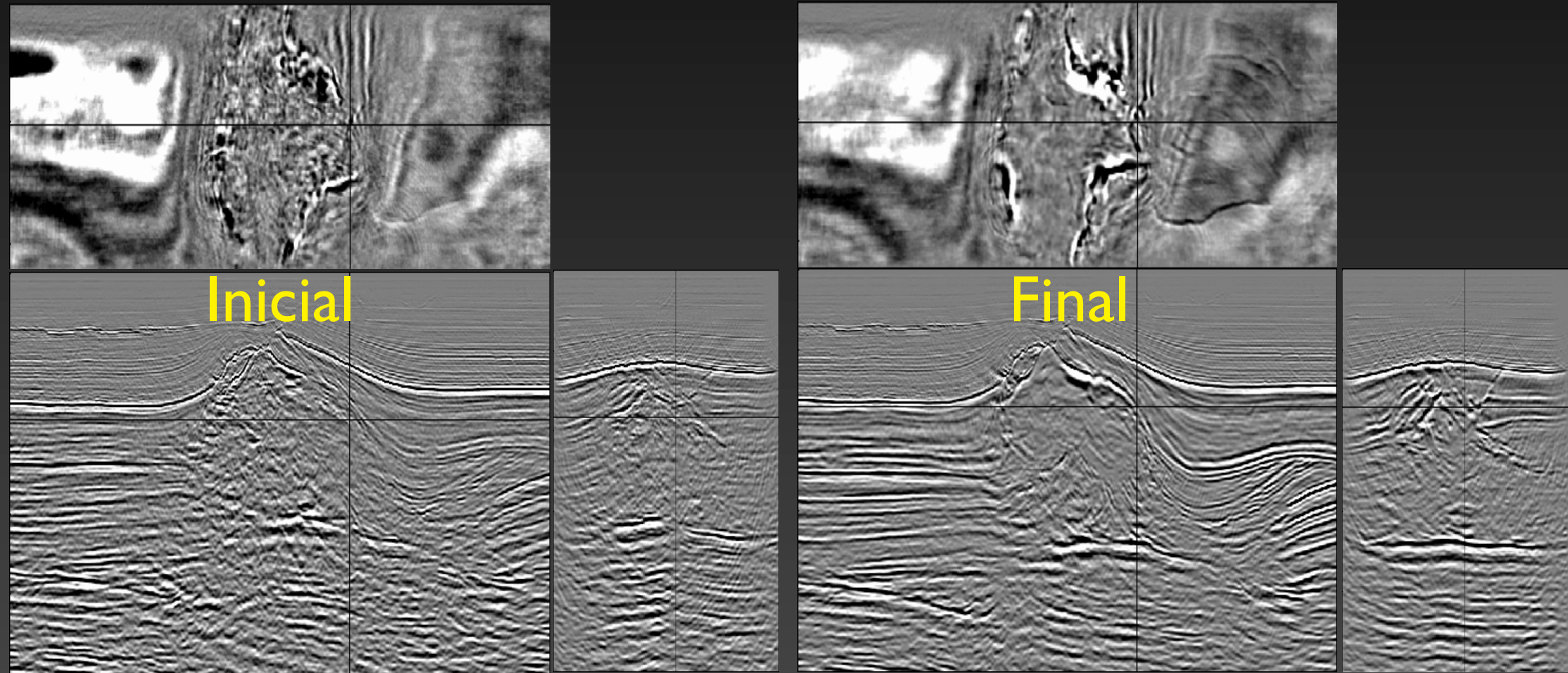
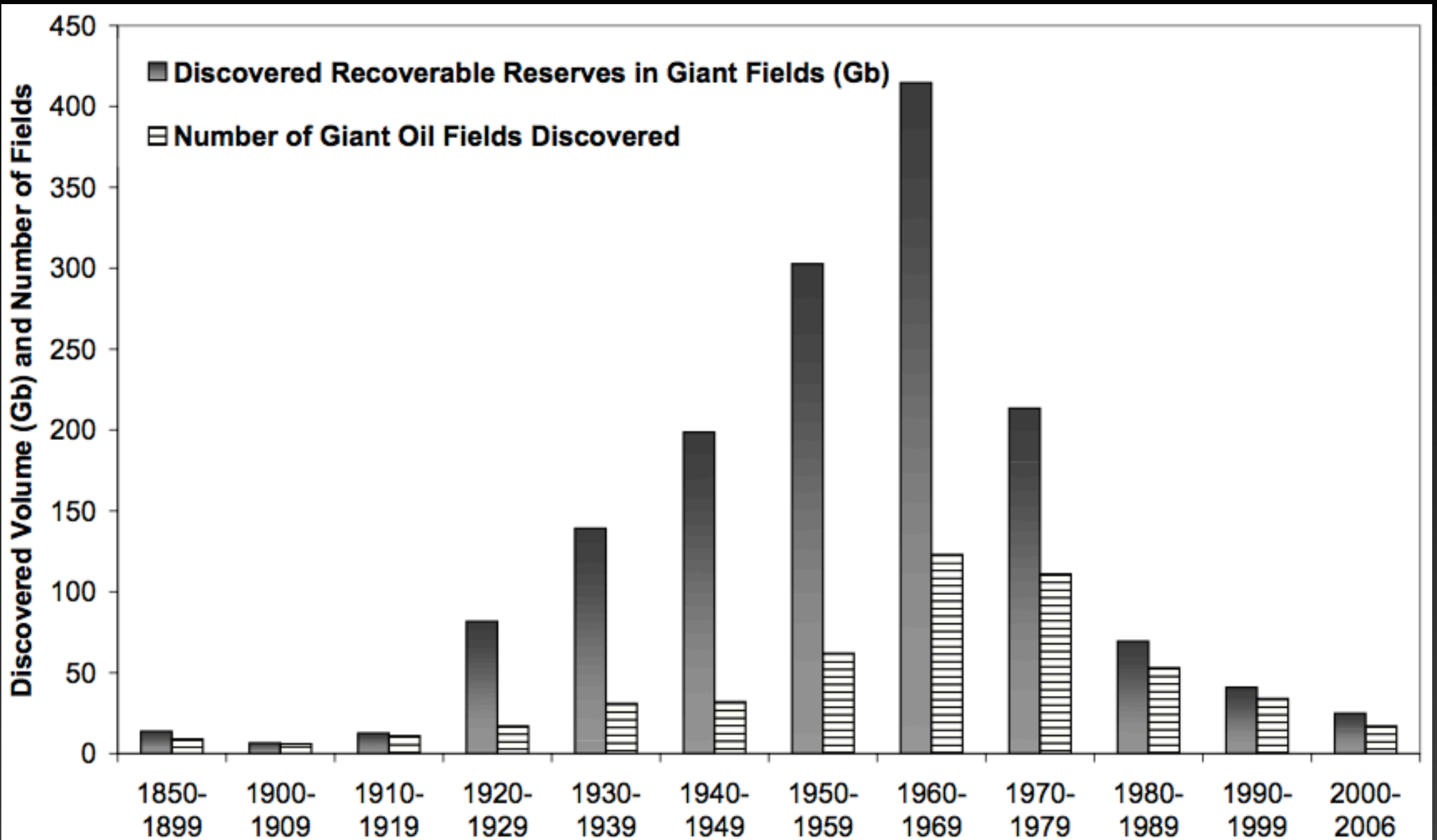


Análise de velocidade de migração com campos de onda generalizados no domínio da imagem

Claudio Guerra



Fim do óleo fácil



Robelius, Fredrik: Giant Oil Fields - The Highway to Oil: Giant Oil Fields and their Importance for Future Oil Production

Produção e prospectividade offshore



Modified from <http://pubs.usgs.gov/fs/fs-062-03/FS-062-03.pdf>

e localização de províncias de sal



Modified from <http://pubs.usgs.gov/fs/fs-062-03/FS-062-03.pdf> and <http://truman.seg.org/TLEreview/November/Sayers.pdf>

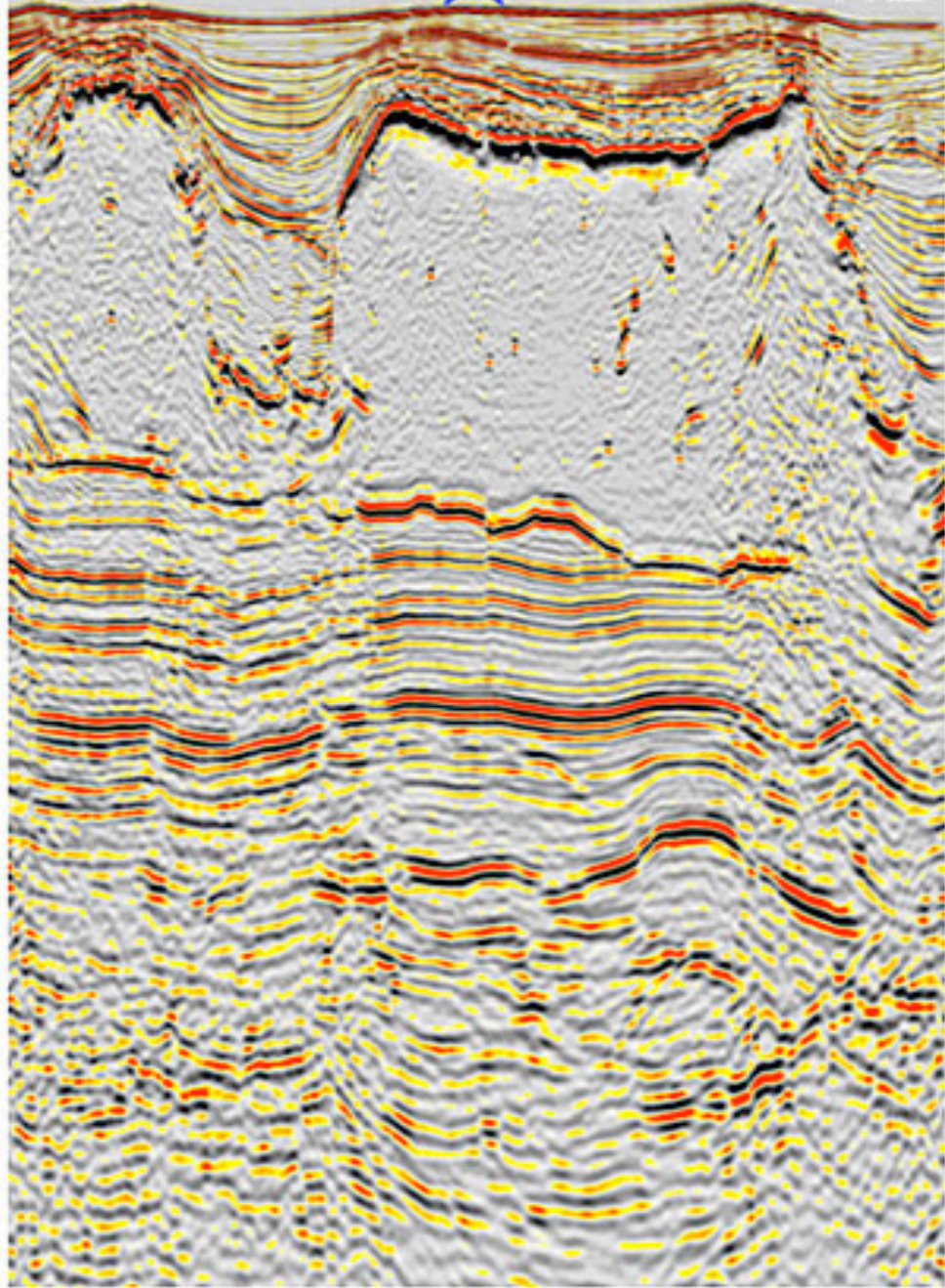
distance

Tiber



SW

NE

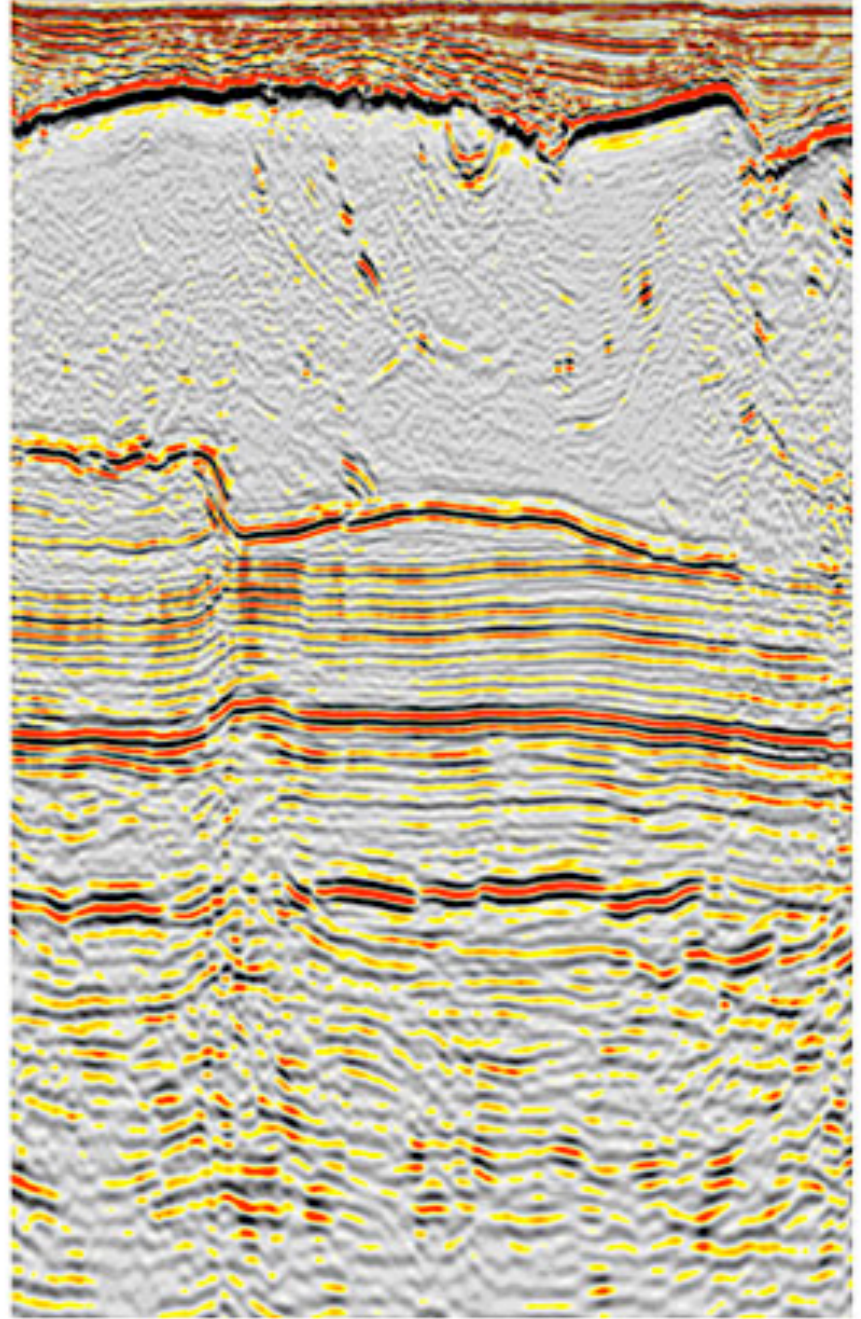


Tiber



SE

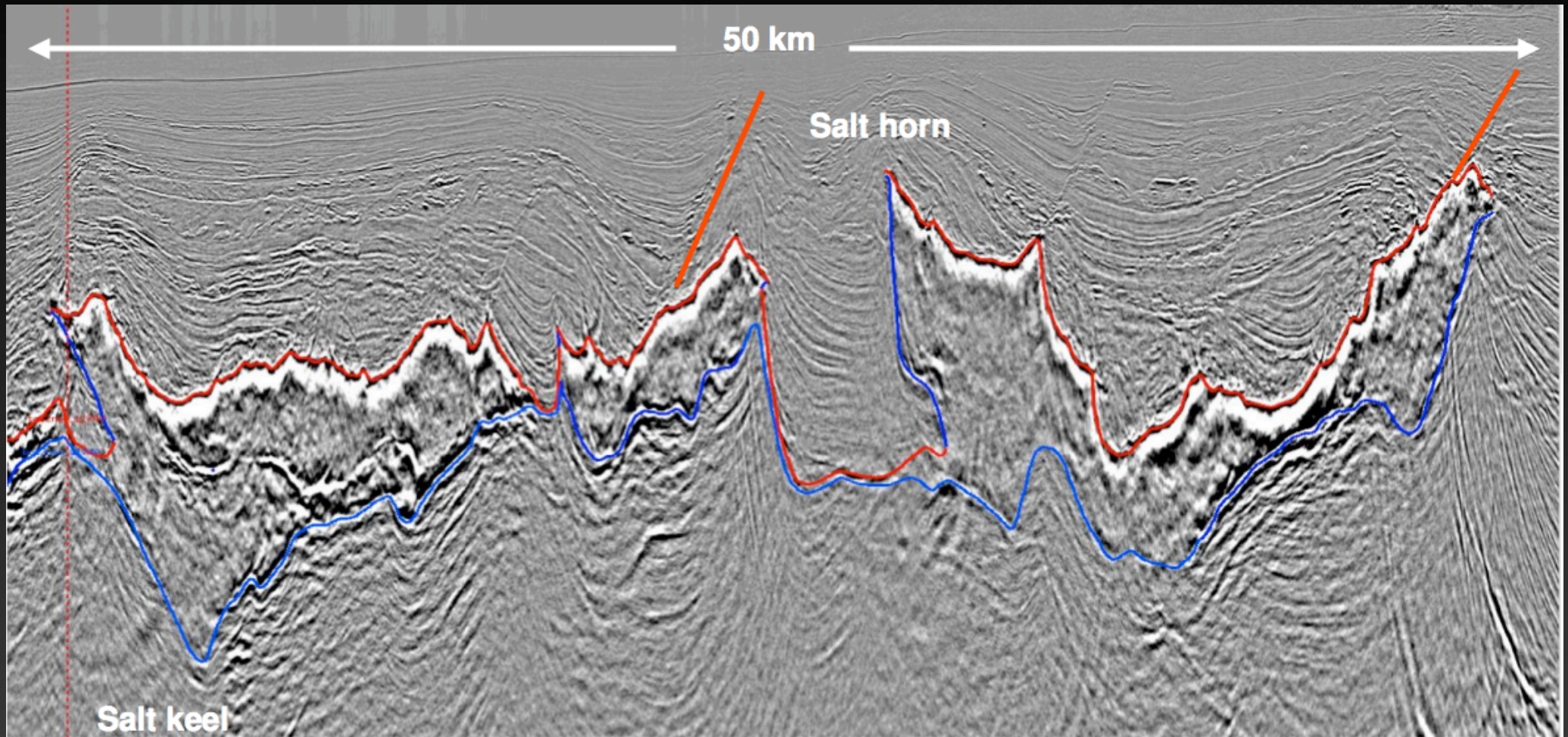
NW



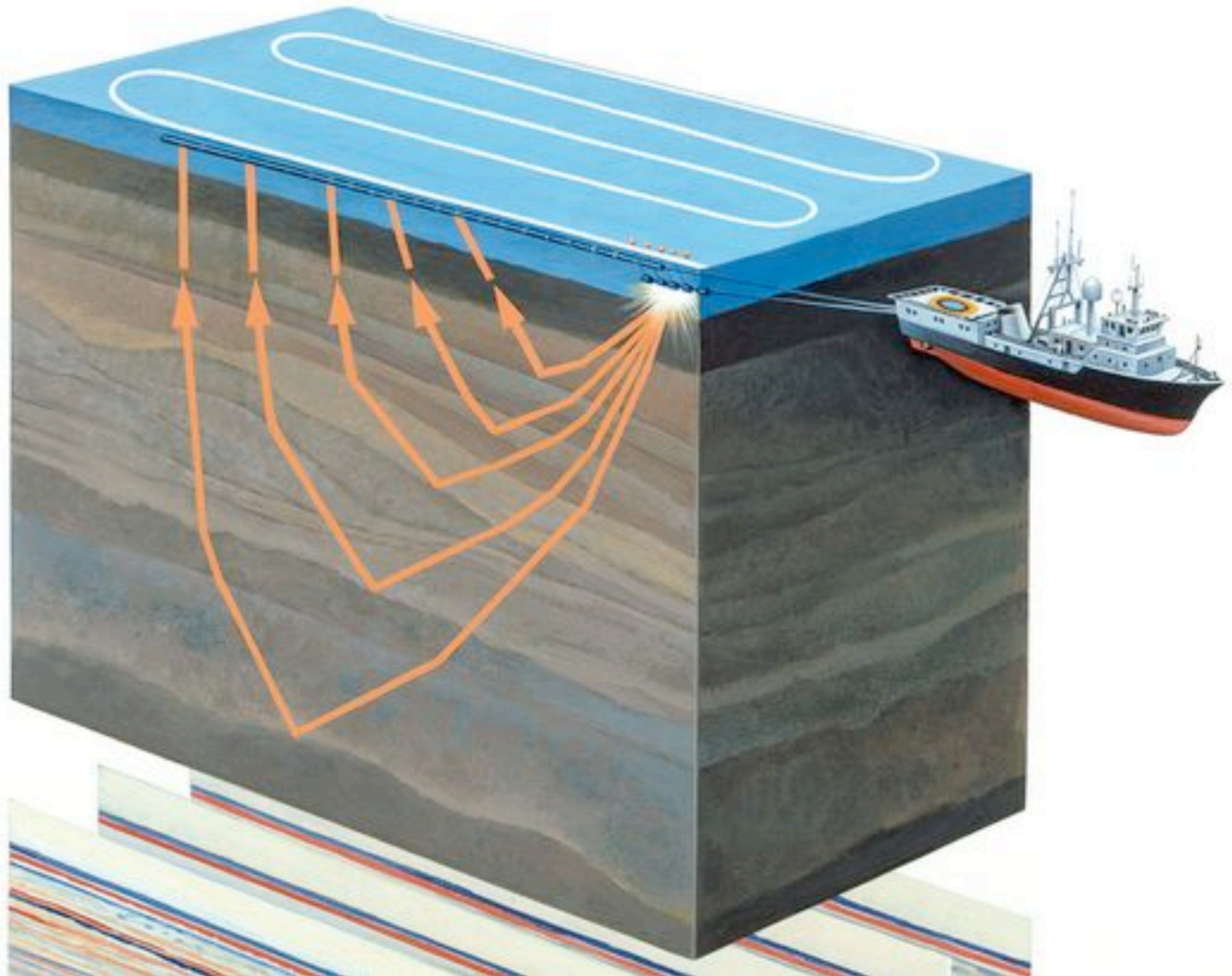
depth

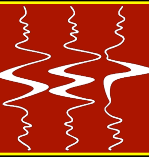
distance

depth

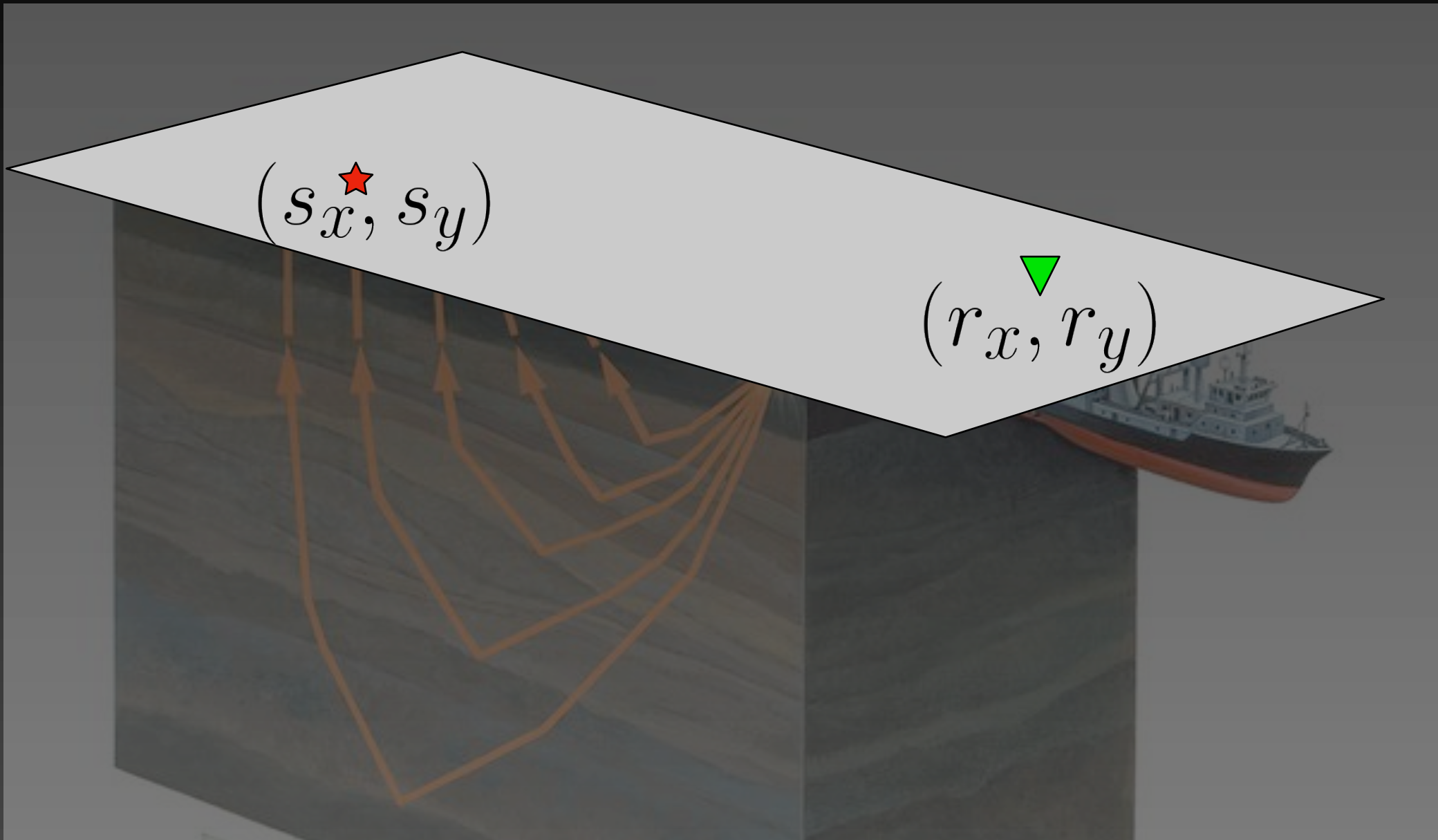


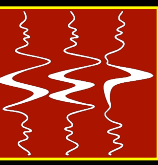
Li et al., 2009



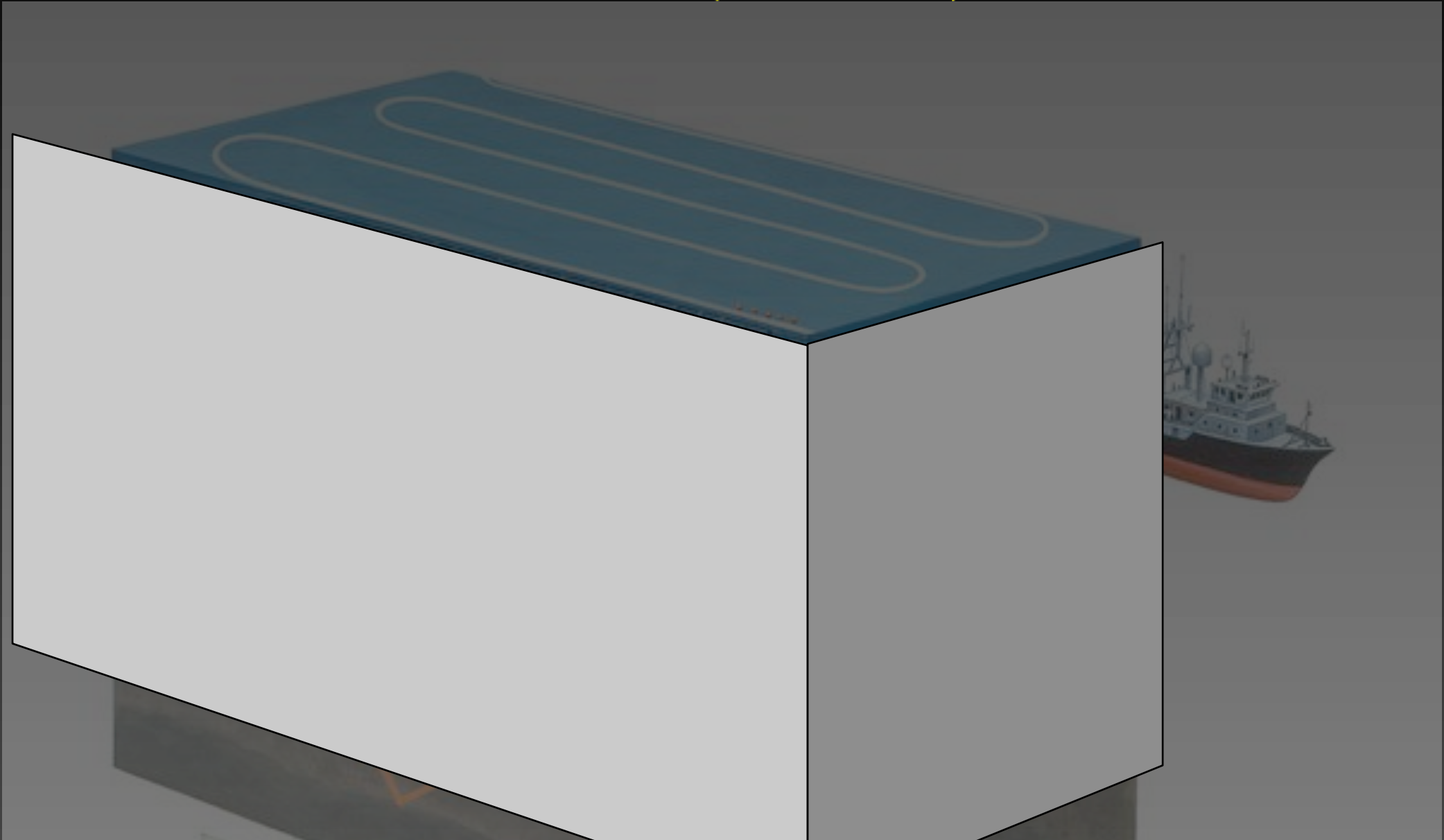


$$d = d(\mathbf{s}, \mathbf{r}, t)$$





$$I = I(\mathbf{x}, \mathbf{h})$$

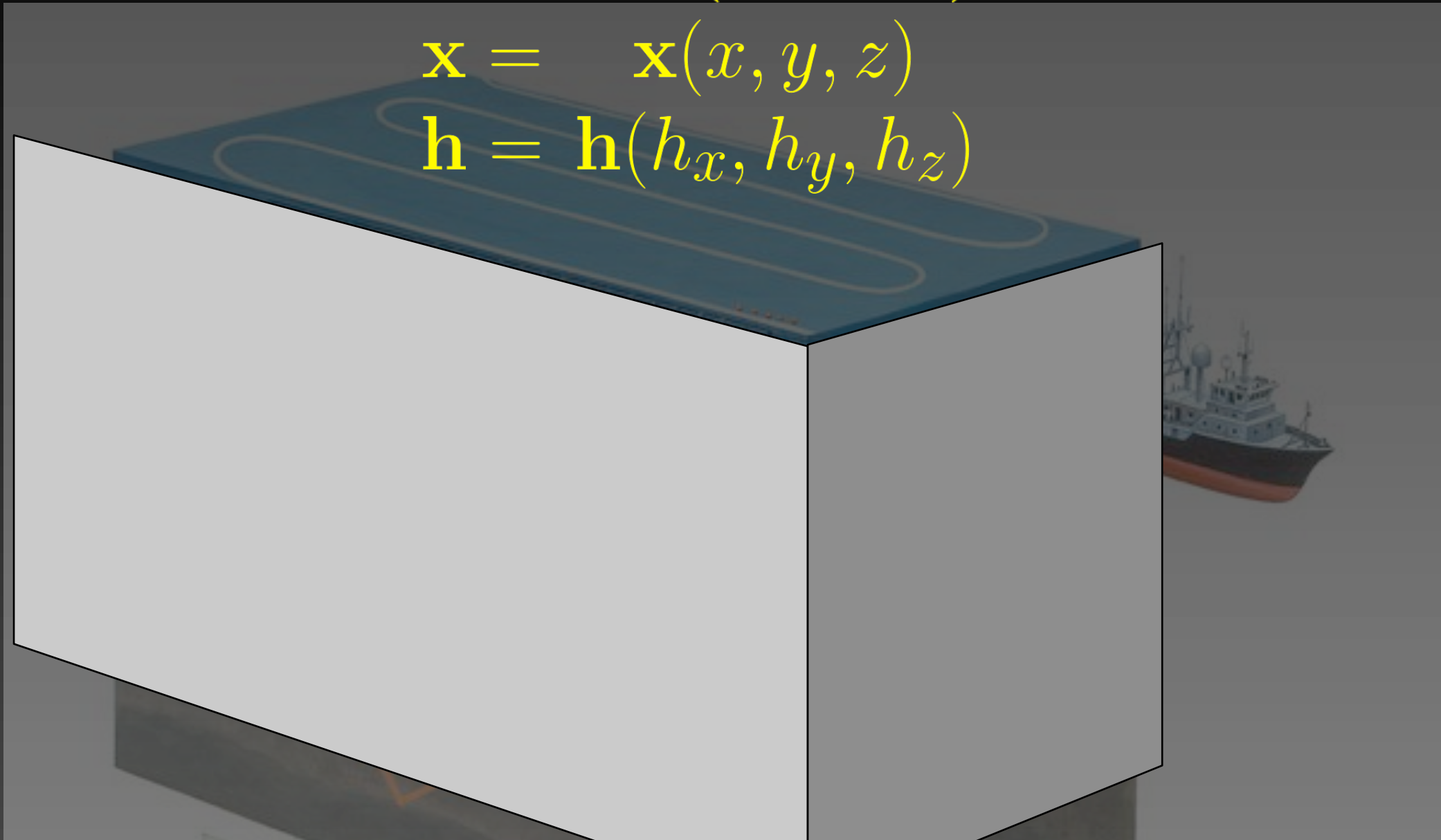


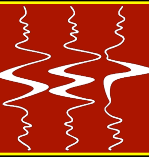


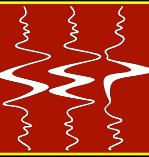
$$I = I(\mathbf{x}, \mathbf{h})$$

$$\mathbf{x} = \mathbf{x}(x, y, z)$$

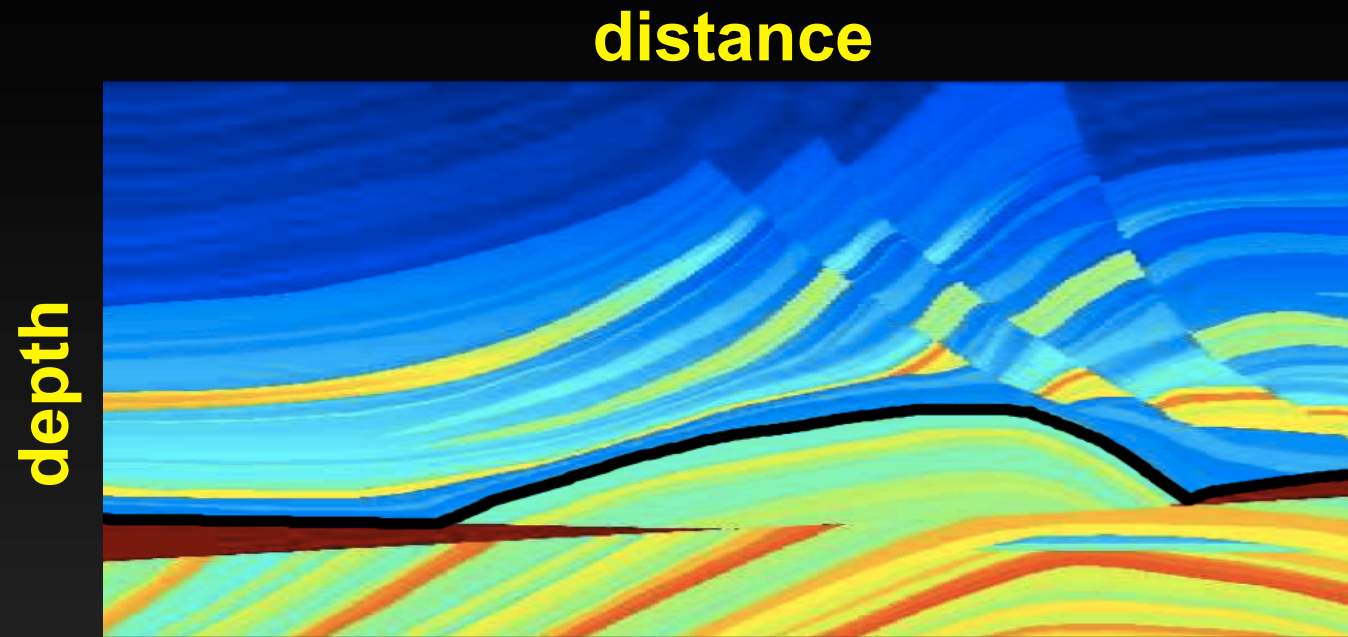
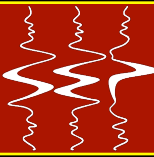
$$\mathbf{h} = \mathbf{h}(h_x, h_y, h_z)$$



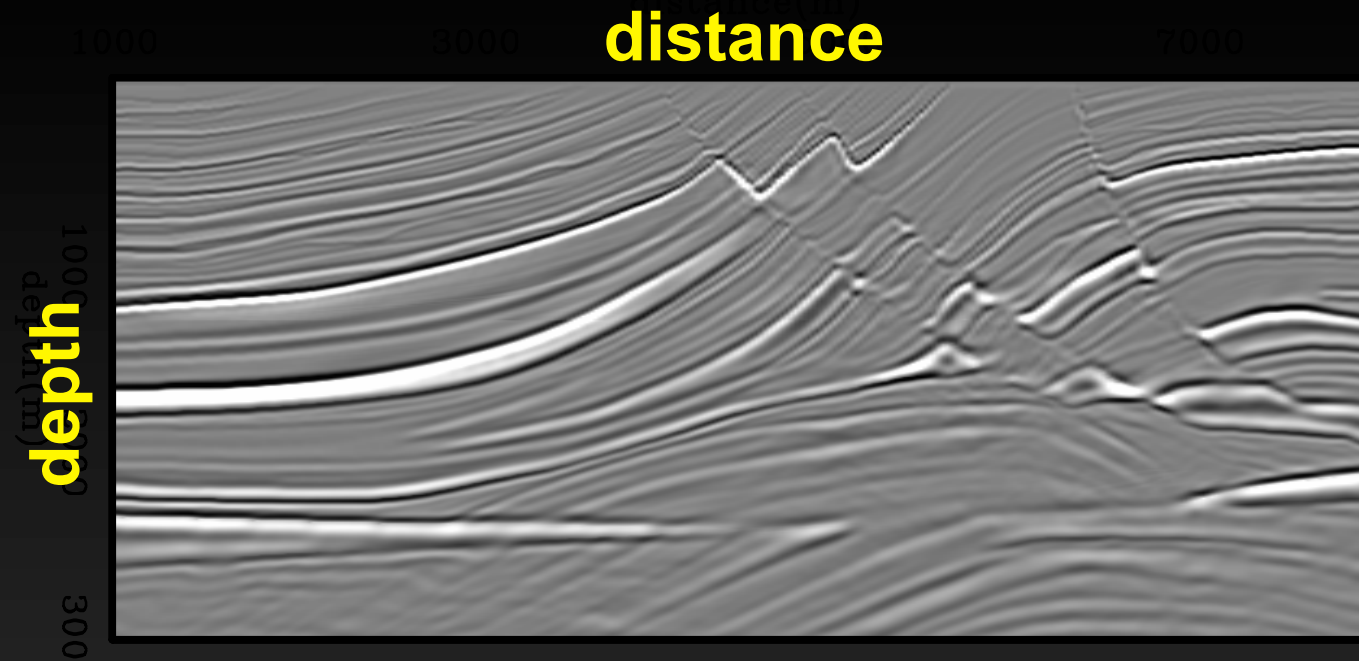
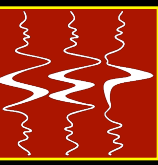




Importância da velocidade de migração

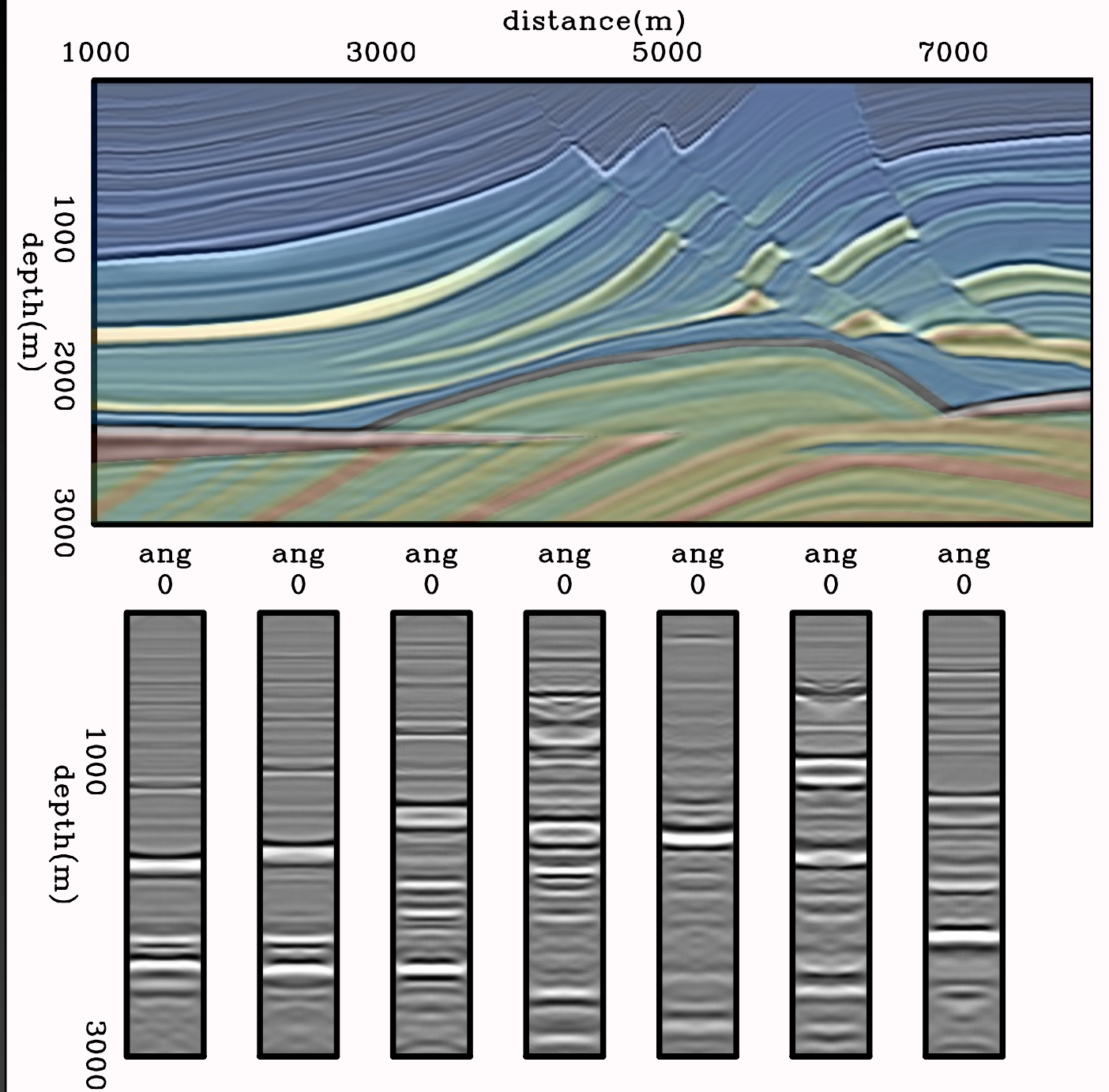


Migração com velocidade correta



Reconstrução razoável da
subsuperfície

Refletores horizontais no CRP



Migração com velocidade incorreta

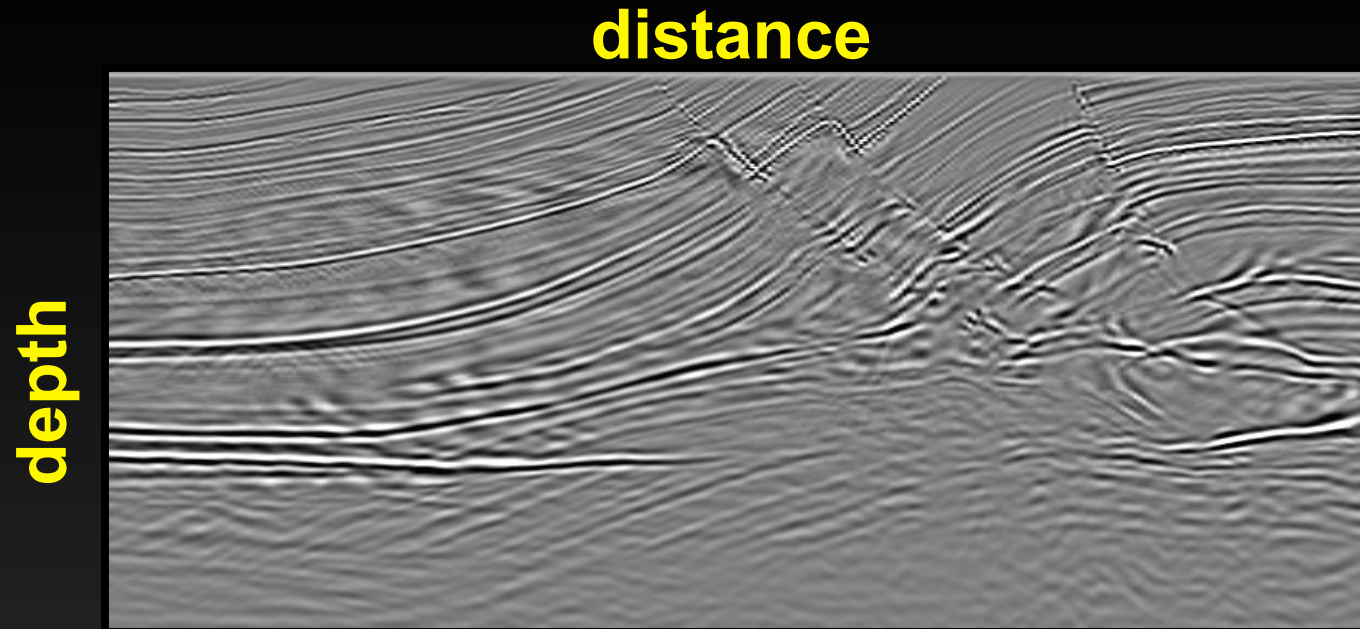
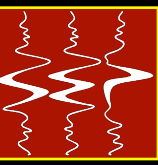
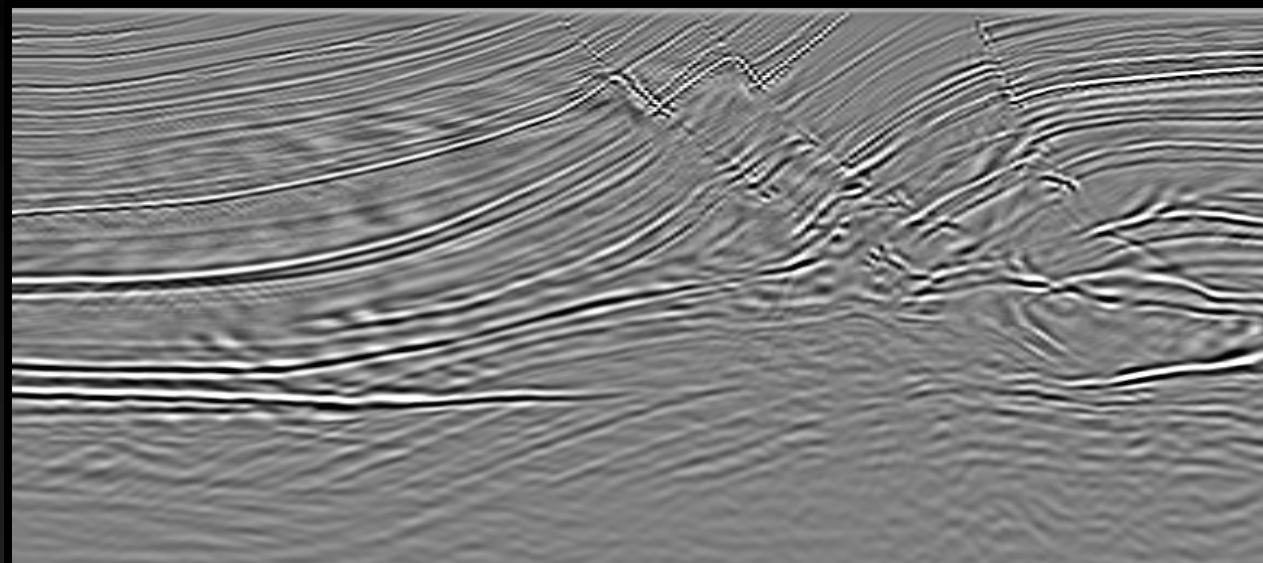


Imagem desfocada, posicionamento errado

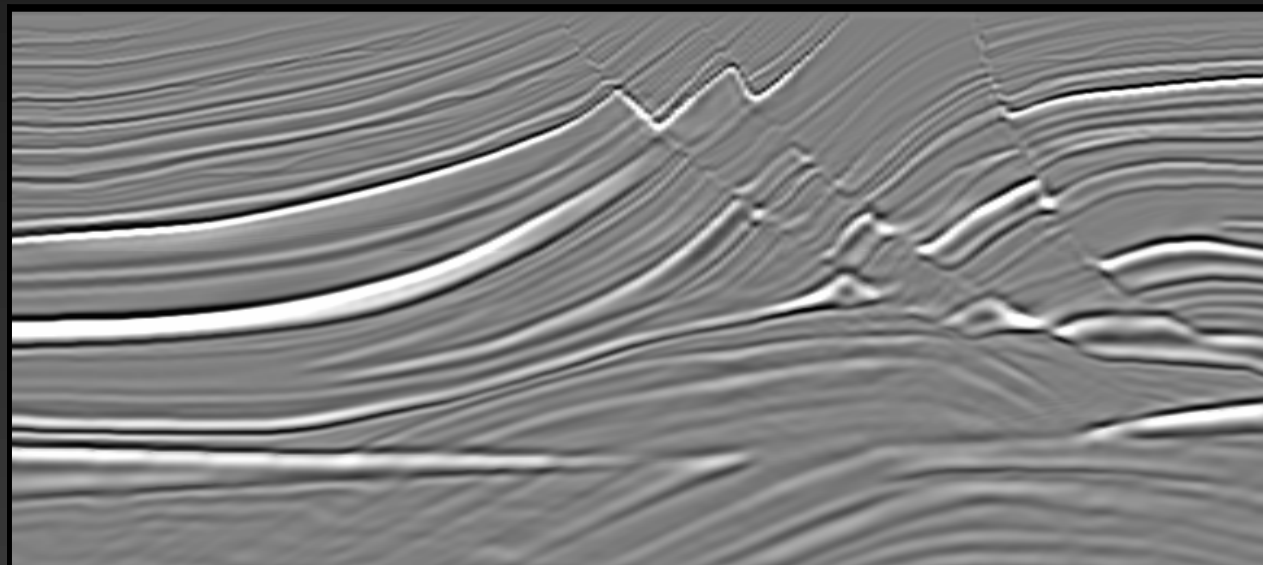


distance

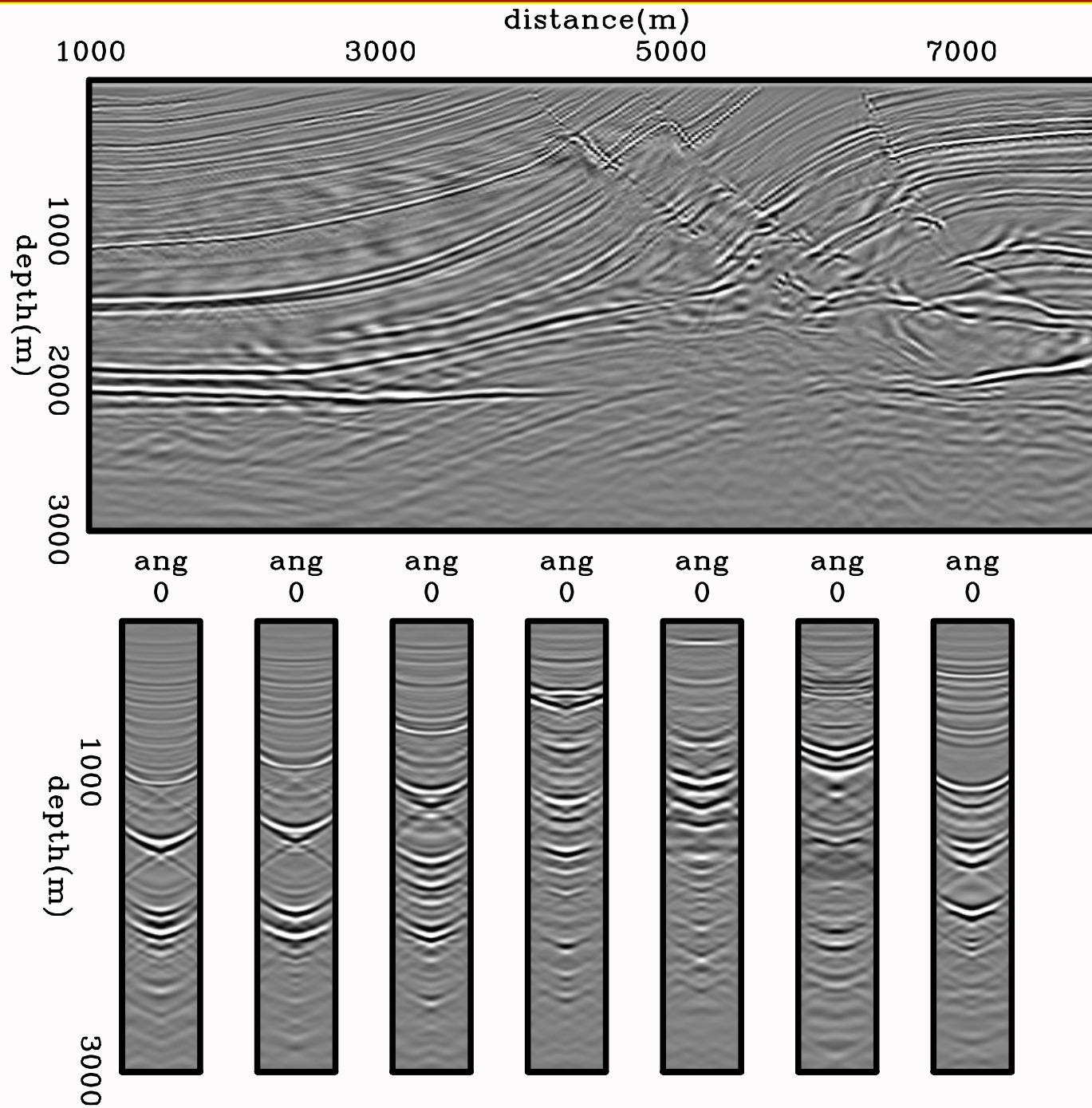
depth



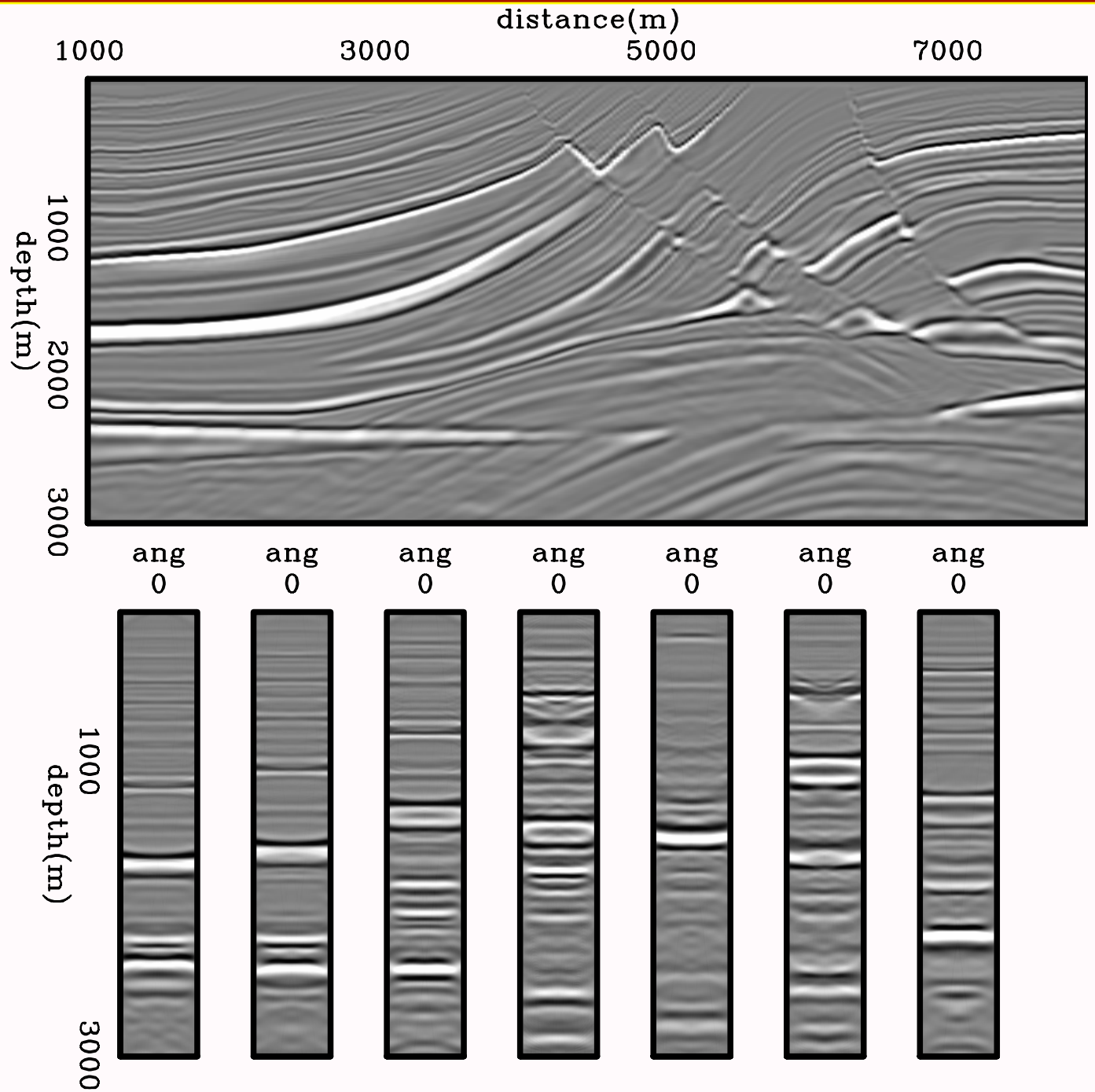
depth



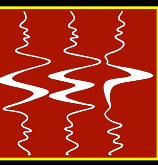
Refletores com curvatura no CRP



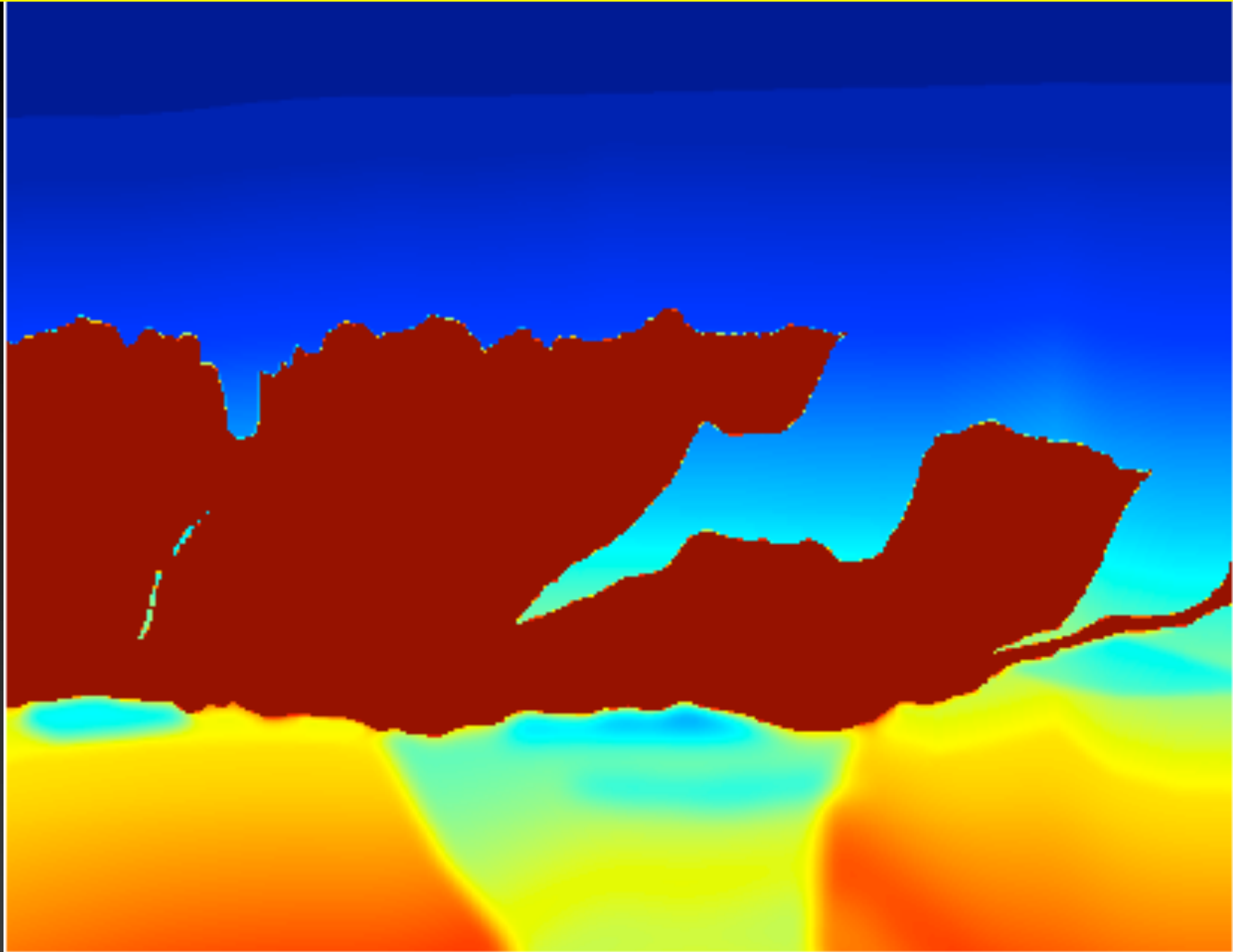
Refletores horizontais no CRP



Propagação de campos de onda

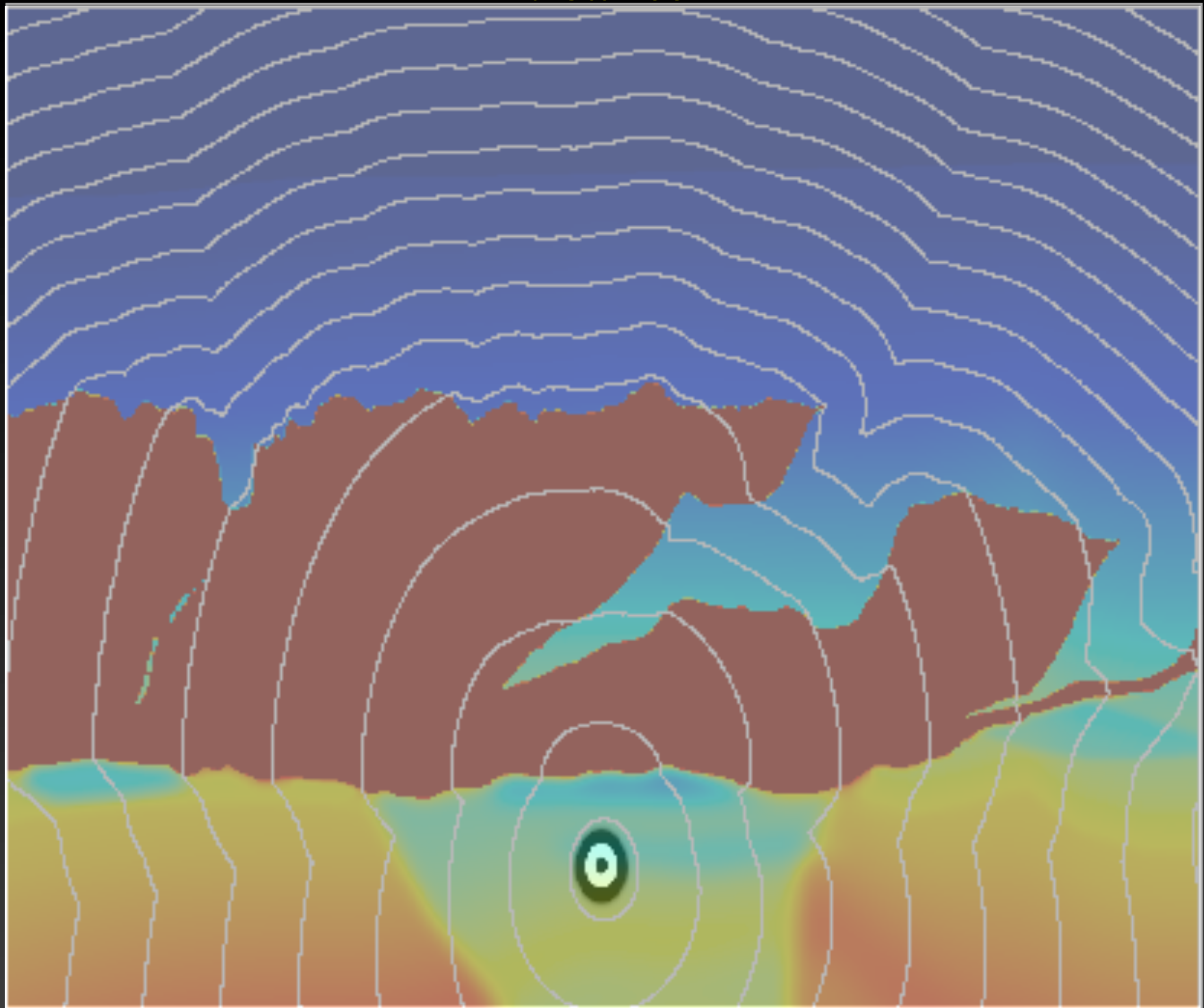


depth



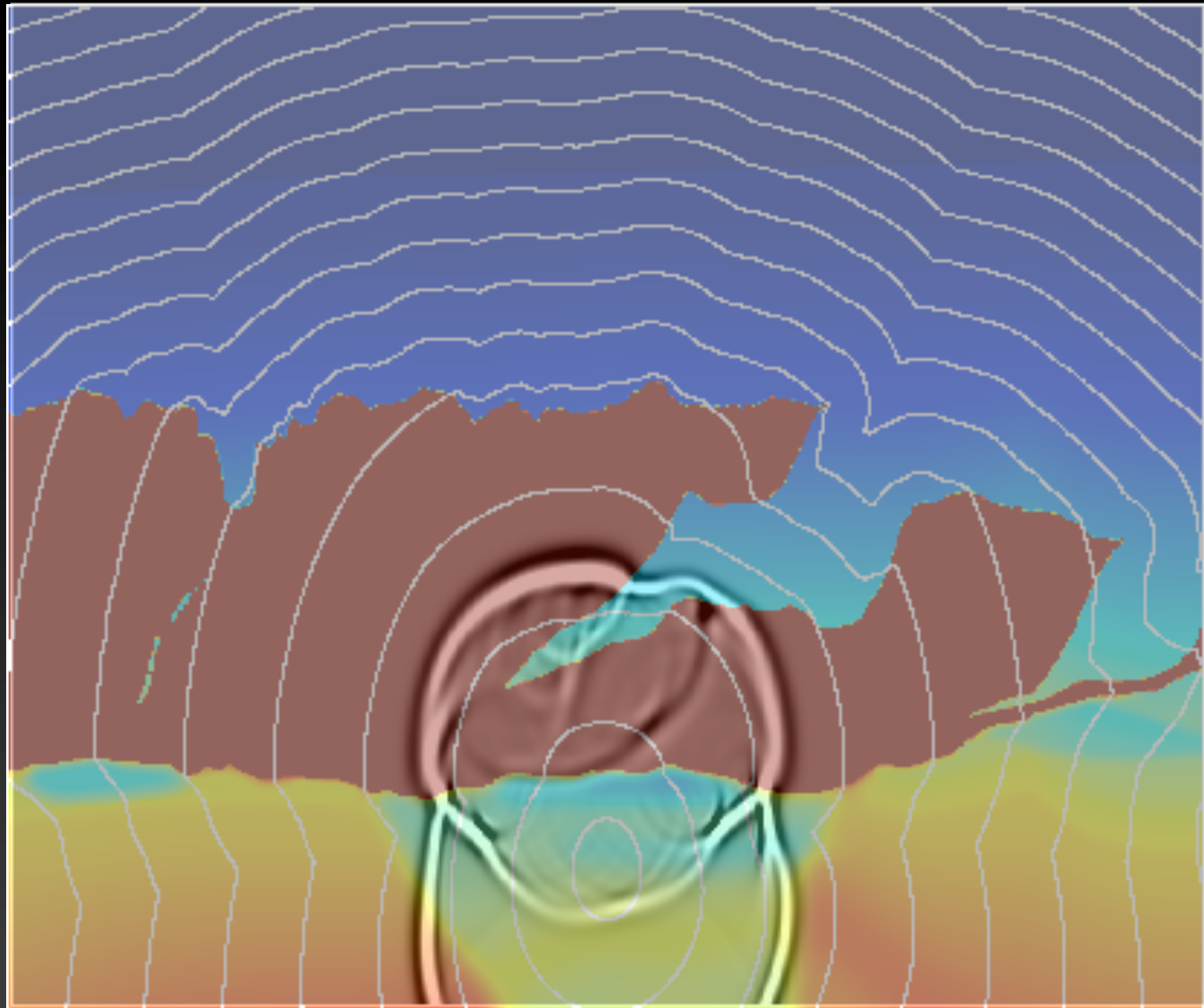
distance

depth



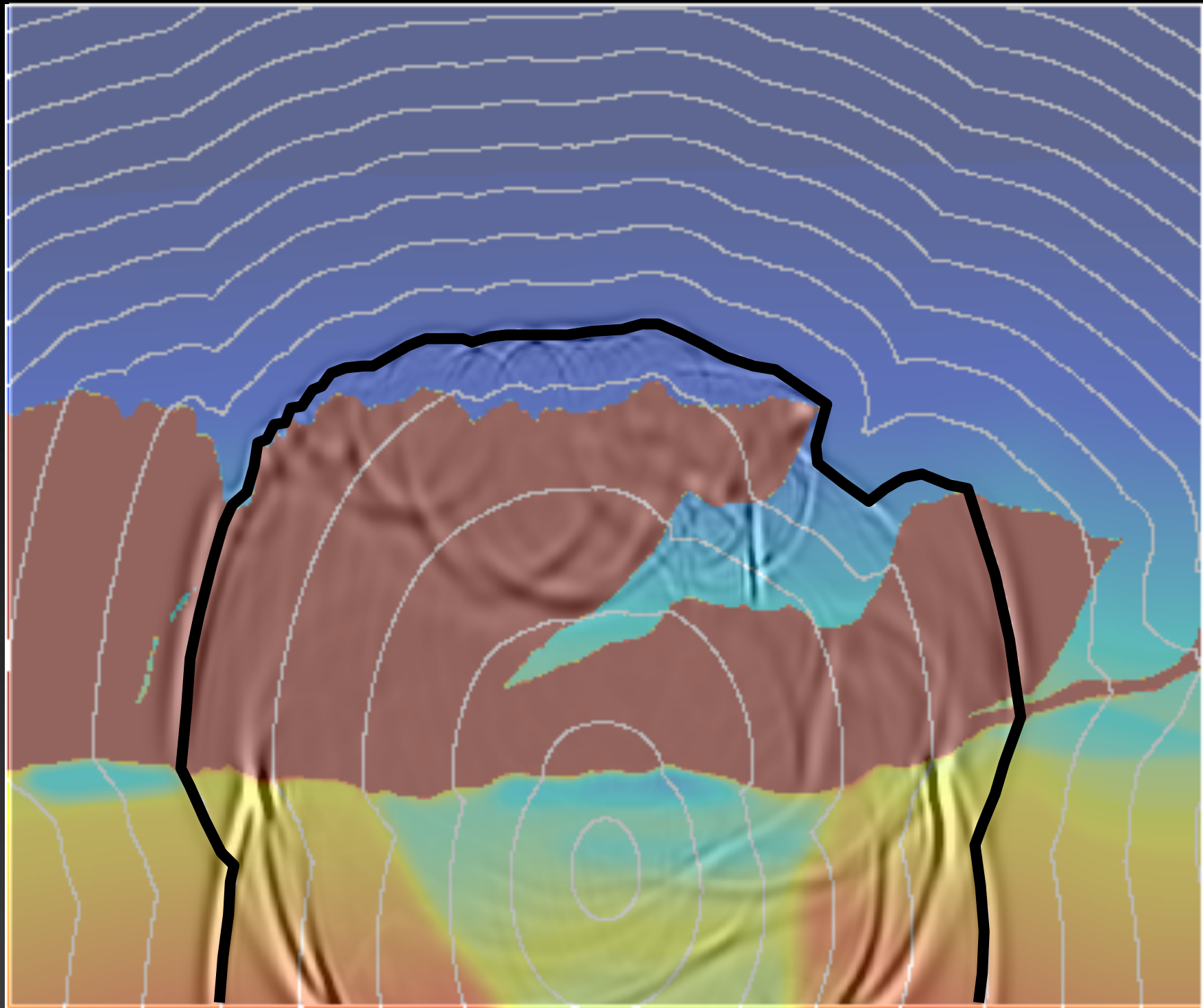
distance

depth



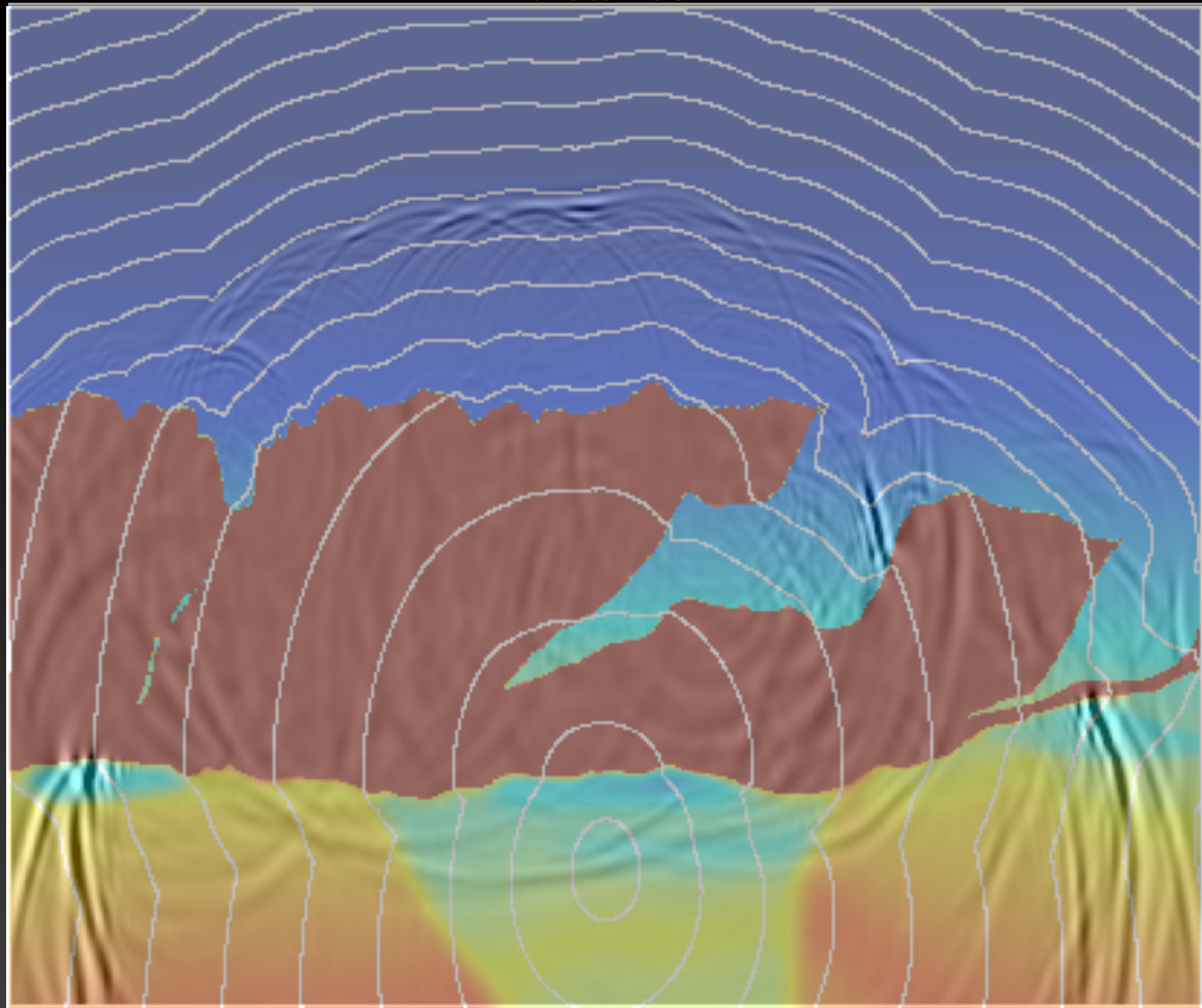
distance

depth



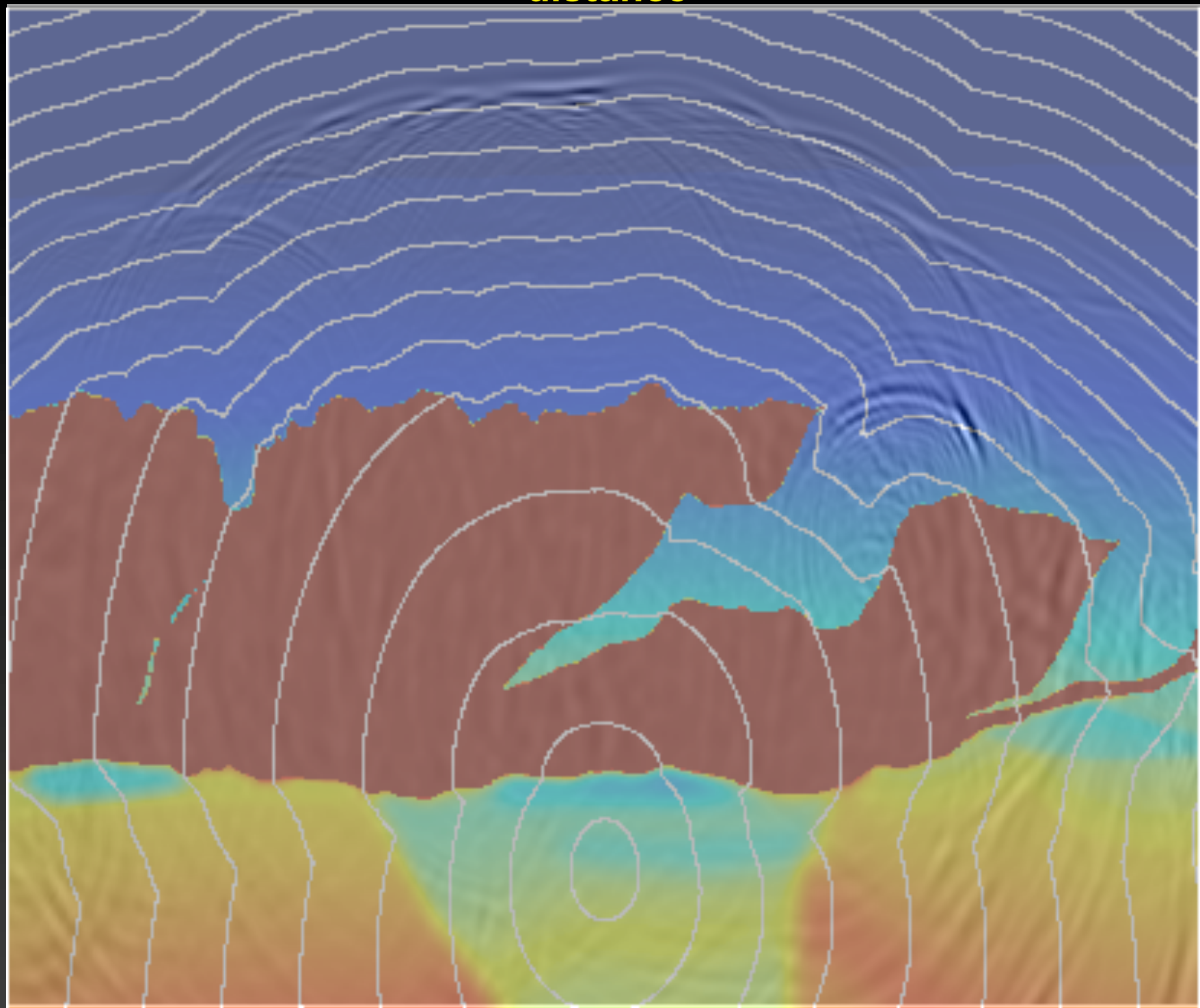
distance

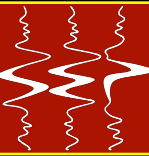
depth



distance

depth





- **No espaço de dados**
 - inversão da forma de onda

$$J(s) = \|\mathbf{F}[s] - d_{obs}\|_n$$

J = objective function

\mathbf{F} = nonlinear operator

n = norm

s = slowness

d_{obs} = observed data



- **Espaço da imagem (ISWET)**

$$I(s) \approx I_o + \left. \frac{\partial I}{\partial s} \right|_{s=s_o} \Delta s$$

$$\Delta I(s) = \mathbf{T} \Delta s$$

s = slowness

s_o = background slowness

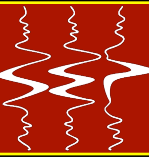
Δs = slowness perturbation

\mathbf{T} = IS – tomographic operator

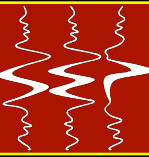
I = image

I_o = background image

ΔI = image perturbation



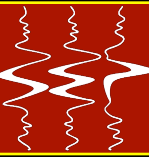
- **Espaço da imagem (ISWET)**
 - Análise de velocidade de migração com equação da onda (WEMVA) (Sava and Biondi, 2004)
 - Análise de velocidade de migração com semblance diferencial (DVSA) (Shen and Symes, 2008)



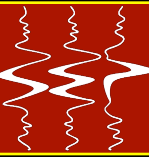
- **Espaço da imagem (ISWET)**

- Análise de velocidade de migração com equação da onda (WEMVA) (Sava and Biondi, 2004)
- Análise de velocidade de migração com semblance diferencial (DVSA) (Shen and Symes, 2008)

Para geologia complexa ...

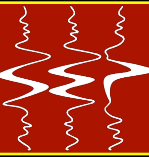


- **ISWET é mais robusto que métodos baseados em traçado de raios**



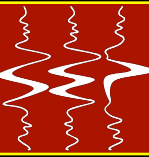
- **ISWET é mais robusto que métodos baseados em traçado de raios**
- **Raramente aplicada em 3D**
 - **Maior custo e menor flexibilidade que métodos por traçado de raios**

3D-ISWET como rotina



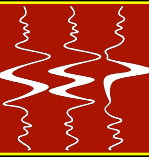
- **Reduzir custo**

3D-ISWET como rotina



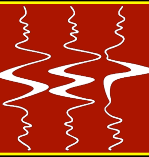
- **Reduzir custo**
- **Aumentar flexibilidade**

3D-ISWET como rotina

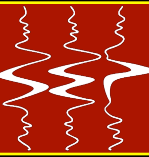


- **Reduzir custo**
- **Aumentar flexibilidade**
- **Manter robustez**

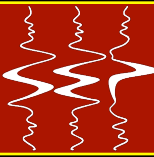
Reduzindo o custo do 3D-ISWET



- **Diminuir tamanho dos dados**

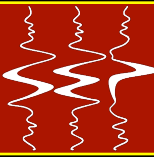


- **Diminuir tamanho dos dados**
- **Resolver focado num alvo**
 - **Propagação dos campos de onda restrita à parte com erros de velocidades**

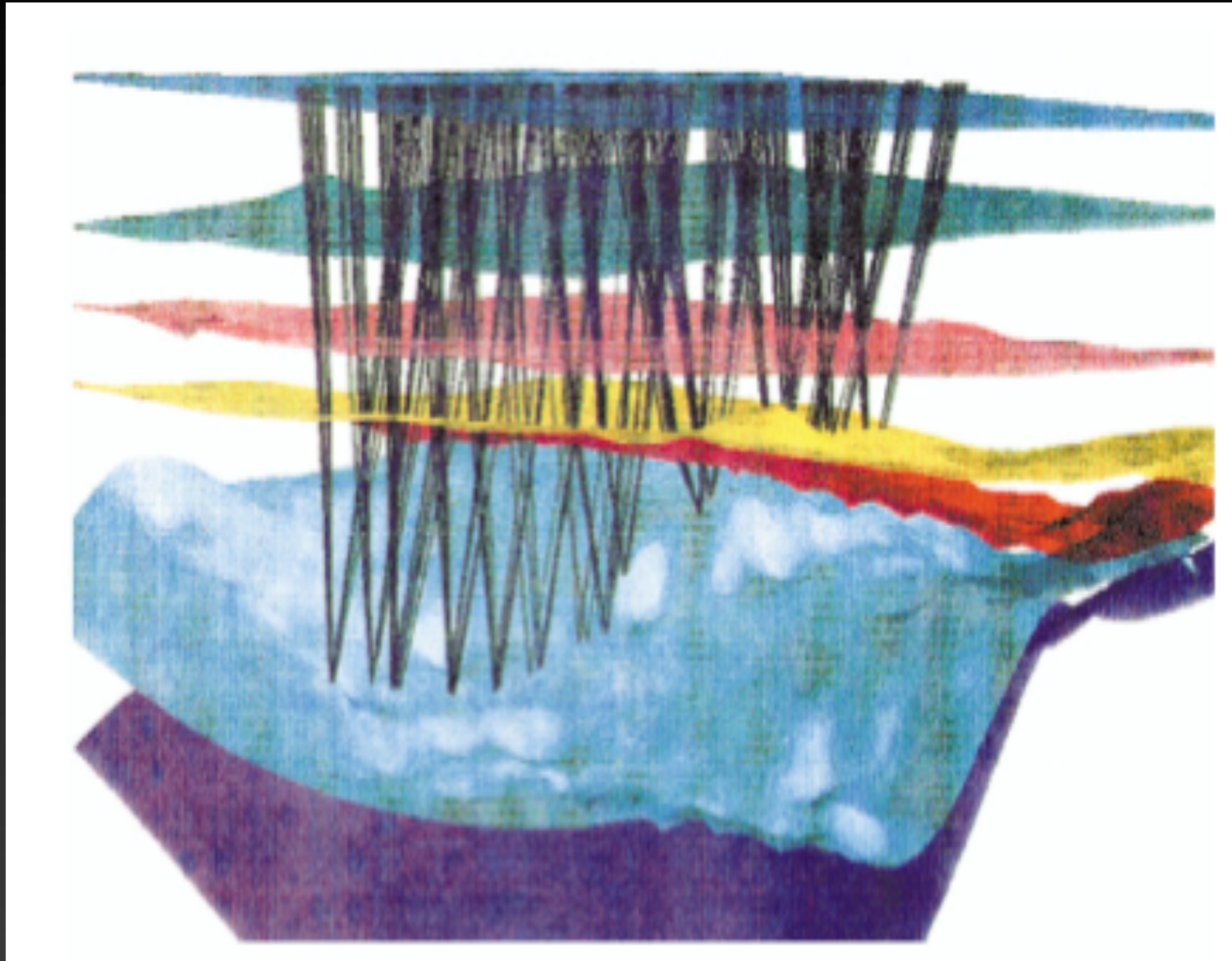


- **Incorporar estratégias de métodos por traçado de raios no ISWET**

Estratégias usadas com traçado de raios

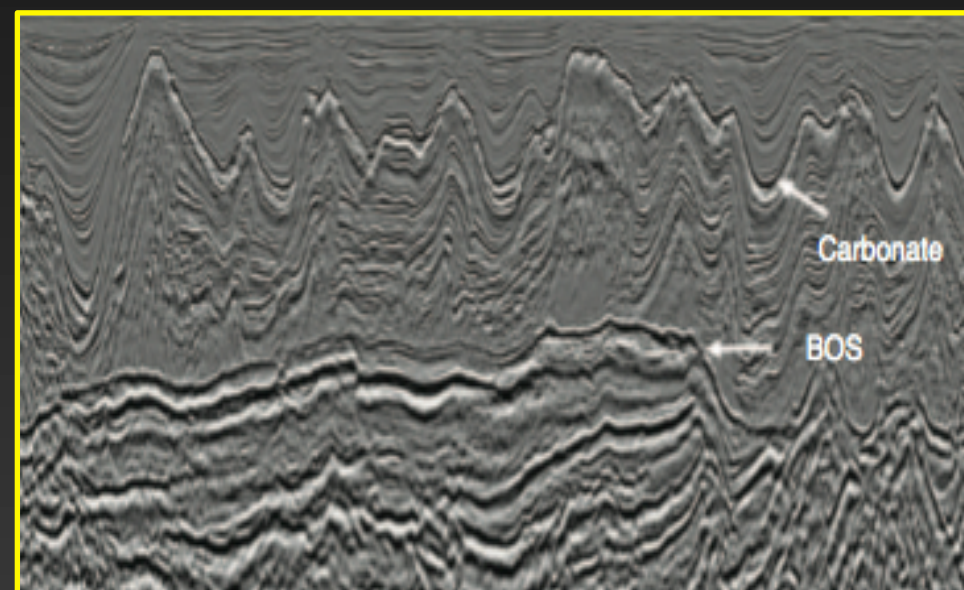
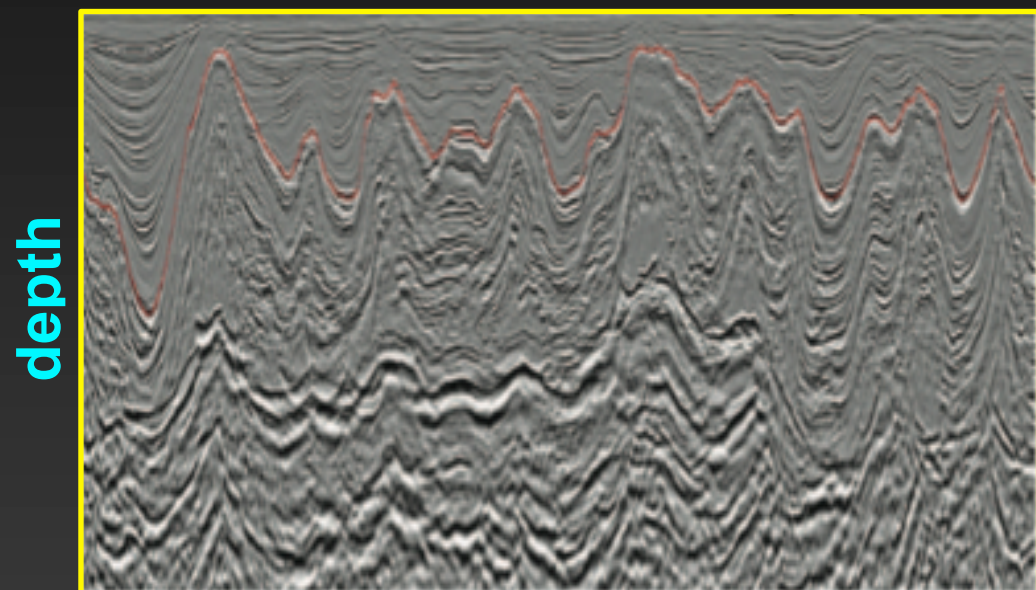
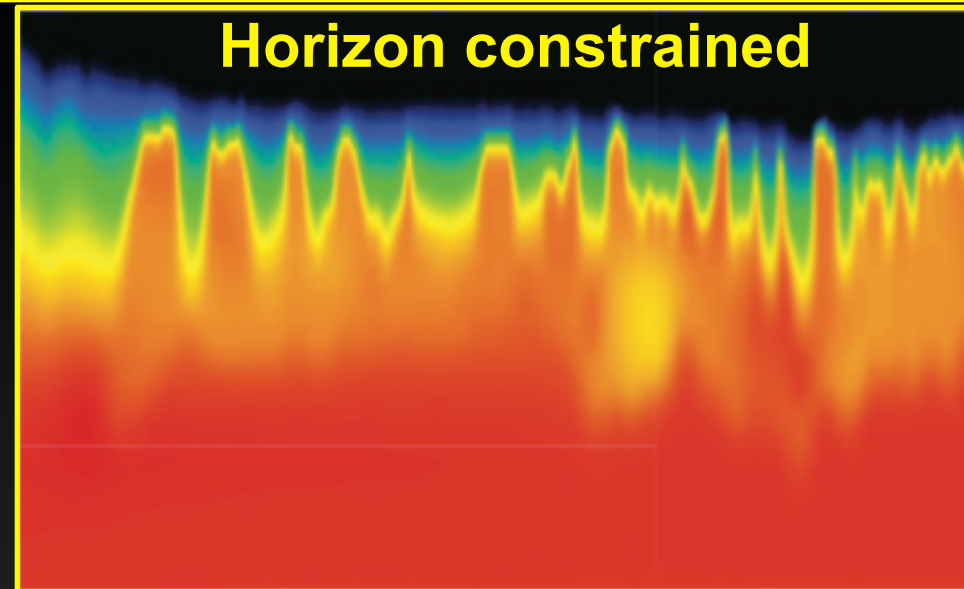
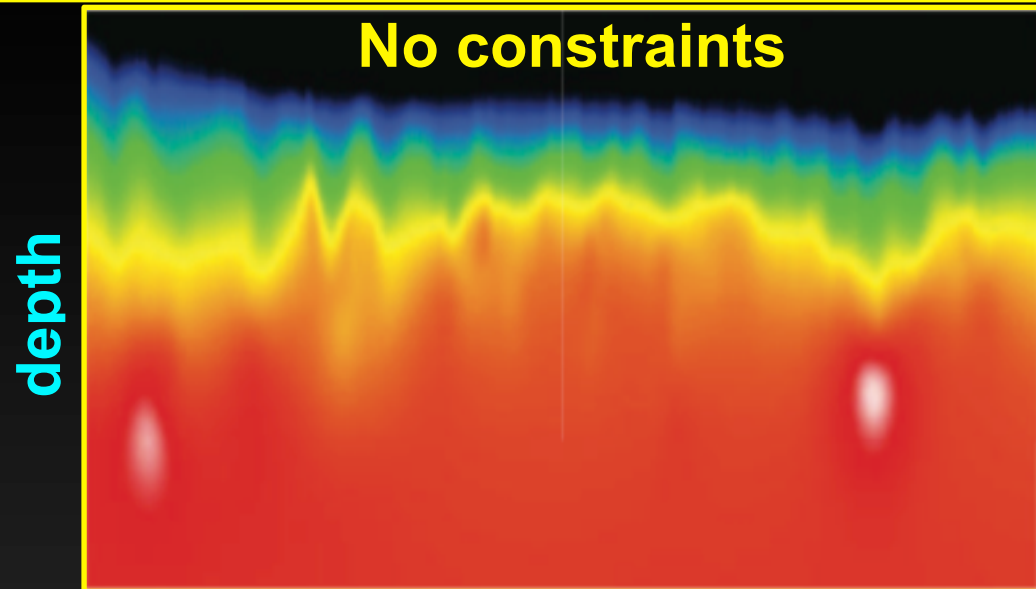


Uso de horizontes



Jones et al., 1998

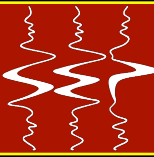
Estratégias usadas com traçado de raios



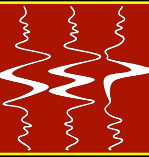
distance

Wang et al., 2008

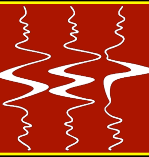
distance



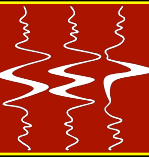
- **Incorporar estratégias de métodos por traçado de raios no ISWET**
 - **Usar campos de ondas generalizados no domínio da imagem**



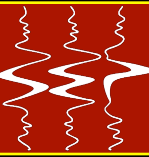
- **Garantir cinemática correta e amplitudes razoáveis**



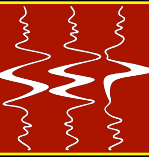
- **Campos de onda são combinados usando a linearidade da propagação de ondas**



- **Campos de onda são combinados usando a linearidade da propagação de onda**
 - **Menor número de experimentos sísmicos**



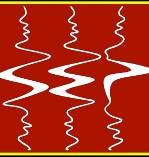
- **Campos de onda são combinados usando a linearidade da propagação de onda**
 - **Menor número de experimentos sísmicos**
 - **Manter intacta a informação cinemática**



- **Campos de onda são combinados usando a linearidade da propagação de onda**
- **Aquisição sísmica**
 - fontes simultâneas



- **Campos de onda são combinados usando a linearidade da propagação de onda**
- **Aquisição sísmica**
 - fontes simultâneas
- **Processamento sísmico**
 - síntese de ondas planas (Whitmore, 1995)
 - phase-encoding aleatório (Romero et al., 2000)

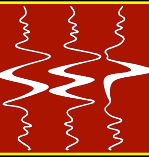


- **No espaço de dados**
 - **síntese de ondas planas**
 - **phase-encoding aleatório**



- **No espaço de dados**
 - **síntese de ondas planas**
 - **phase-encoding aleatório**

- **No espaço da imagem**
 - **refletor explosivo prestack - PERM**
(Biondi, 2006)
 - **Campos de onda phase-encoded na imagem - ISPEW** (Guerra and Biondi, 2008)



Domínio de fontes generalizadas

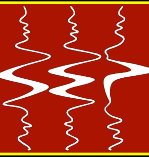
```
graph TD; A[Domínio de fontes generalizadas] --> B[Espaço de dados]; A --> C[Espaço da imagem];
```

Espaço de dados

- ondas planas
- fases aleatórias

Espaço da imagem

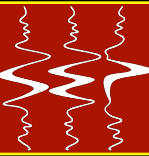
- PERM
- ISPEW



**Domínio de fontes
generalizadas**

Espaço de dados
• ondas planas
• fases aleatórias

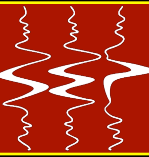
Espaço da imagem
• PERM
• ISPEW



- **Capítulo 2: Modelo do refletor explosivo prestack**
- **Capítulo 3: Campos de onda aleatoriamente combinados no espaço da imagem**
- **Capítulo 4: AVM com fontes generalizadas no espaço da imagem**
- **Capítulo 5: Exemplo com dados reais 3D**

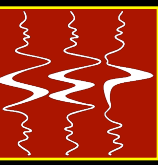


- **O modelo do refletor explosivo sintetiza dados de afastamento nulo, assumindo refletores focados no afastamento nulo em subsuperfície**



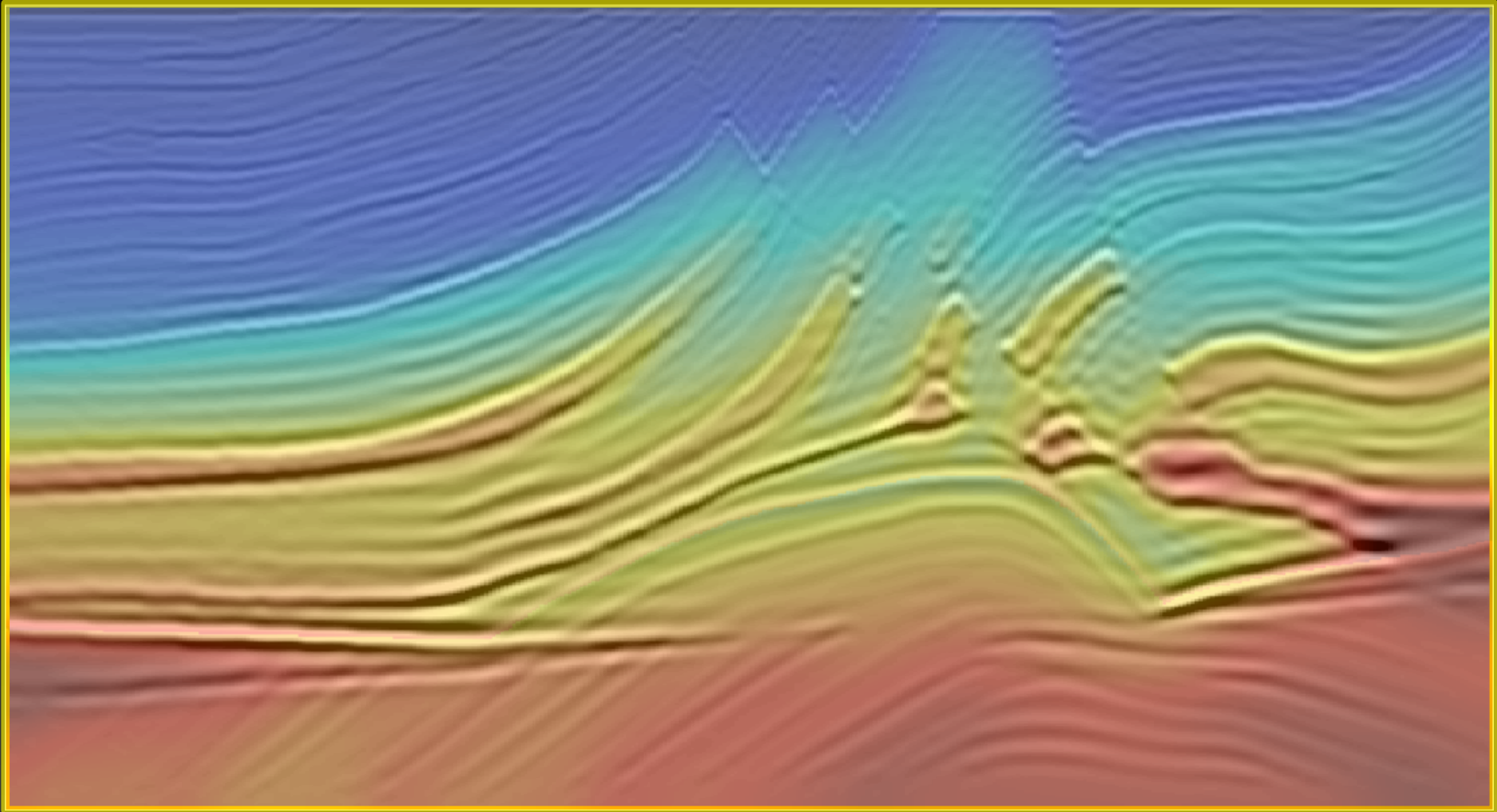
- **O modelo do refletor explosivo sintetiza dados de afastamento nulo, assumindo refletores focados no afastamento nulo em subsuperfície**
 - **velocidade acurada e iluminação completa**

Refletores explosivos

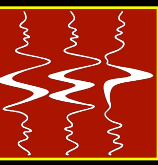


distance

depth

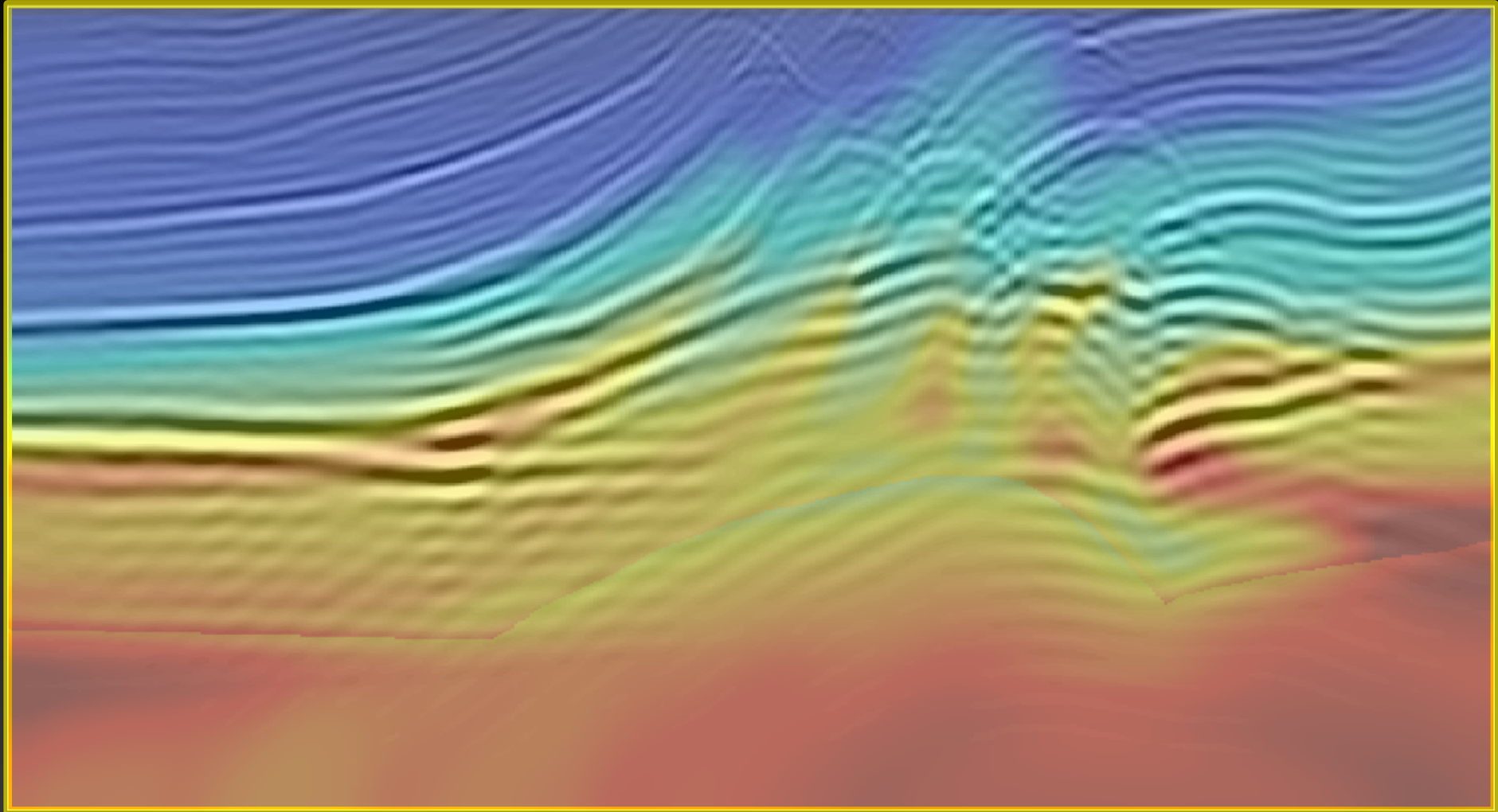


Refletores explosivos

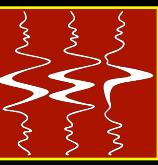


distance

depth

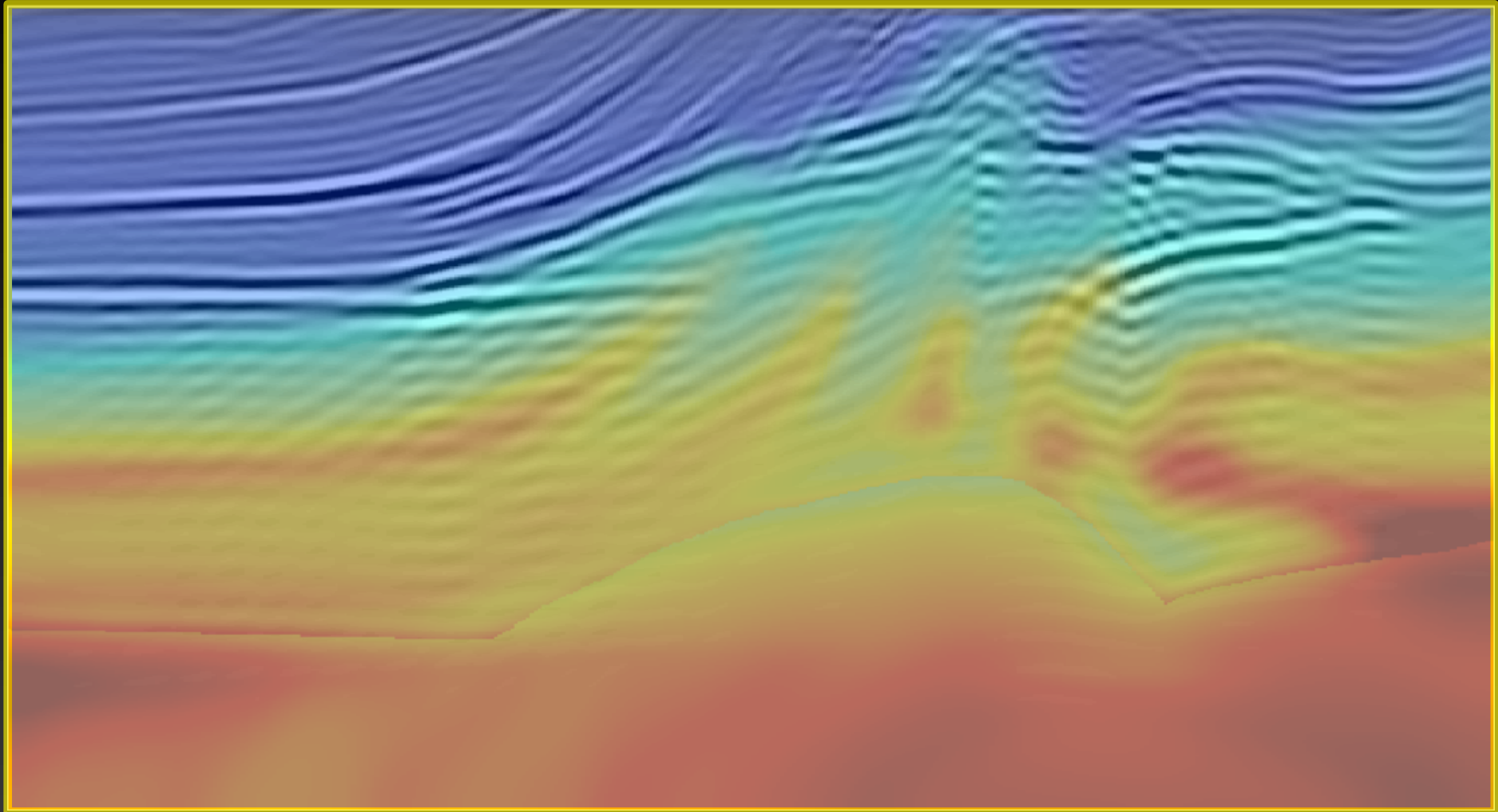


Refletores explosivos

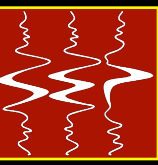


distance

depth

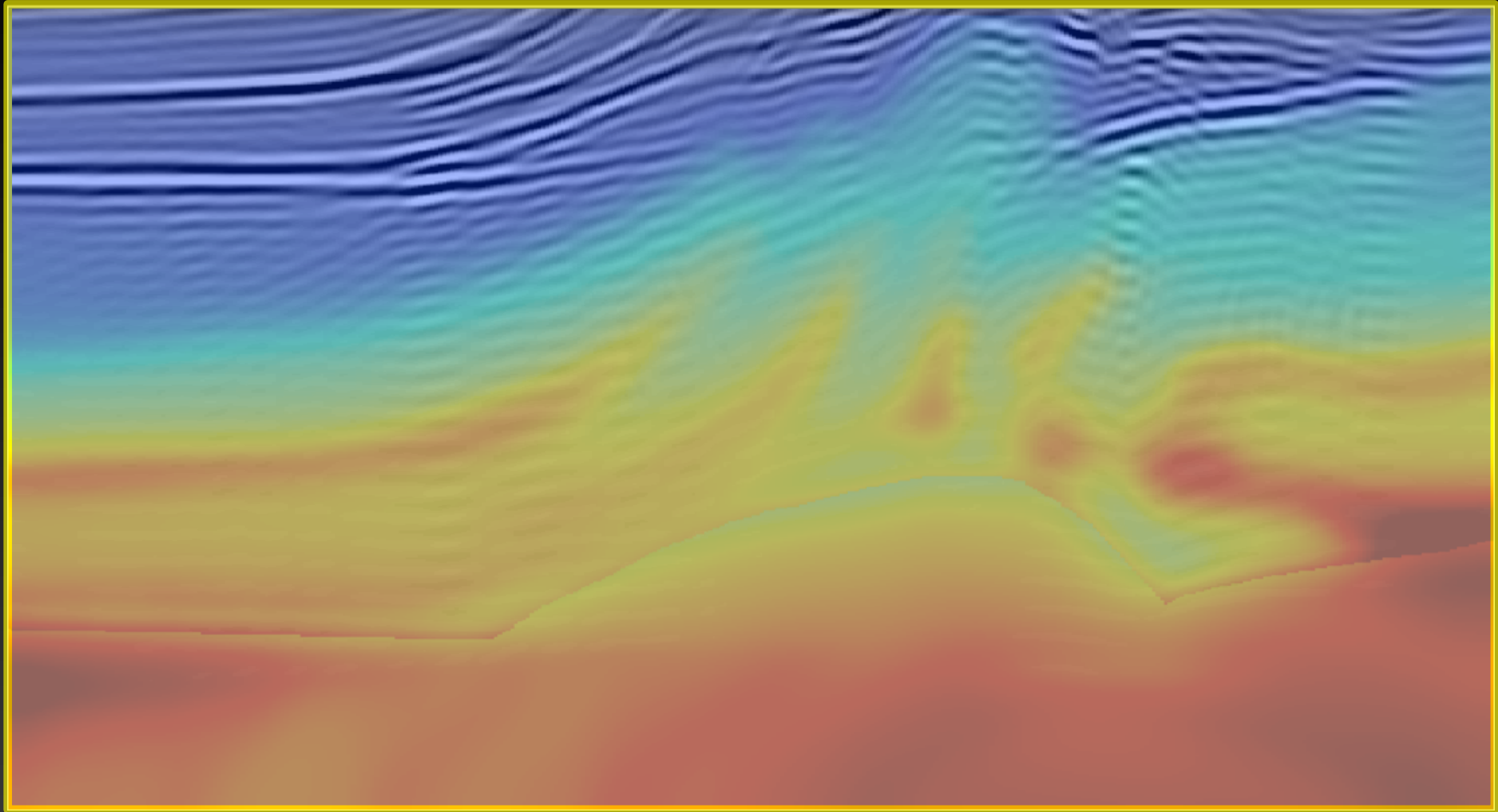


Refletores explosivos

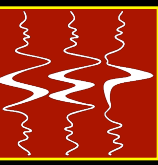


distance

depth

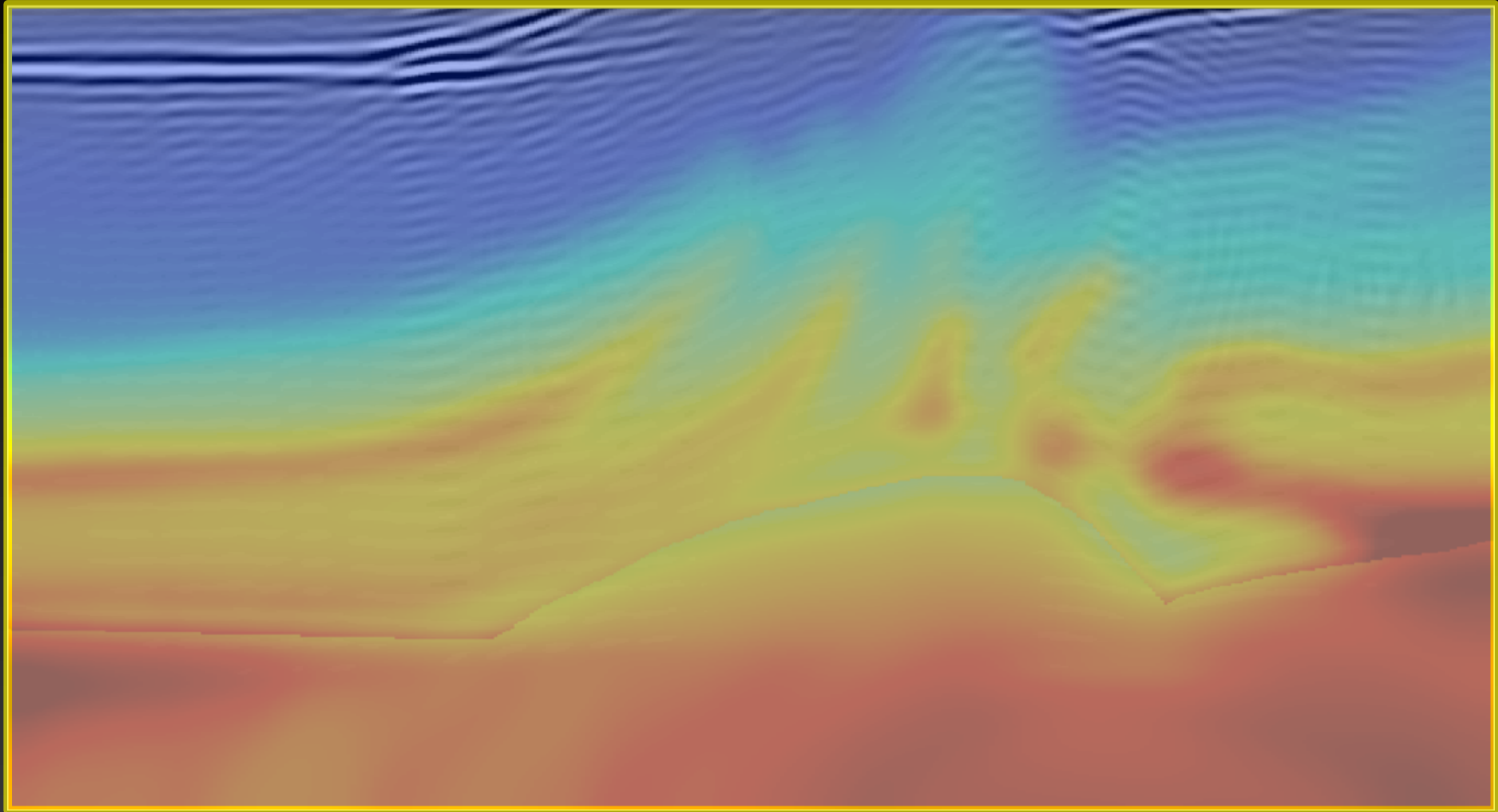


Refletores explosivos

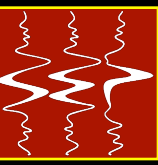


distance

depth

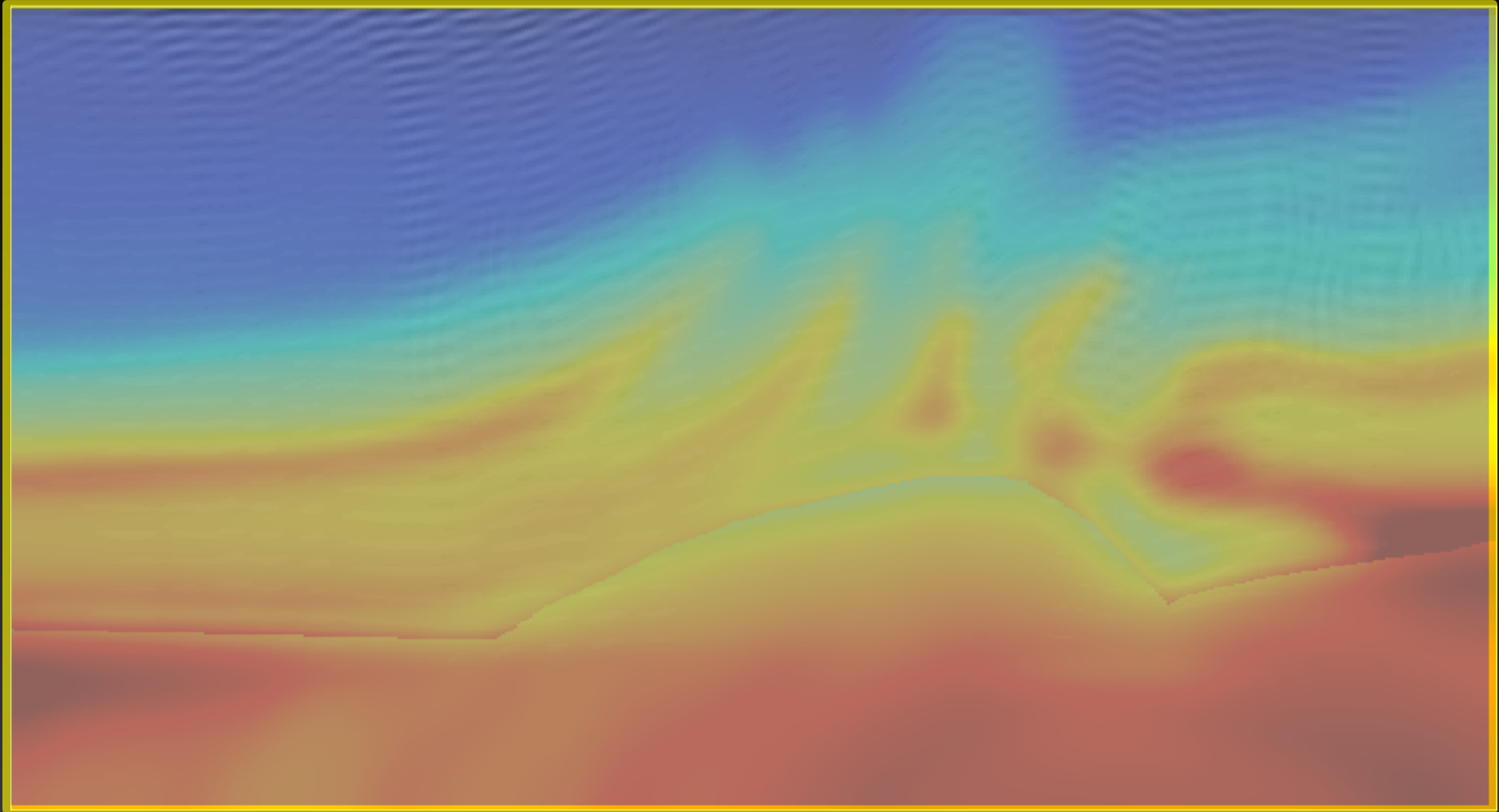


Refletores explosivos

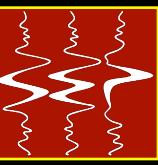


distance

depth

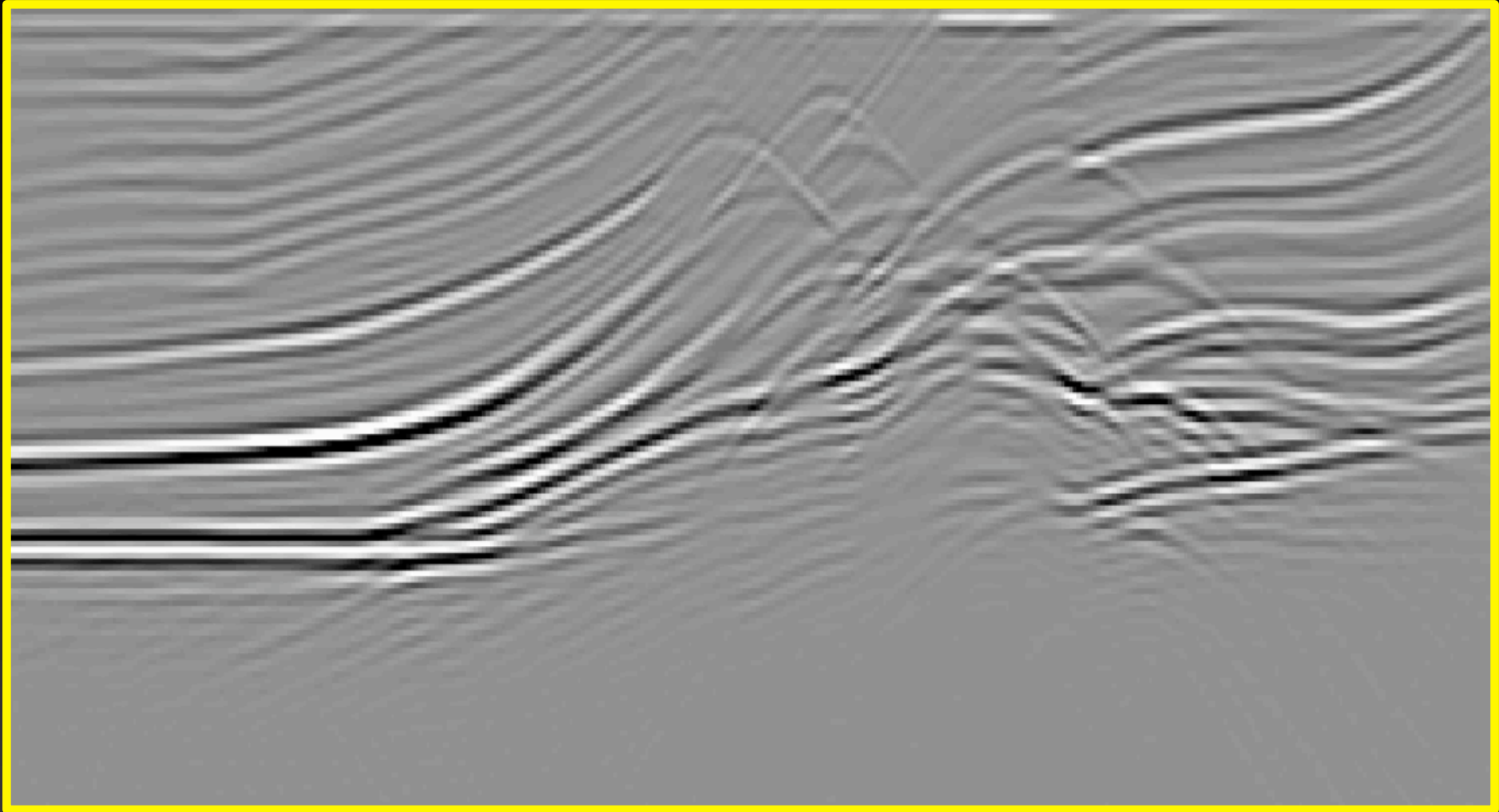


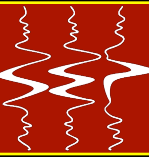
Seção de afastamento nulo



distance

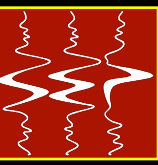
time





- **Generaliza o modelo do refletor explosivo**
 - **CRP computados com migração por equação da onda (SODCIGs) são usados como condição inicial para modelar campos de onda de fonte e receptores**

Subsurface-offset gathers

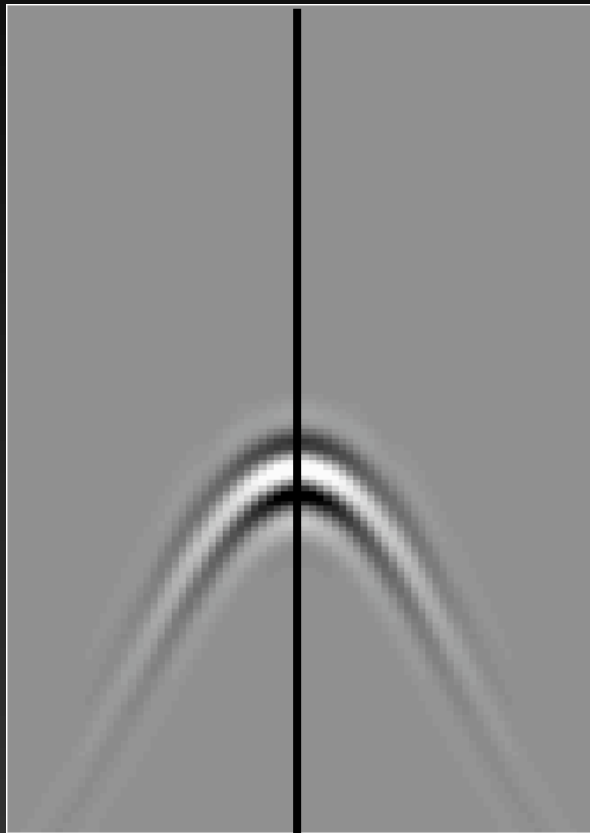


**VELOCIDADE
MAIS BAIXA**

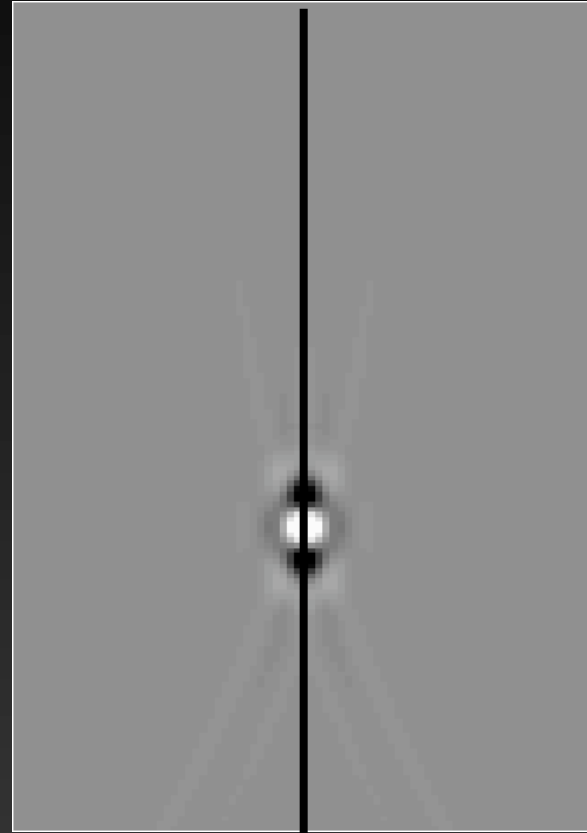
**VELOCIDADE
CORRETA**

**VELOCIDADE
MAIS ALTA**

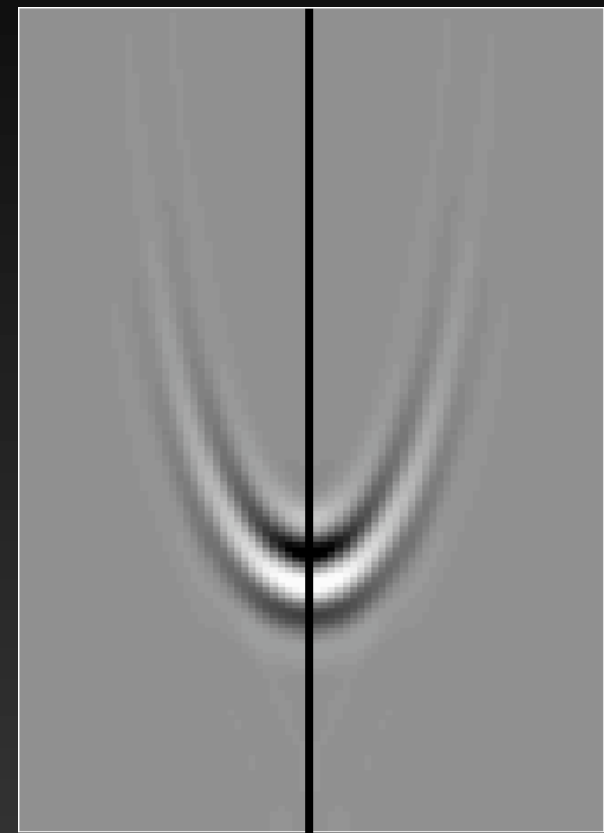
depth



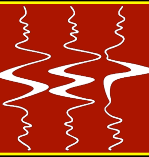
offset



offset

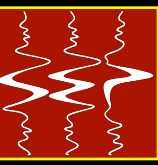


offset



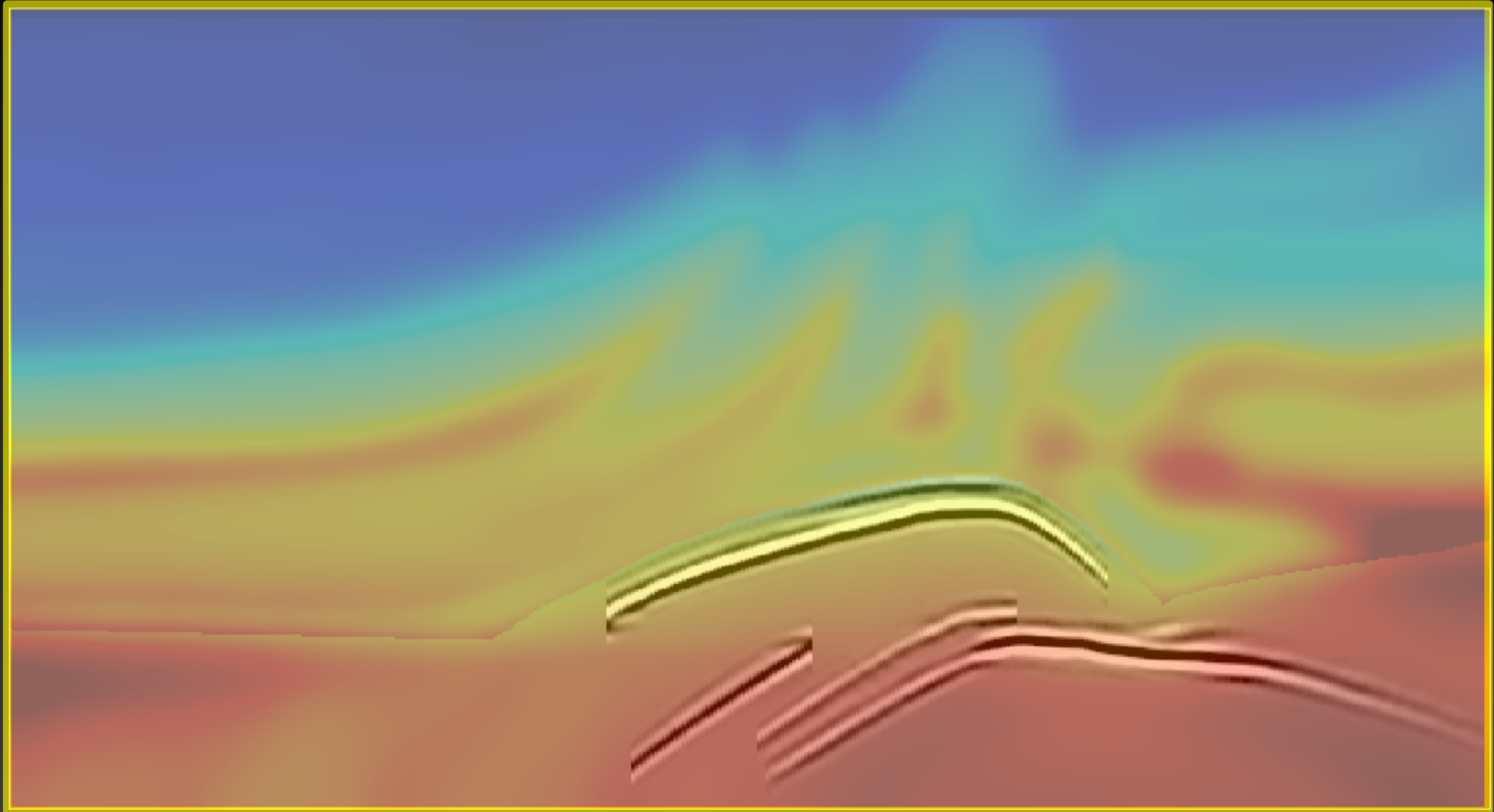
- **Generaliza o modelo do refletor explosivo**
- **Usa refletores selecionados como condições iniciais**
 - **Naturalmente incorpora a estratégia baseada em horizontes nos métodos que usam a equação da onda**

Modelagem do campo de receptores

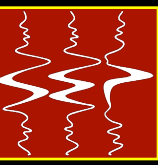


distance

depth

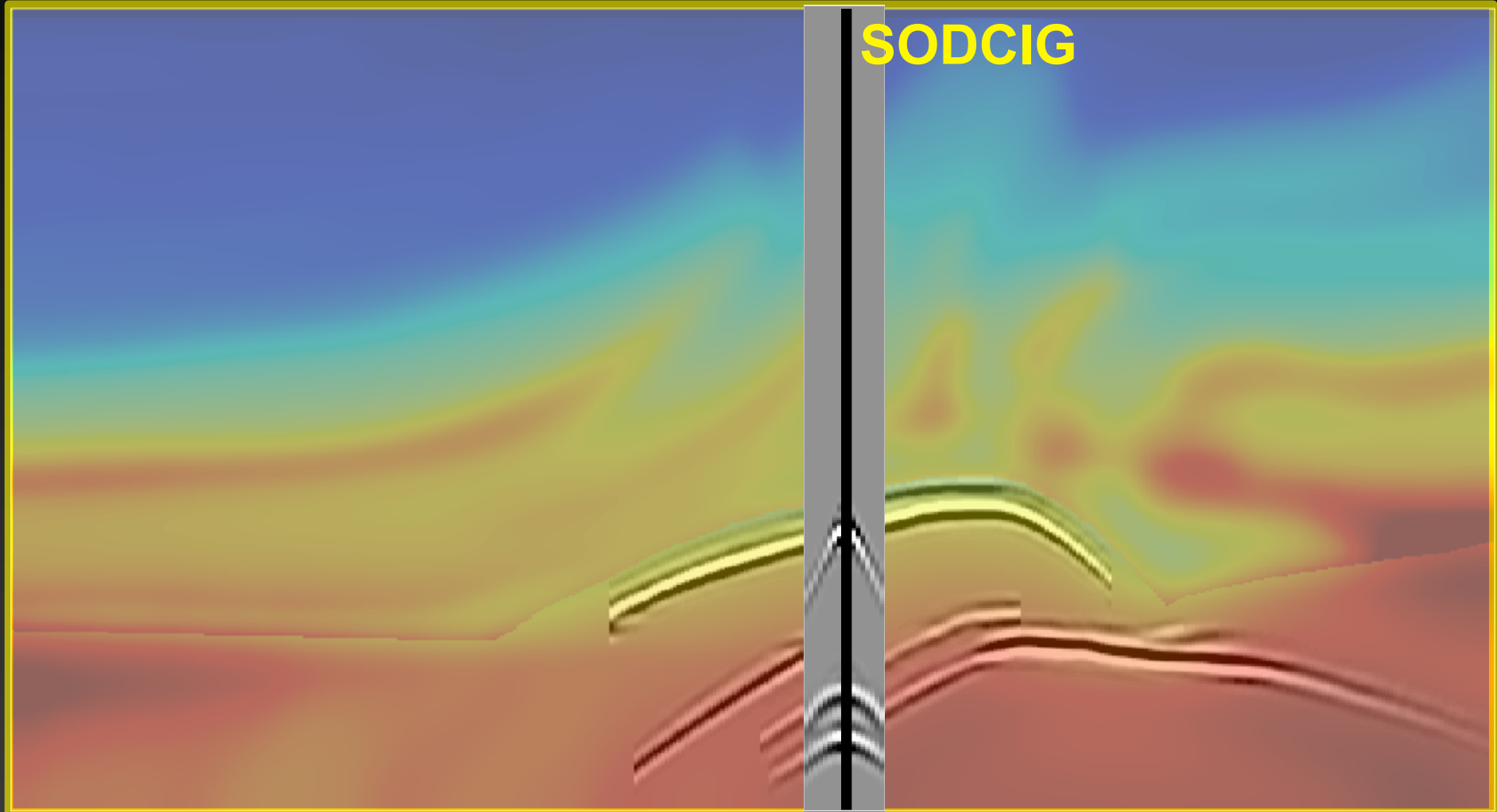


Modelagem do campo de receptores

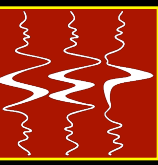


distance

depth

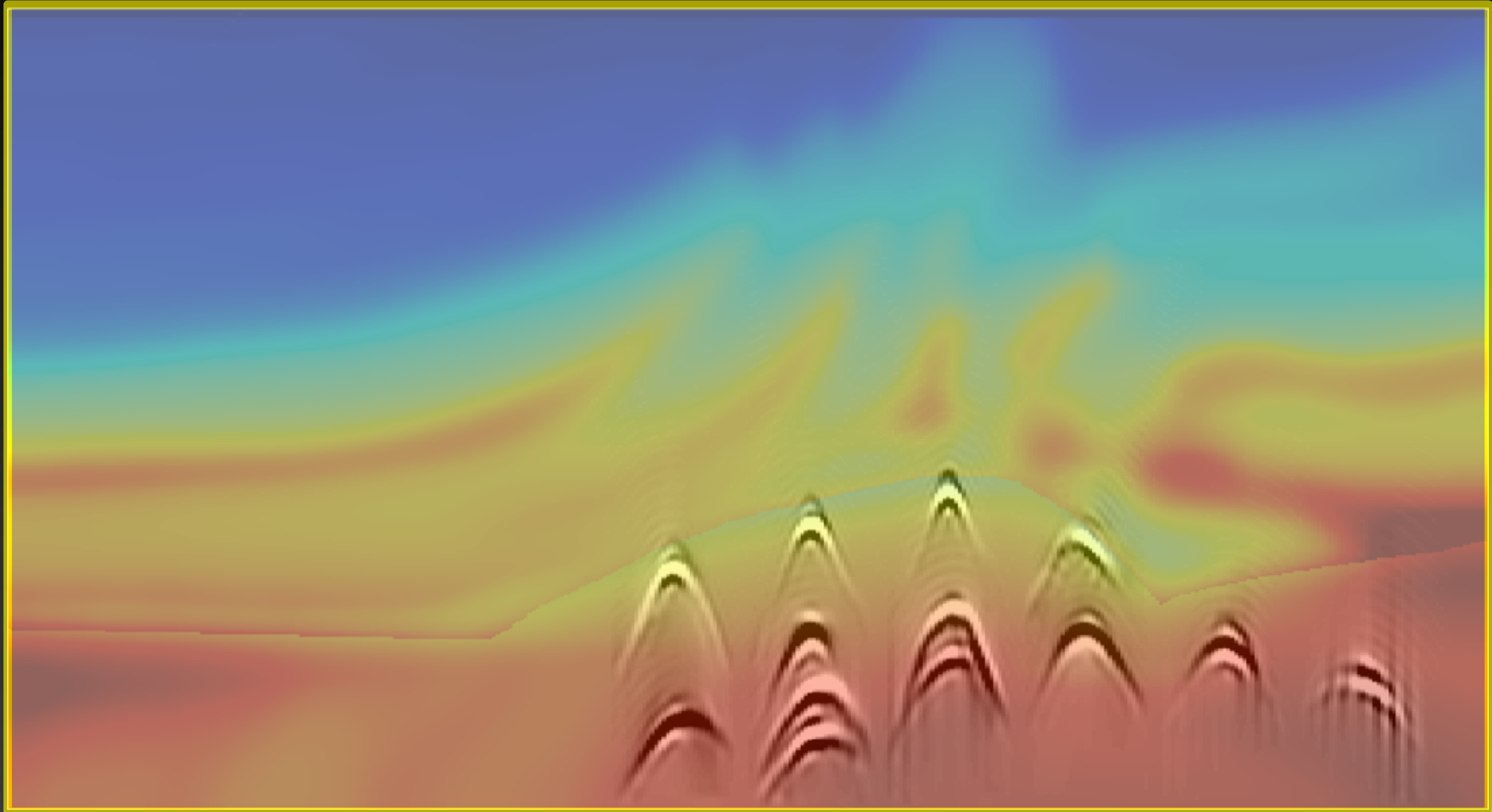


Modelagem do campo de receptores

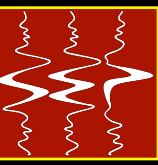


distance

depth

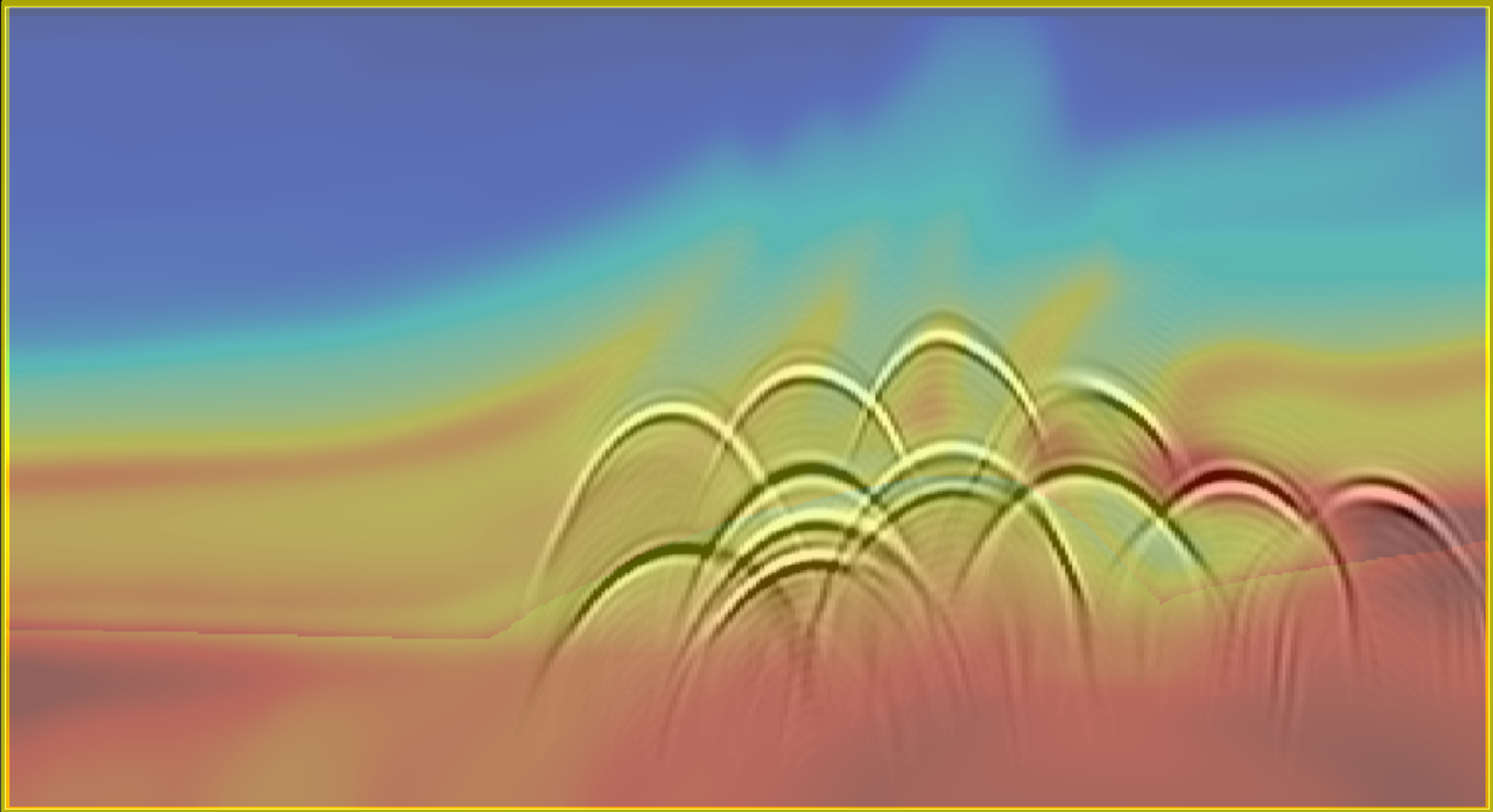


Modelagem do campo de receptores

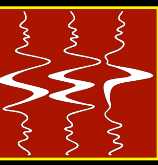


distance

depth

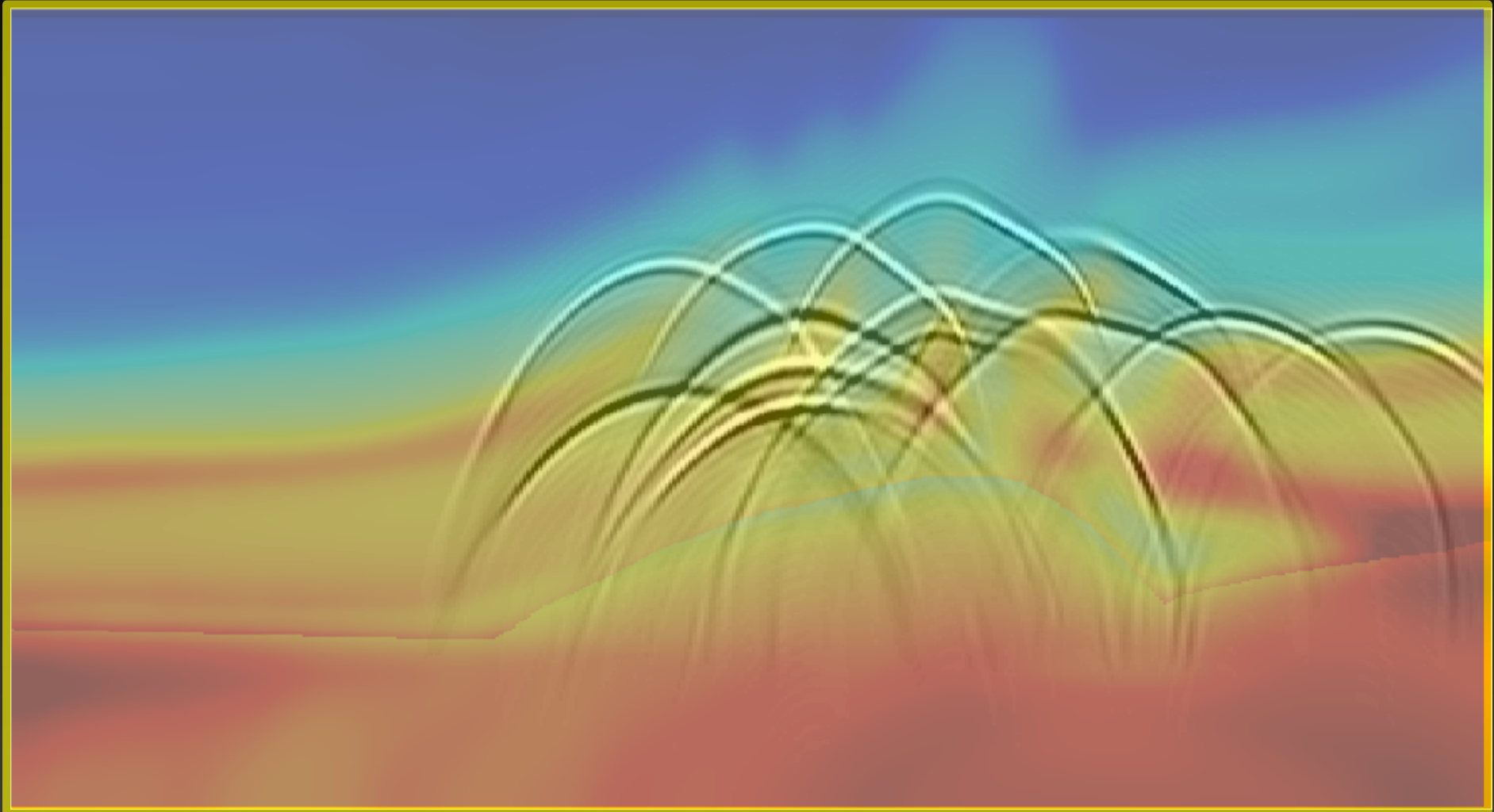


Modelagem do campo de receptores

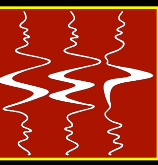


distance

depth

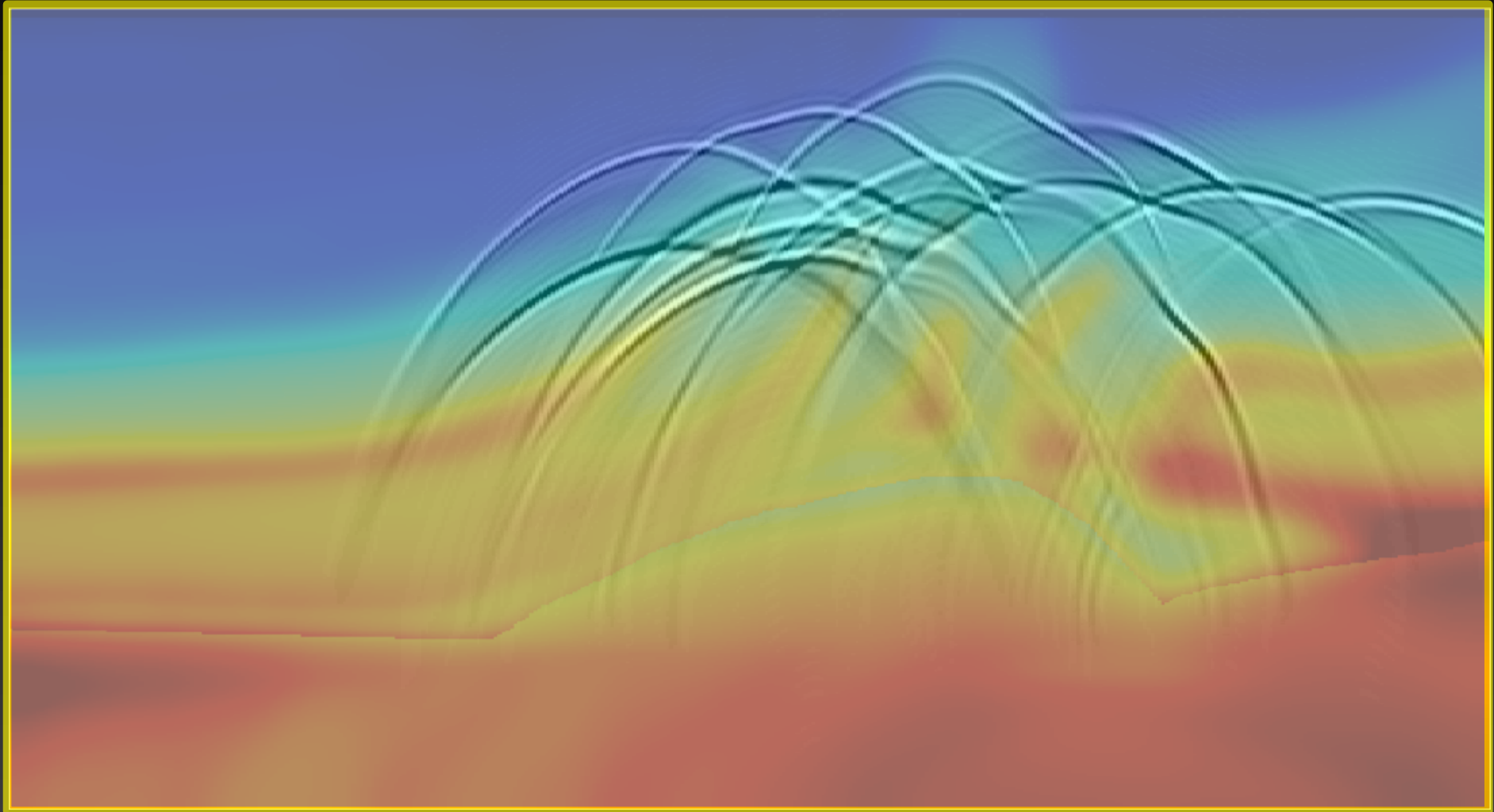


Modelagem do campo de receptores

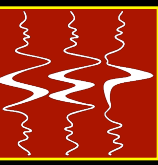


distance

depth

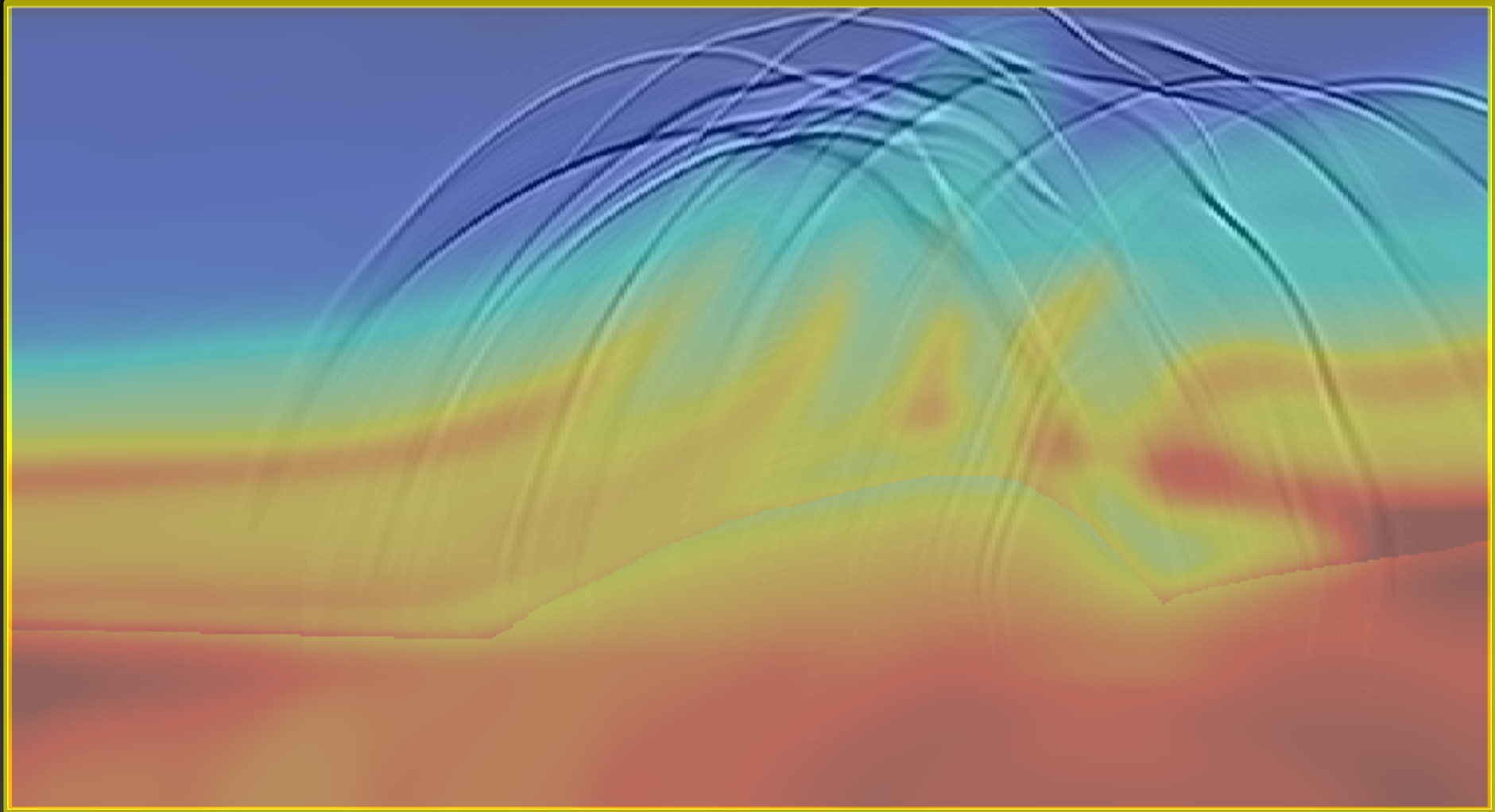


Modelagem do campo de receptores

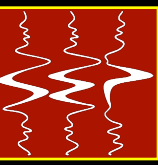


distance

depth

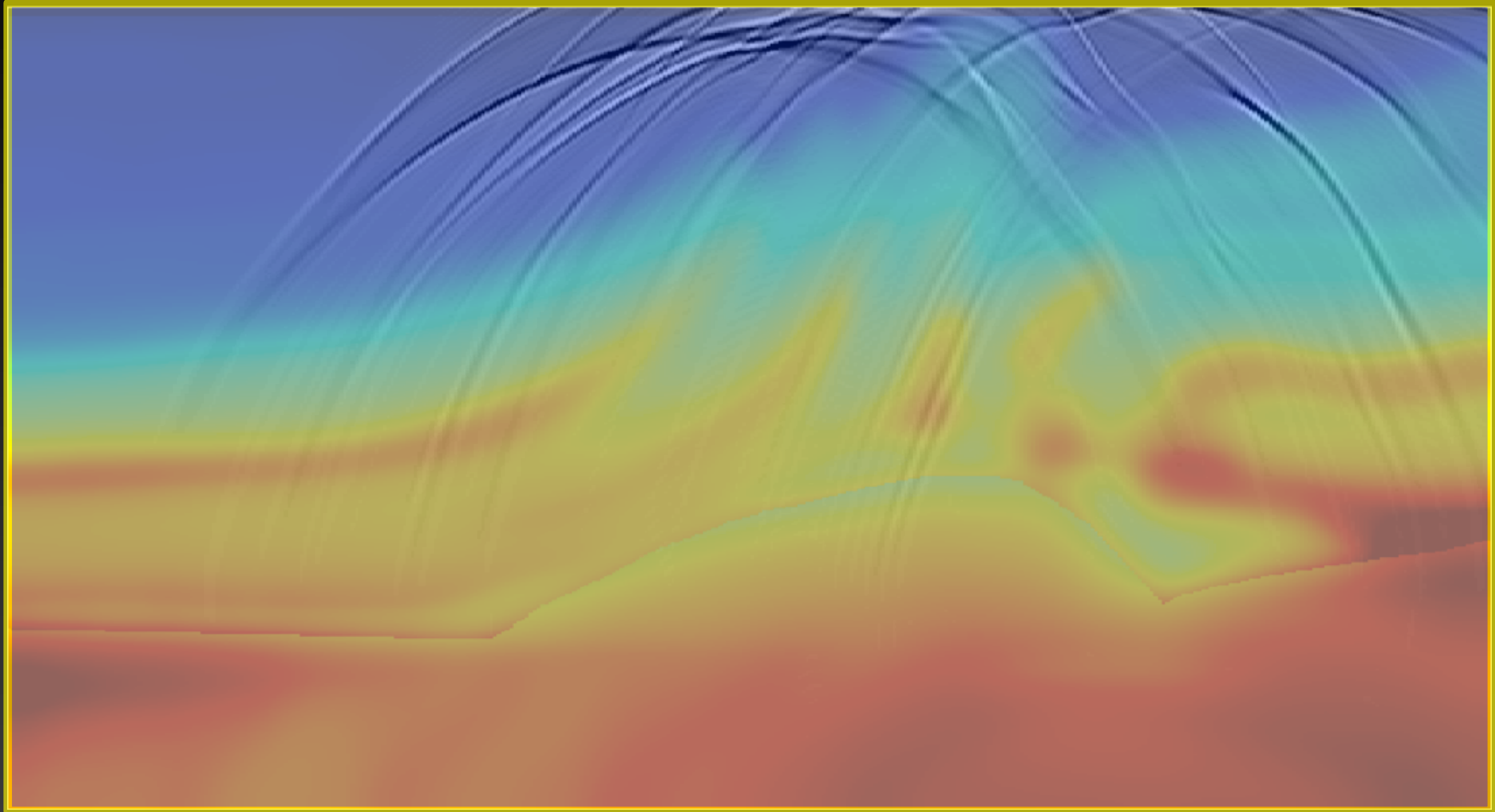


Modelagem do campo de receptores

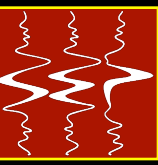


distance

depth

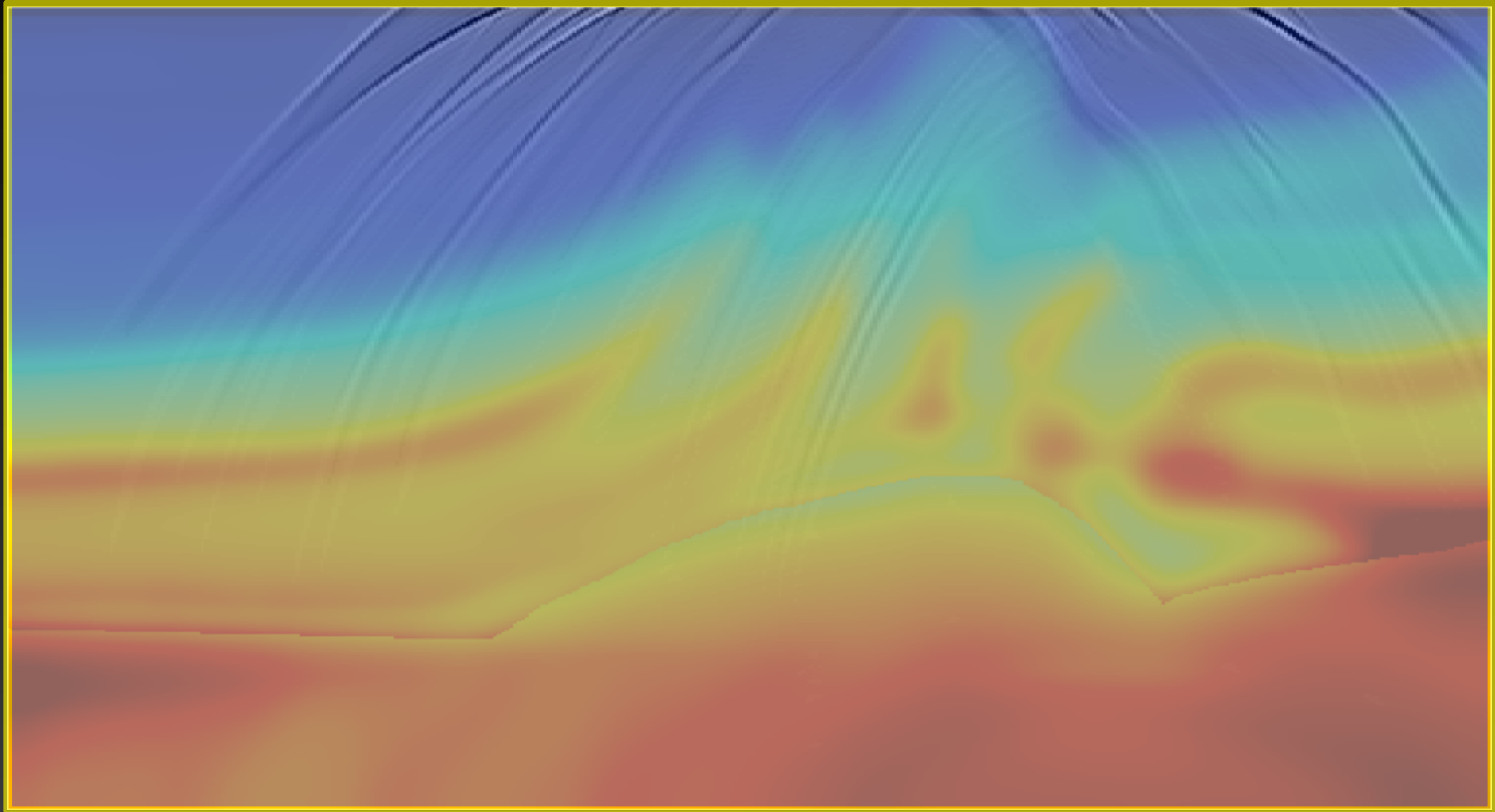


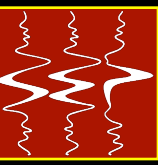
Modelagem do campo de receptores



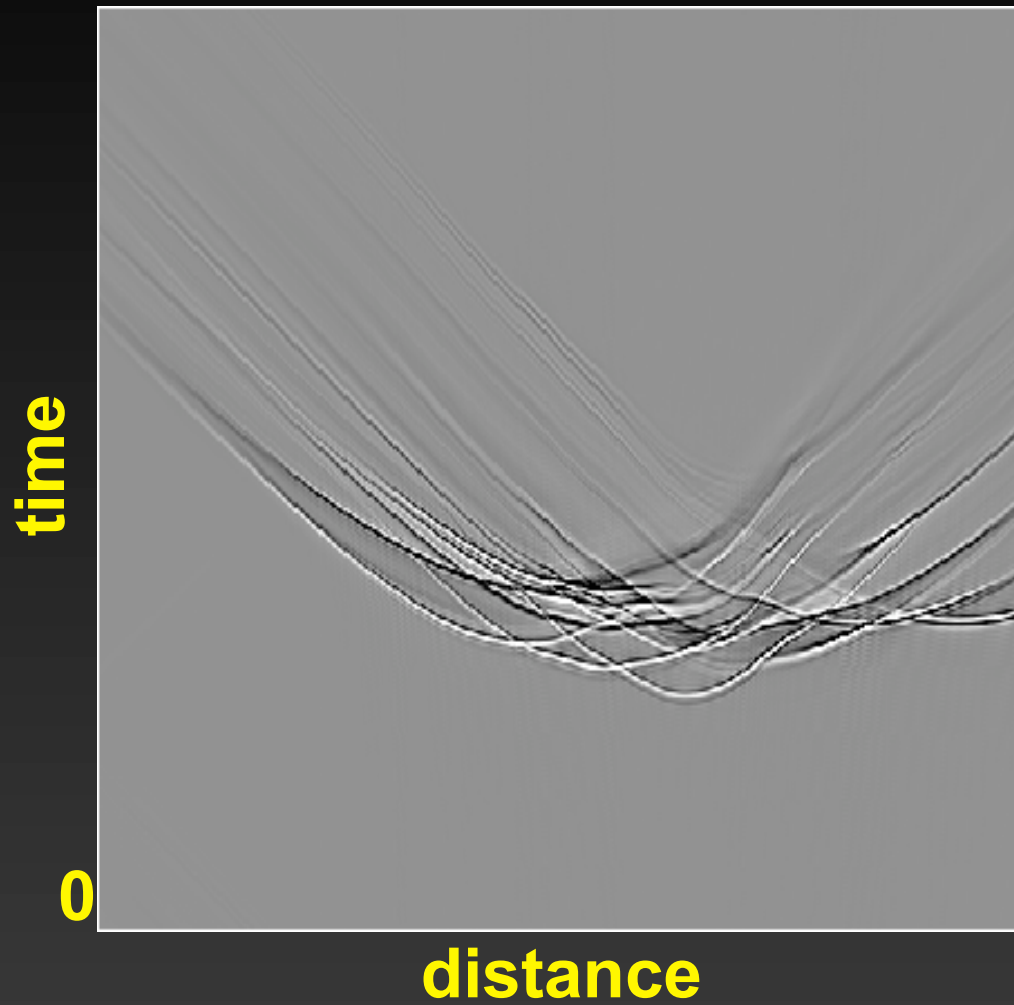
distance

depth

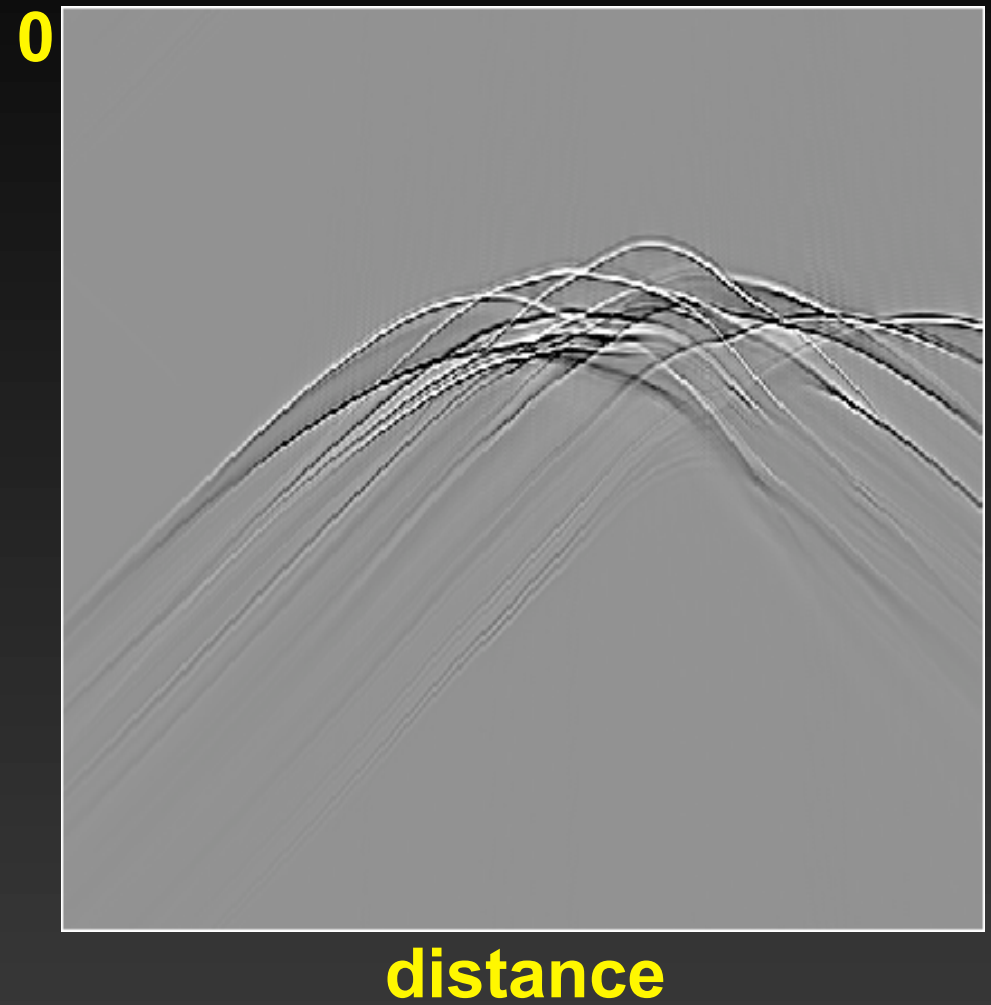


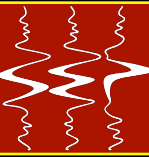


Fonte



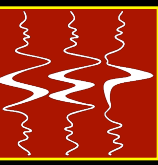
Receptor





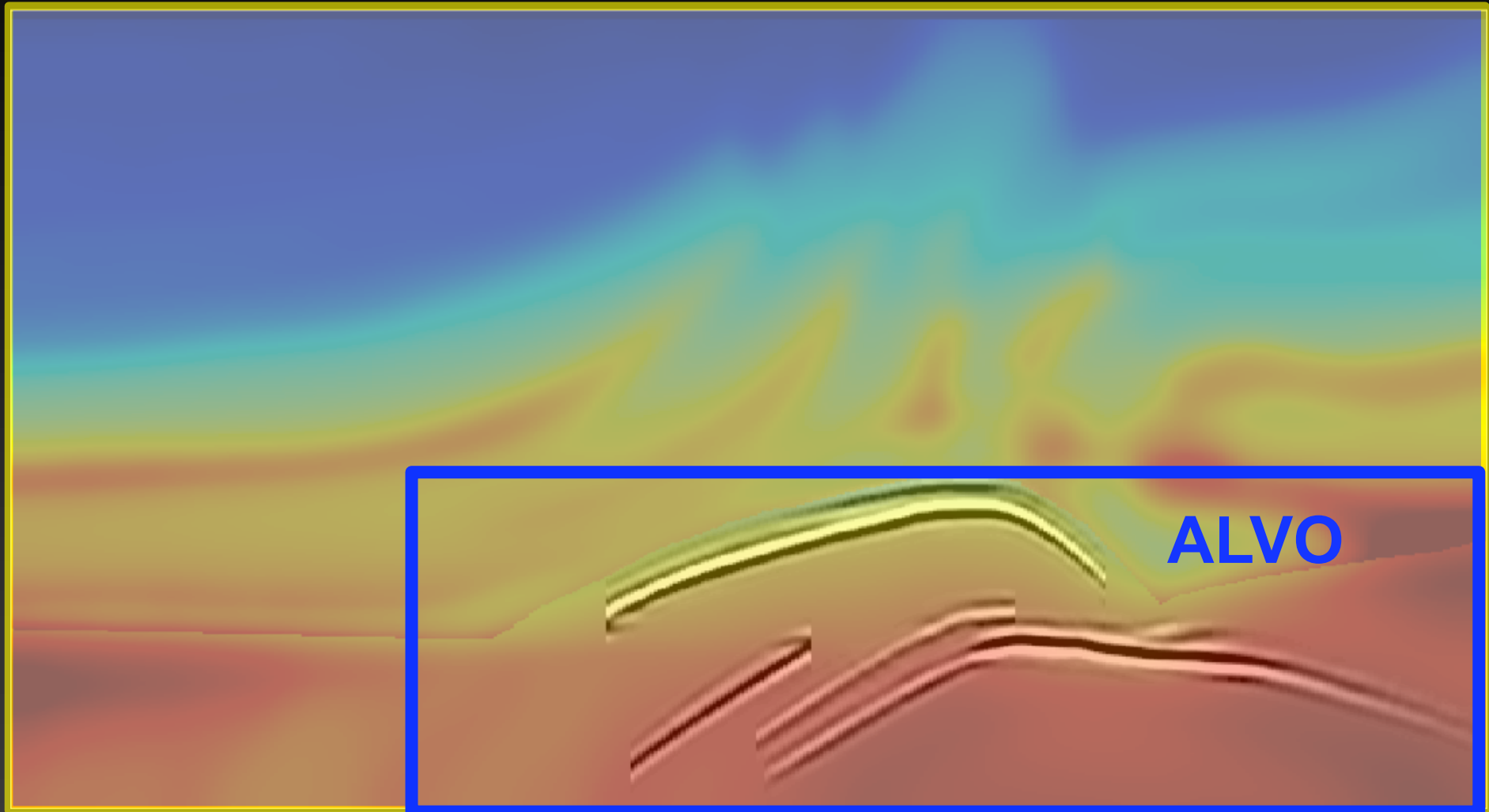
- **Generaliza o modelo do refletor explosivo**
- **Usa refletores selecionados como condições iniciais**
- **Usa um distância de decorrelação para evitar crosstalk**
 - **Número de campos de onda depende da separação dos SODCIGs**

Estratégia focada num alvo



distance

depth

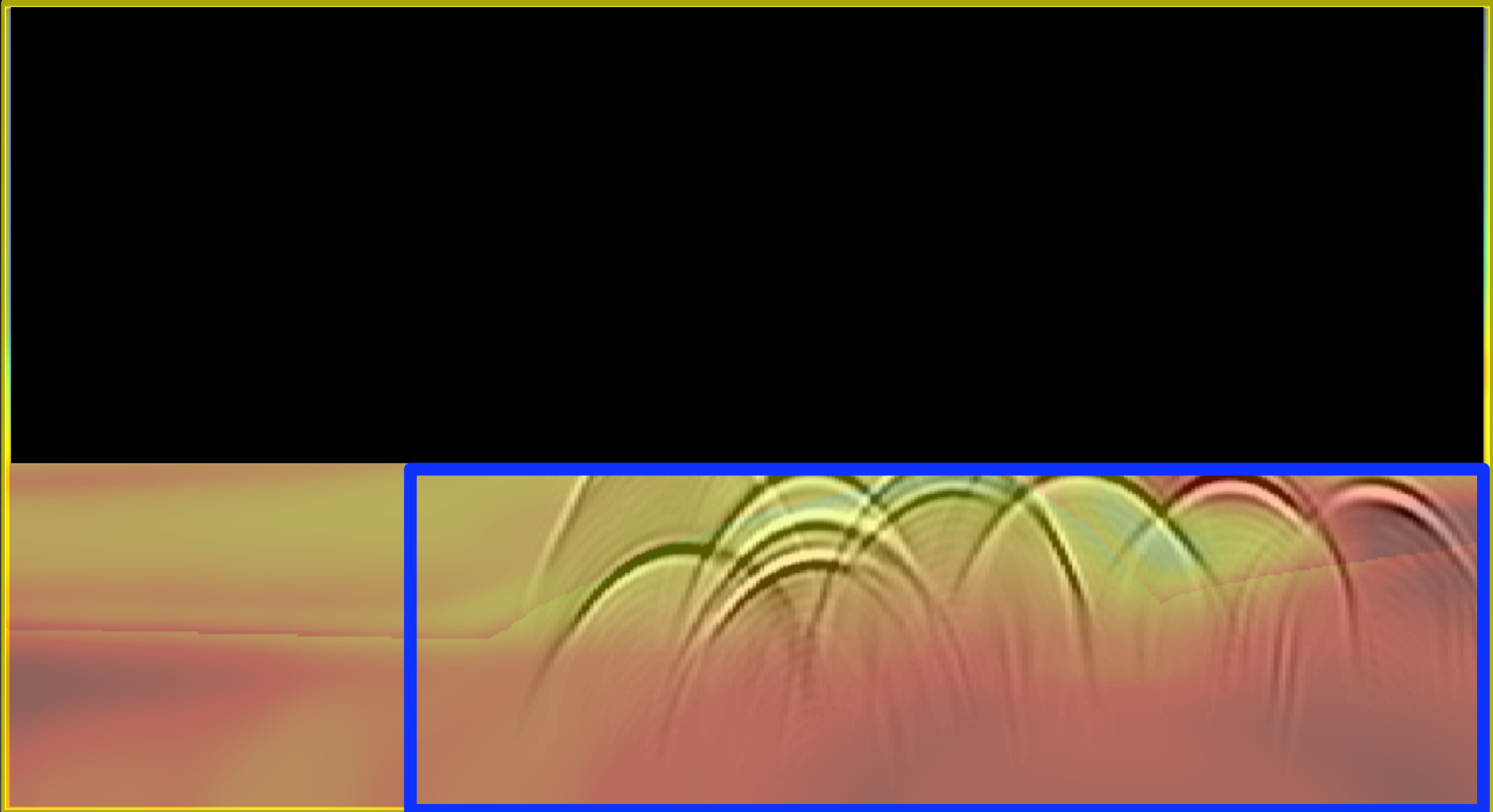


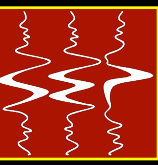


Campos de onda coletados no topo do alvo

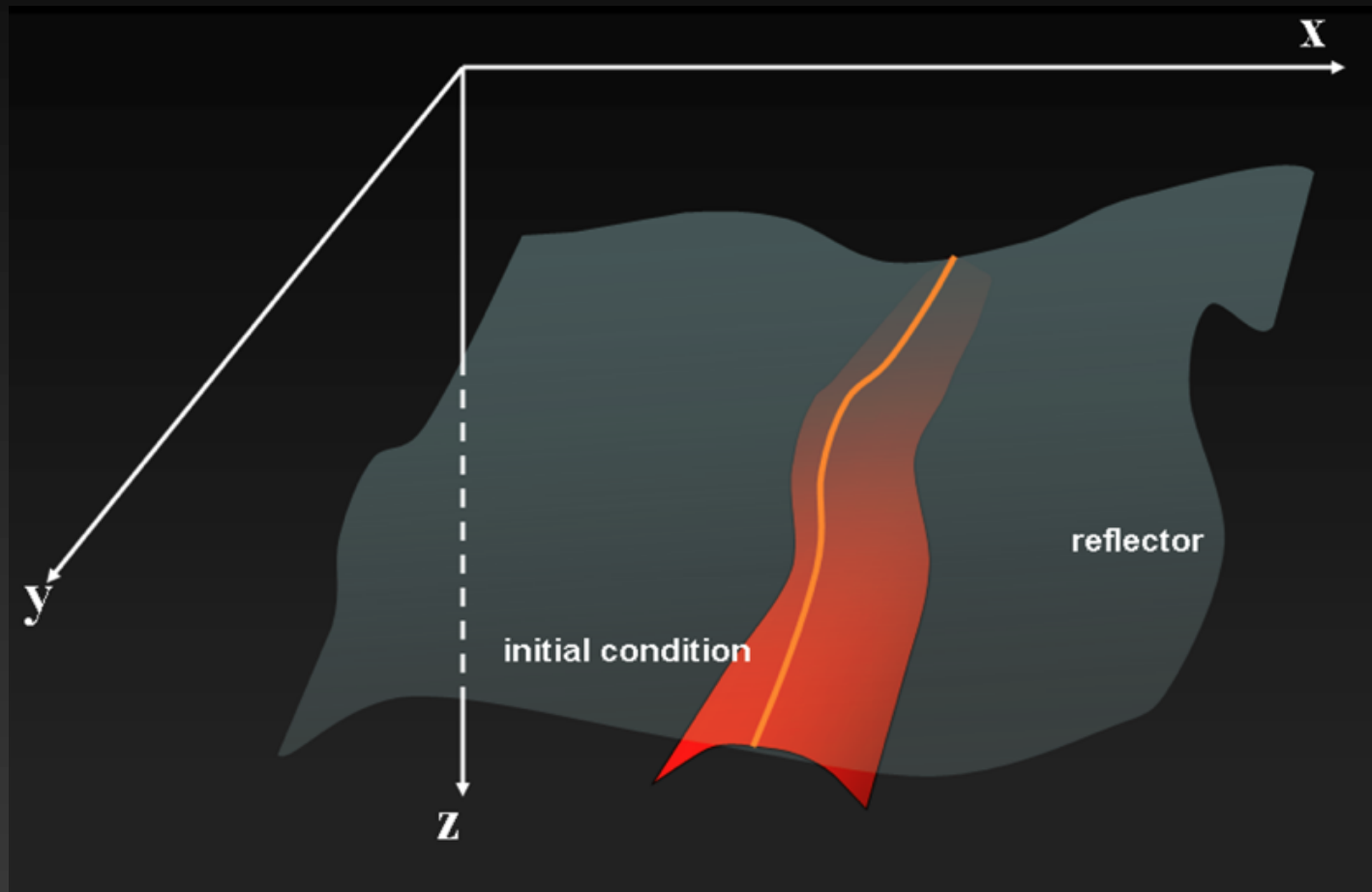
distance

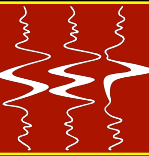
depth



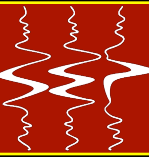


- **Redução dos dados pode ser de algumas ordens de magnitude**



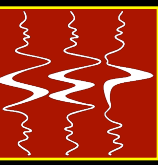


- ✓ **Capítulo 2: Modelo do refletor explosivo prestack**
- **Capítulo 3: Campos de onda aleatoriamente combinados no espaço da imagem**
- **Capítulo 4: AVM com fontes generalizadas no espaço da imagem**
- **Capítulo 5: Exemplo com dados reais 3D**



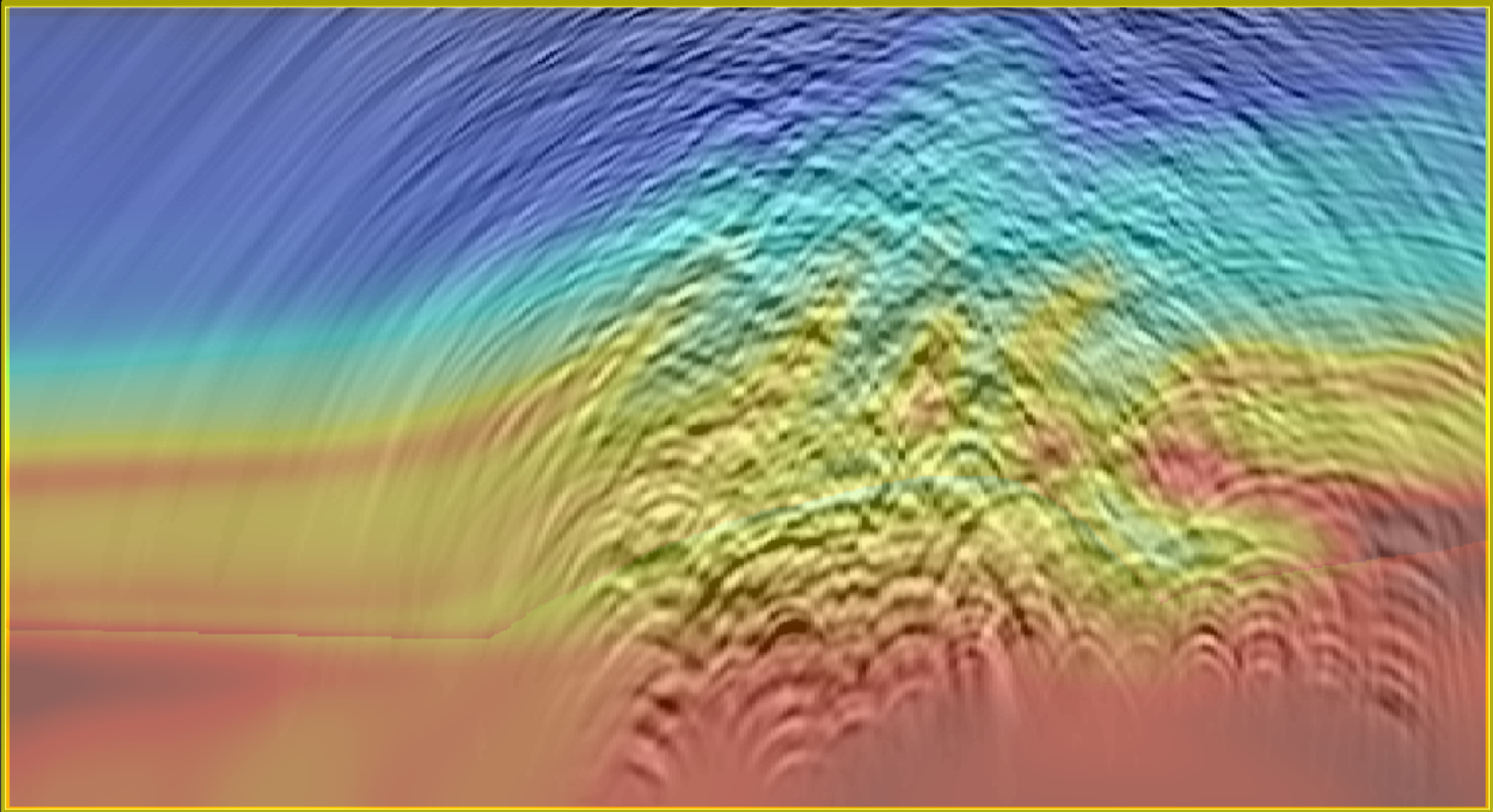
**Redução adicional de dados
combinando aleatoriamente os
experimentos de modelagem**

Campos de receptor aleatório

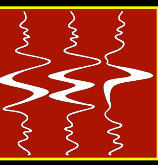


distance

depth

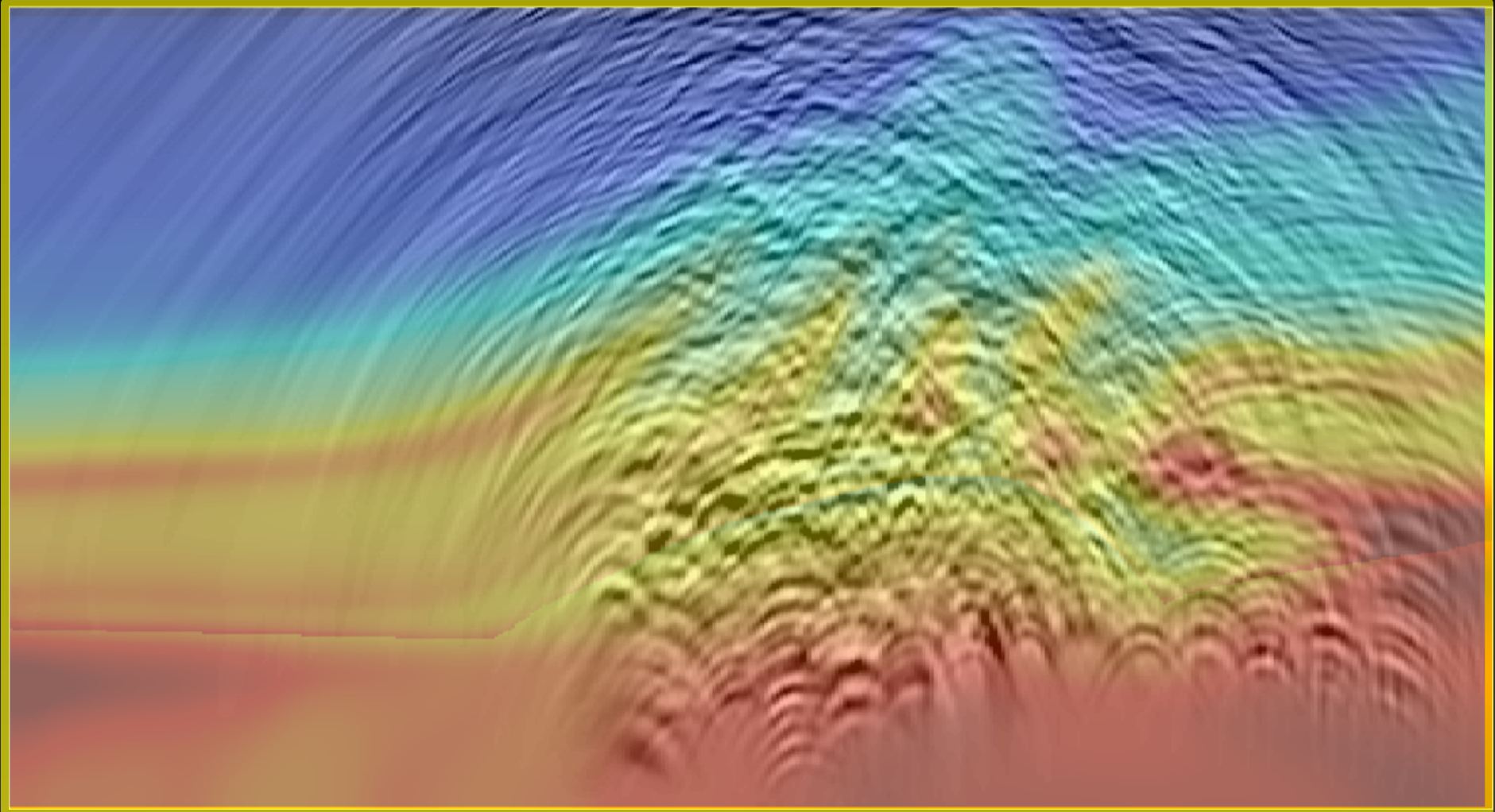


Campos de receptor aleatório

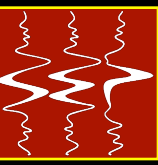


distance

depth

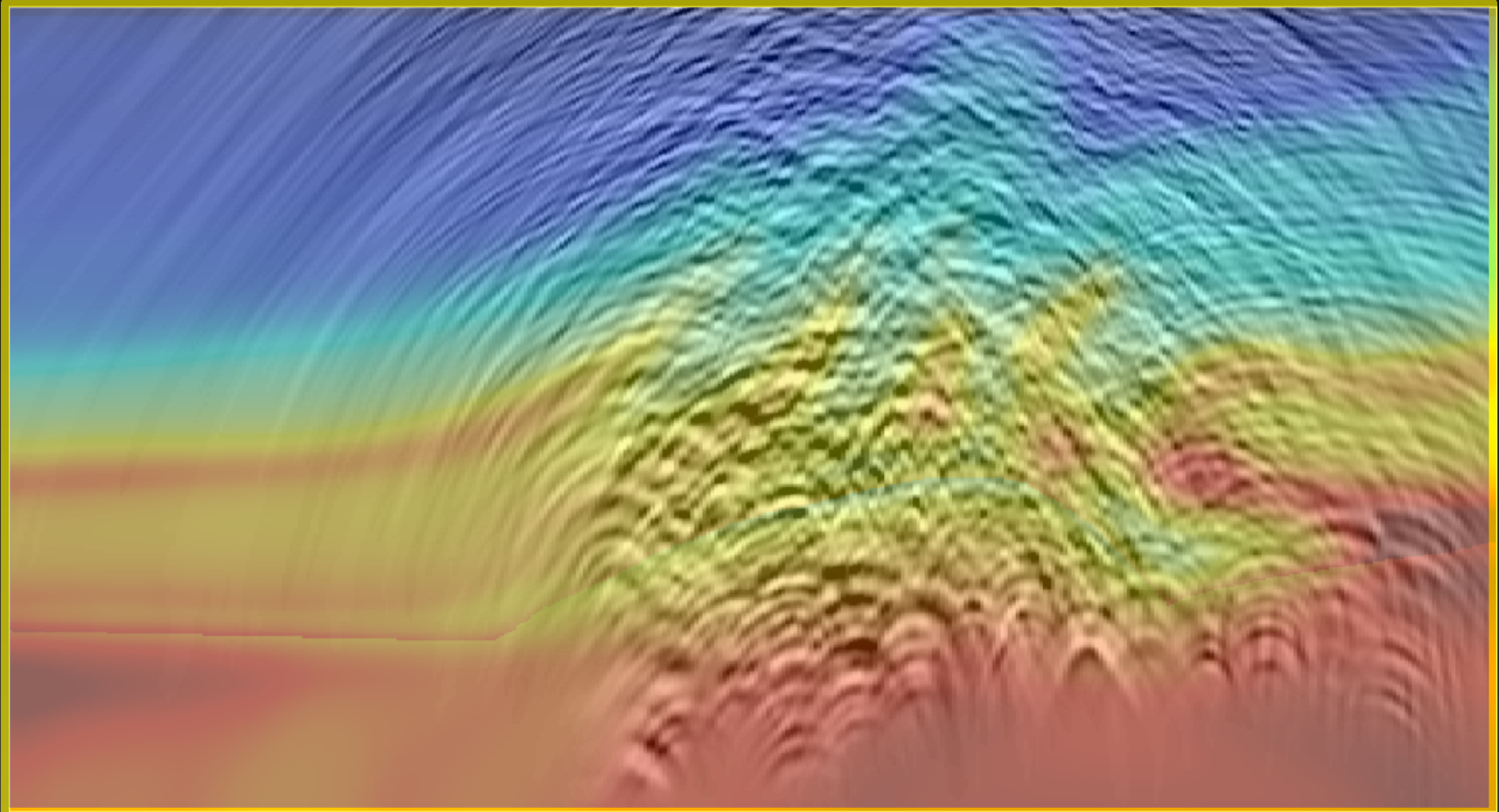


Campos de receptor aleatório

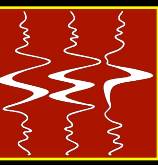


distance

depth

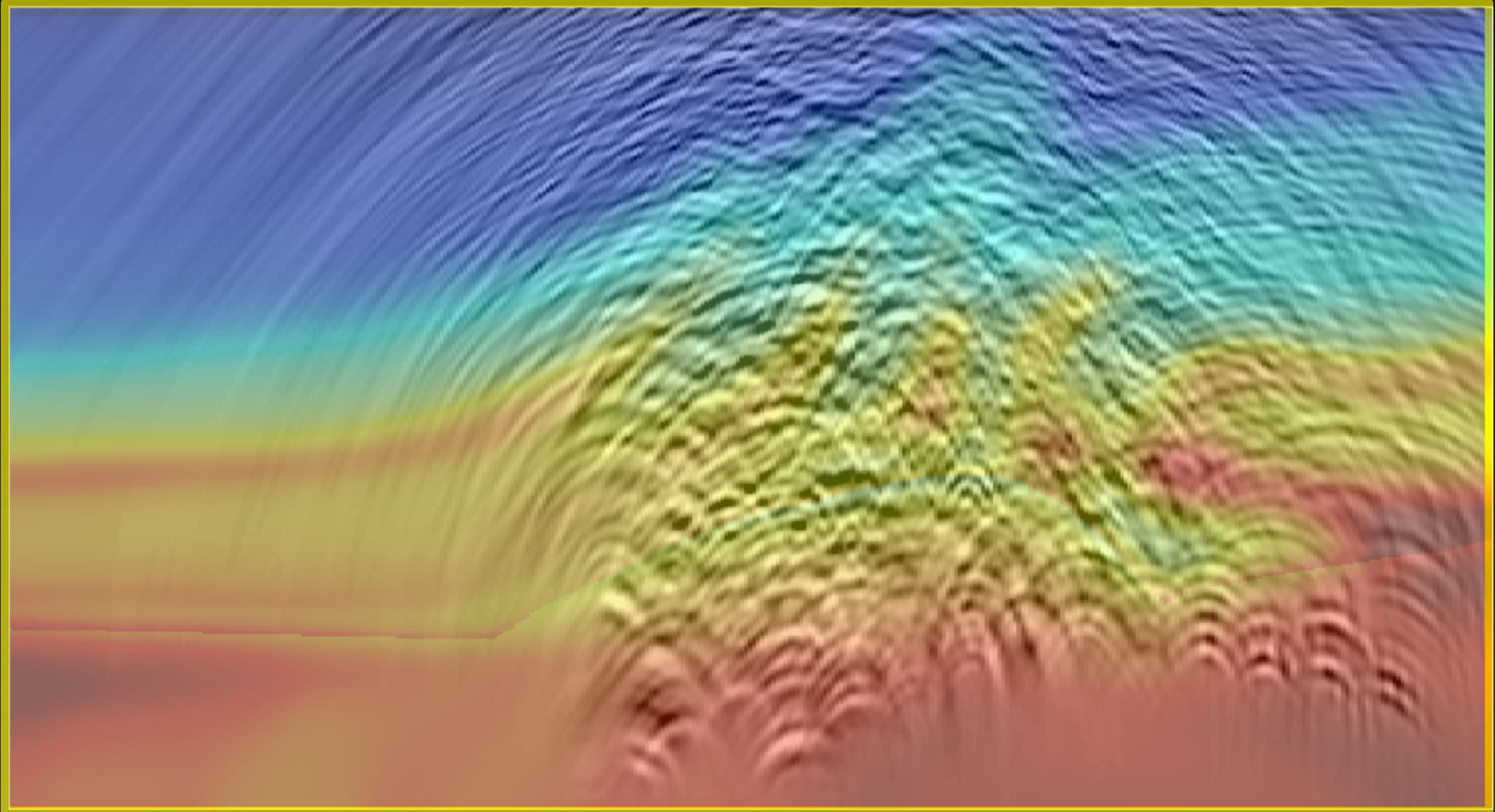


Campos de receptor aleatório

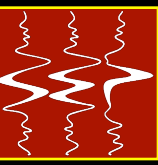


distance

depth

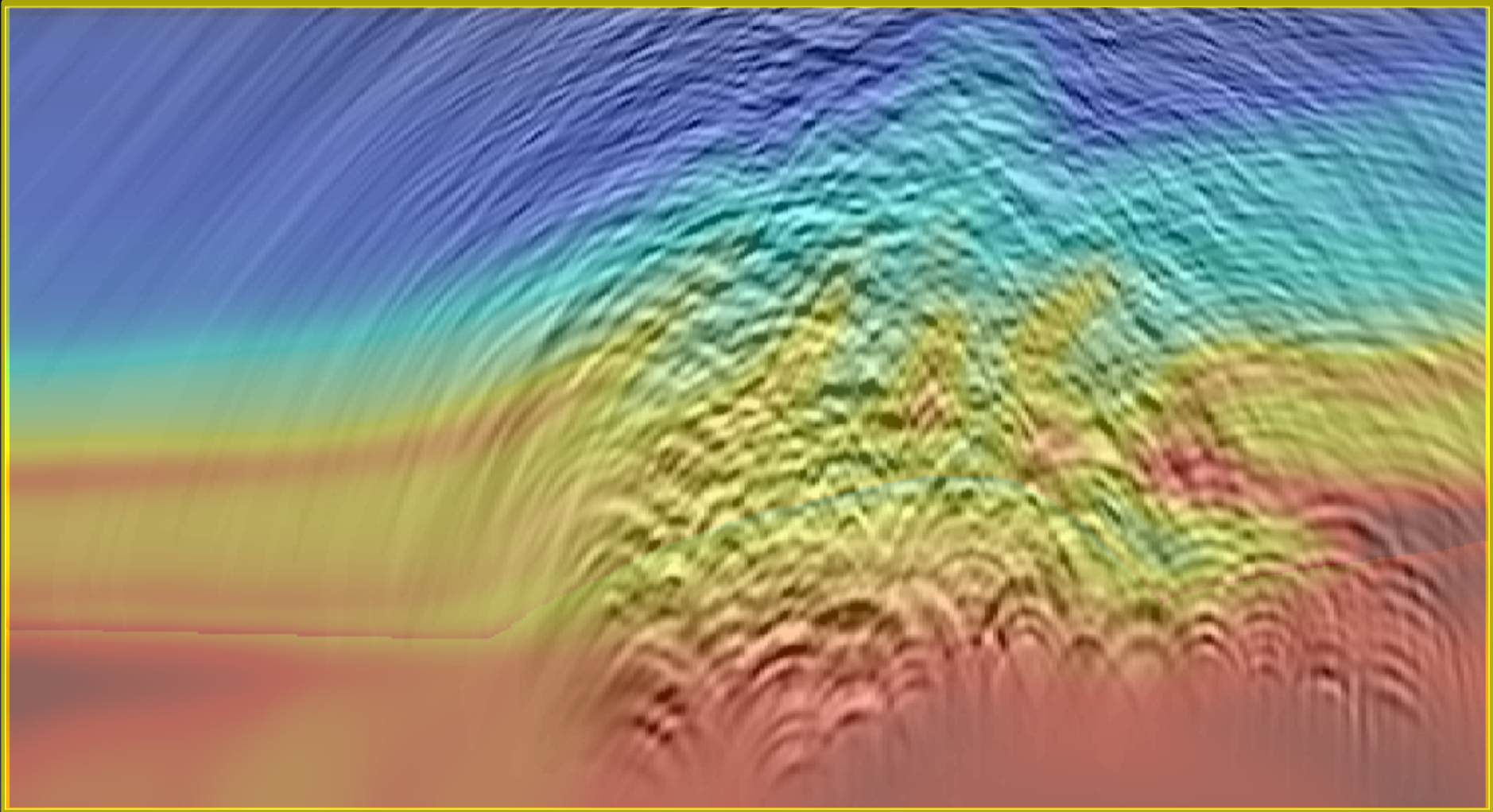


Campos de receptor aleatório

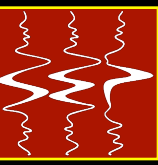


distance

depth

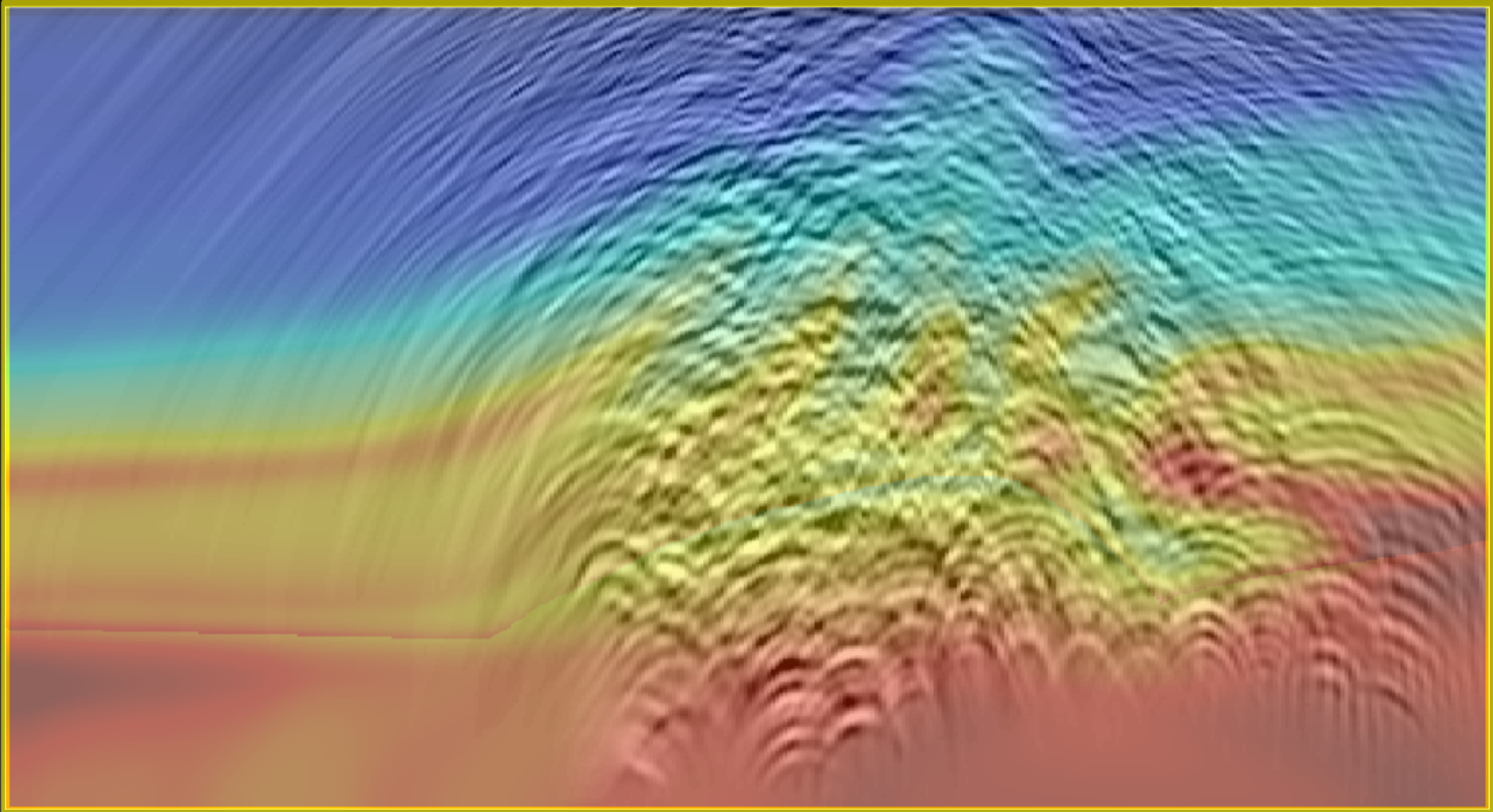


Campos de receptor aleatório

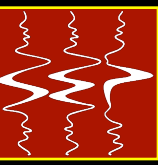


distance

depth

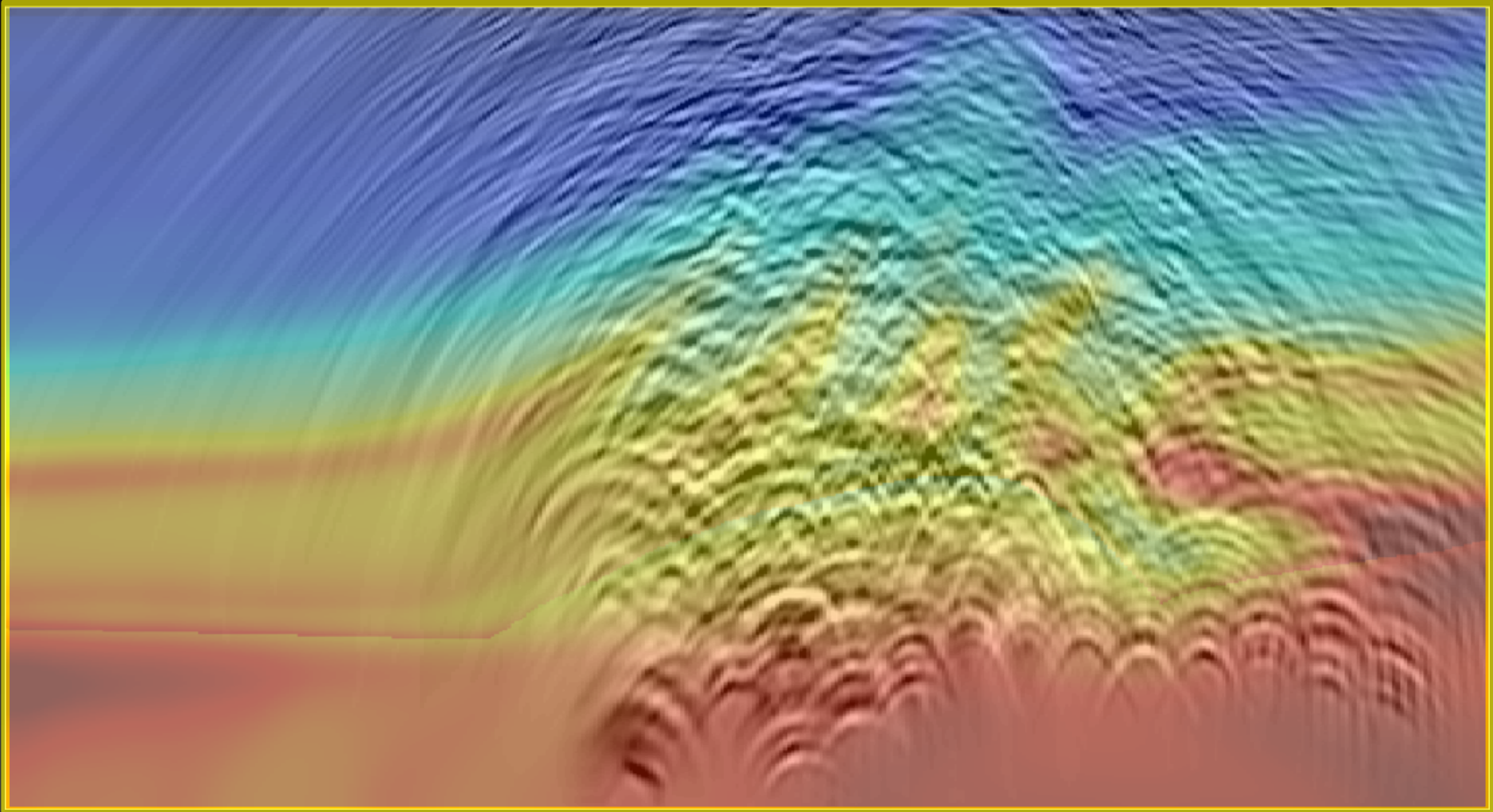


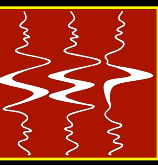
Campos de receptor aleatório



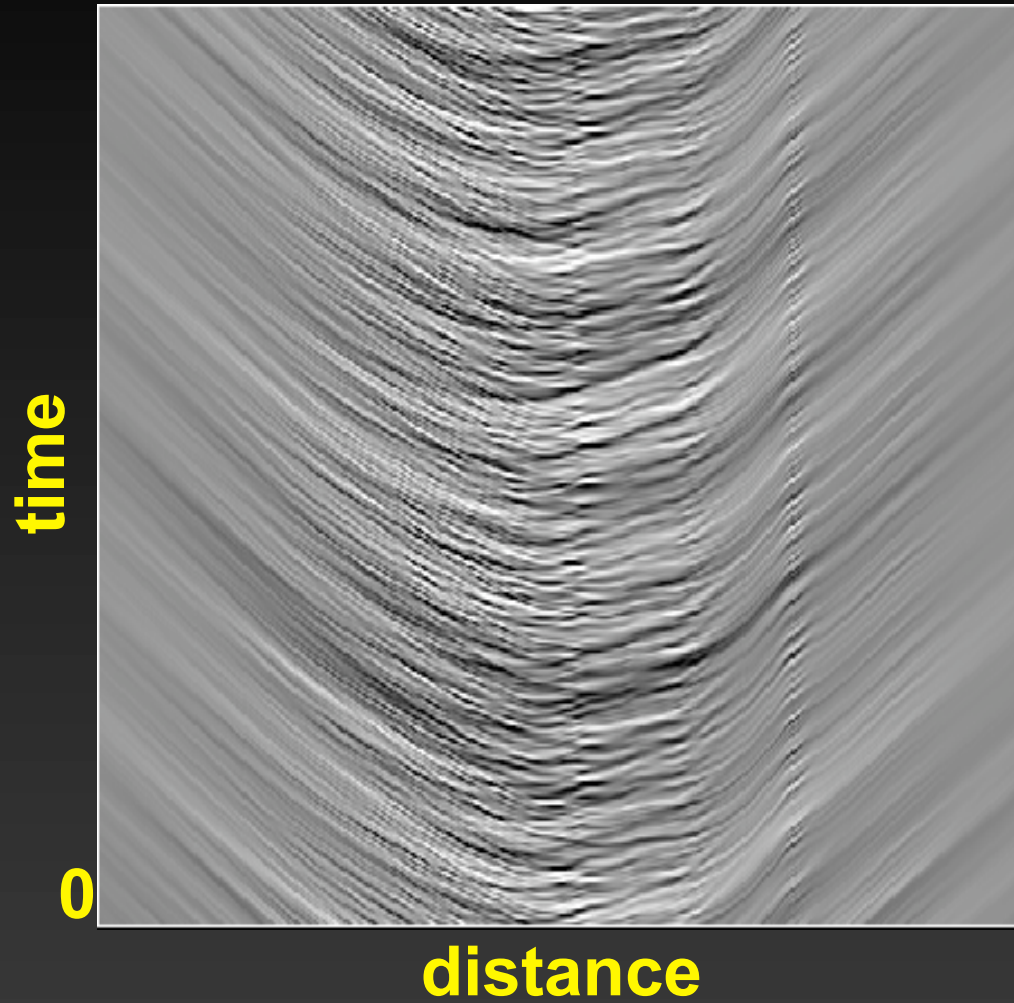
distance

depth

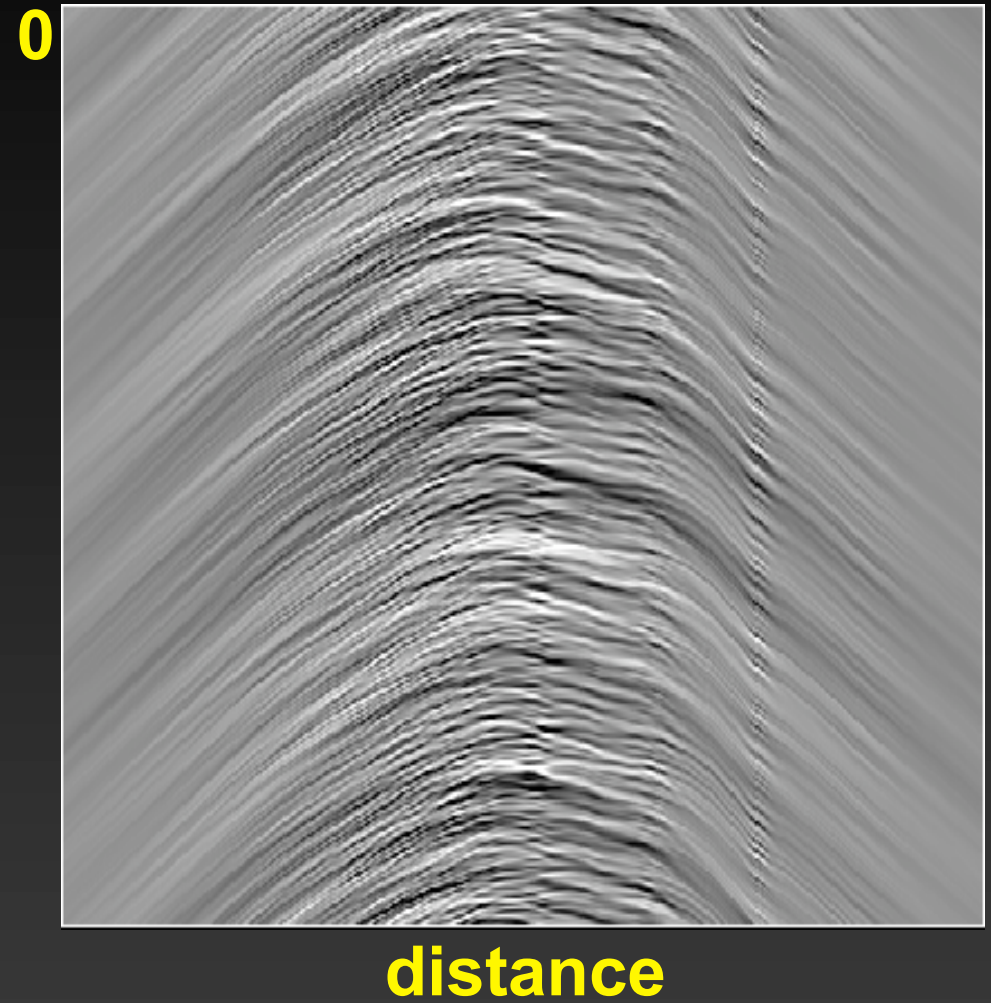




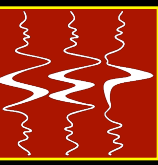
Fonte



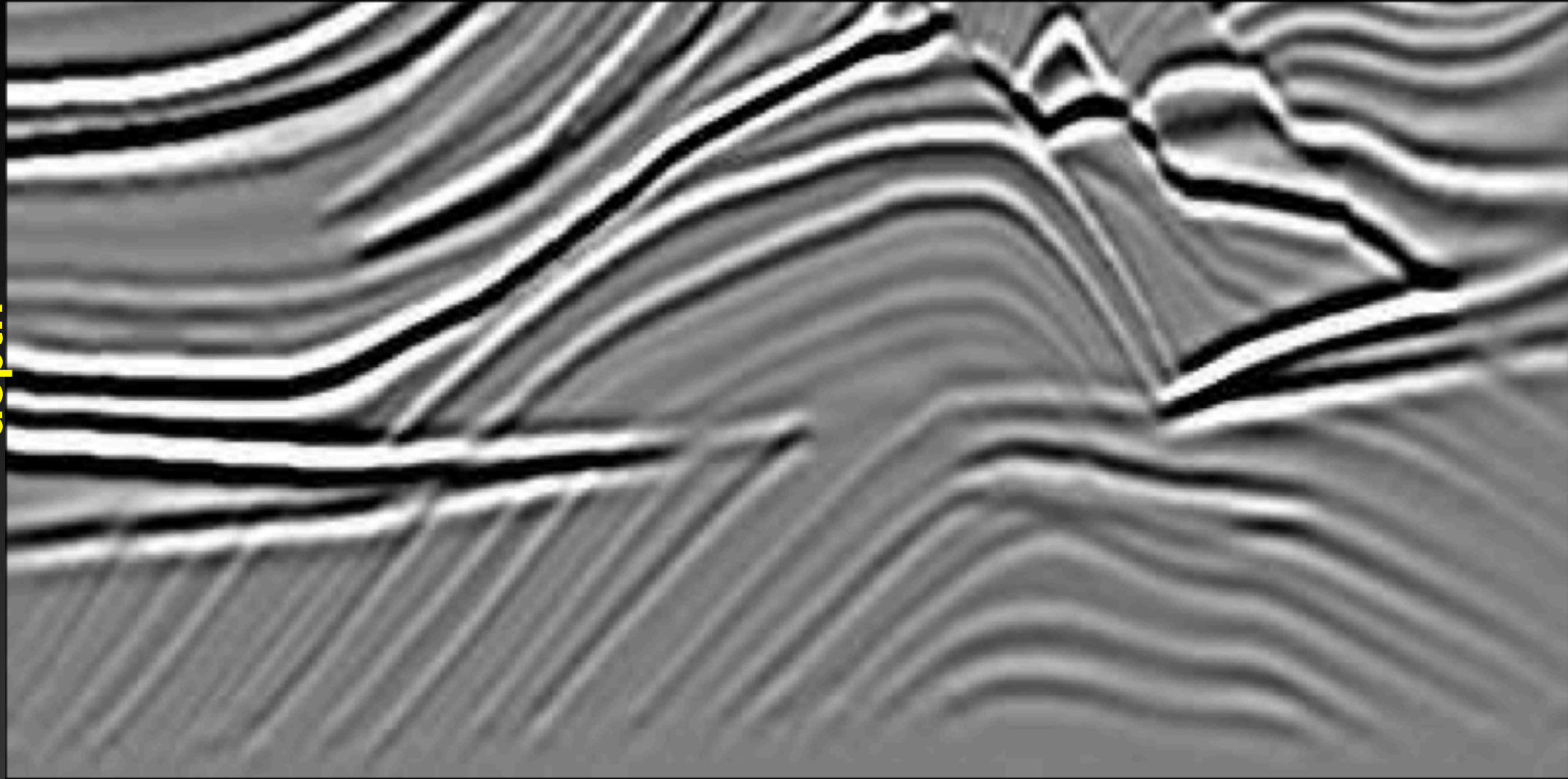
Receptor



Migração de 375 tiros

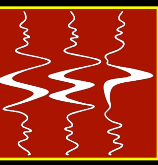


distance



depth

Refletores seleccionados

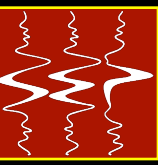


distance

depth



Migração de 35 PERM

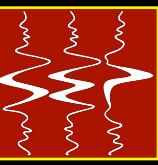


distance

depth

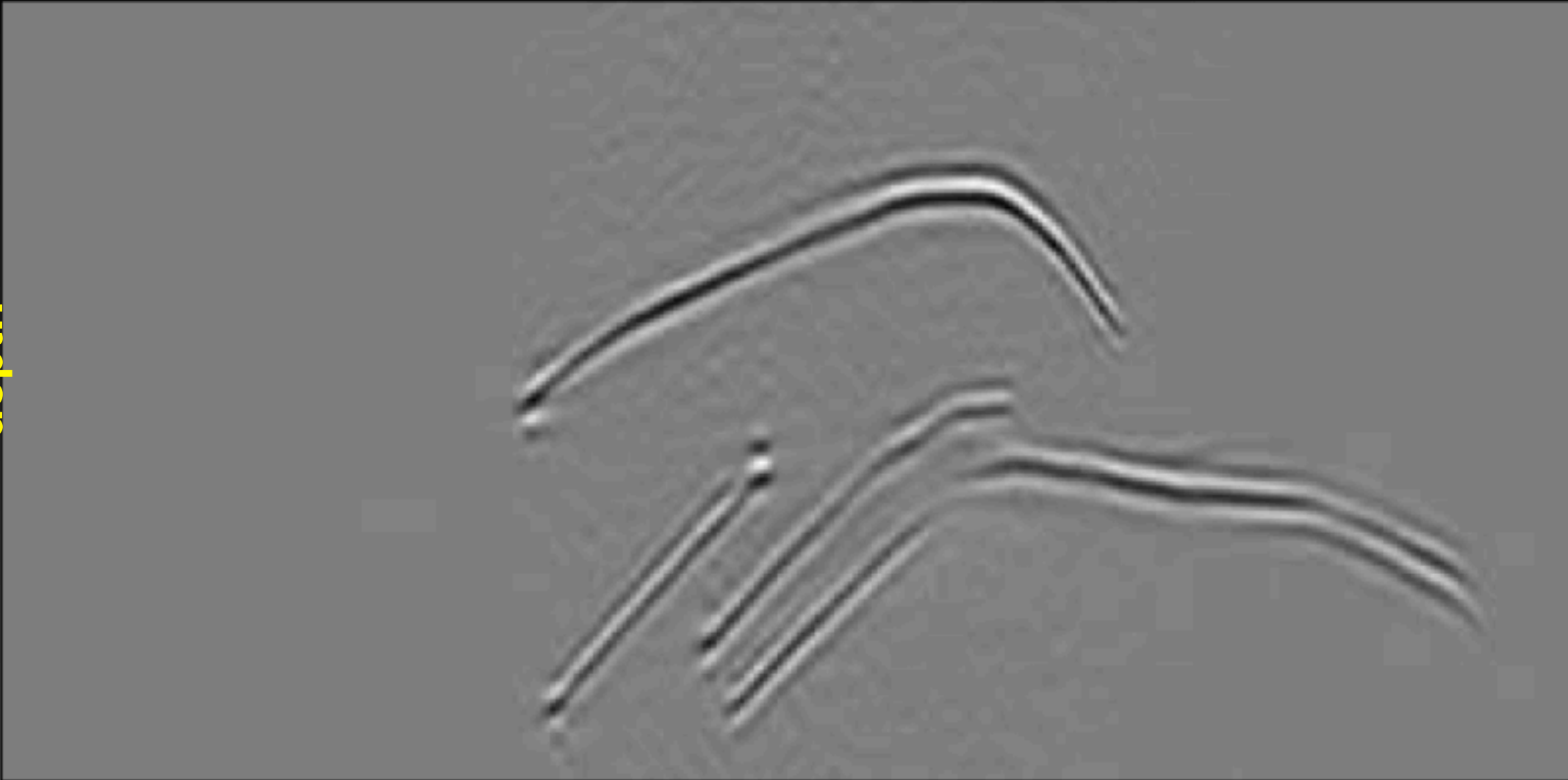


Migração de 11 ISPEW

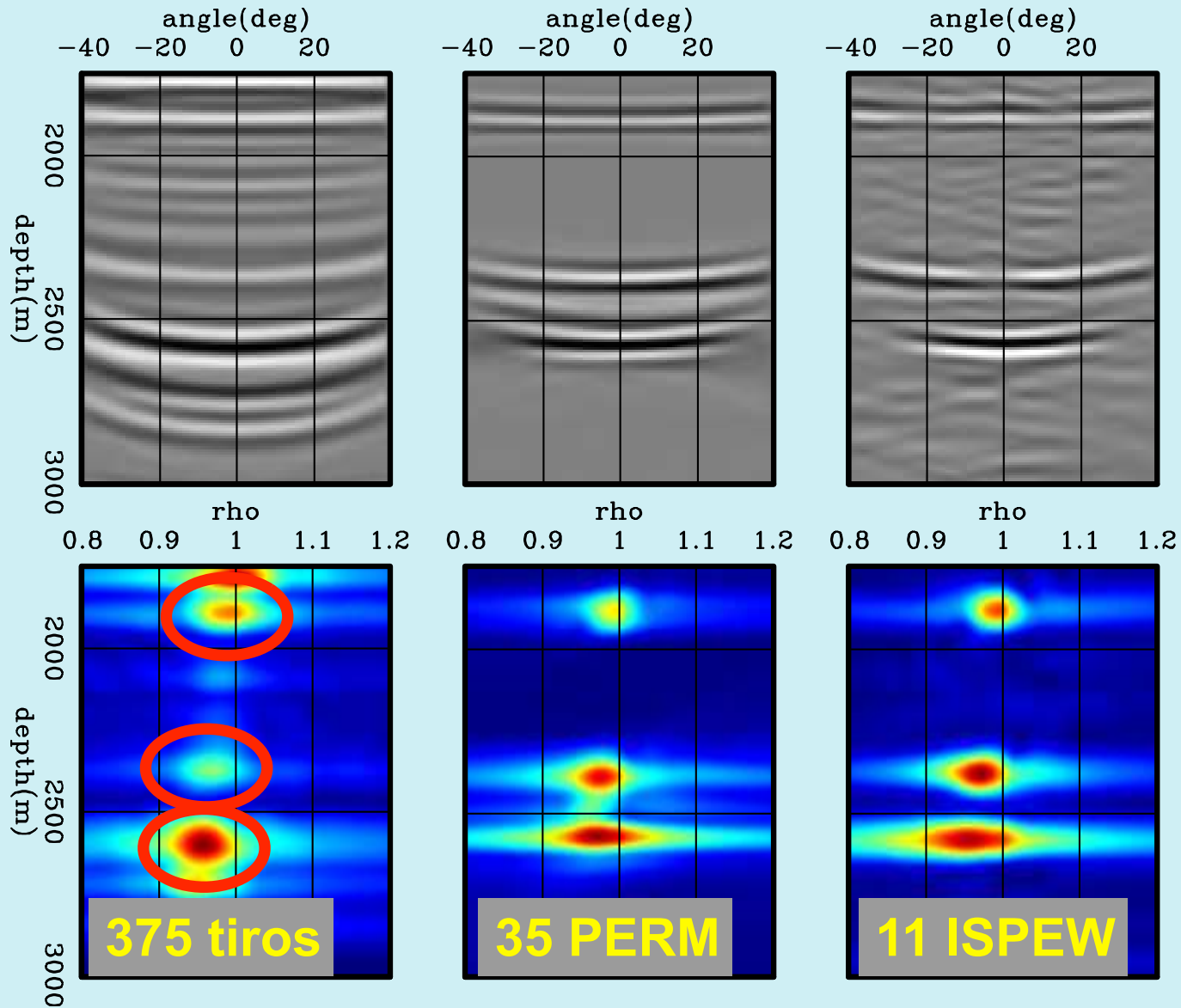
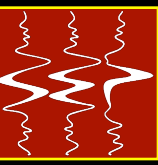


distance

depth



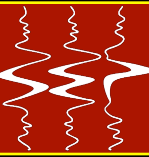
Informação de velocidade mantida



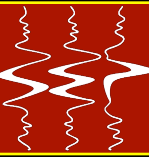
rho - parâmetro de curvatura



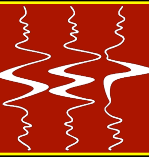
- ✓ **Capítulo 2: Modelo do refletor explosivo prestack**
- ✓ **Capítulo 3: Campos de onda aleatoriamente combinados no espaço da imagem**
- **Capítulo 4: AVM com fontes generalizadas no espaço da imagem**
- **Capítulo 5: Exemplo com dados reais 3D**



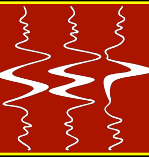
- **Extensão do ISWET para o domínio de fontes generalizadas (Tang et al., 2009 - SEP136)**



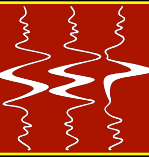
- **Extensão do ISWET para o domínio de fontes generalizadas (Tang et al., 2009 - SEP136)**
- **Menor número de campos de onda**



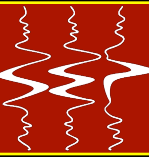
- **Campos de onda iniciados em refletores selecionados**



- **Campos de onda iniciados em refletores selecionados**
 - **ISWET baseado em horizontes**



- **Campos de onda iniciados em refletores selecionados**
 - **ISWET baseado em horizontes**
- **Facilmente resolvido focado num alvo**

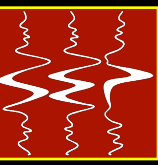


$$J(\mathbf{s}) = \frac{1}{2} \left\| \mathbf{h} \tilde{I}(\mathbf{s}) \right\|_2$$

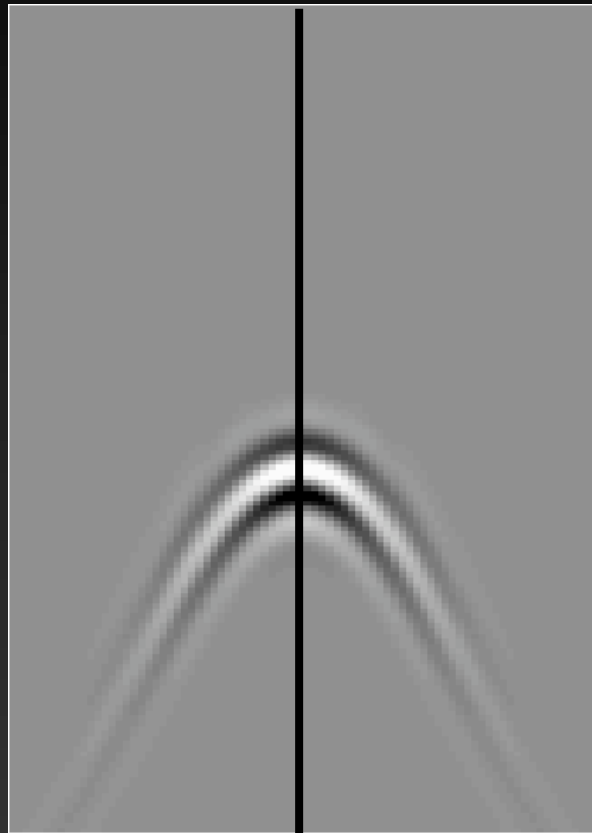
operador DSO (Symes and Carazzone, 1991)

$J(\mathbf{s})$ = objective function $\Delta \tilde{I}(\mathbf{s})$ = perturbed image
 \mathbf{h} = DSO operator $\tilde{I}(\mathbf{s})$ = current image

Operador DSO = $|h|$

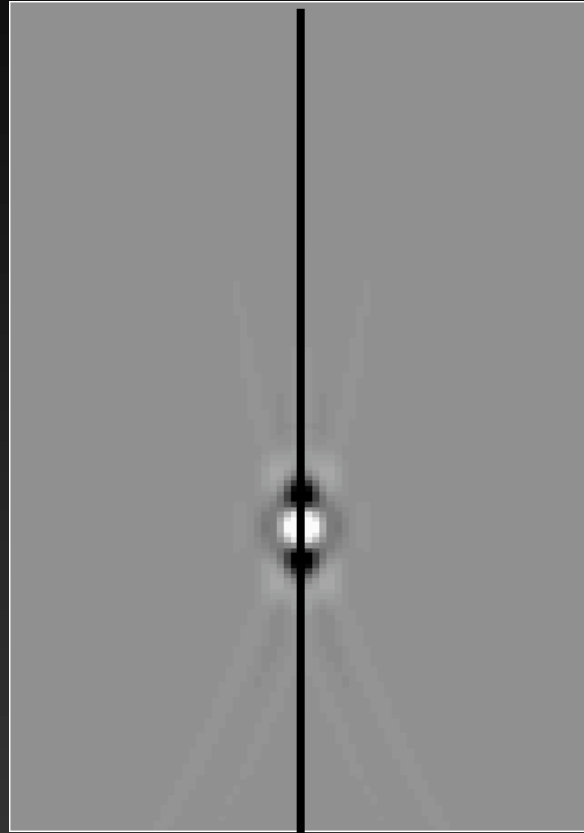


**VELOCIDADE
MAIS BAIXA**



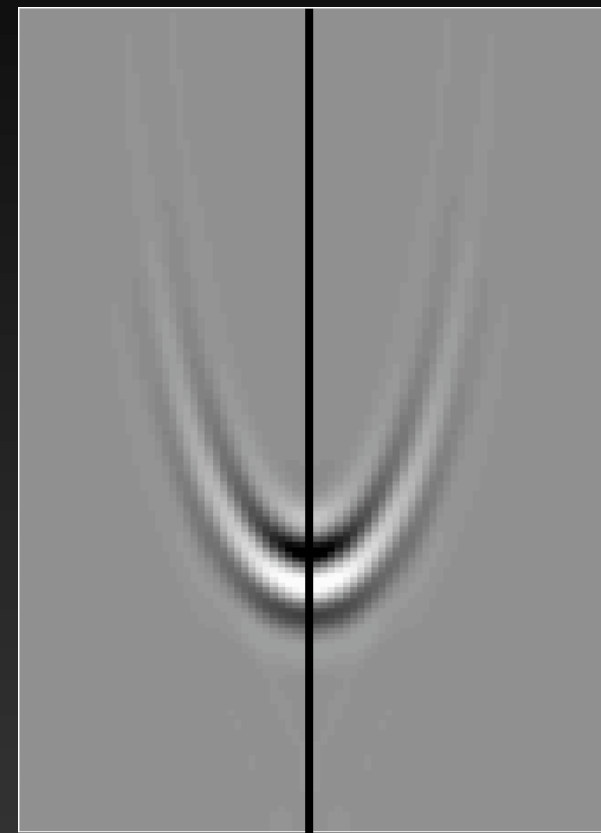
offset

**VELOCIDADE
CORRETA**



offset

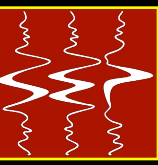
**VELOCIDADE
MAIS ALTA**



offset

depth

Operador DSO = $|h|$

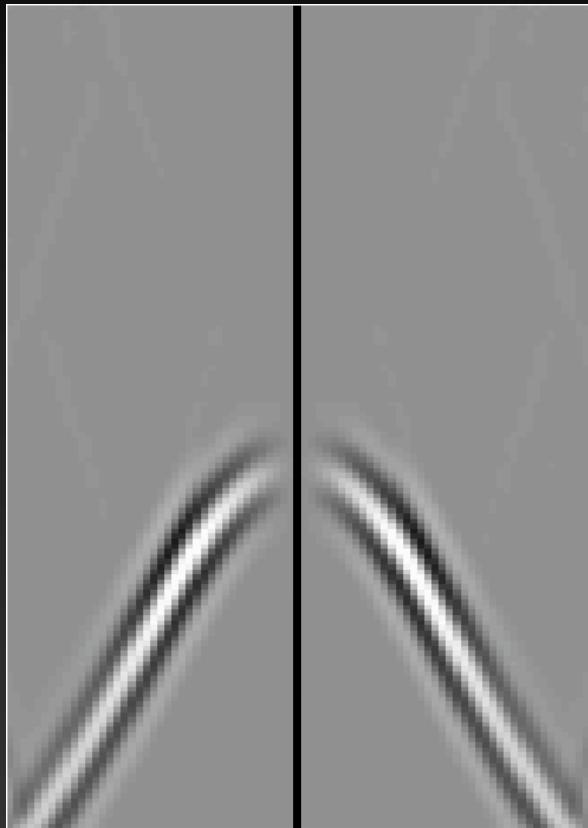


**VELOCIDADE
MAIS BAIXA**

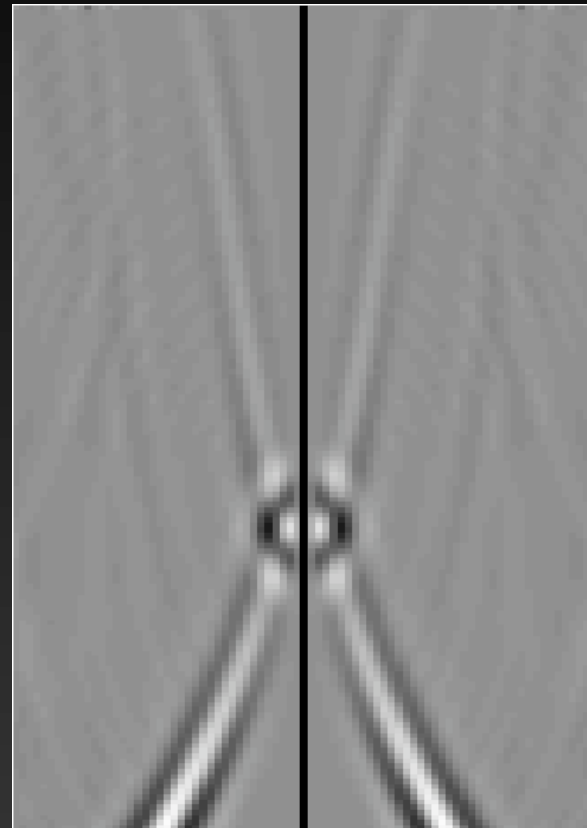
**VELOCIDADE
CORRETA**

**VELOCIDADE
MAIS ALTA**

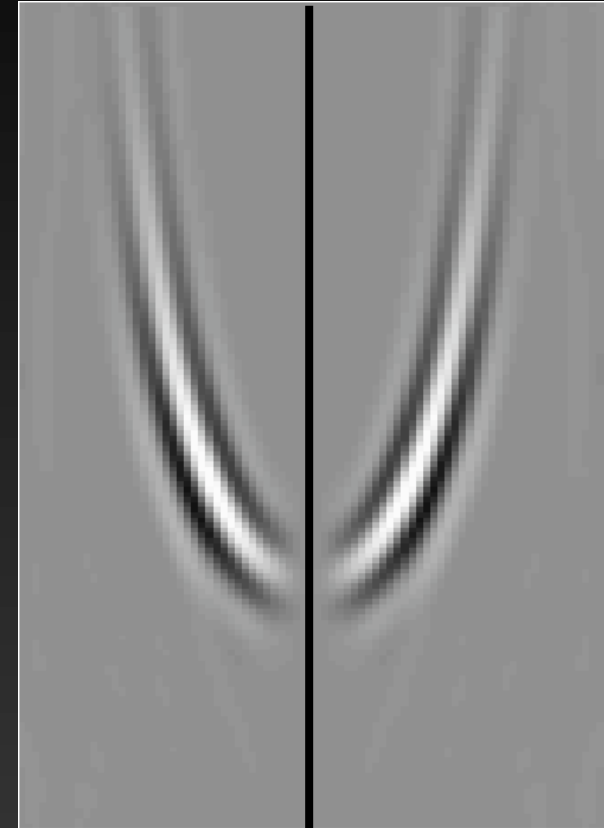
depth



offset



offset



offset



$$J(s) = \frac{1}{2} \left\| \mathbf{h} \tilde{I}(s) \right\|_2$$

$$\nabla J(s) = \left(\frac{\partial \tilde{I}}{\partial s} \right)' \mathbf{h}^2 \tilde{I} \Big|_{s=s_0}$$

$J(s)$ = objective function

\mathbf{h} = DSO operator

s_0 = current velocity

$\Delta \tilde{I}(s)$ = perturbed image

$\tilde{I}(s)$ = current image

Exemplo sintético 2D

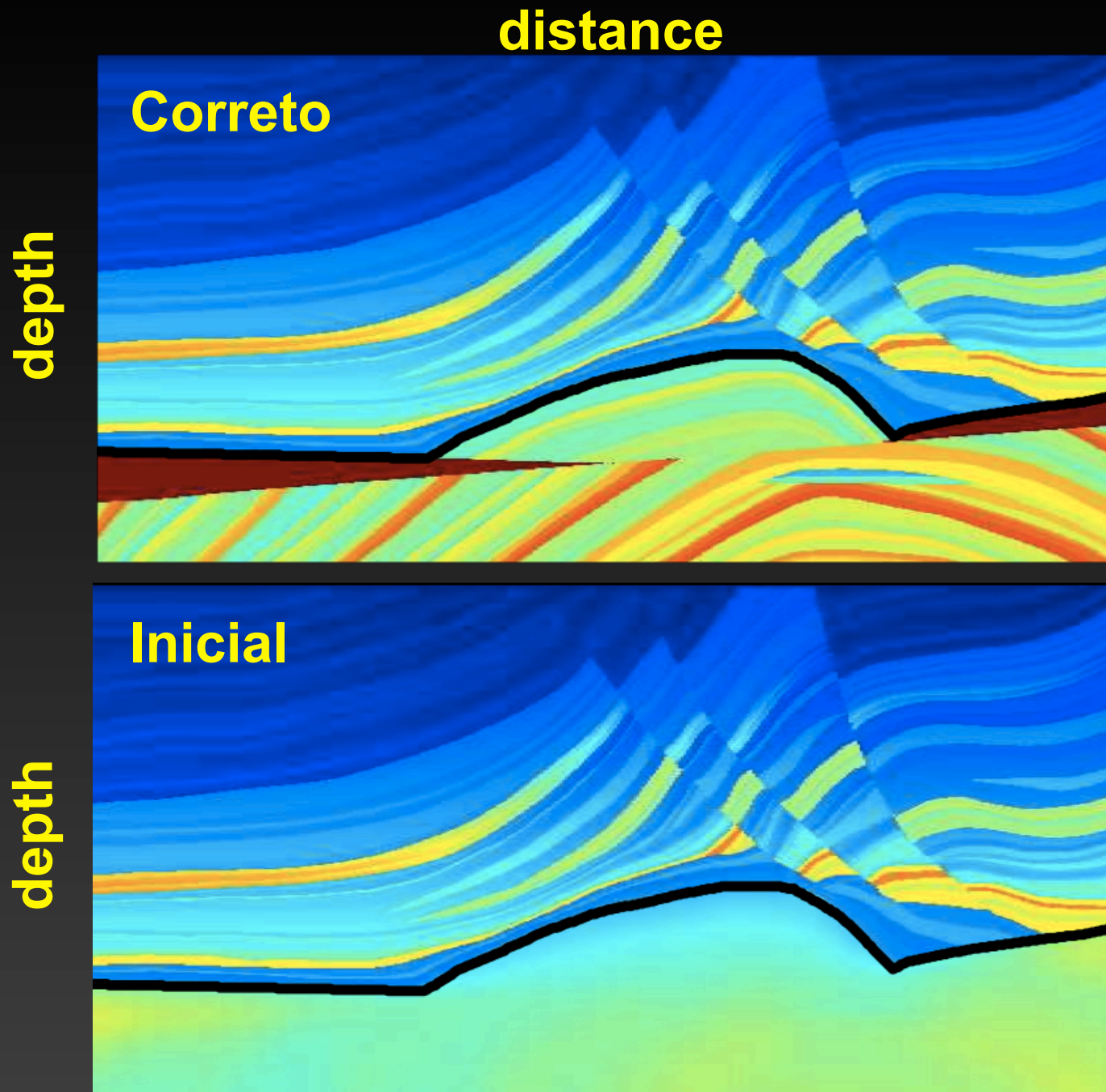
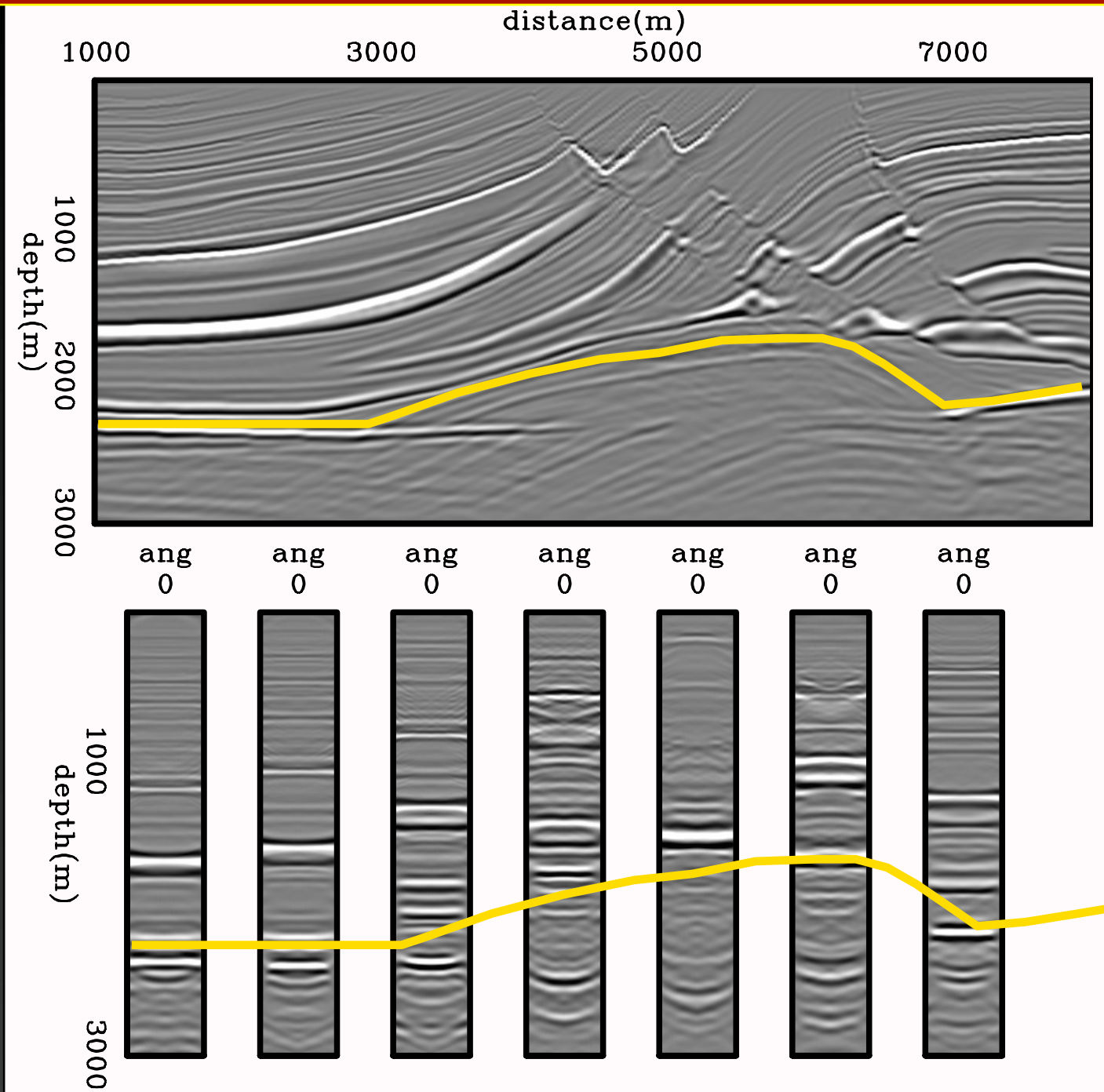
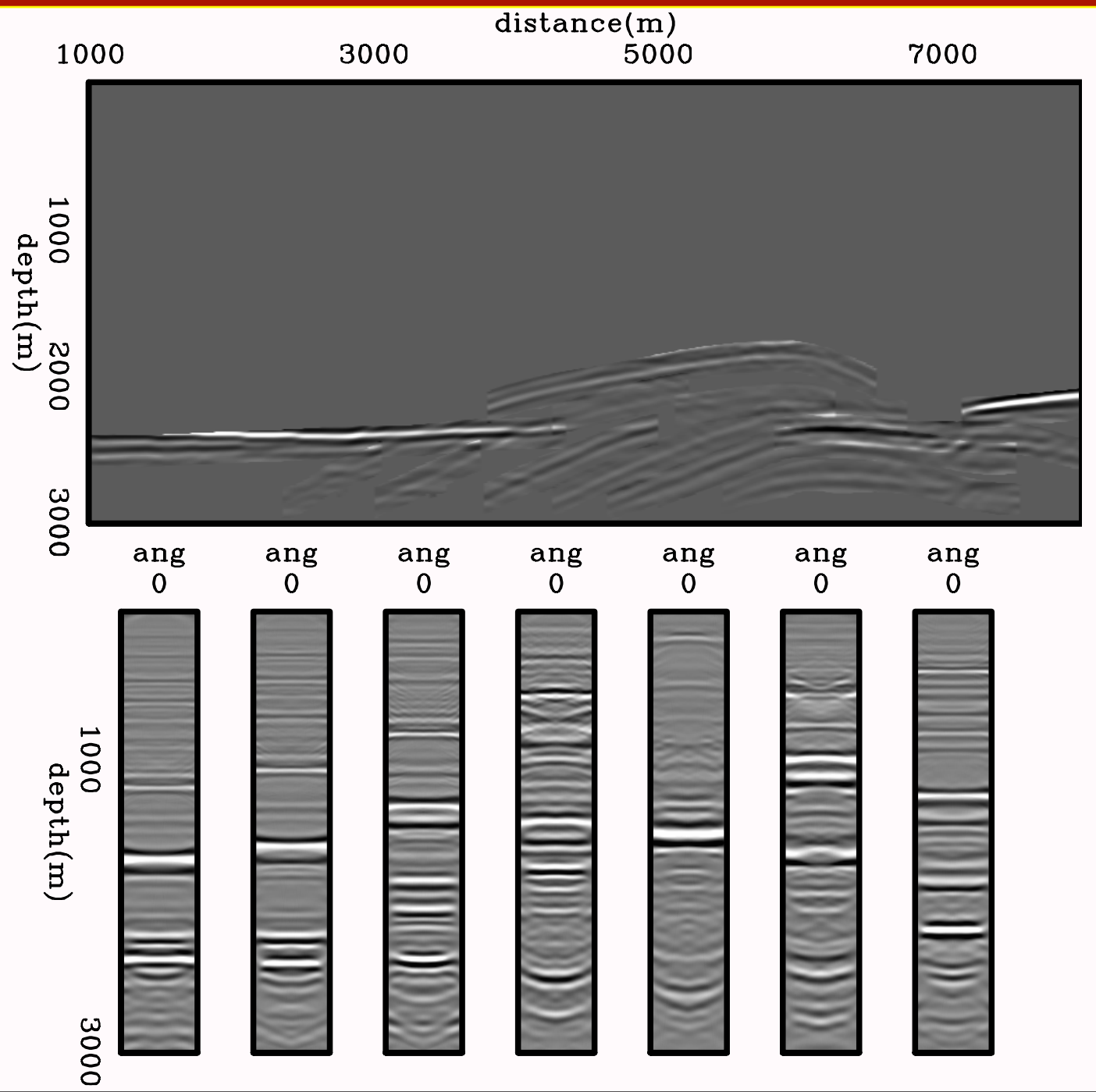
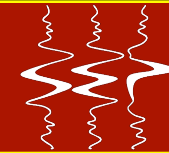


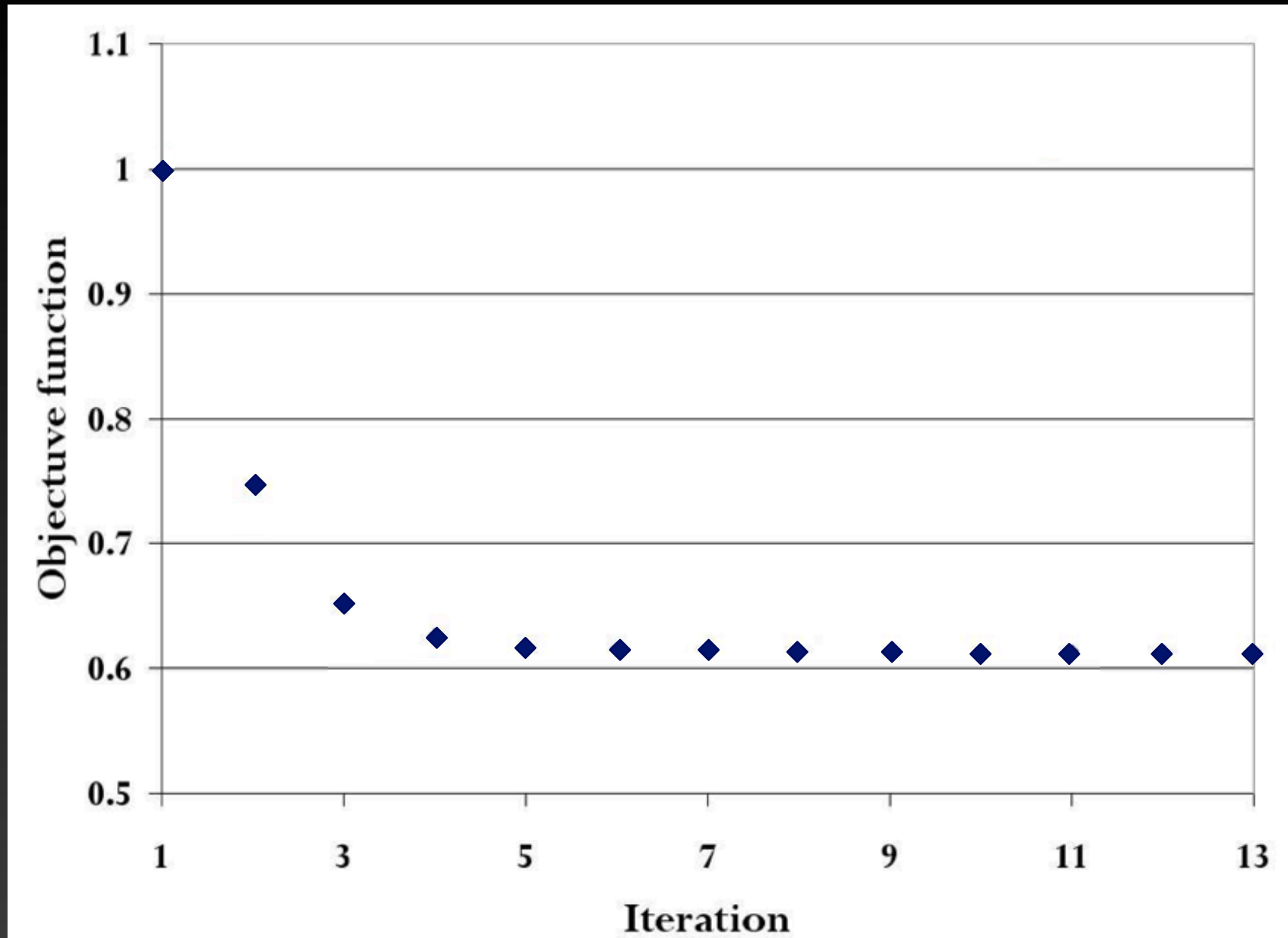
Imagem inicial



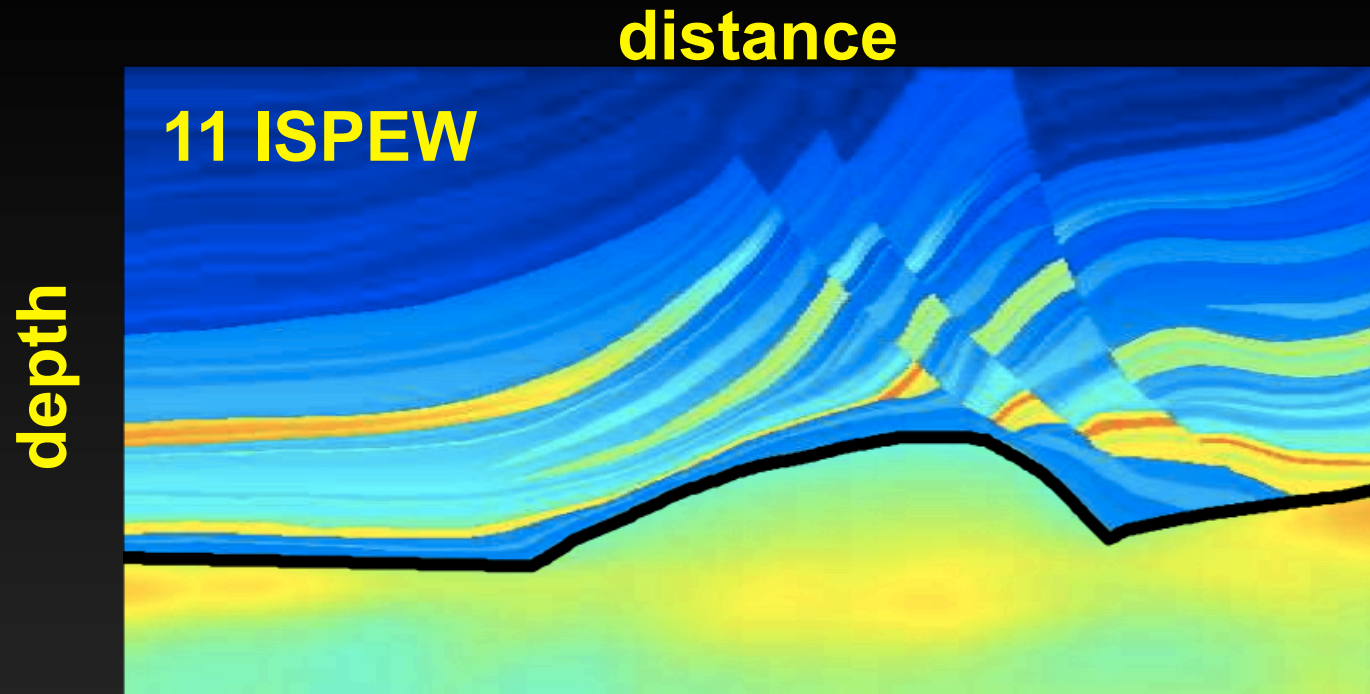
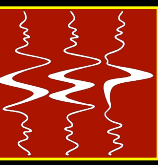
12 refletores



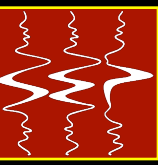
Evolução do funcional



Velocidades otimizadas



Acurácia da solução



depth

distance

Correta suavizada

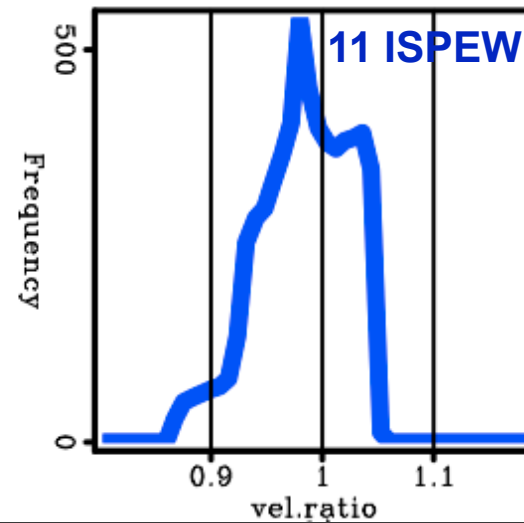
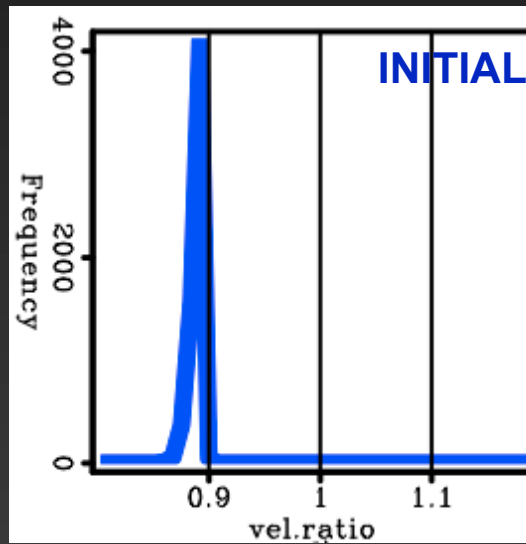
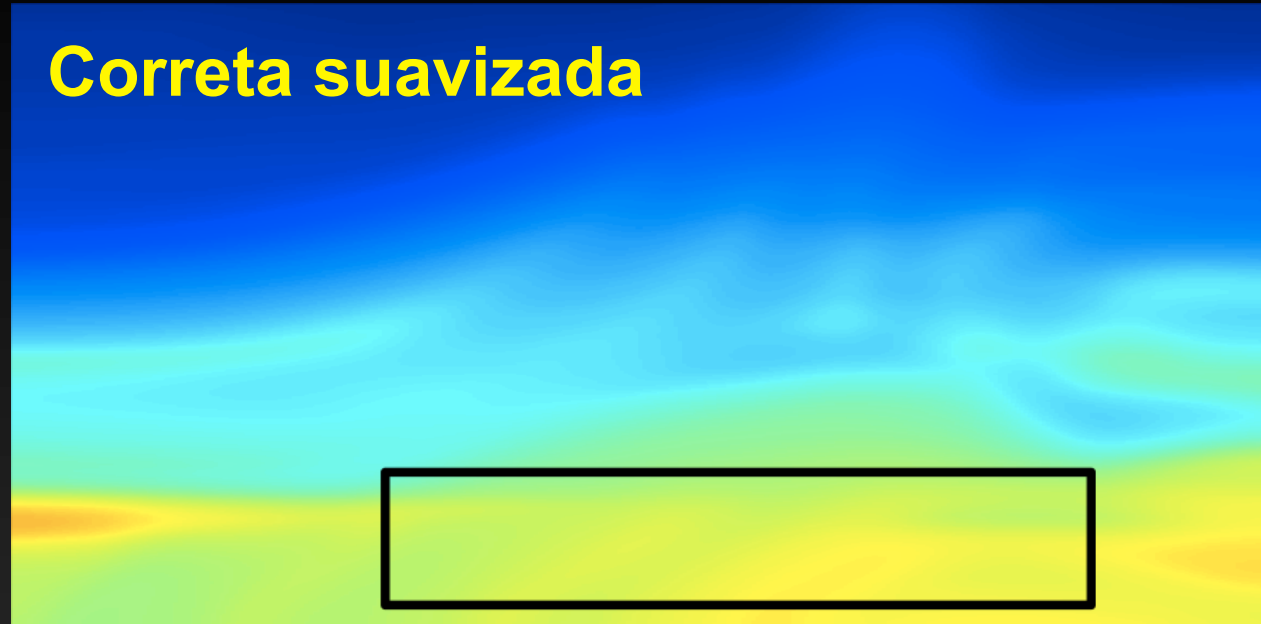
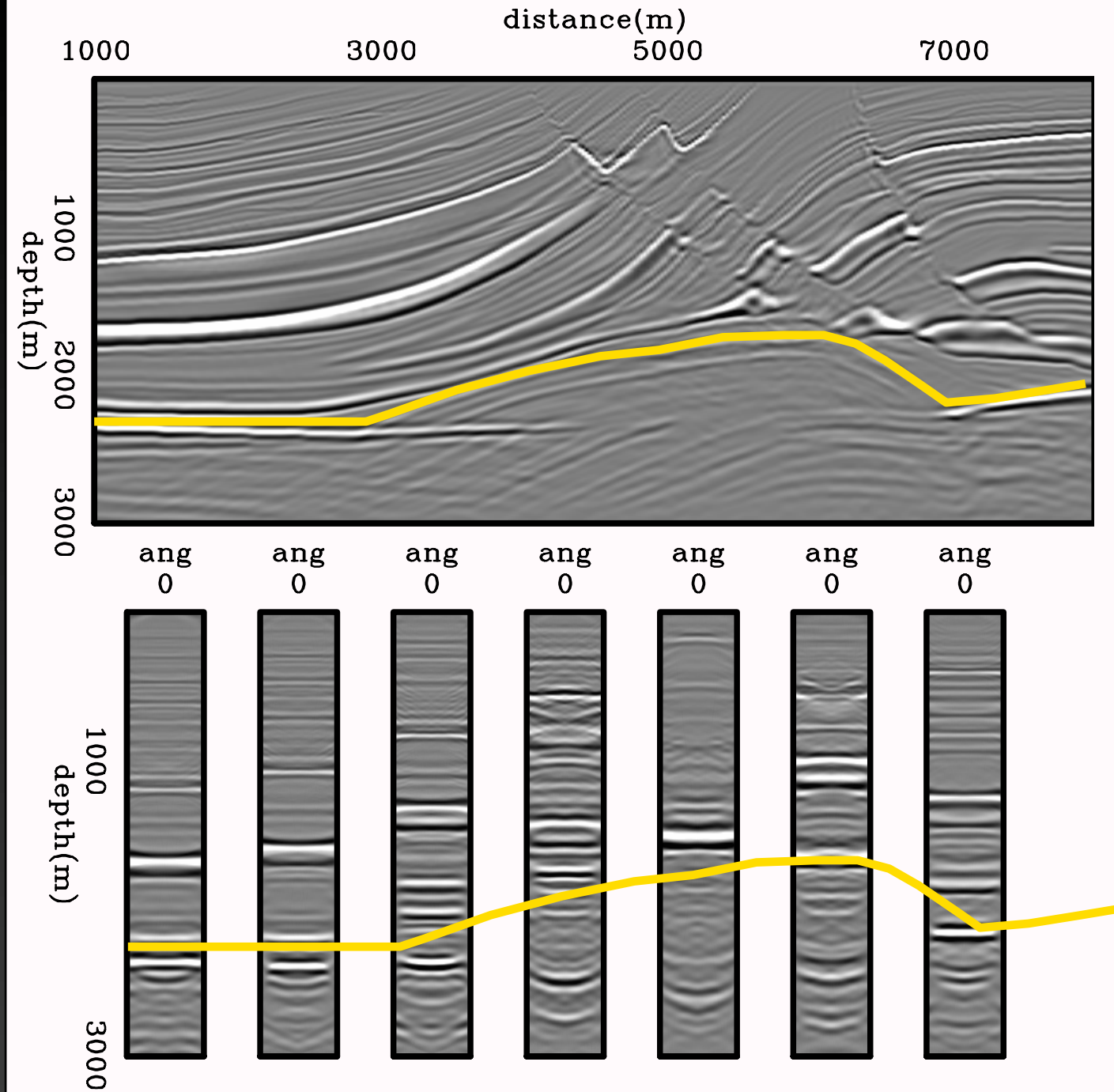
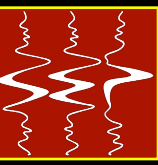
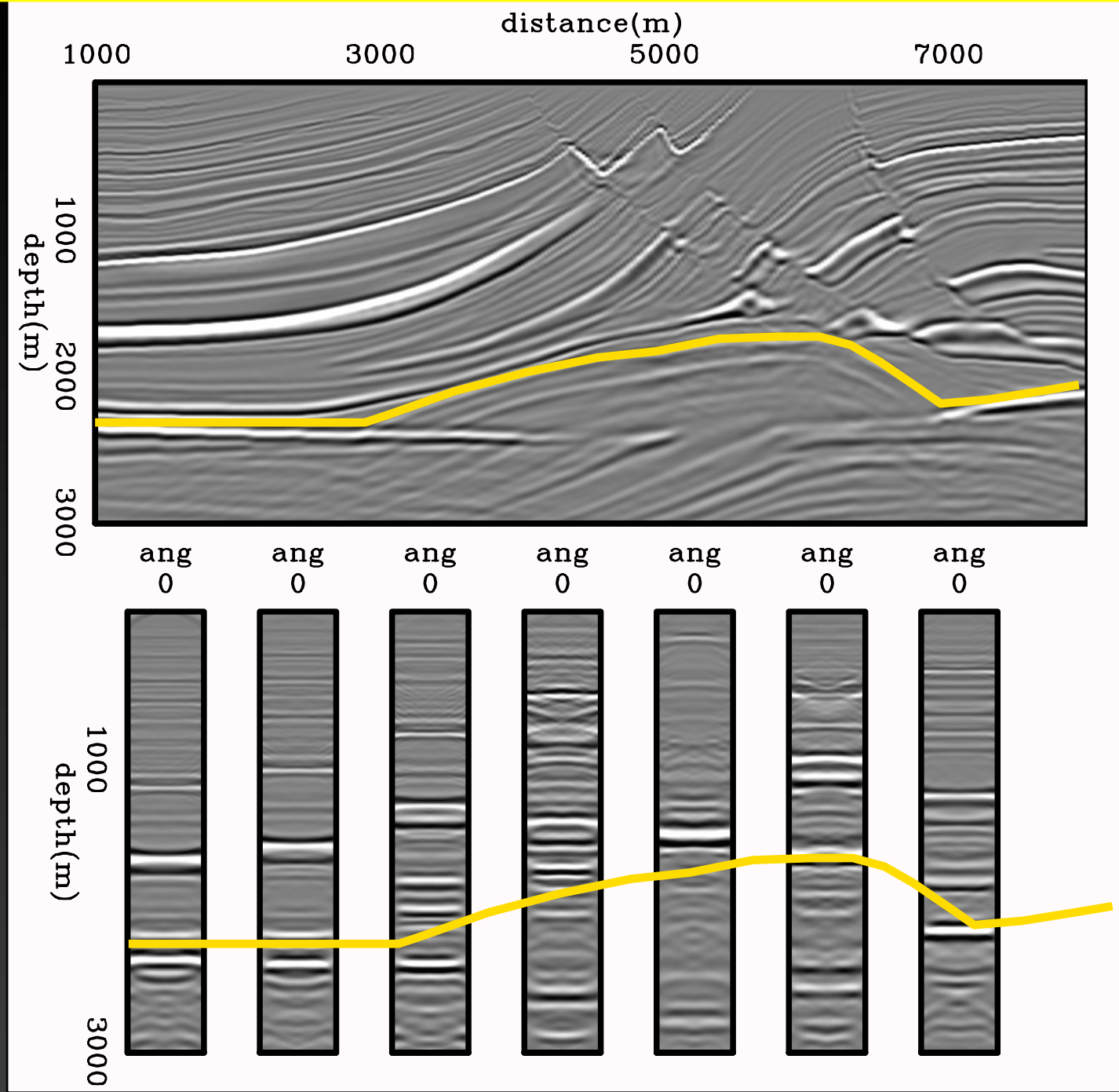


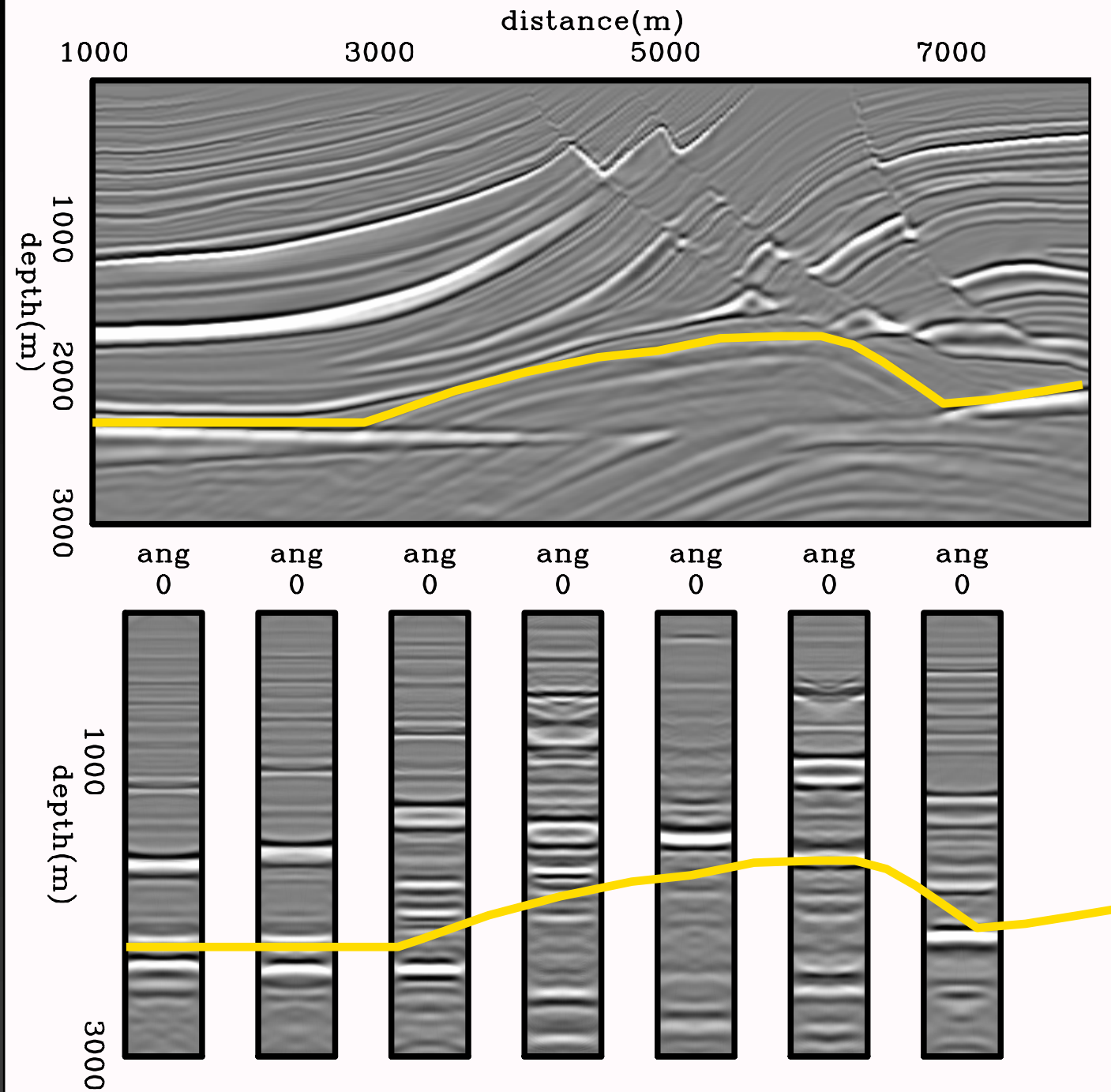
Imagem inicial



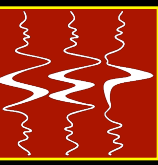
Migração com velocidade otimizada



Migração com velocidade correta



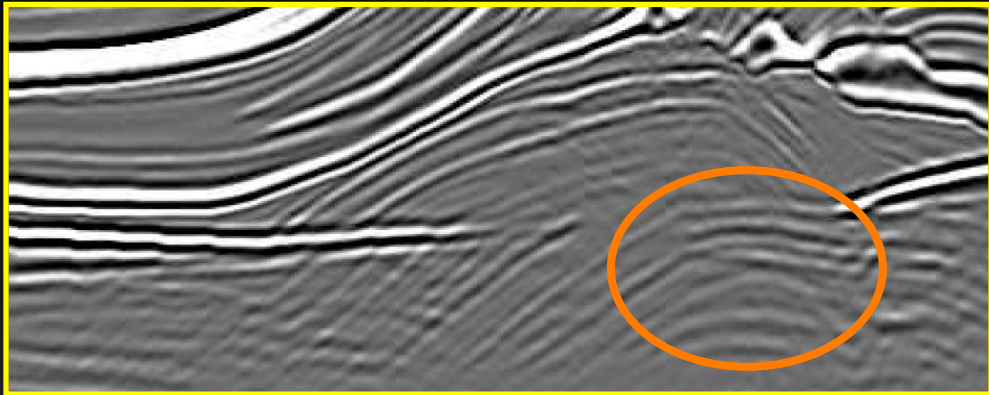
Ganho computacional



Inicial

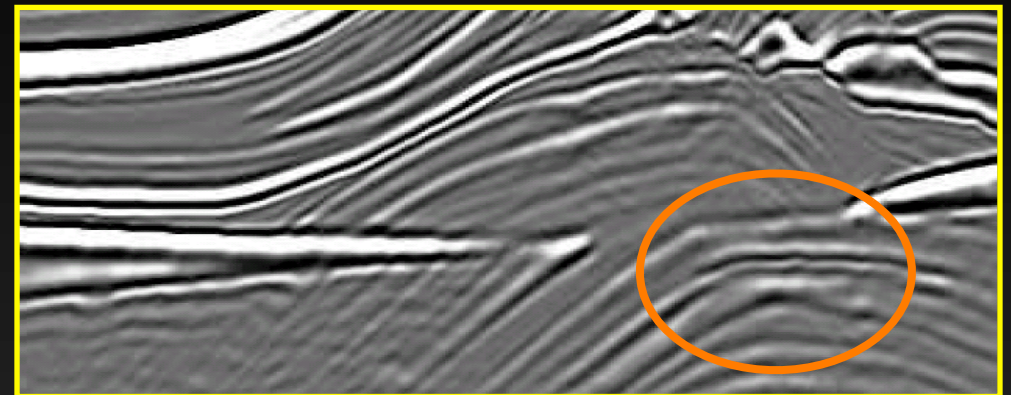
x

z



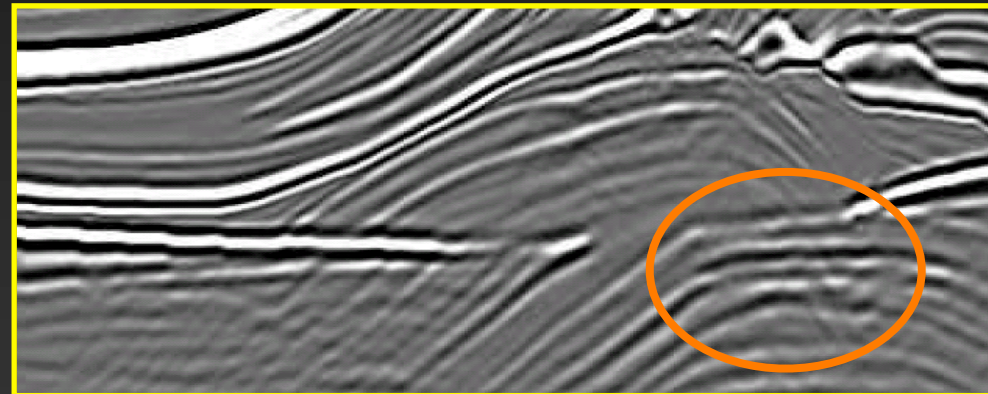
Correta

x

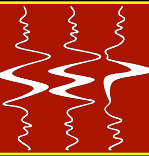


Otimizada

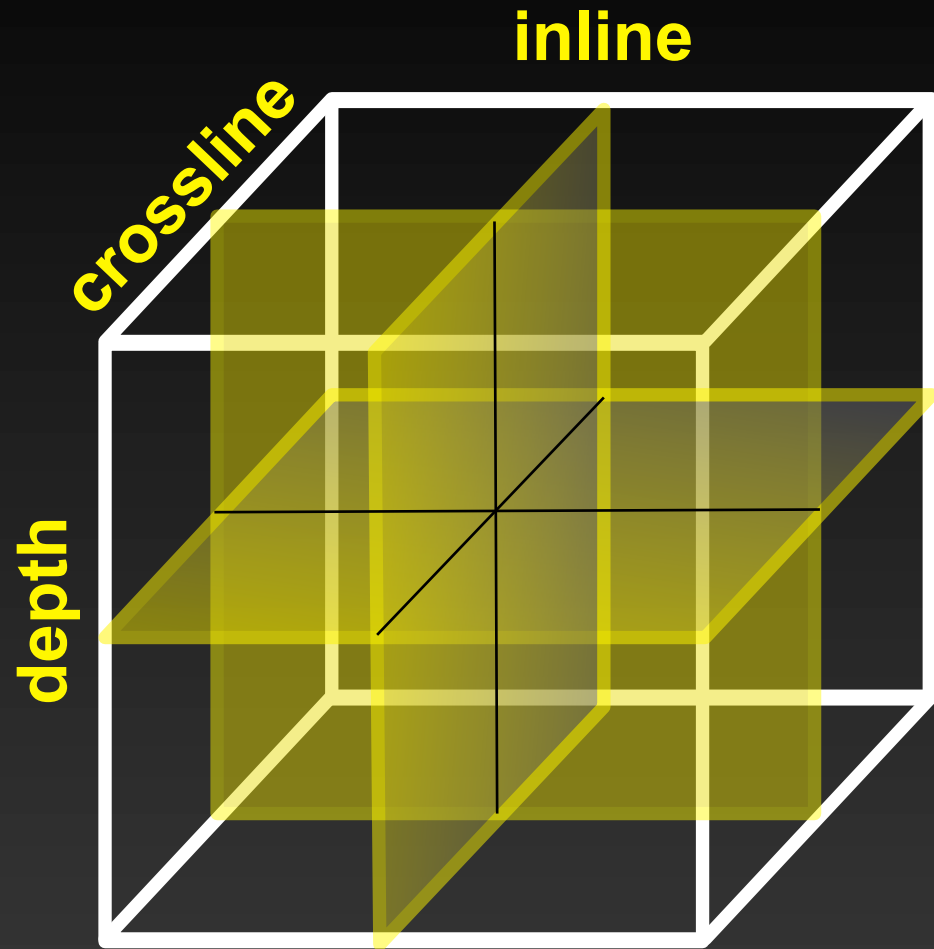
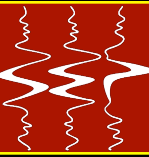
z



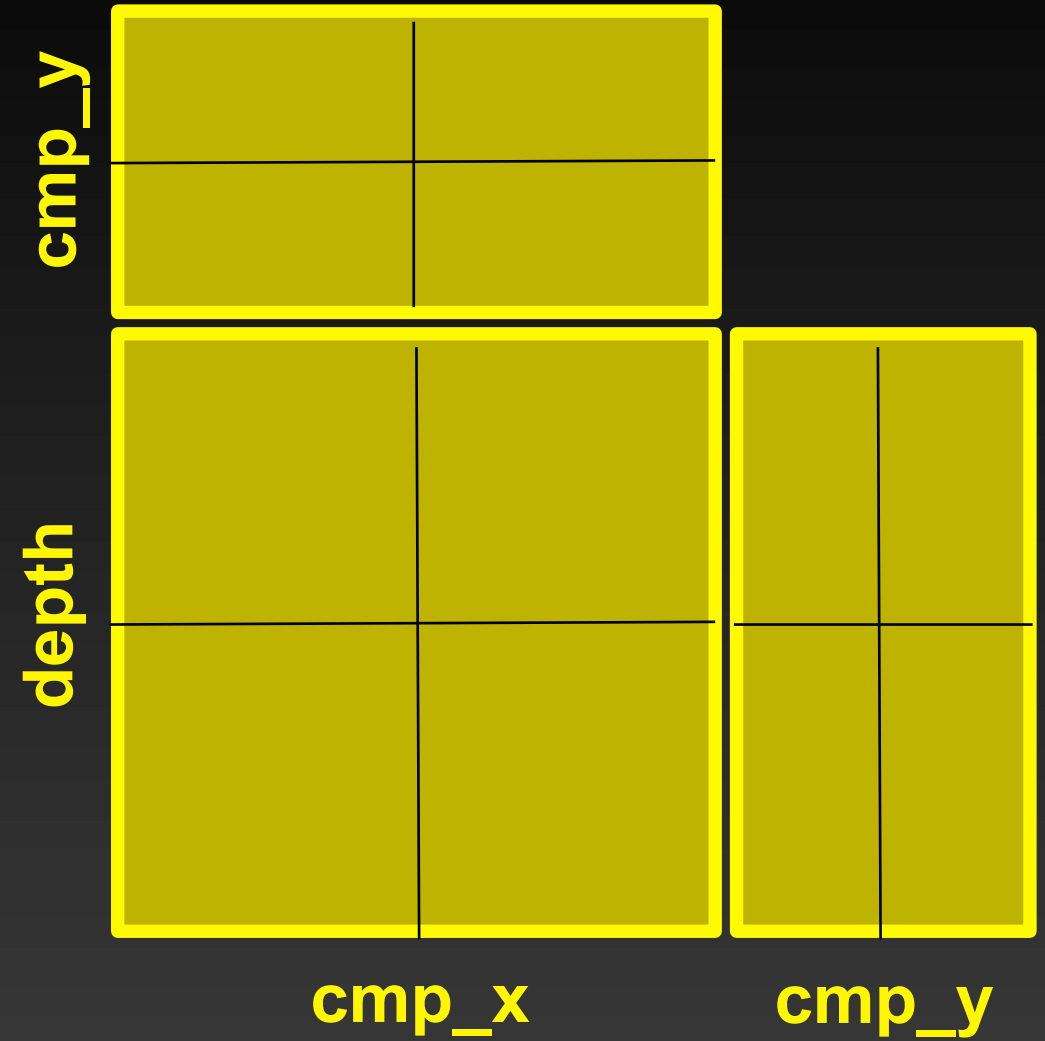
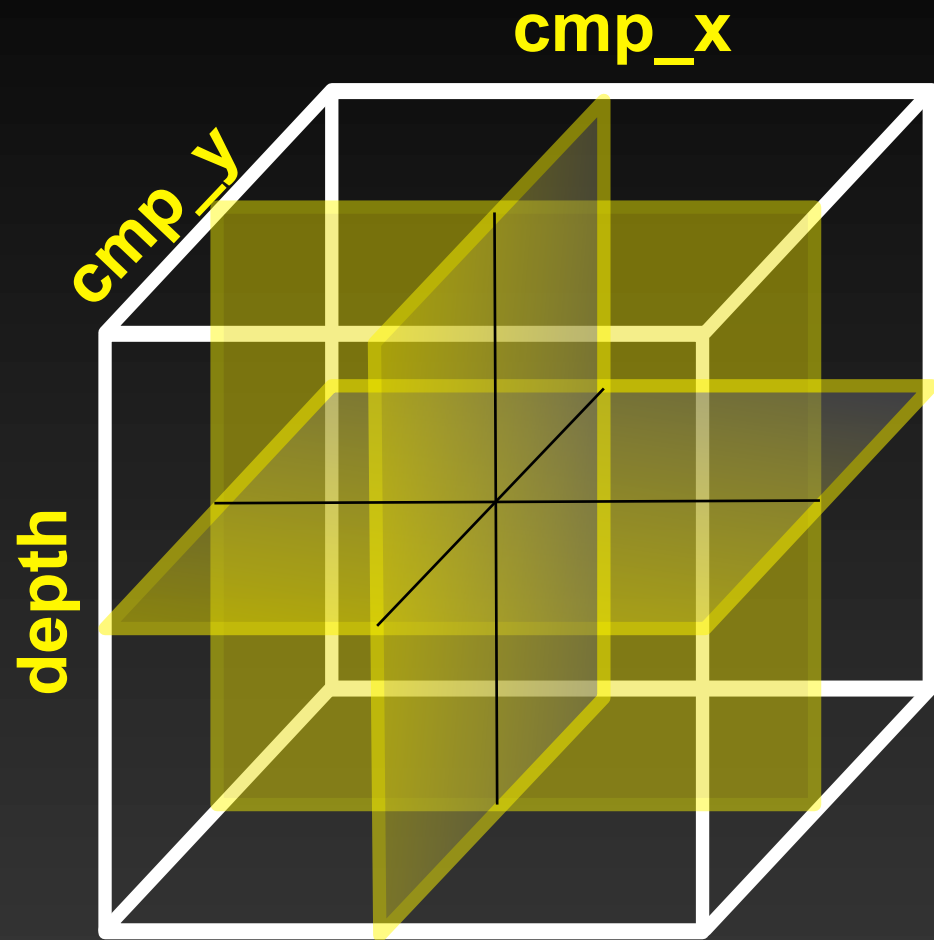
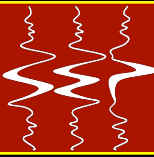
30x mais rápido

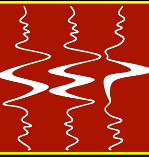


- ✓ **Capítulo 2: Modelo do refletor explosivo prestack**
- ✓ **Capítulo 3: Campos de onda aleatoriamente combinados no espaço da imagem**
- ✓ **Capítulo 4: AVM com fontes generalizadas no espaço da imagem**
- **Capítulo 5: Exemplo com dados reais 3D**

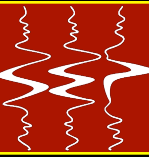


Visualização 3D

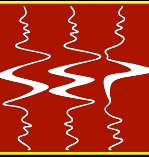




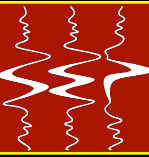
- **Tamanho : 12 x 4 km**



- **Tamanho: 12 x 4 km**
- **Afastamento máximo: 3.6 km**



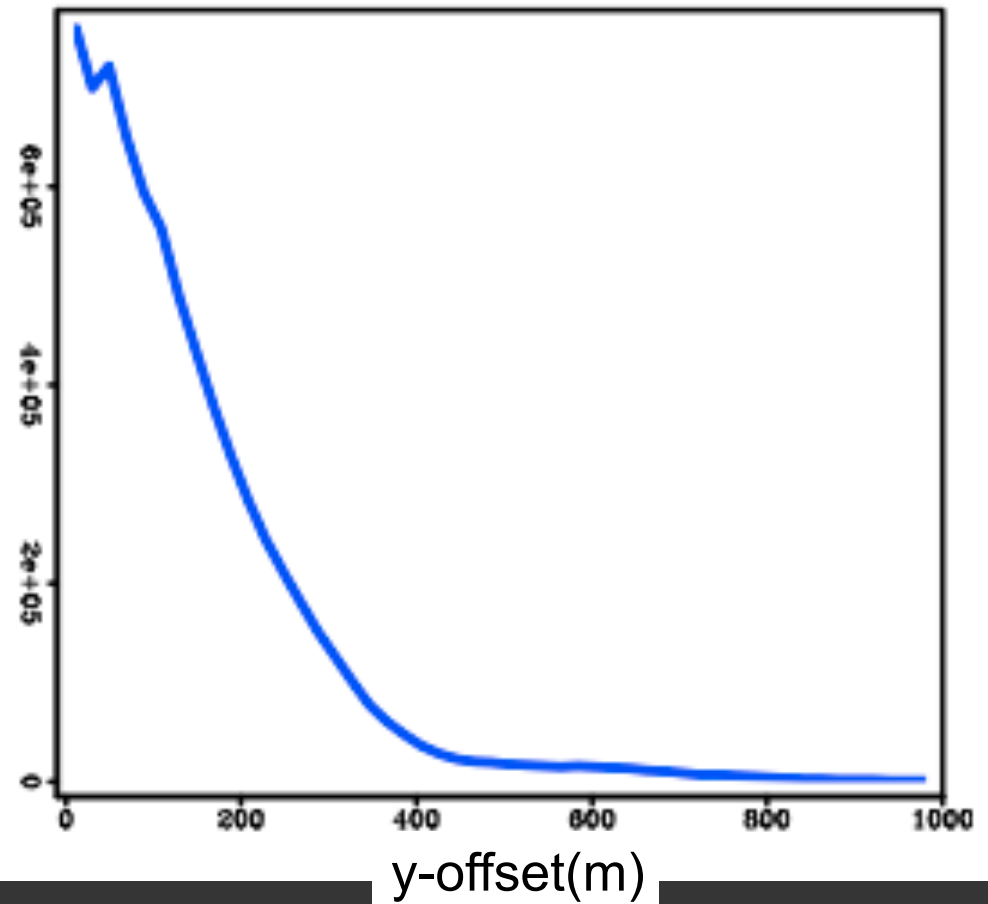
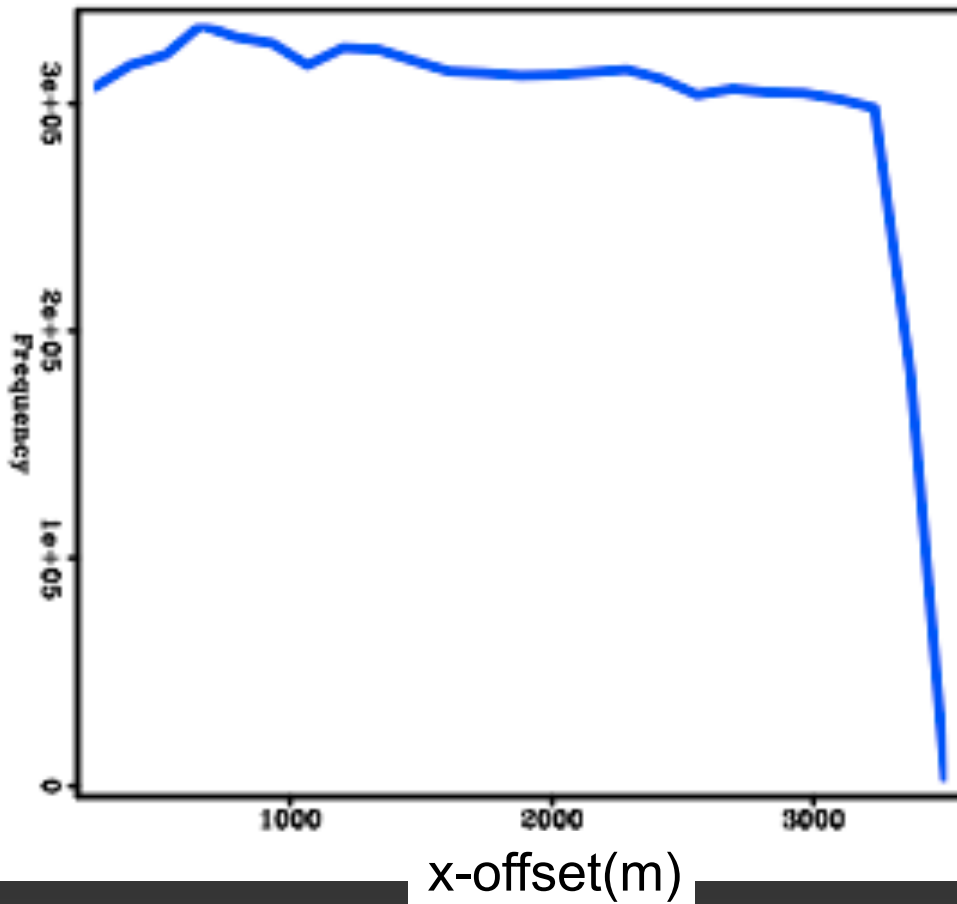
- **Tamanho: 12 x 4 km**
- **Afastamento máximo: 3.6 km**
- **30 ISPEW**

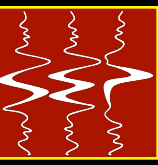


- **Falhamento intenso, sal irregular**
 - **inacurácia na interpretação**

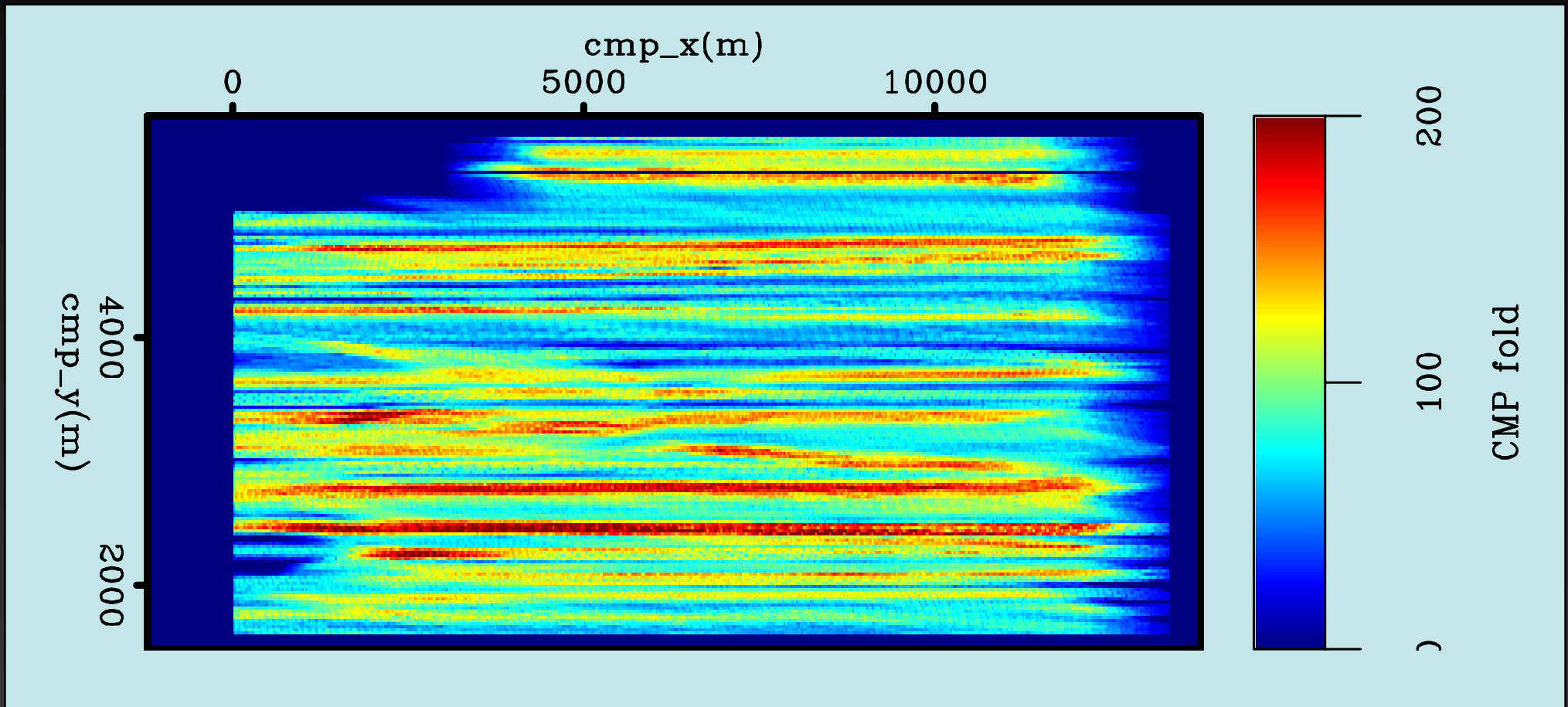


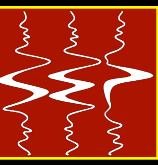
- Cobertura angular e offsets limitados



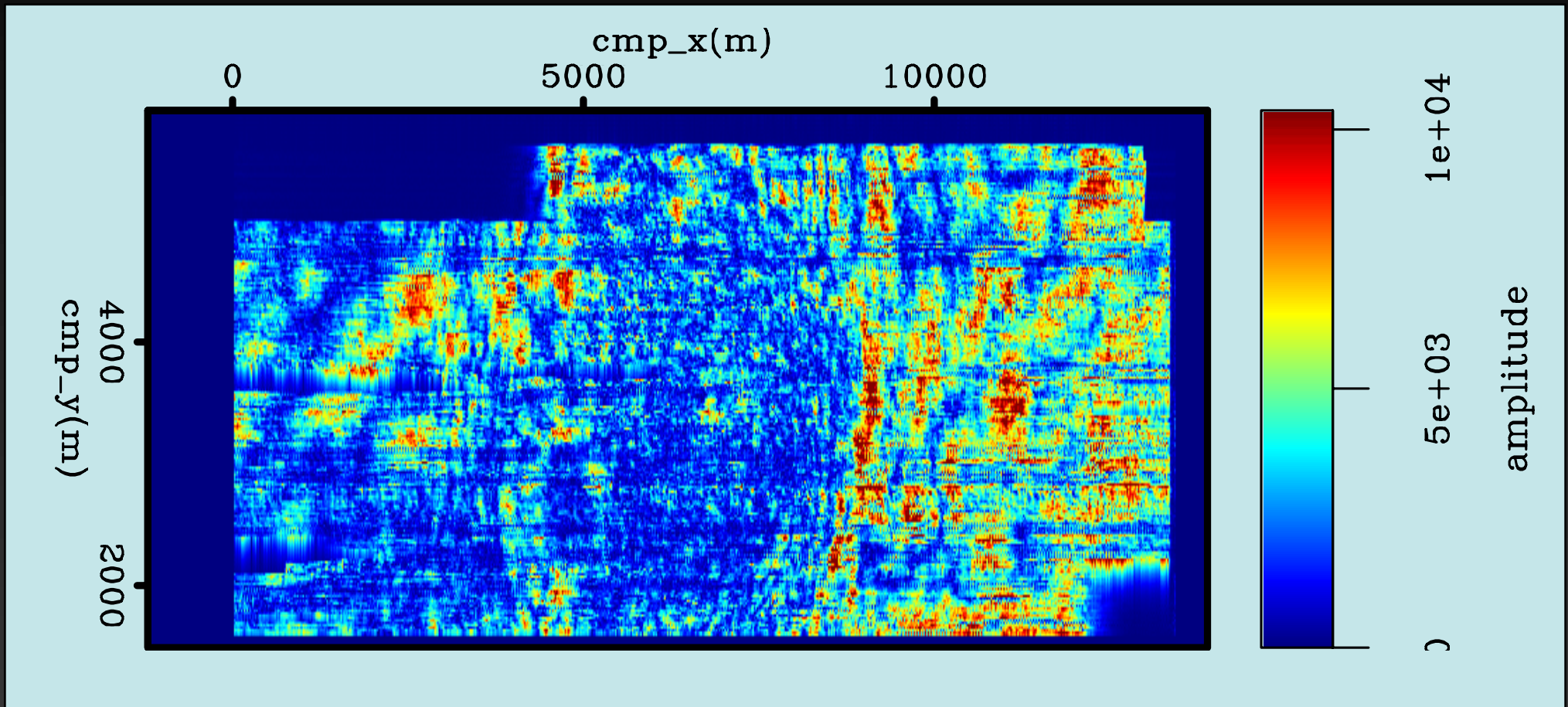


- **Marcas de aquisição**
 - **cobertura CMP**



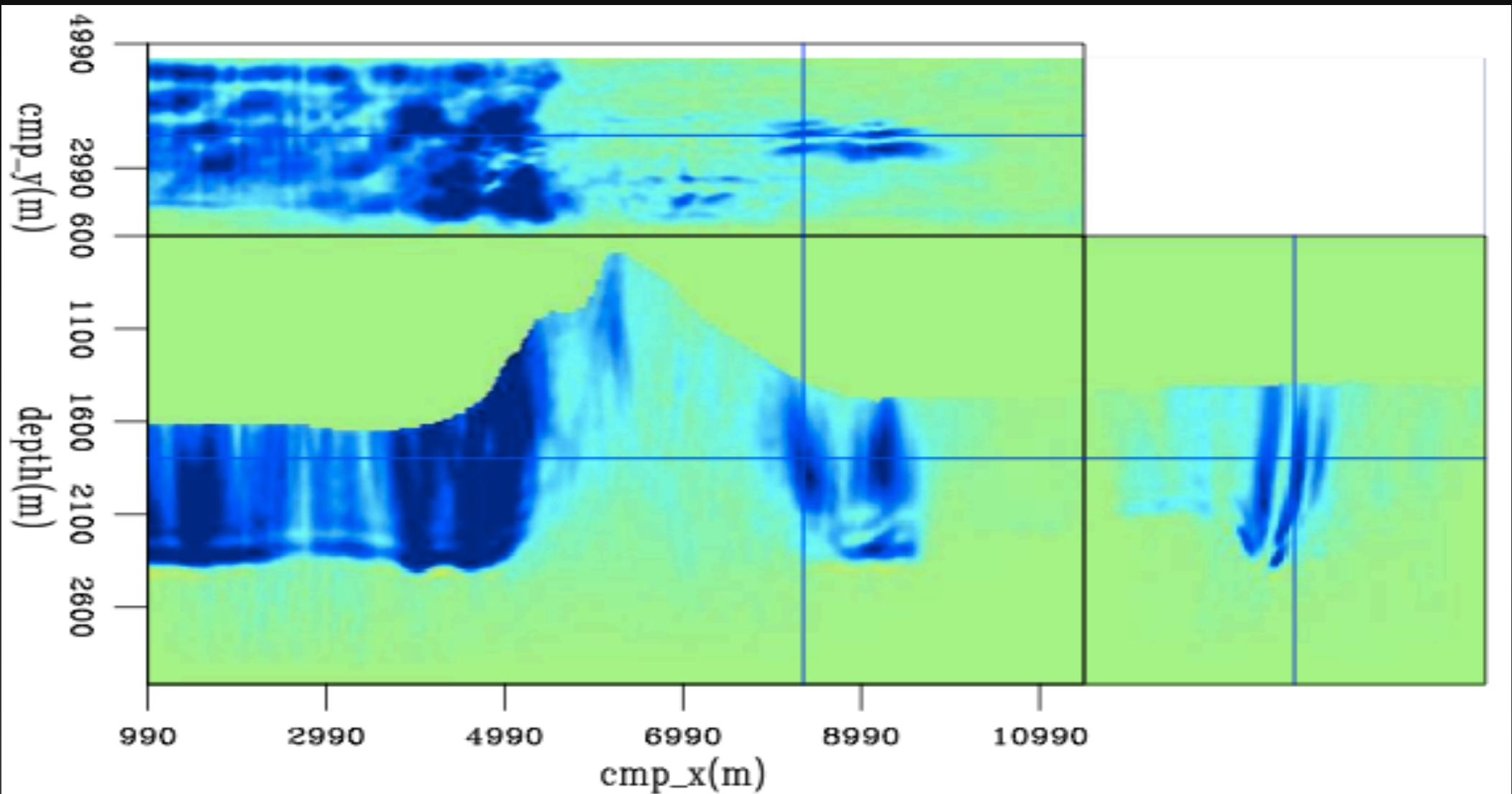


- **Marcas de aquisição**
 - **Mapa de amplitudes RMS**

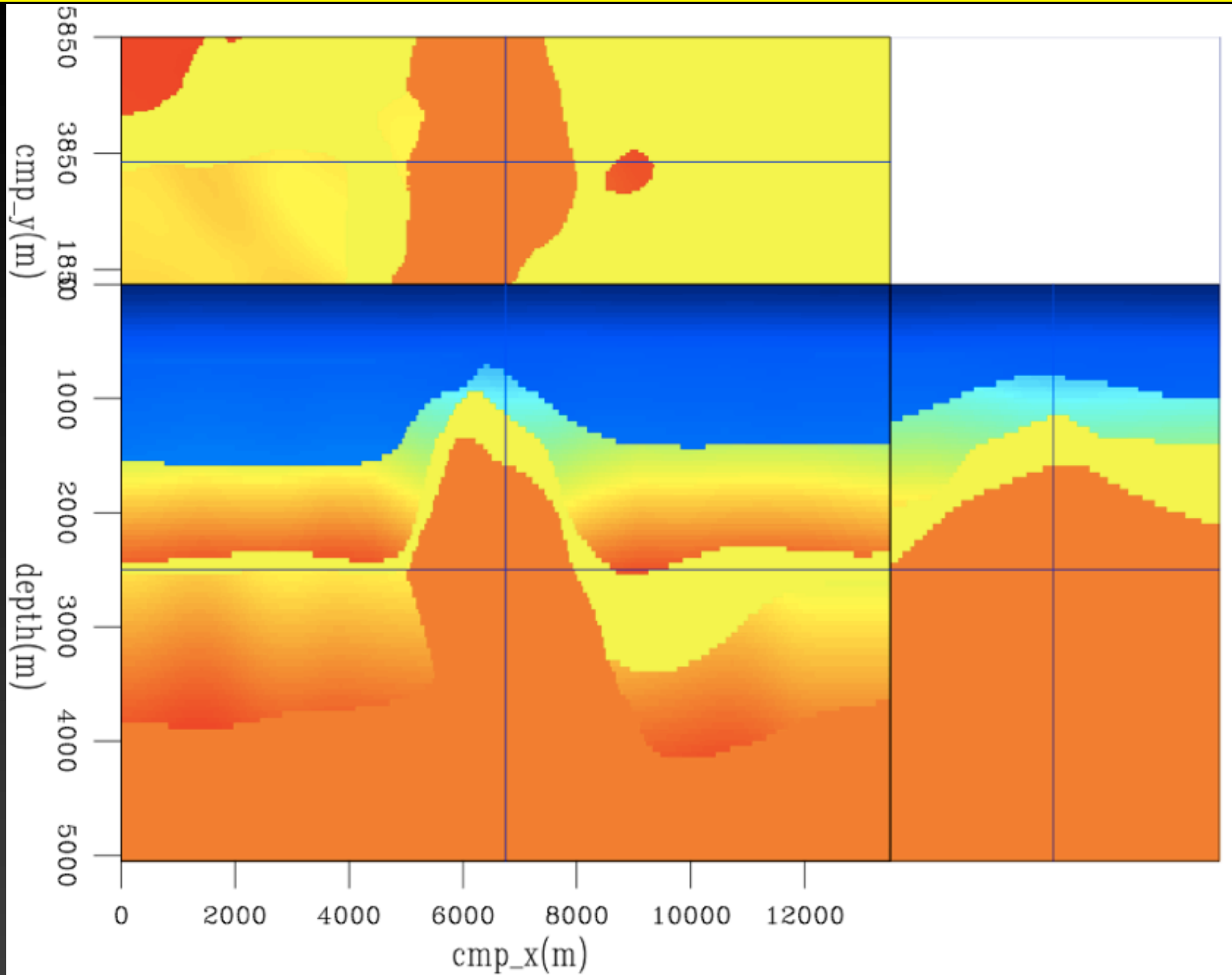




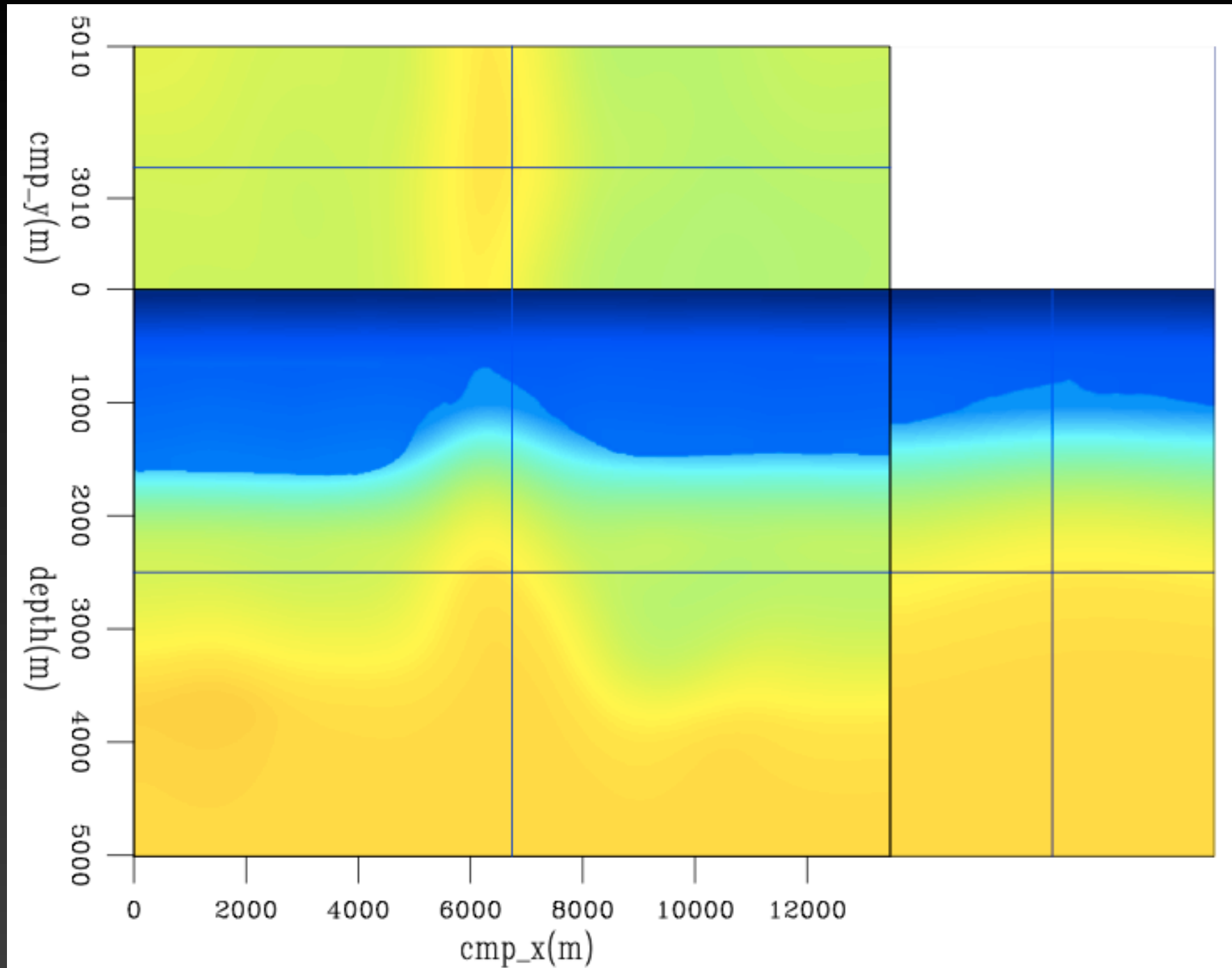
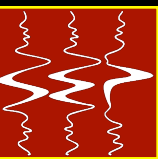
- **Marcas de aquisição**
- deteriora o gradiente

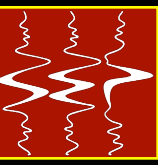


Velocidade original



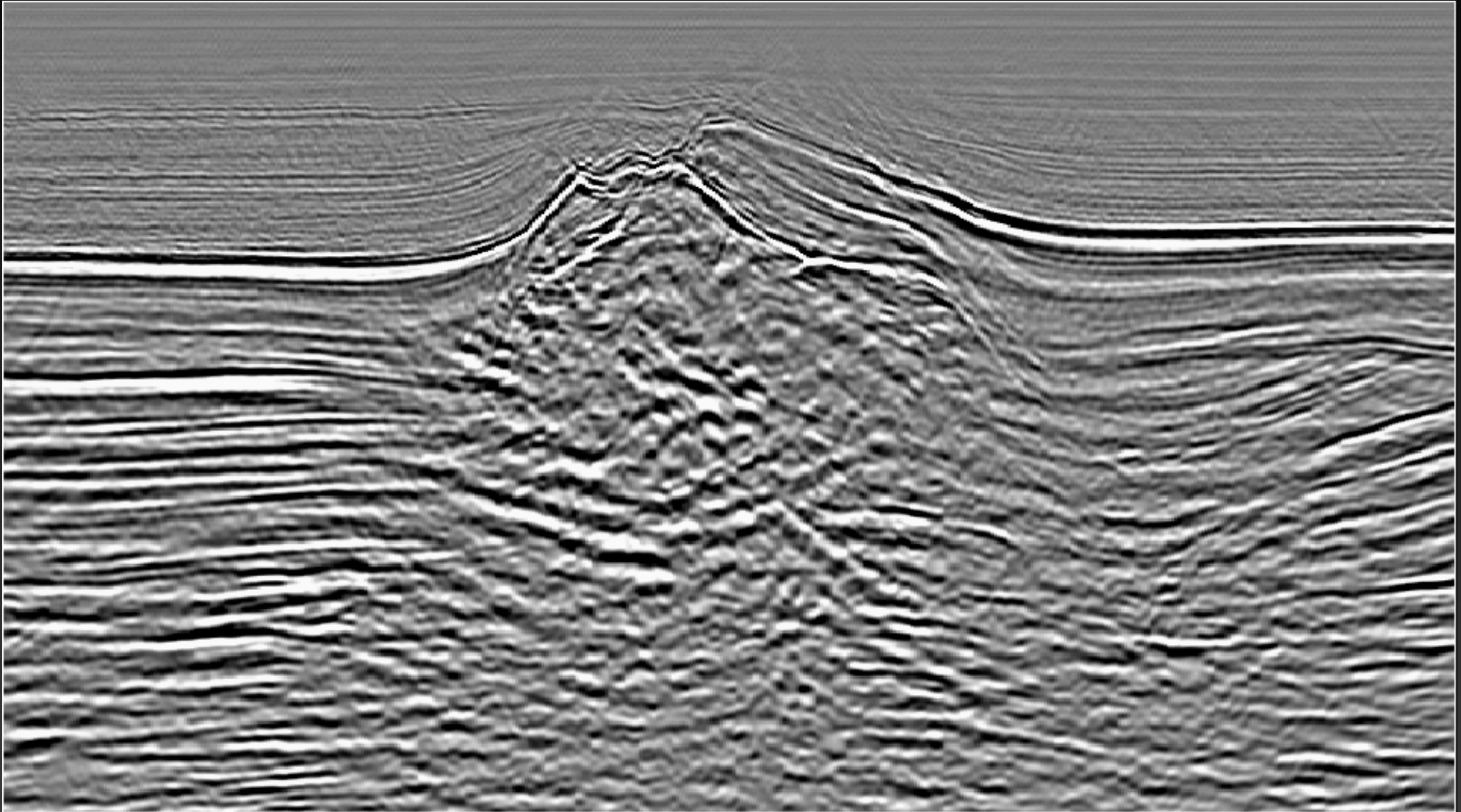
Velocidade inicial

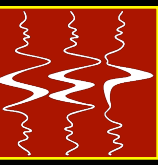




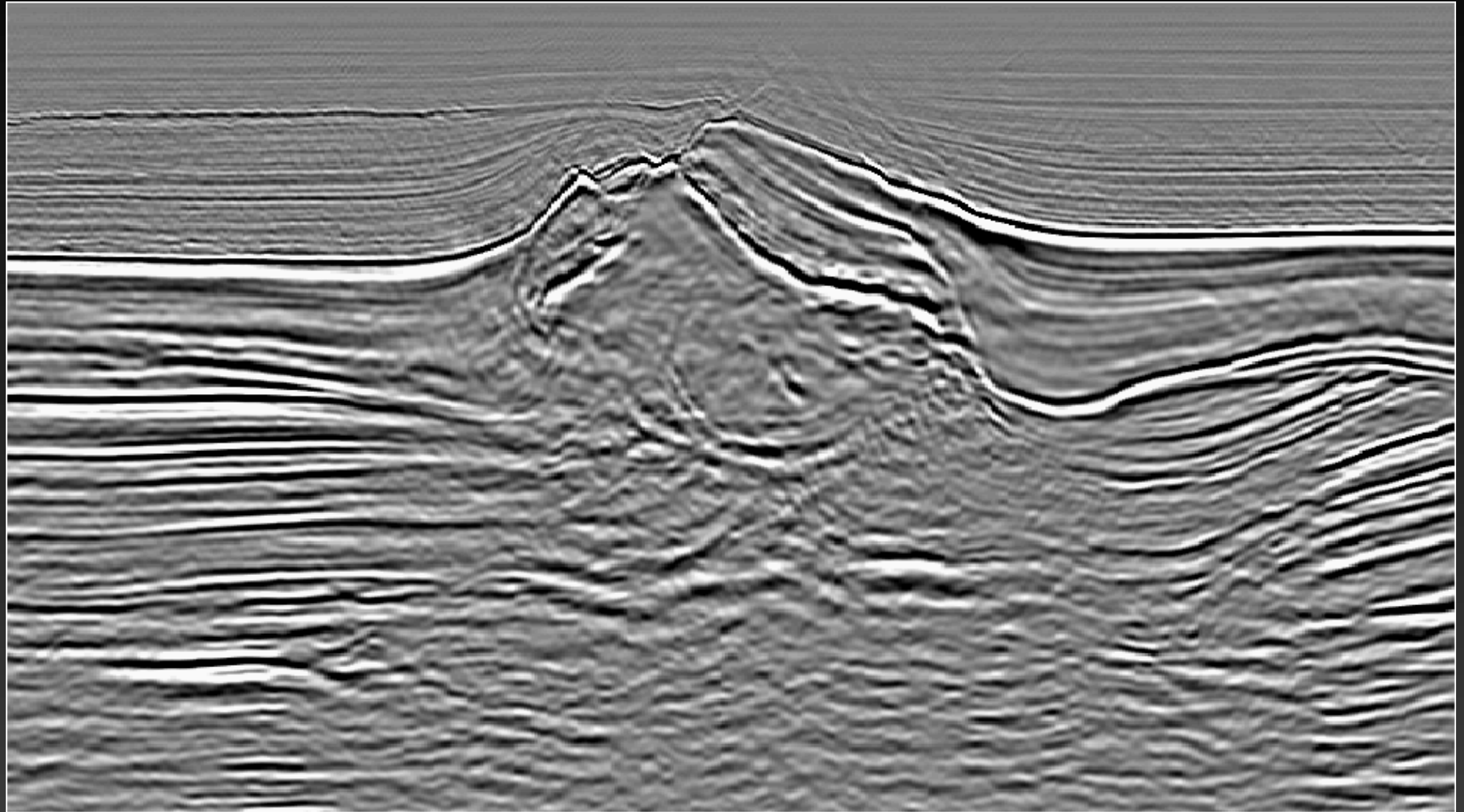
distance

depth





distance



depth

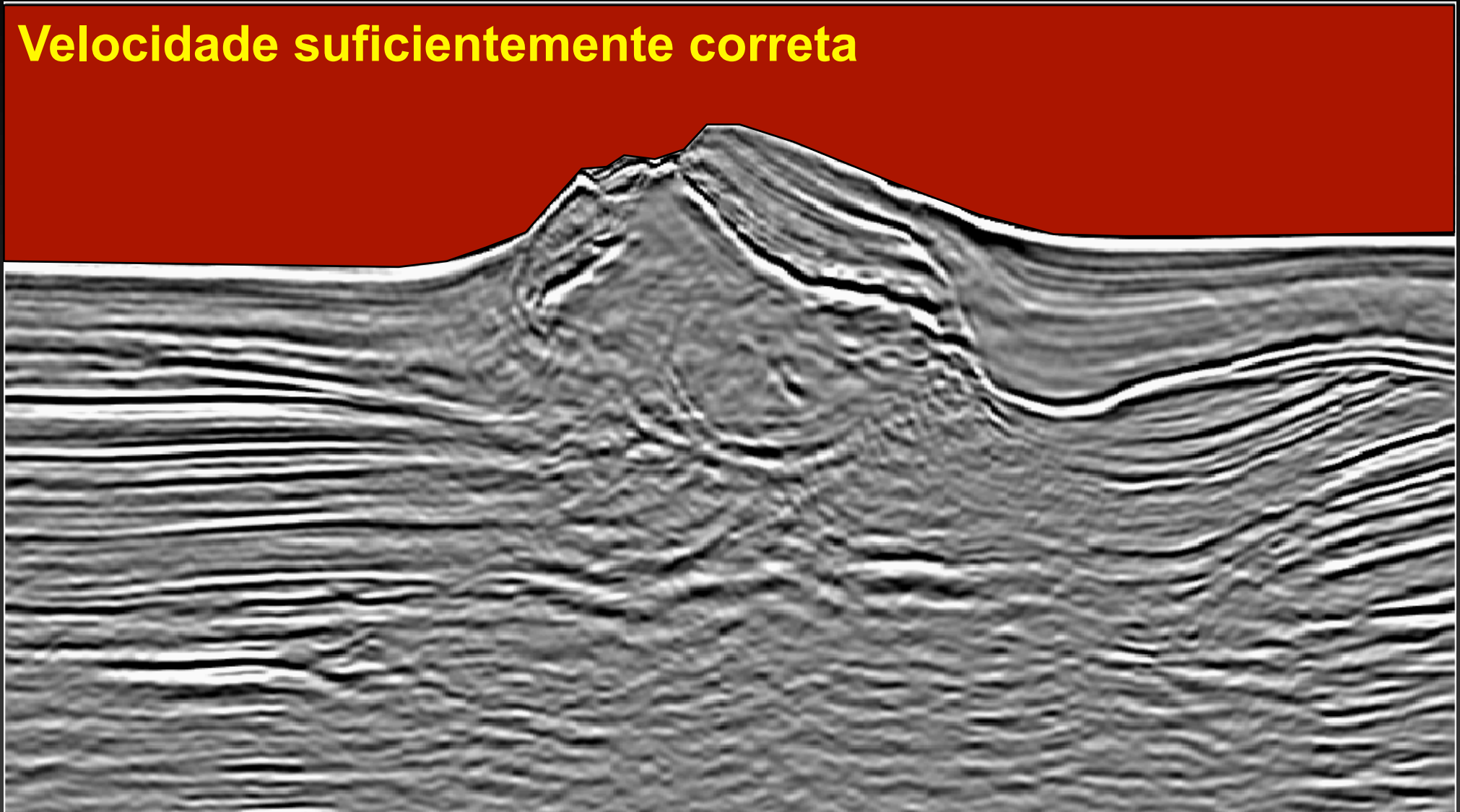
Estratégia para MVA



distance

Velocidade suficientemente correta

depth



Estratégia para MVA



distance

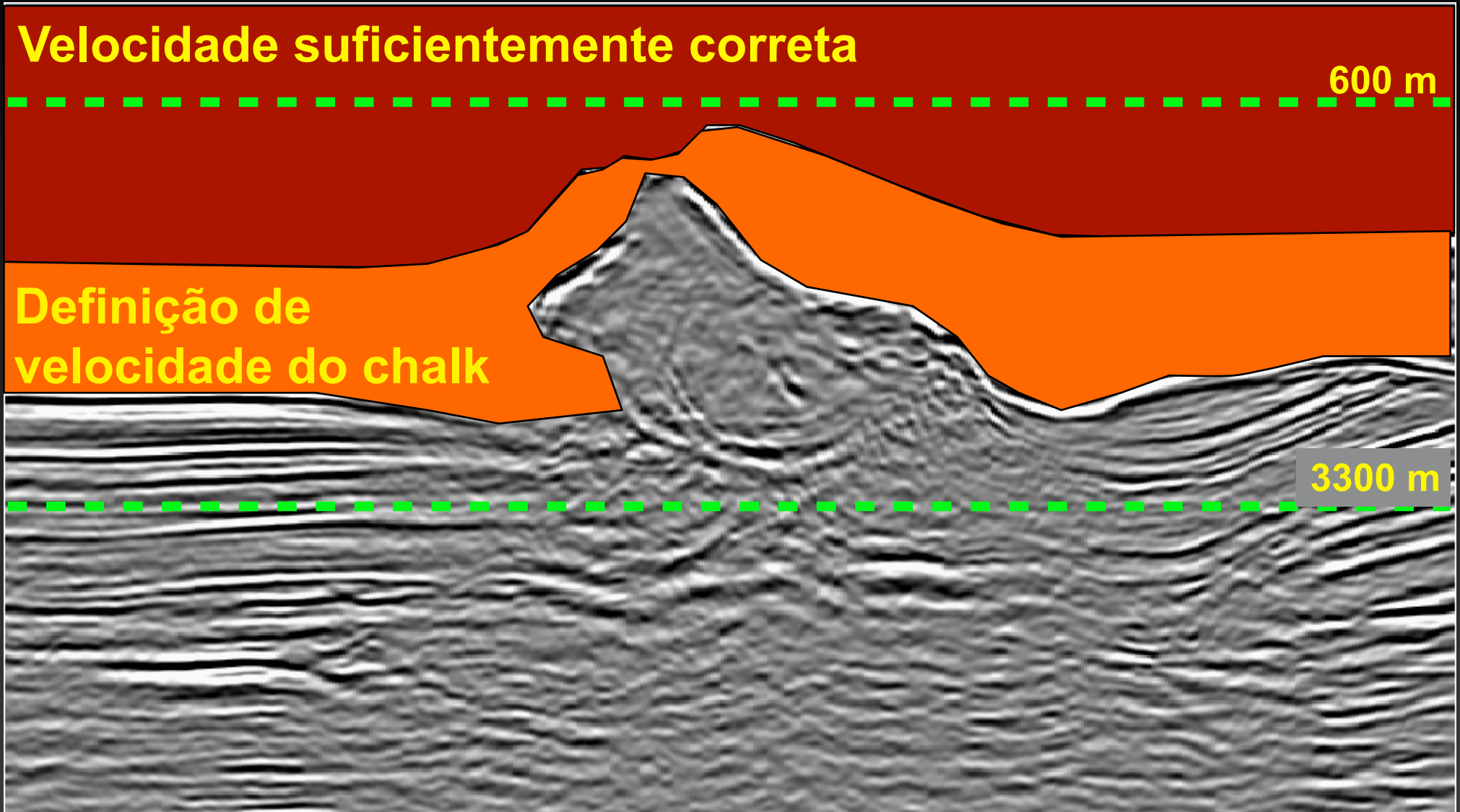
Velocidade suficientemente correta

600 m

Definição de
velocidade do chalk

3300 m

depth



Estratégia para MVA



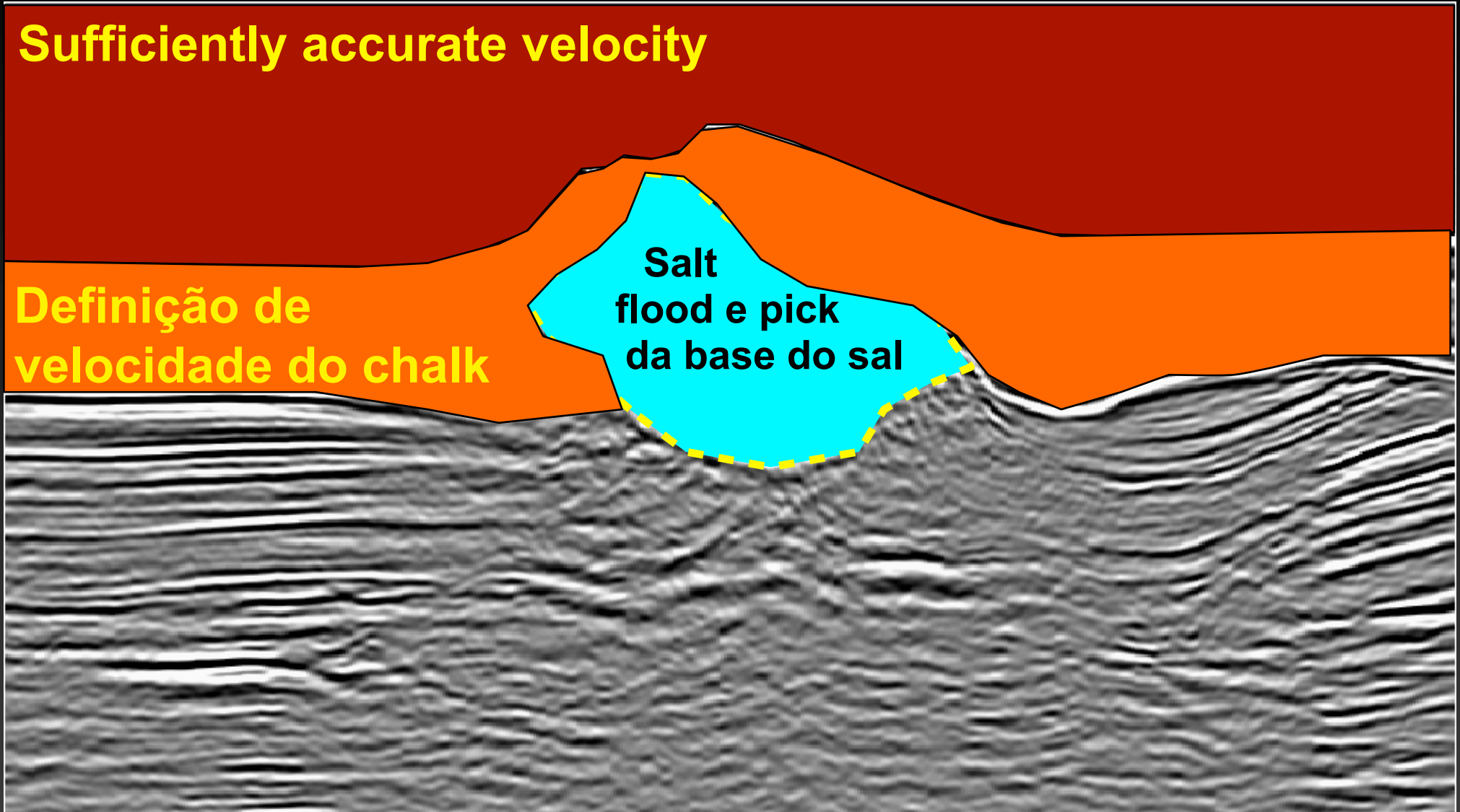
distance

Sufficiently accurate velocity

Definição de
velocidade do chalk

Salt
flood e pick
da base do sal

depth



Estratégia para MVA



distance

Sufficiently accurate velocity

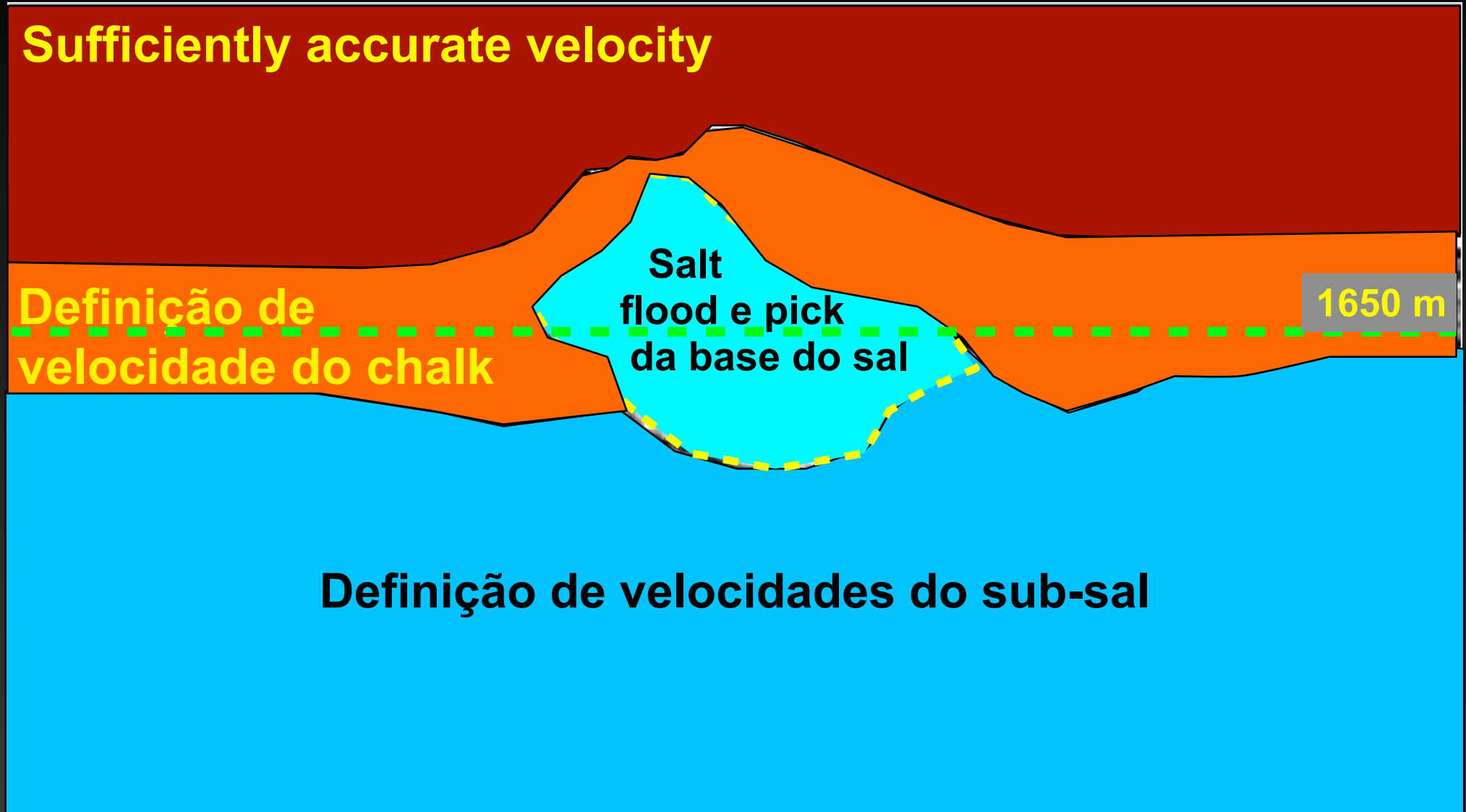
Definição de
velocidade do chalk

Salt
flood e pick
da base do sal

1650 m

Definição de velocidades do sub-sal

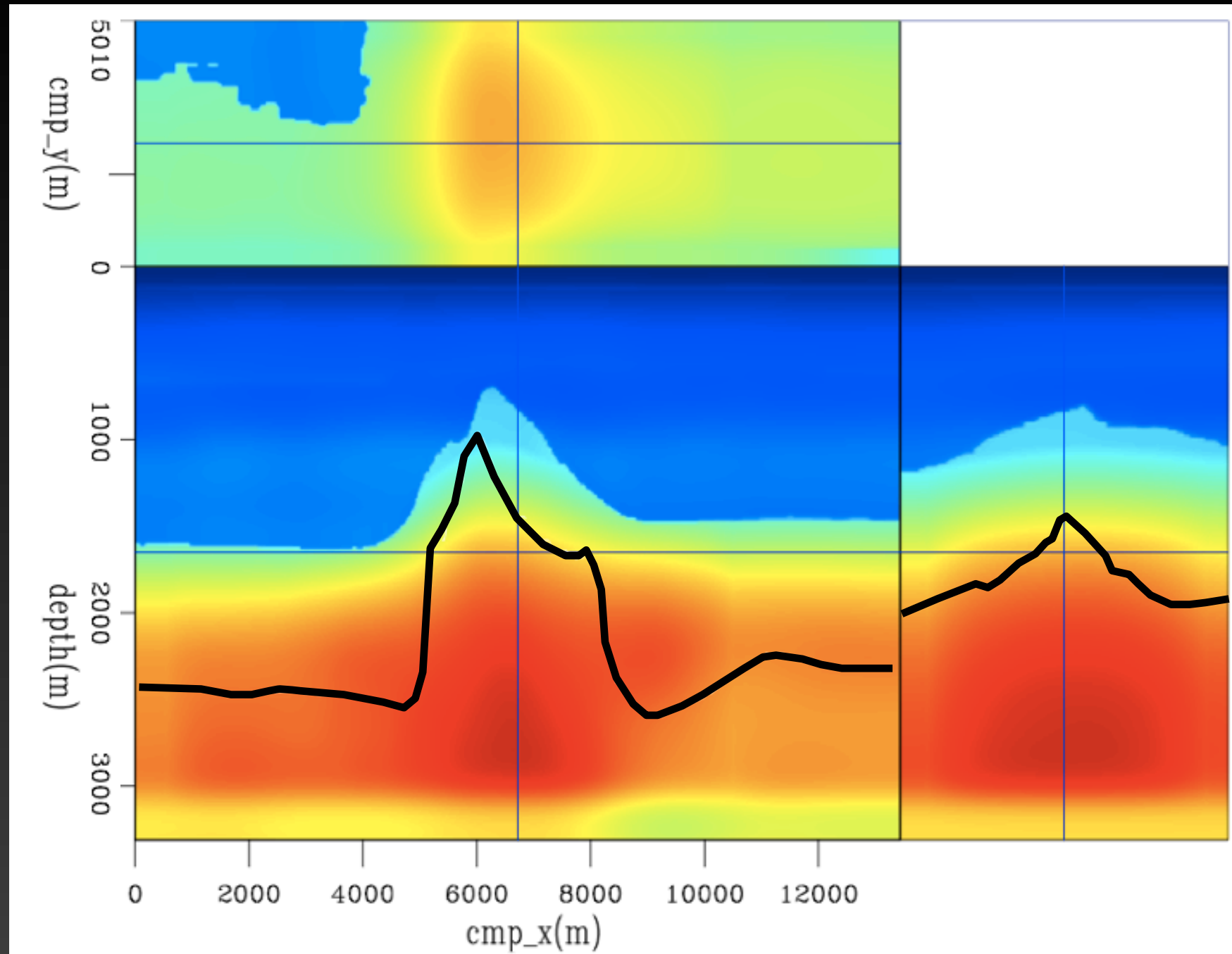
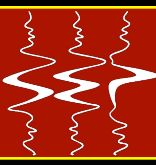
depth





- **Gradientes conjugados não linear**
- **máximo de 10% de variação velocidade entre iterações**
- **Duas avaliações de funcional por iteração**
- **CEES: 30 Dual Nehalem 5520, 24Gb RAM**
 - **Funcional: 20 min**
 - **Gradiente: 40 min**

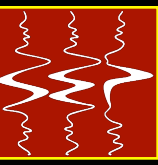
Velocidade otimizada do chalk



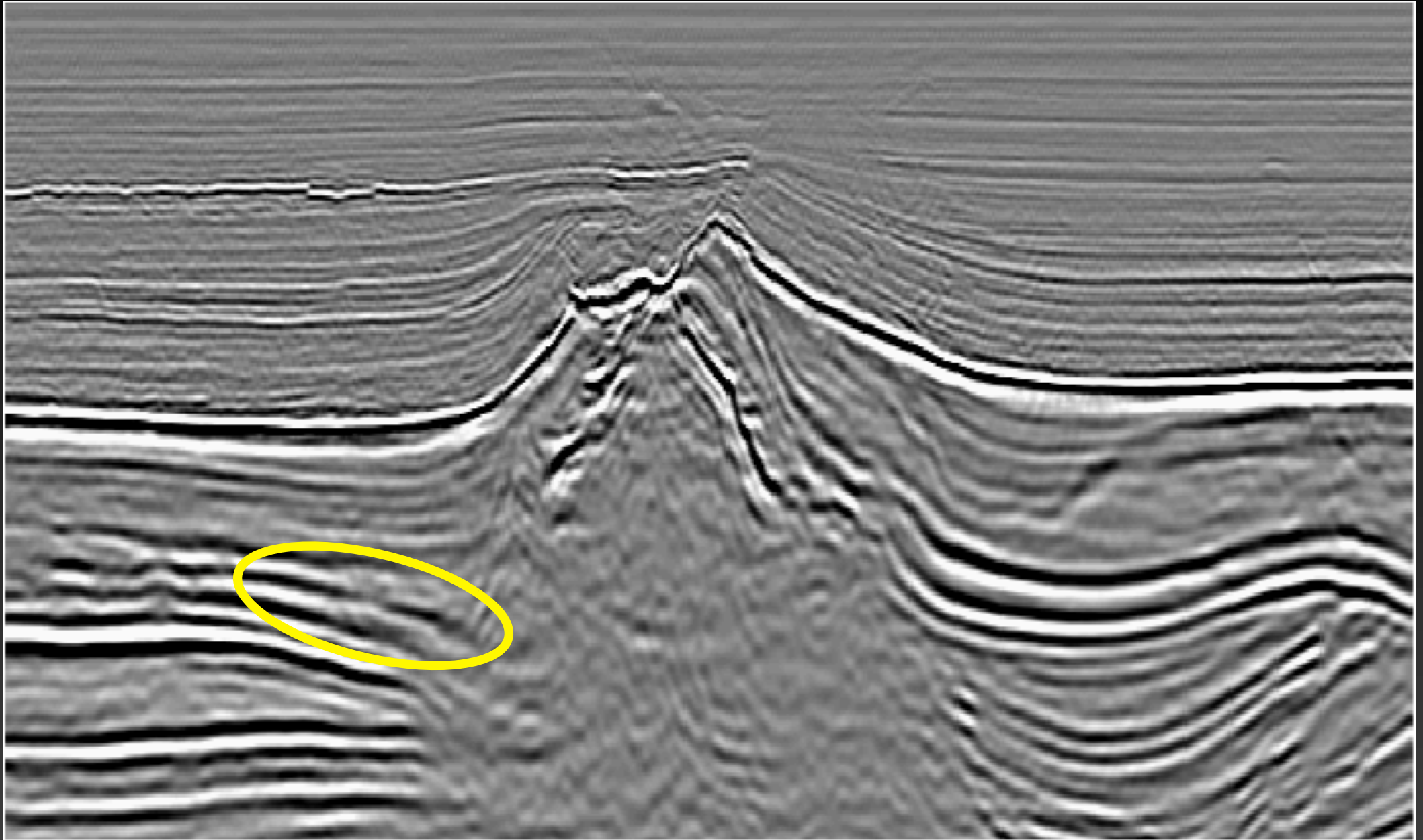


- **Duas corridas de otimização**
 - ✓ para toda camada de chalk
 - ✓ somente para a região do flanco do sal
- **3D-ISPEW modelados para o flanco do sal**

ISWET focado no alvo



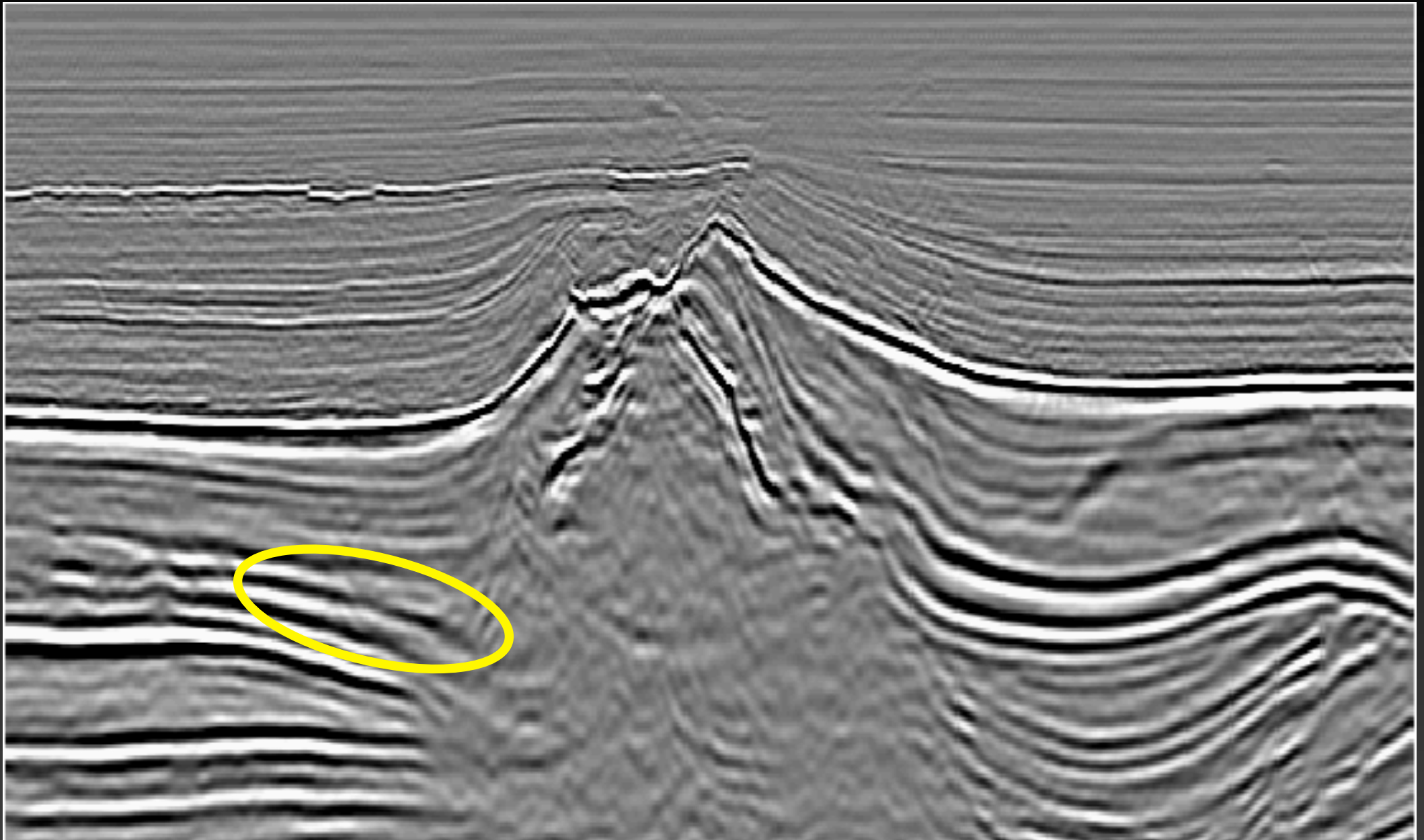
Antes



ISWET focado no alvo



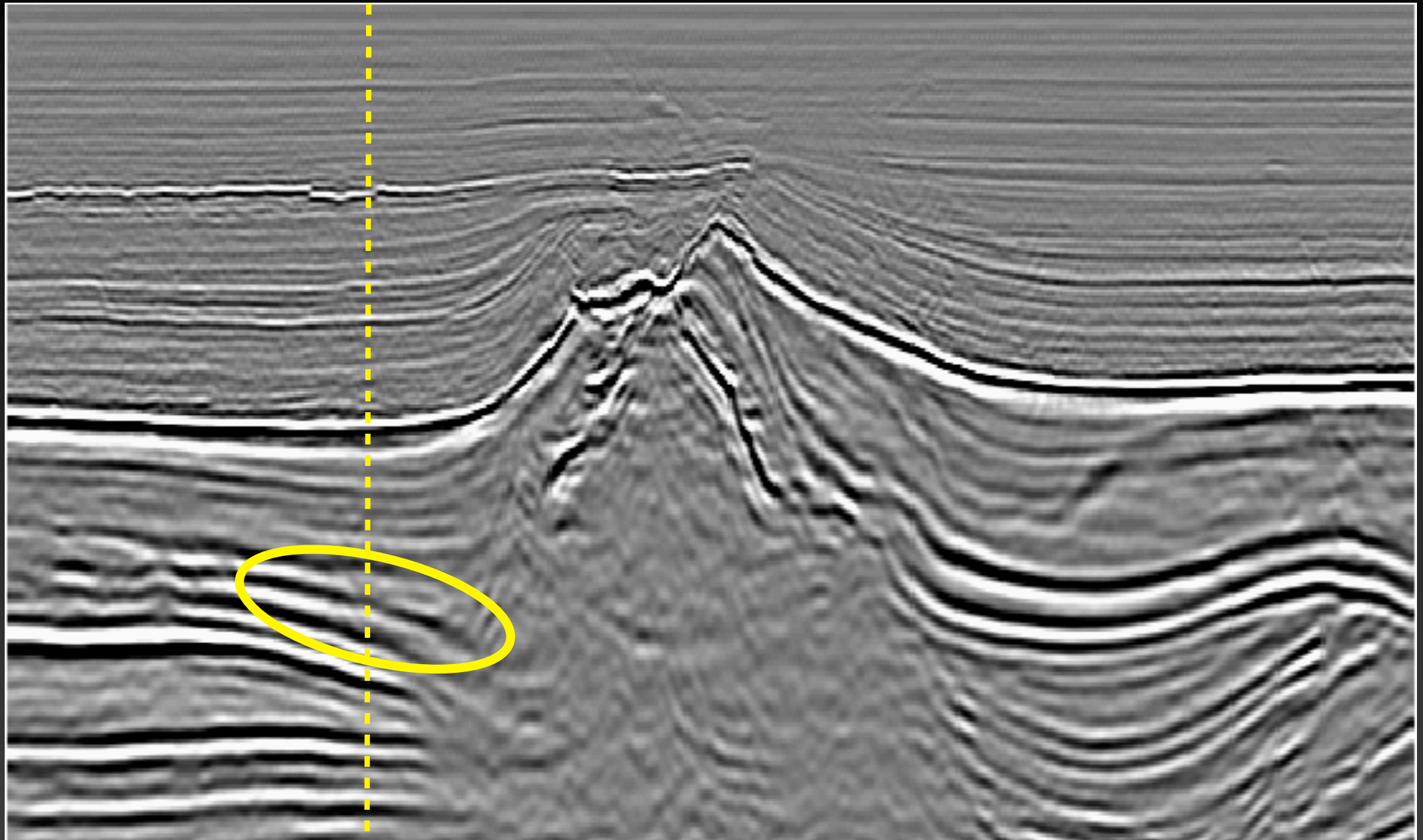
Depois



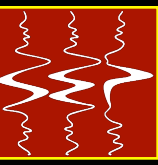
ISWET focado no alvo



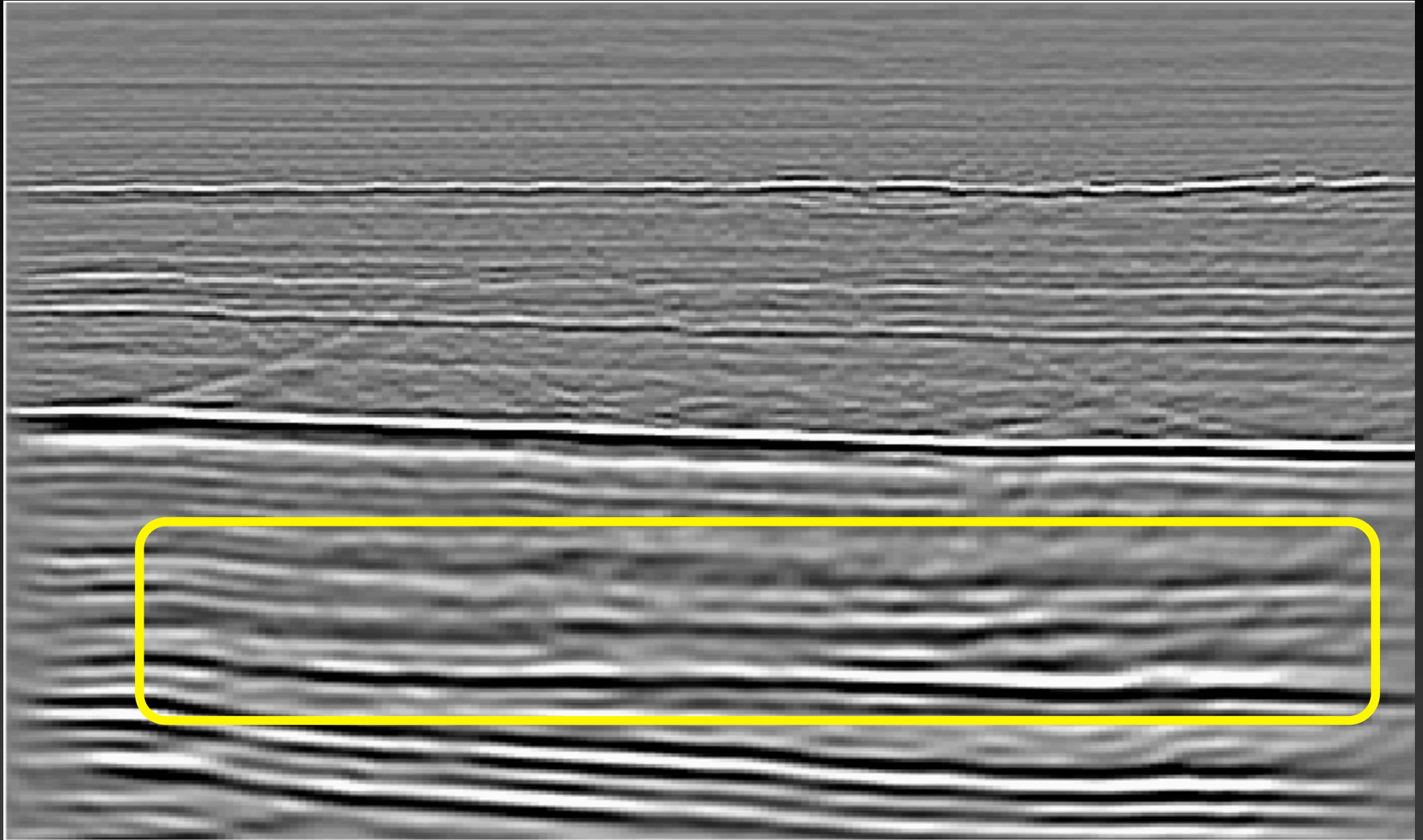
Depois



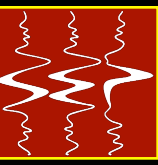
ISWET focado no alvo



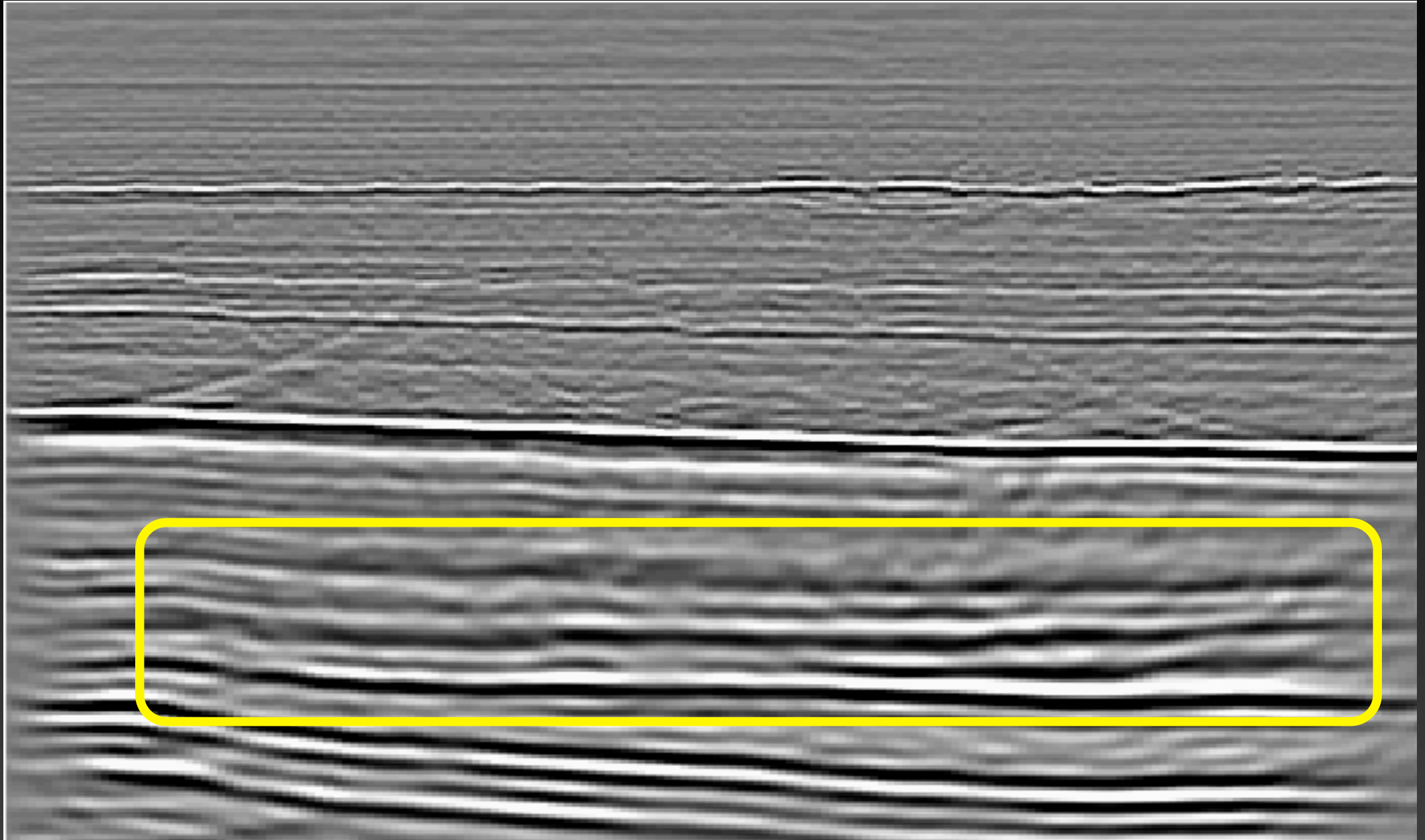
Antes



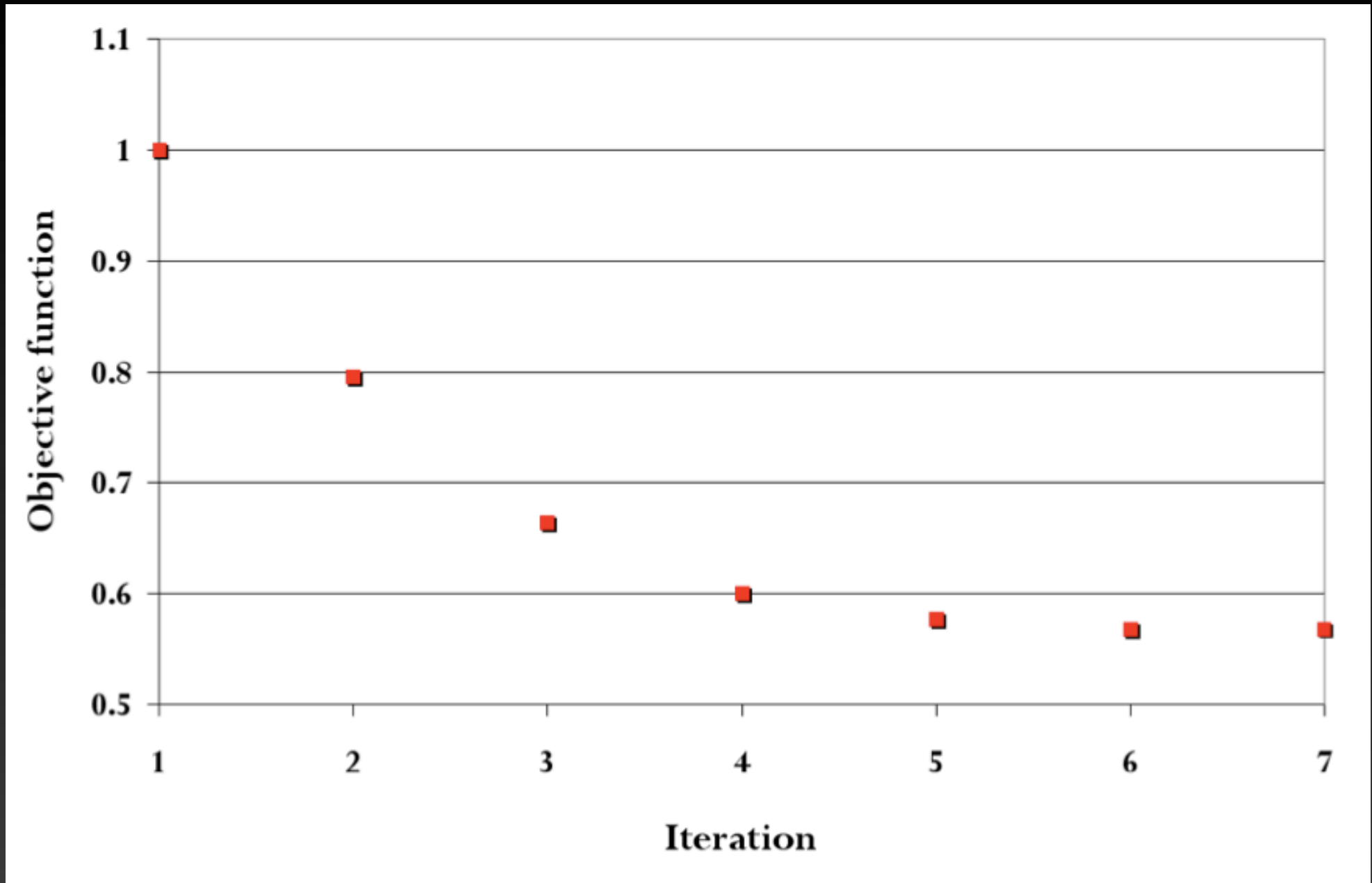
ISWET focado no alvo



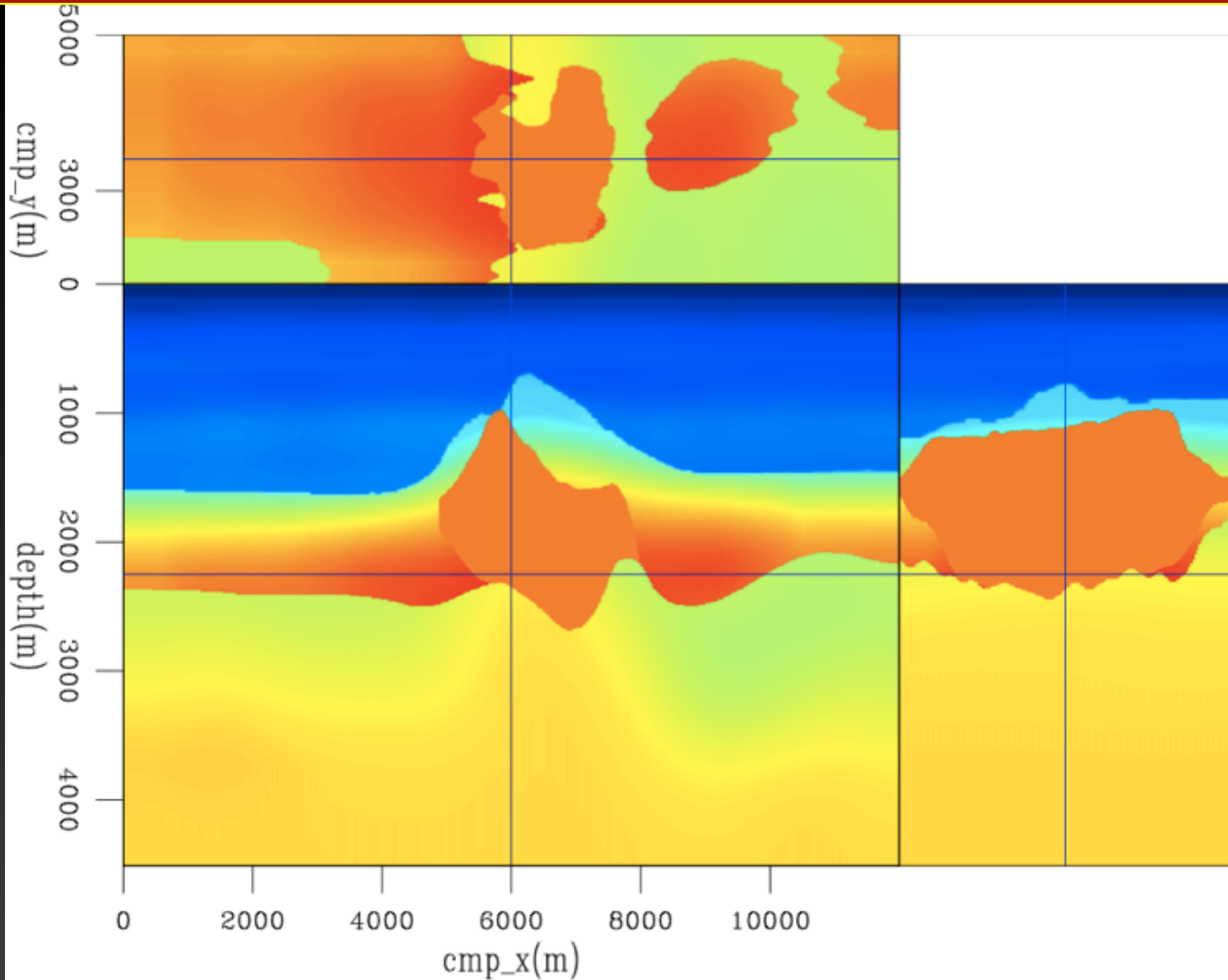
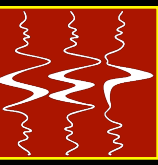
Depois



Funcional



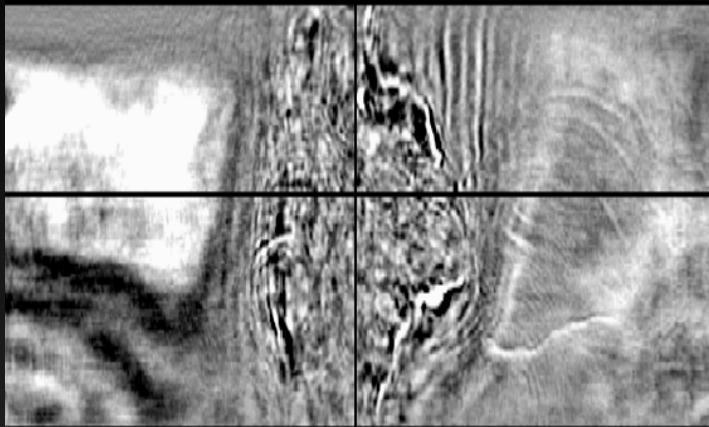
Velocidade depois de interpretar o sal



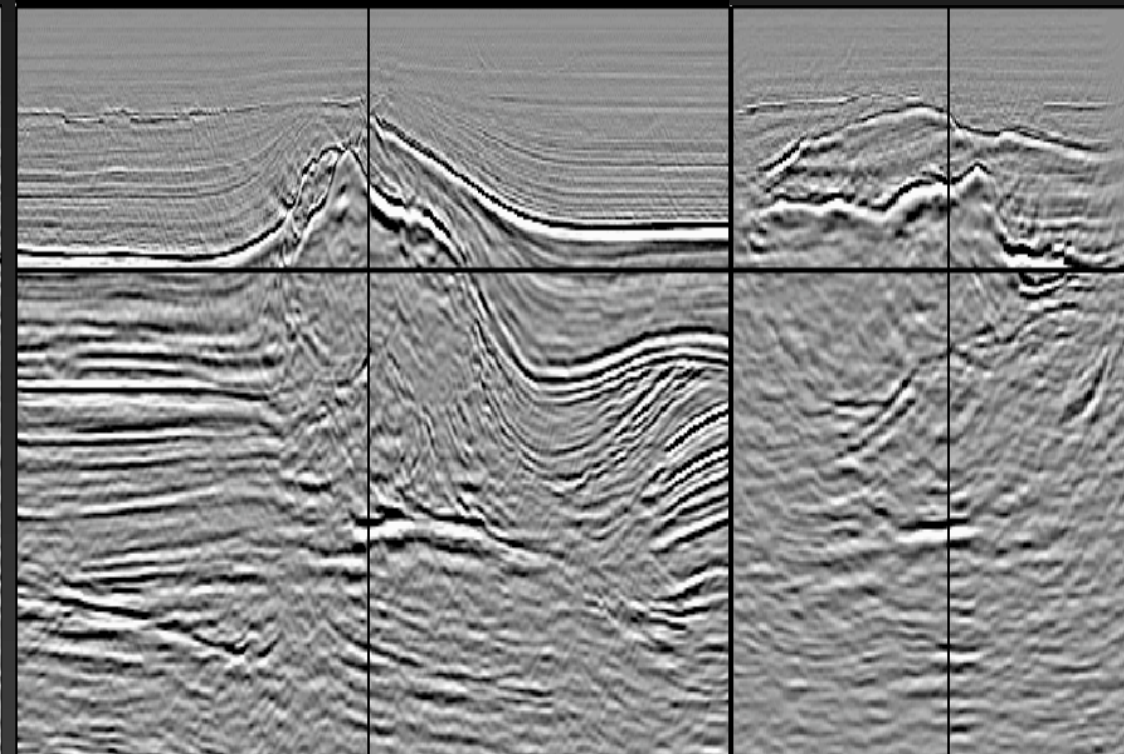
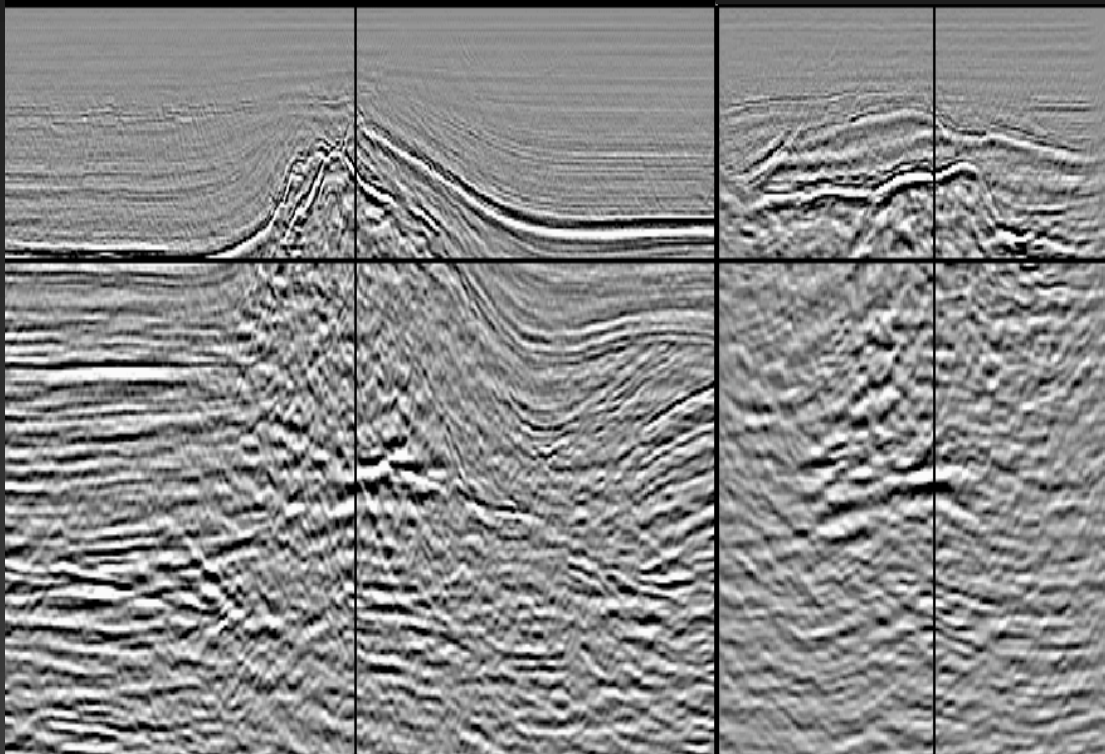
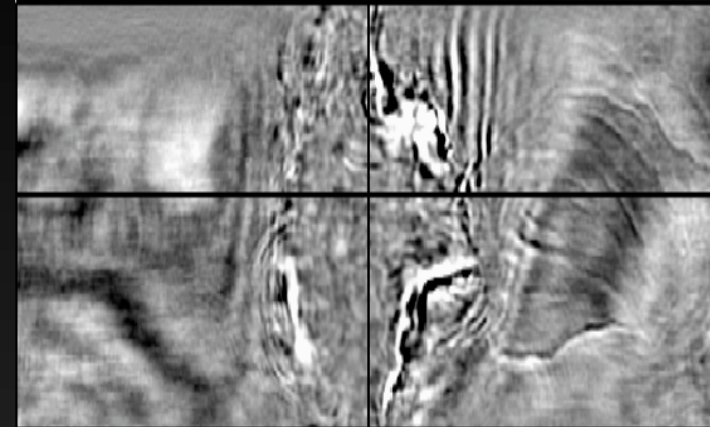
Melhor base do sal e foco



Initial



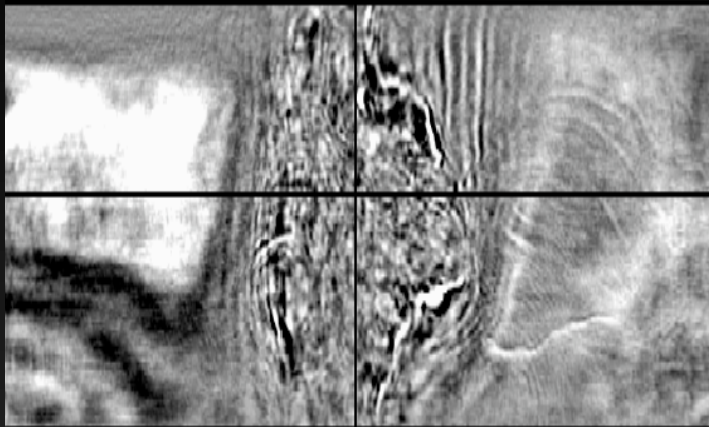
After salt body



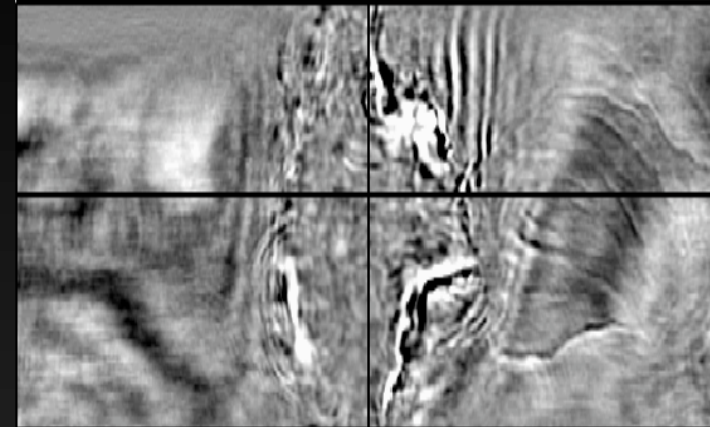
Melhor base do sal e foco



Initial



After salt body

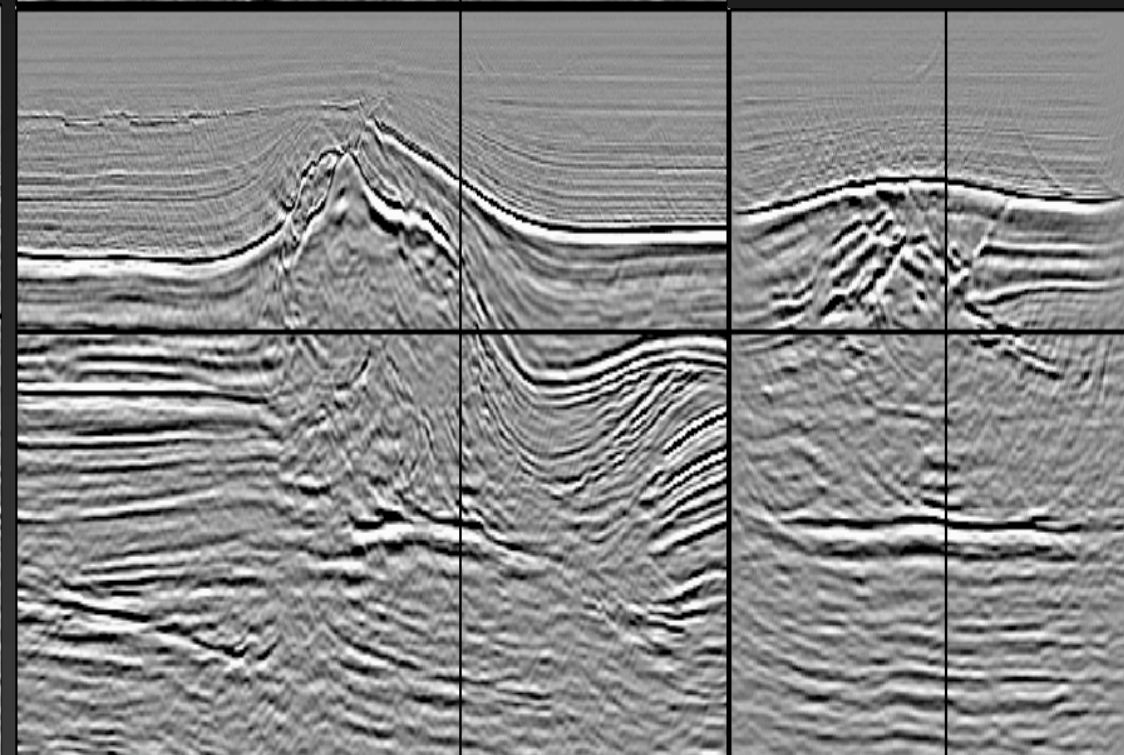
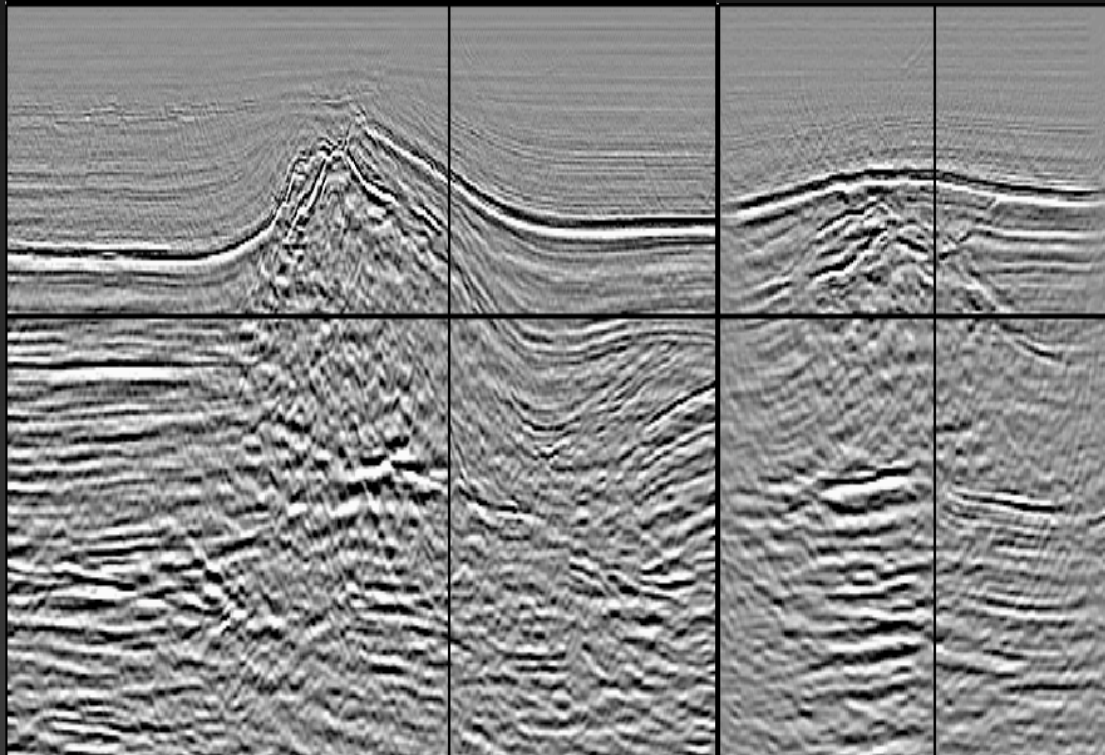
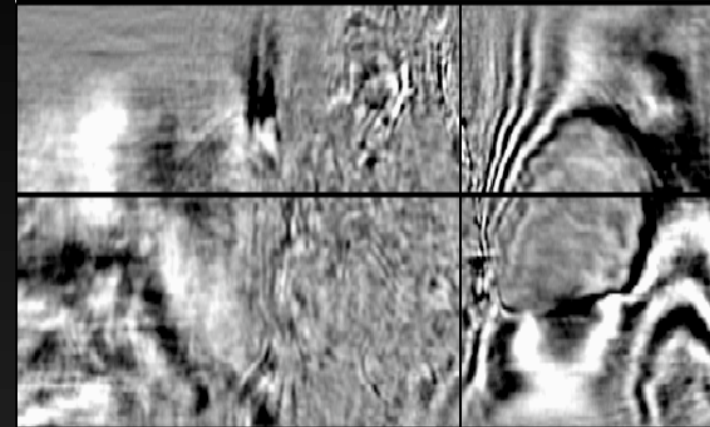
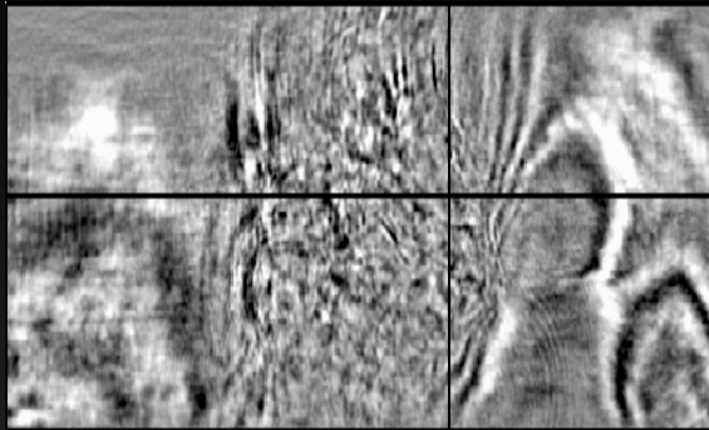


Refletores mais contínuos e falhas

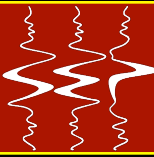


Initial

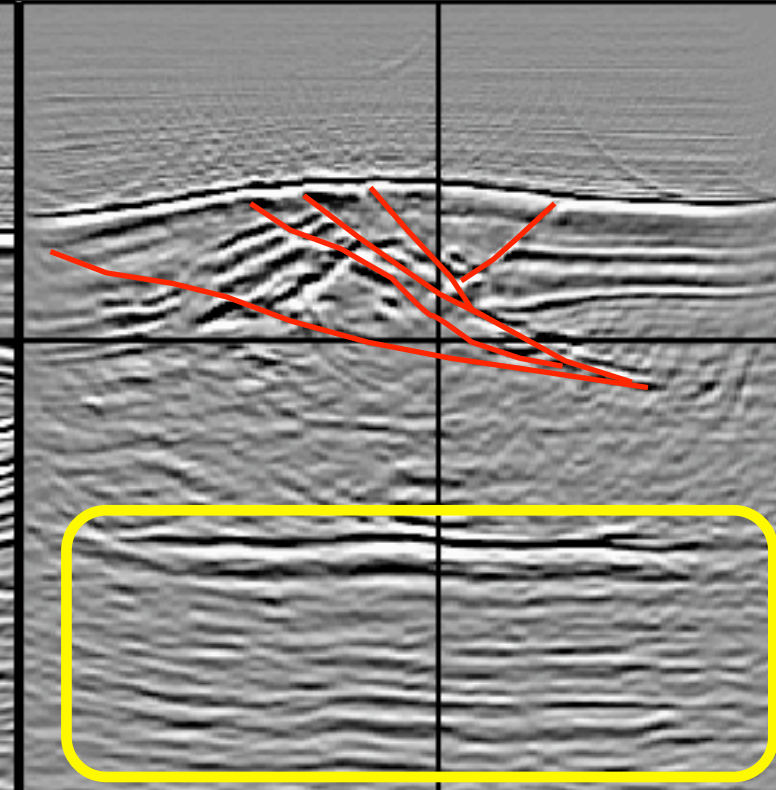
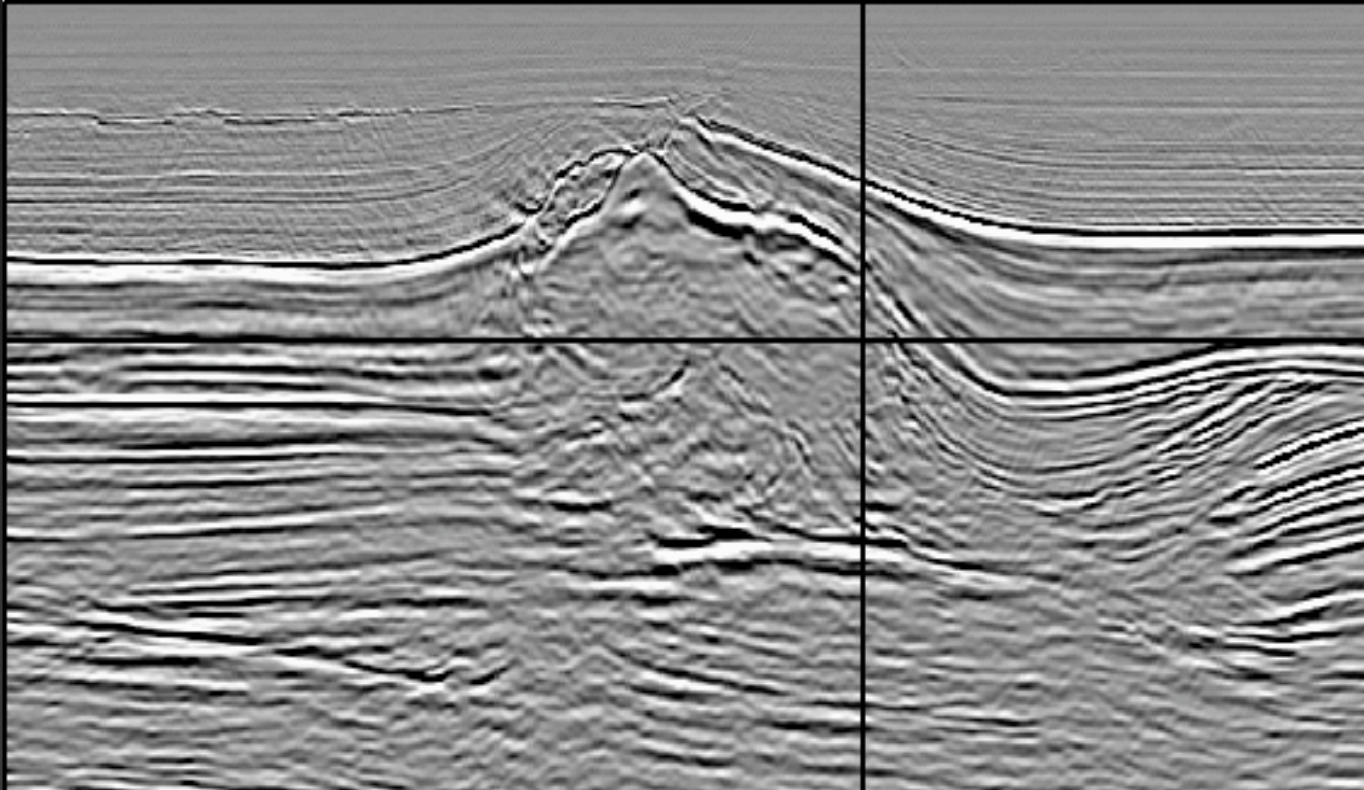
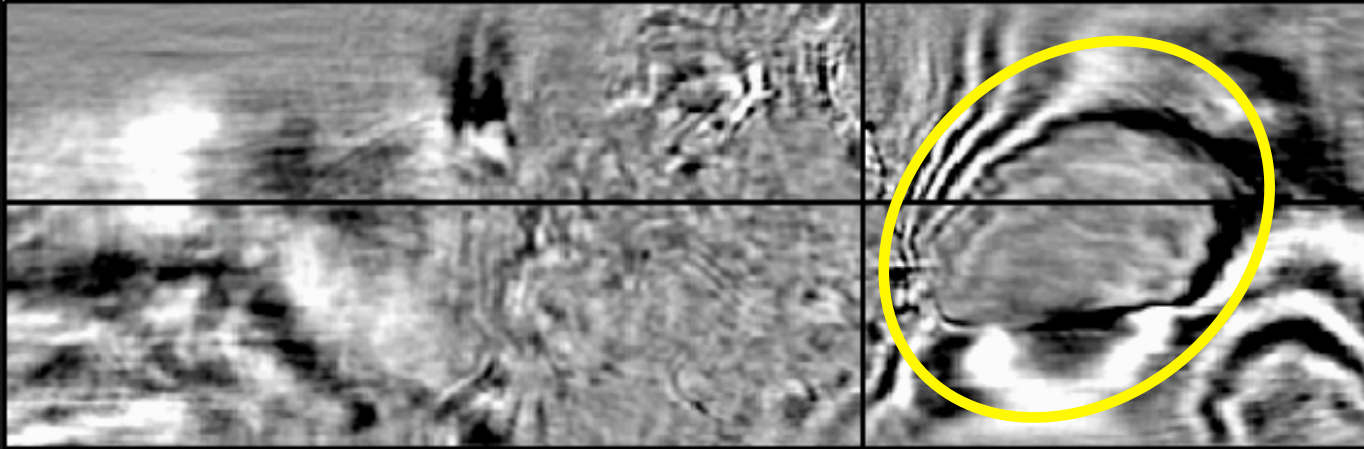
After salt body



Refletores mais contínuos e falhas



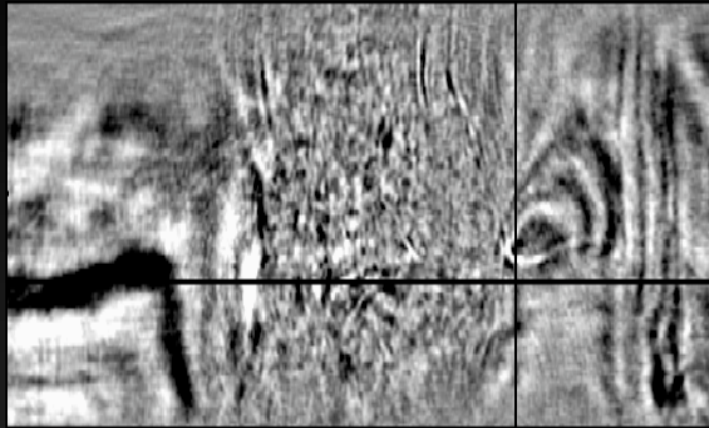
After salt body



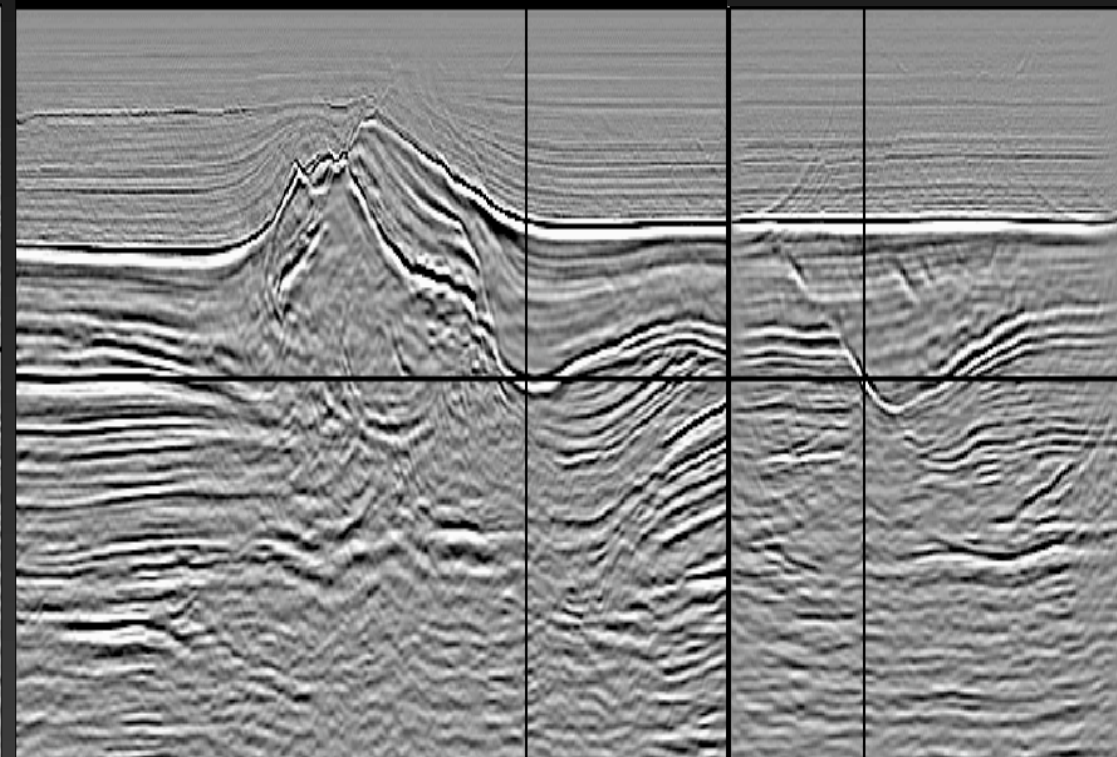
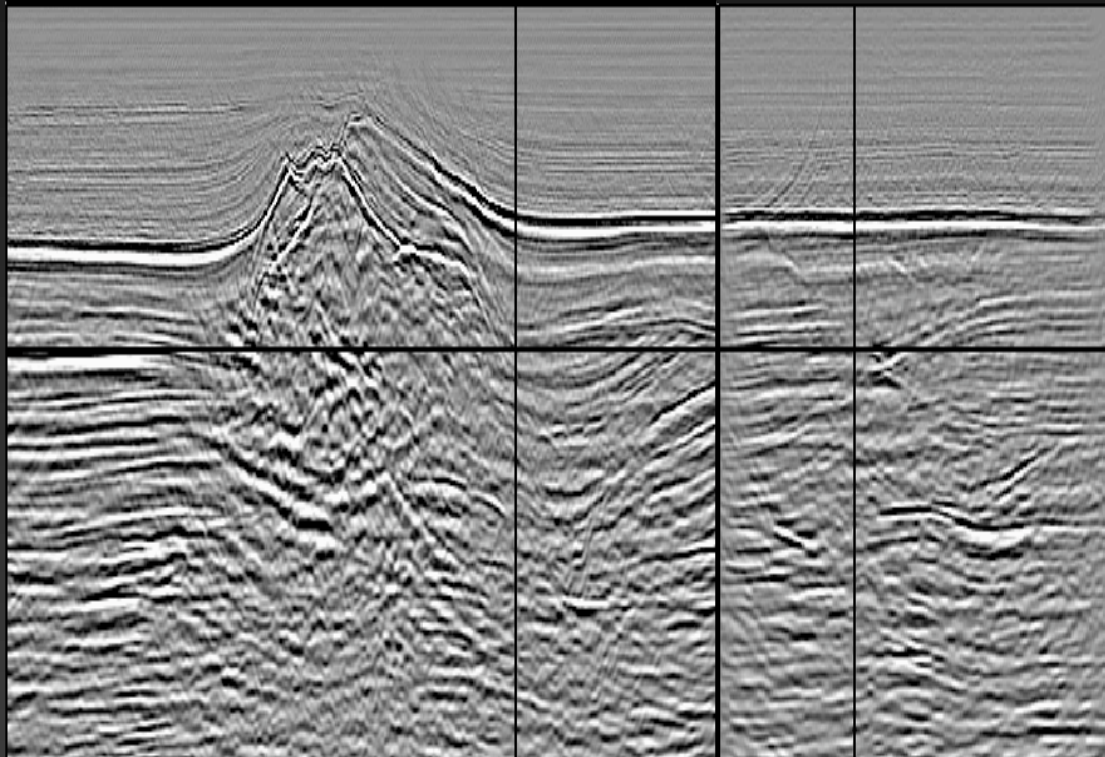
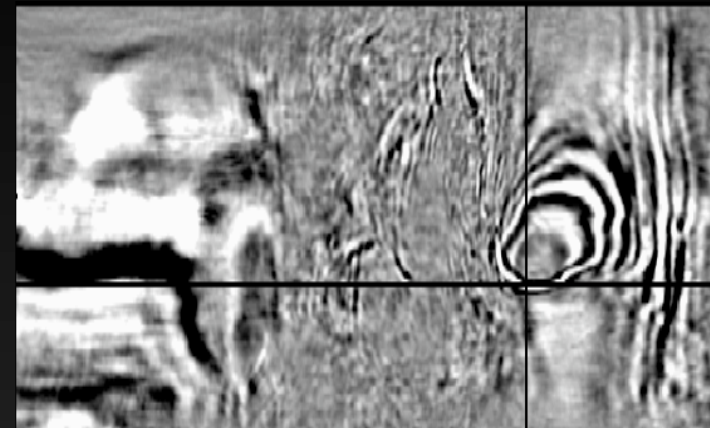
Melhores falhas e foco



Initial



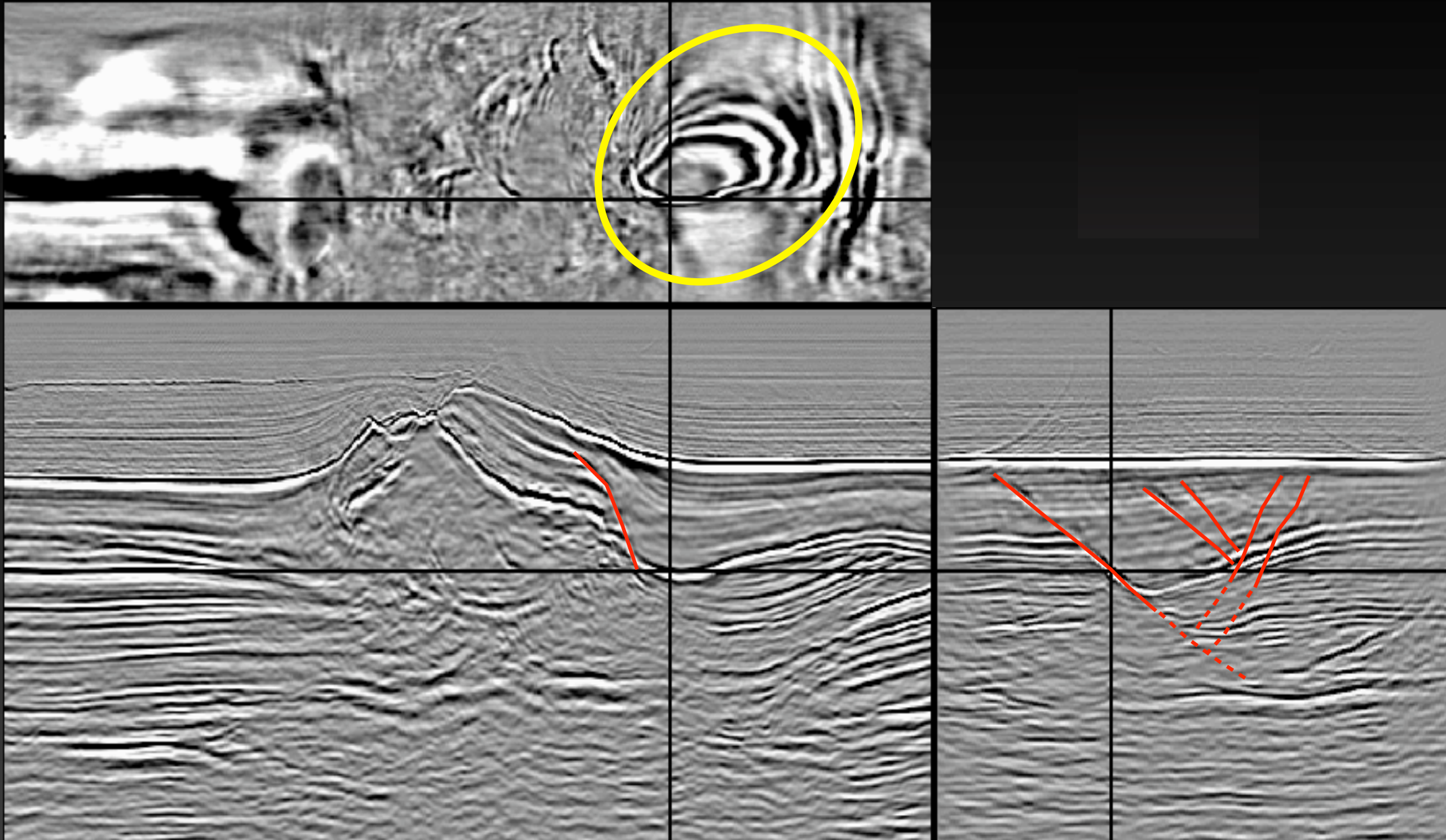
After salt body



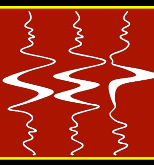
Melhores falhas e foco



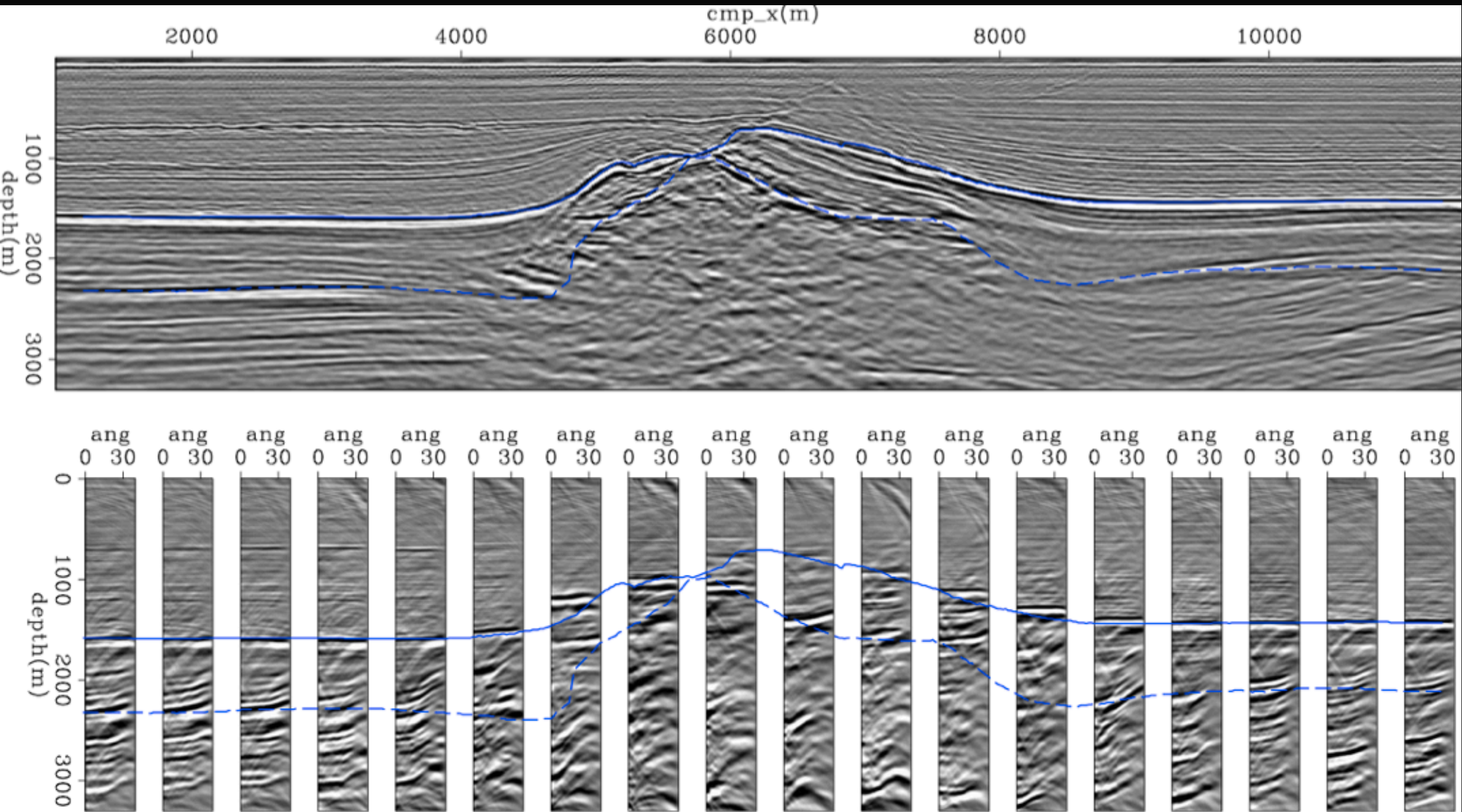
After salt body



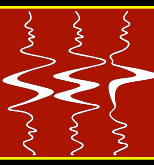
iline = 3200 m



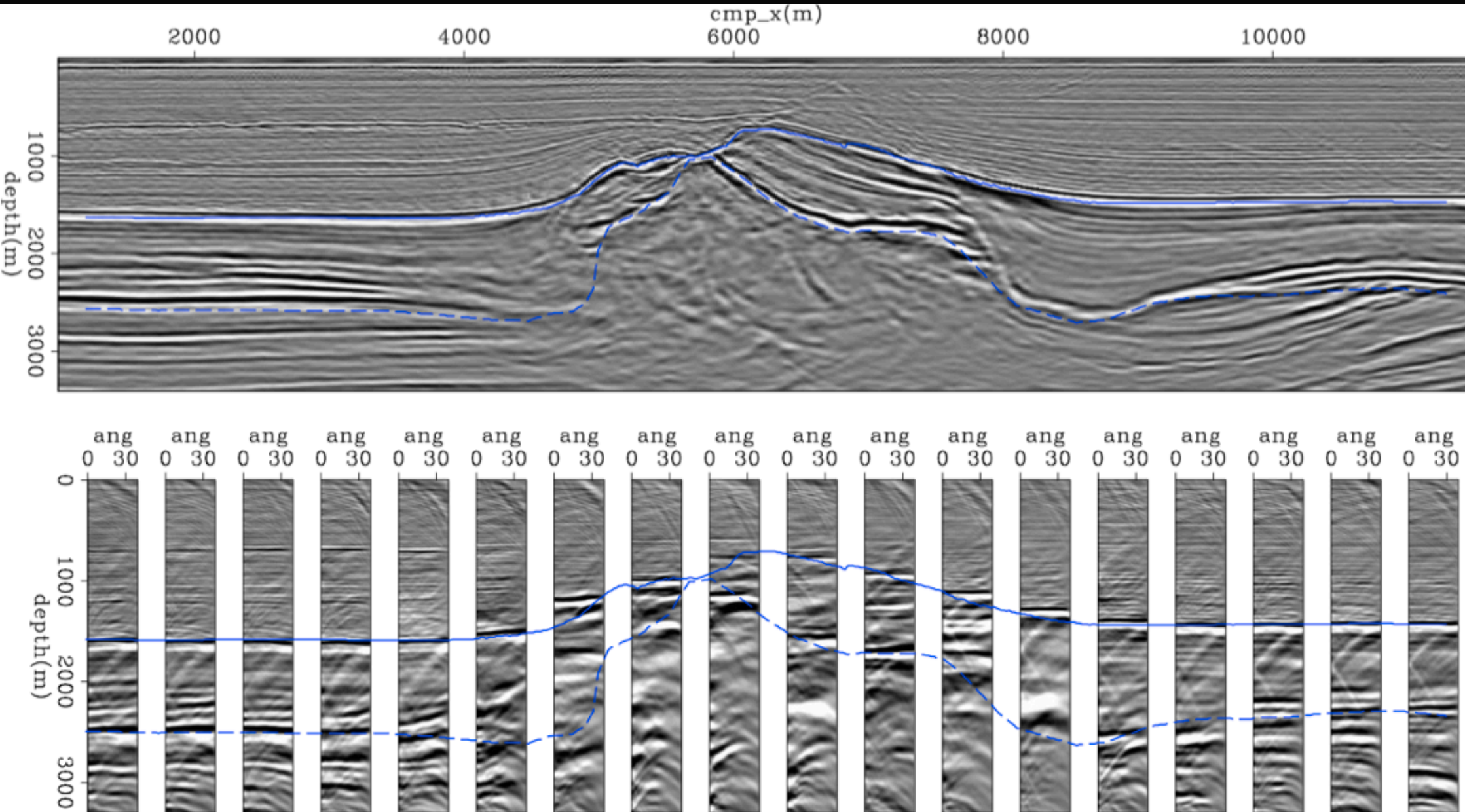
Initial



Refletores planos no CRP



Chalk optimized velocity

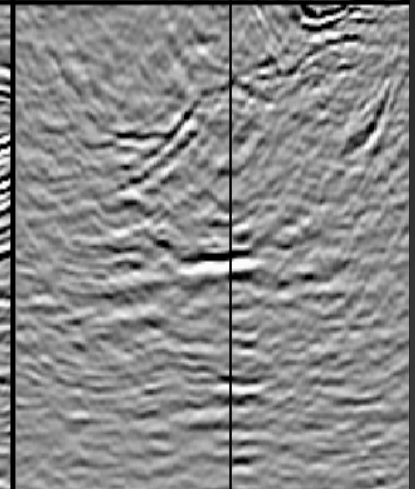
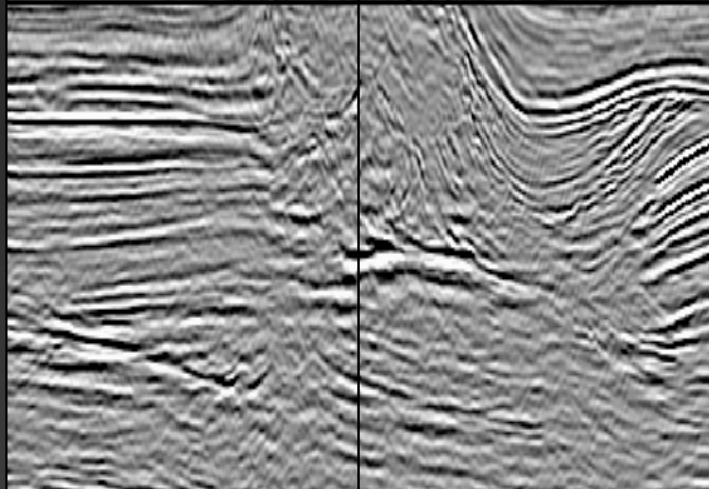
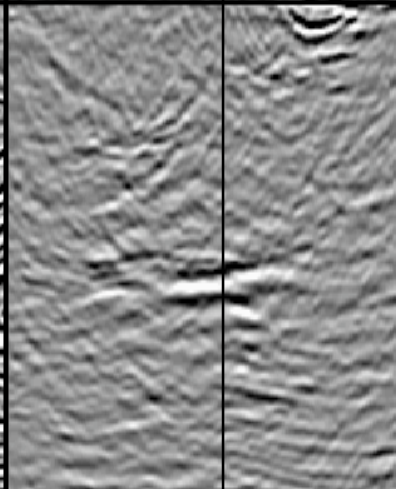
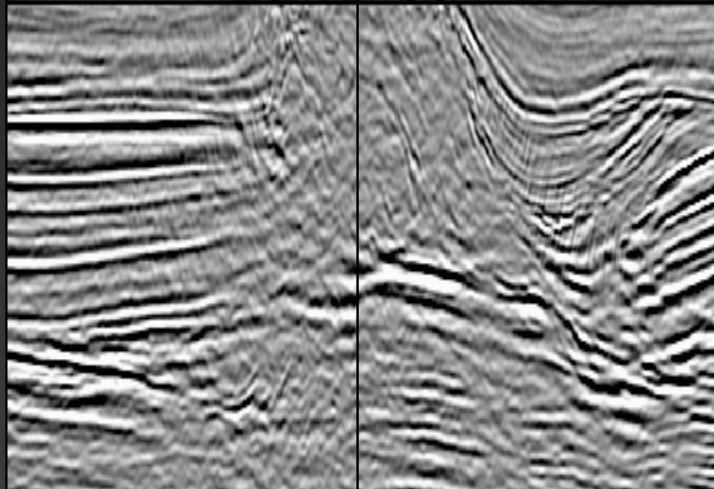
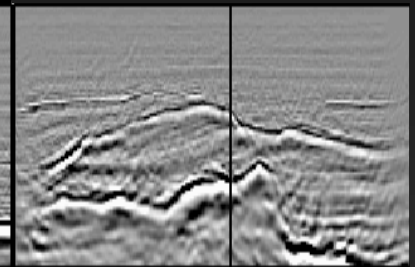
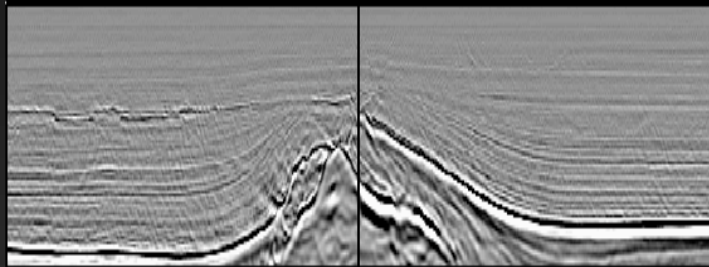
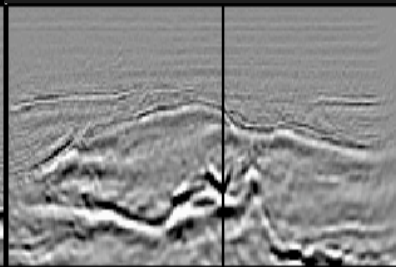
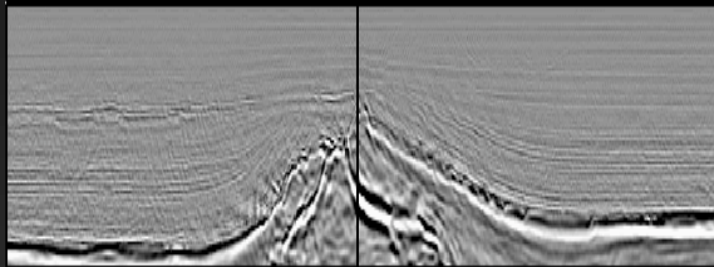
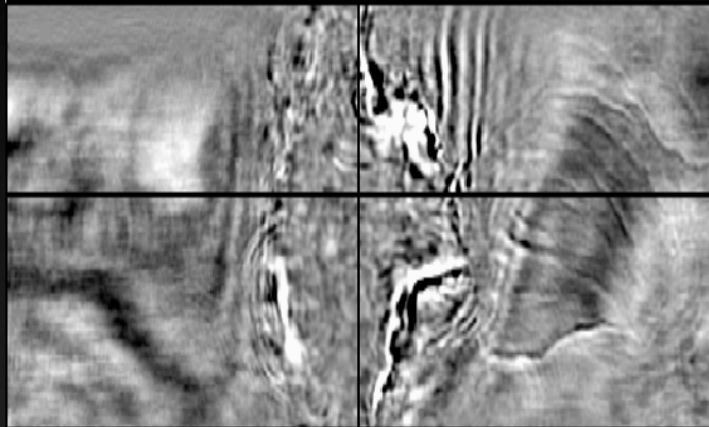
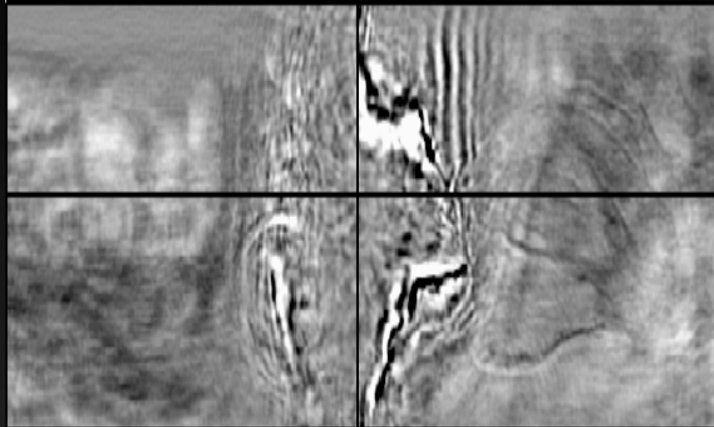


Melhor base do sal e foco

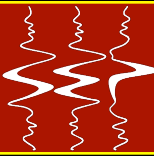


Original

After salt body

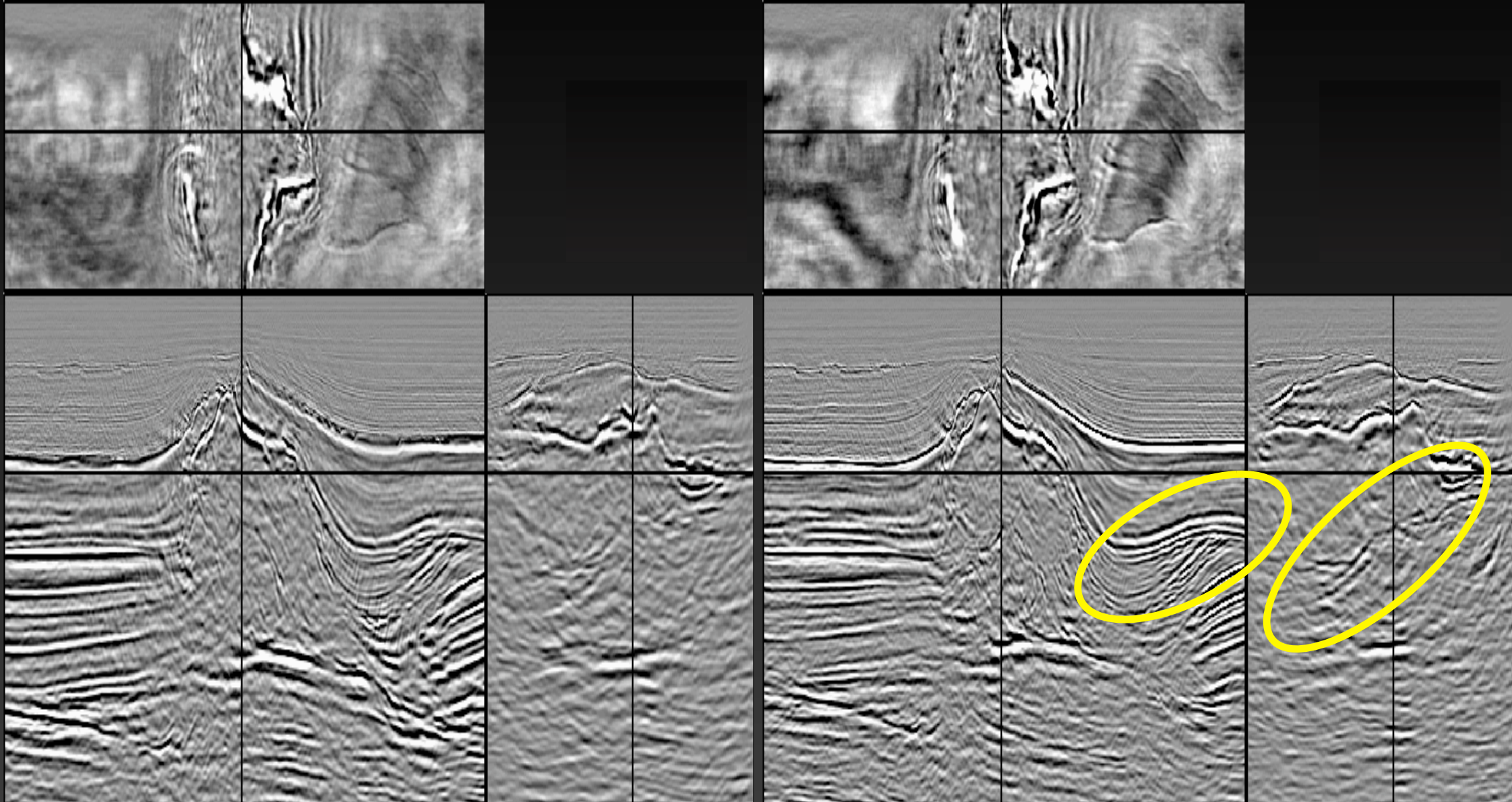


Melhor base do sal e foco



Original

After salt body

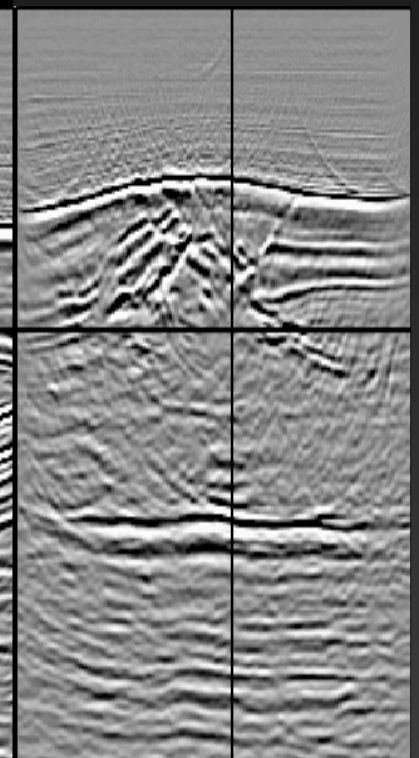
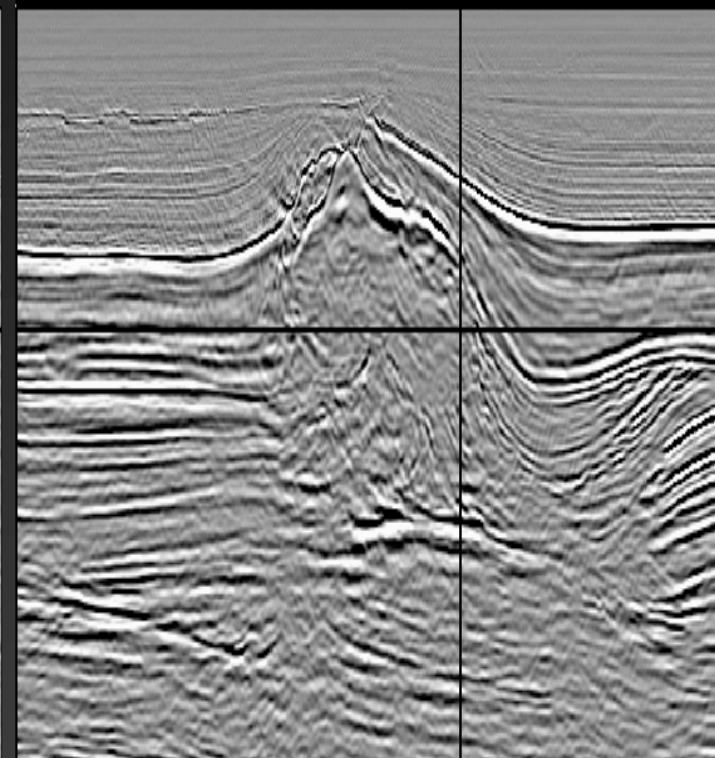
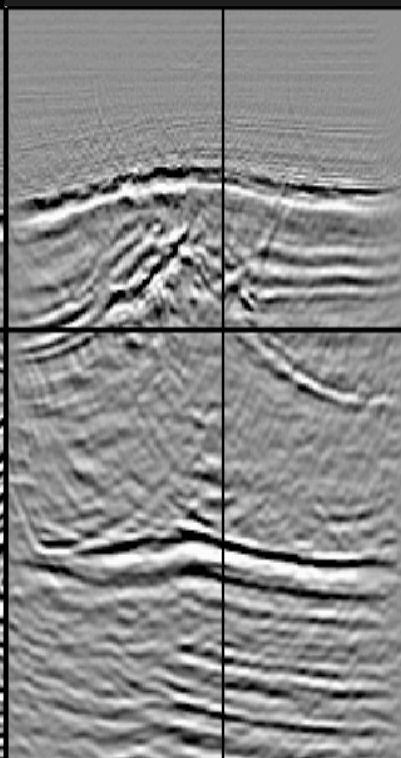
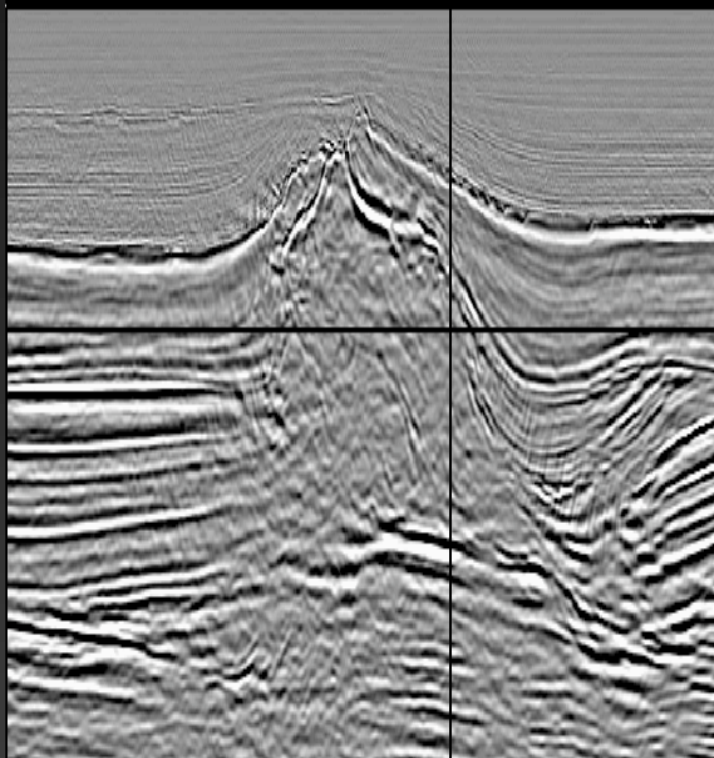
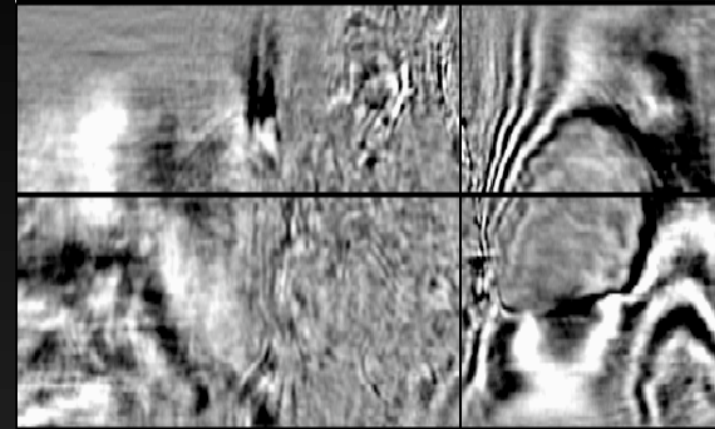
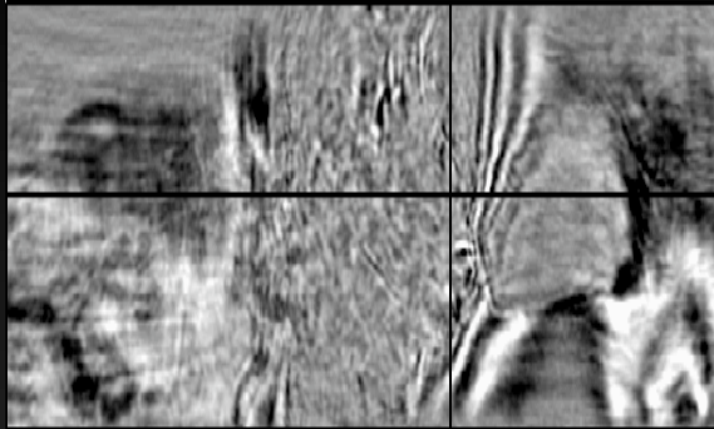


Melhores refletores sub-sal e falhas

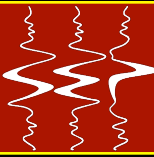


Original

After salt body

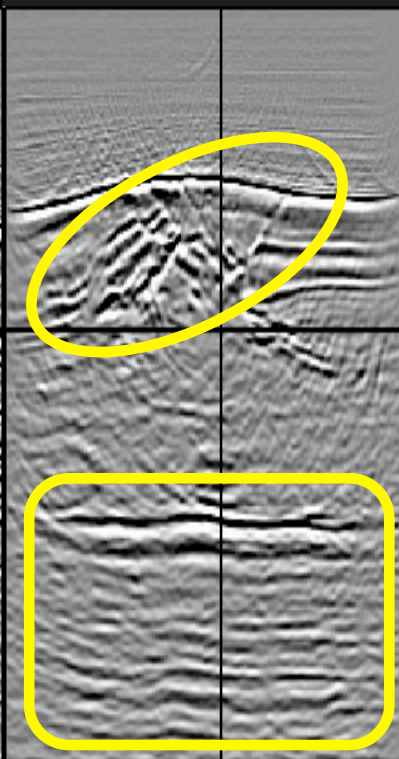
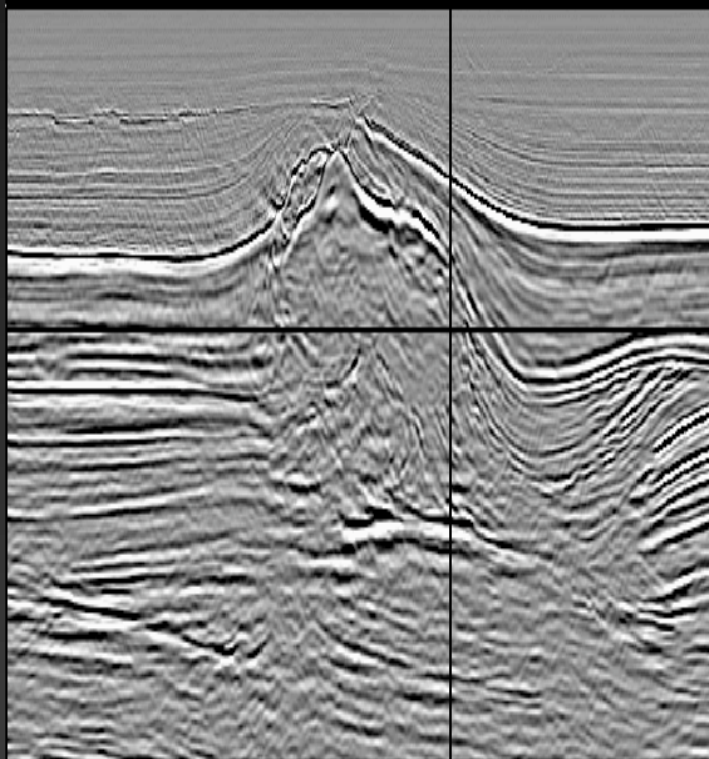
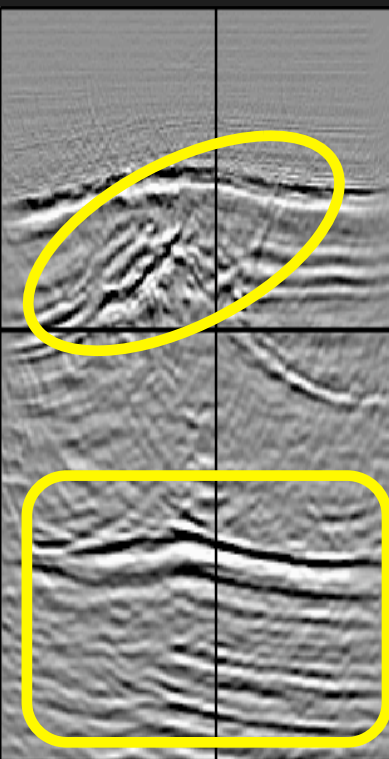
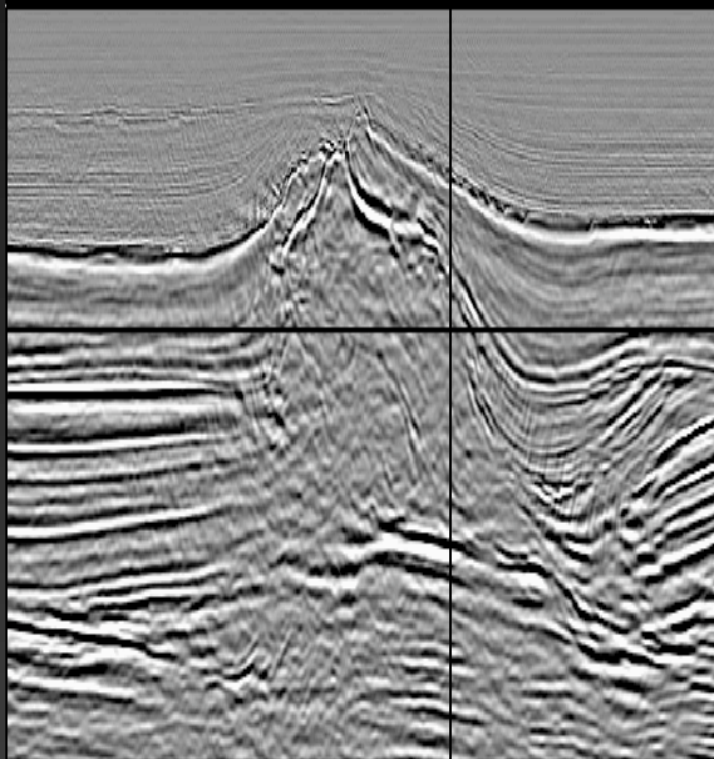
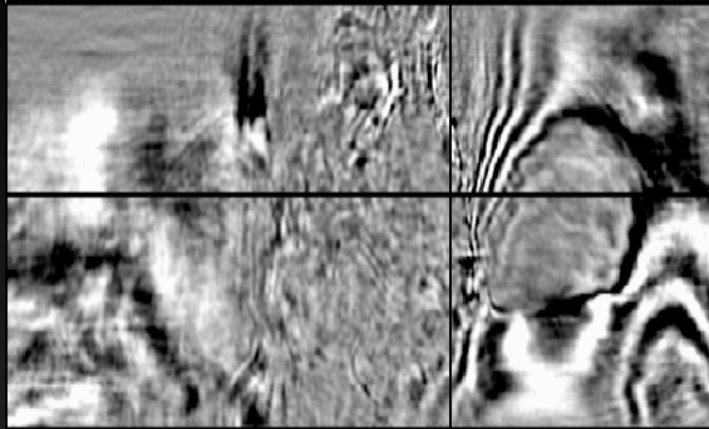
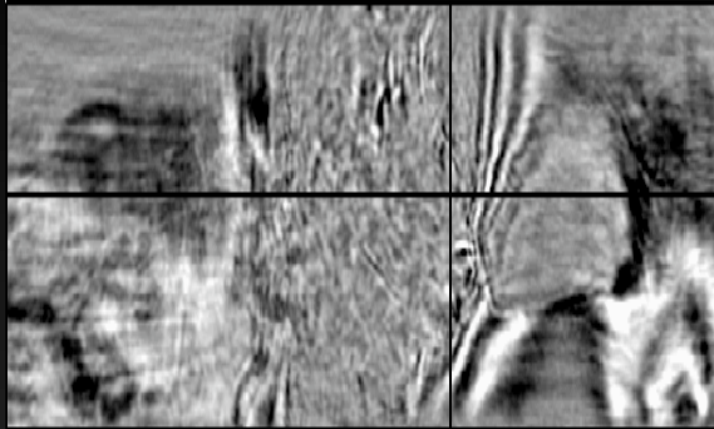


Melhores refletores sub-sal e falhas



Original

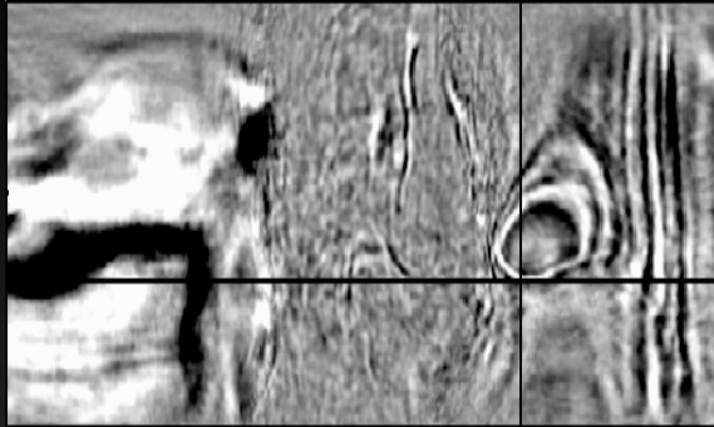
After salt body



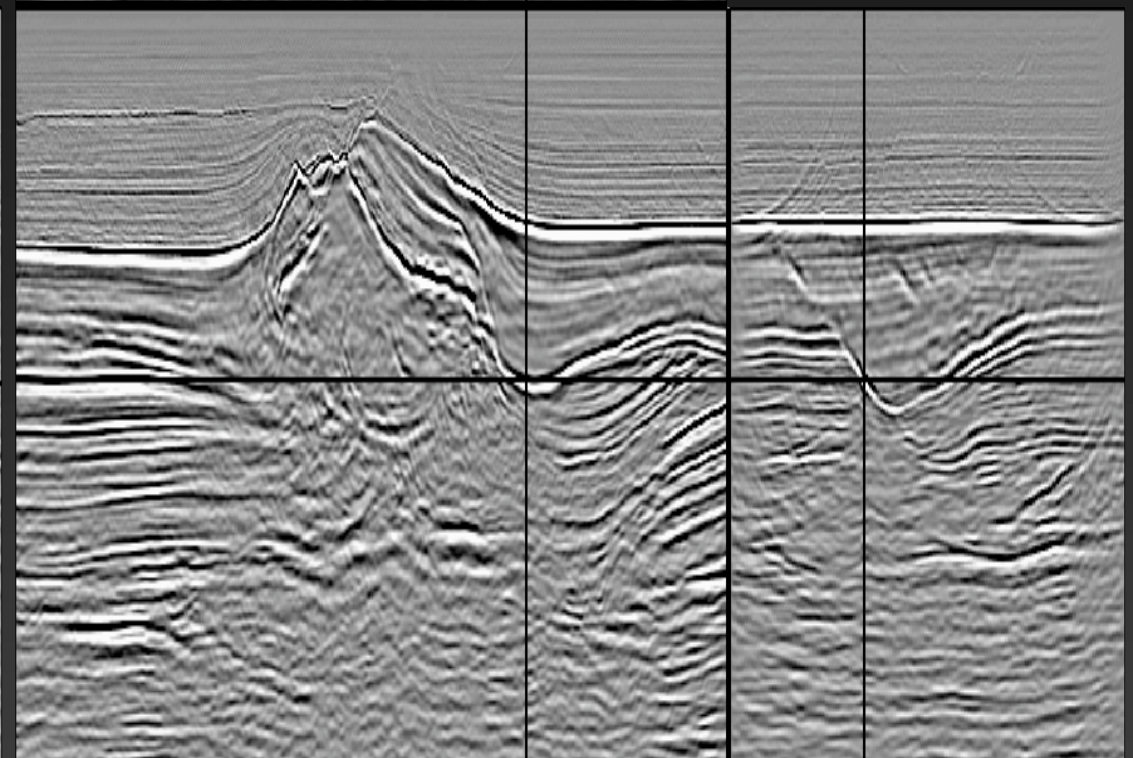
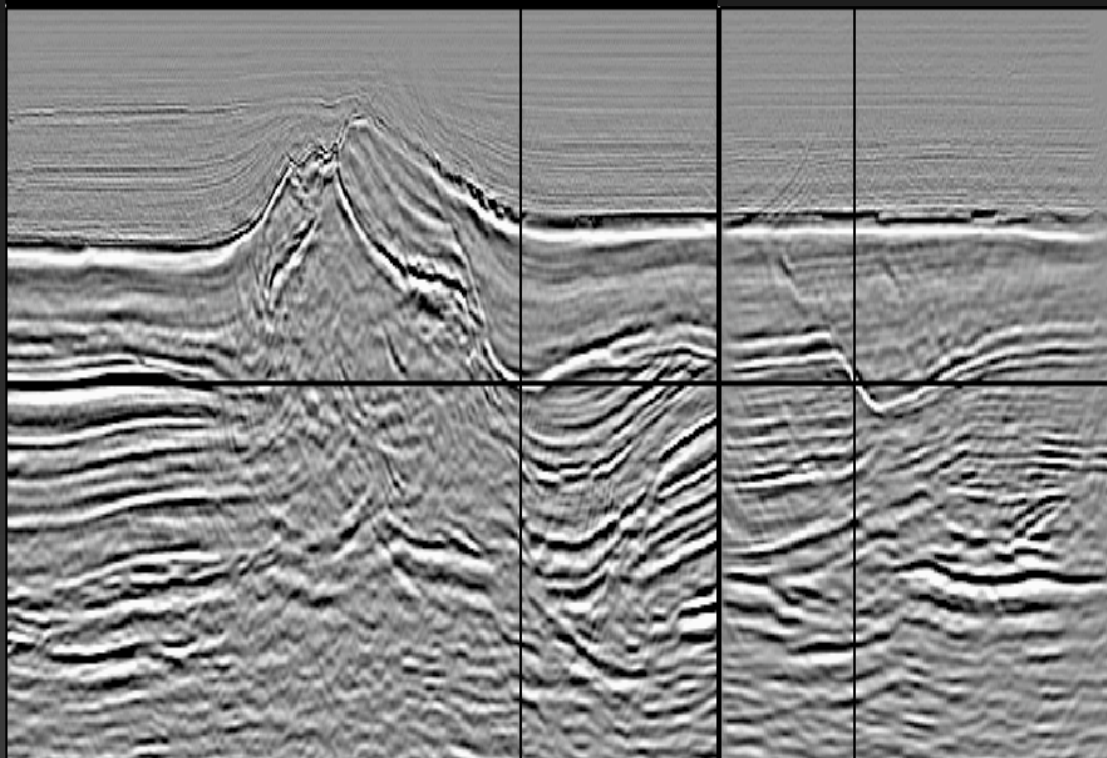
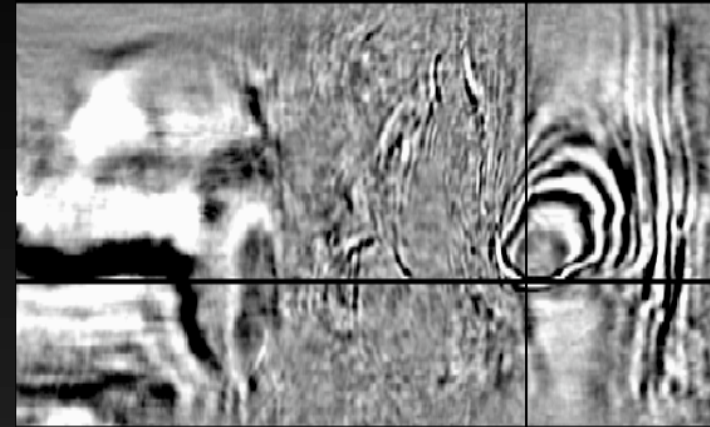
Melhores falhas e foco



Original



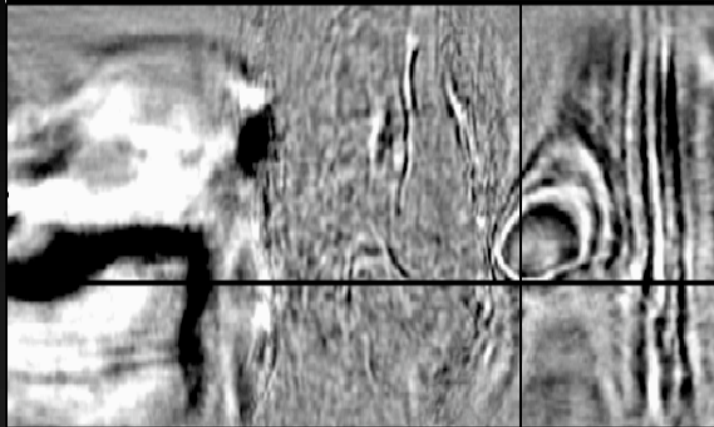
After salt body



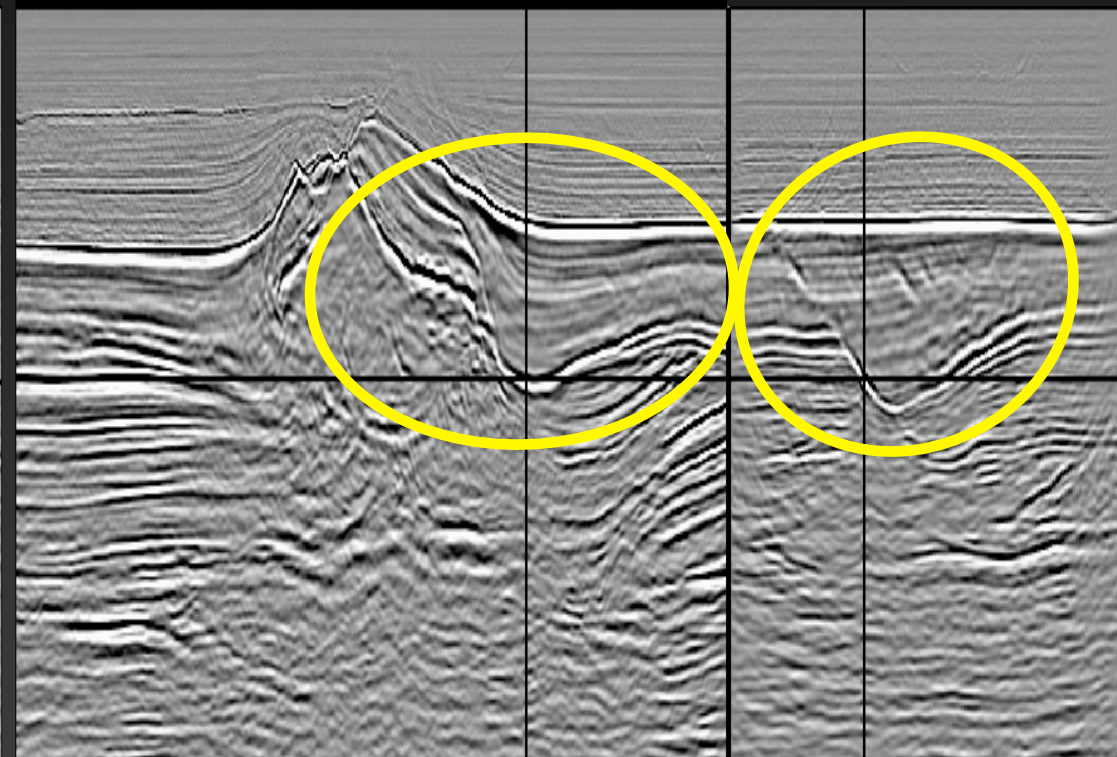
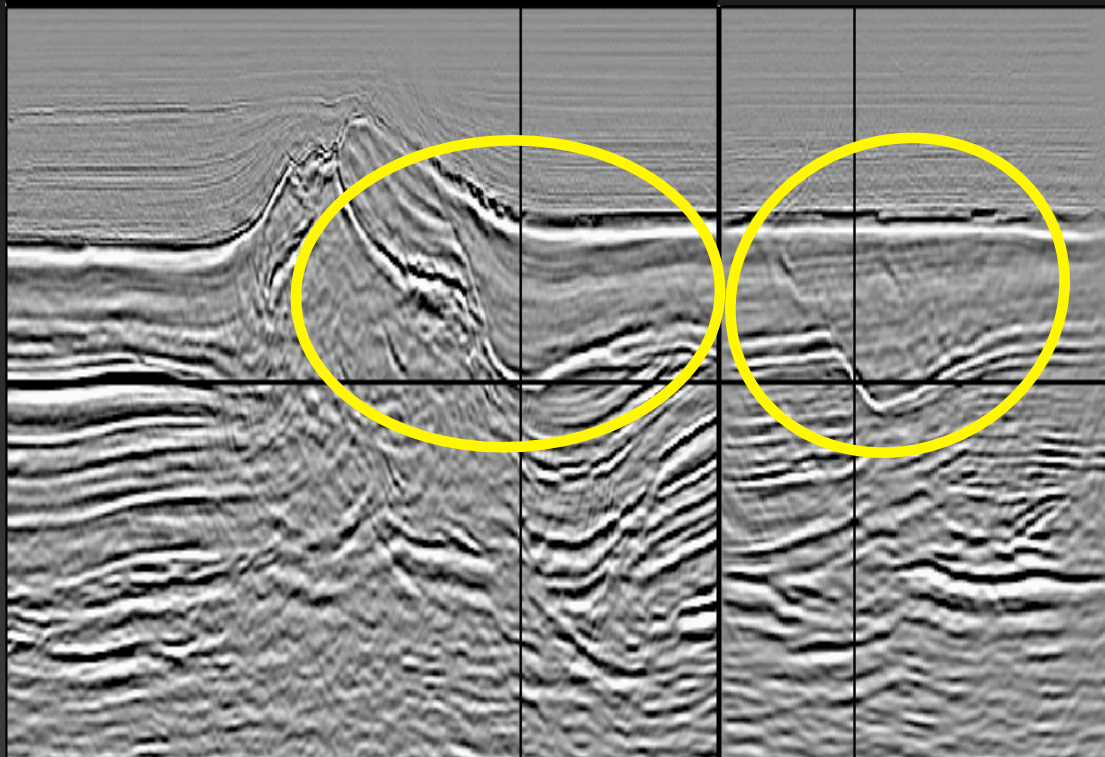
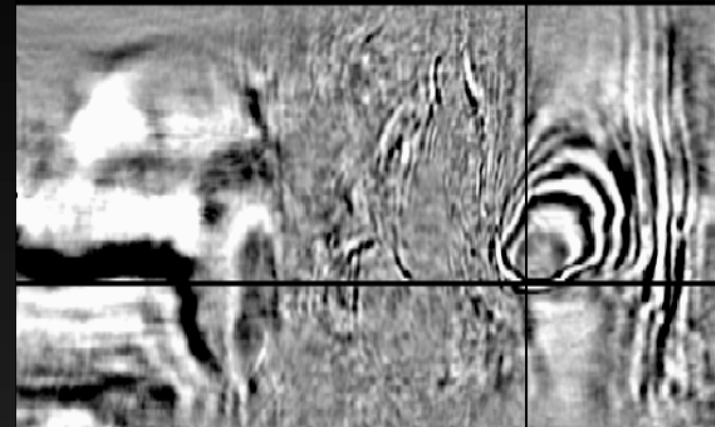
Melhores falhas e foco



Original



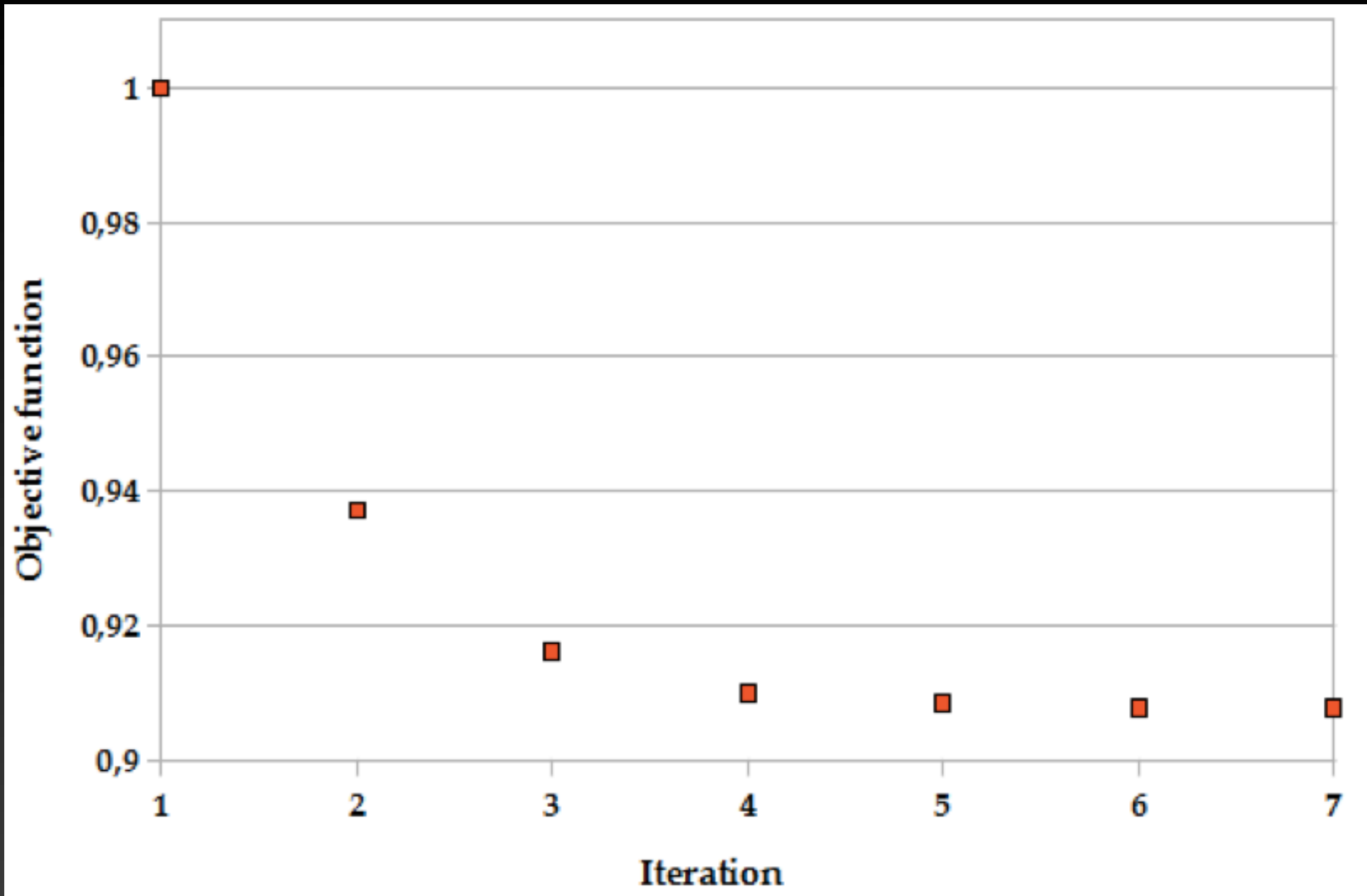
After salt body



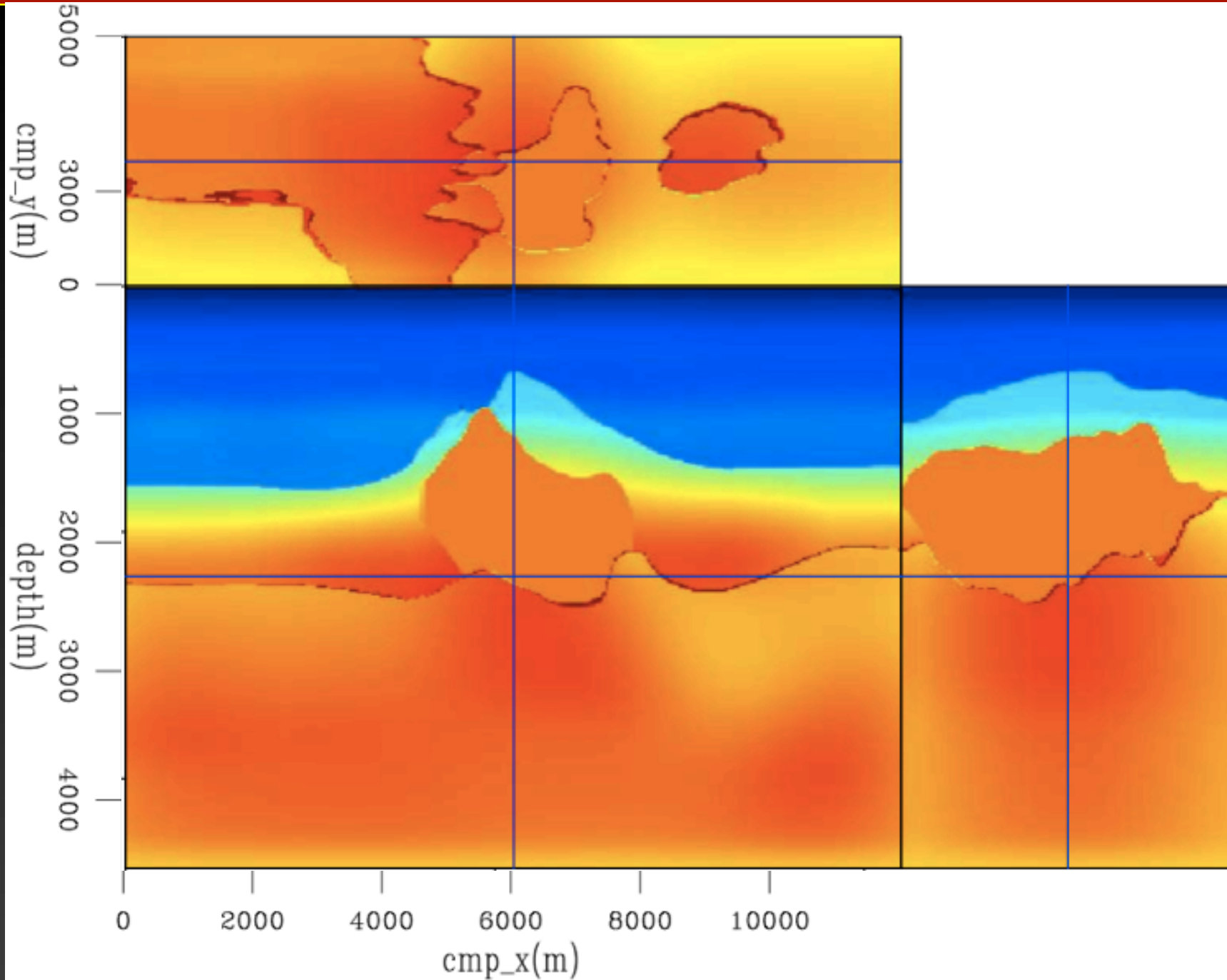
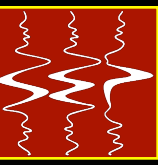


- **Gradientes conjugados não linear**
- **máximo de 5% de variação velocidade entre iterações**
- **Duas avaliações de funcional por iteração**
- **CEES: 30 Dual Nehalem 5520, 24Gb RAM**
 - **Funcional: 30 min**
 - **Gradiente: 60 min**

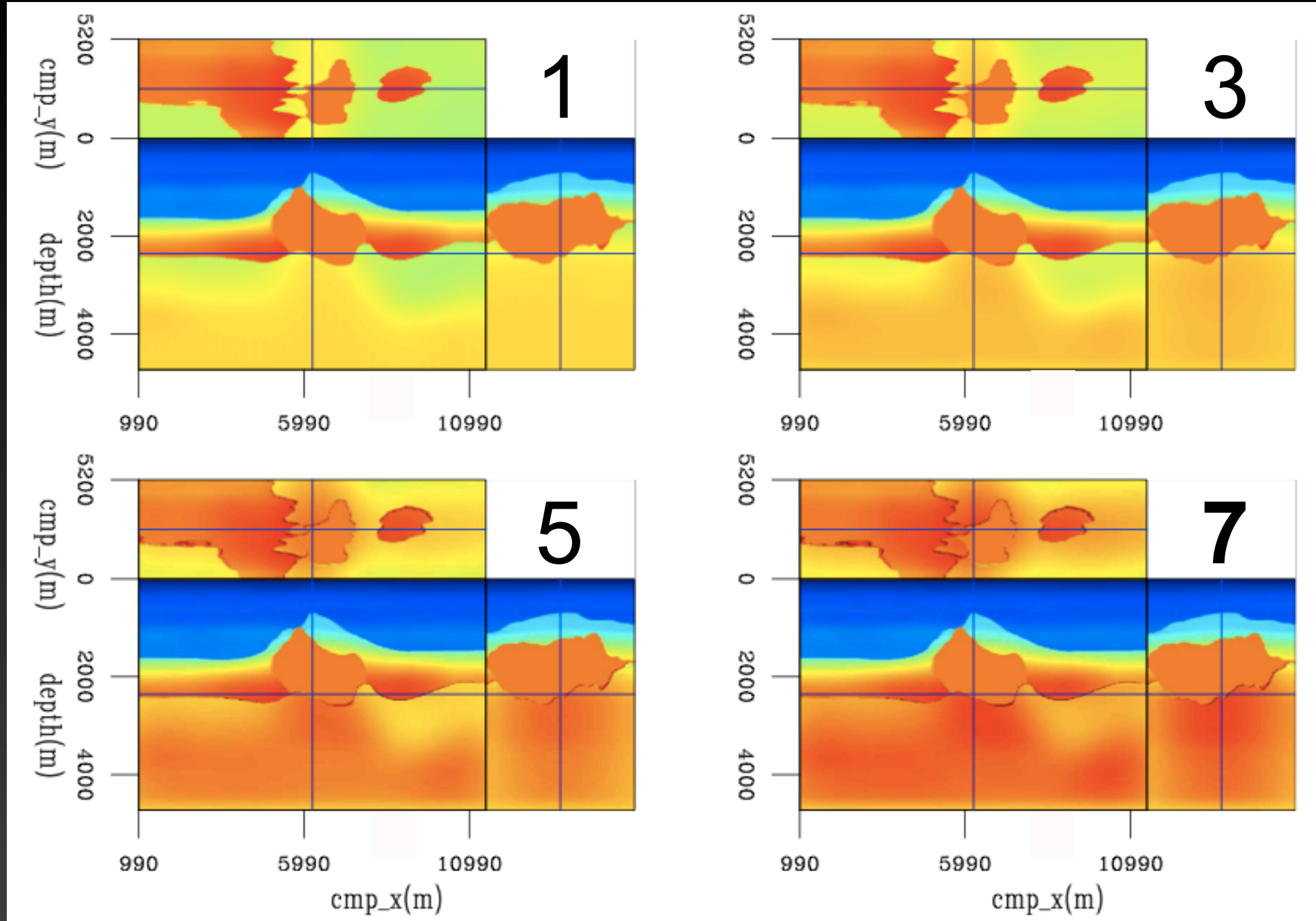
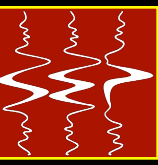
Funcional



Velocidade final



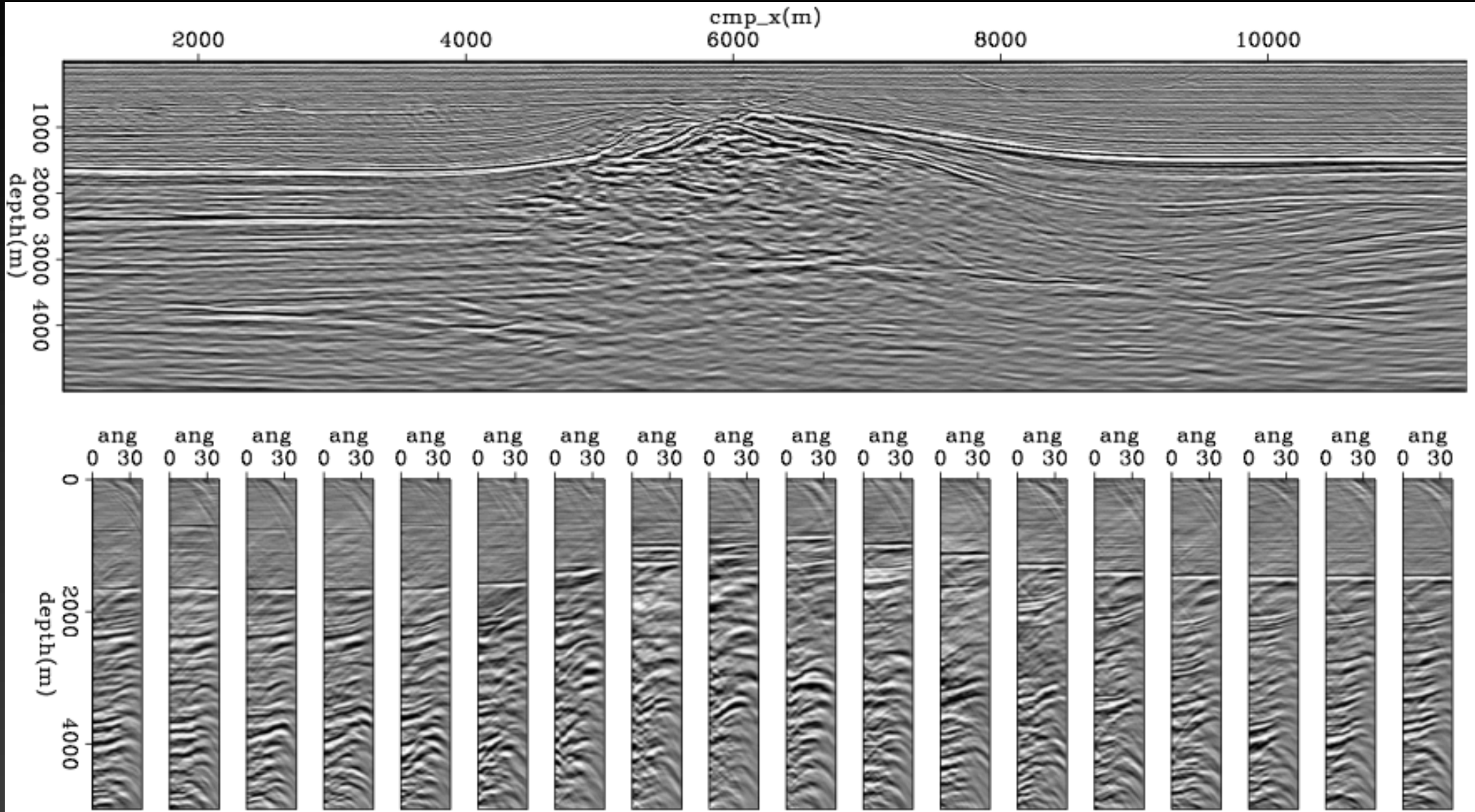
Evolução das velocidades



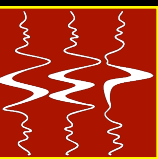
iline = 3200 m



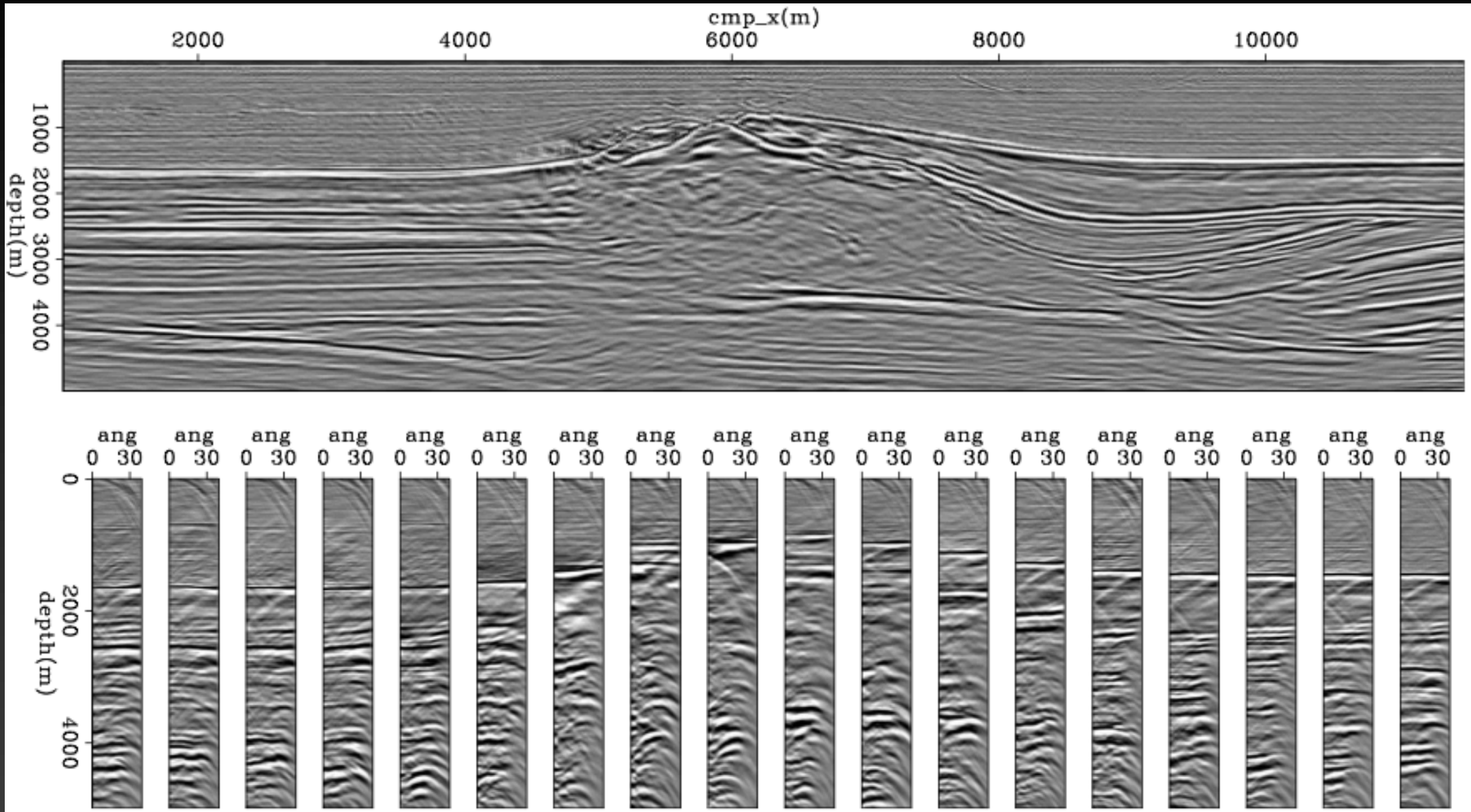
Initial



Refletores planos no CRP



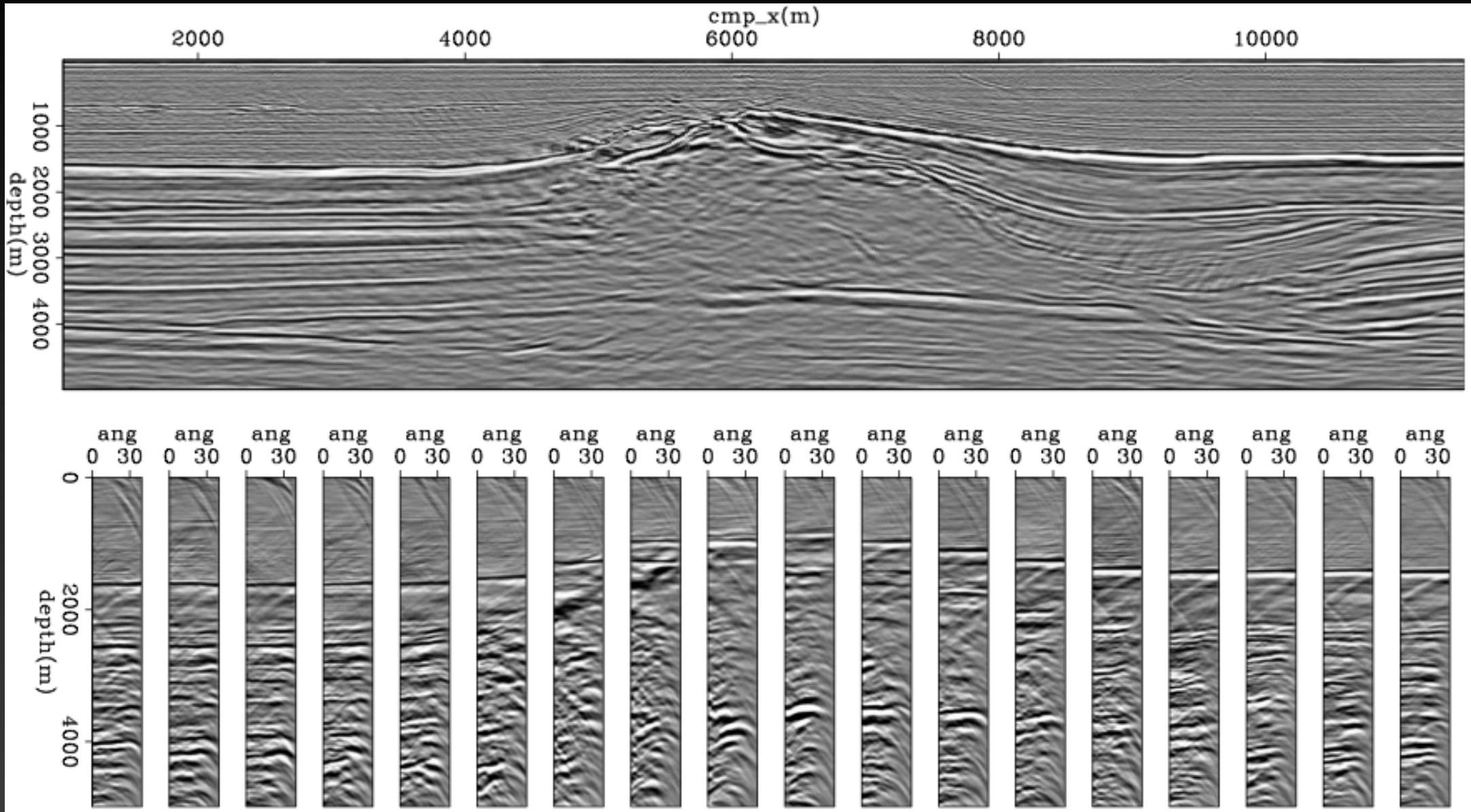
Final



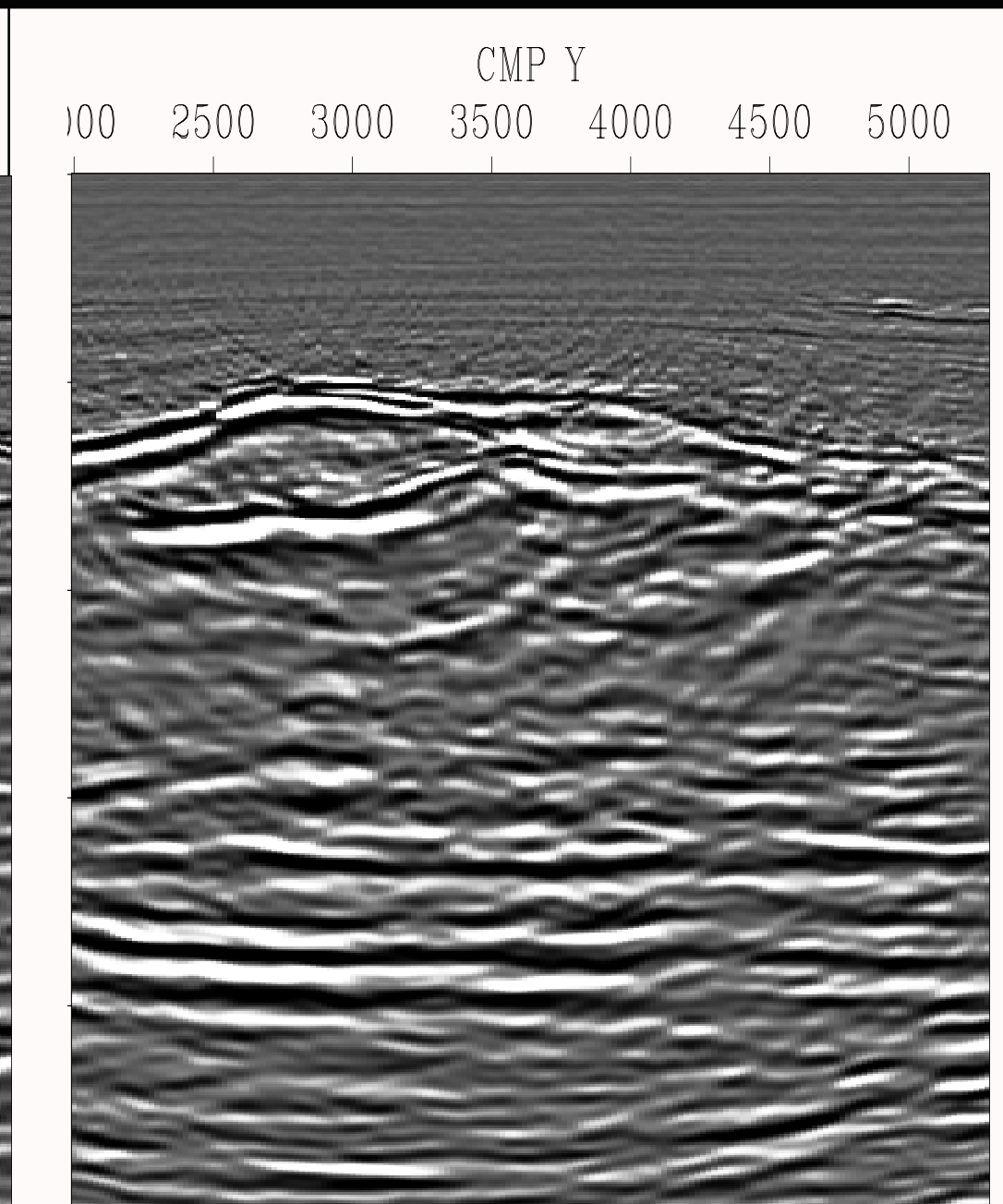
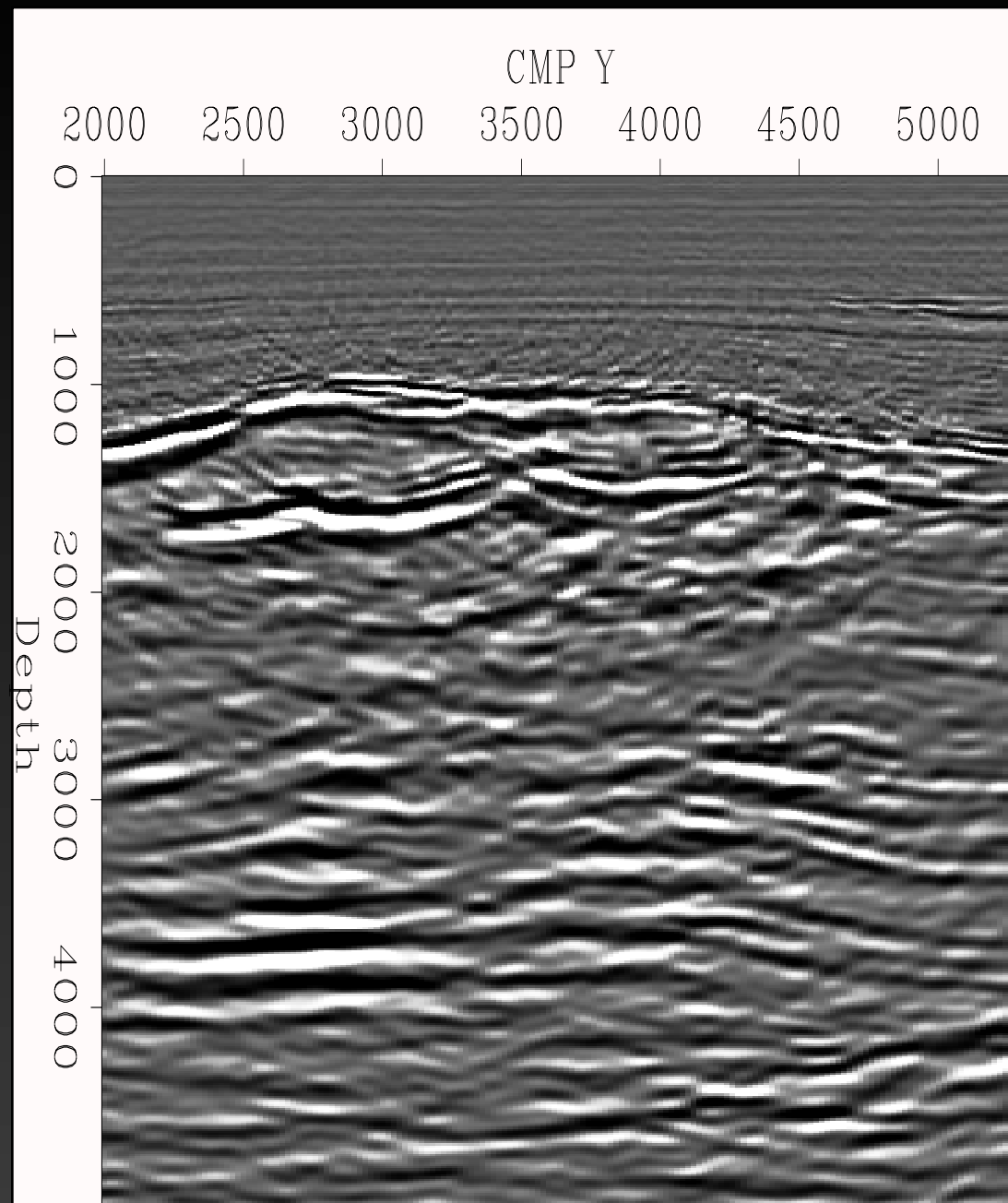
Refletores planos no CRP



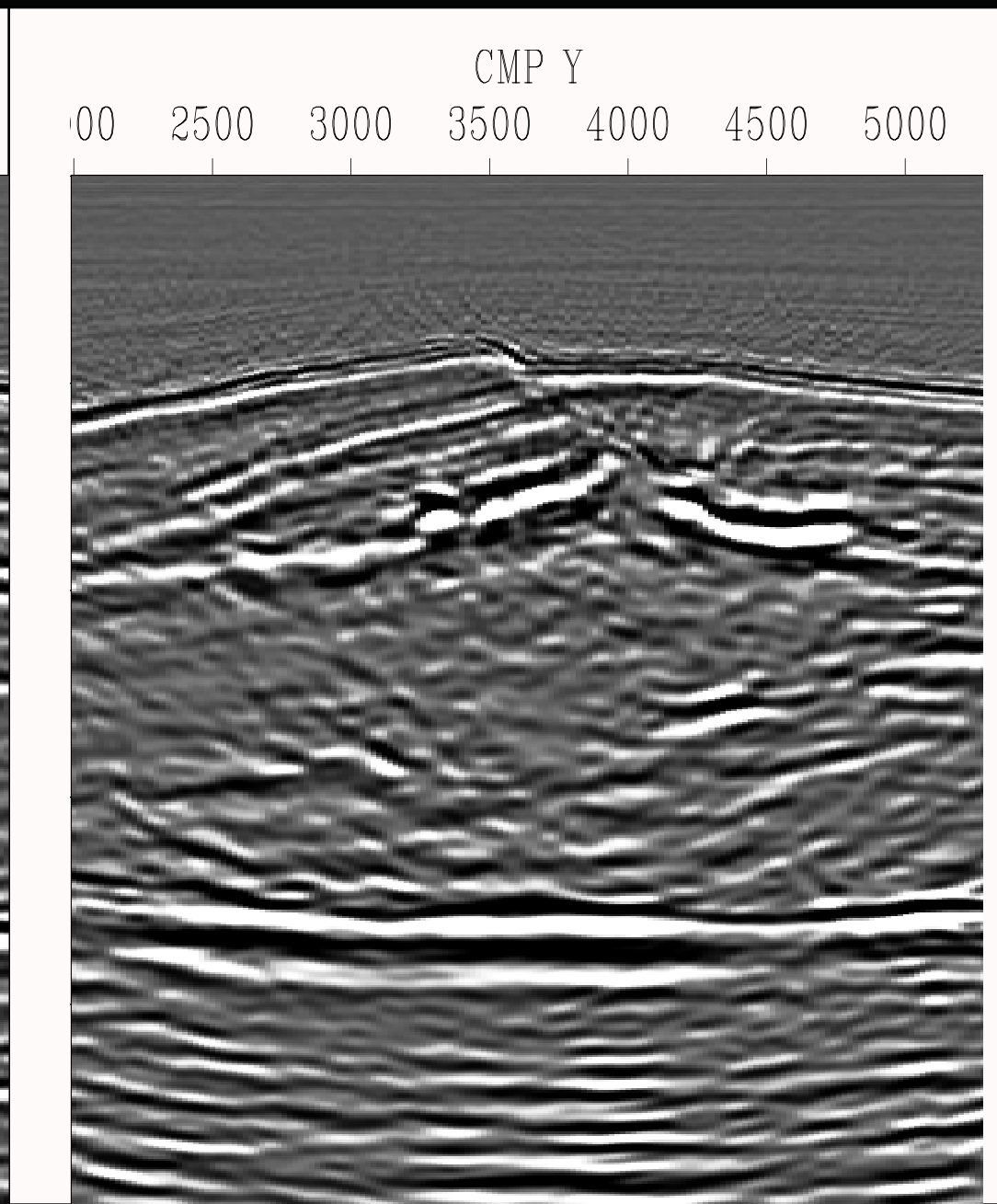
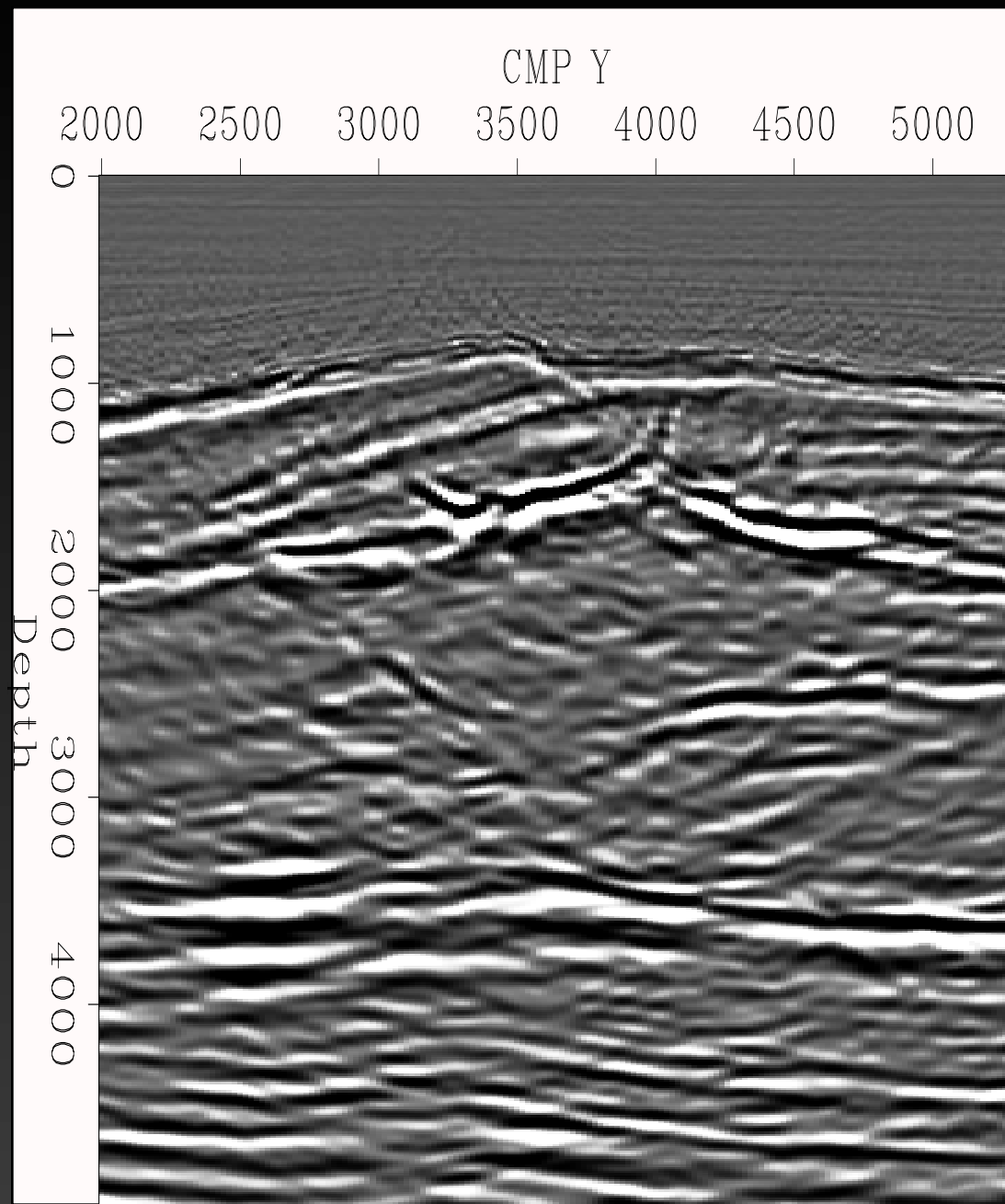
Original



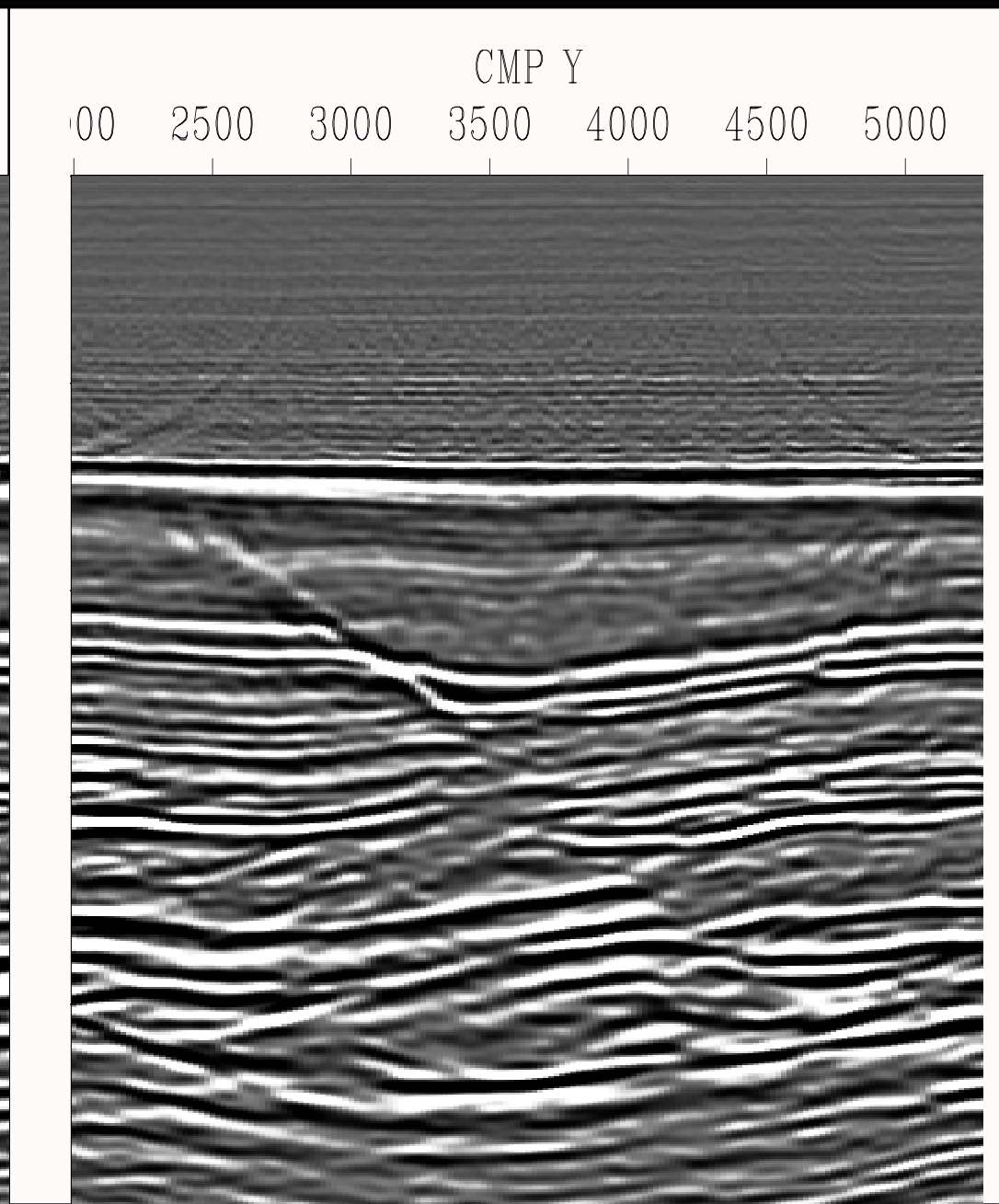
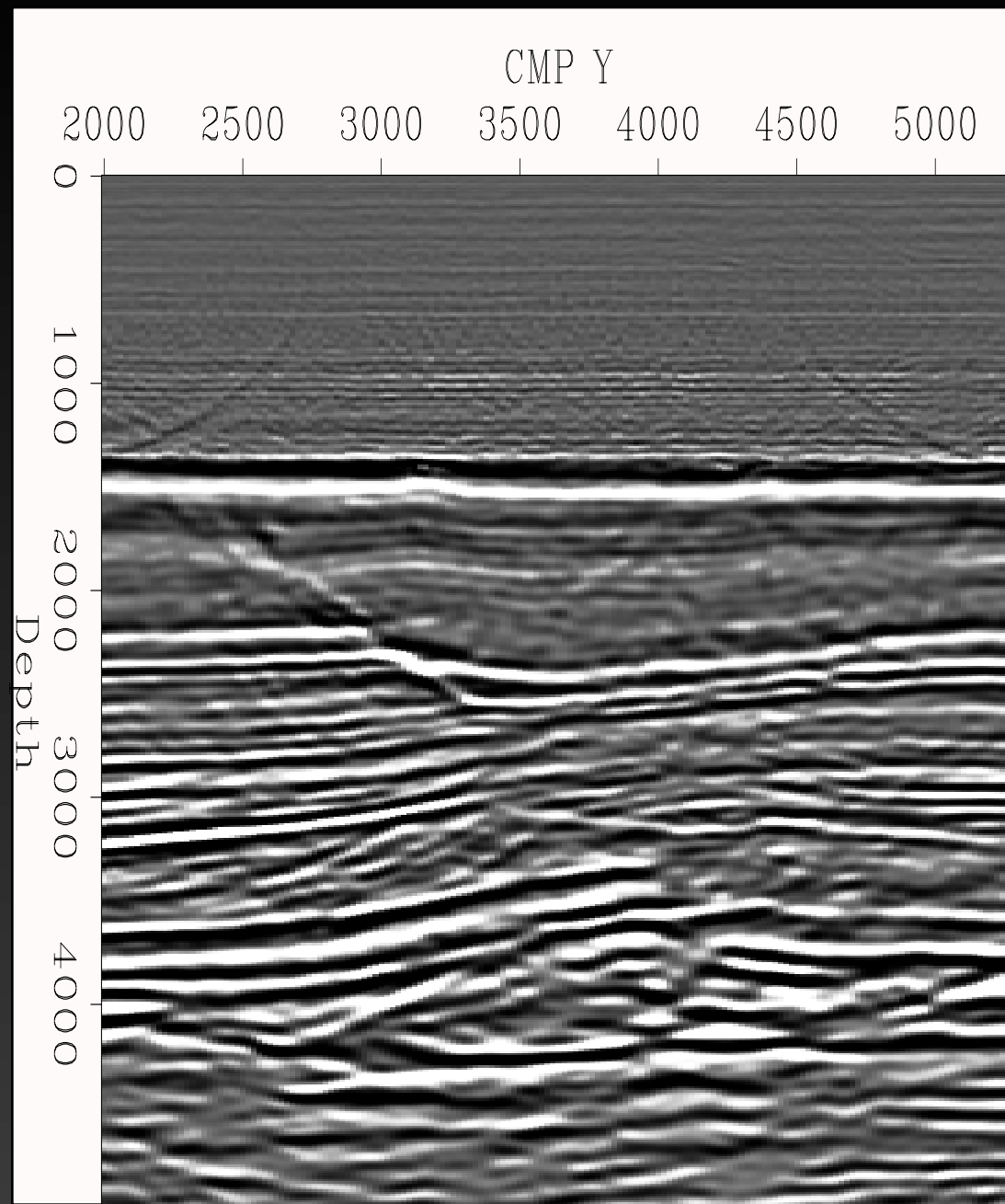
Original vs. Final (x5220)



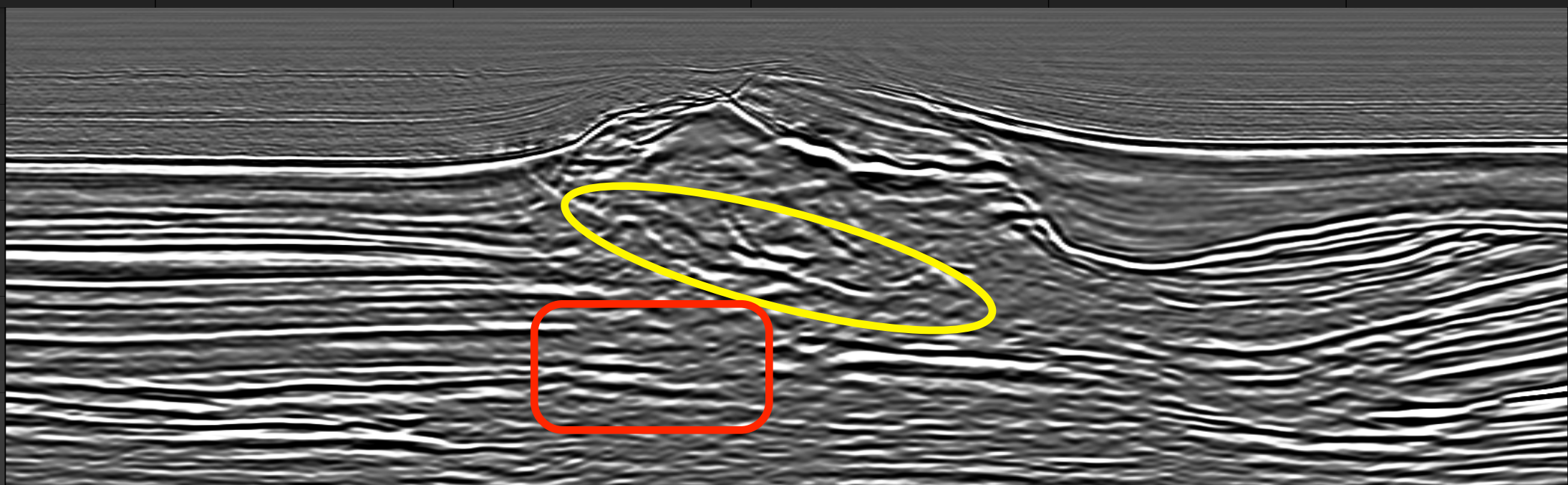
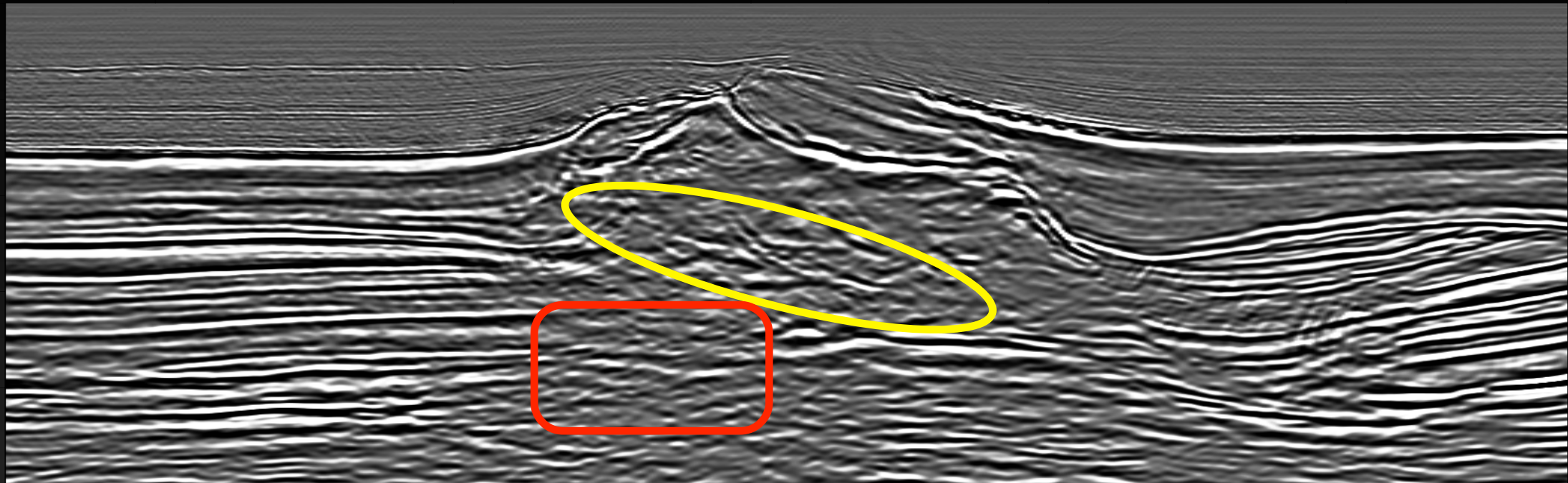
Original vs. Final (x6880)



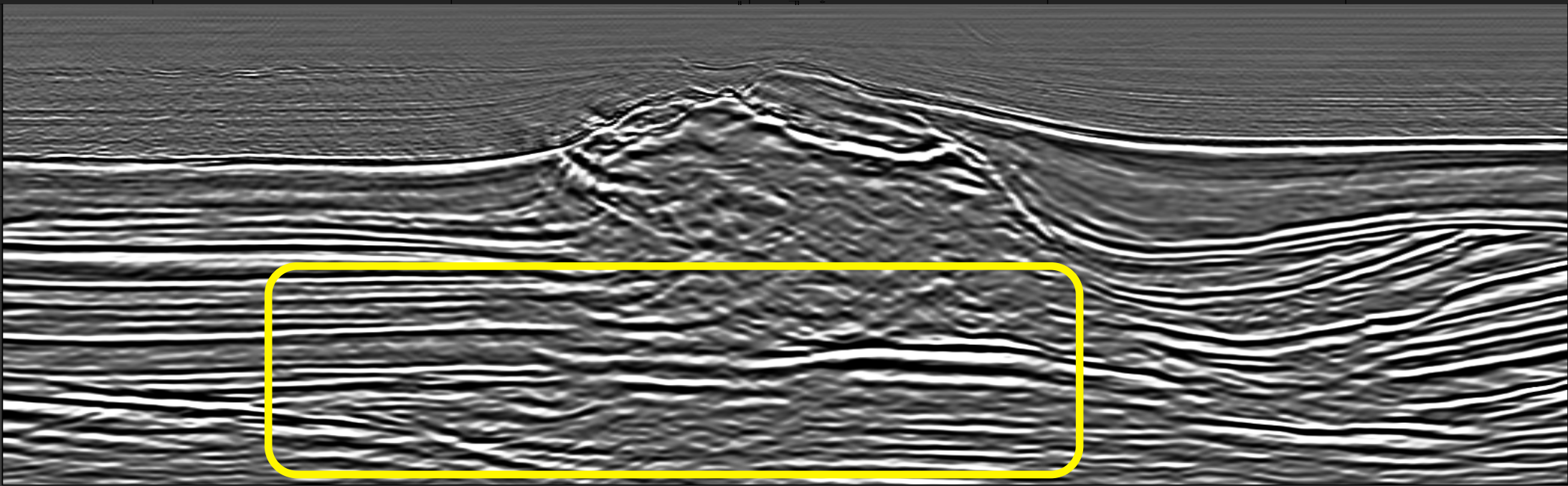
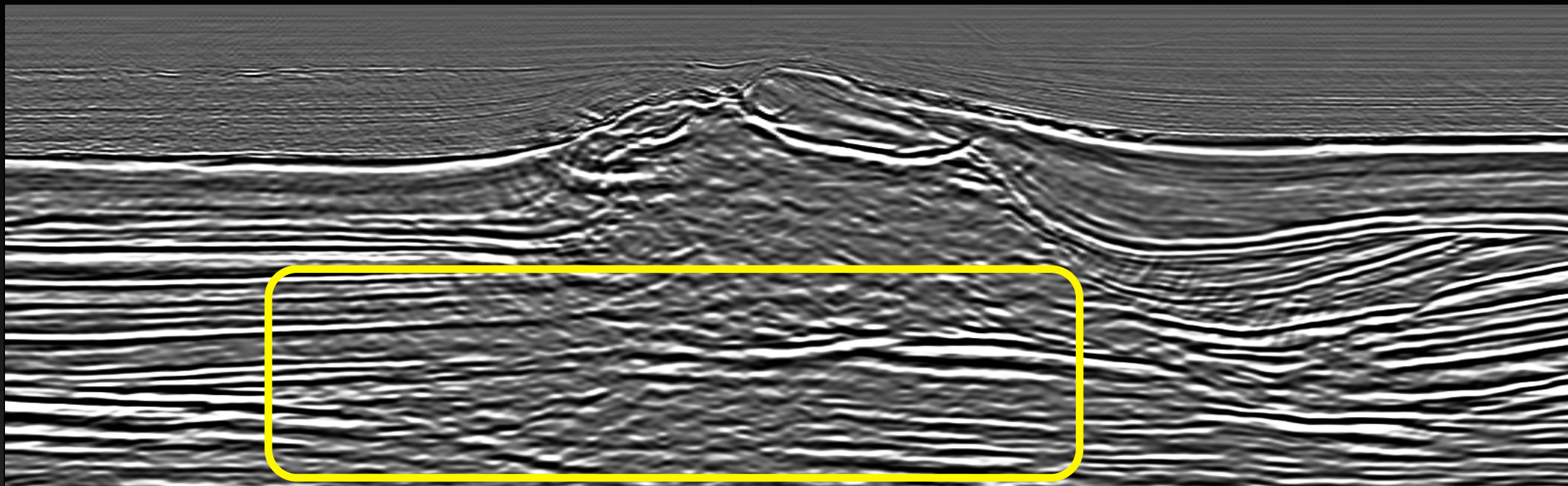
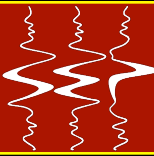
Original vs. Final (x9400)



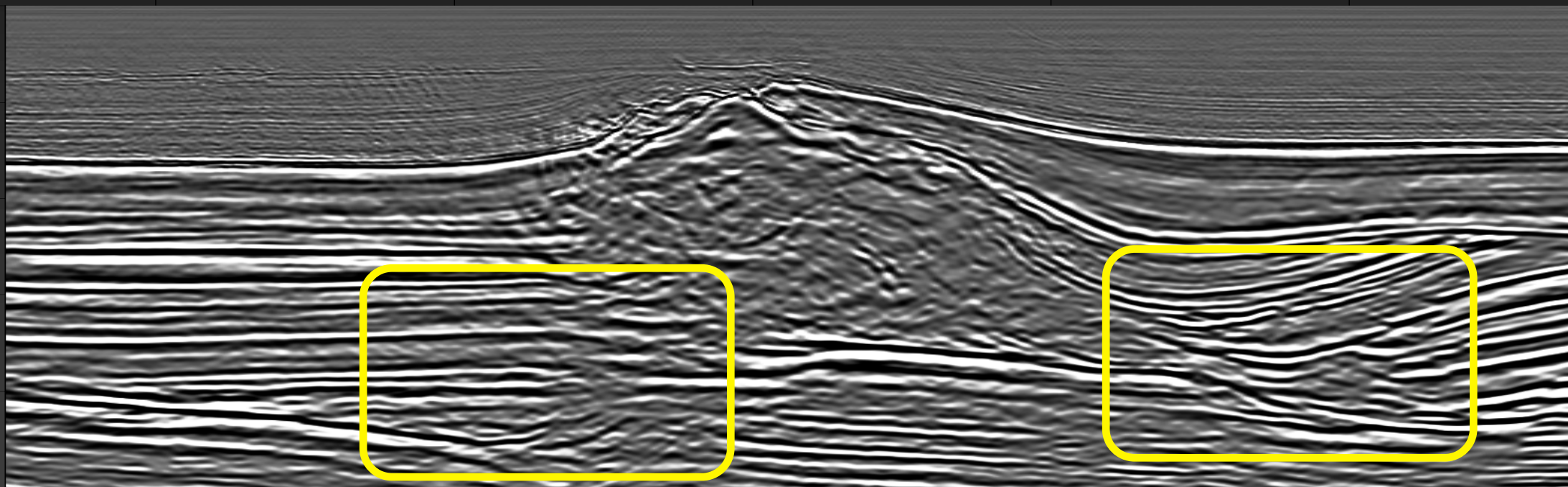
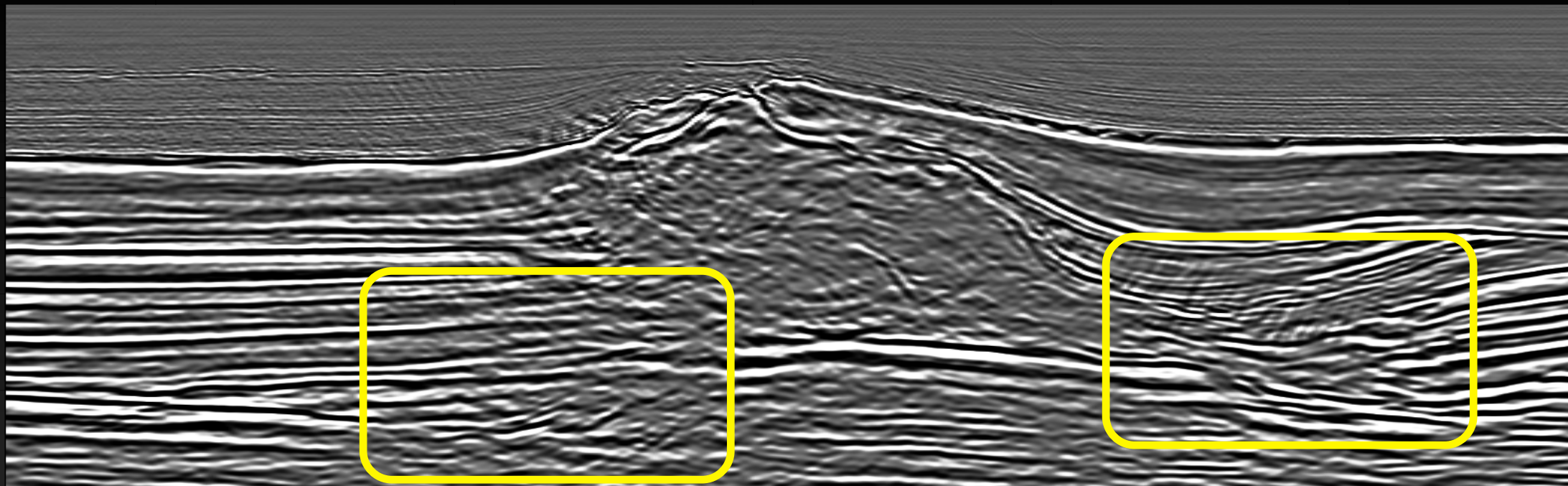
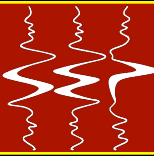
Original vs. Final (i3320)



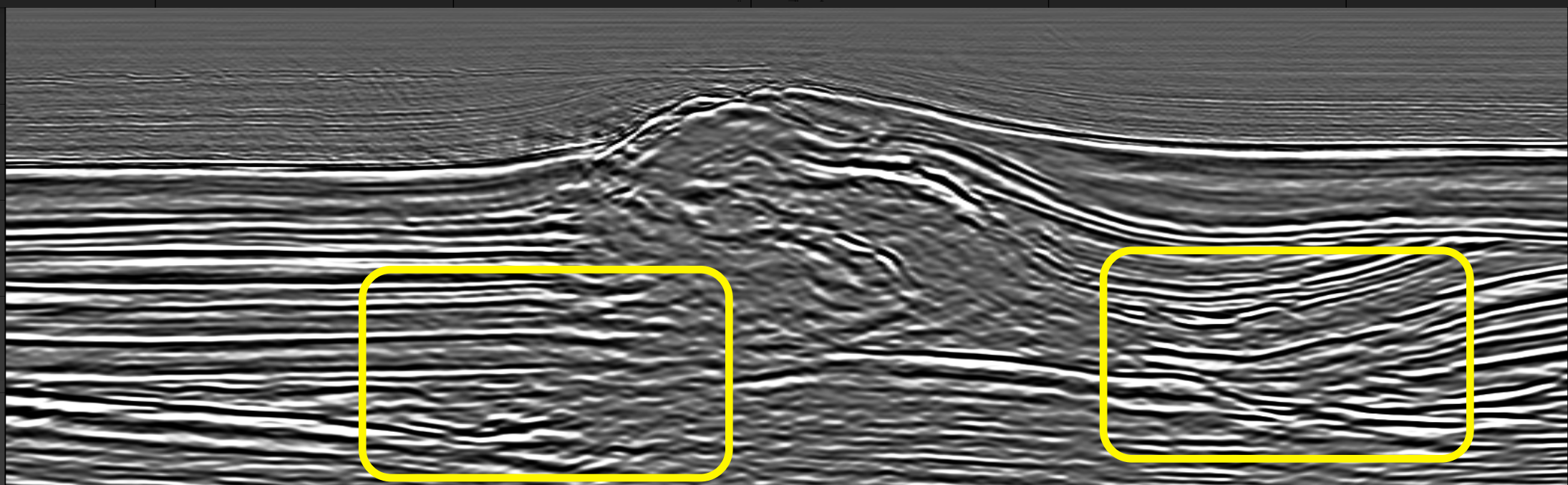
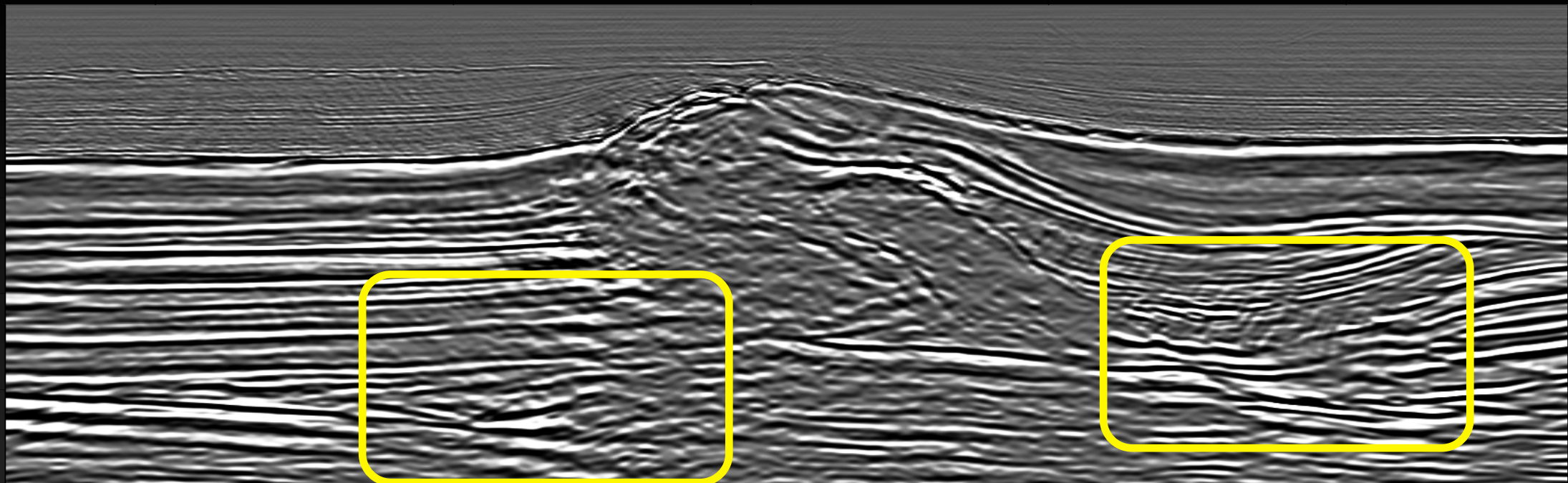
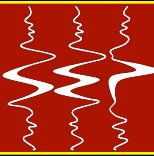
Original vs. Final (i3680)



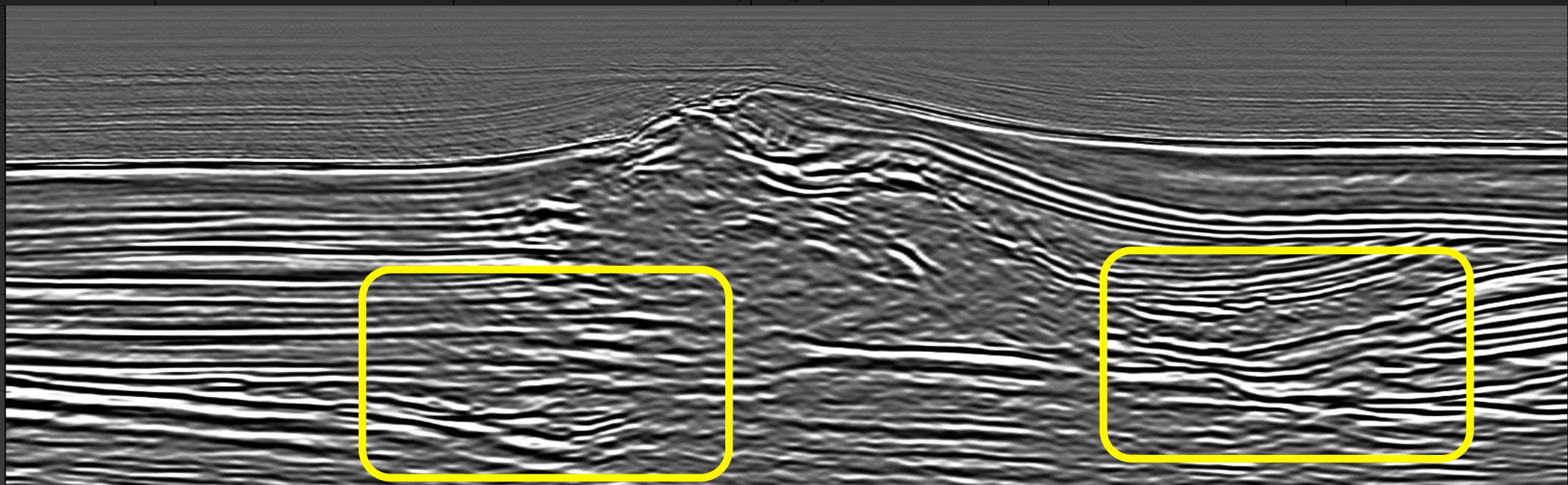
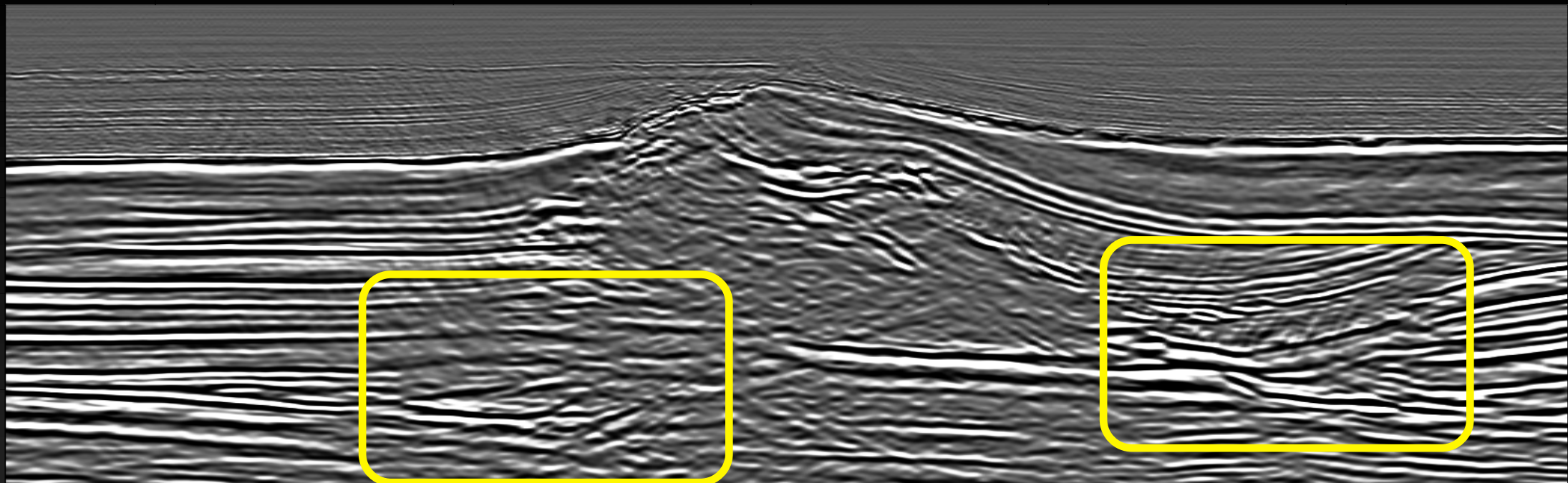
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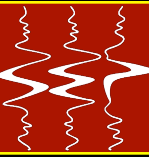


Original vs. Final (i4420)

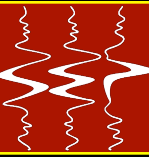


Original vs. Final (i4800)

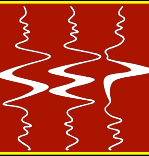




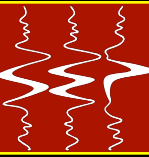
- **Campos de onda generalizados no espaço da imagem acelera ISWET**
 - tamanho reduzido dos dados
 - estratégia focada no alvo



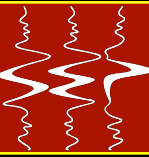
- **Campos de onda generalizados no espaço da imagem acelera ISWET**
 - tamanho reduzido dos dados
 - estratégia focada no alvo
- **ISWET com campos de onda generalizados no espaço da imagem naturalmente incorpora uma estratégia baseada em horizontes**



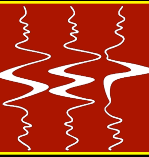
- **Campos de onda generalizados no espaço da imagem acelera ISWET**
 - tamanho reduzido dos dados
 - estratégia focada no alvo
- **ISWET com campos de onda generalizados no espaço da imagem naturalmente incorpora uma estratégia baseada em horizontes**
- **Campos de onda generalizados no espaço da imagem fornecem velocidades acuradas**



Campos de onda generalizados no espaço da imagem permitem o uso rotineiro de ISWET

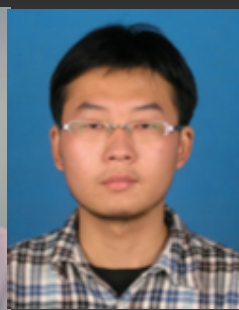
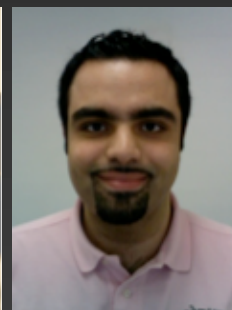
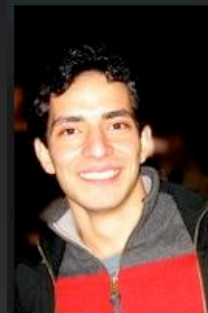
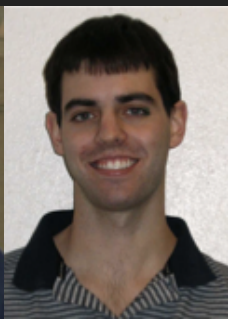
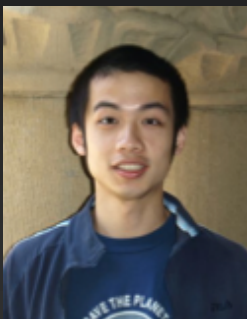
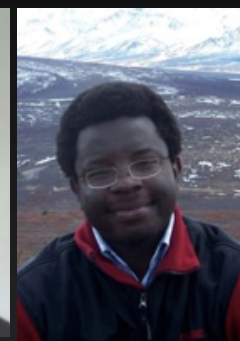


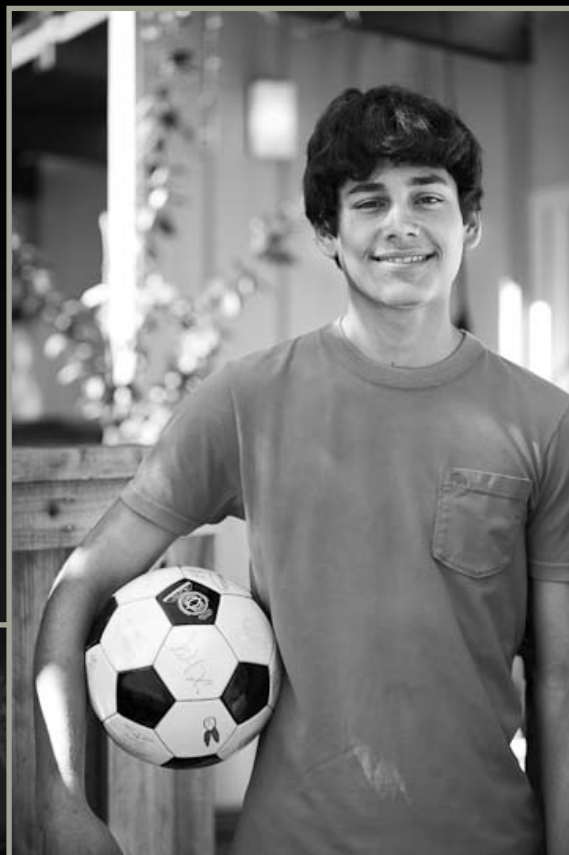
- **À Petrobras** por todo apoio necessário
- **Biondo Biondi** por manter-me no rumo certo e pelo constante encorajamento
- **Jon Claerbout** pelas discussões esclarecedoras
- **Bob Clapp** por sempre estar à nossa frente definindo as necessidades computacionais do SEP
- **Tapan Mukerji** por presidir o comitê



- Aos administradores de sistema por tomarem conta dos computadores
- **TotalFinaElf** pelo dataset do Mar do Norte

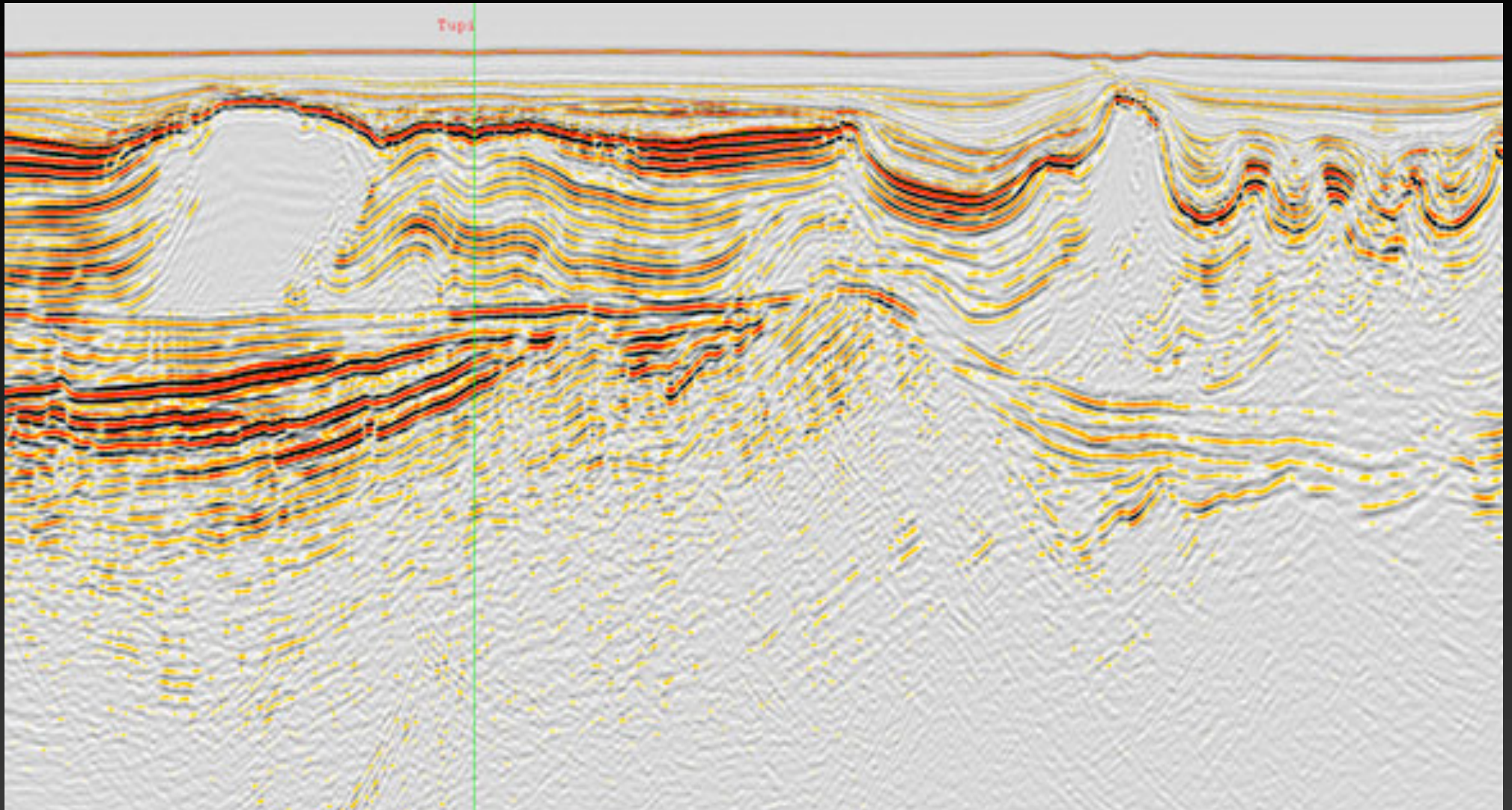
Agradeço





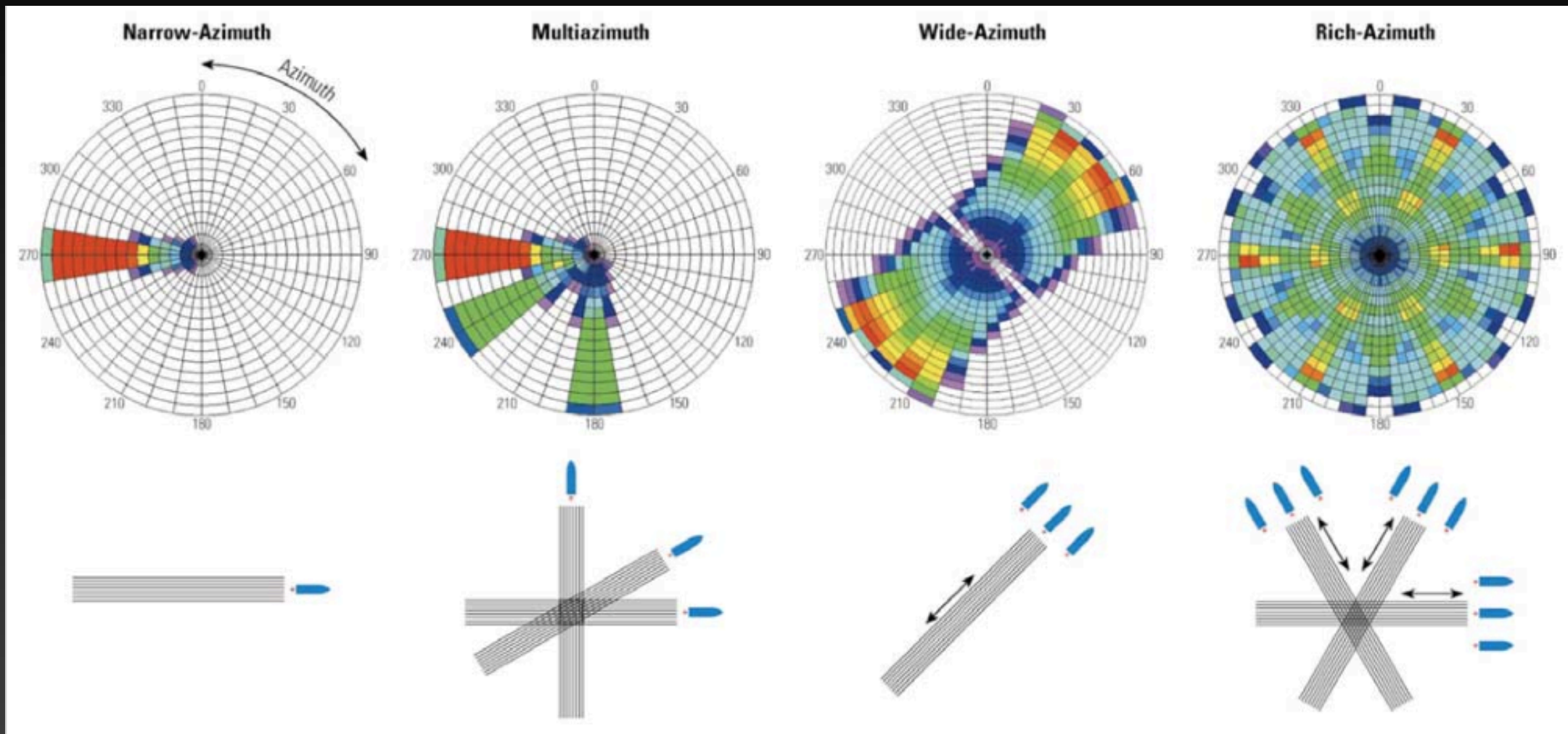
distance

depth



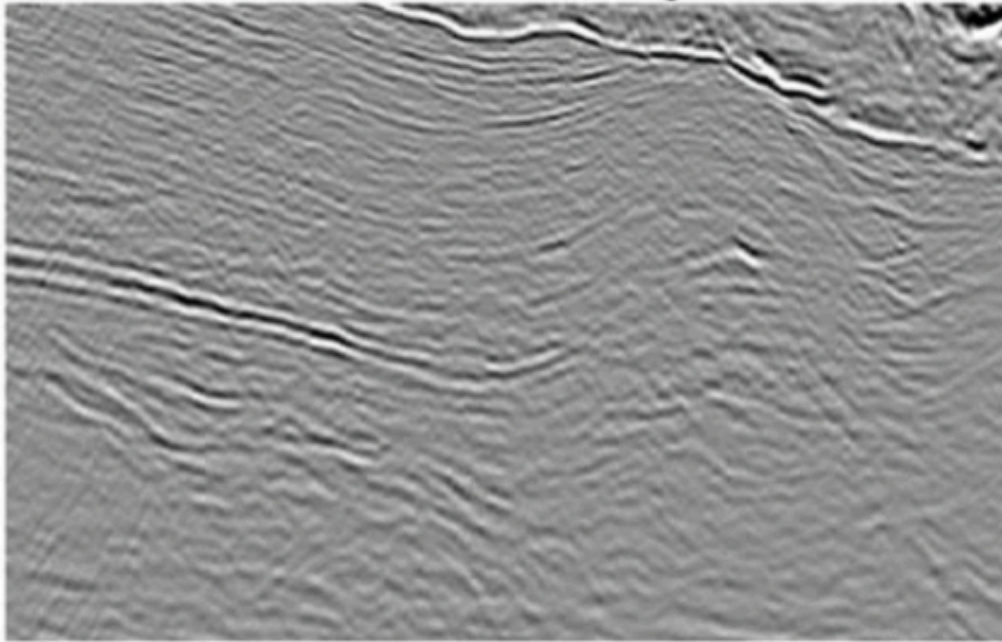
http://www.cggveritas.com/data//1/rec_imgs/4147_news2.jpg

Acquisition

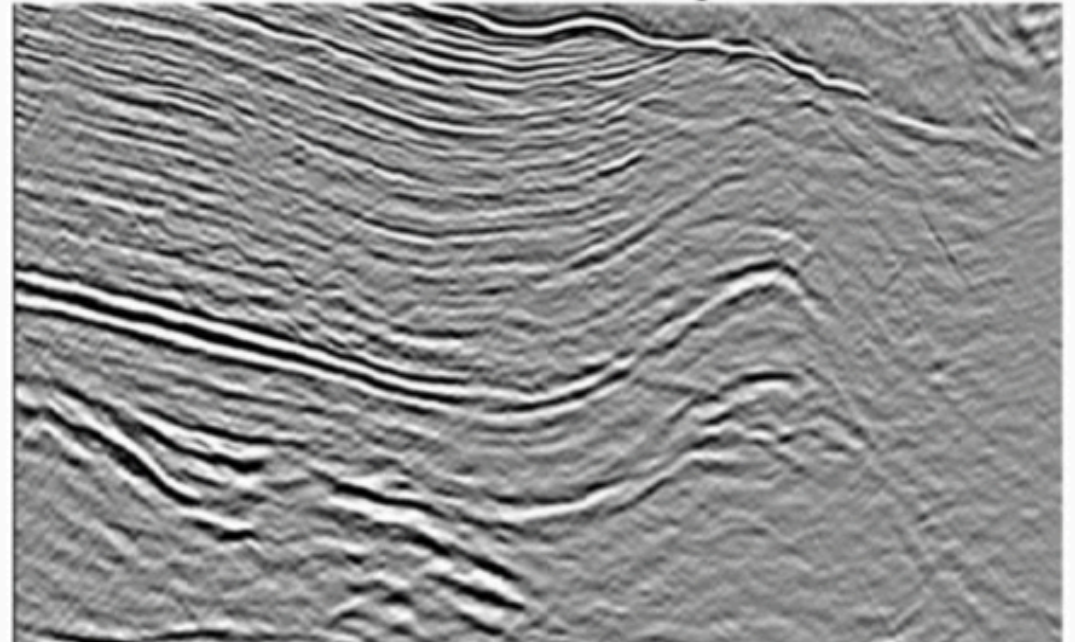


Acquisition

NAZ with demultiple

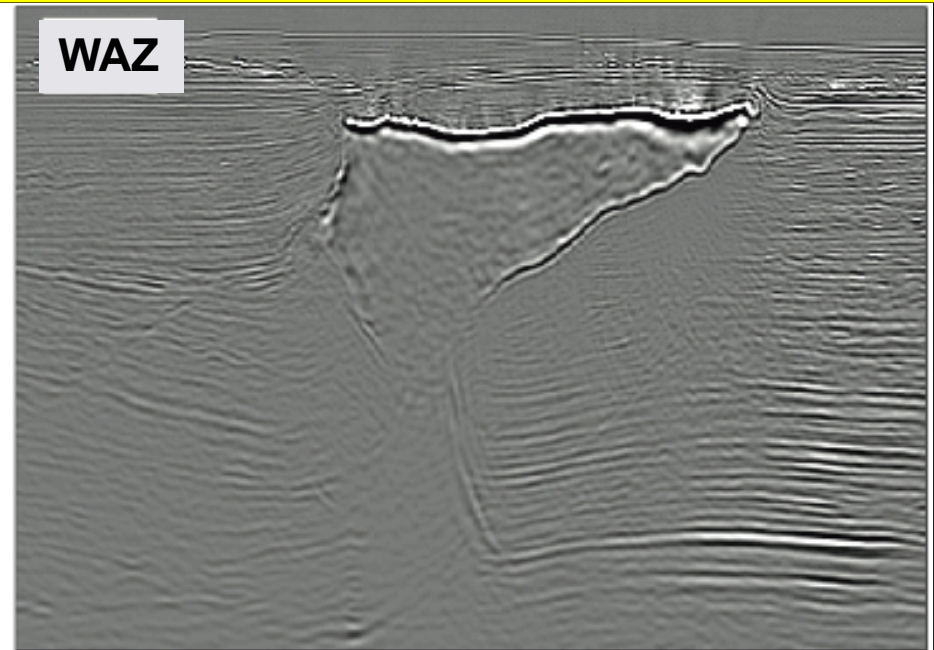
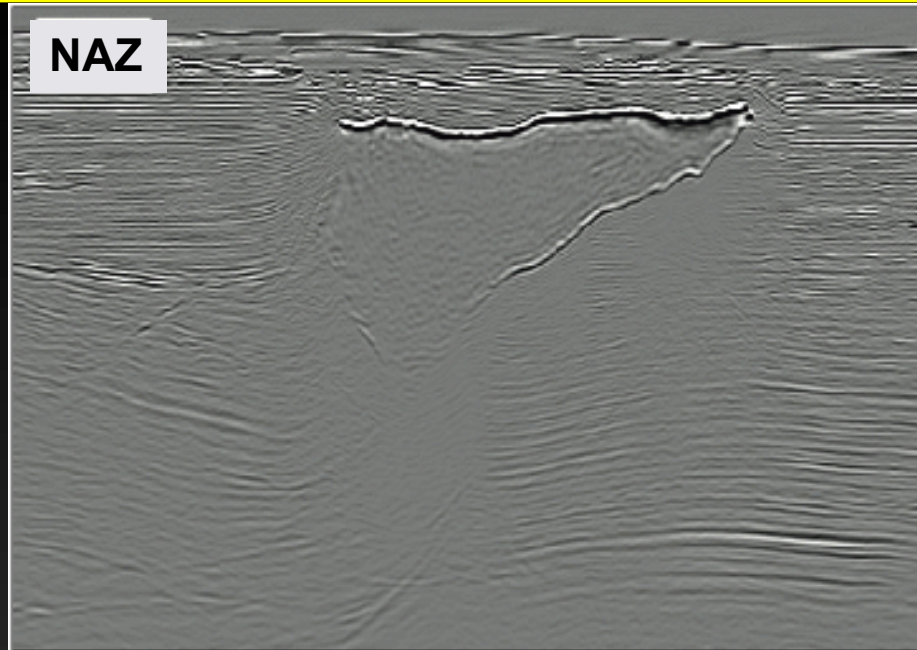


RAZ no demultiple



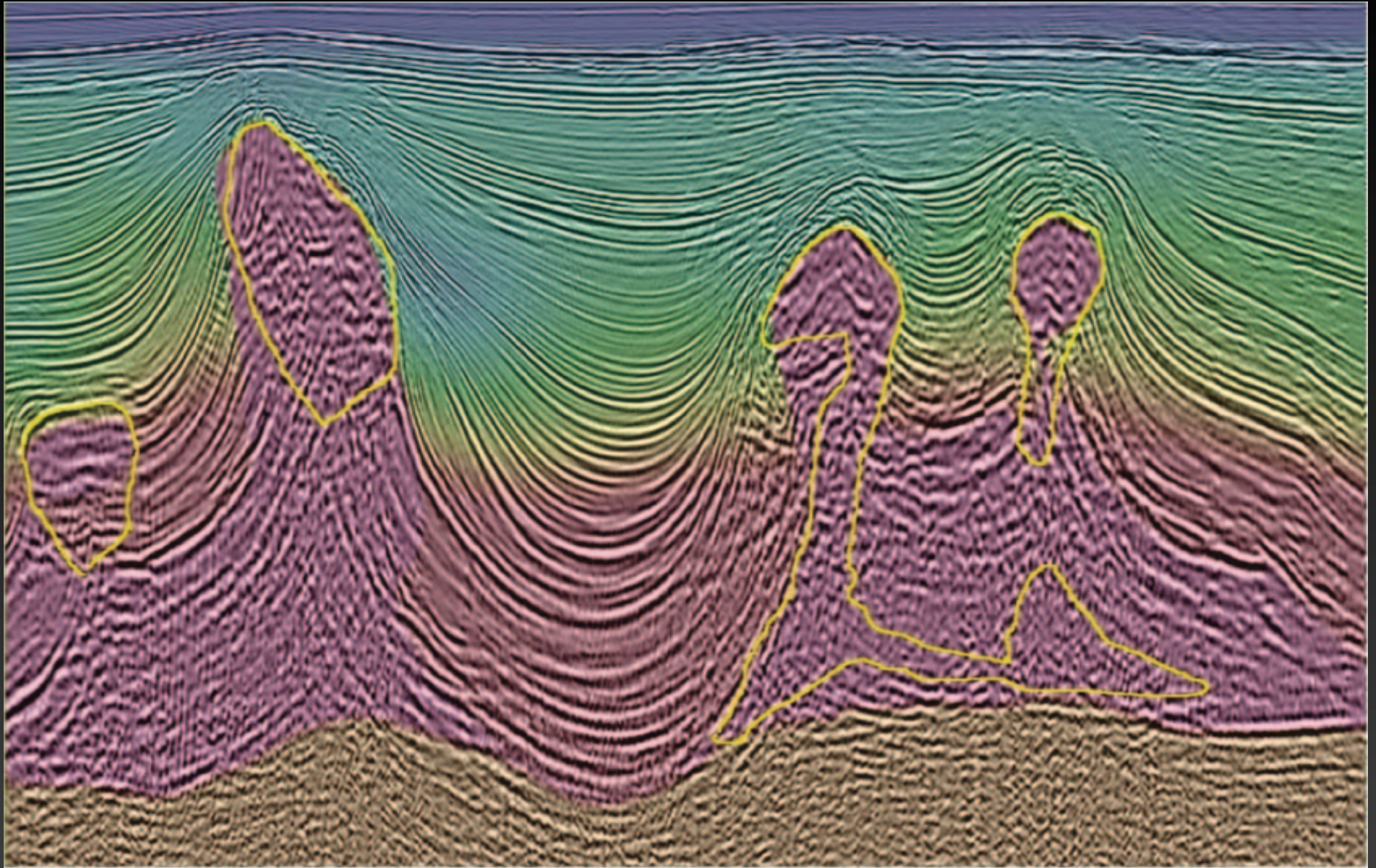
Kapoor et al., 2007

Acquisition and velocity model



distance

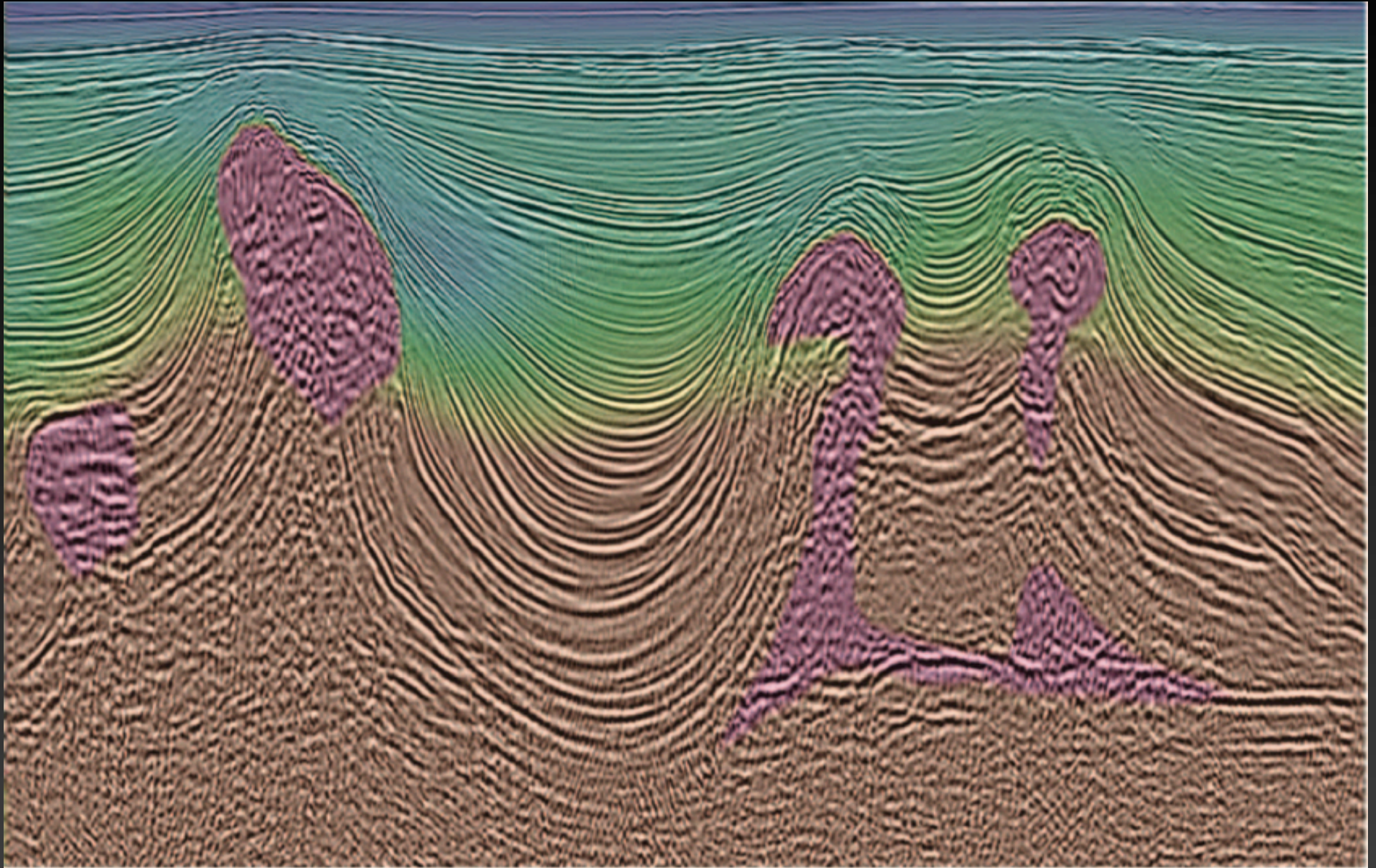
depth



Li et al., 2009

distance

depth



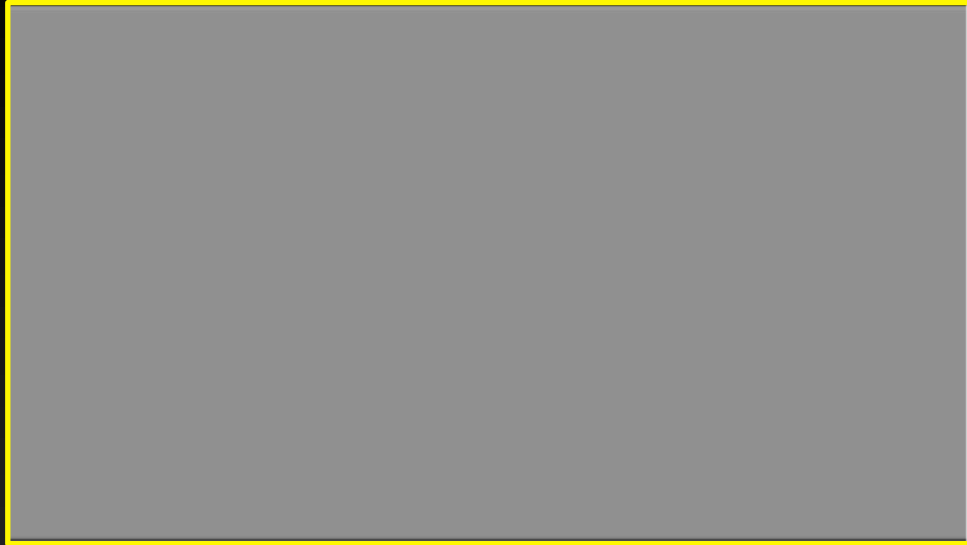
Li et al., 2009

Data-space: 0° plane wave



source

time



distance

receiver

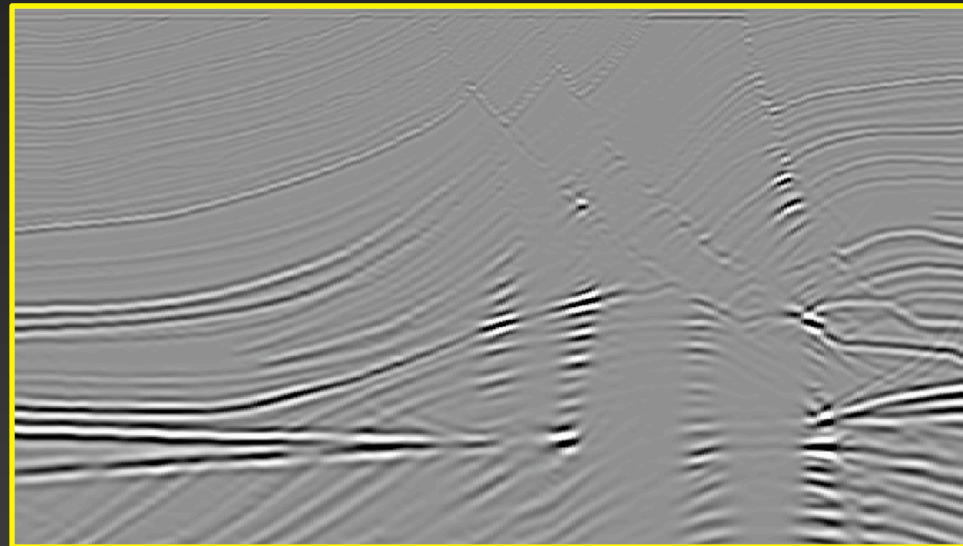
time



distance

image

depth



distance

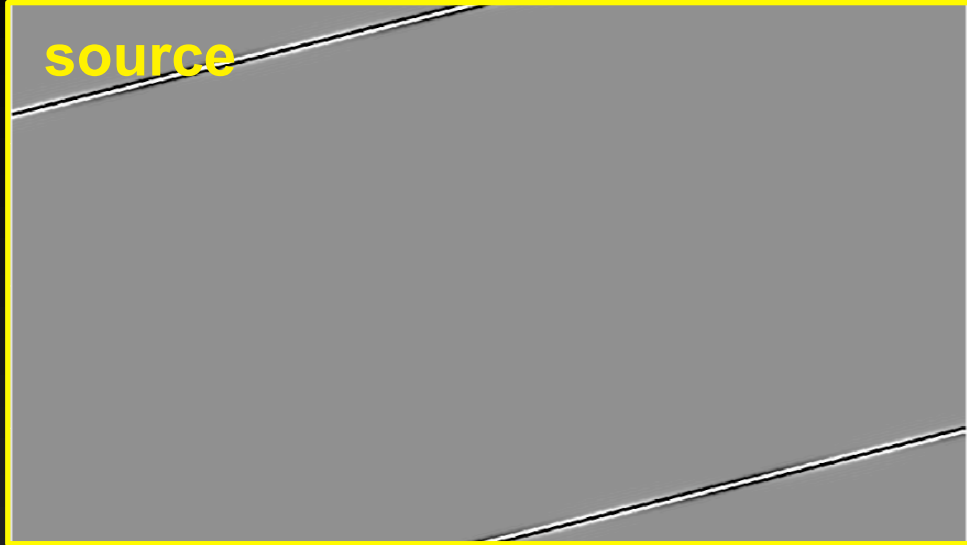
Data-space: plane waves



distance

source

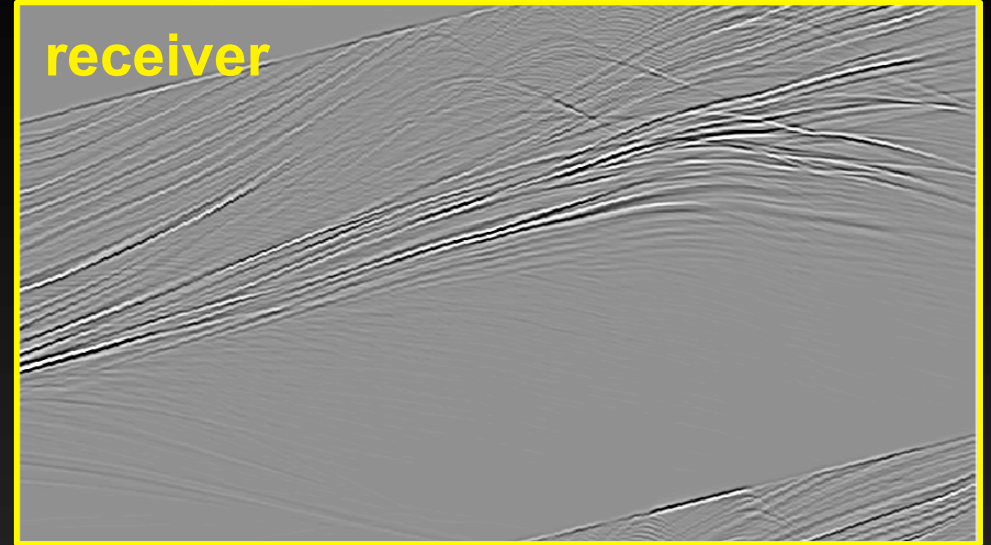
time



distance

receiver

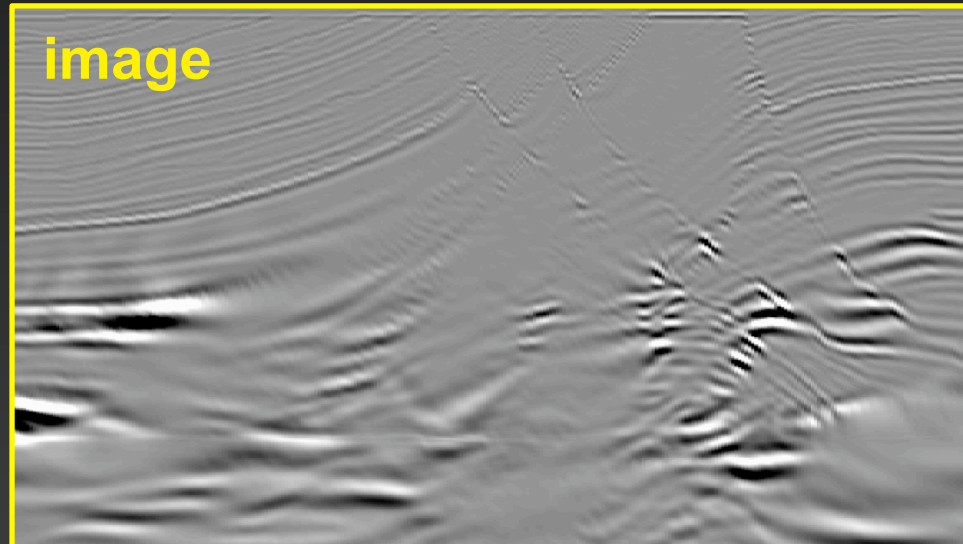
time



distance

image

depth

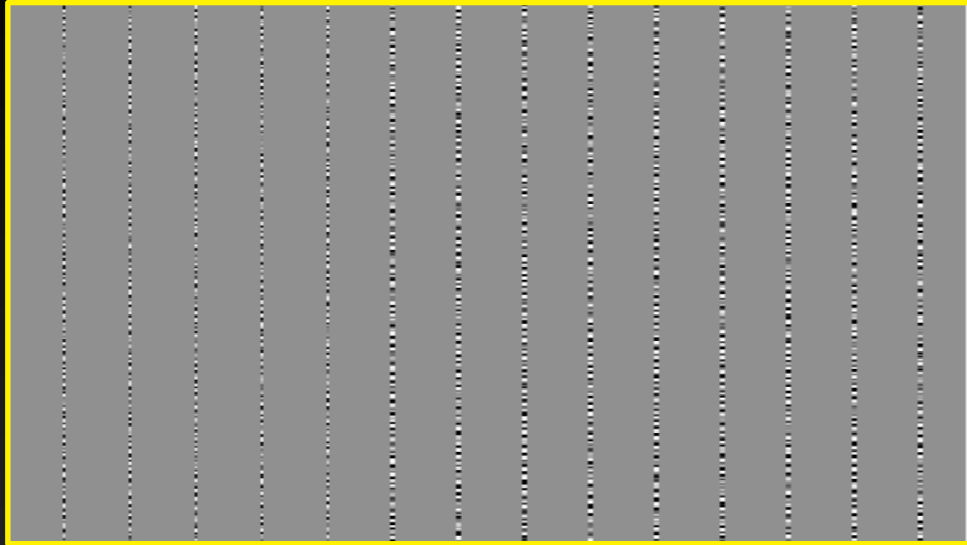


Data-space: random phases



source

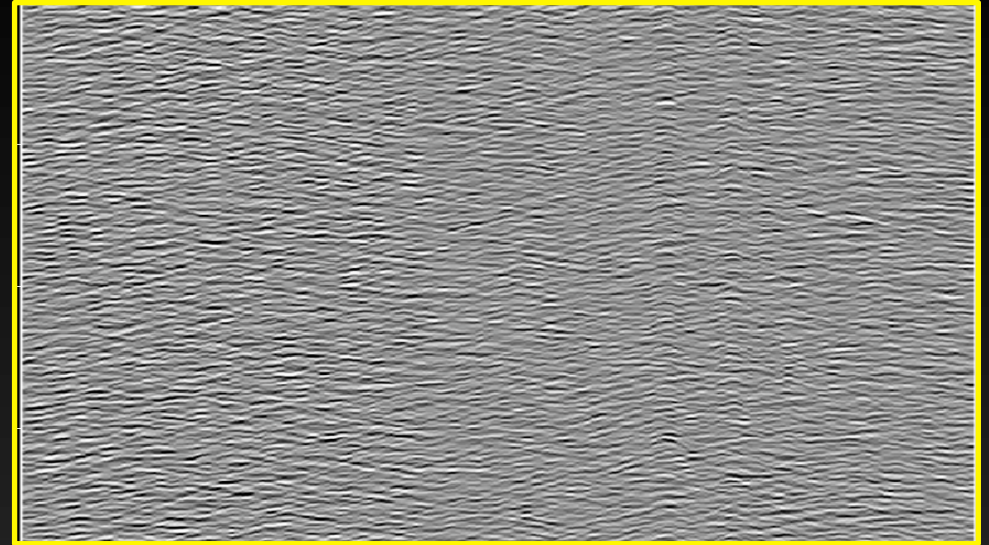
time



distance

receiver

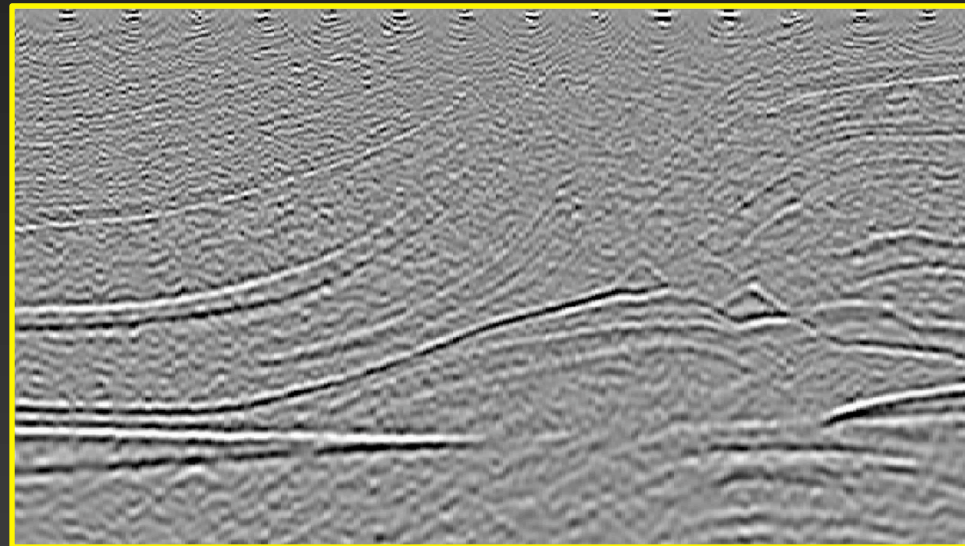
time



distance

image

depth



distance

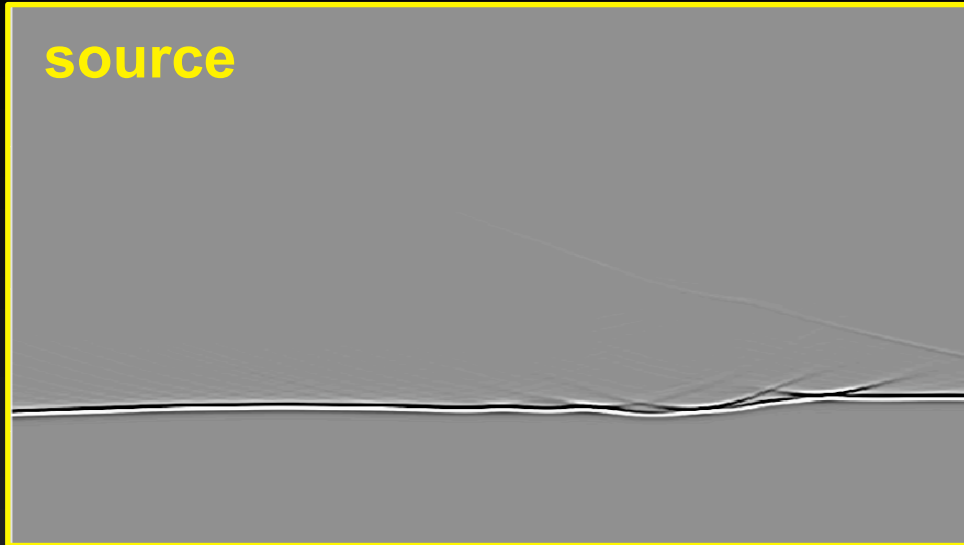
Data-space: controlled illumination



distance

source

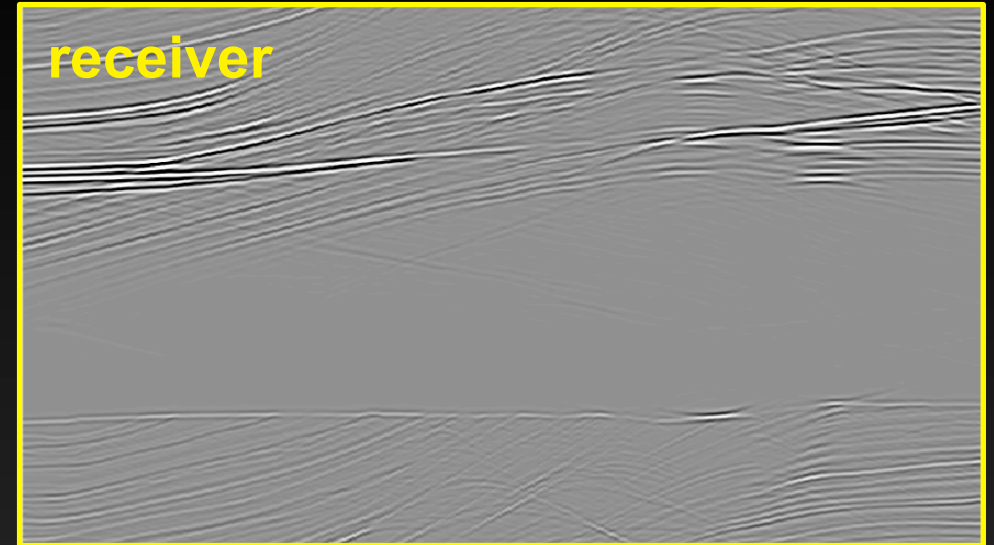
time



distance

receiver

time



distance

image

depth

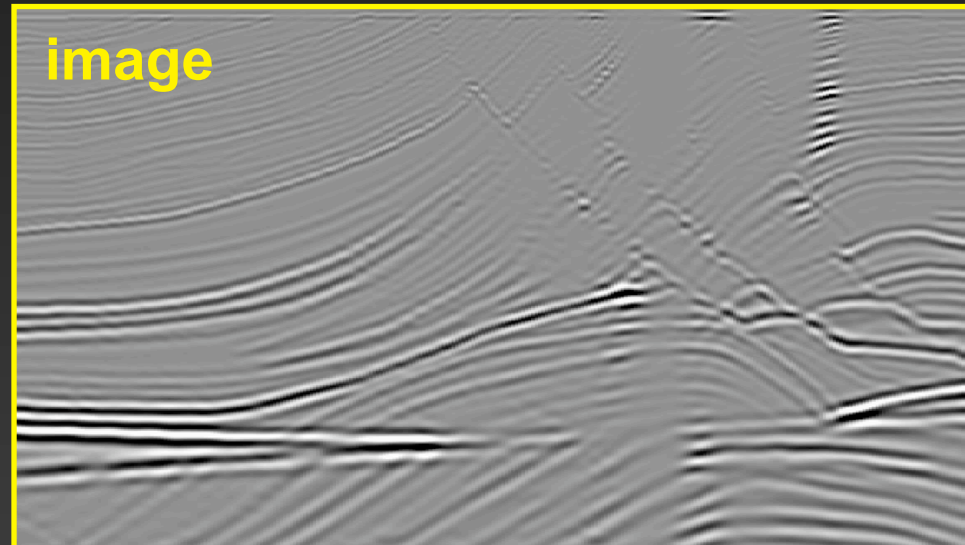


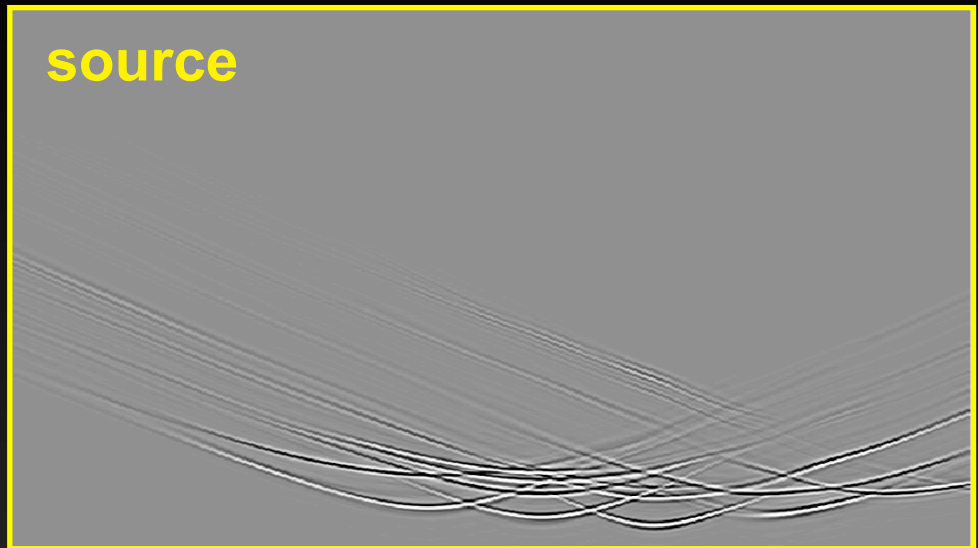
Image-space: prestack-exploding reflector



distance

source

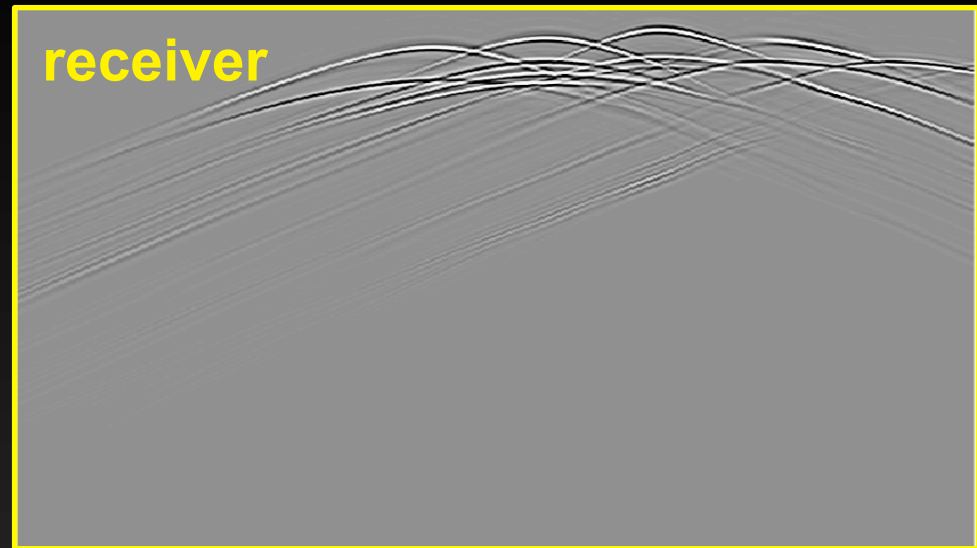
time



distance

receiver

time



distance

image

depth

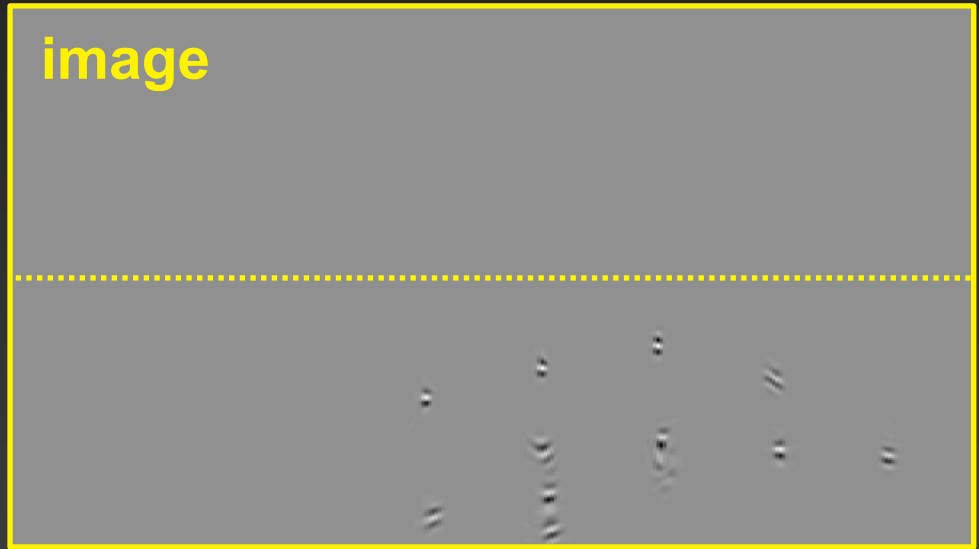


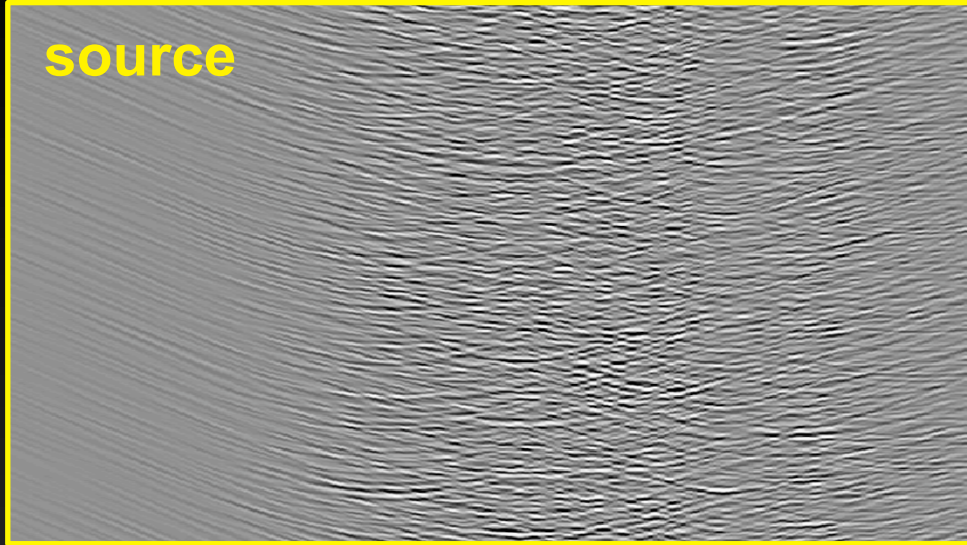
Image-space: random phases (ISPEW)



distance

source

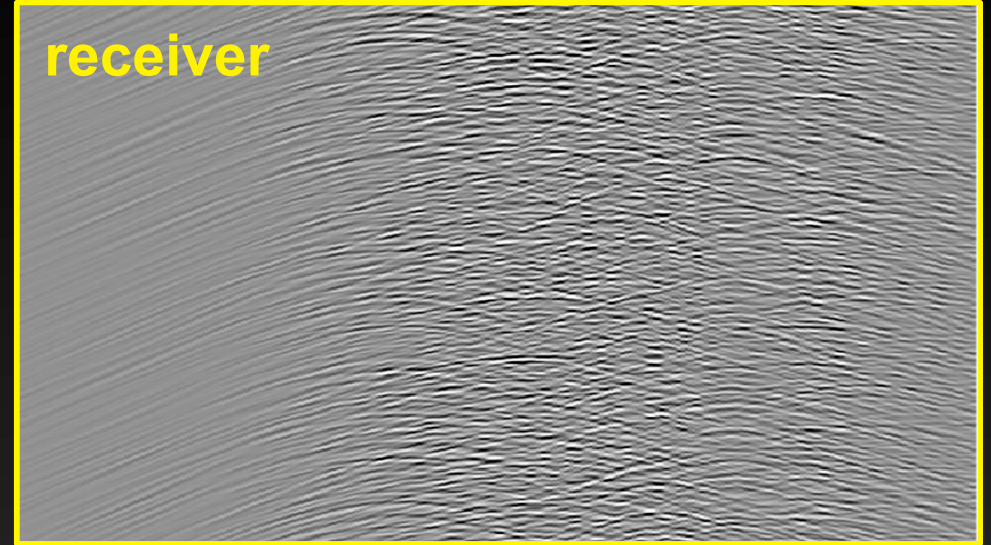
time



distance

receiver

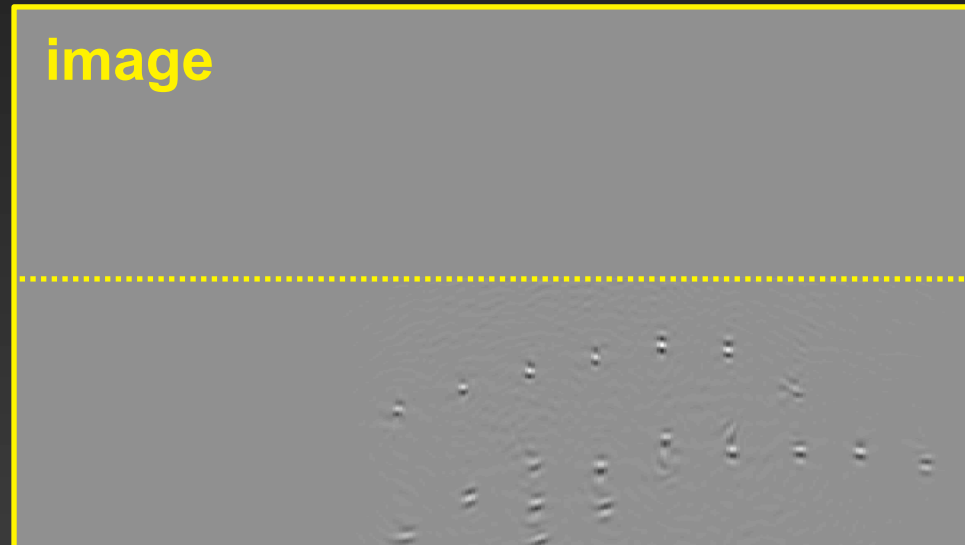
time

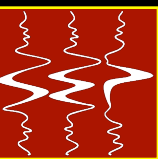


distance

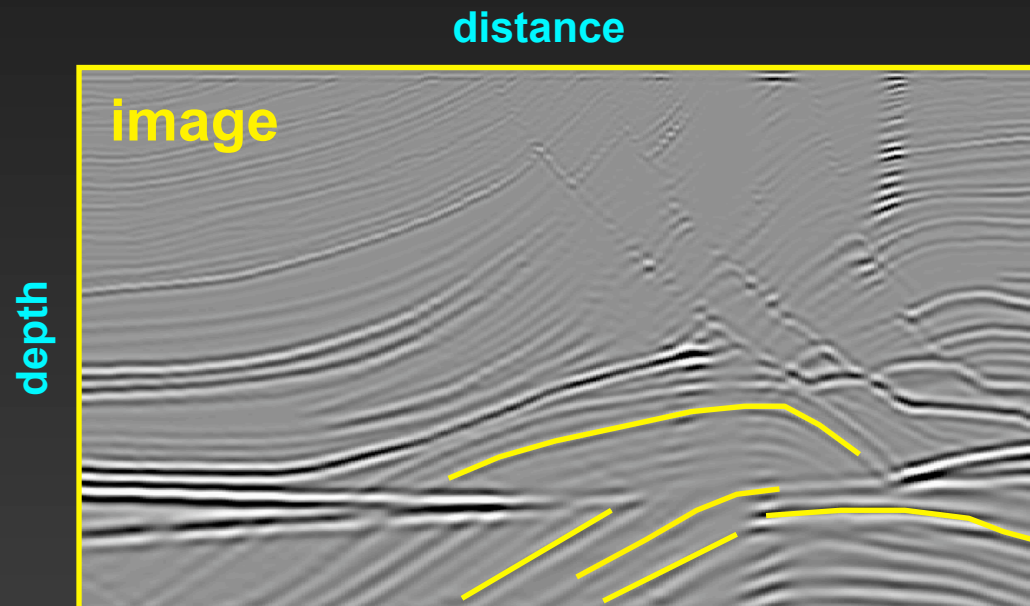
image

depth

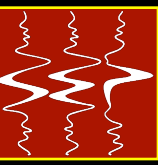




- Models wavefields from selected reflectors



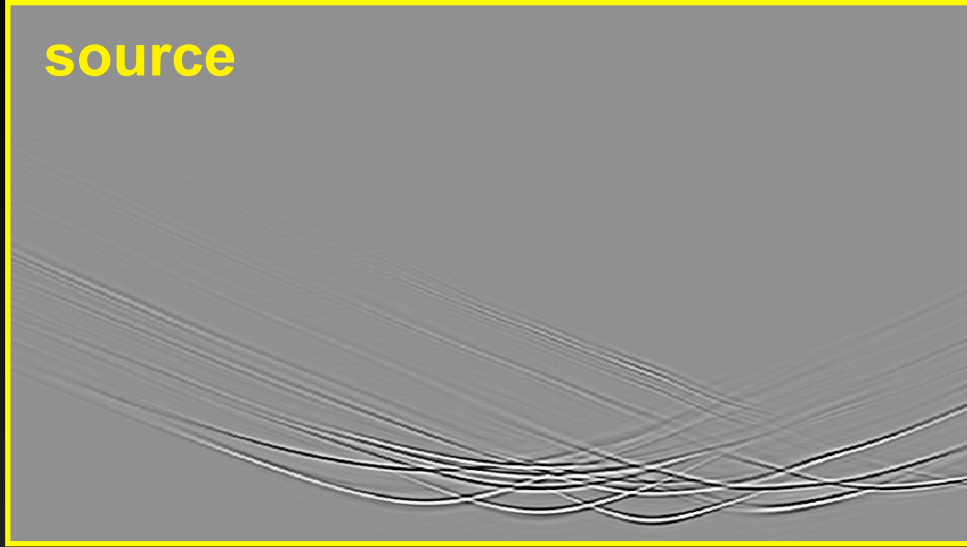
PERM



distance

source

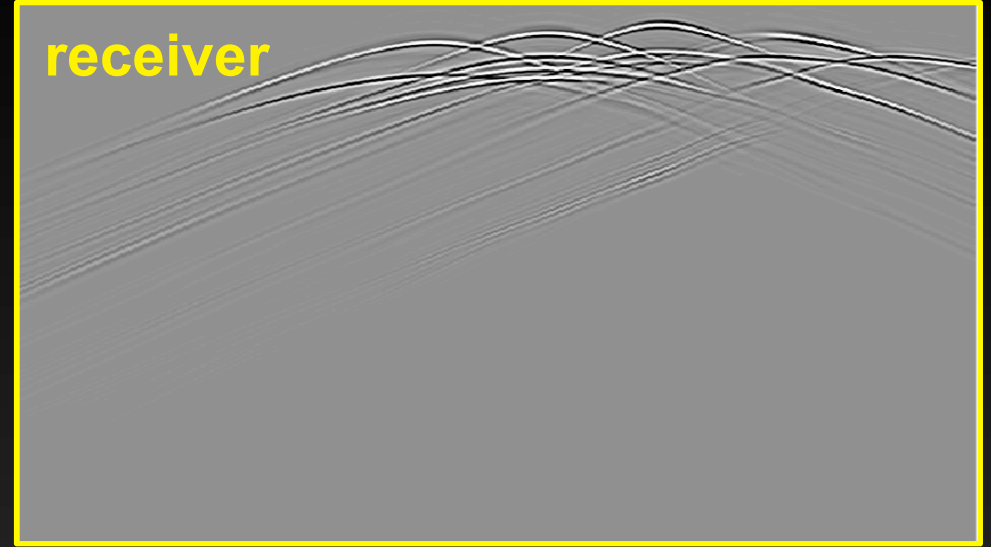
time



distance

receiver

time

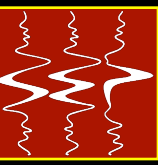


distance

image

depth

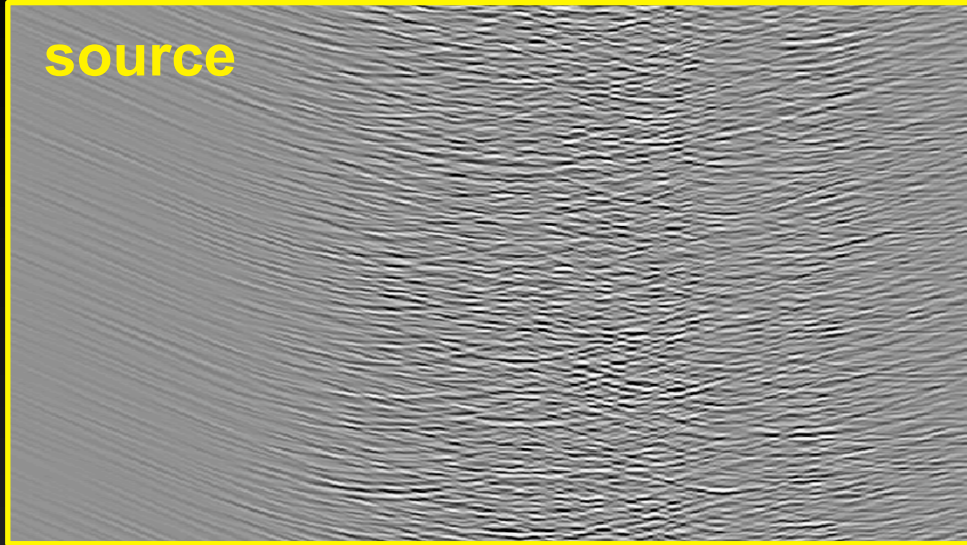




distance

source

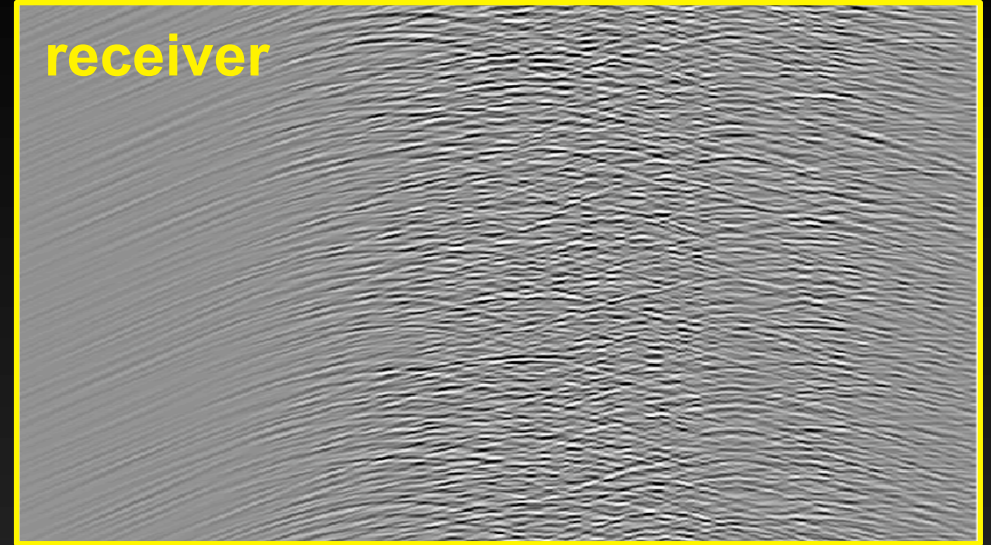
time



distance

receiver

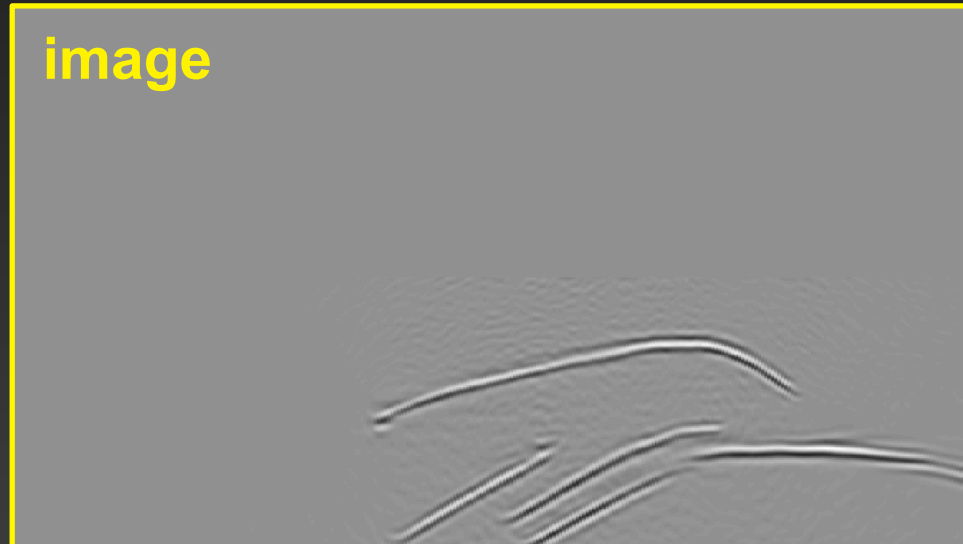
time



distance

image

depth





$$I(s) = \mathbf{F}[s]$$

s = slowness

I = image



$$I(\mathbf{s}) = \mathbf{F}[\mathbf{s}]$$
$$I(\mathbf{s}) \approx I_o + \left. \frac{\partial I}{\partial \mathbf{s}} \right|_{\mathbf{s}=\mathbf{s}_o} \Delta \mathbf{s}$$

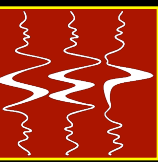
s = slowness

s_o = background slowness

Δs = slowness perturbation

I = image

I_o = background image



$$I(s) \approx I_o + \left. \frac{\partial I}{\partial s} \right|_{s=s_o} \Delta s$$
$$\Delta I(s) = \mathbf{T} \Delta s$$

s = slowness

s_o = background slowness

Δs = slowness perturbation

\mathbf{T} = IS – tomographic operator

I = image

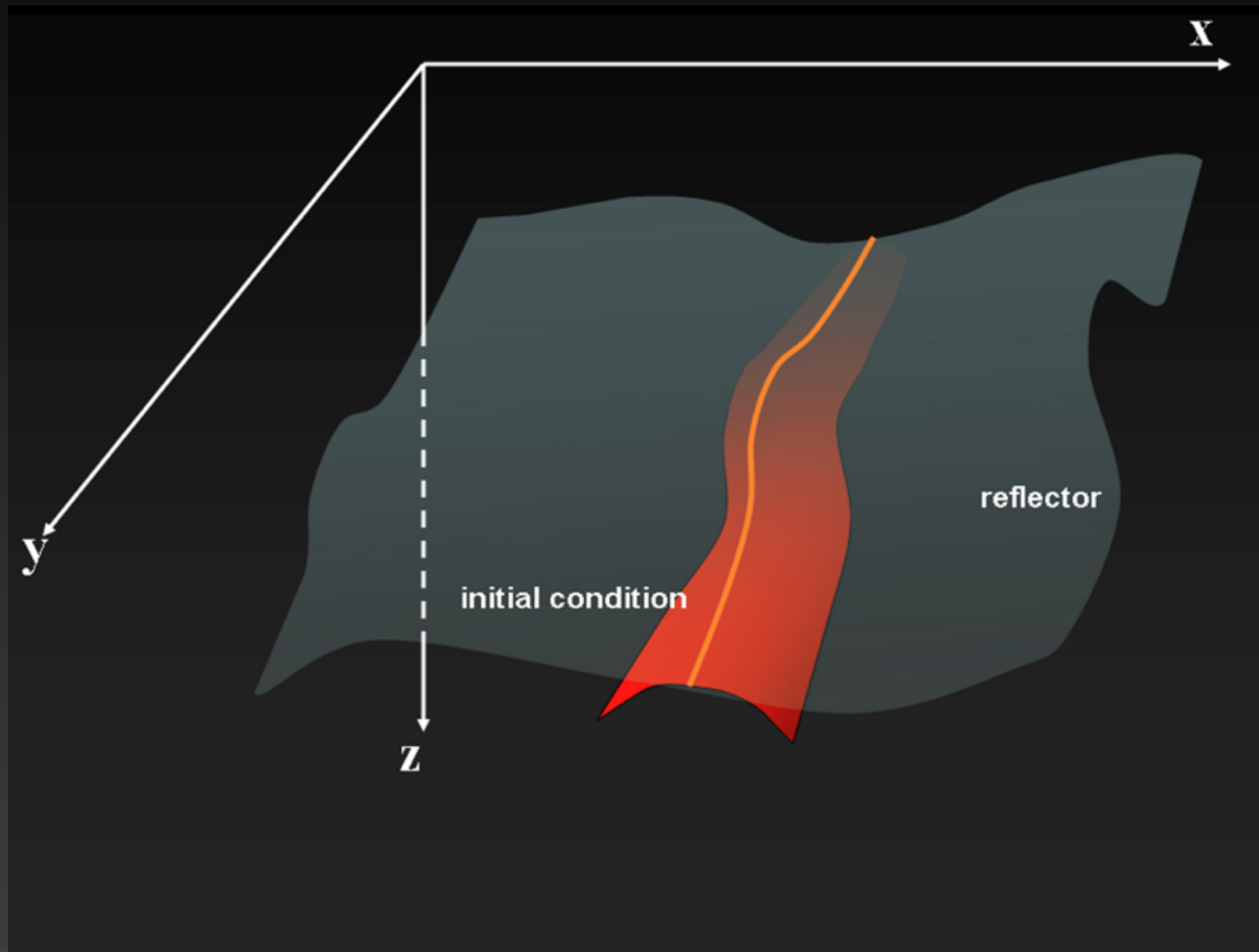
I_o = background image

ΔI = image perturbation

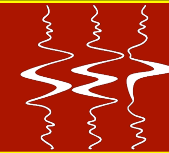
Using Common-azimuth migrated images



- **Less than 100 PERM wavefields**
 - **Only inline subsurface-offsets are computed**

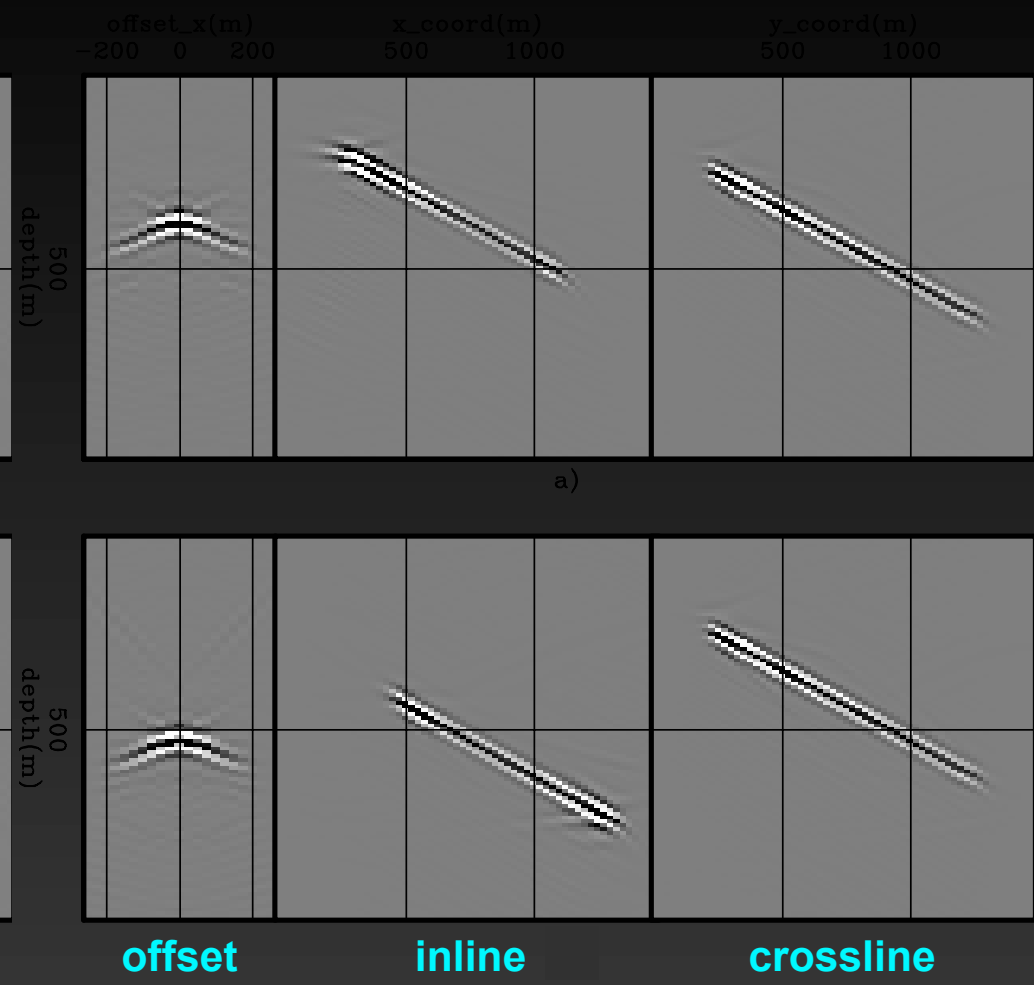
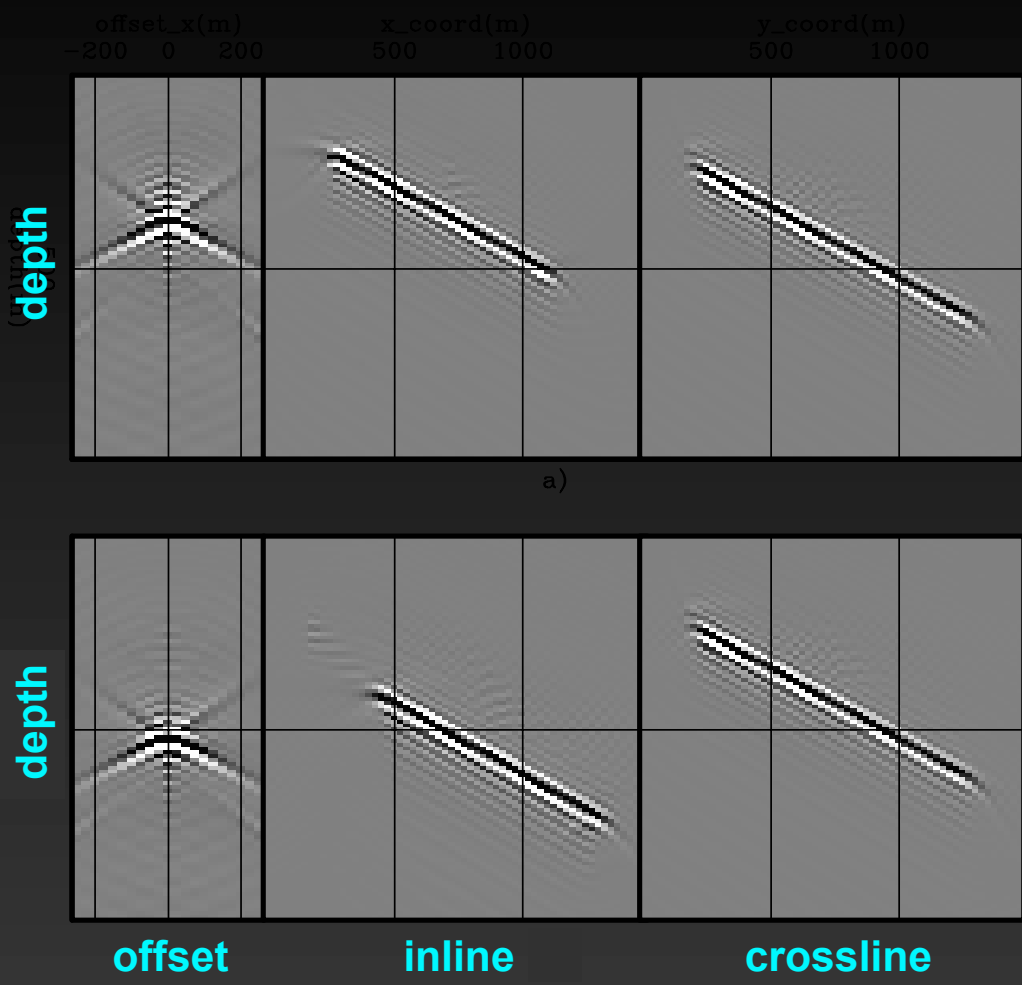


Using CAM images as the initial conditions



CAM

PERM

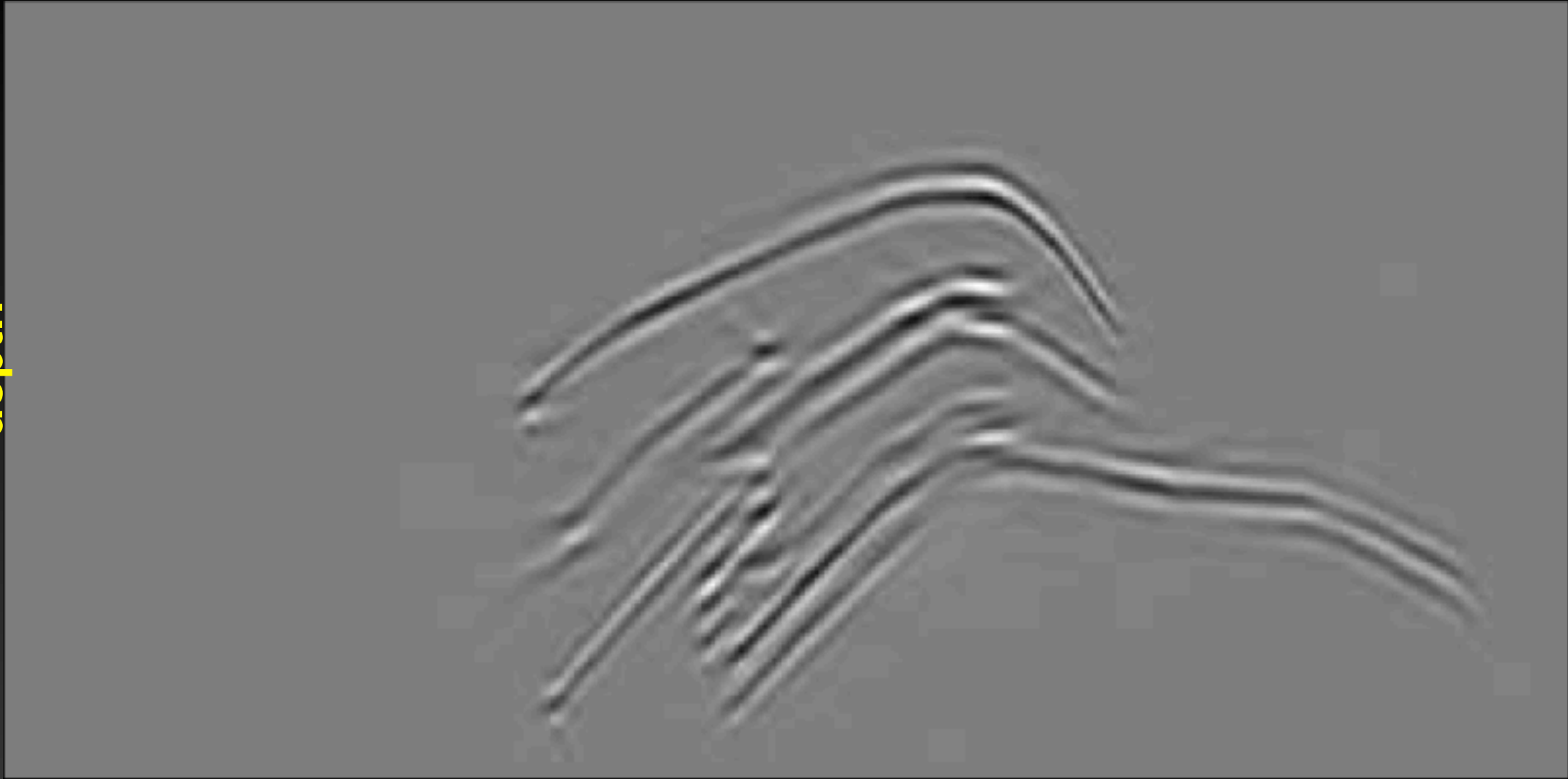


35 PERM migrated image



distance

depth





Source wavefield

$$\begin{cases} \left(\frac{\partial}{\partial z} - i\Lambda \right) \tilde{P}_d(\mathbf{x}, \mathbf{r}_m, \omega) & = \tilde{I}_d(\mathbf{x}, \mathbf{h}, \mathbf{r}_m, \omega) \\ \tilde{P}_d(x, y, z = z_{\max}, \mathbf{r}_m, \omega) & = 0 \end{cases}$$

Receiver wavefield

$$\begin{cases} \left(\frac{\partial}{\partial z} + i\Lambda \right) \tilde{P}_u(\mathbf{x}, \mathbf{r}_m, \omega) & = \tilde{I}_u(\mathbf{x}, \mathbf{h}, \mathbf{r}_m, \omega) \\ \tilde{P}_u(x, y, z = z_{\max}, \mathbf{r}_m, \omega) & = 0 \end{cases}$$

Λ = SSR operator

\tilde{P}_d = phase encoded source wavefield

\tilde{I}_d = source wavefield initial condition

\mathbf{r}_m = index of random realizations

\tilde{P}_u = phase encoded receiver wavefield

\tilde{I}_u = receiver wavefield initial condition

Image-space phase-encoded wavefields

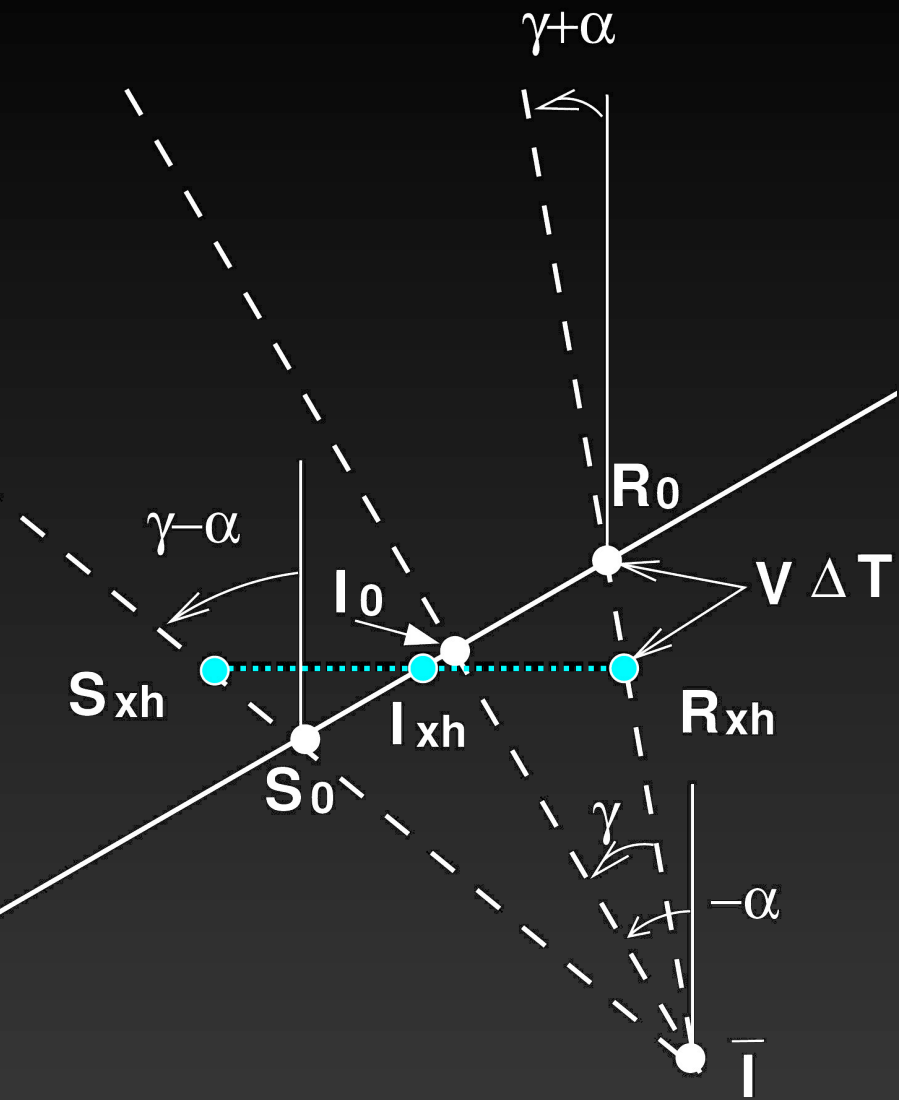
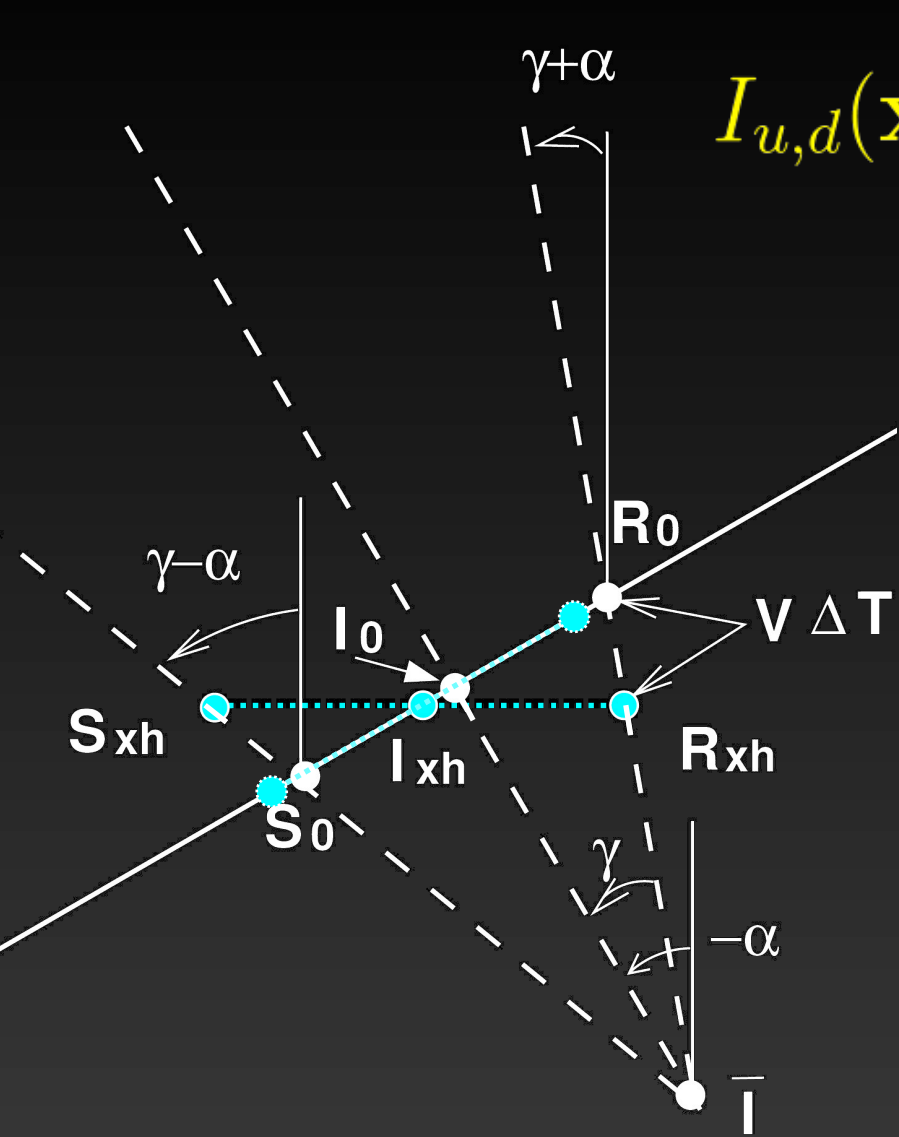


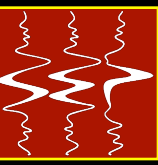
Image-space phase-encoded wavefields



$$I_{u,d}(\mathbf{x}, \mathbf{h}) = \iiint_{\alpha\gamma x'} \varrho I(\mathbf{x}, \mathbf{h}; x') dx' d\gamma d\alpha \Big|_{\zeta}$$

$$\zeta(\alpha, \gamma, \mathbf{h}, x') = z - htg(\gamma) - x'tg(\alpha) \pm htg(\gamma \pm \alpha)$$

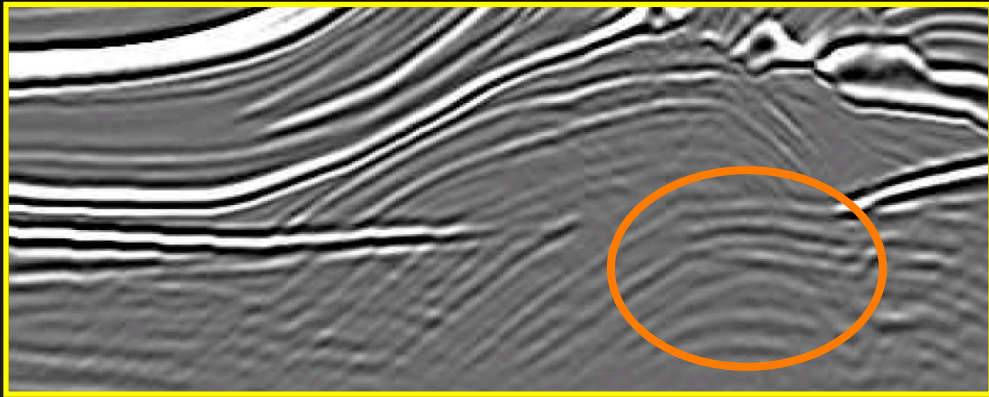
Motivation



Initial

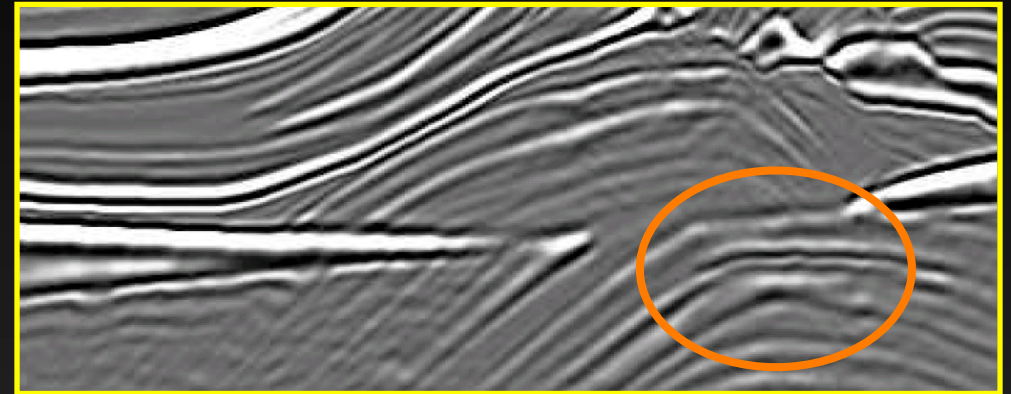
x

z



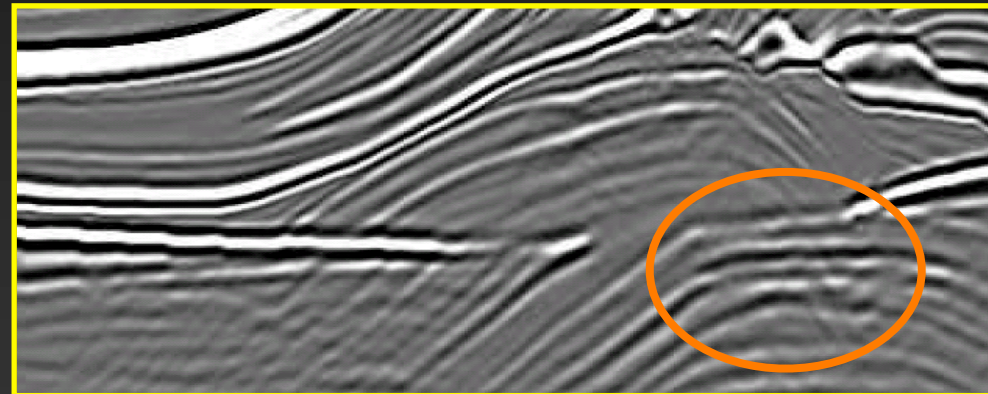
True

x



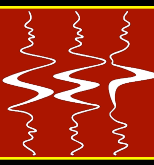
Optimized

z

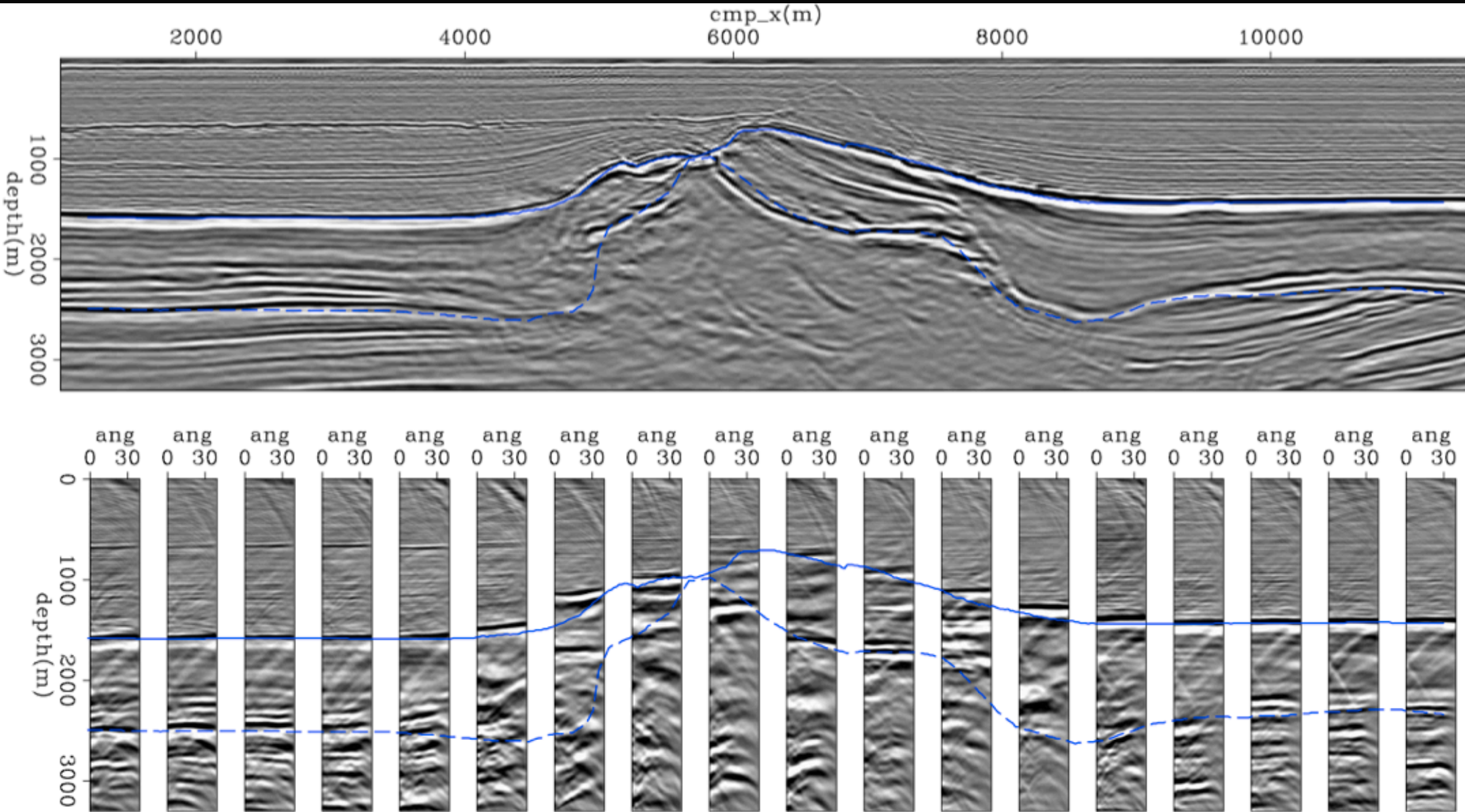


20x faster

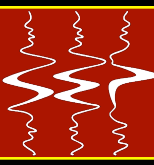
Comparisons: iline = 3200 m



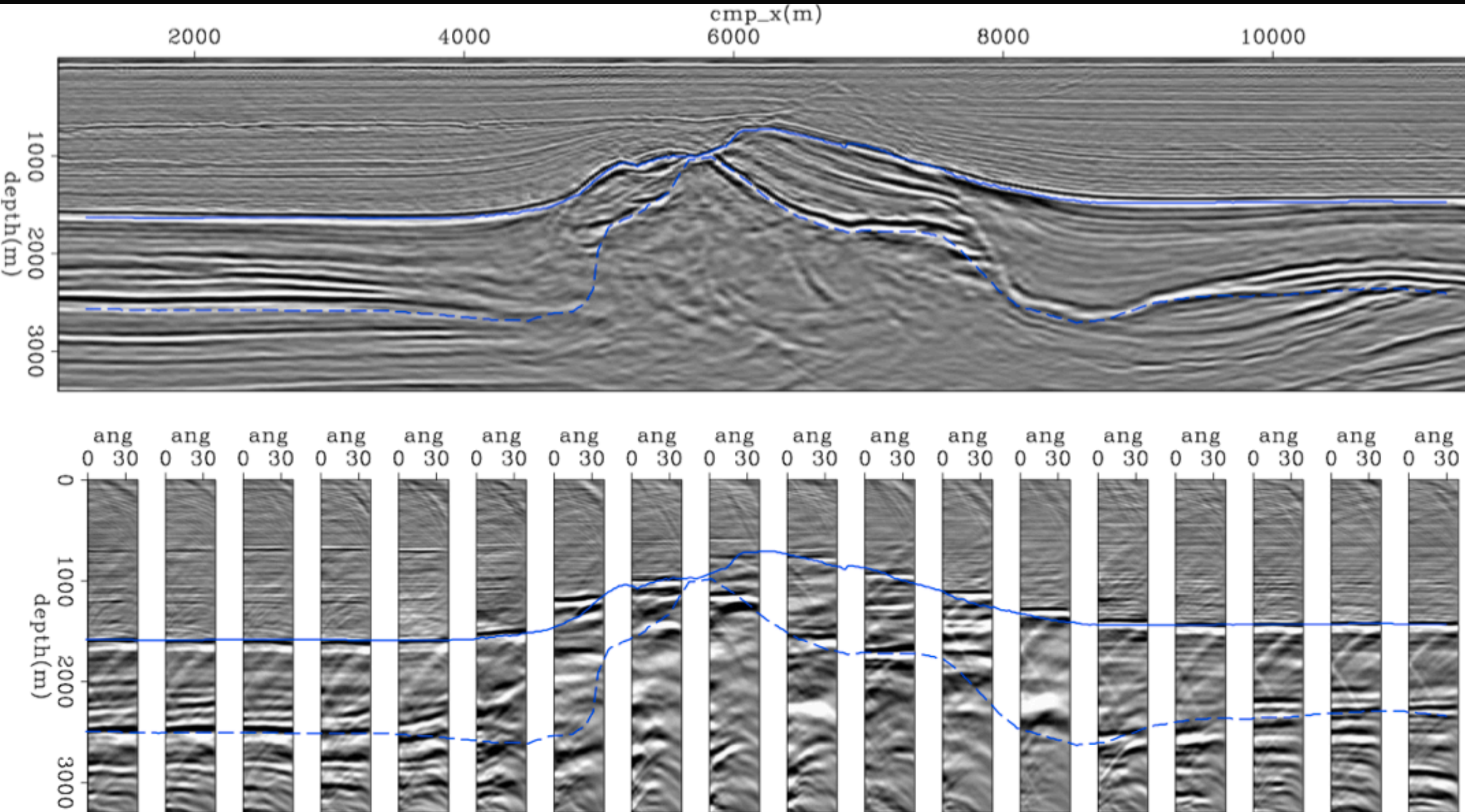
IFP



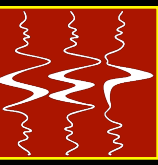
Comparisons: iline = 3200 m



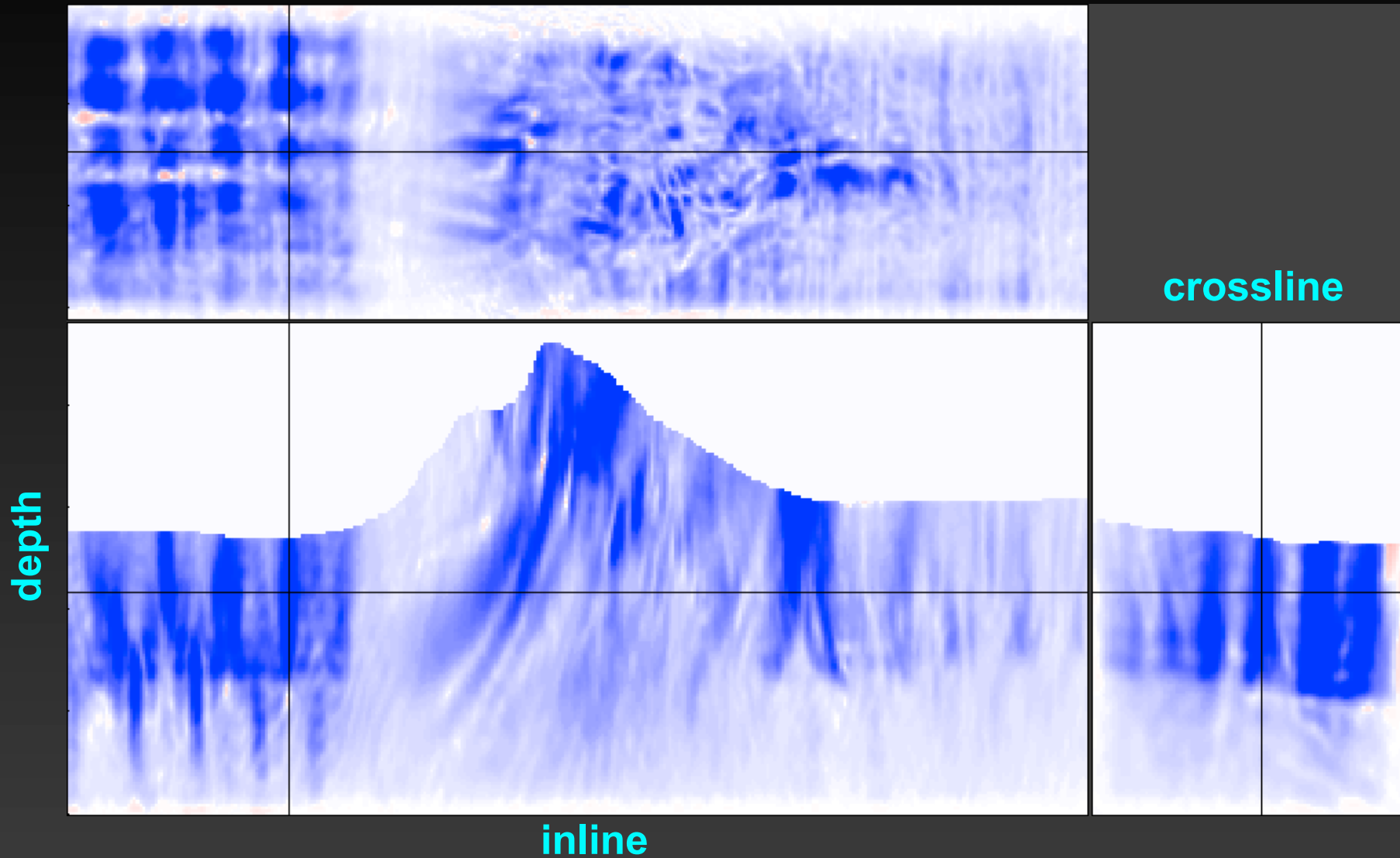
Chalk optimized velocity



Potential for grid-tomography



Gradient with 1 pair of ISPEW

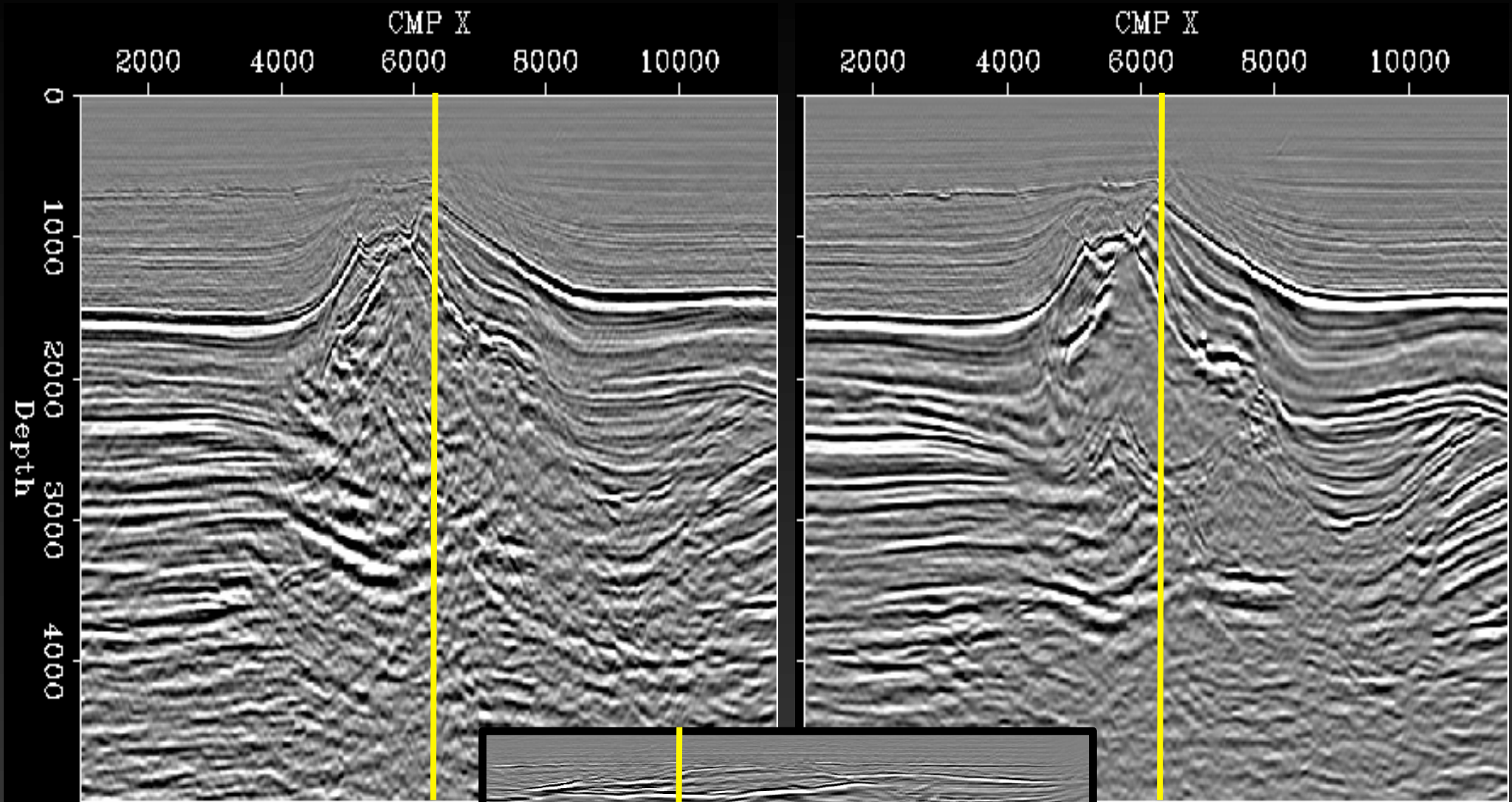


Comparisons: inline = 2900 m



Initial

After salt body

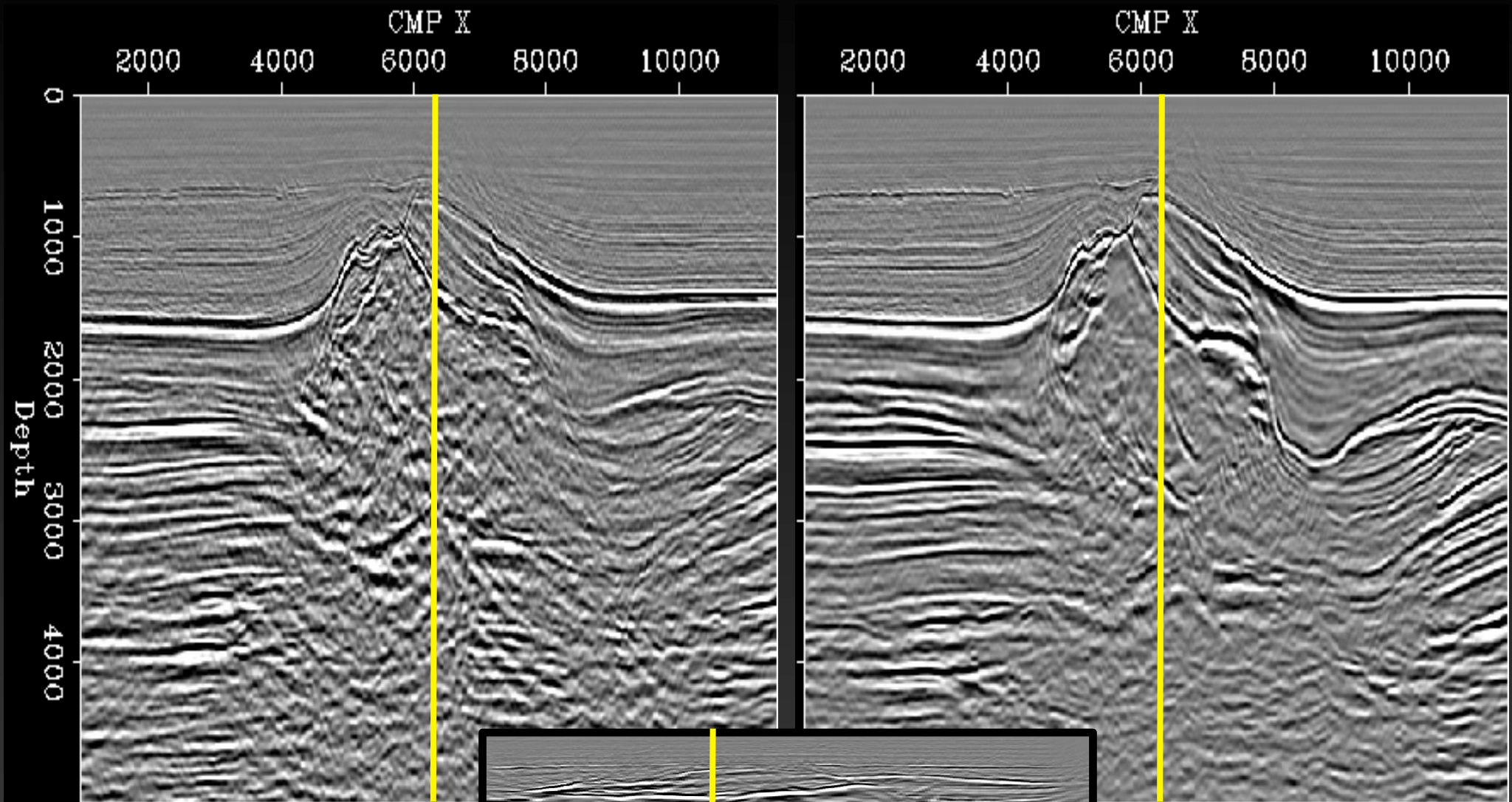


Comparisons: inline = 3200 m



Initial

After salt body

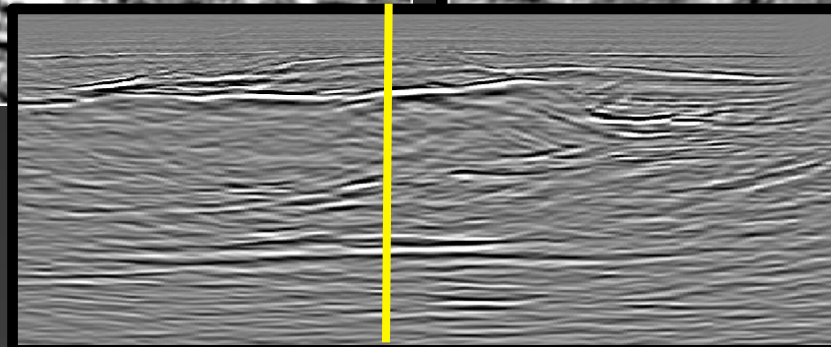
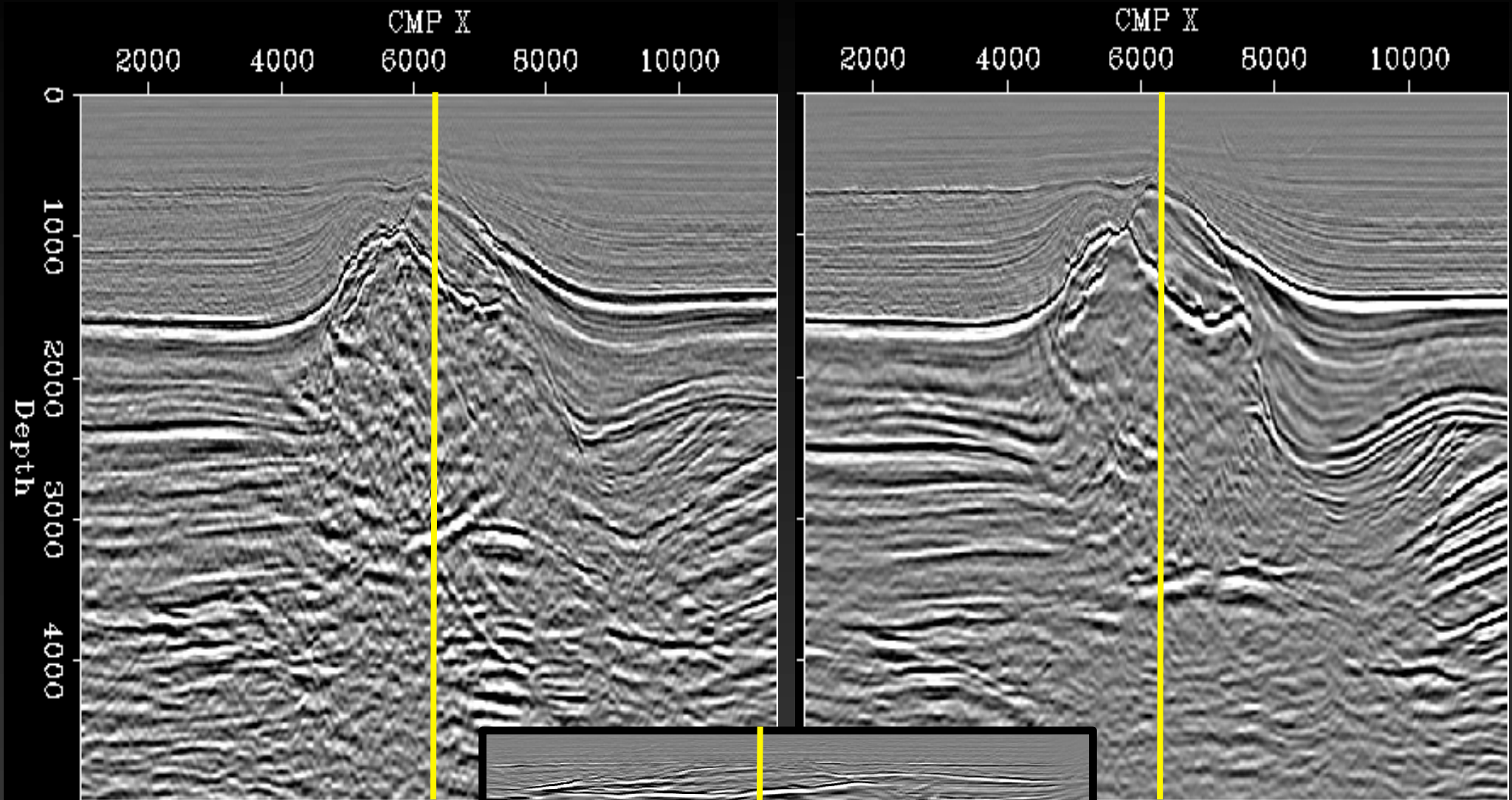


Comparisons: inline = 3500 m

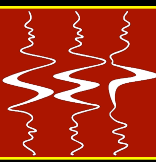


Initial

After salt body

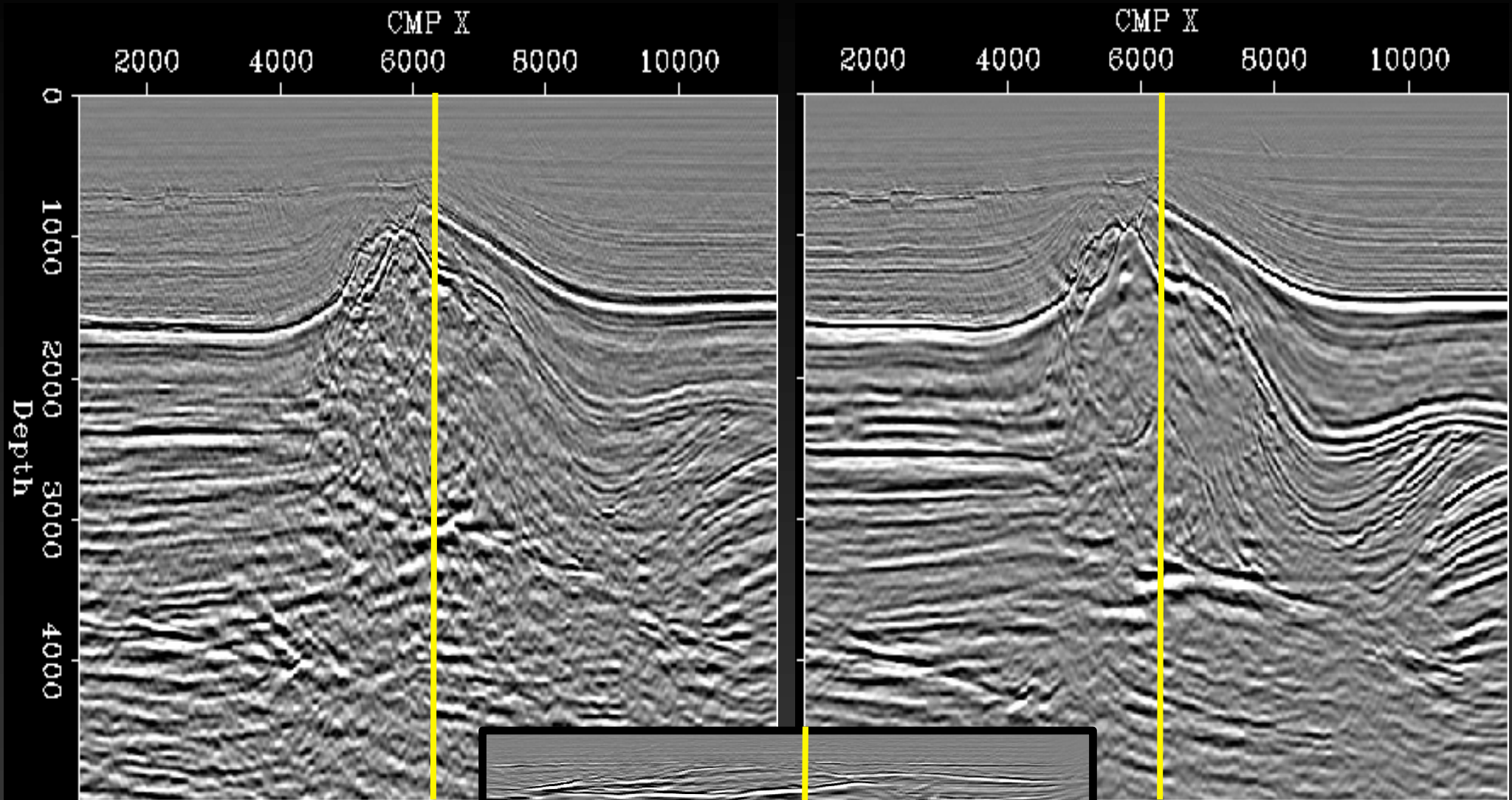


Comparisons: inline = 4000 m

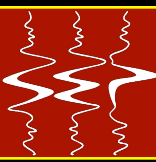


Initial

After salt body

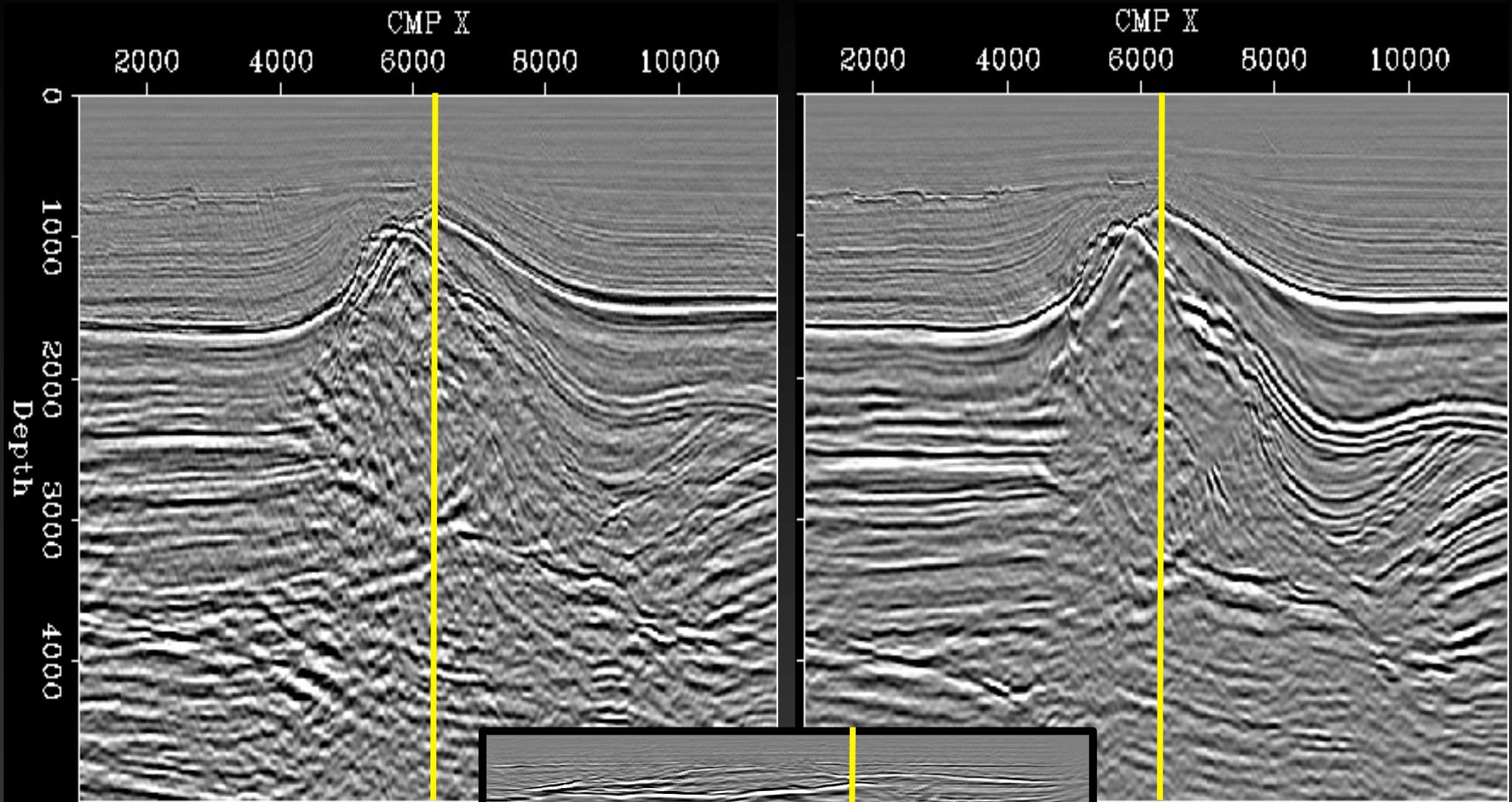


Comparisons: inline = 4200 m



Initial

After salt body

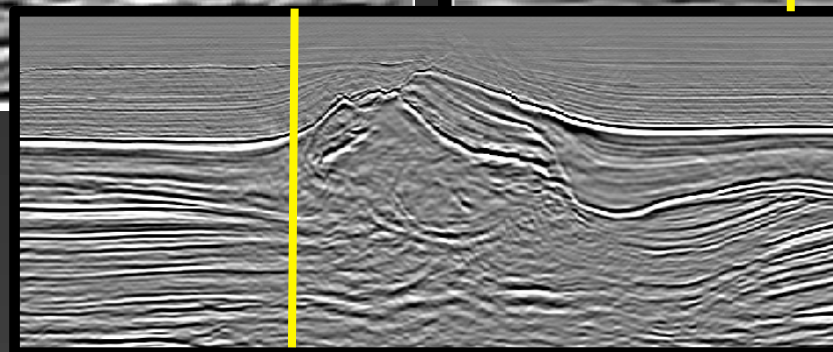
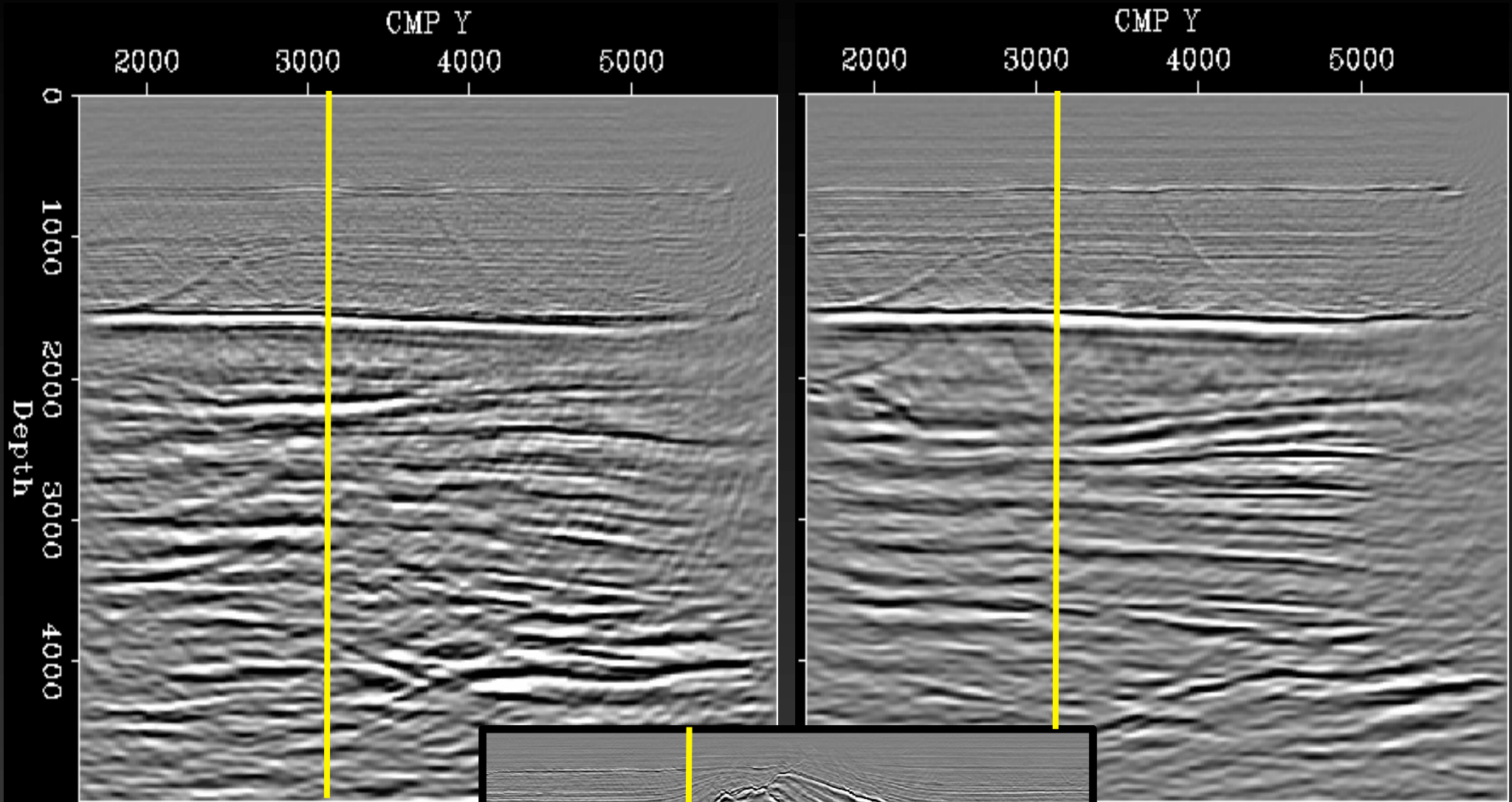


Comparisons: xline = 4400 m



Initial

After salt body

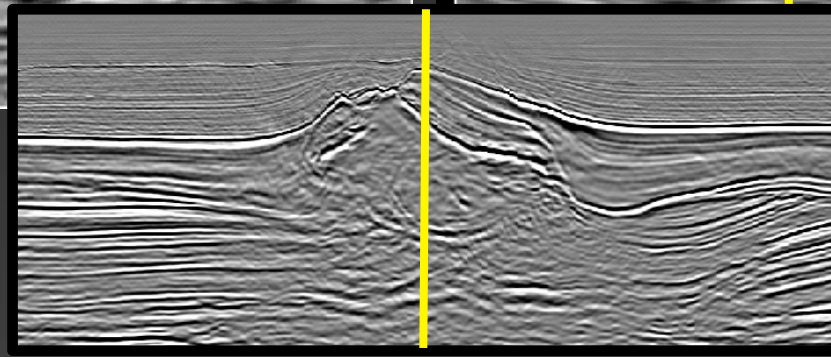
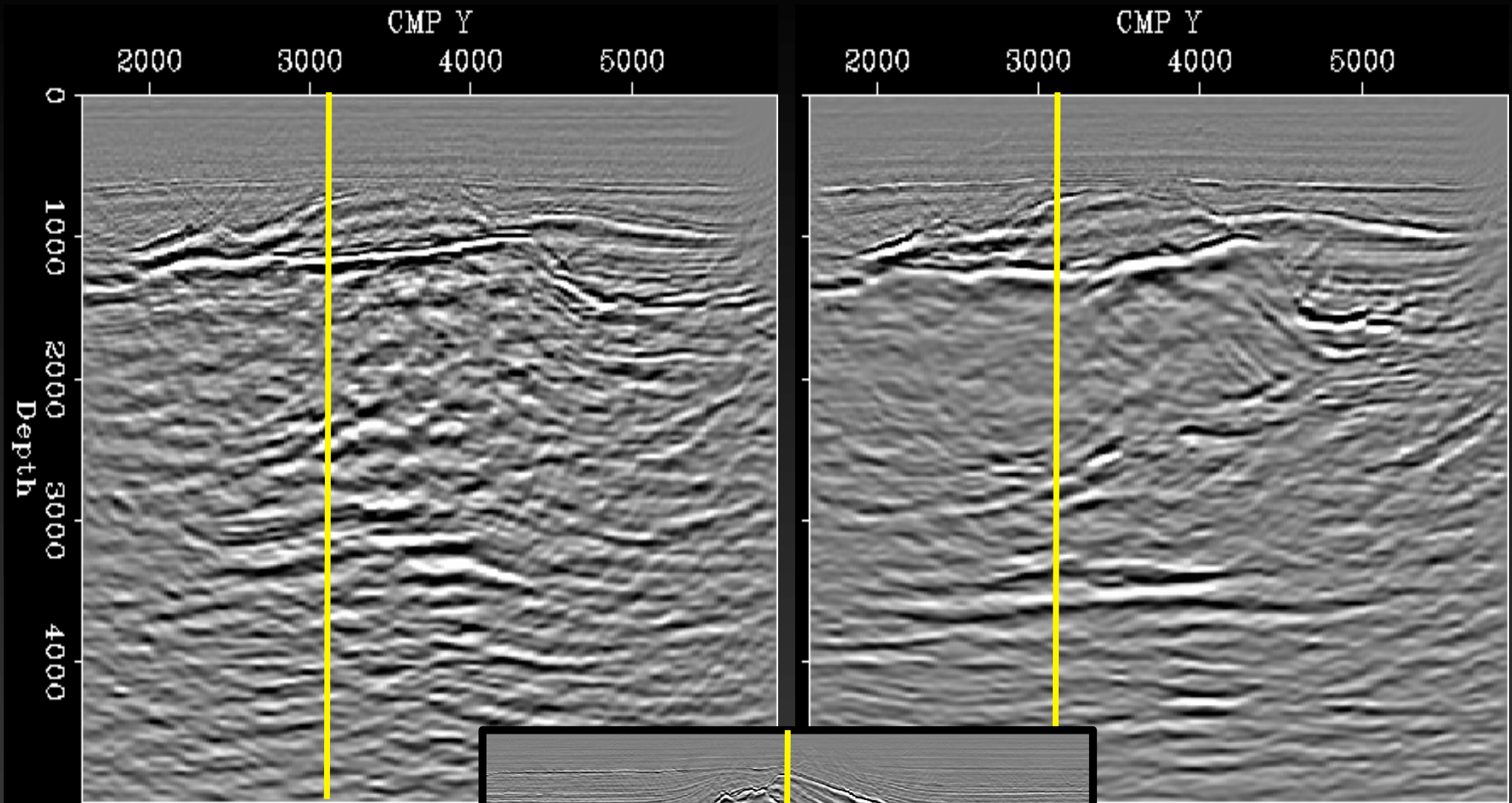


Comparisons: xline = 6100 m



Initial

After salt body

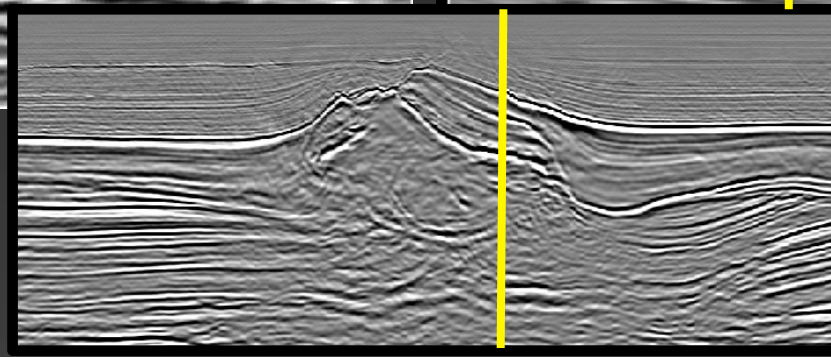
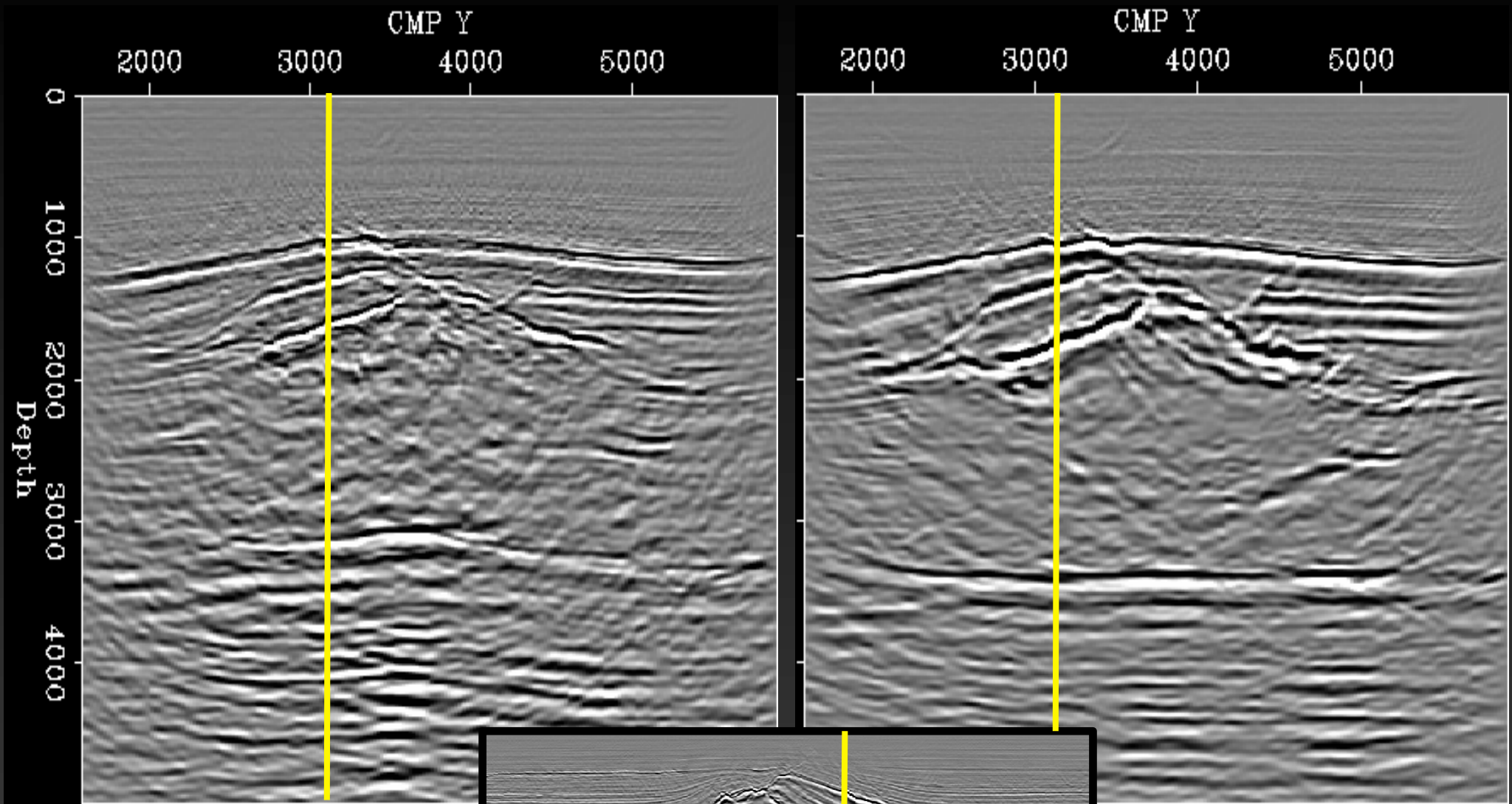


Comparisons: xline = 7300 m



Initial

After salt body

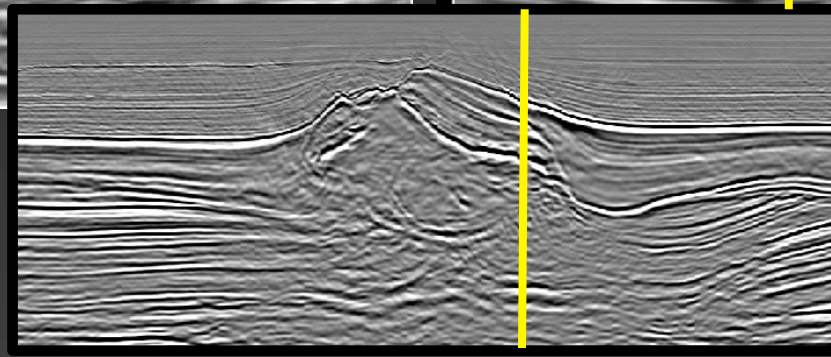
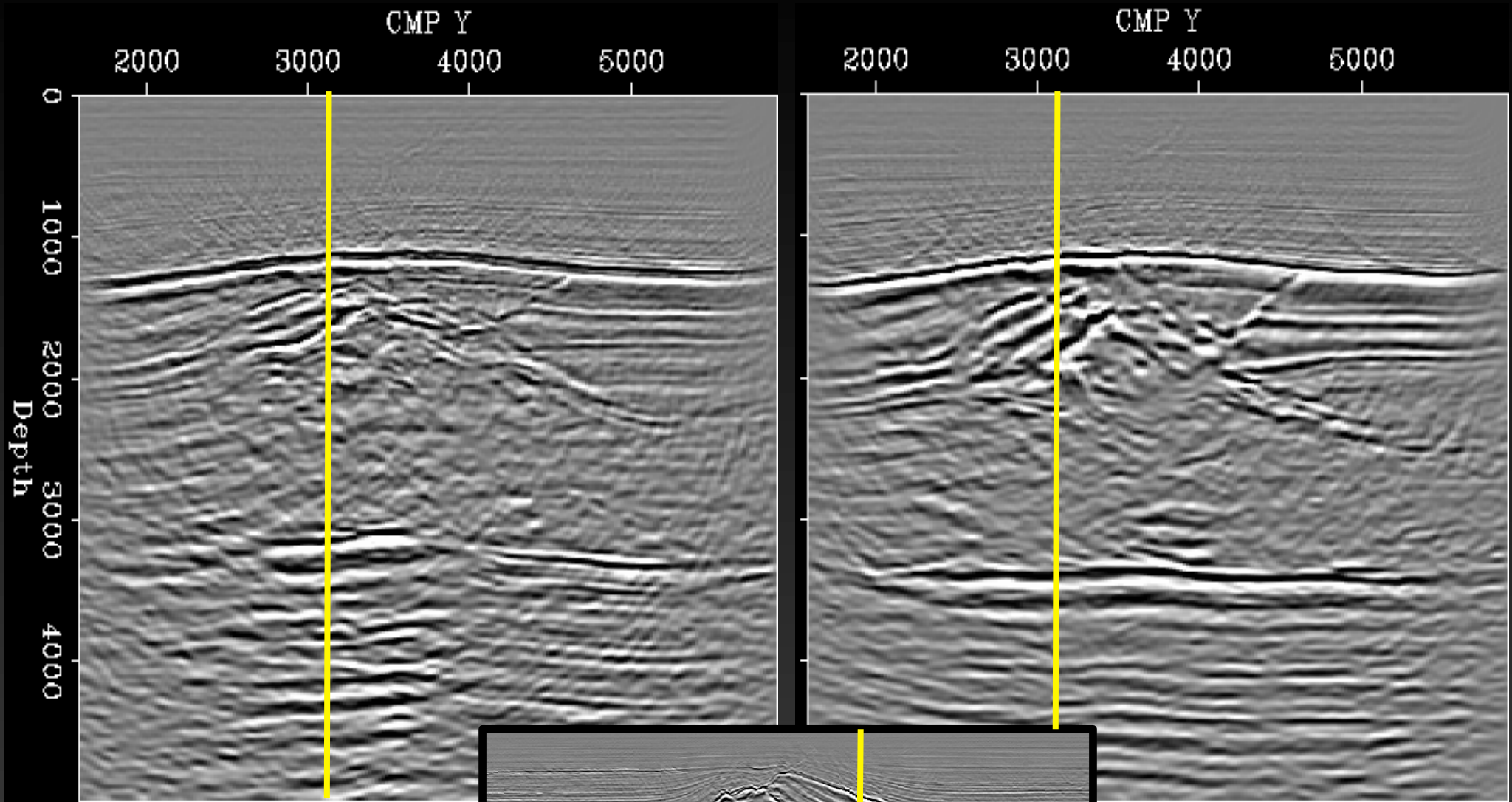


Comparisons: xline = 7600 m



Initial

After salt body

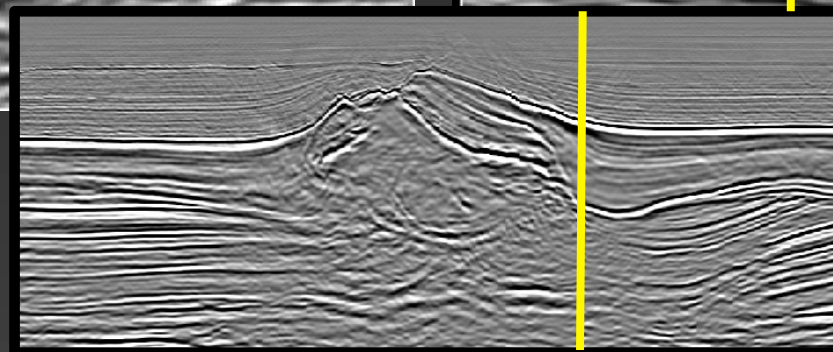
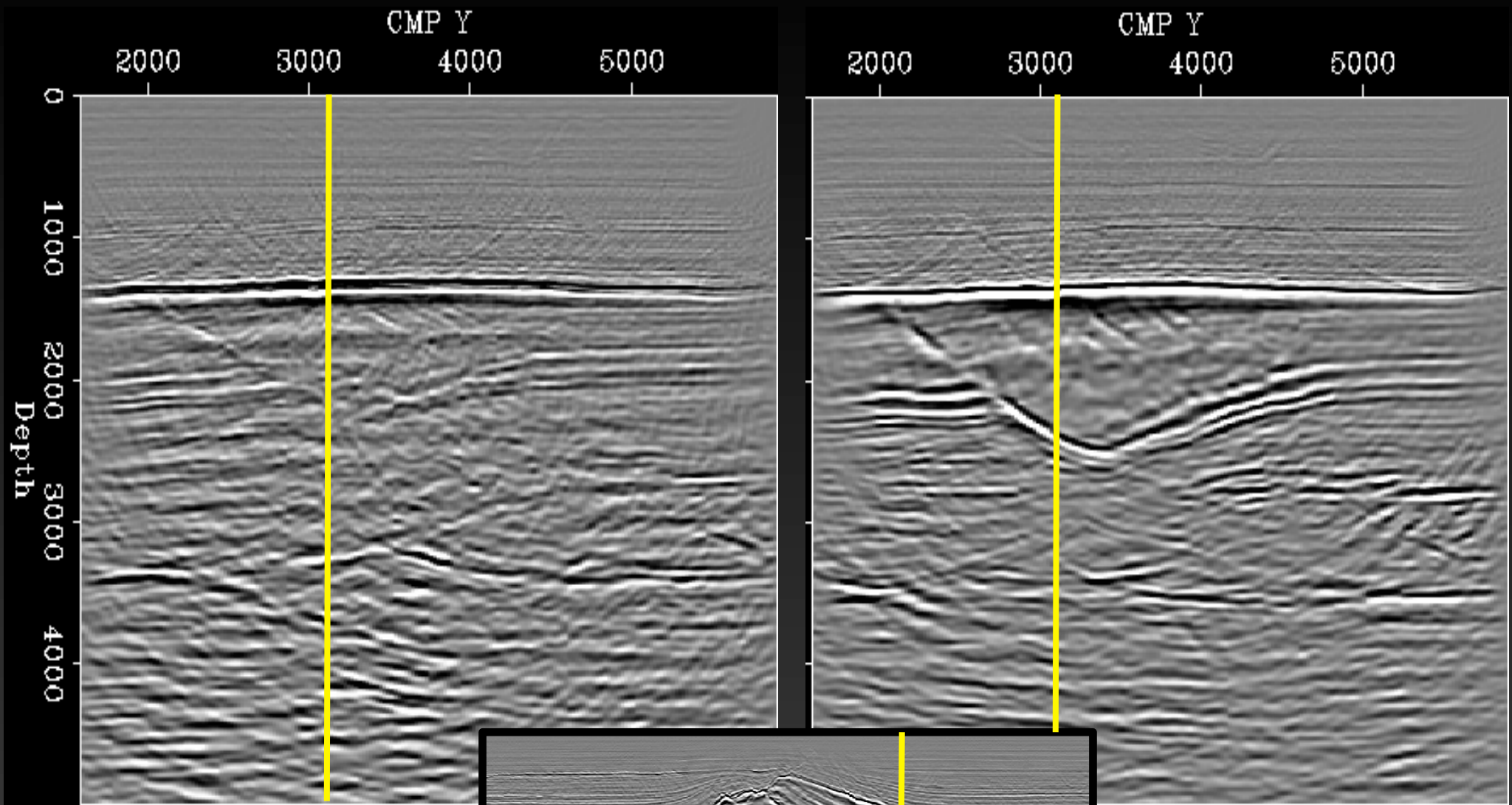


Comparisons: xline = 8200 m



Initial

After salt body

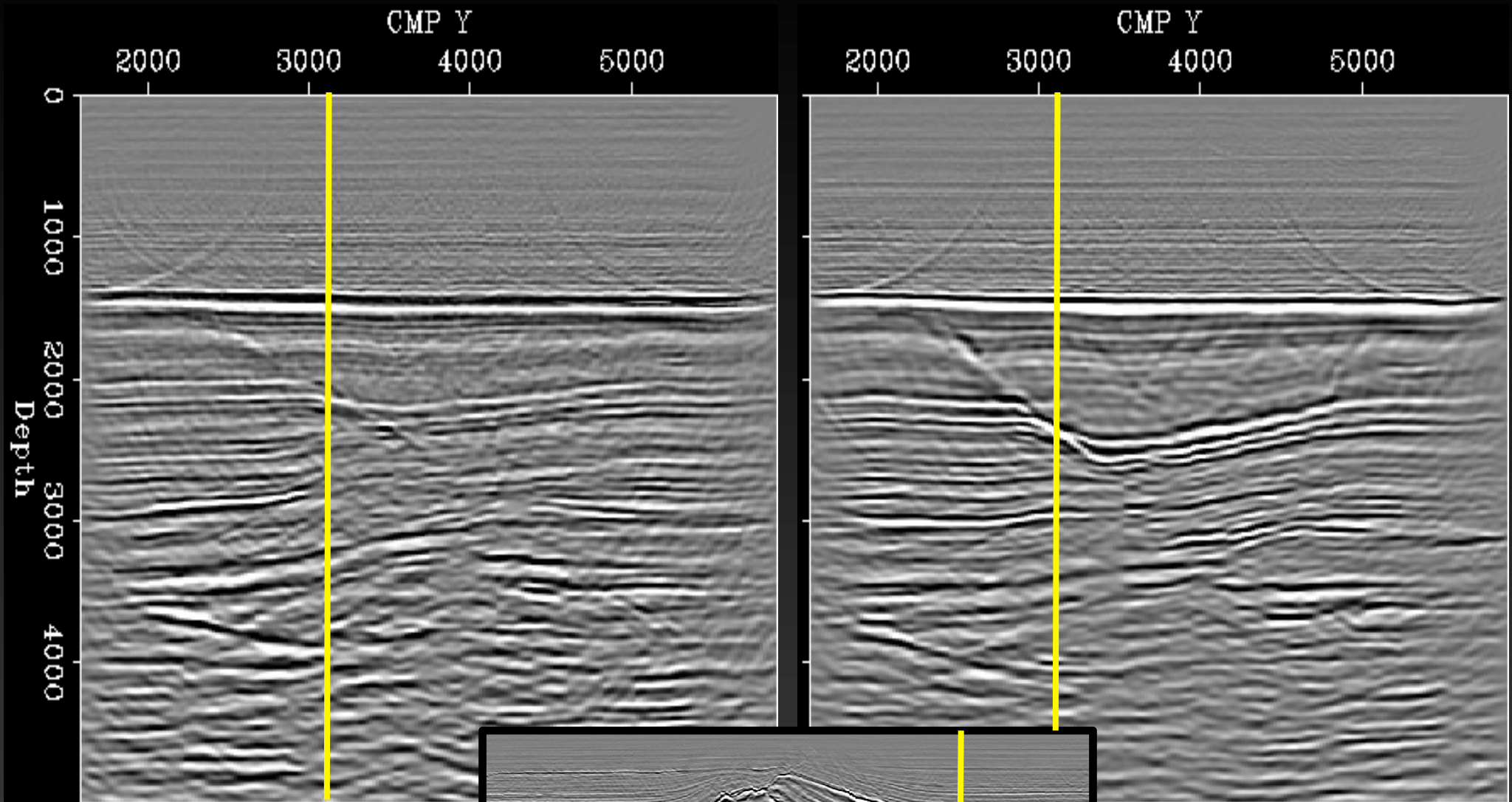


Comparisons: xline = 9300 m

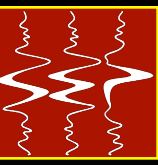


Initial

After salt body

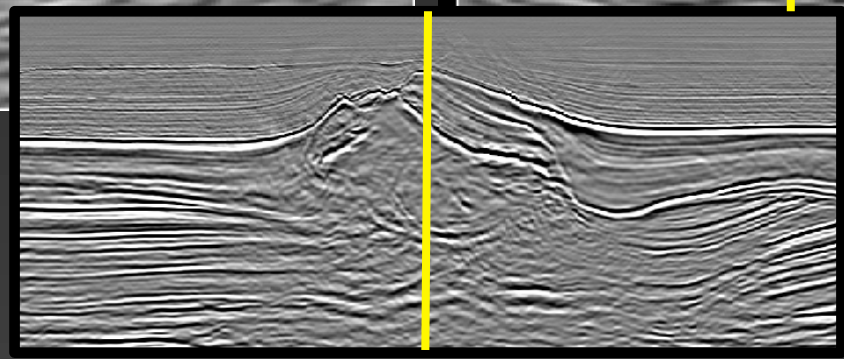
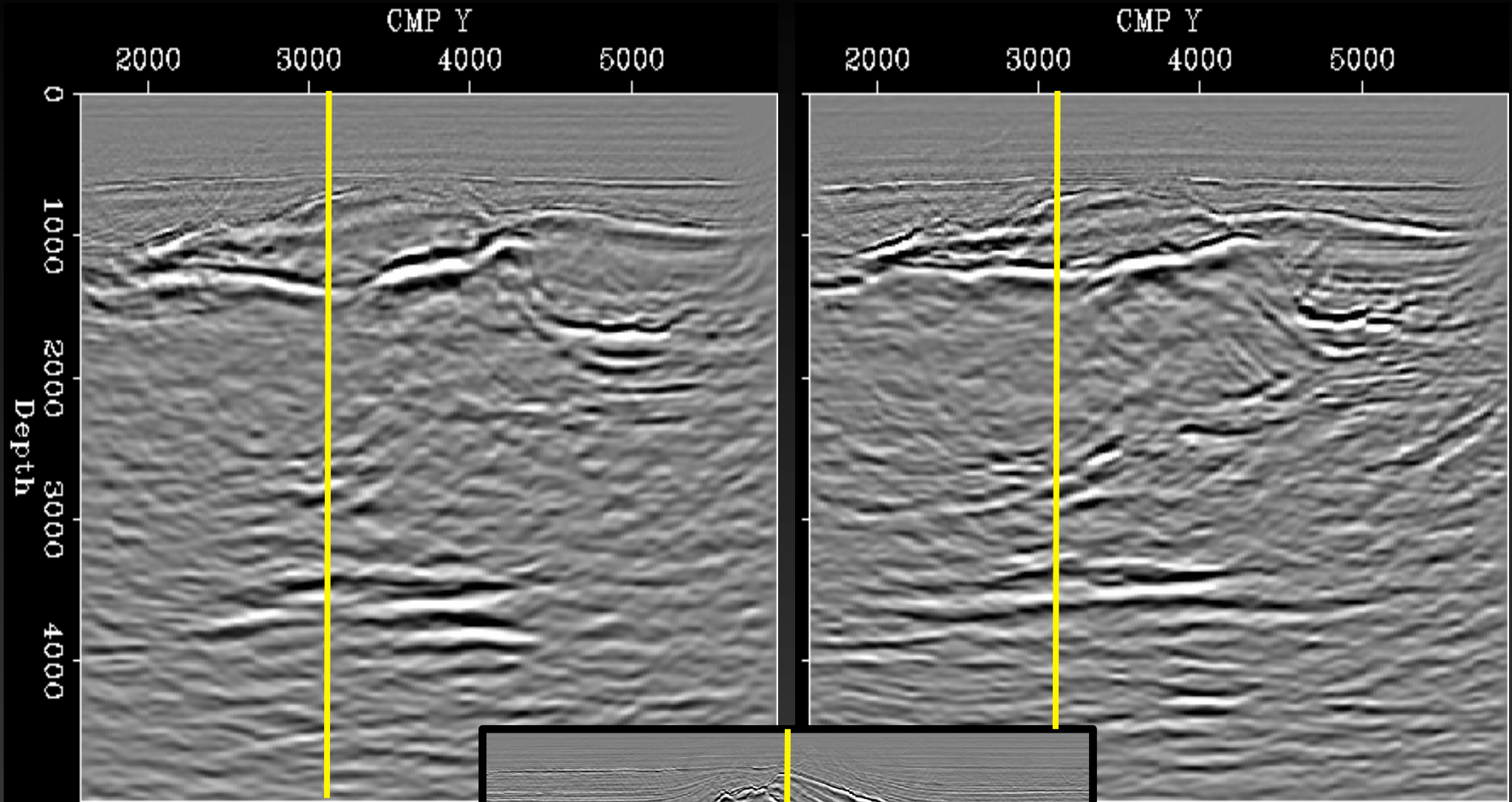


Comparisons: xline = 6100 m



Original

After salt body

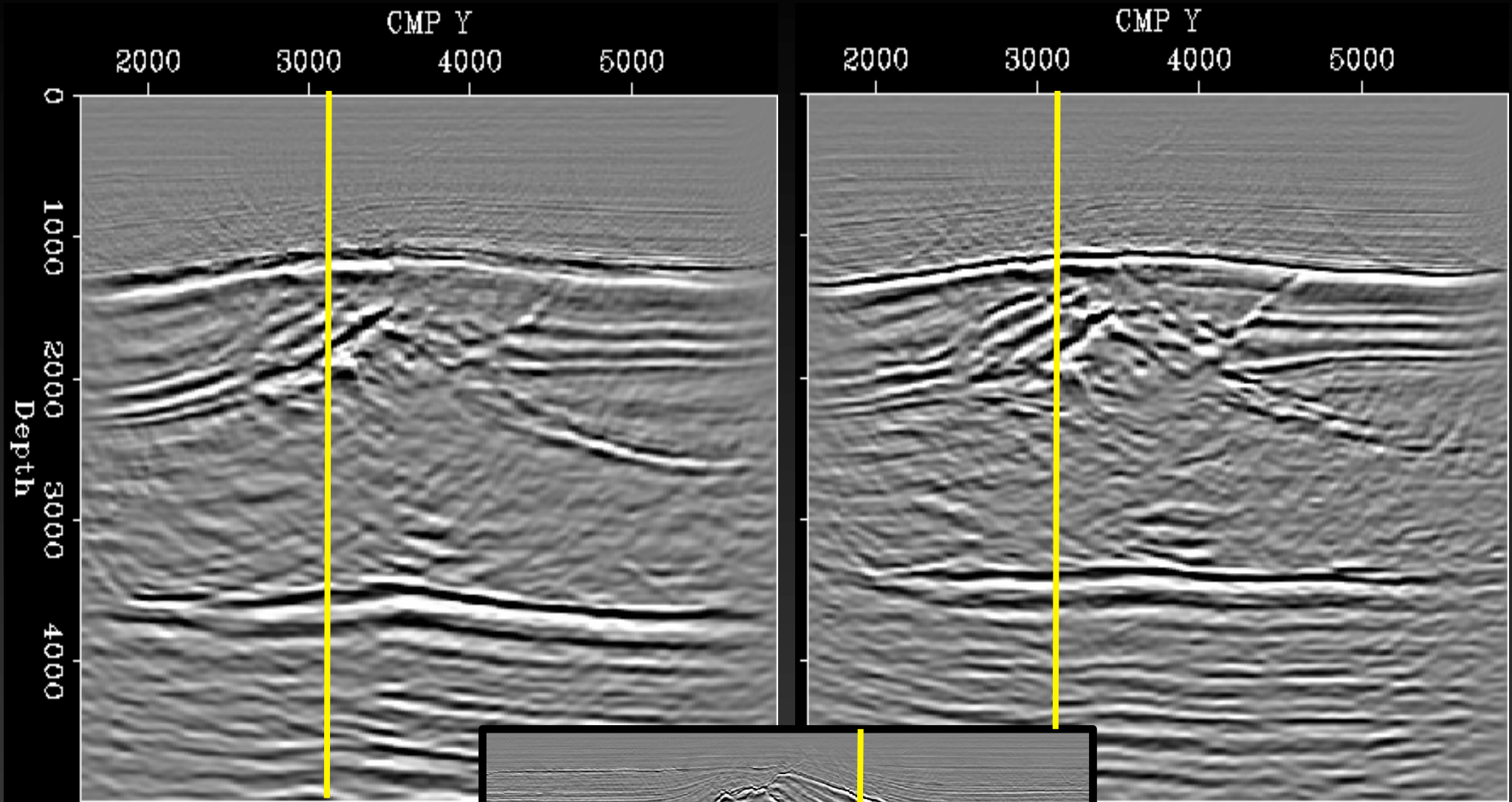


Comparisons: xline = 7600 m



Original

After salt body

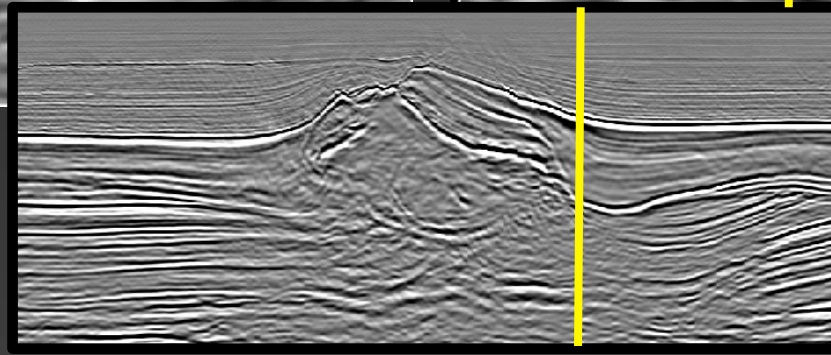
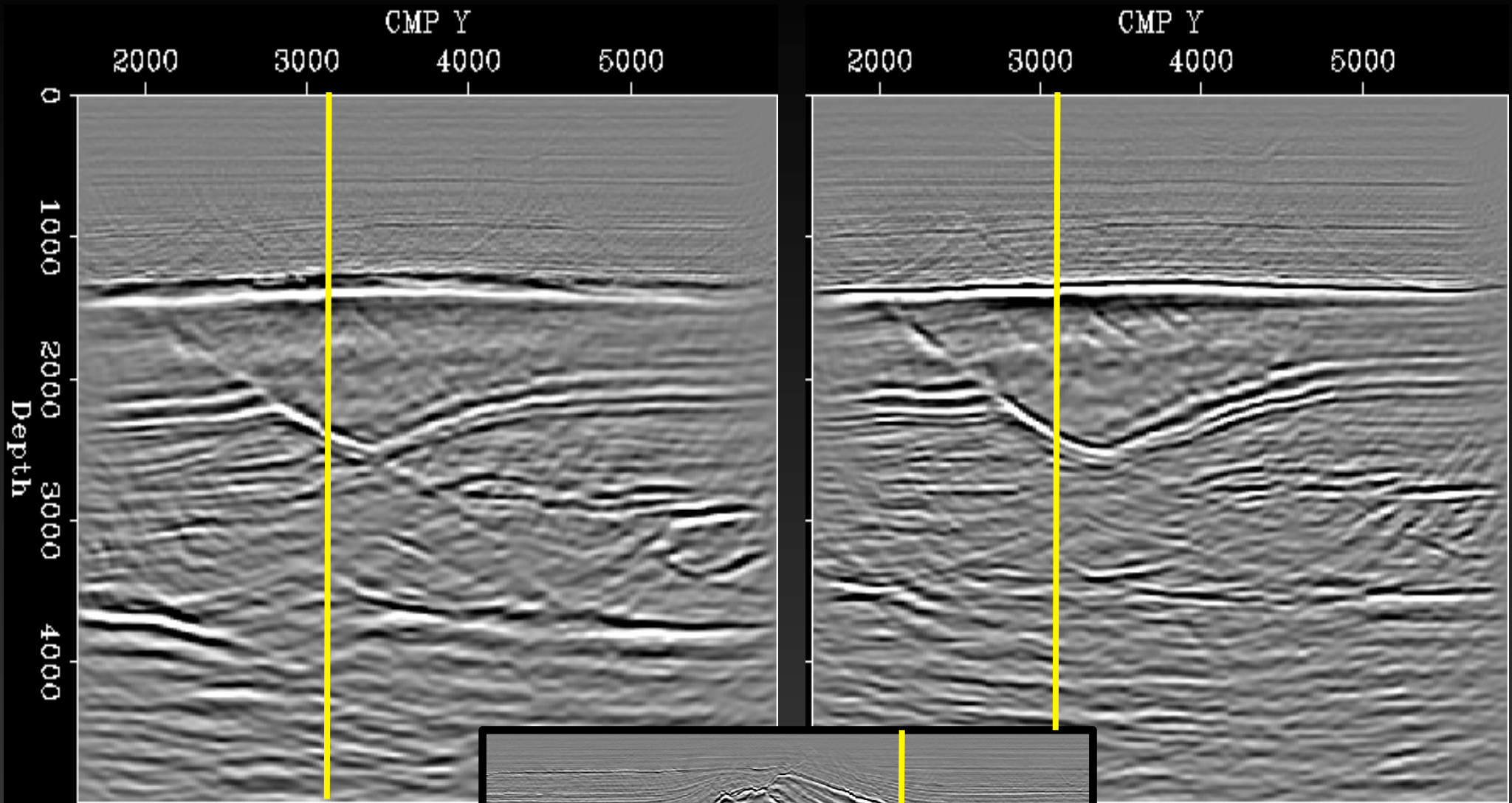


Comparisons: xline = 8200 m



Original

After salt body

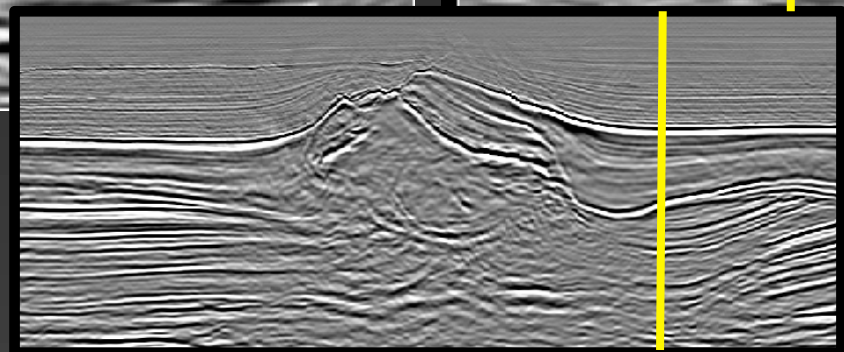
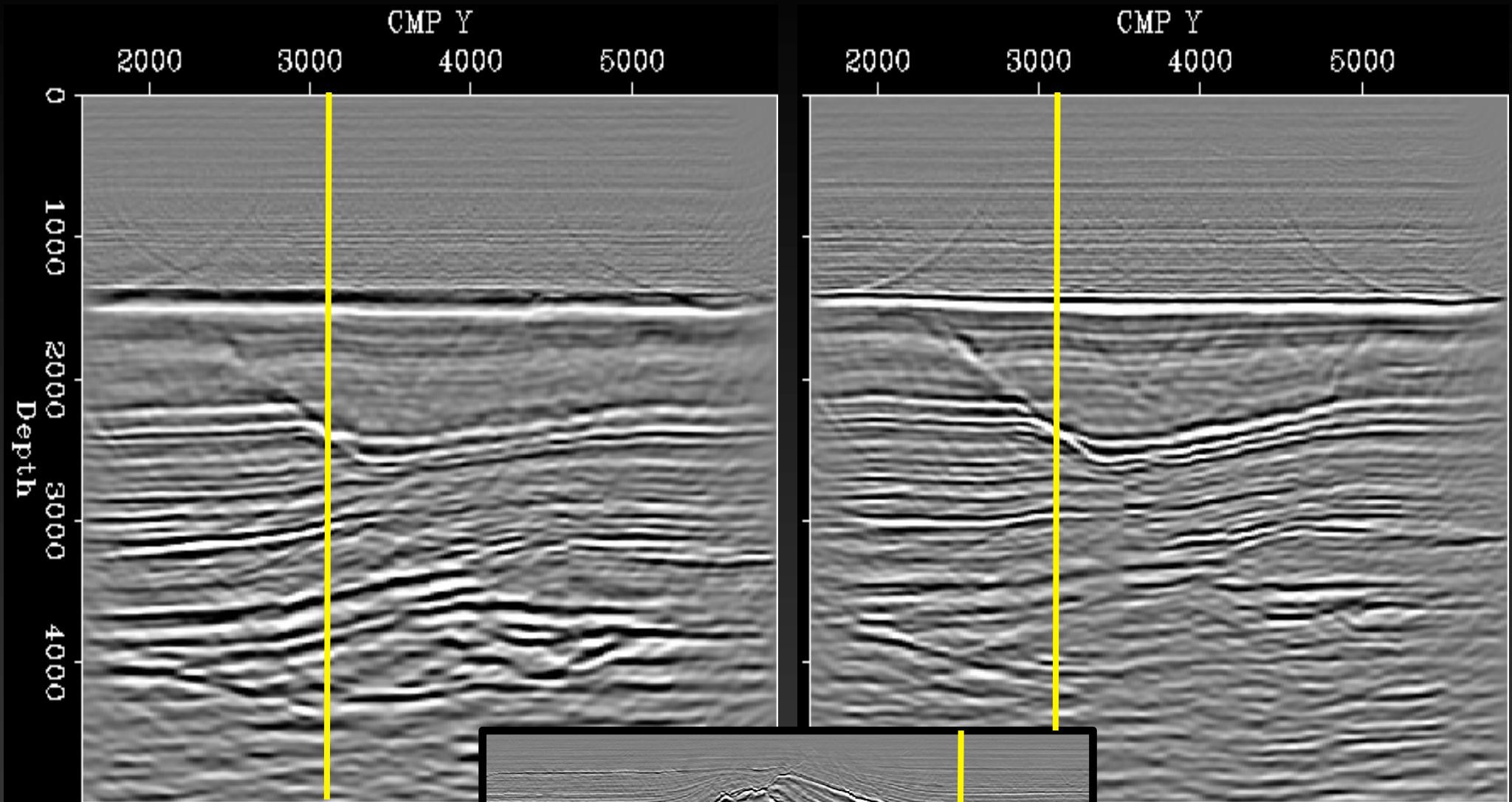


Comparisons: xline = 9300 m

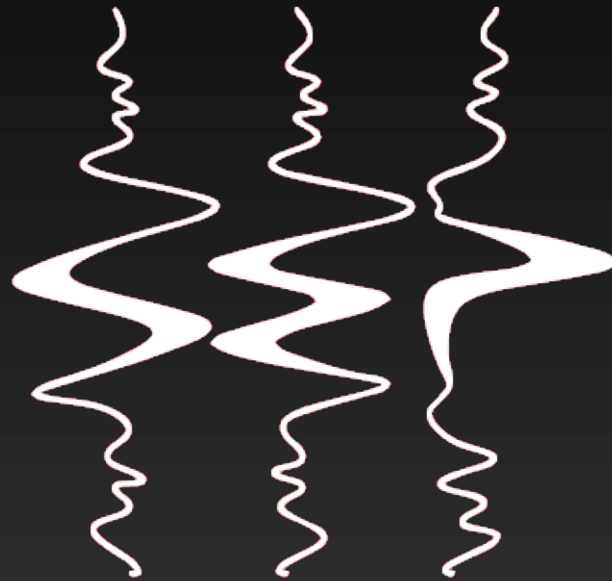


Original

After salt body



Thanks



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