Migration and angle gathers: some experiments

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CREWES Weekly Meeting

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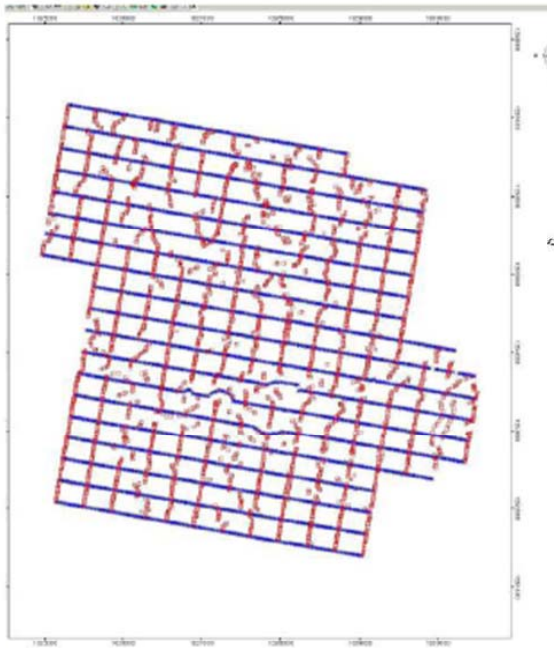
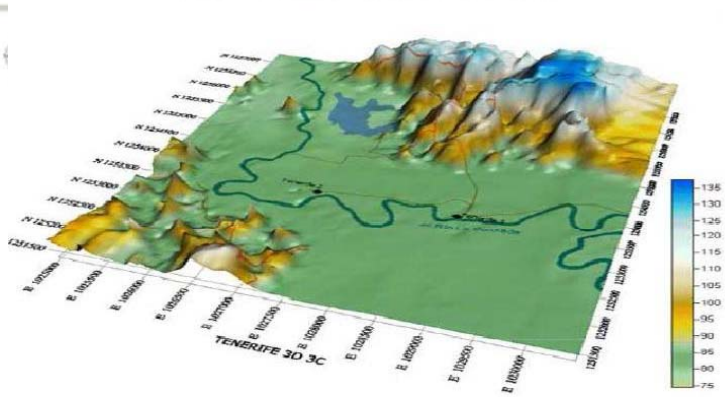
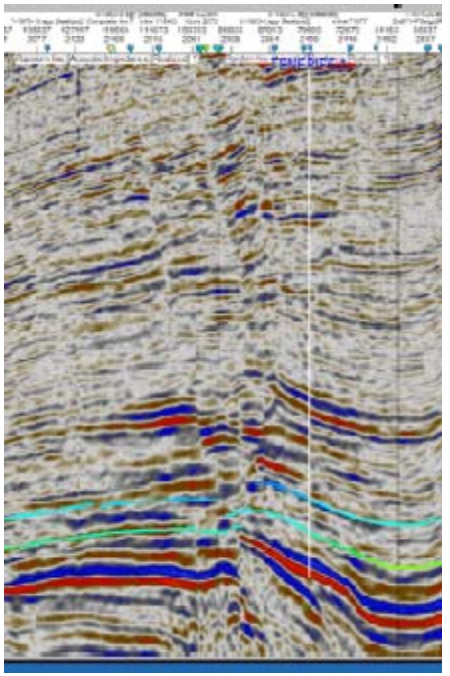
A real case





ecopetrol



(Agudelo *et al*., 2012,SEG)

Potential of PP and PS waves in complex settings.

Issues of 3C data in land

- Some important challenges in land for multicomponent (PP and PS) data:
  - The near surface S-wave propagation.
  - Noise - Wave mode separation.
  - The deep imaging.
  - Relationship between PP and PS

OVERVIEW

- Introduction:
  - Why angle gathers in depth
  - About the angle gathers.
- The ray trace approach
- The extended imaging condition approach.
- Final remarks

Focus: angle gathers and pre-stack depth migration

- Offset is a surface property that in complex areas can not be related to the depth properties
- Taking advantage of PP and PS information content about angles and amplitudes.
- Angle gathers provides additional information for the velocity model improvement.
- Depth Migration: where PP and PS waves meet.

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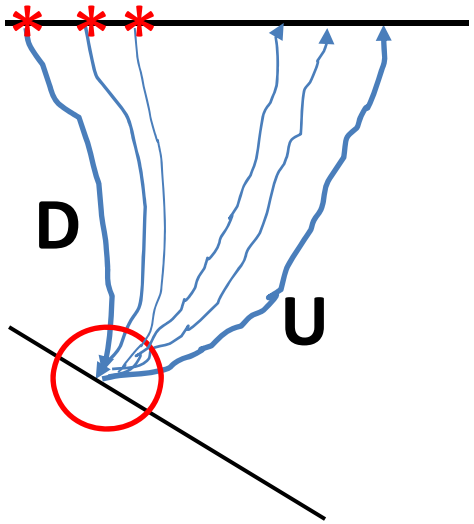
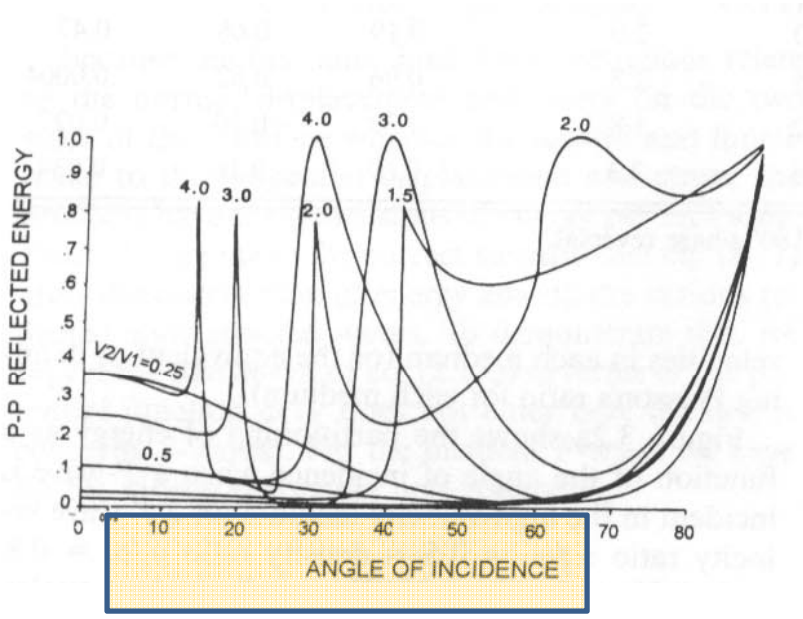
Gathers in the Angle Domain:

Seismic data from many experiments image at a reflection point with different angles



This events can be related with lithological properties, as shown by the Zoeppritz Equations



AVO -> AVA

Approaching to the Angle Gather domain

- A variety of approaches:
  - Slowness (τ-p) imaging (De Bruin et al., 1990)
  - Angle gathers for Kirchhoff migration (Xu, et al. 1999)
  - Extended imaging condition for WEM, specially source-receiver (Sava & Fomel, 2003)
  - Poynting vector (Yoon and Marfurt, 2006).
- Two methods investigated here:
  - Ray Tracing approach (Margrave & Guevara)
  - Extended imaging condition approach for the shot profile migration (Rickett & Sava, 2002).

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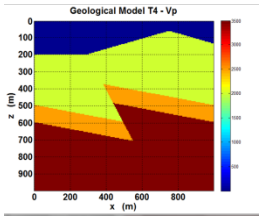
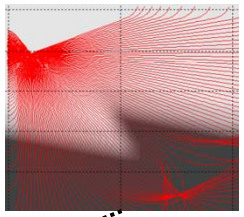
Ray tracing approach

- A velocity model is assumed.
- Then it is possible to obtain:
  - the direction of incidence by ray tracing and
  - the geology by the gradient of the velocity field.
- For each shots, these angles are mapped to the shot migrated section in depth.

Ray Trace approach



Ray Tracing

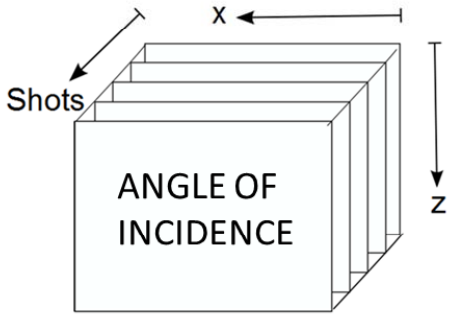


Slowness Matrices

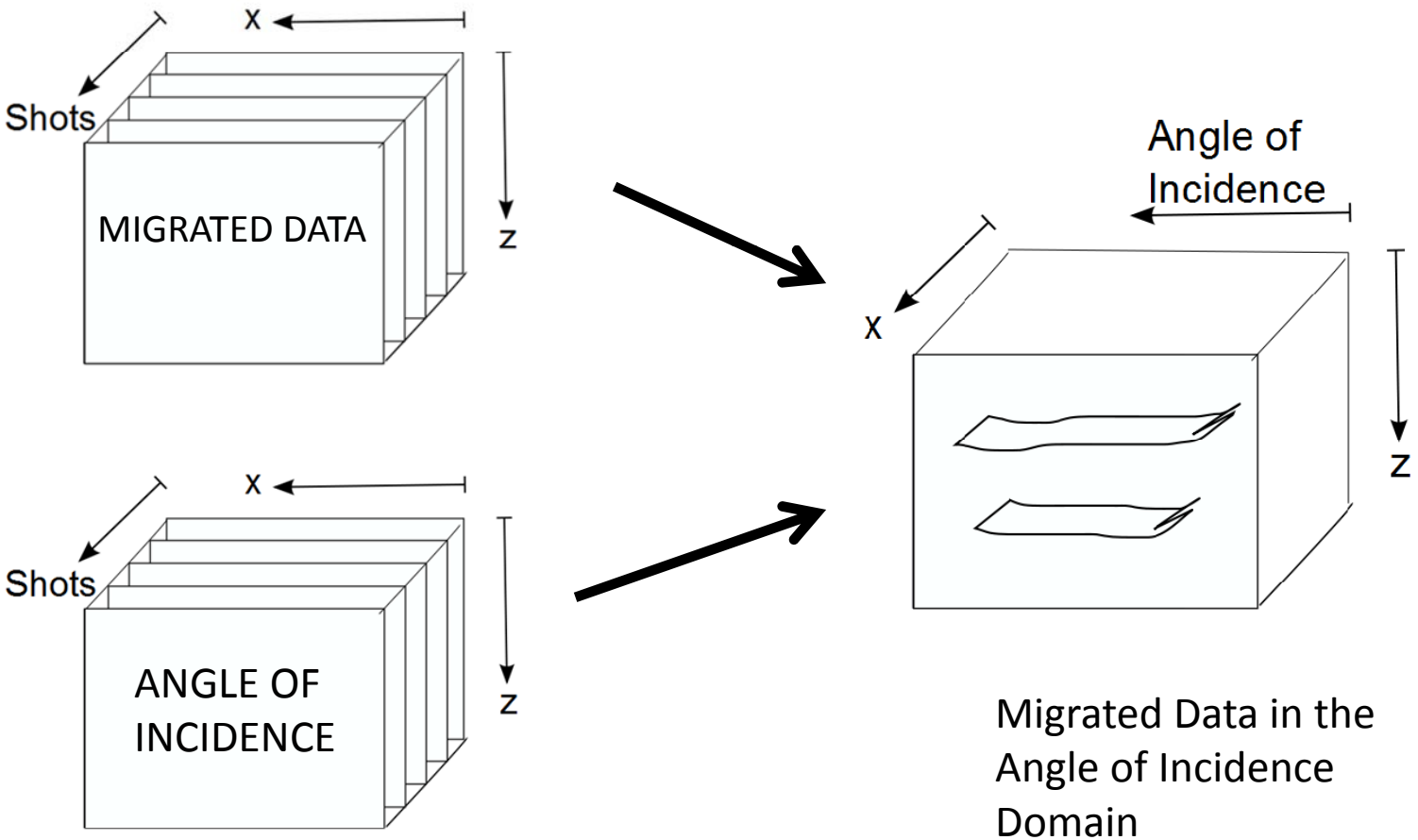
Px, Pz

Velocity gradient *G*

$$cos\theta = \frac{P \cdot G}{|P||G|}$$

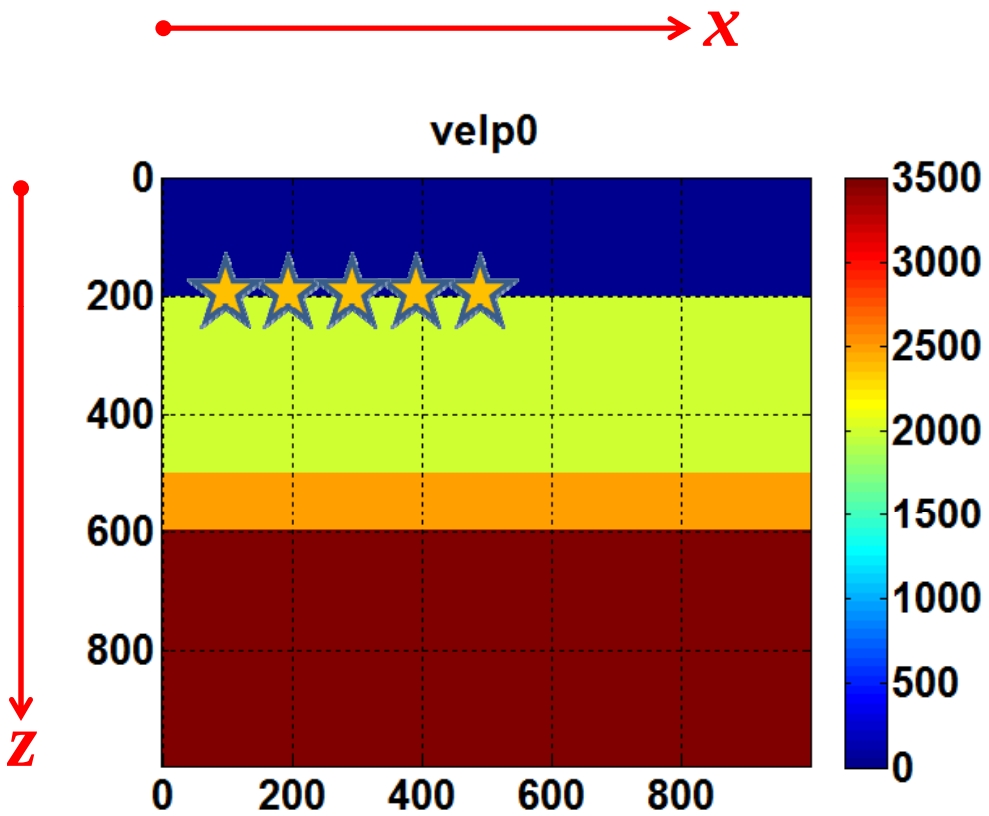


Ray Trace Approach: Angle Mapping



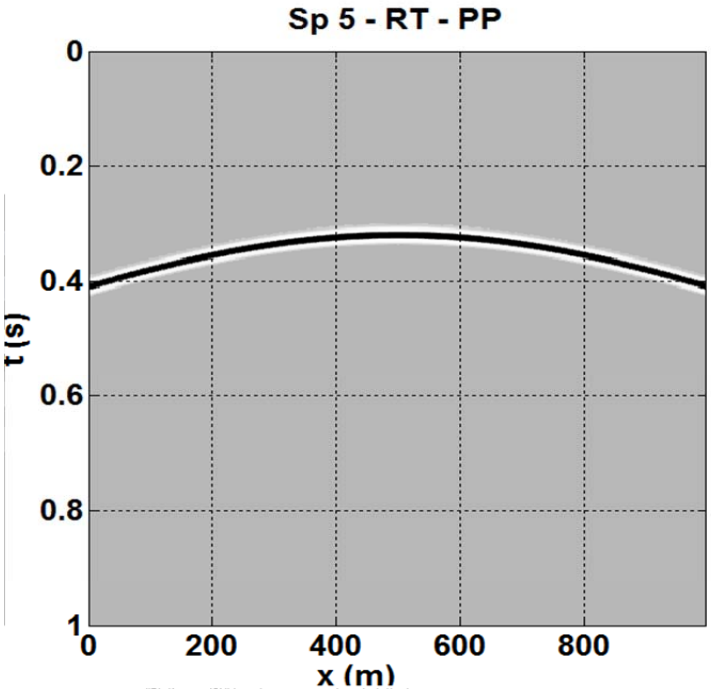
Migrated Data in the Angle of Incidence Domain

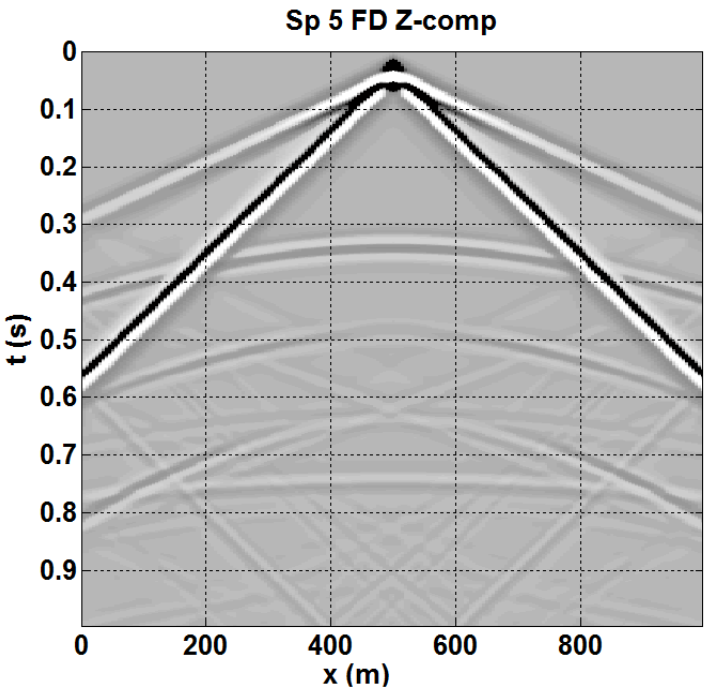
A simple geological Model



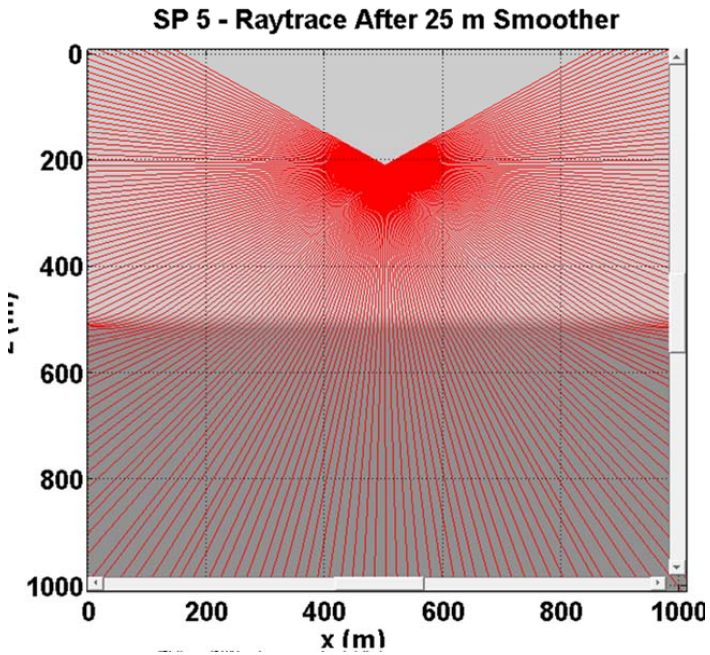
Five sources separated by 100 m to each other.

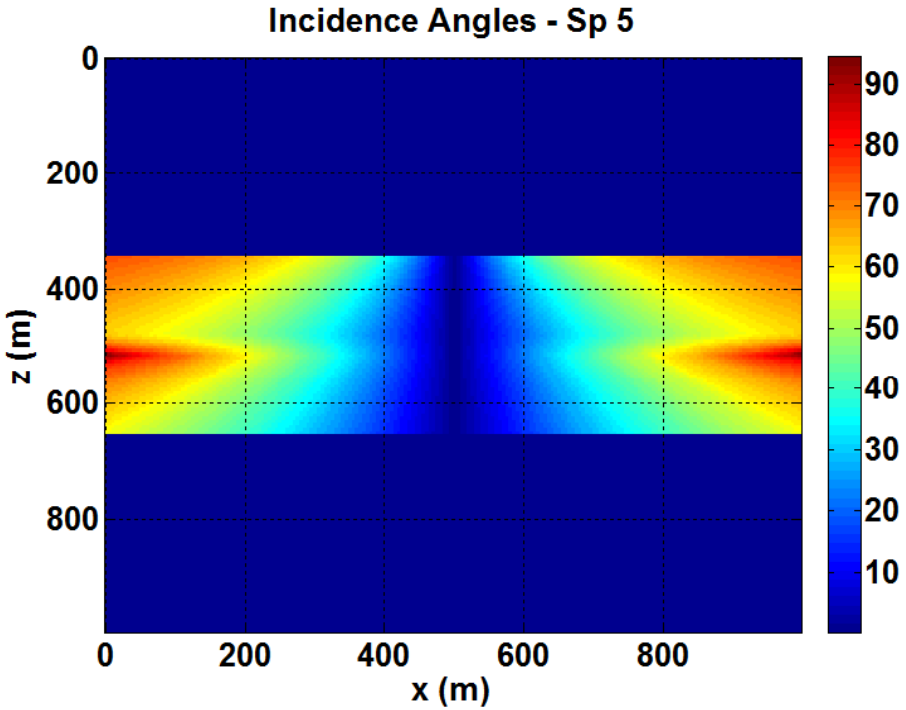
Modeling: Ray tracing and Finite Differences



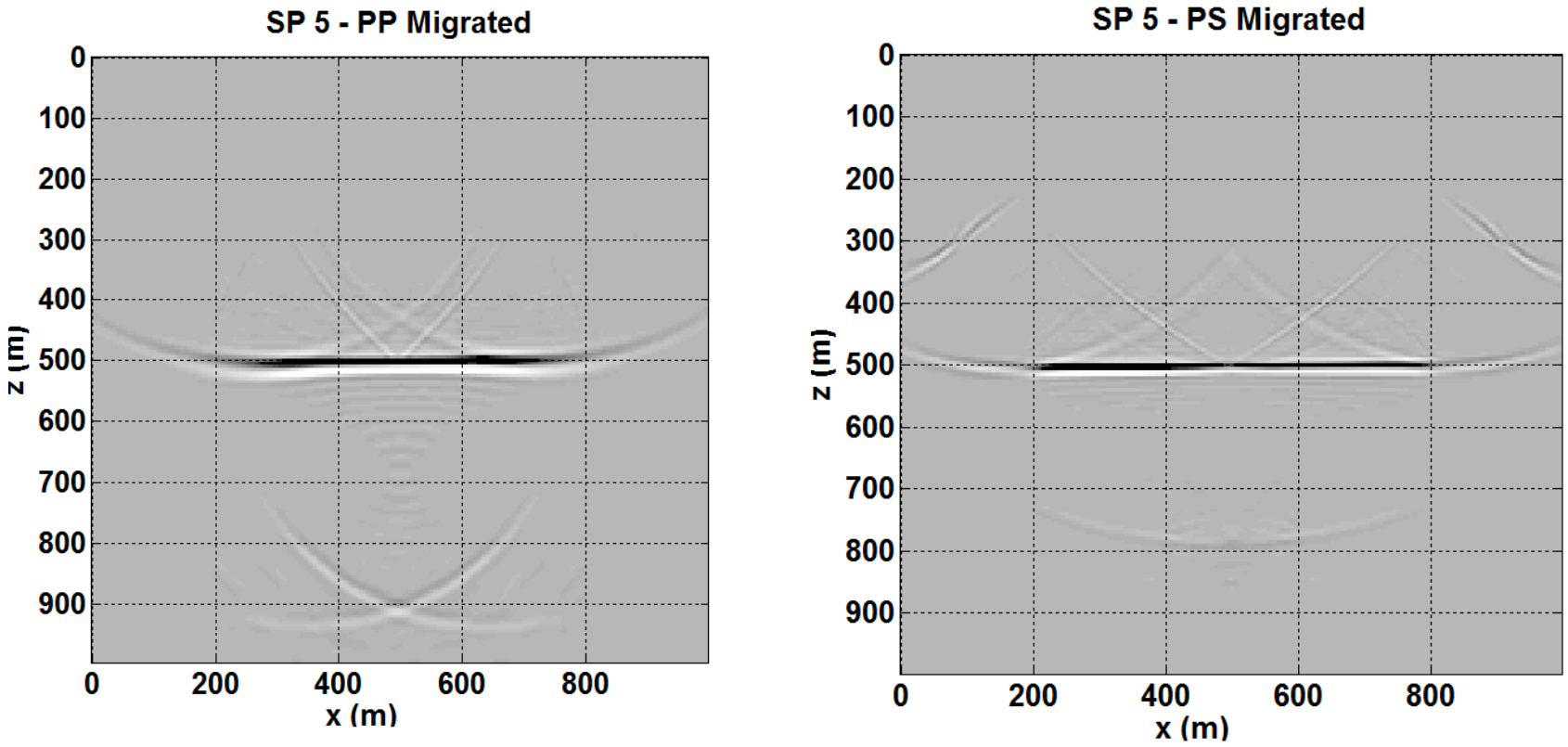


Ray Trace and Incidence Angle - Shot 5



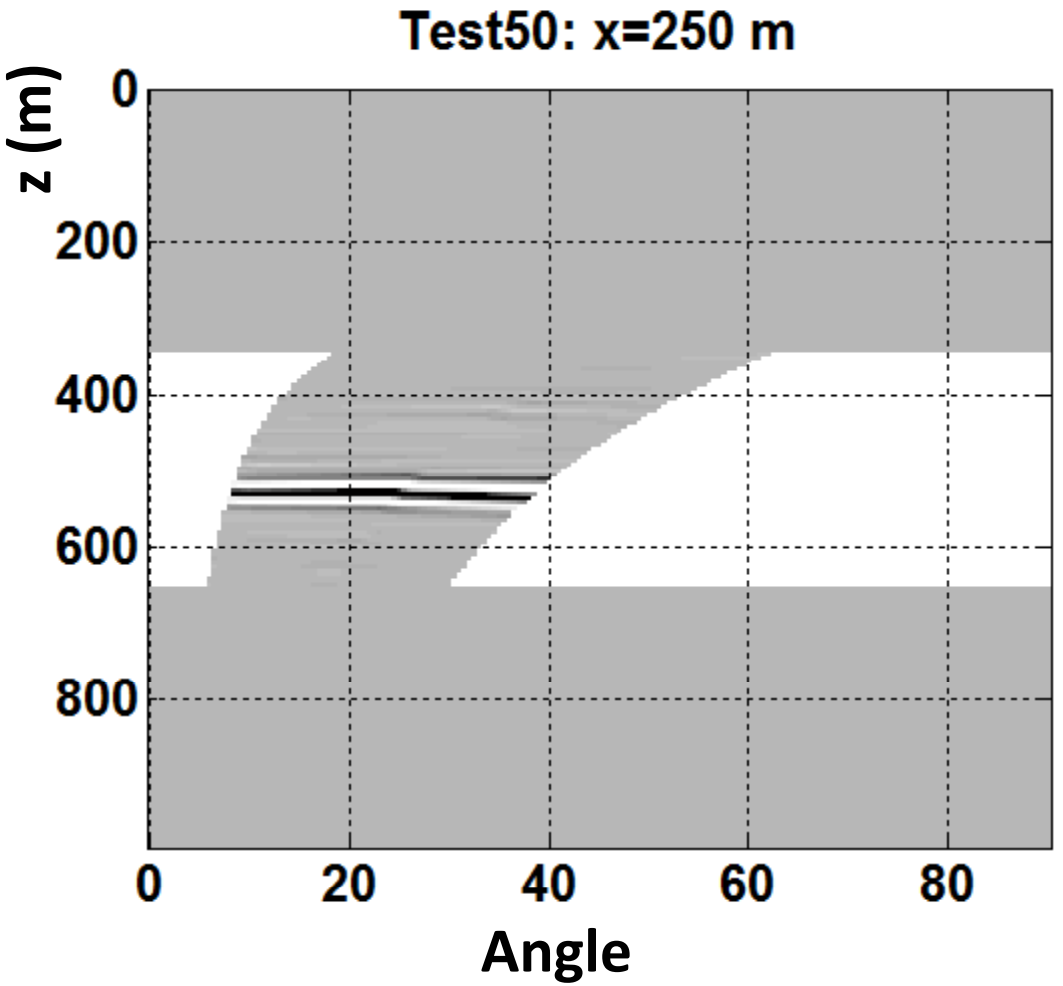


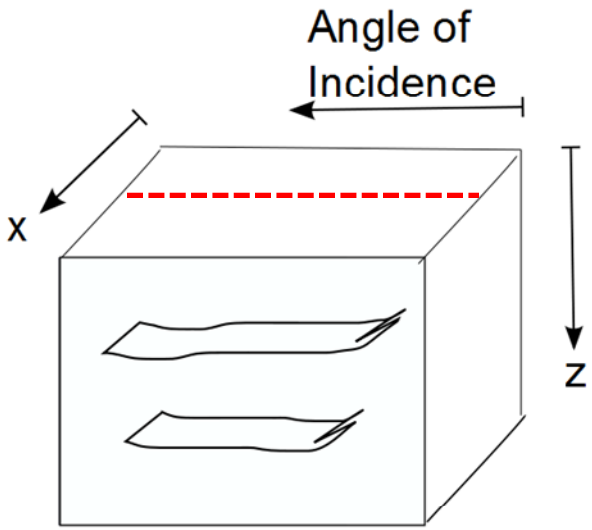
Migrated Sp 5



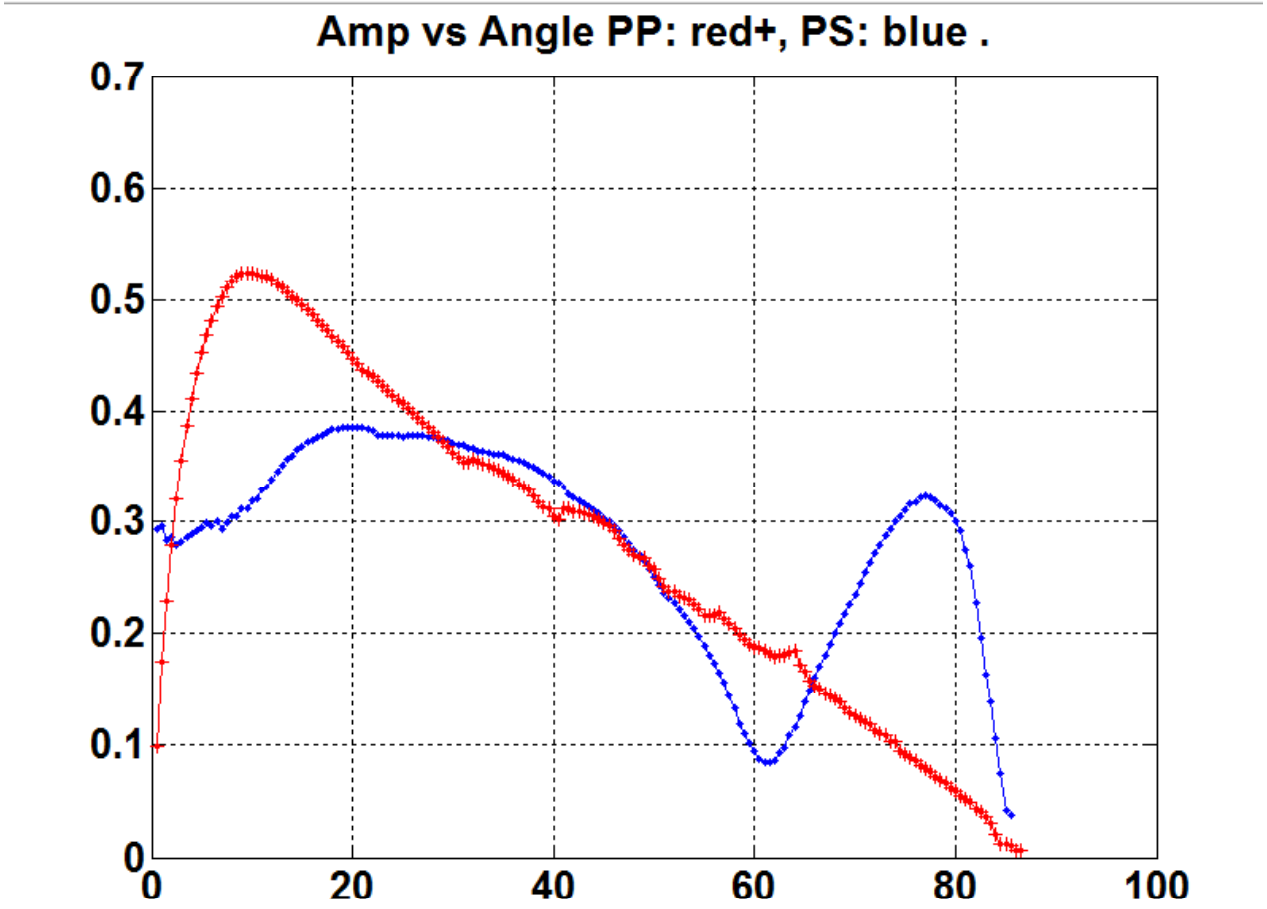
Modified from the Method PSPI developed at CREWES by Ferguson and Margrave.

Image Angle Gather x=250 m

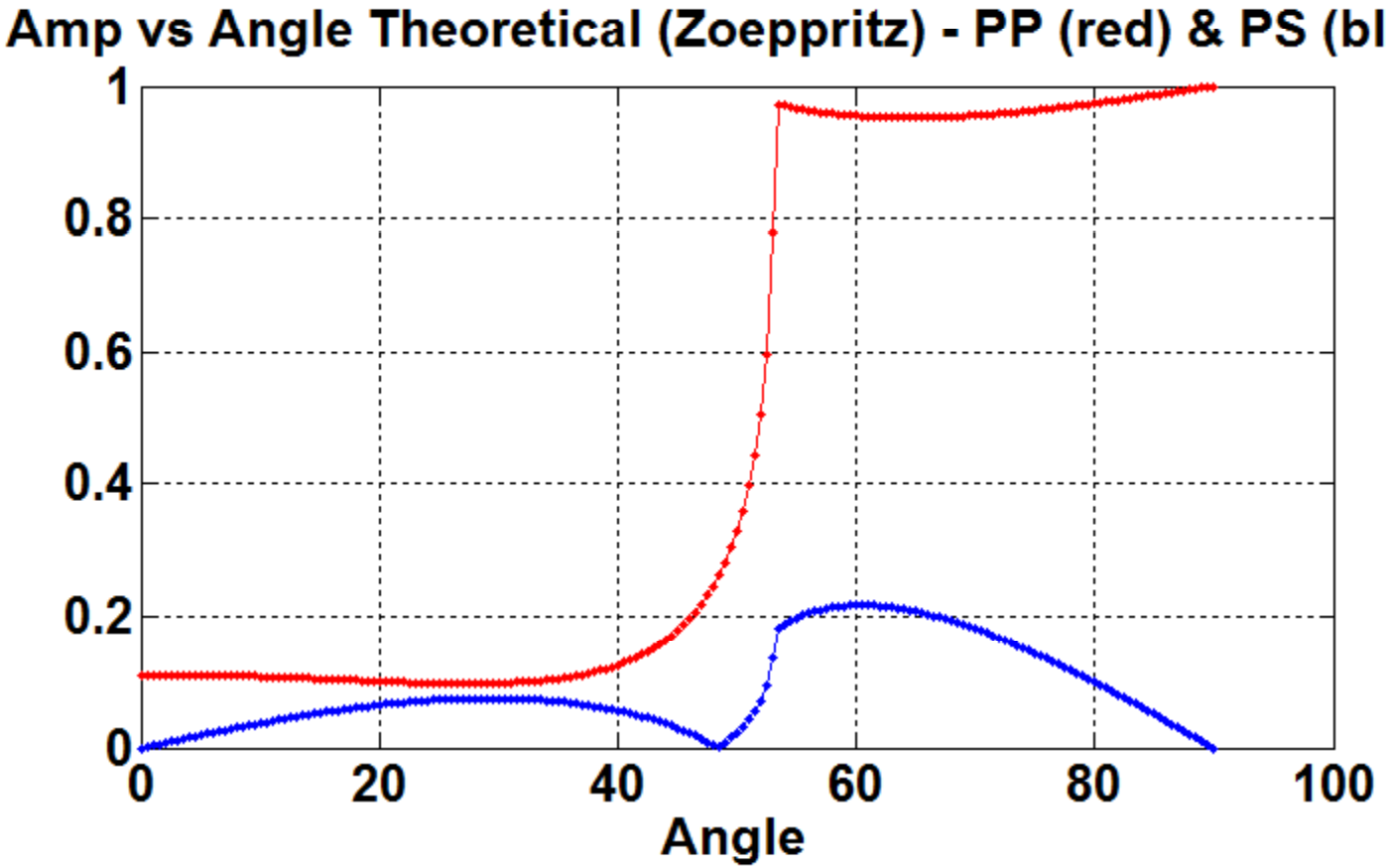




PP and PS vs Angle: average of 9 shots



Amplitudes according to Zoeppritz



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The extended imaging condition approach

- Can be understood as that the reflections come from an area, not a point, then have information about angles and amplitude variation with angle.
- Proposed by De Bruin (Delft University):

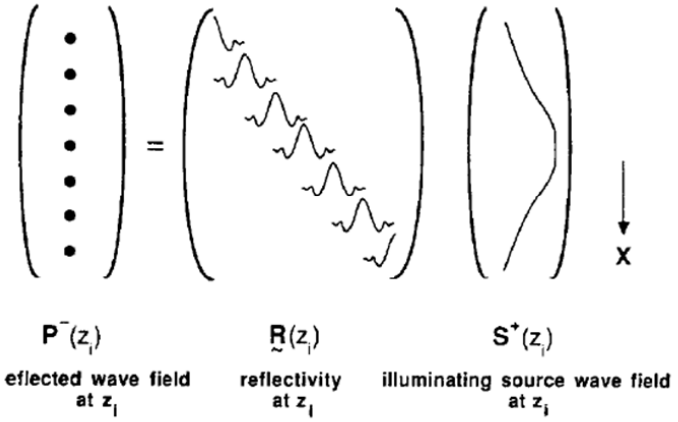
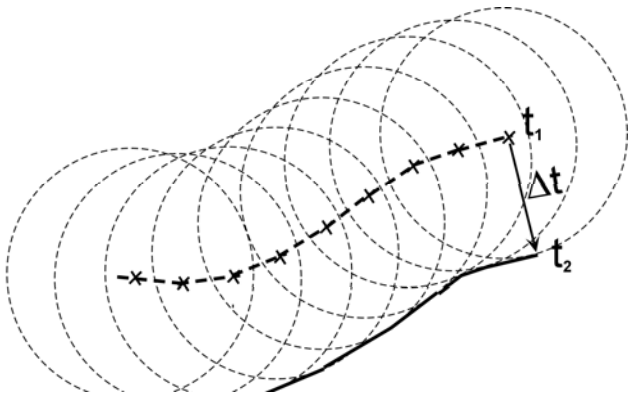
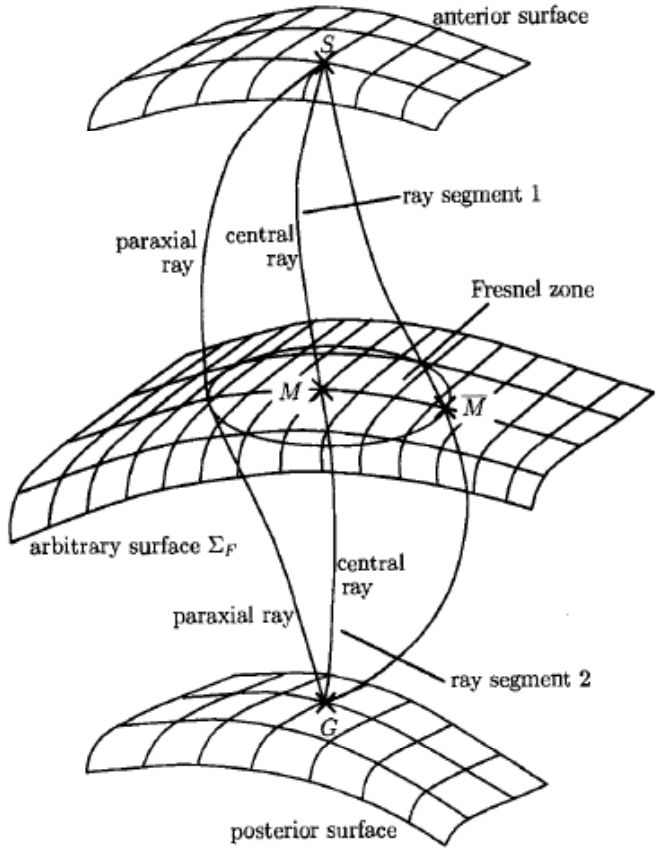


FIG. 3. Each row of the reflectivity matrix $\underset{\sim}{\mathbf{R}}$ represents a reflectivity convolution operator.

(De Bruin et al., 1990)

Related principles:





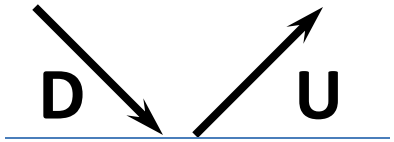
Huygens principle

Fresnel Zone

(Schleicher et al., 1997)

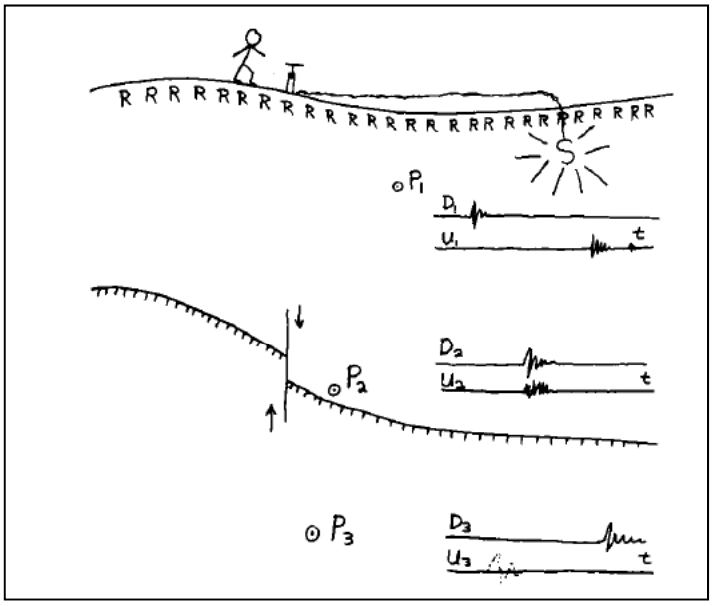
The extended imaging condition

- Migration involves
  - ***wavefield propagation***
    $U(k_x, \omega, z + \Delta z) = U(k_x, \omega, z)e^{-ikz\Delta z}$
    (PSPI,Ferguson and Margrave, 2005)
  - ***imaging condition.*** $R(x,z) = \frac{U(x,z)}{D(x,z)}$



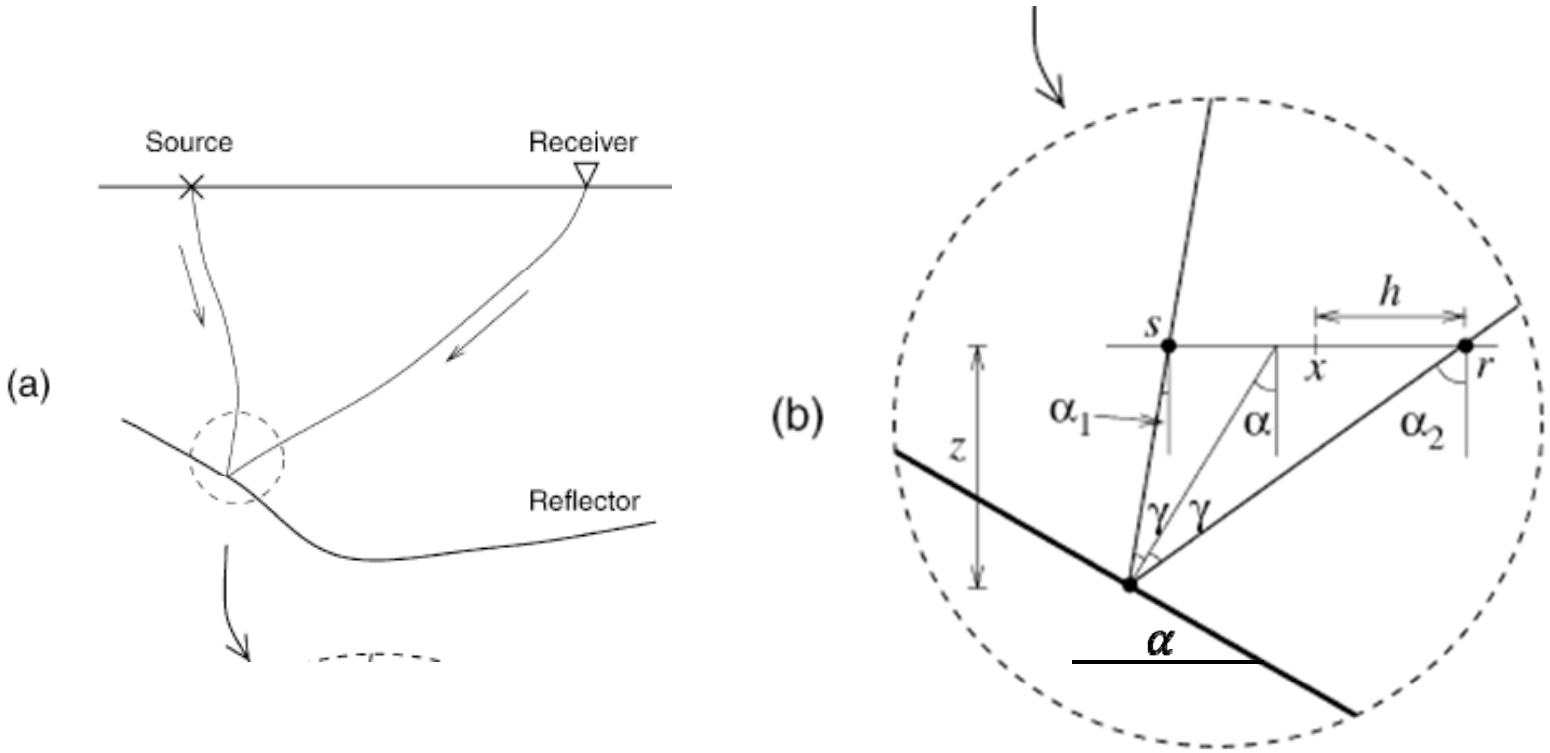
- The extended imaging condition: applied to variable offset:

$$R(x,h,z) = \frac{U(x+h,z)}{D(x-h,z)}$$



(Claerbout, 1971))

Offset Domain to Angle Domain



$\alpha - \gamma = \alpha_1$ $\alpha + \gamma = \alpha_2$

(Rickett & Sava, 2002)

The aperture angle equation

- $\frac{\partial t}{\partial s} = \frac{sin\alpha_1}{v}$
- $\frac{\partial t}{\partial r} = \frac{sin\alpha_2}{v}$

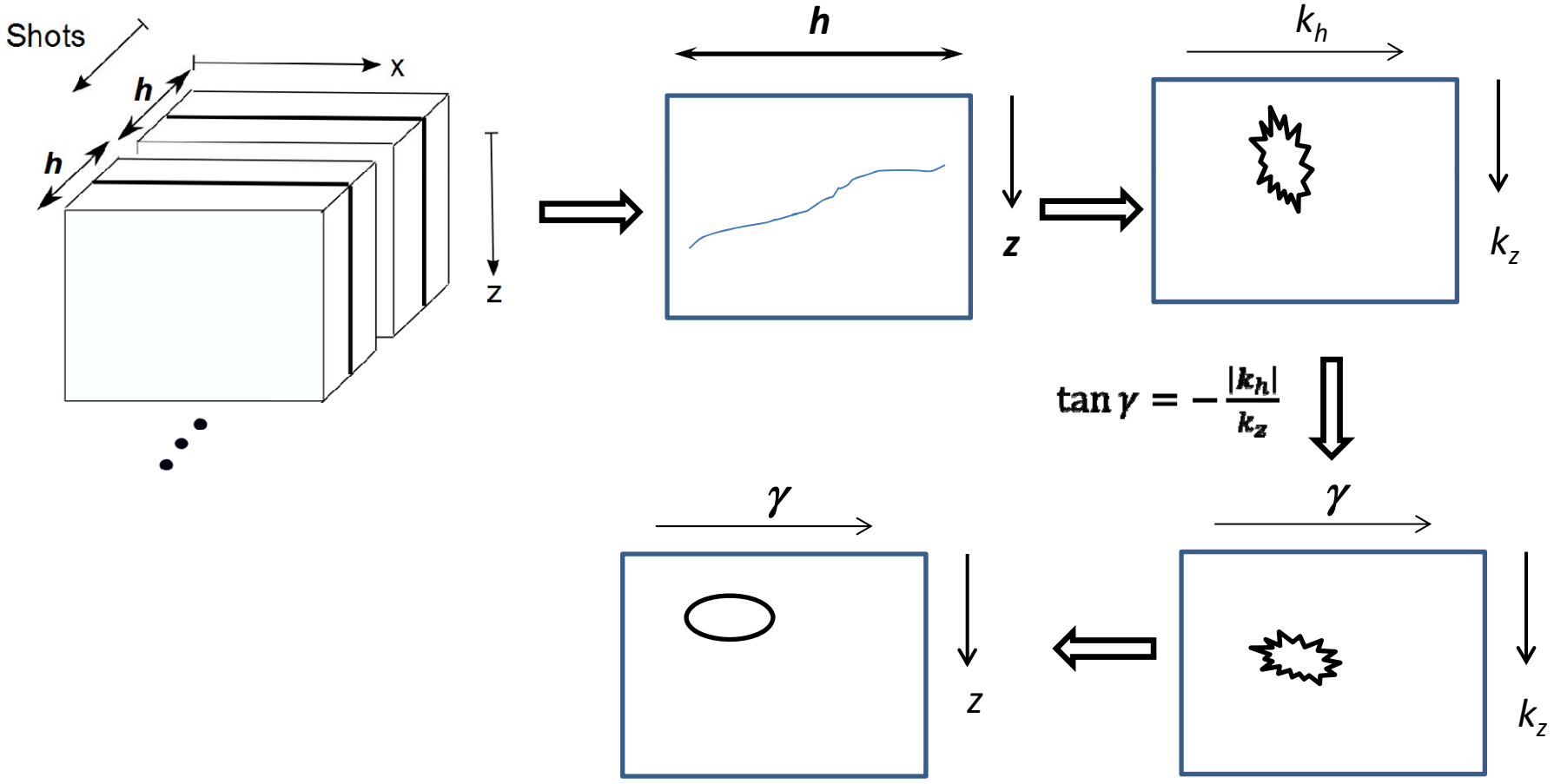
$$\frac{\partial t}{\partial h} = \frac{2}{v}\cos\alpha\,\sin\gamma$$

- $-\frac{\partial t}{\partial z} = \frac{\cos\alpha_1}{v} + \frac{\cos\alpha_2}{v} \Rightarrow -\frac{\partial t}{\partial z} = \frac{2}{v}\cos\alpha\cos\gamma$

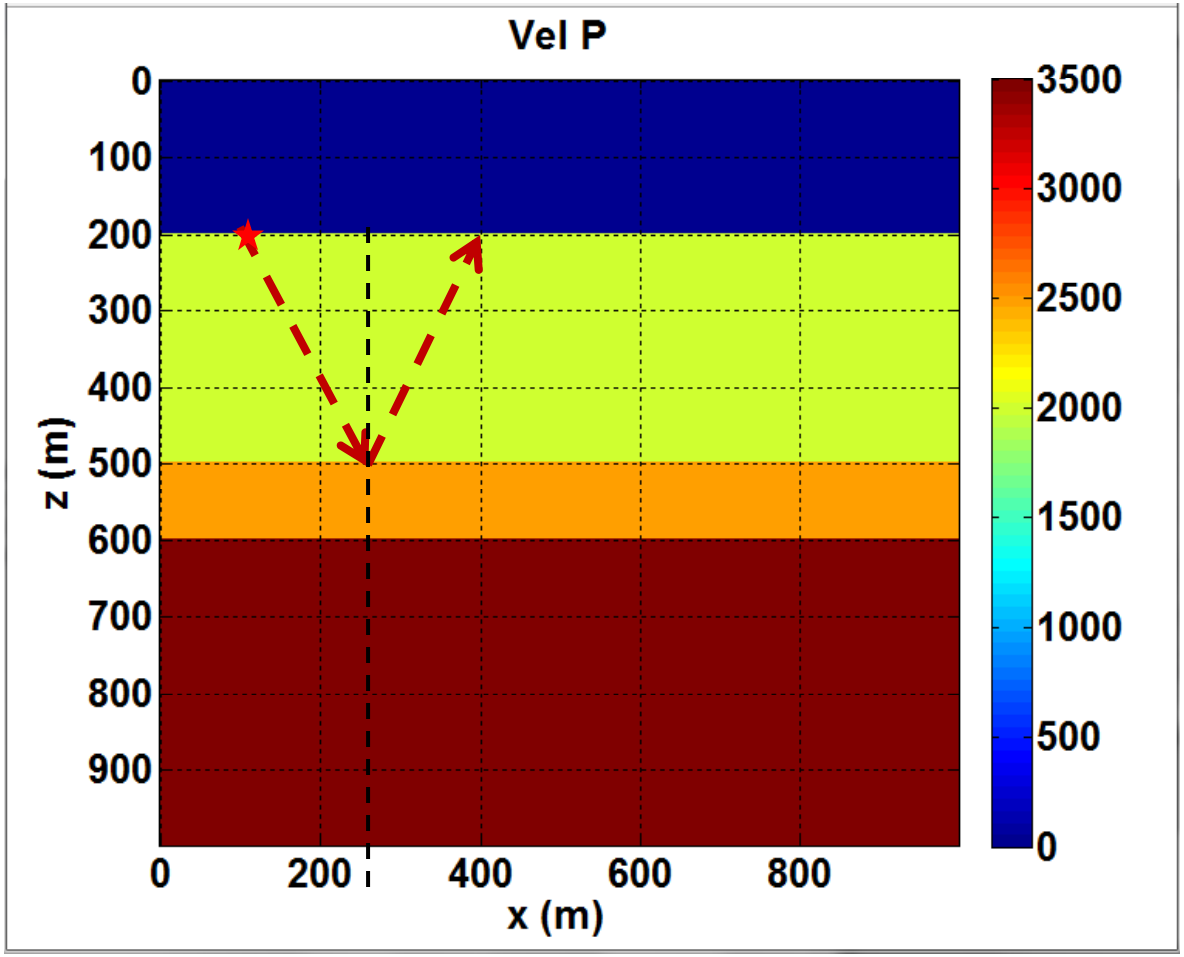
Then:

$$\tan\gamma = -\frac{\partial z}{\partial h} \quad \text{or} \quad \boxed{\tan\gamma = -\frac{|k_h|}{k_z}}$$

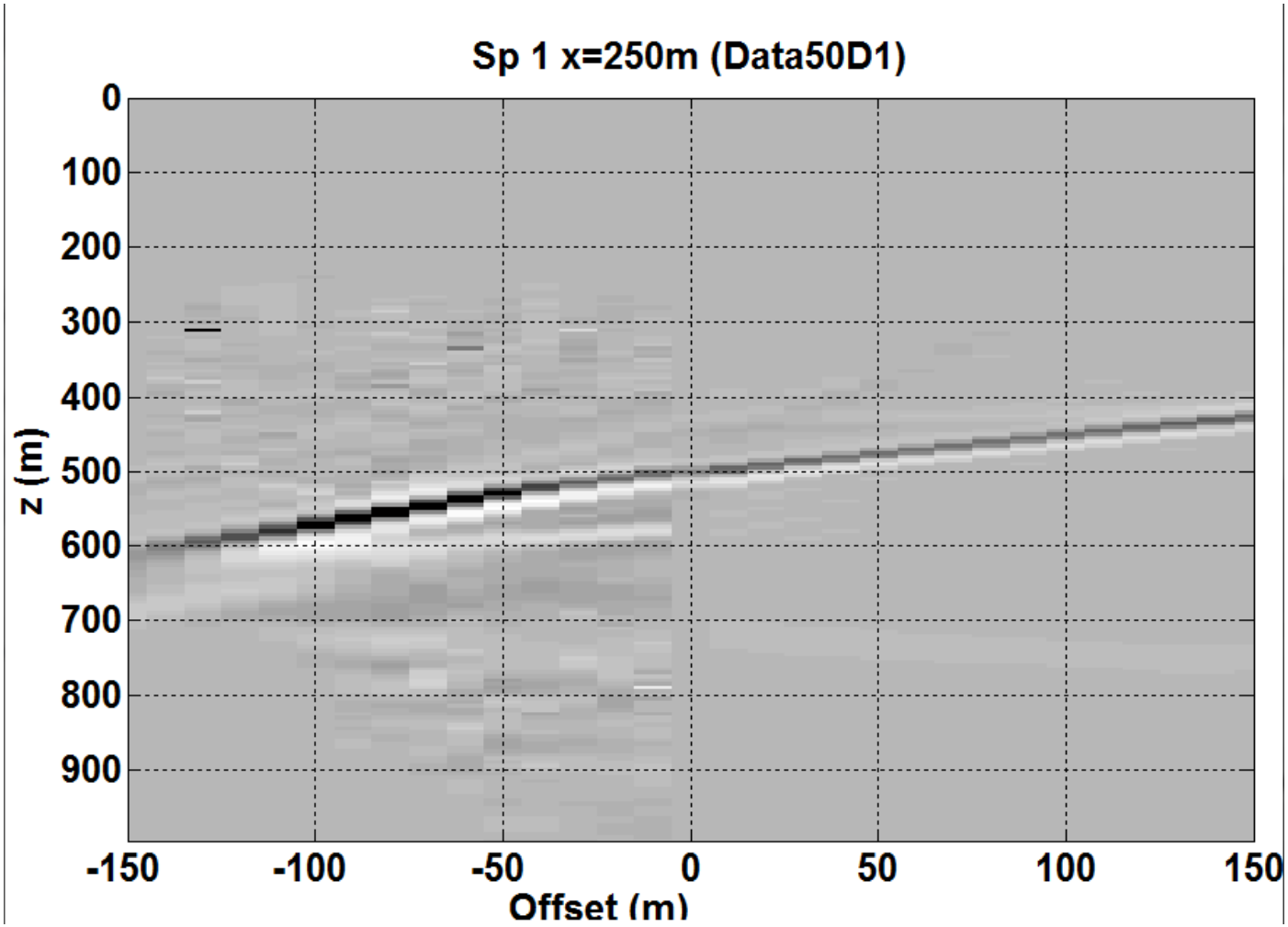
Extended imaging method



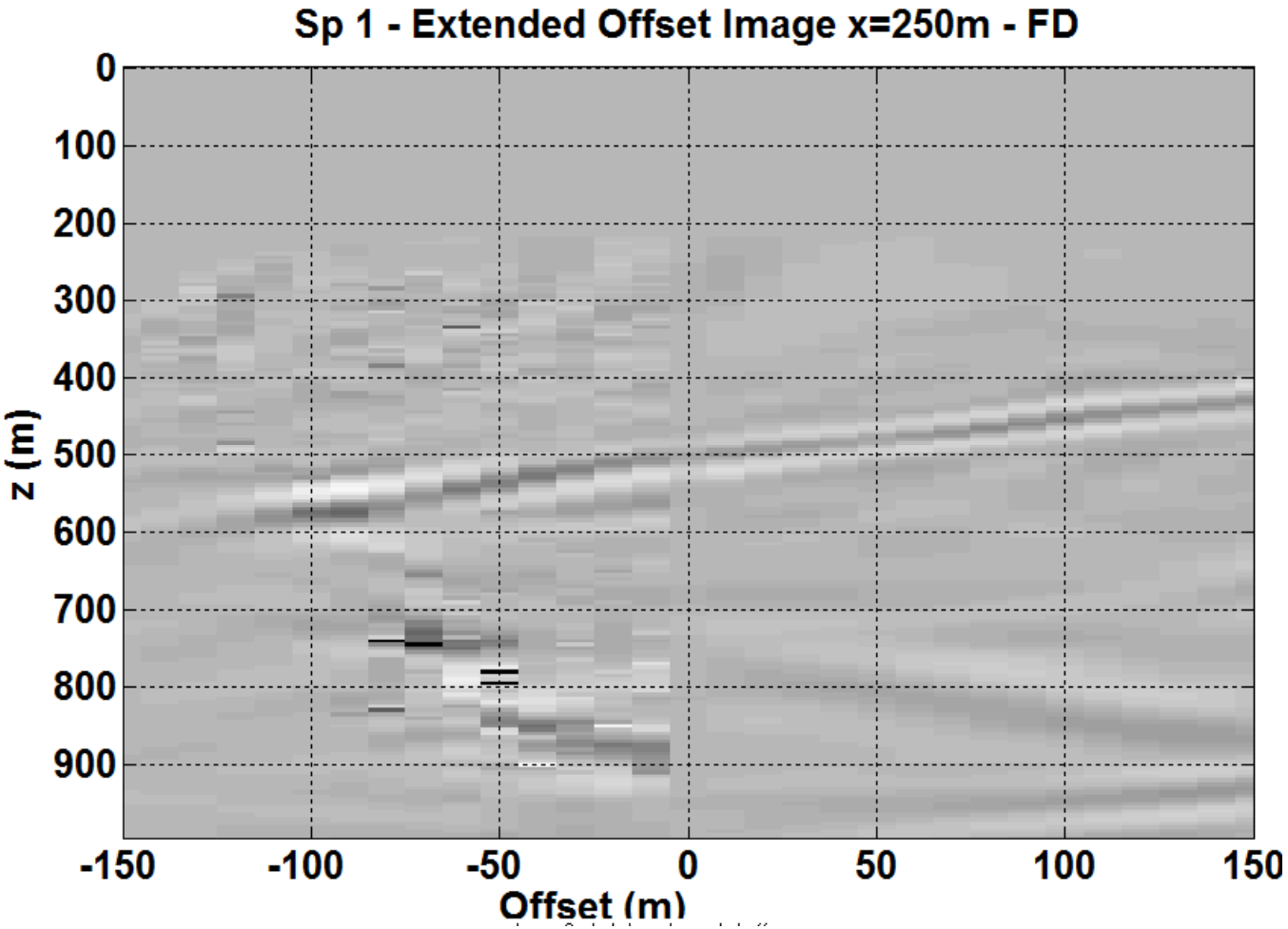
Sp 1 , x=250 m


Vel P
0
100
200
300
400
500
600
700
800
900
z (m)
0
200
400
600
800
x (m)
3500
3000
2500
2000
1500
1000
500
0

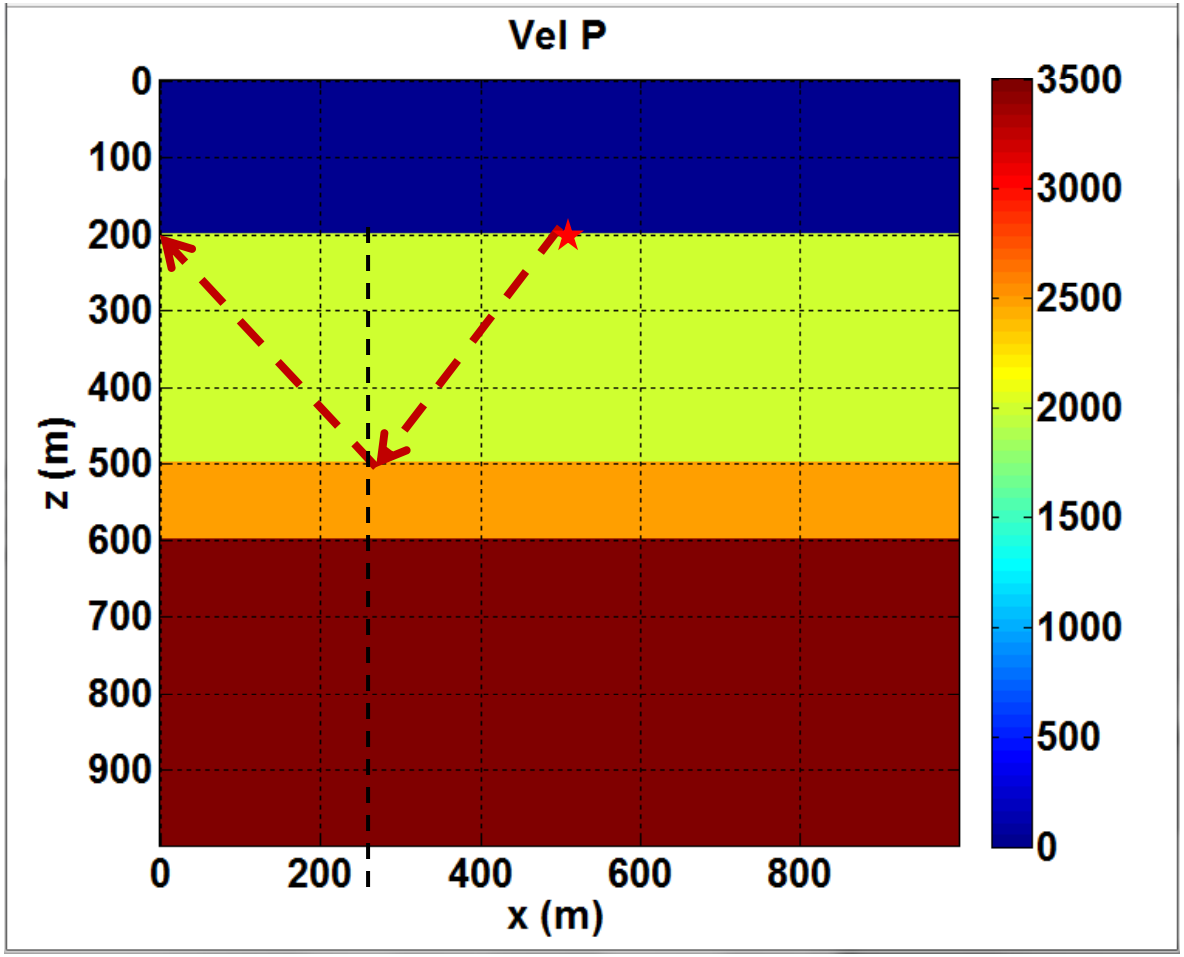
Extended imaging: Sp1 x=250m - RayT



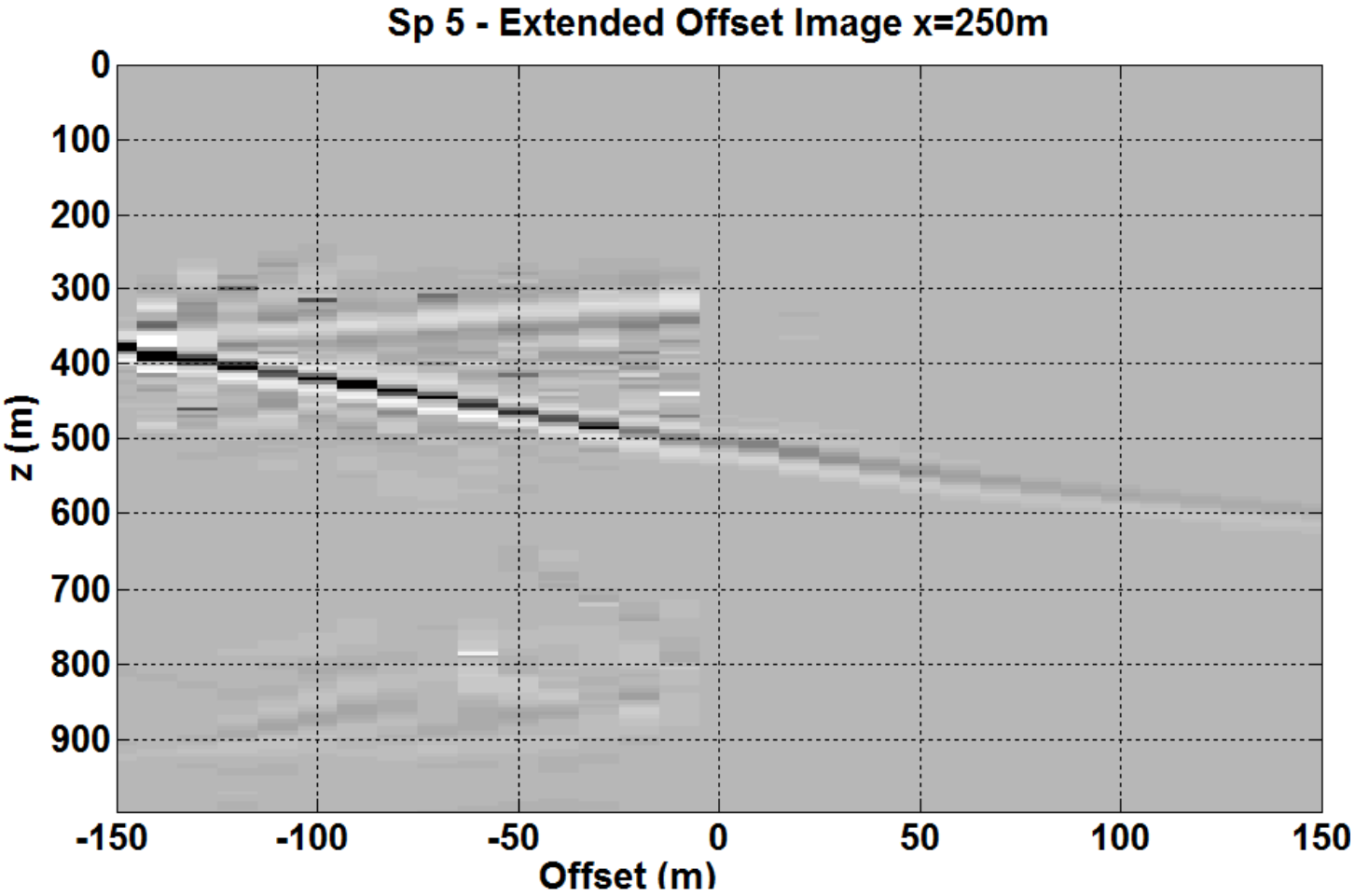
Sp 1 – x=250m – Finite Differences



Sp 5 , x=250 m


Vel P
0
100
200
300
400
500
600
700
800
900
z (m)
0
200
400
600
800
x (m)
3500
3000
2500
2000
1500
1000
500
0

Migrated: Sp5 x=250m - RayTracing



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FINAL REMARKS

- The Angle domain is an attractive approach to obtain more information of seismic data.
- Better images in complex areas can be expected and more consistent migration velocity models.
- Not good quantitative amplitude information yet.
- Future results can be expected. Efforts toward dipping reflectors and PS wave.

Acknowledgements

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