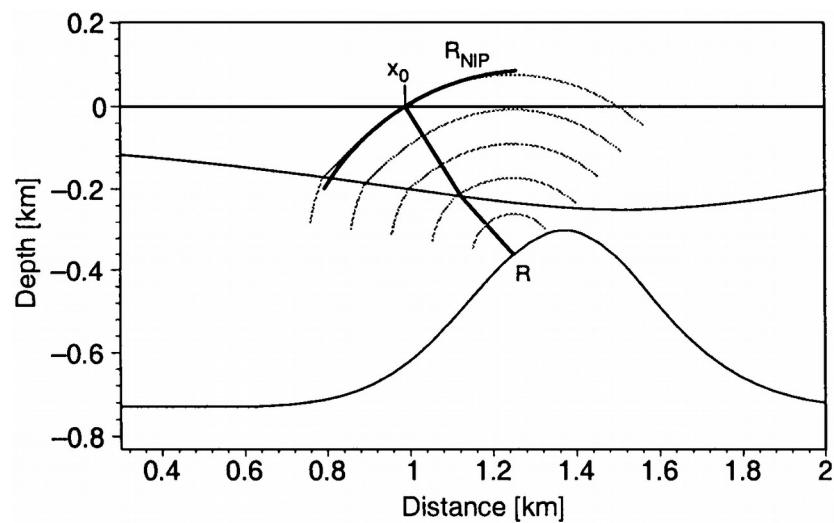
RELATÓRIO DE QUALIFICAÇÃO DE DOUTORADO

Relatório apresentado ao Programa de Pós-Graduação
em Geofísica do Instituto de Geociências da Universidade
Federal do Pará, em cumprimento às exigências para
obtenção do grau de Doutor em Geofísica.

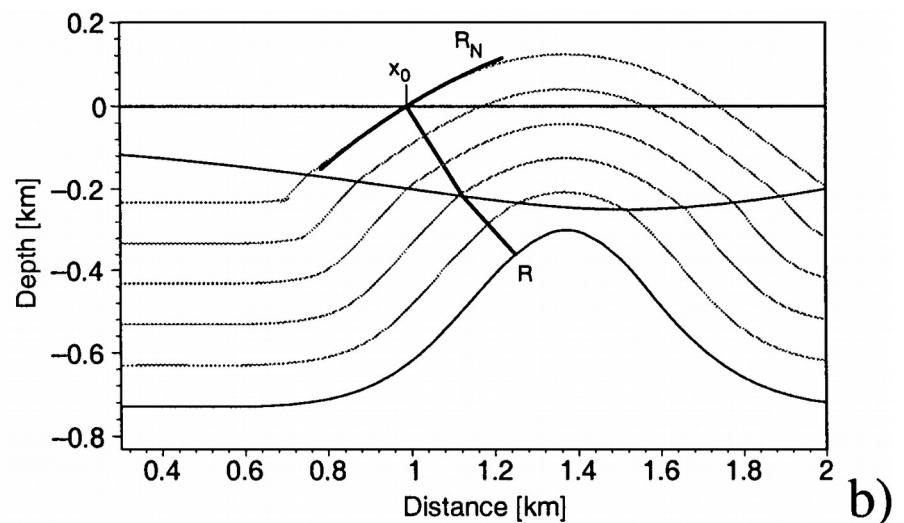
Orientador: Prof. Dr. João Carlos Ribeiro Cruz

Belém-Pará
2020

Método Superfície de reflexão comum (SRC)



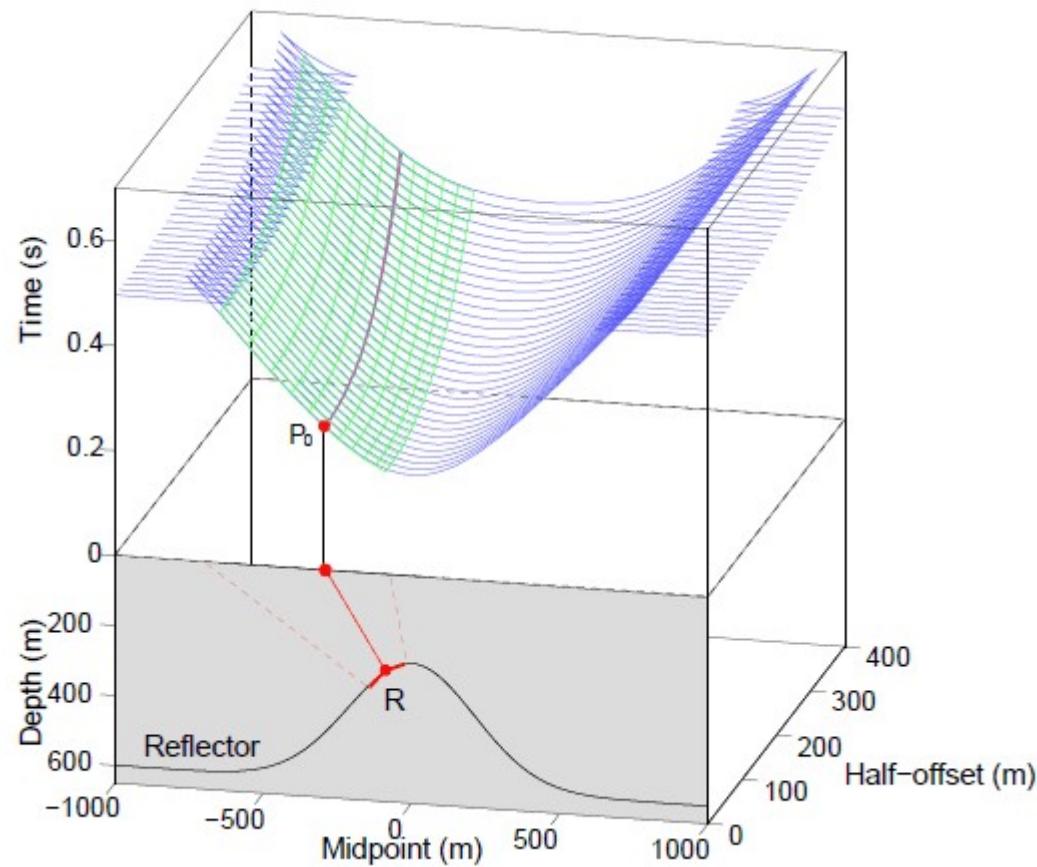
a)



b)

Fonte: (JAGER et al, 2001).

Método Superfície de reflexão comum (SRC)



Aproximação de tempo SRC não hiperbólica

$$\Phi_{CRS}(h, d; t_0) = \sqrt{\frac{F(d) + ch^2 + \sqrt{F(d-h)F(d+h)}}{2}}$$

$$c = 2b_2 + a_1^2 - a_2$$

$$F(d-h) = (t_0 + a_1(d-h))^2 + a_2(d-h)^2$$

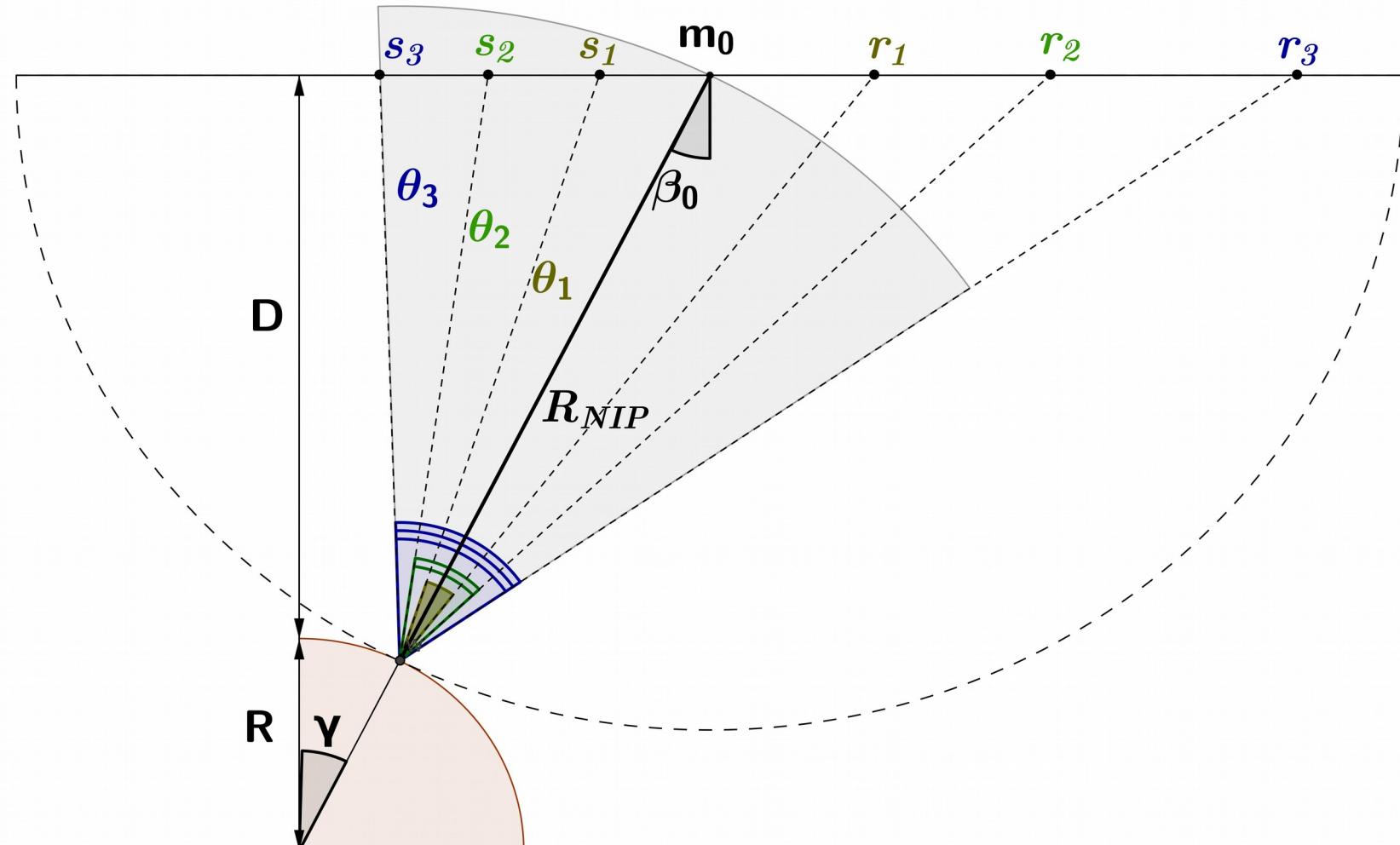
$$F(d+h) = (t_0 + a_1(d+h))^2 + a_2(d+h)^2$$

$$a_1 = \frac{2 \sin(\beta_0)}{v_0}$$

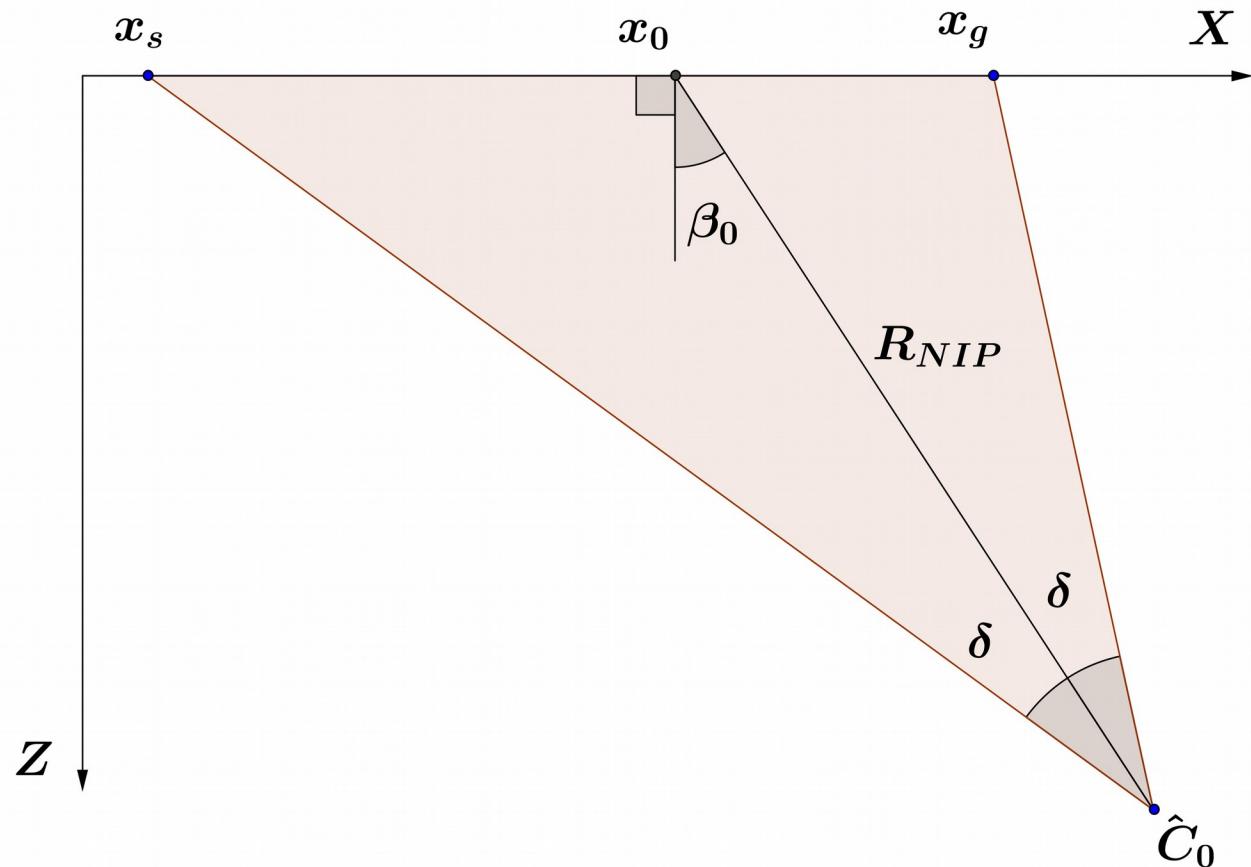
$$a_2 = \frac{2 \cos^2(\beta_0)t_0}{R_N v_0}$$

$$b_2 = \frac{2 \cos^2(\beta_0)t_0}{R_{NIP} v_0}$$

Método Elemento de reflexão comum (ERC)



Método Elemento de reflexão comum (ERC)

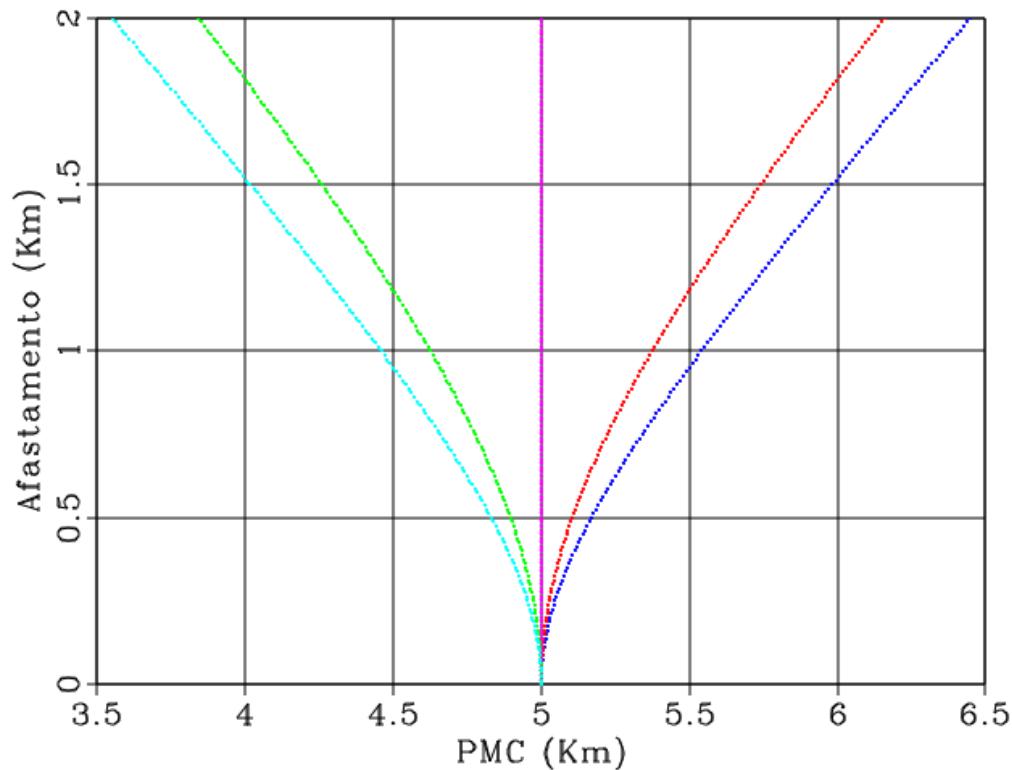


Equações de tempo ERC

$$m = m_0 + \frac{1}{2\alpha} (1 - \sqrt{1 + 4\alpha^2 h^2})$$

$$\begin{aligned} t(m, h) &= \left(\tau_0 - \frac{2R_{NIP}}{v_0} \right) \\ &+ \frac{R_{NIP}}{v_0} \sqrt{1 - 2\alpha(m - m_0 + h) + \frac{(m - m_0 + h)^2}{R_{NIP}^2}} \\ &+ \frac{R_{NIP}}{v_0} \sqrt{1 - 2\alpha(m - m_0 - h) + \frac{(m - m_0 - h)^2}{R_{NIP}^2}} \end{aligned}$$

Parâmetro de assimetria (alfa)



$$\alpha = \frac{\sin \beta_0}{R_{NIP}}$$

O problema da bola de tênis e da folha de papel

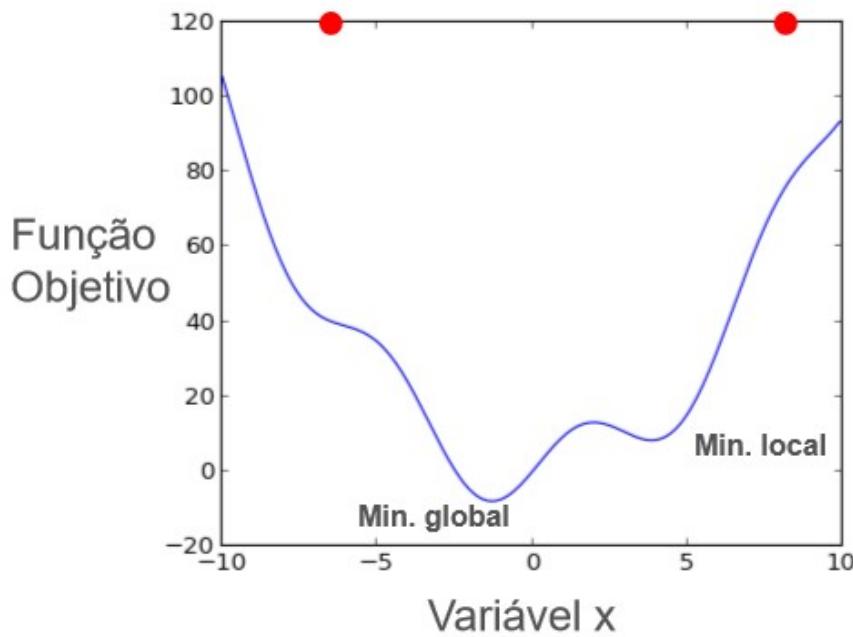


$$\Theta(\alpha, \beta, \gamma)$$



Fonte: <https://pixabay.com/>

Otimização dos parâmetros do SRC com o Very Fast Simulated Annealing (VFSA)



Para atualizar utilize o critério probabilístico de aceitação (critério de Metropolis):

$$P = \exp\left(\frac{-\Delta E}{T}\right);$$

se $\Delta E \leq 0$ então

 Atualize:

$$m_0 = m_{new};$$

$$E(m_0) = E(m_{new});$$

fim

se $\Delta E > 0$ então

 Escreva um numero aleatório $r = U[0, 1]$;

 se $P > 0$ então

 Atualize:

$$m_0 = m_{new};$$

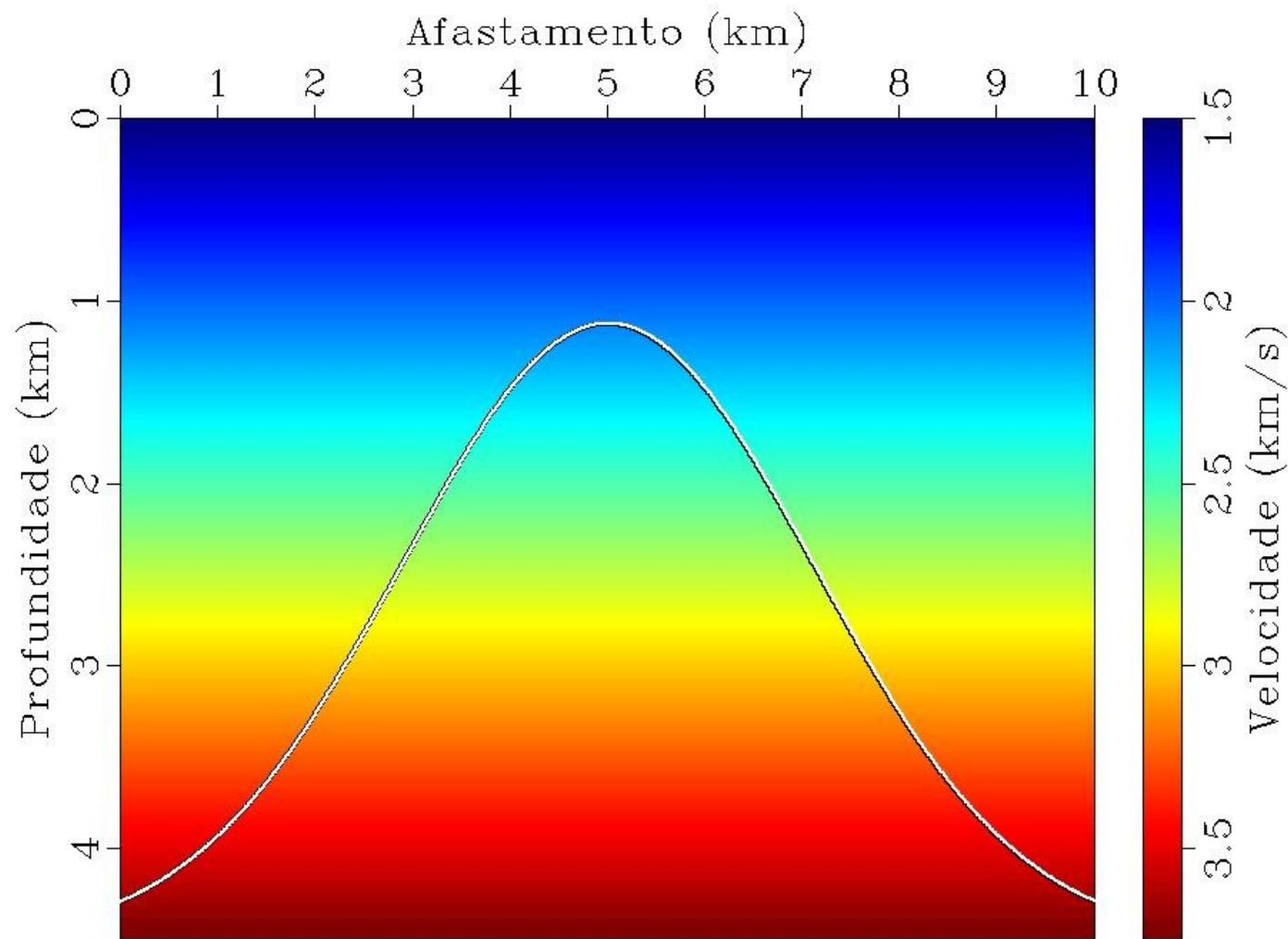
$$E(m_0) = E(m_{new});$$

fim

fim

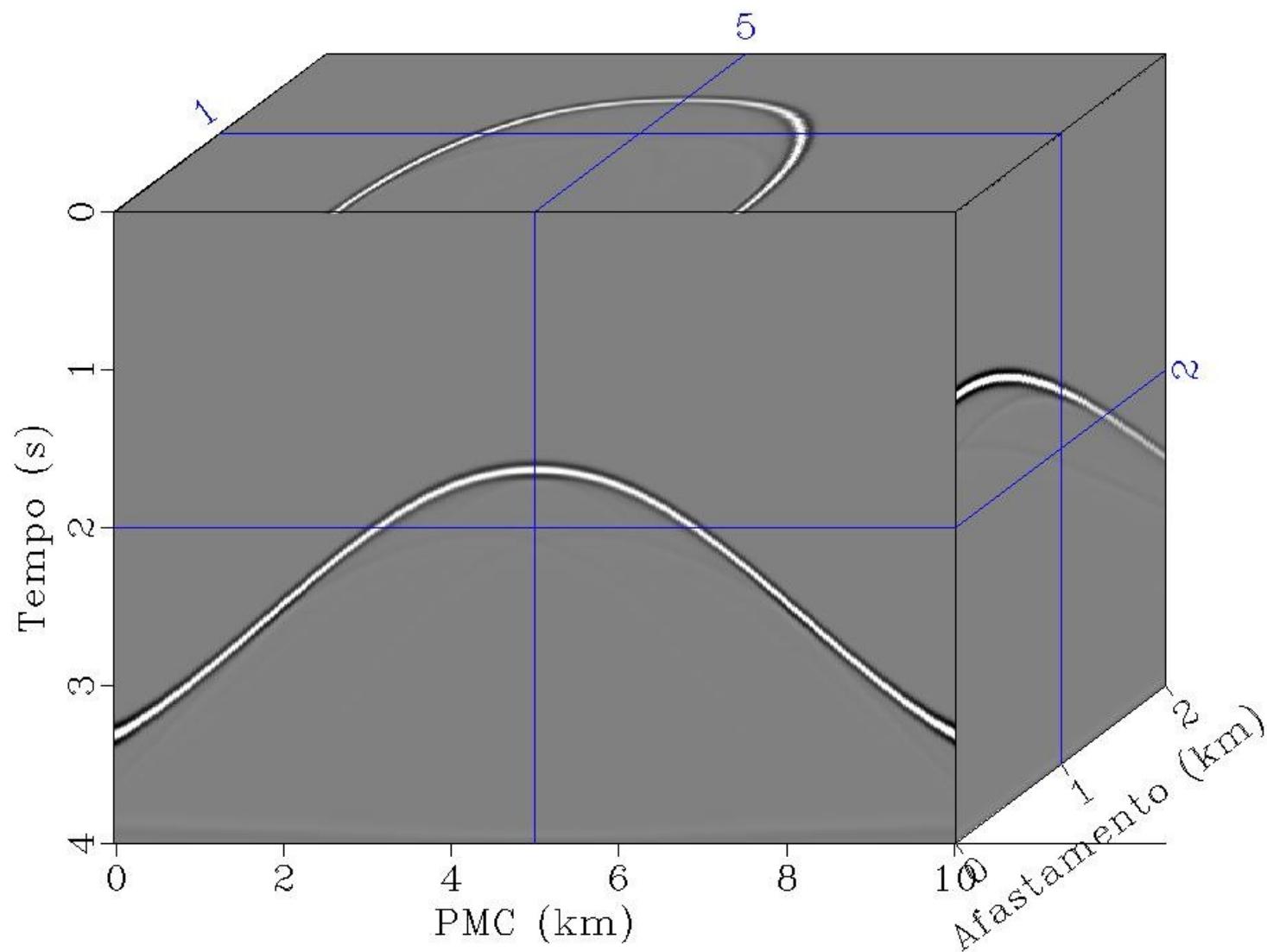
Fonte: <https://altairuniversity.com/>

Modelo do refletor gaussiano

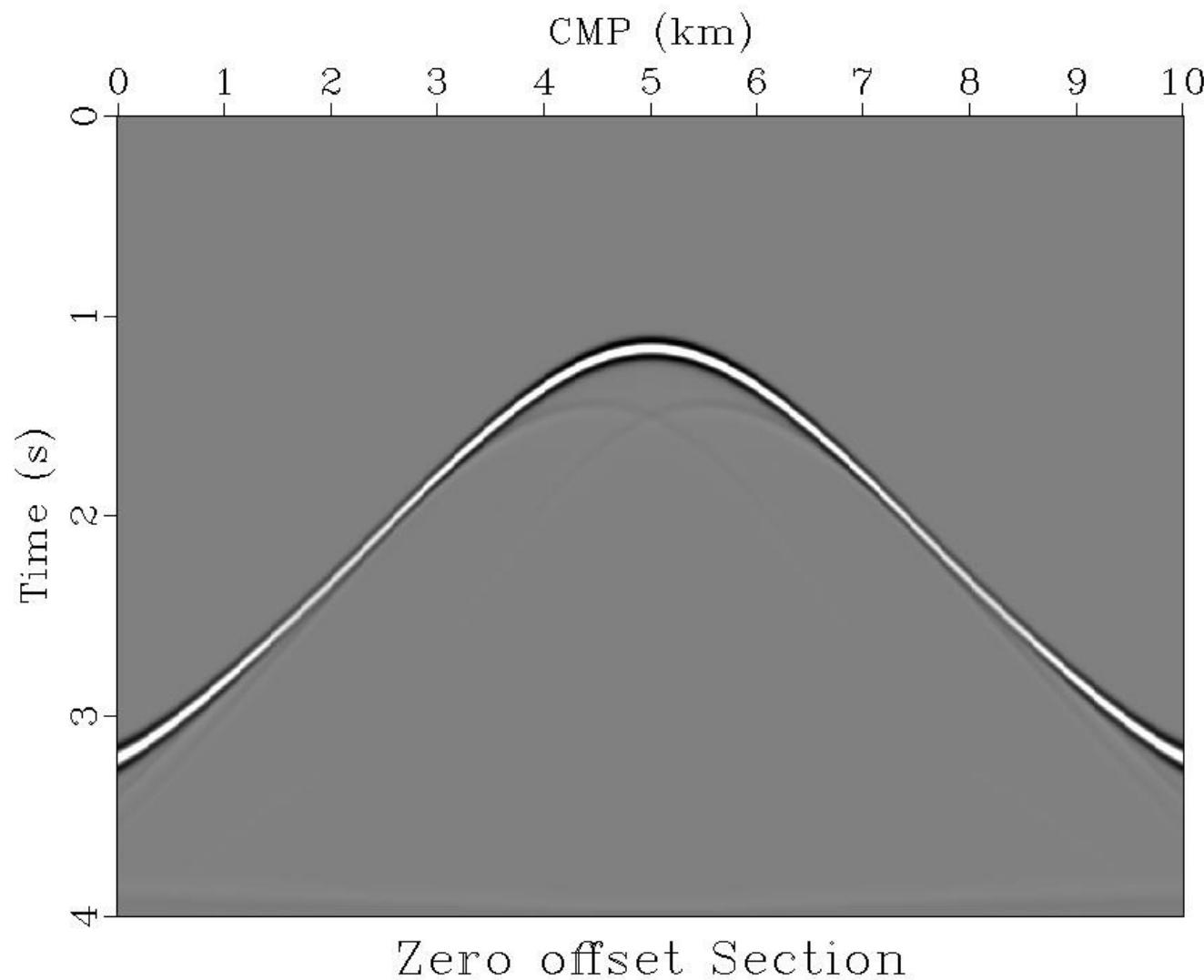


O “cubo de dados”

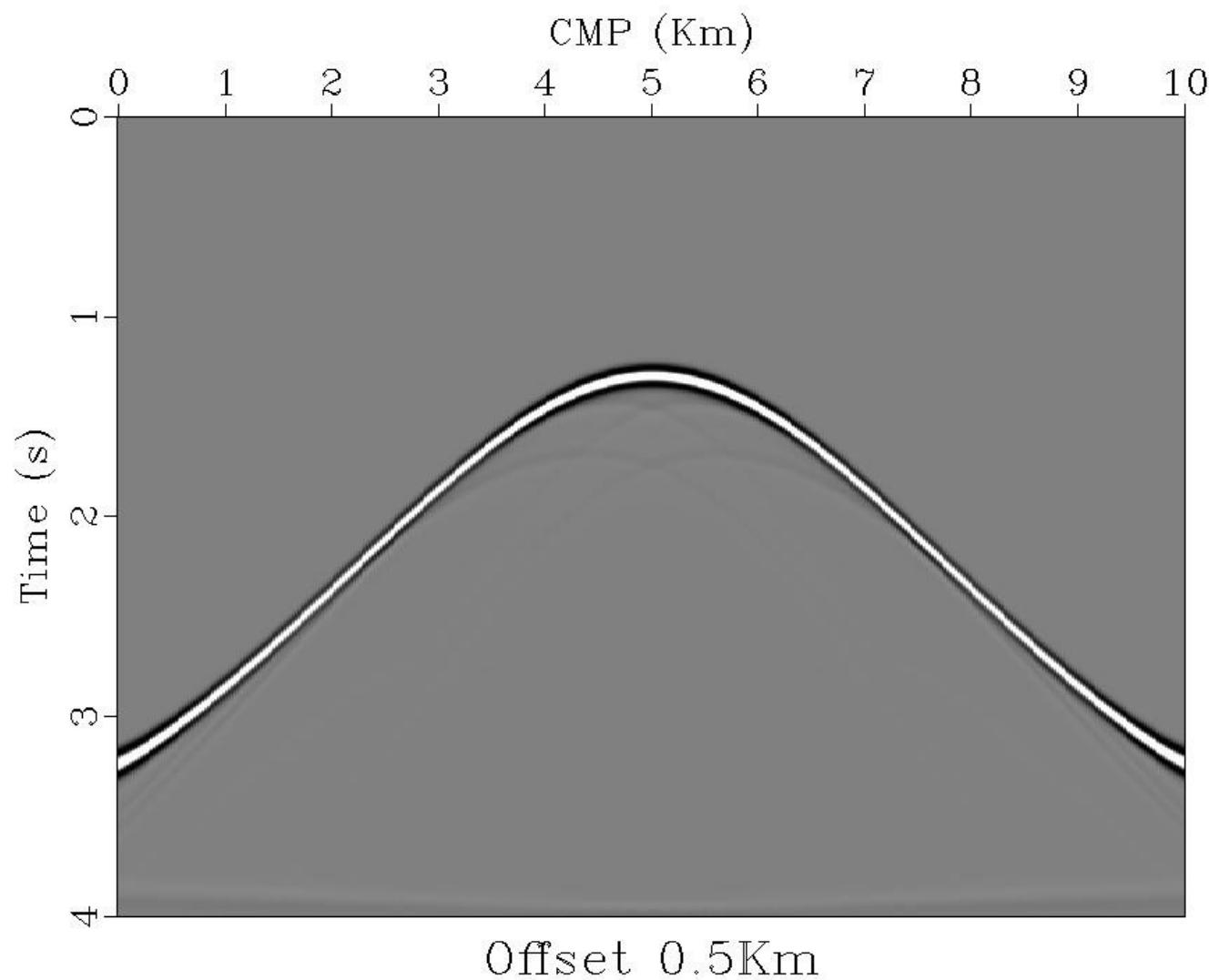
Cubo de dados modelado



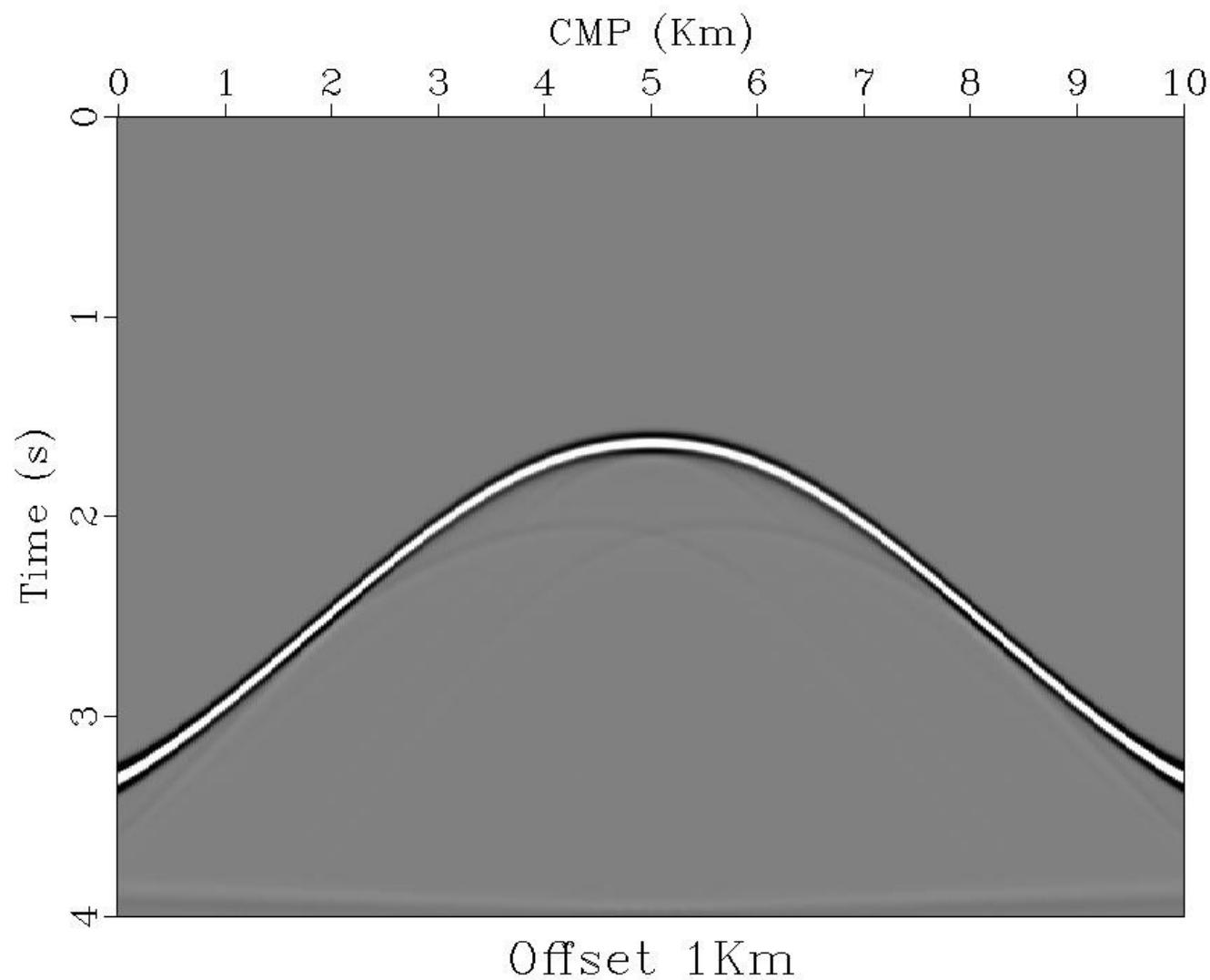
Seção de afastamento nulo



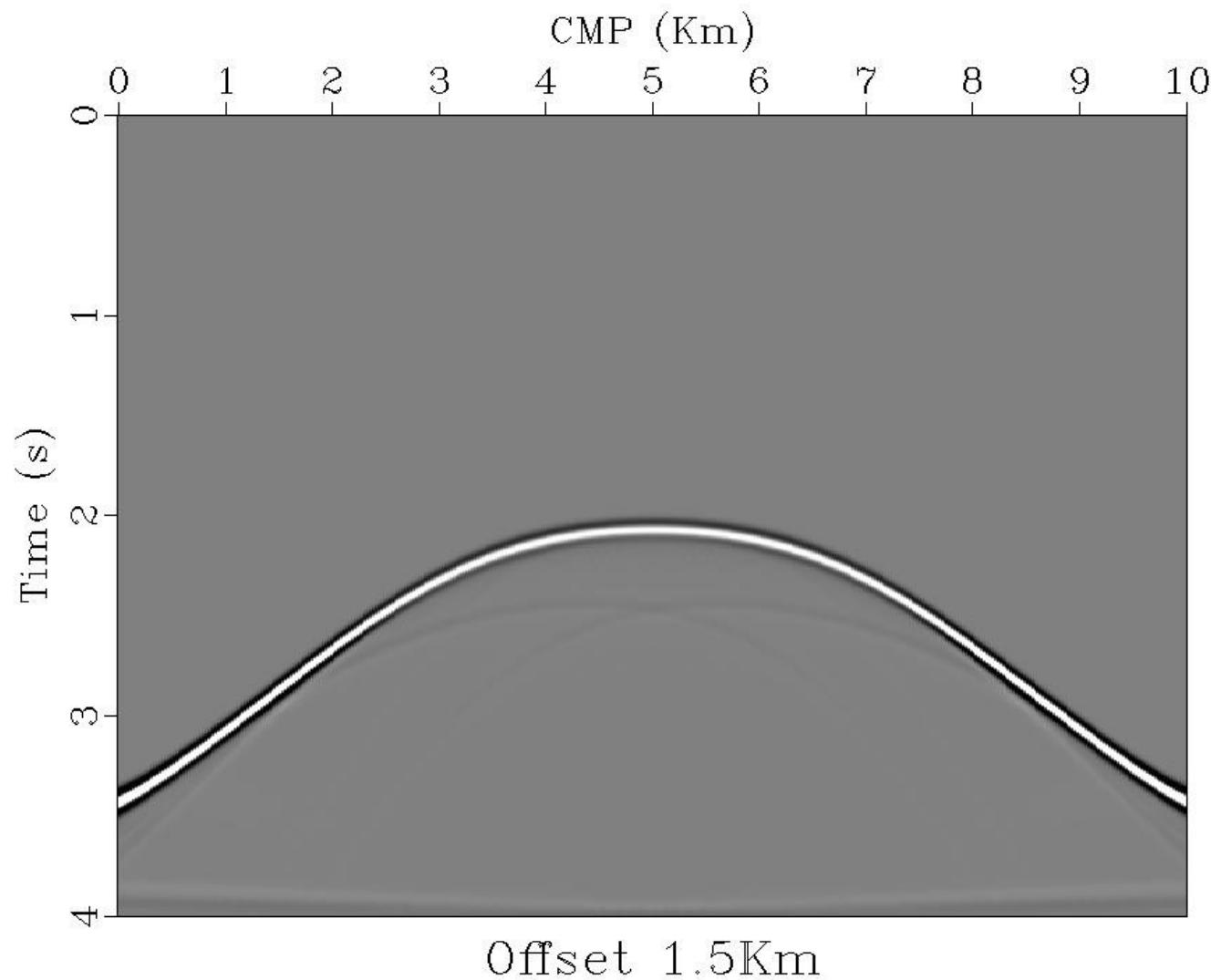
Seção de afastamento constante ($h=0.5\text{Km}$)



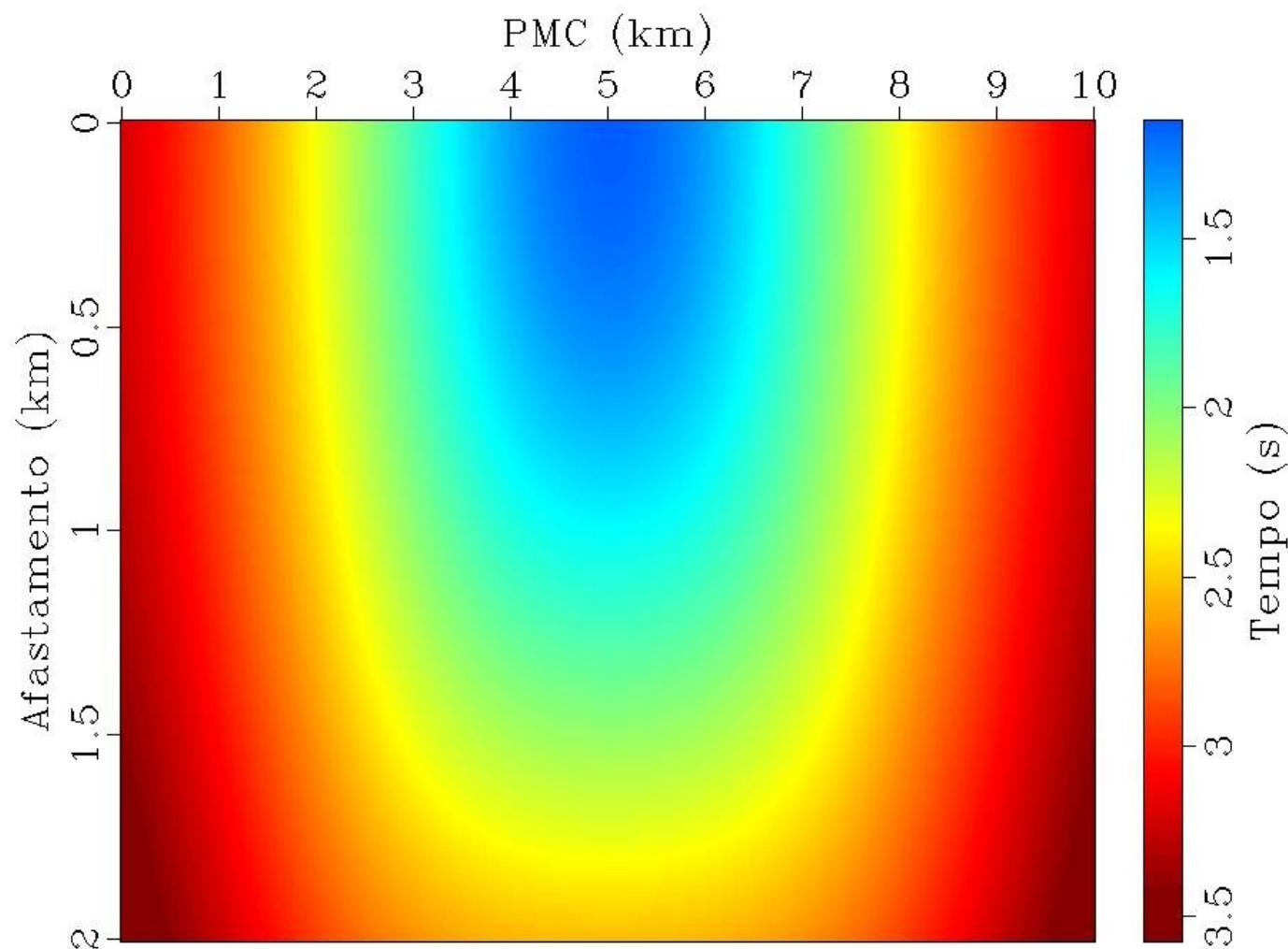
Seção de afastamento constante ($h=1.0\text{Km}$)



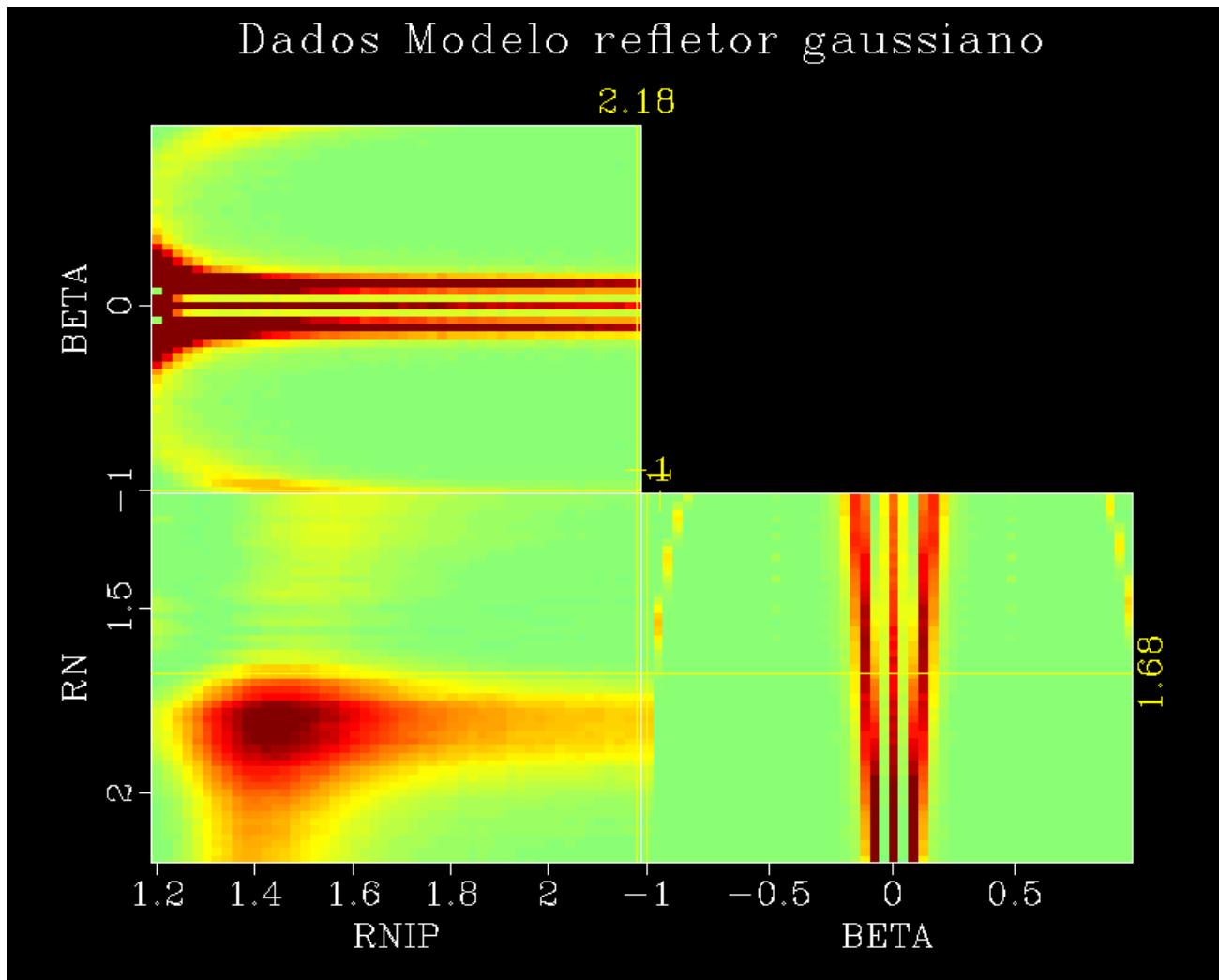
Seção de afastamento constante ($h=1.5\text{Km}$)



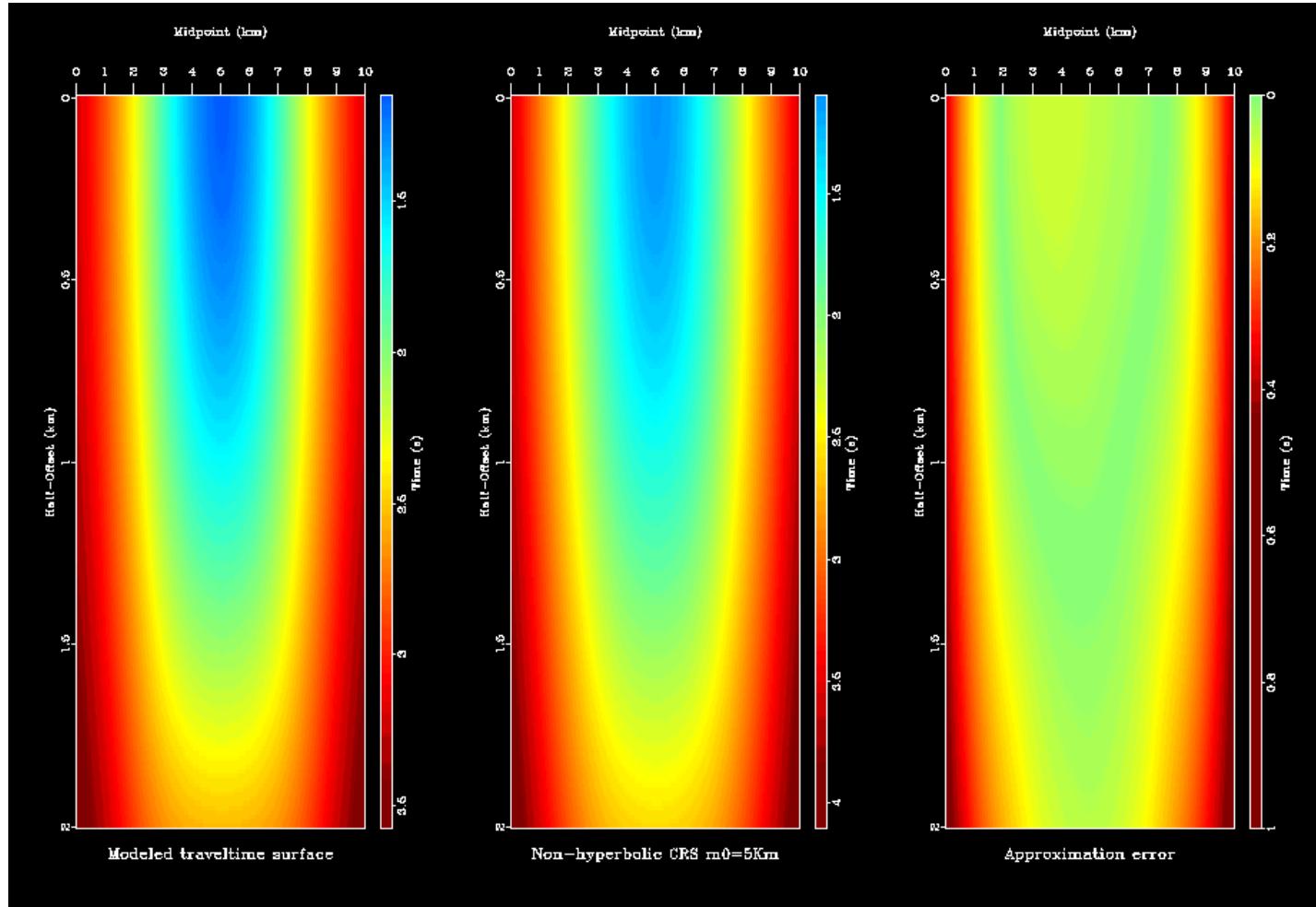
Superfície de tempo de trânsito de reflexão



Análise de coerência dos parâmetros do SRC



Erro de aproximação



Contribuição ao pacote Madagascar

← → ⌂ 🔒 github.com/ahay/src/pull/178

Contribuição ao pacote Madagascar

github.com/ahay/src/tree/master/user/dirack

 sfomei python3 compatibility ✓ Latest commit 8b62f62 10 hours ago

..

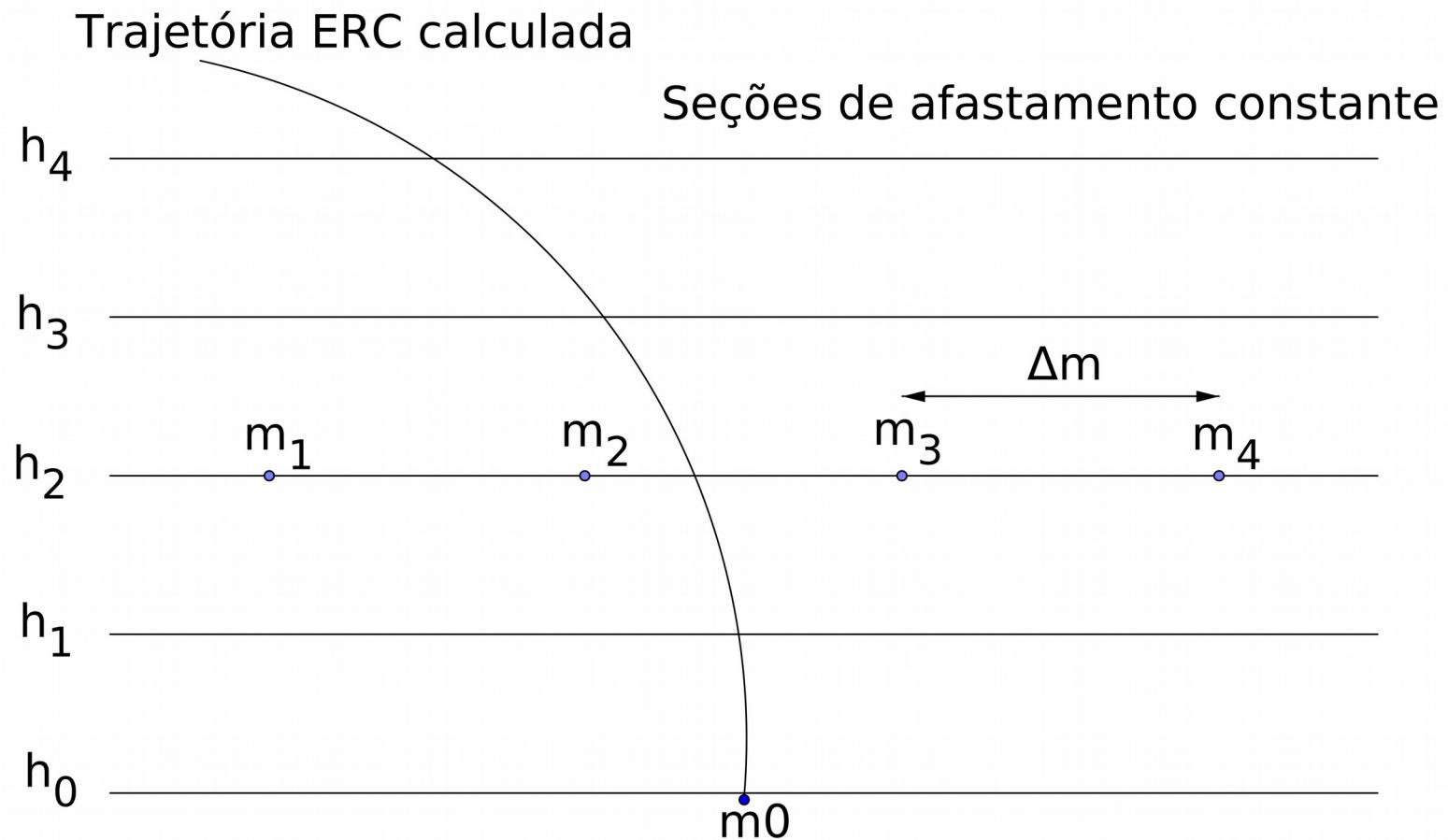
usage_examples	Usage example of sfvfsacrsnh and sfnhcrrsurf	3 days ago
Mnhcrrsurf.c	Add program sfvfsacrsnh and sfnhcrrsurf	3 days ago
Mvfsacrsnh.c	Add program sfvfsacrsnh and sfnhcrrsurf	3 days ago
README.md	Create README.md	3 days ago
SConstruct	python3 compatibility	10 hours ago
vfsacrsnh_lib.c	Add program sfvfsacrsnh and sfnhcrrsurf	3 days ago
vfsacrsnh_lib.h	Add program sfvfsacrsnh and sfnhcrrsurf	3 days ago

[README.md](#)

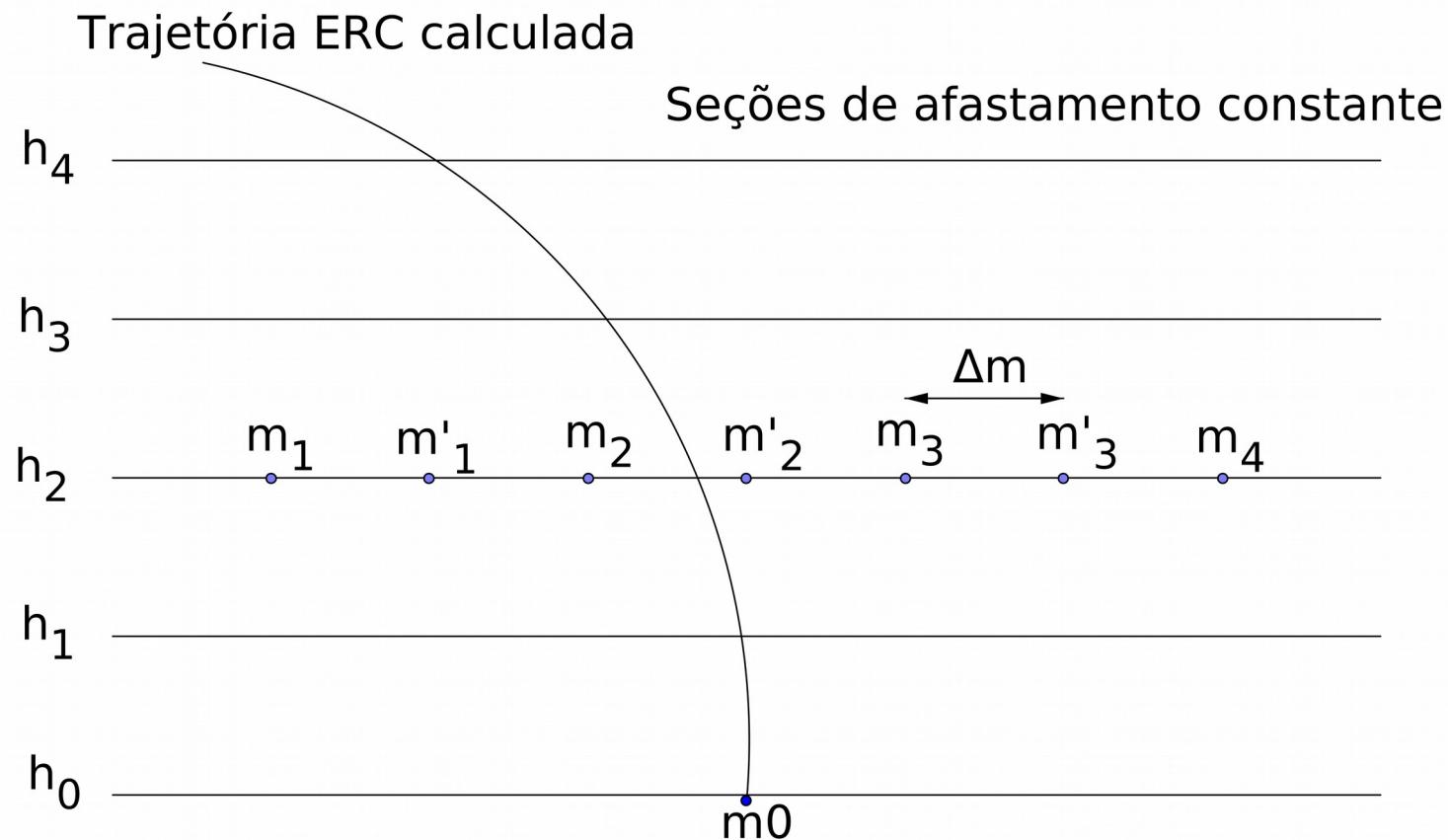
Rodolfo A C Neves (Dirack)

This is a open source repository with programs developed for Madagascar package version 3.0. Any doubt? please contact me by email rodolfo_profissional@hotmail.com (email) or [github](#)

Estratégia de interpolação



Estratégia de interpolação



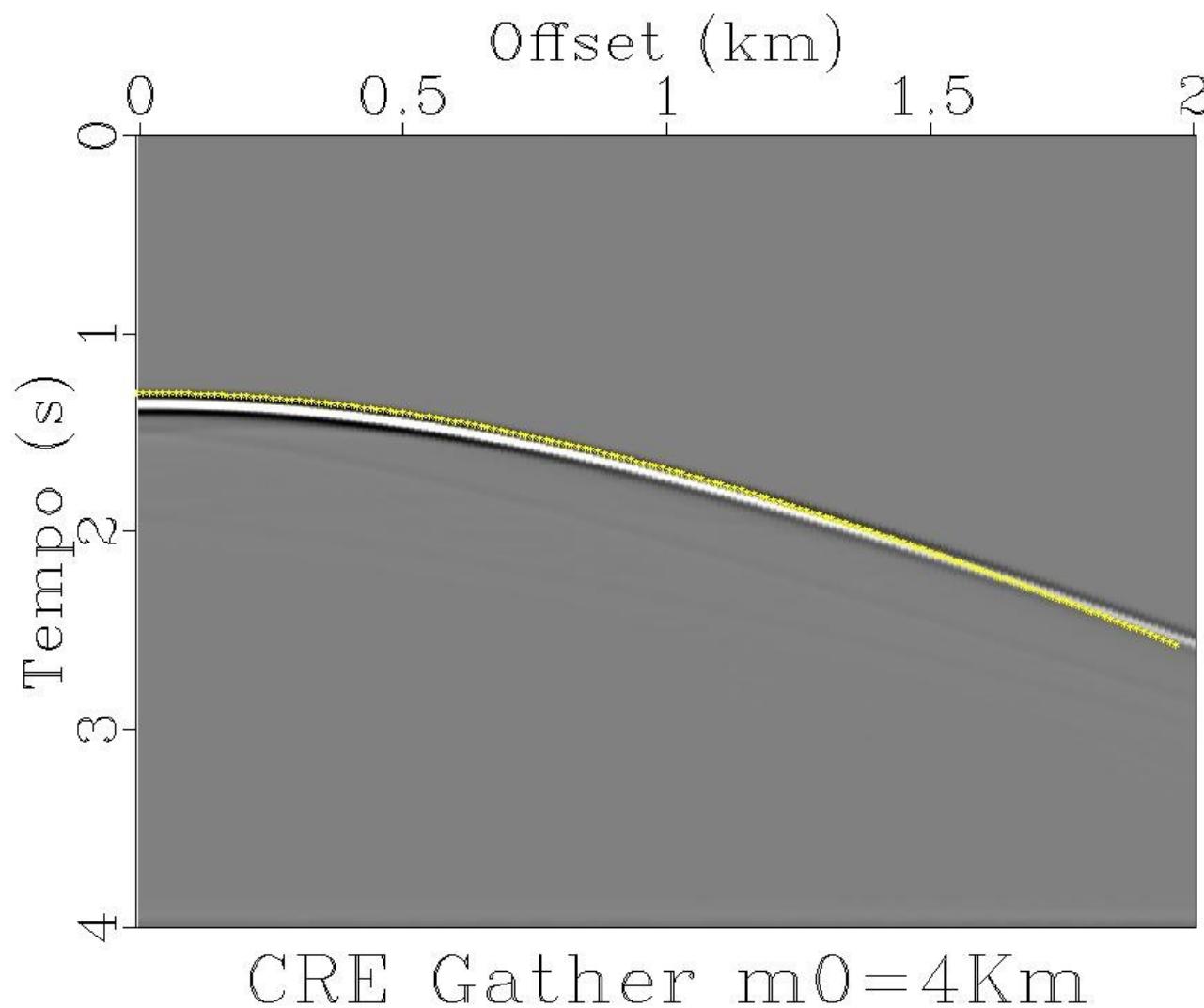
Filtros adaptativos de predição de erro (FPE)

$$\hat{B}_n(t, x) = \arg \min_{B_n} \left\| K(t, x) \left[S(t, x) - \sum_{n=1}^N B_n(t, x) S_n(t, x) \right] \right\|_2^2 + \epsilon^2 \sum_{n=1}^N \|D[B_n(t, x)]\|_2^2$$

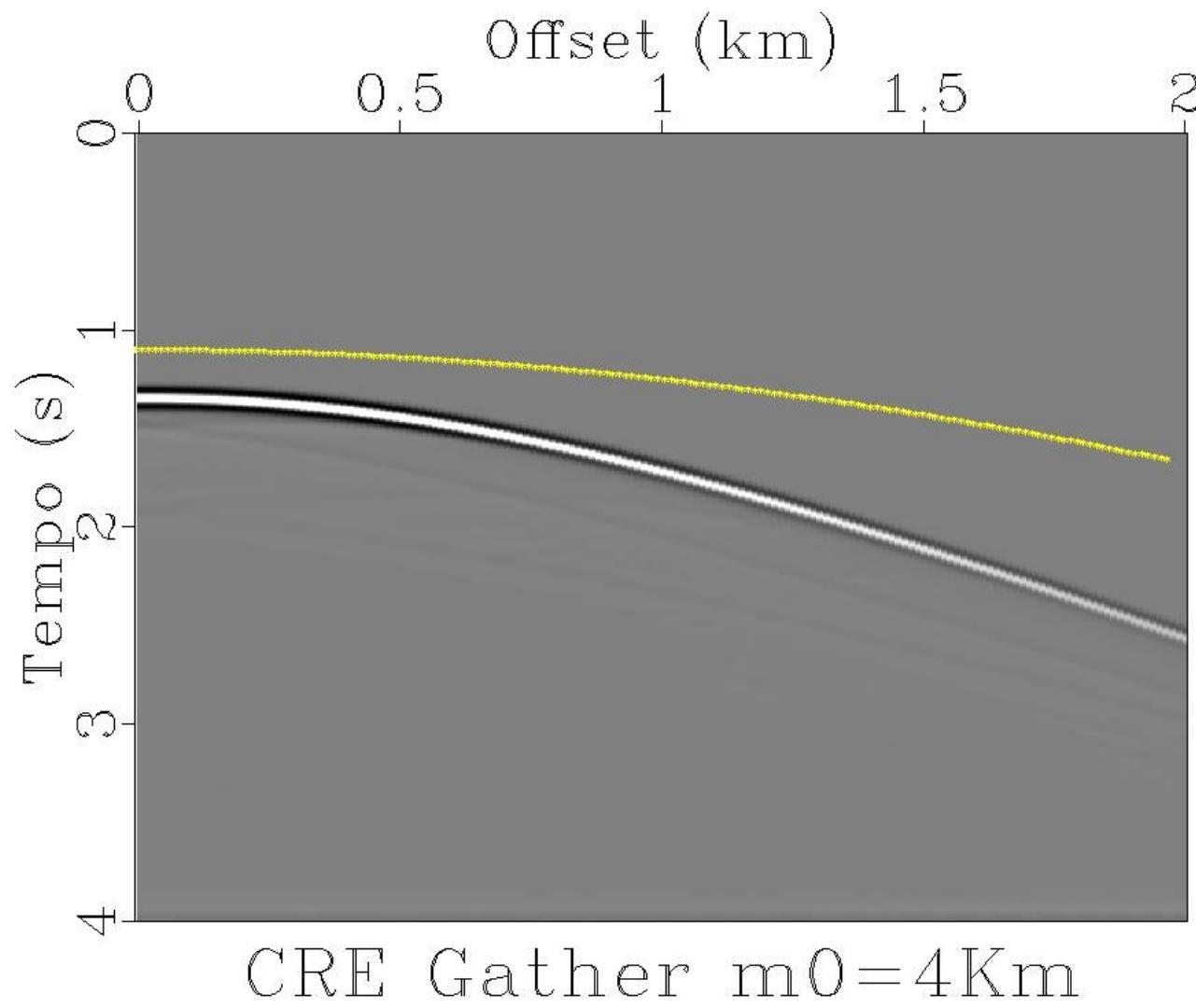
$$\hat{S}(t, x) = \arg \min_S \left\| S(t, x) - \sum_{n=1}^N \hat{B}_n(t, x) S_n(t, x) \right\|_2^2$$

$$\hat{S}(t, x) = S_{known}(t, x_k)$$

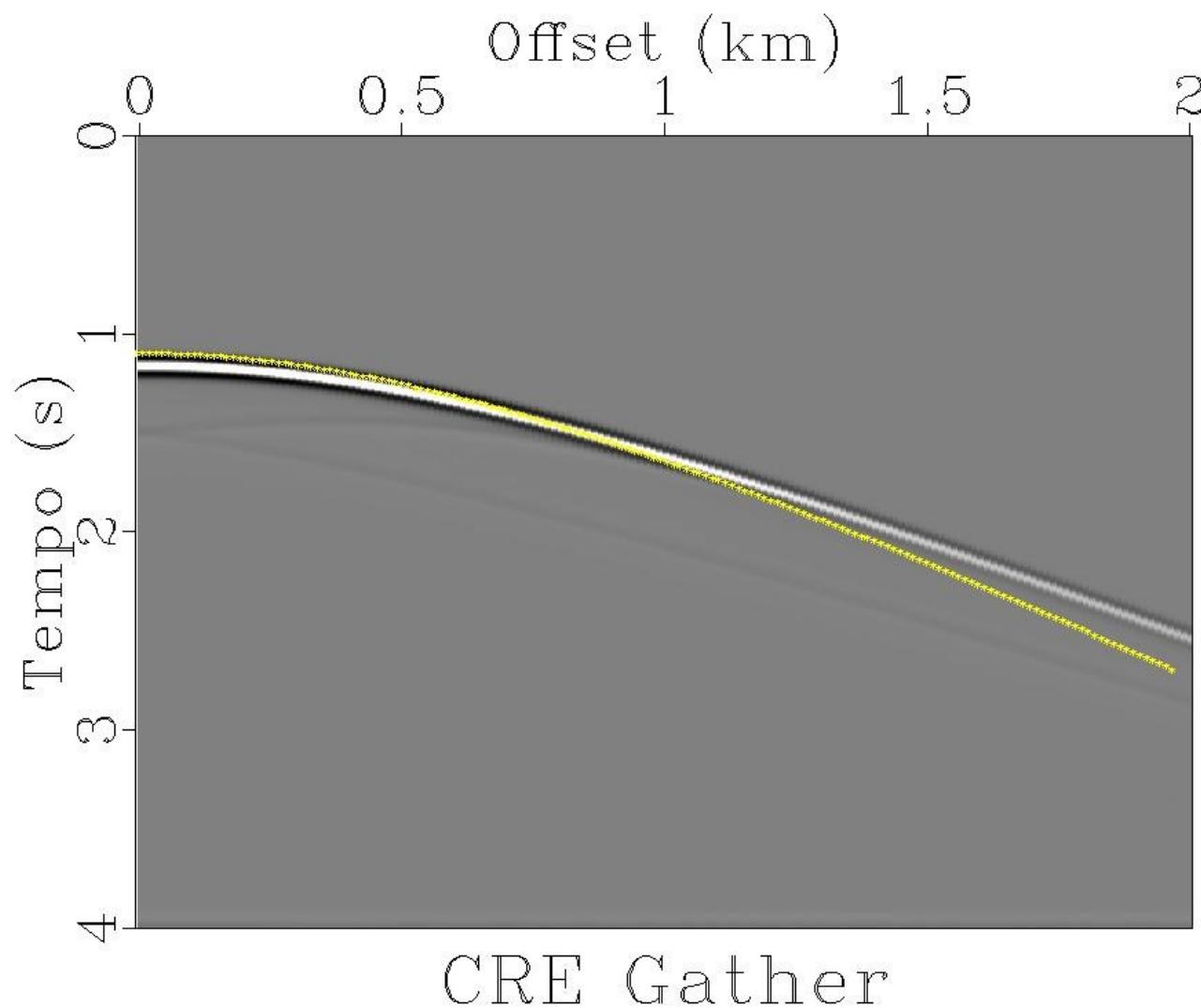
Ajuste das famílias ERC



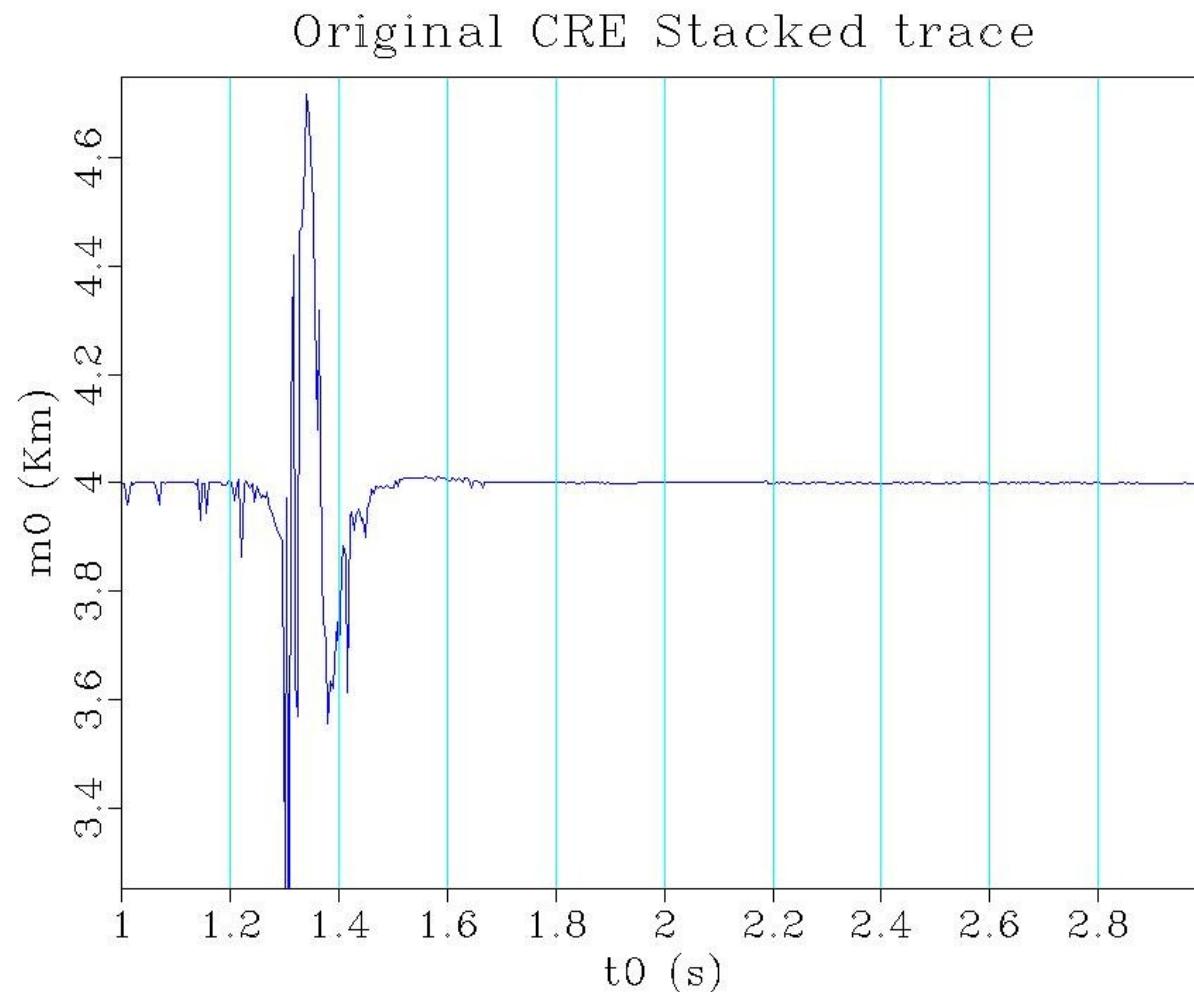
Ajuste das famílias ERC



Ajuste das famílias ERC

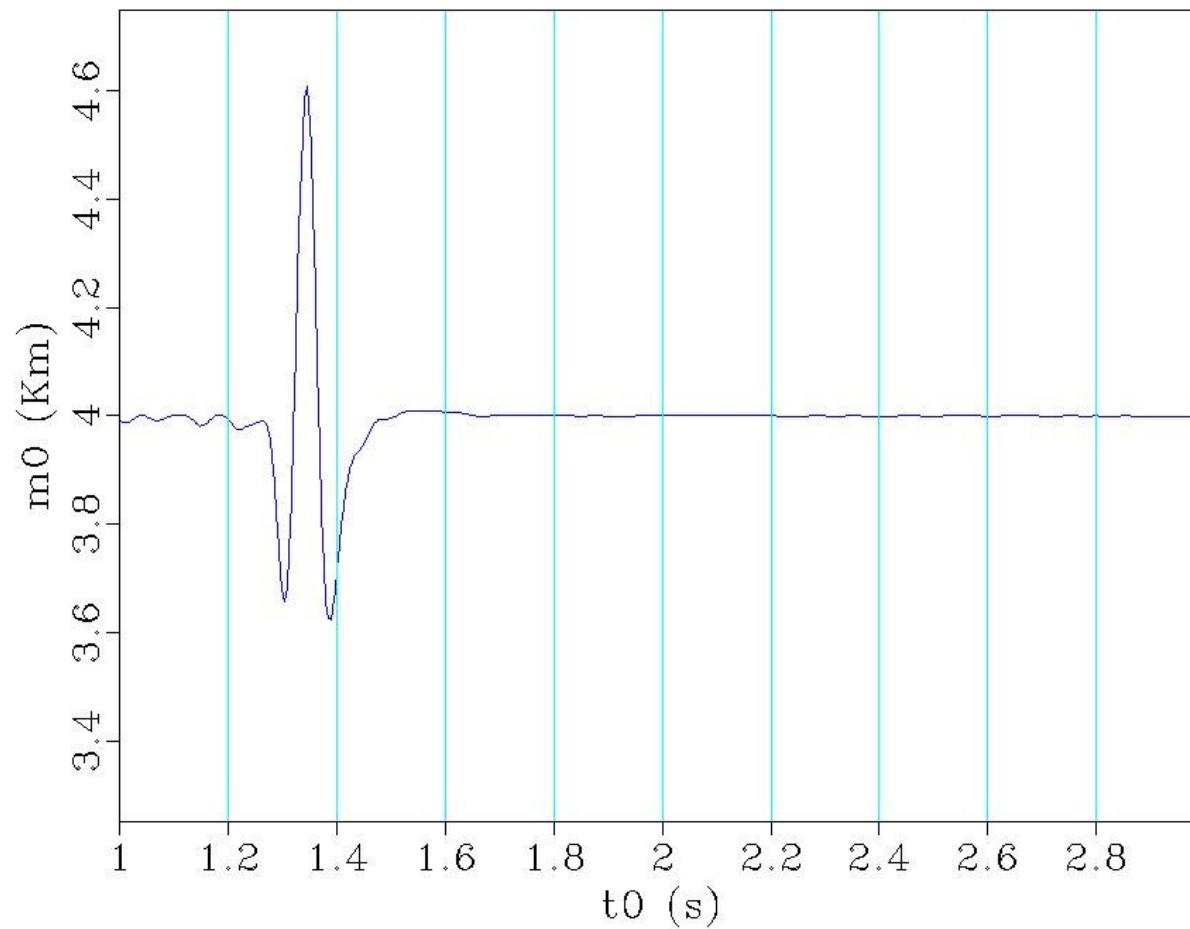


Supertraços ERC

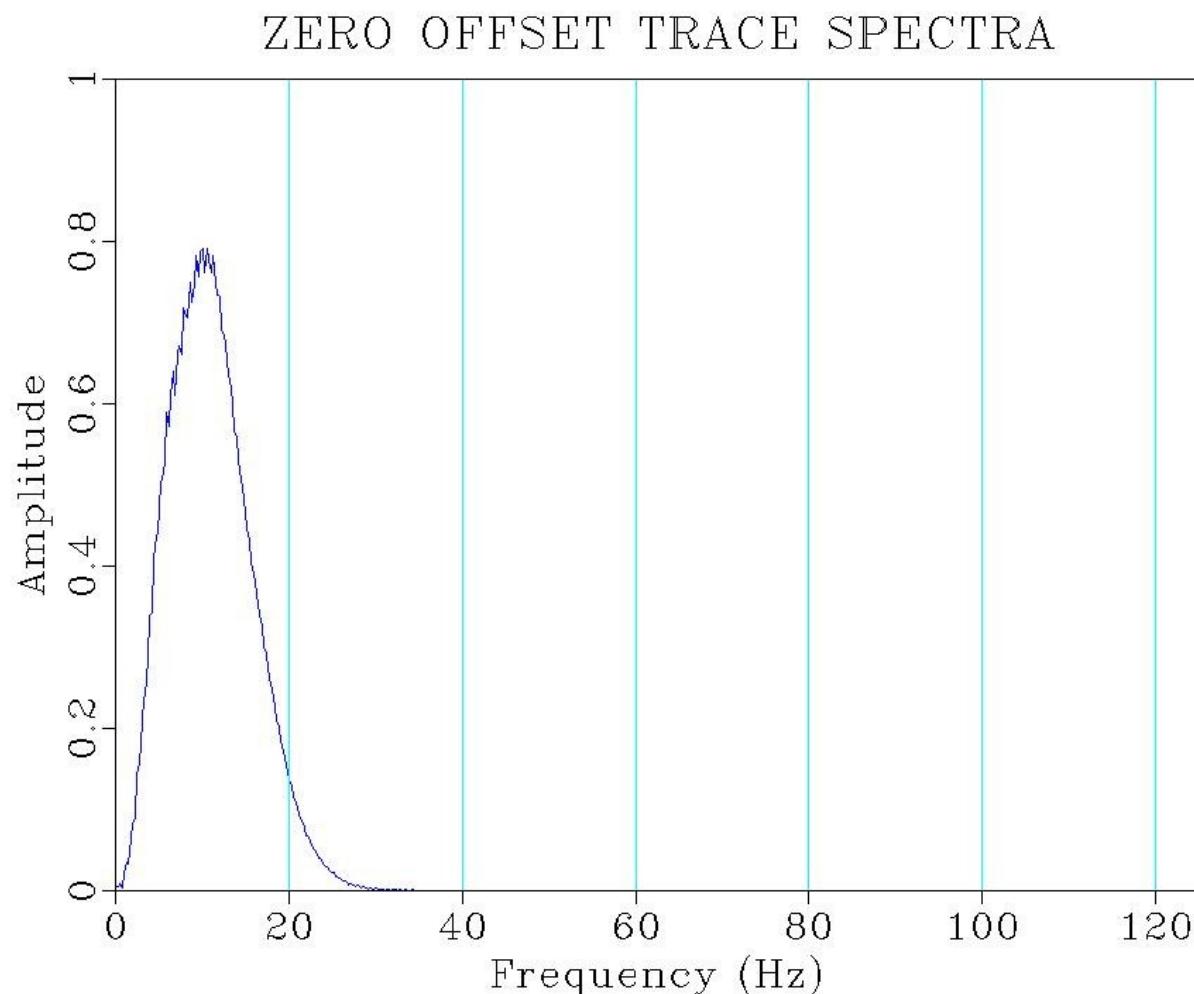


Supertraços ERC

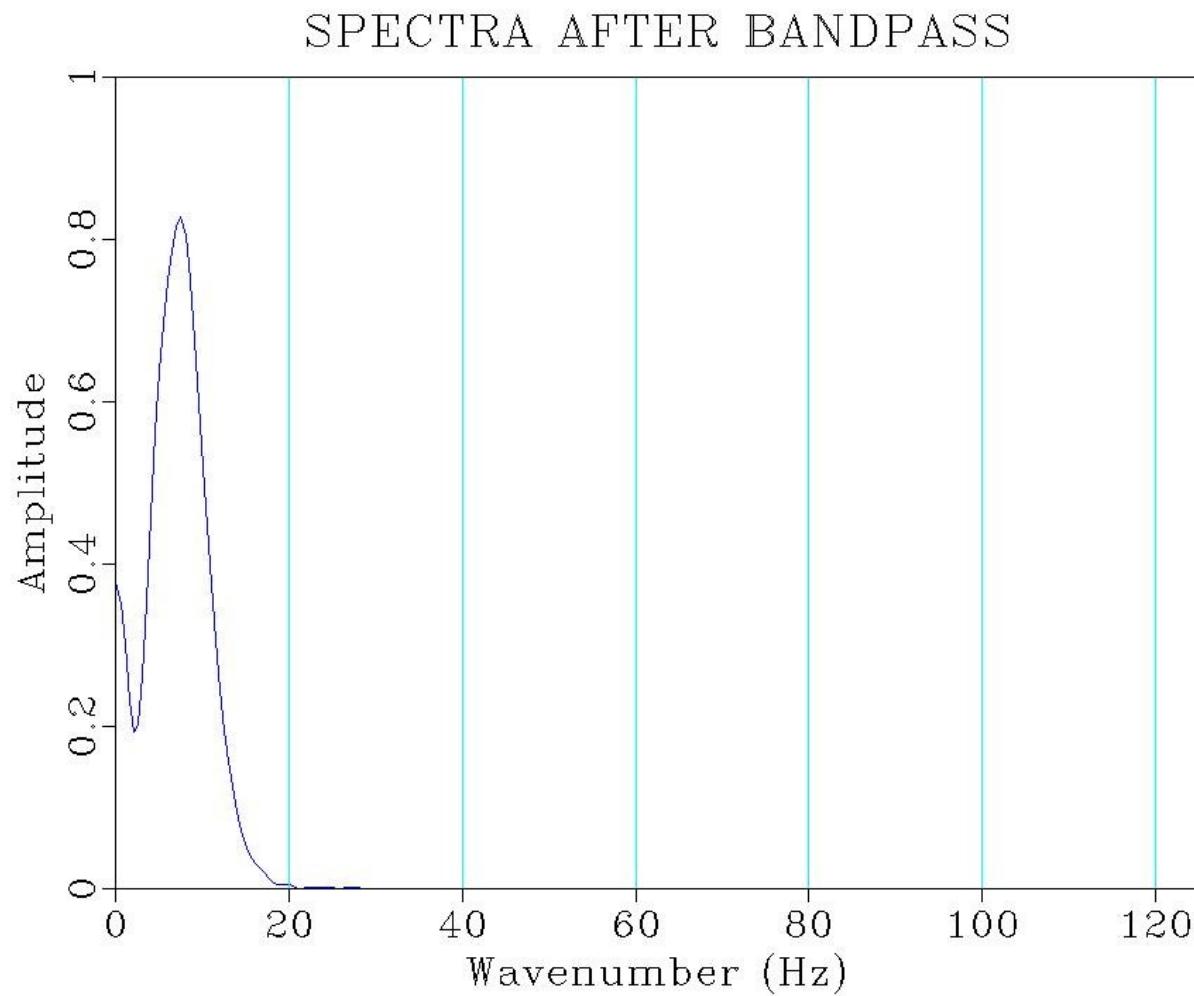
Filtered CRE Stacked trace



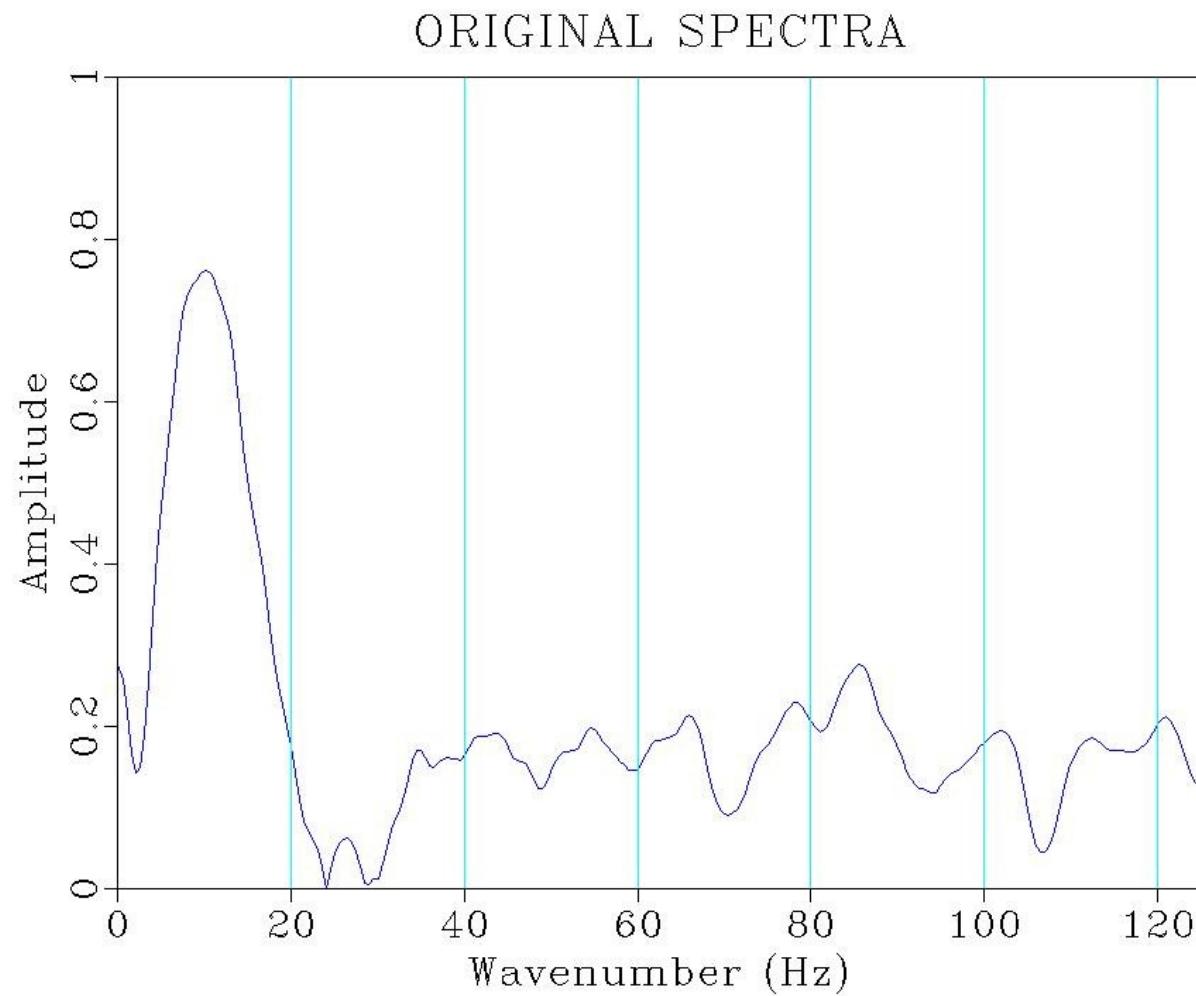
Supertraços ERC



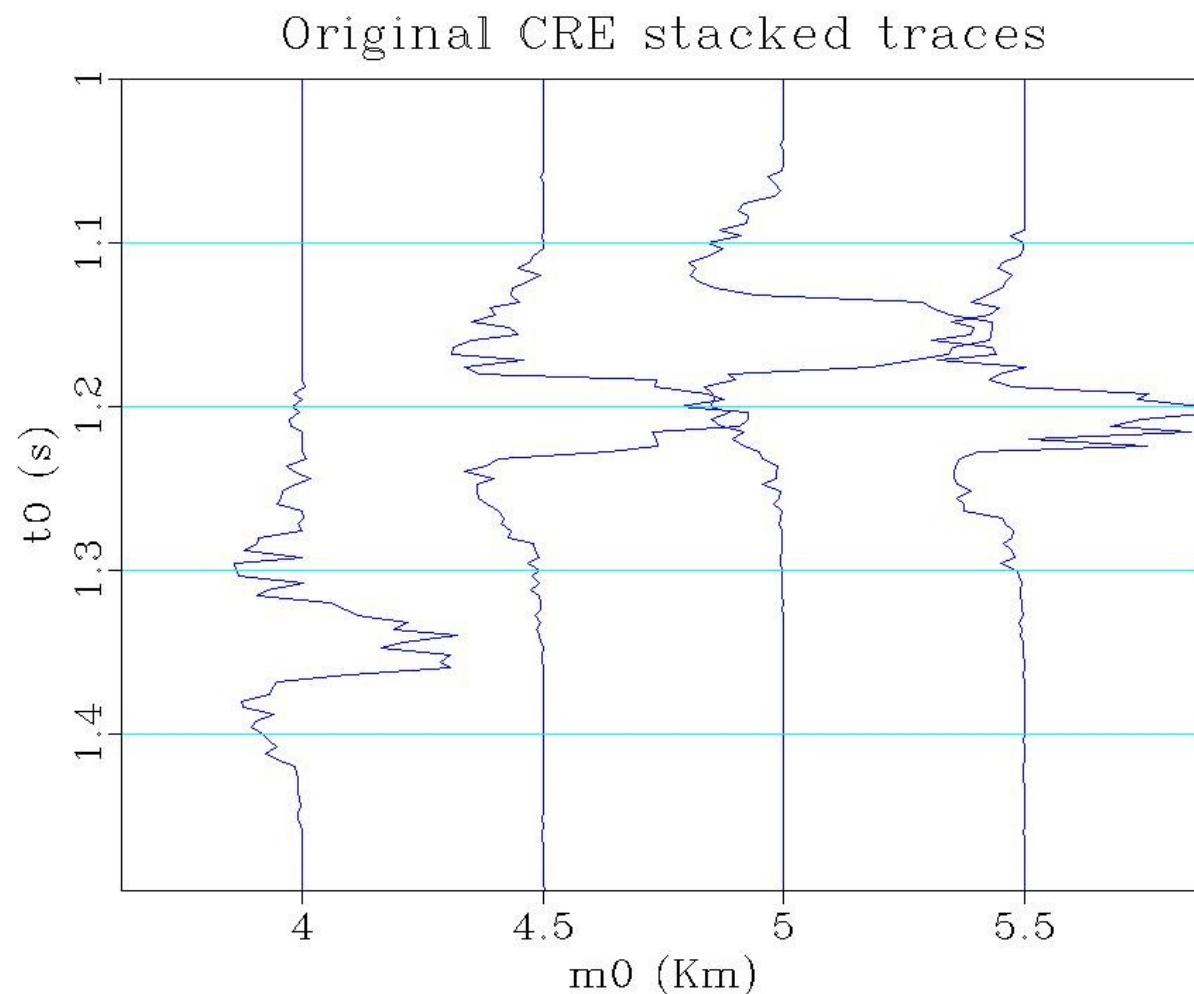
Supertraços ERC



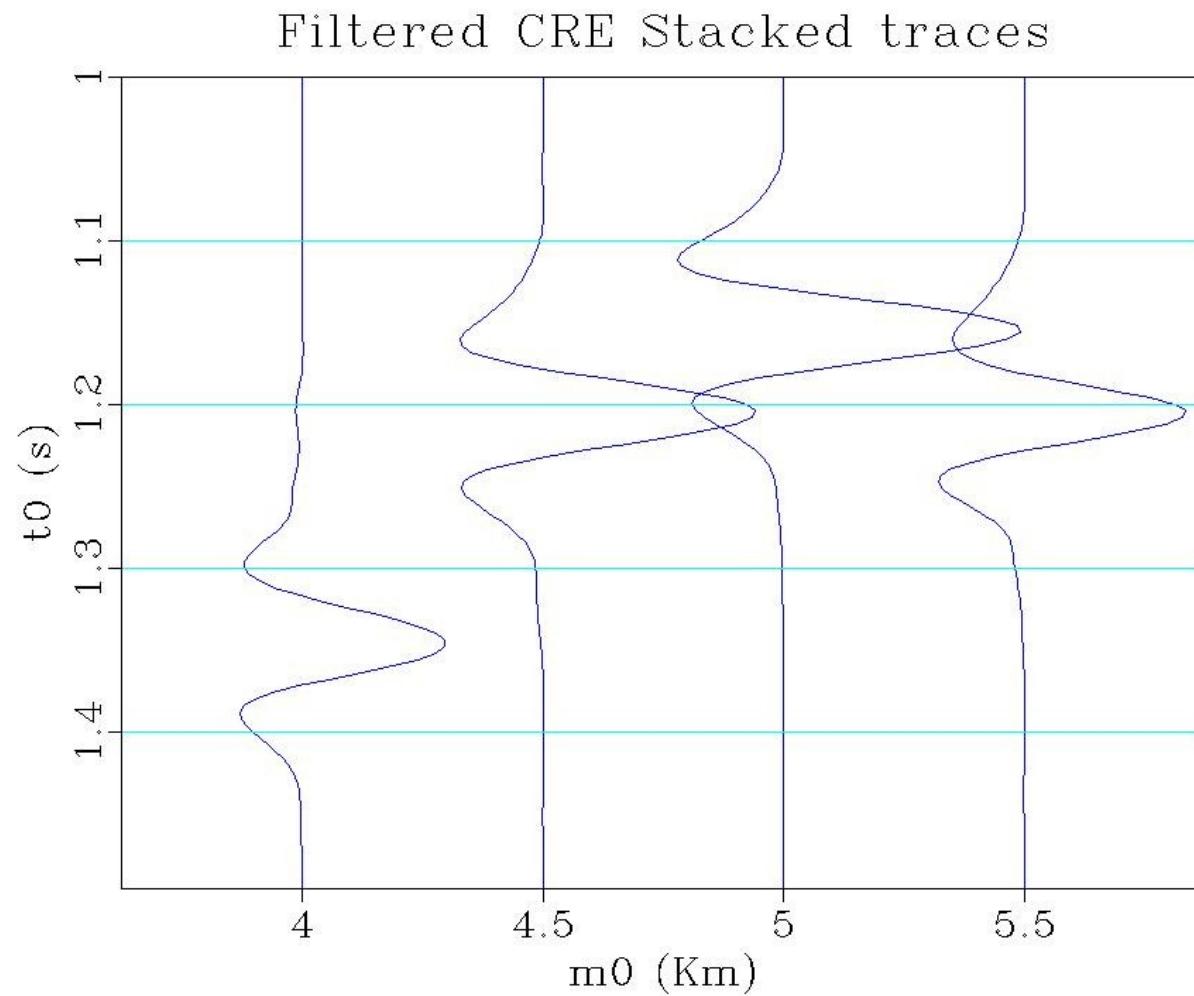
Supertraços ERC



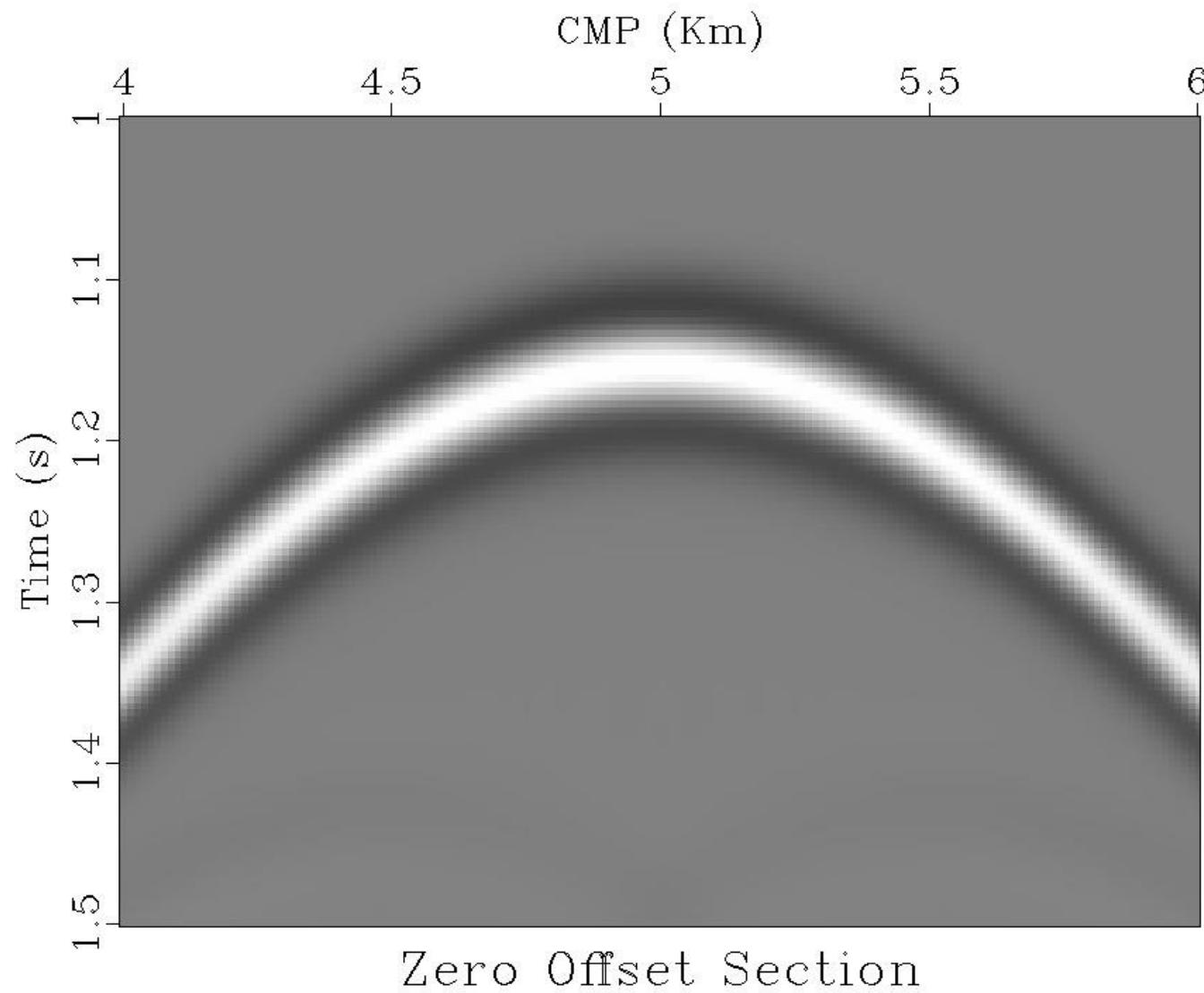
Supertraços ERC



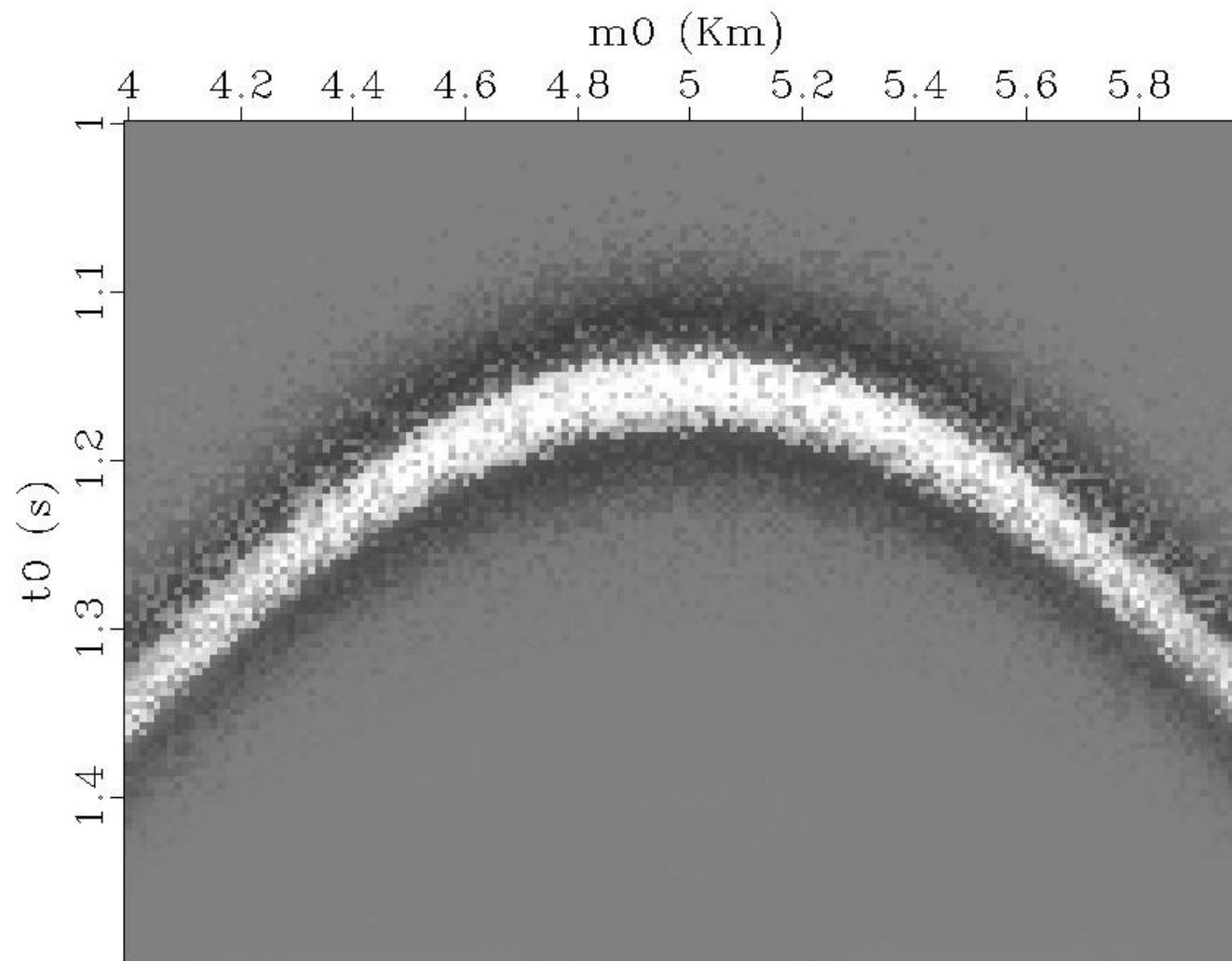
Supertraços ERC



Seção empilhada ERC

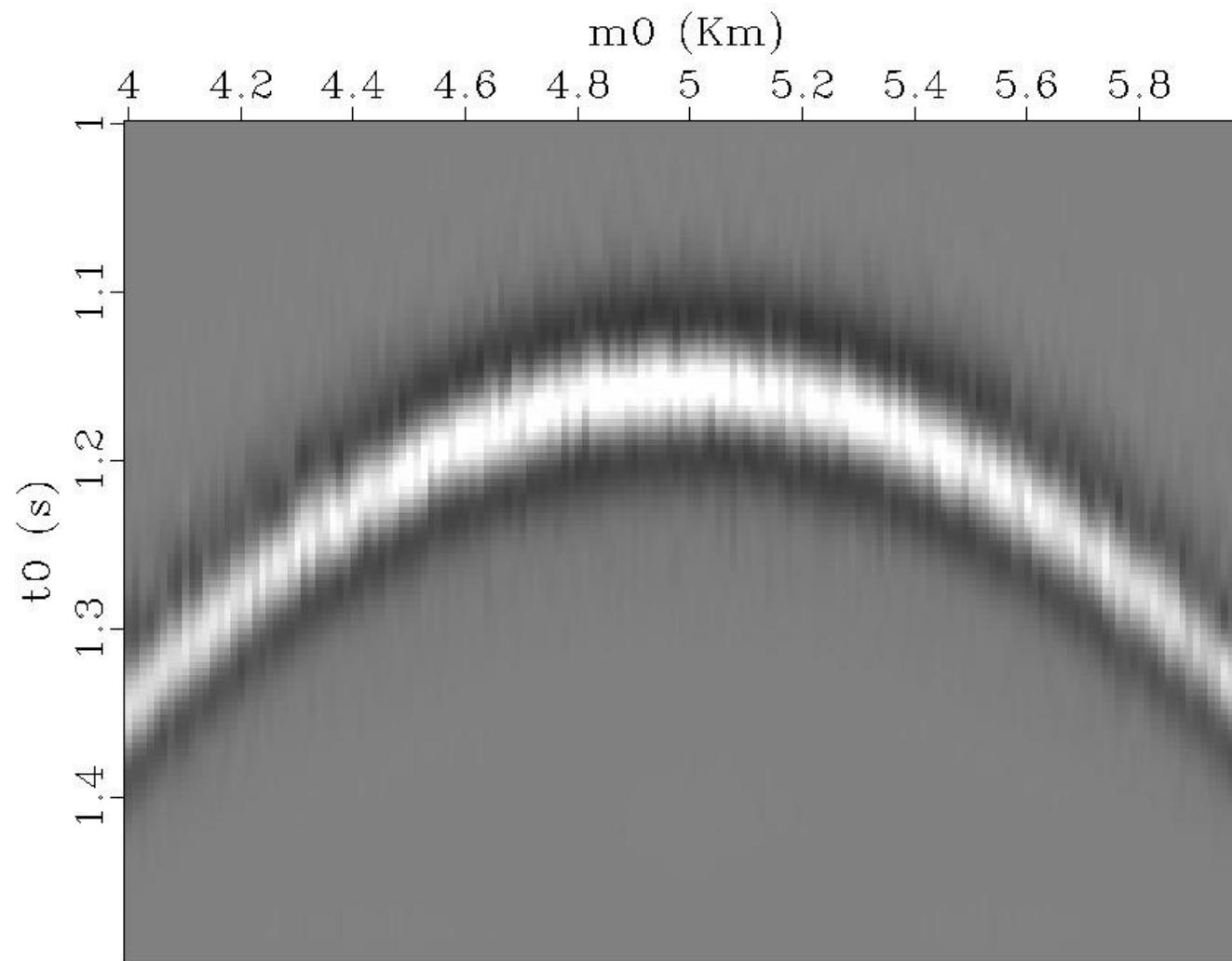


Seção empilhada ERC



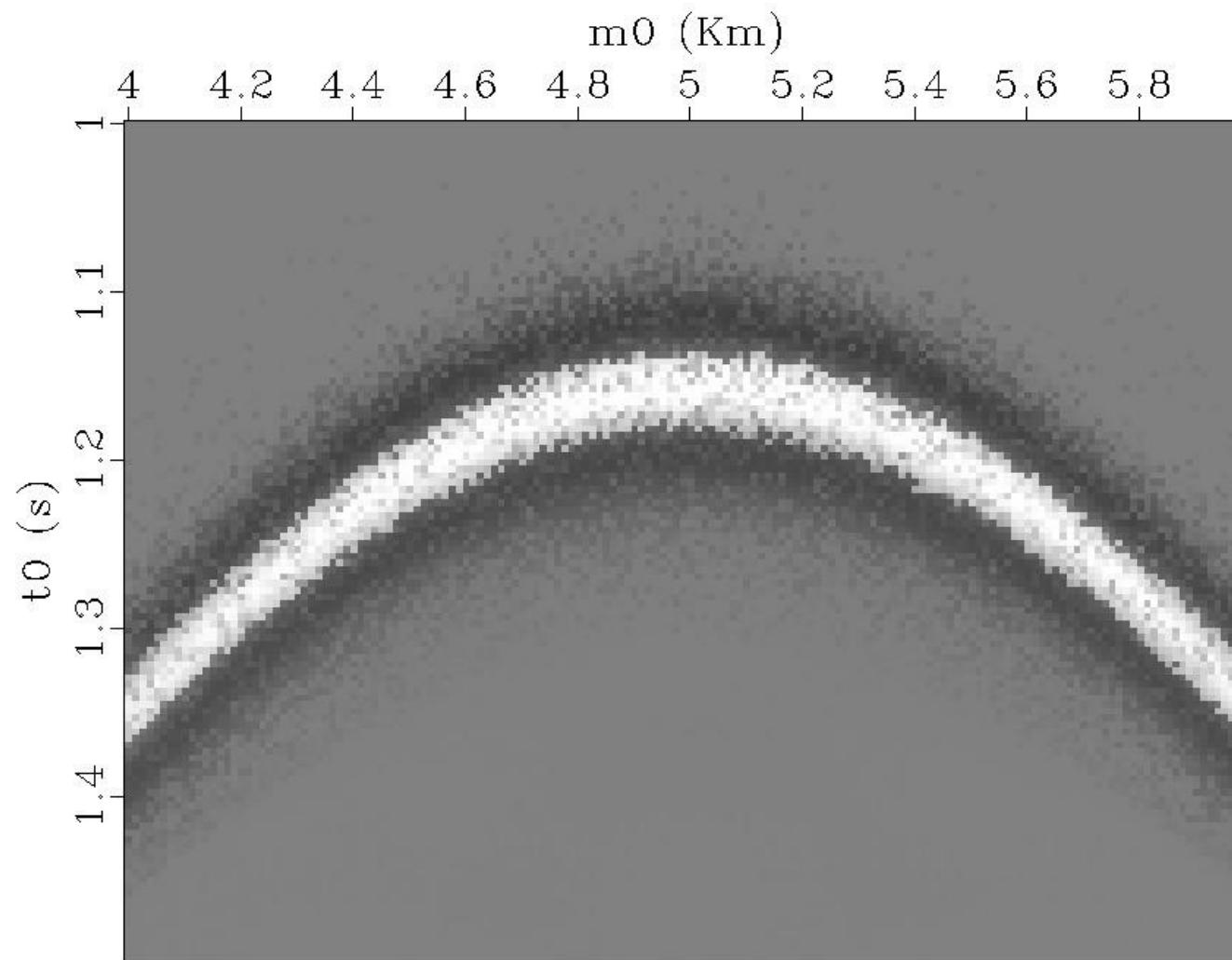
Stacked Section

Seção empilhada ERC



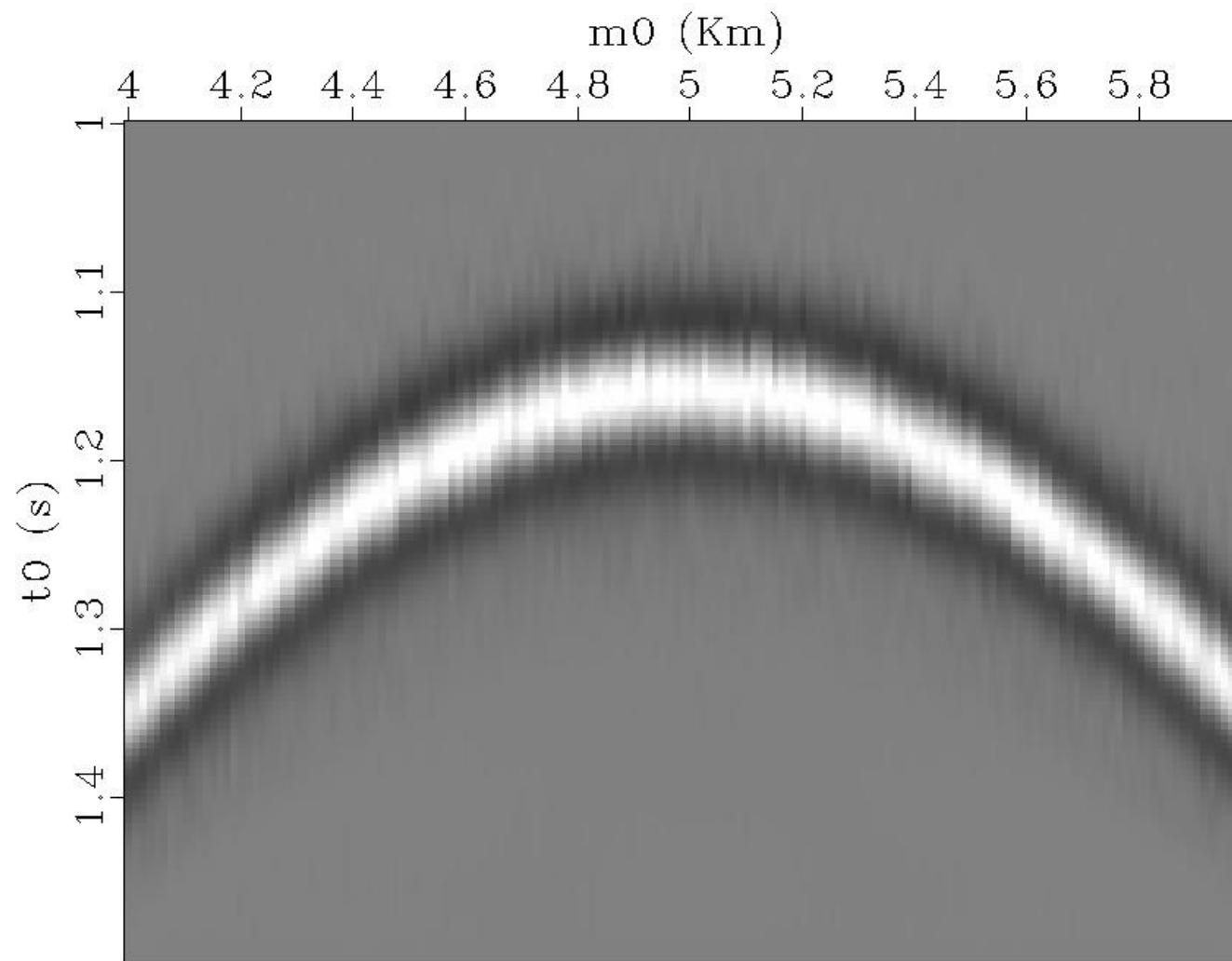
Filtered Stacked Section

Seção empilhada ERC



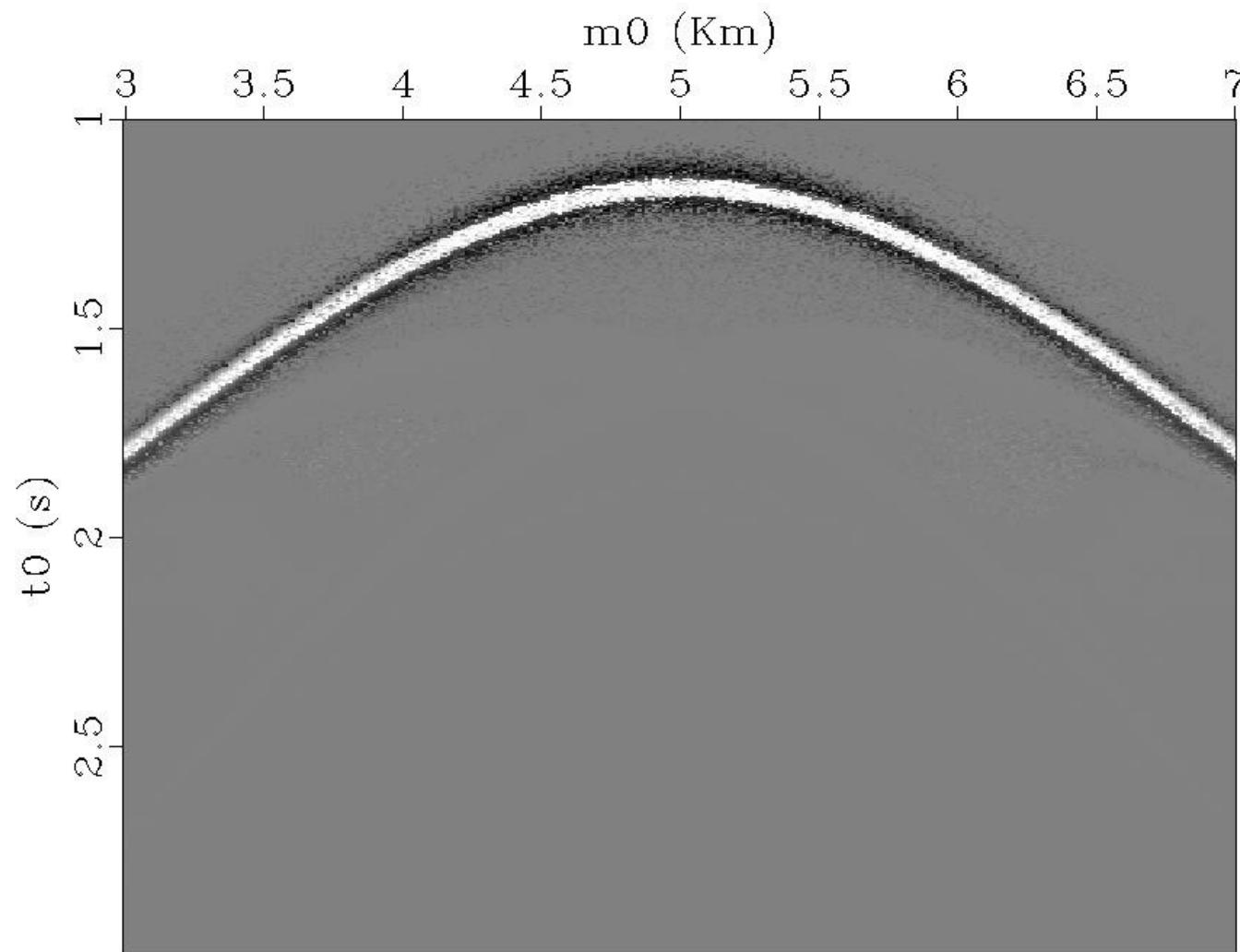
Stacked Section Non Hyperbolic CRS

Seção empilhada ERC



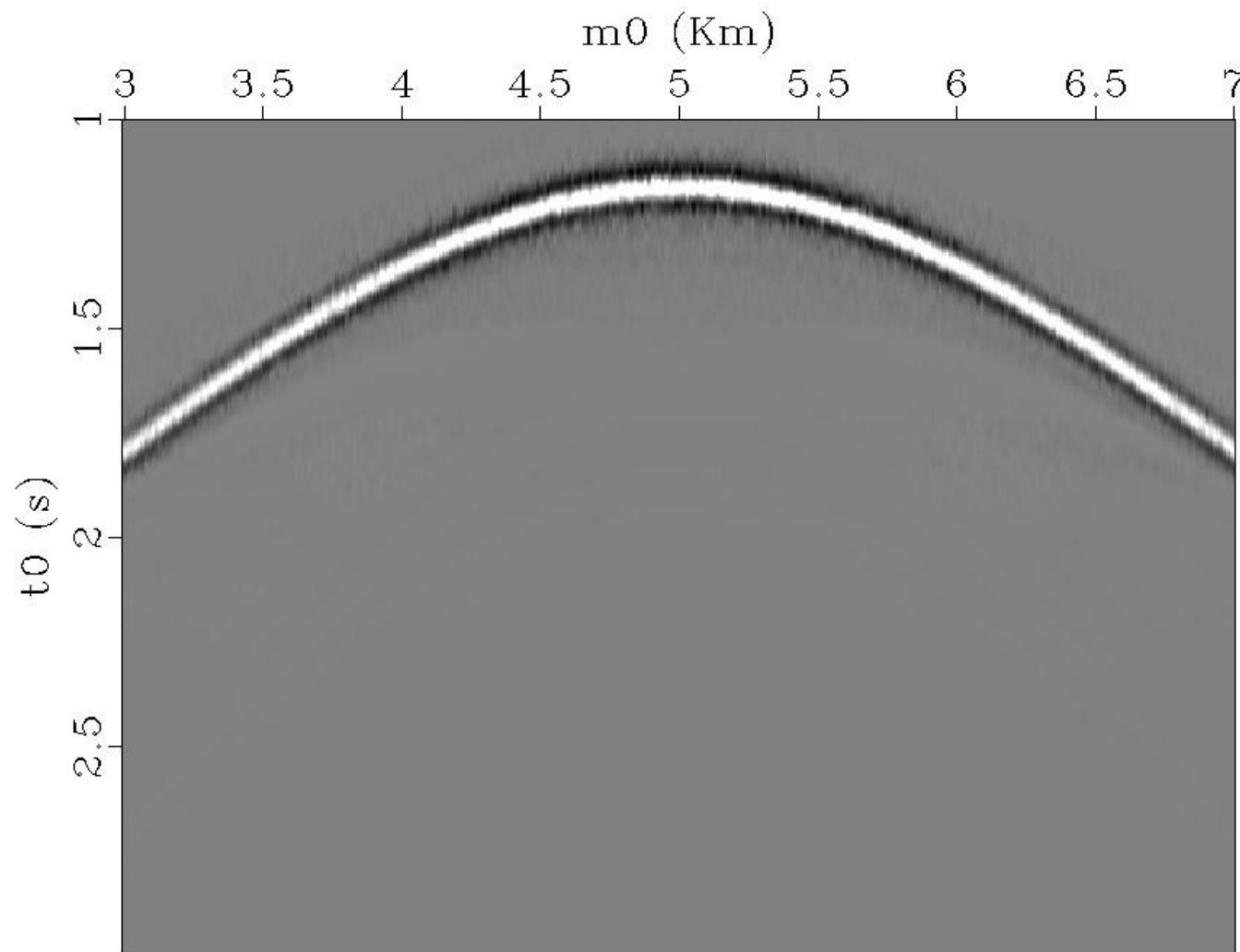
Filtered Stacked Section Non hyperbolic CRS

Seção empilhada ERC



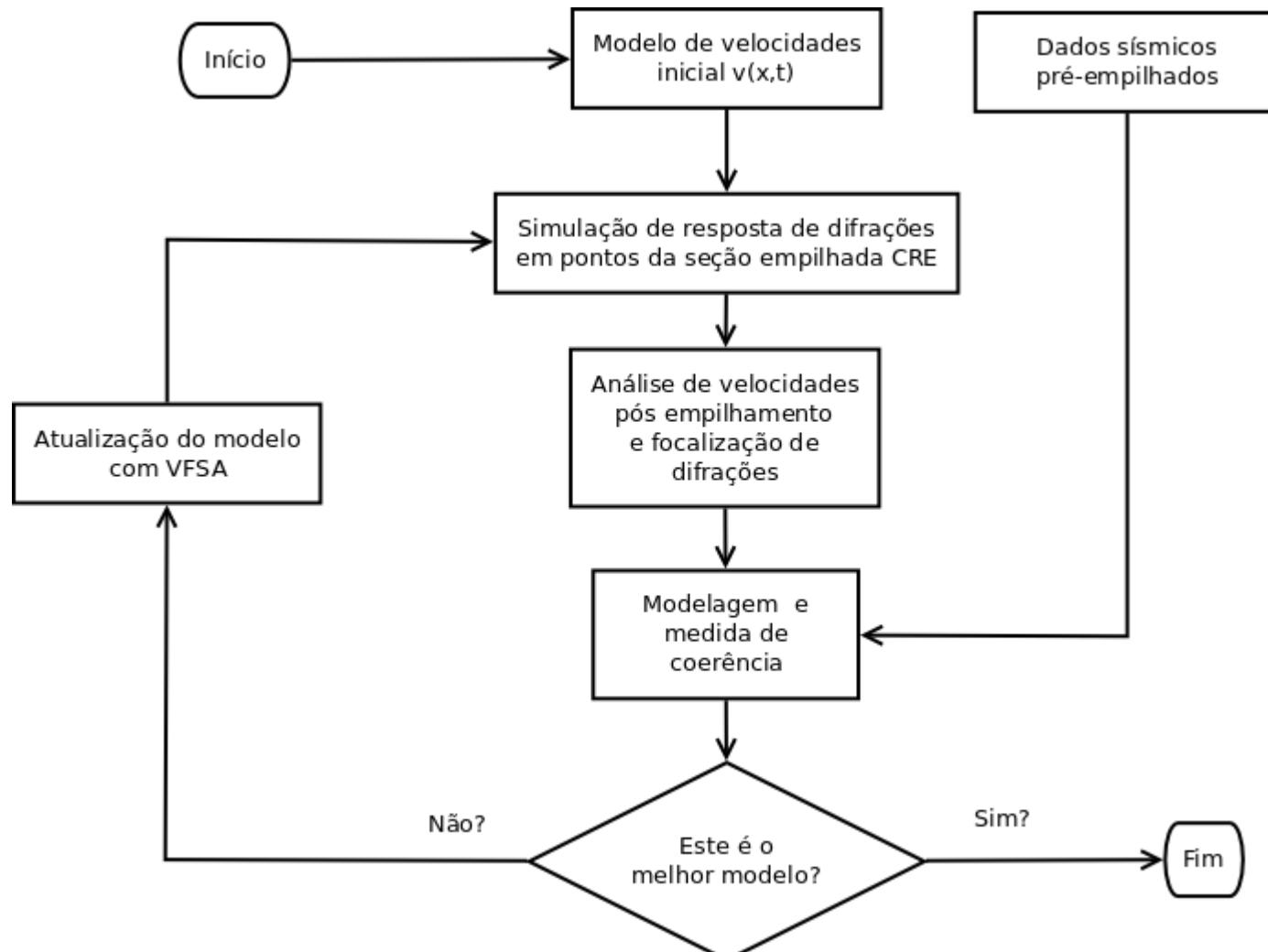
Brute Stacked Section

Seção empilhada ERC

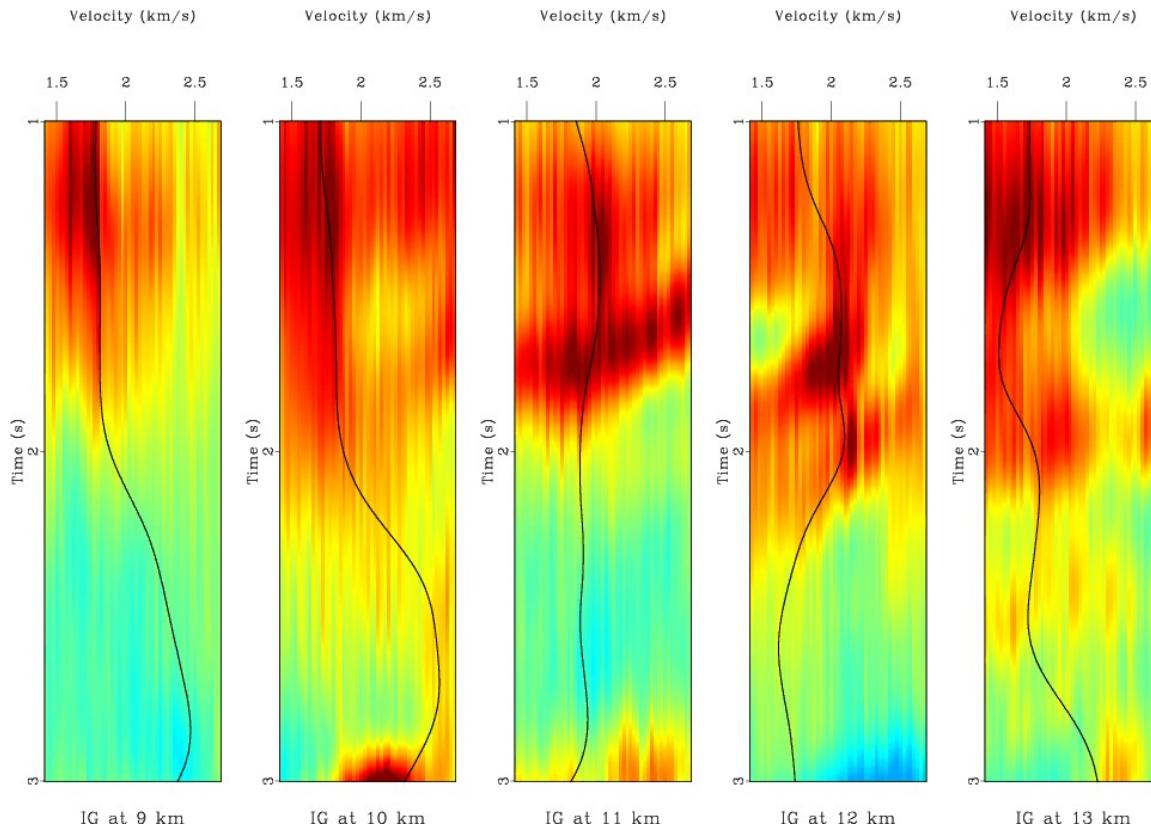


Filtered Stacked Section

Estratégia de inversão do modelo de velocidades



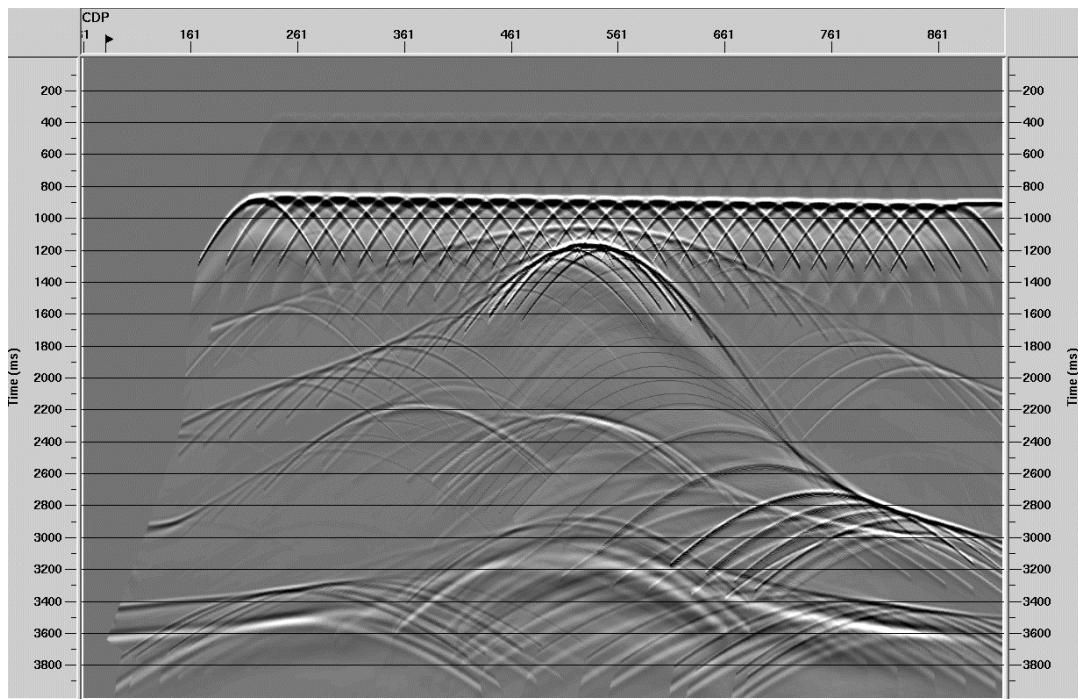
Variação máxima local



$$\phi_i = \frac{N \sum_{i=1}^N s_i^4}{\left(\sum_{i=1}^N s_i^2 \right)}$$

Fonte: (FOMEL; LANDA; TANER, 2007).

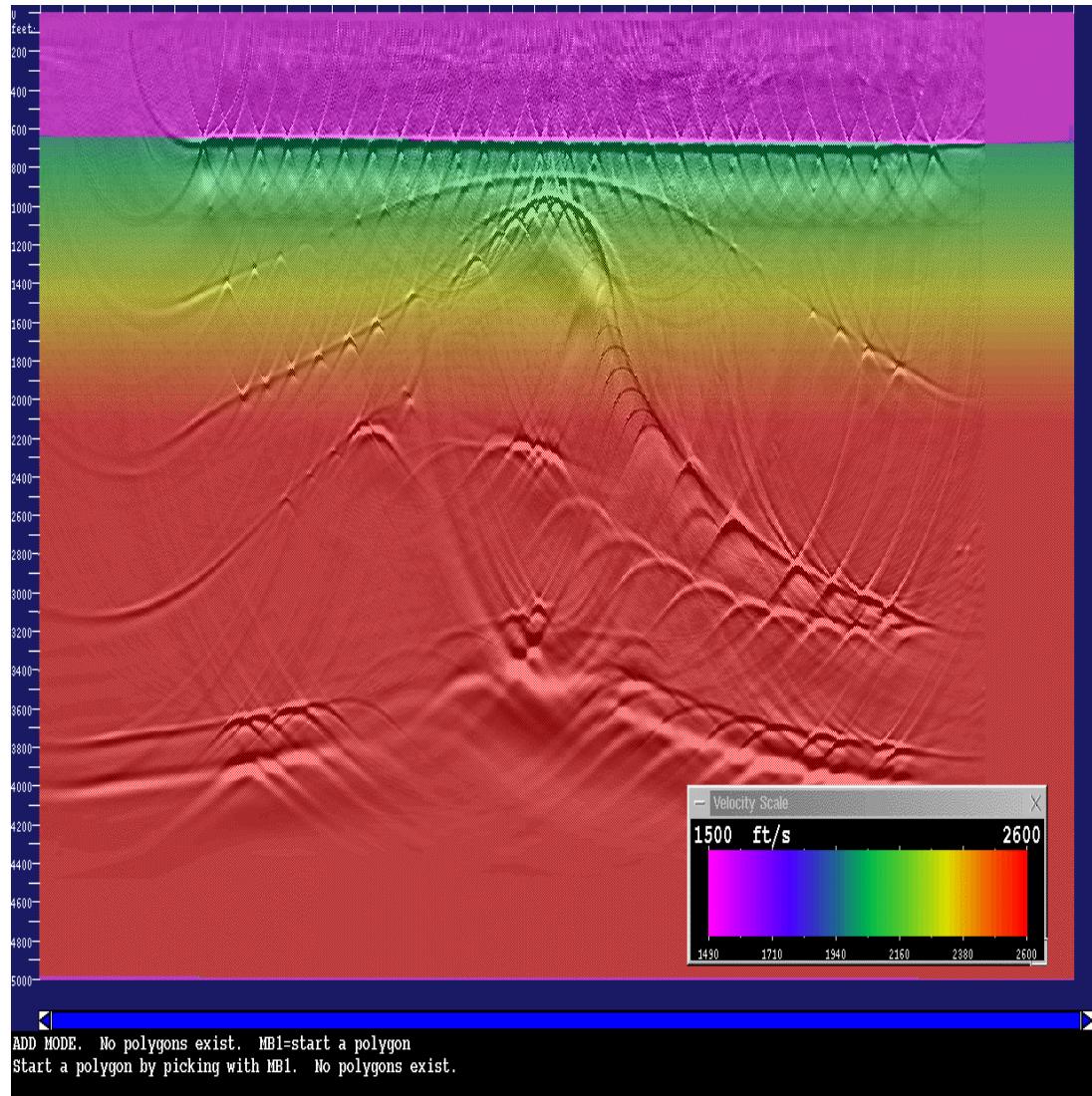
Resposta de difração simulada



$$T_D^2 = [t_0 - 2m(p_0 \cos \beta_0)]^2 + \frac{4m^2}{v_{NMO}^2}$$

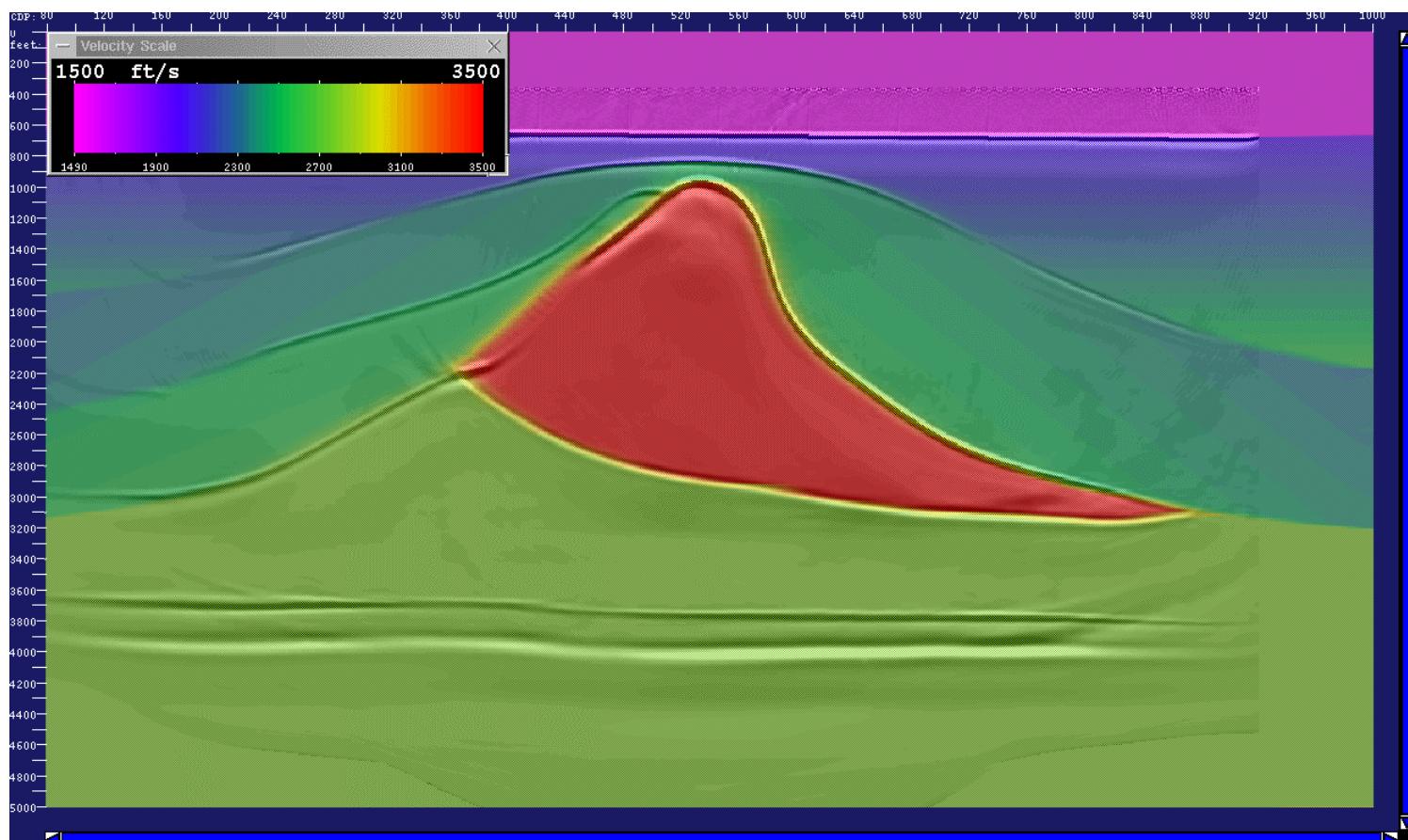
Fonte: (SOLLNER; YANG, 2002).

Resposta de difração simulada



Fonte: (SOLLNER; YANG, 2002).

Resposta de difração simulada



Fonte: (SOLLNER; YANG, 2002).

Referências

ABMA, R. Least-squares separation of signal and noise with multidimensional filters. Tese (Doutorado) — Stanford University, 1995.

CARMO, K. Métodos de otimização global aplicados na busca dos parâmetros SRC. Dissertação (Mestrado) — Universidade Federal do Pará - UFPa, Belém - PA, 2004.

CLAERBOUT, J. F. EARTH SOUNDINGS ANALYSIS: Processing versus Inversion.

[S.I.]: Blackwell Scientific Publications, 1992.

CLAERBOUT, J. F. Stan-ford Exploration Project | Image estimation by example: Geophysical soundings image construction—Multidimensional autoregression. 2010. Disponível em: <<http://sepwww.stanford.edu/sep/prof/>>. Acesso em: 08 de Novembro de 2019.

CRUZ, J. et al. The common reflecting element (cre) method revisited. *Geophysics*, v. 65, p. 979-993, 2000.

CURRY, W. Interpolation with multi-shifted-scale prediction-error filters. 74th Annual International Meeting, SEG, Expanded Abstracts,, 2005–2008.

DIX, C. H. Seismic velocities from surface measurements. *Geophysics*, n. 20, p. 68-86, 1955.

FOMEL, S. Application of plane wave destruction filters. *Geophysics*, v. 67, p. 1946-1960, 2002.

FOMEL, S. Time-migration velocity analysis by velocity continuation. *Geophysics*, v. 68, p. 1662-1672, 2003.

SOLLNER, W.; YANG, W. Diffraction response simulation: A 3d velocity inversion tool. SEG Technical Program Expanded Abstracts, p. 2293-2296, 2002.

SPITZ, S. Seismic trace interpolation in the f-x domain. *Geophysics*, v. 56, p. 785-794, 1991.

Referências

- TYGEL, M.; SANTOS, L.; SCHLEICHER, J. Multifocus moveout revisited: derivations and alternative expressions. *Journal of Applied Geophysics*, v. 42, p. 319–331, 1999.
- FOMEL, S. Velocity continuation and the anatomy of residual prestack time migration. *Geophysics*, v. 68, p. 1650–1661, 2003.
- FOMEL, S. Shaping regularization in geophysical-estimation problems. *Geophysics*, v. 72, n. 2, p. R29–R36, 2007.
- FOMEL, S. Adaptive multiple subtraction using regularized nonstationary regression. *Geophysics*, v. 74, n. 1, p. V25–V36, 2009.
- FOMEL, S.; KAZINNIK, R. Nonhyperbolic common reflection surface. *Geophysical Prospecting*, v. 61, p. 21–27, 2013.
- FOMEL, S.; LANDA, E.; TANER, M. Post-stack velocity analysis by separation and imaging of seismic diffractions. *Geophysics*, v. 72, p. U89–U94, 2007.
- HESTENES, M.; STIEFEL, E. Methods of conjugate gradients for solving linear systems. *Journal of Research of the National Bureau of Standards (United States)*, v. 49, p. 409–436, 1952.
- HUBRAL, P. computing true amplitude reflections in a laterally inhomogeneous earth. *Geophysics*, v. 48, p. 1051–1062, 1983.
- HUBRAL, P.; SCHLEICHER, J.; TTYGEL, M. Seismic image waves. *Geophysical Journal International*, v. 125, p. 431–442, 1996.
- HÖCHT, G. Traveltime approximations for 2D and 3D media and kinematic wavefield attributes. Tese (Doutorado) — Faculdade de Física Karlsruhe (TH) genehmigte, 2002.
- INGBER, L. Very fast simulated re-annealing. *Math1. Comput. Modelling*, v. 12, p. 967–973, 1989.
- JAGER, R. et al. Common-reflection-surface stack: image and attributes. *Geophysics*, v. 66, p. 97–109, 2001.

Referências

- LINES, L.; NEWRICK, R. Fundamentals of geophysical interpretation. [S.I.]: Society of Exploration Geophysicists, 2004.
- LIU, Y.; FOMEL, S. Seismic data interpolation beyond aliasing using regularized nonstationary autoregression. *Geophysics*, v. 76, p. 69–77, 2011.
- MESQUITA, M. Inversão de velocidades por otimização global usando a aproximação superfície de reflexão comum com afastamento finito. Tese (Doutorado) — Universidade Federal do Pará (UFPA), 2016.
- SEN, M.; STOFFA, P. Global Optimization Methods in Geophysical Inversion. [S.I.]: ELSEVIER, 1995.
- SHAHSAVANI, H. Processing a multifold ground penetration radar data using common-diffraction-surface stack method. *Journal of Mining and Environment (JME)*, v. 10, n. 3, p. 777–785, 2019.