Applicability of AVO inversion to long-offset data from curved interfaces

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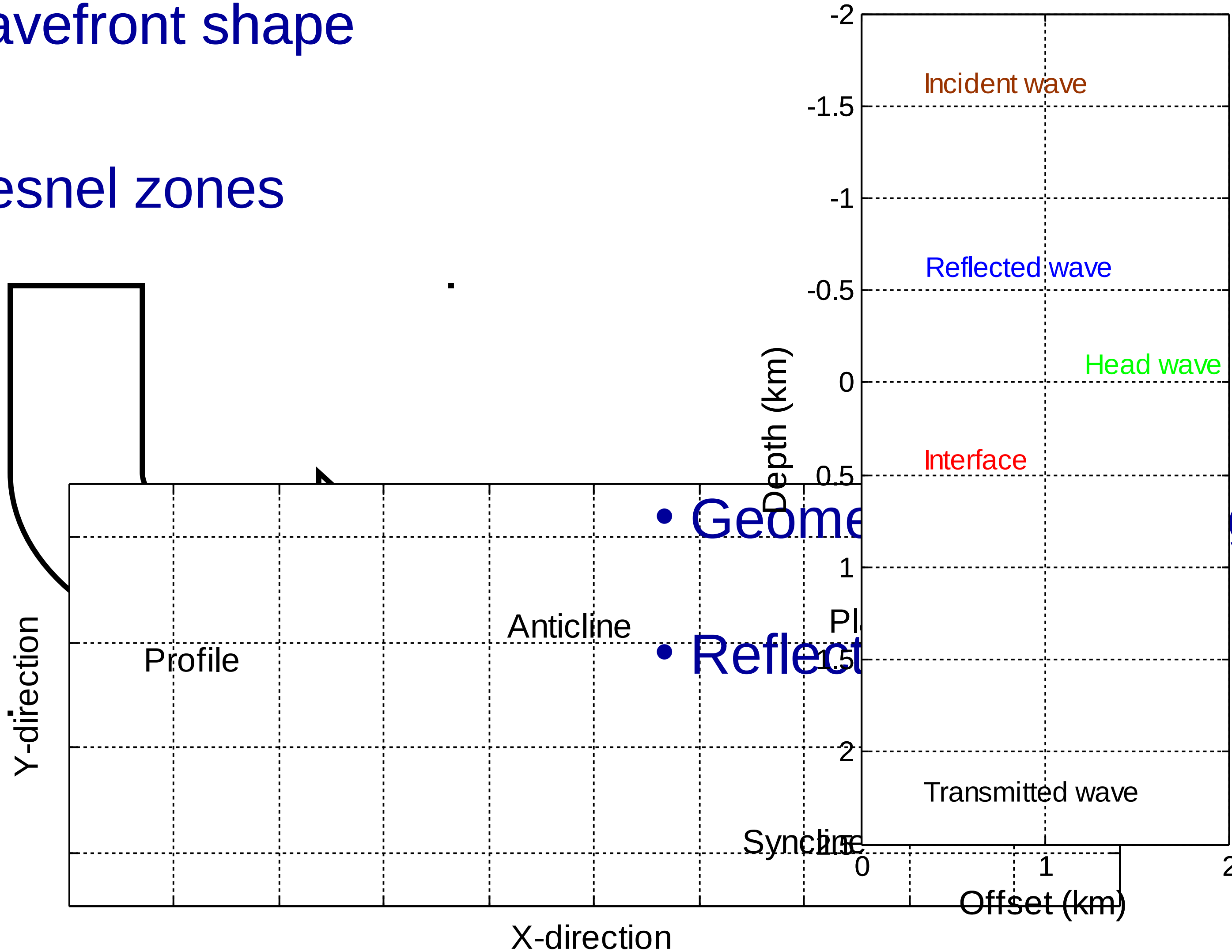
Plane vs. curved interface

- Wavefront shape
- Fresnel zones



- Geome…g
- Reflect…

Outline

- How to deal with curvature
  - Geometrical spreading
  - Reflected wavefield
- Synthetic modelling
- Results
  - Extracted and theoretical AVO
  - Inversion
- Conclusions

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How to account for curvature?

- Geometrical spreading (V. Červený et al., 1974)

$$L = V\left[\left(R_s + R_{s|x} + 2R_sR_{s|x}D_{11}/\cos\theta\right)\left(R_s + R_{s|x} + 2R_sR_{s|x}D_{22}\cos\theta\right)\right]^{\frac{1}{2}}$$

R_s	- source - reflection point distance
$R_{s\|x}$	- reflection point - receiver distance
θ	- incidence angle
D_{11}, D_{22}	- main curvatures
V	- velocity

- Effective reflection coefficient (M. Ayzenberg et al., 2007)

Effective reflection coefficient (ERC)

Incident wave

↓

Plane-wave decomposition

↓

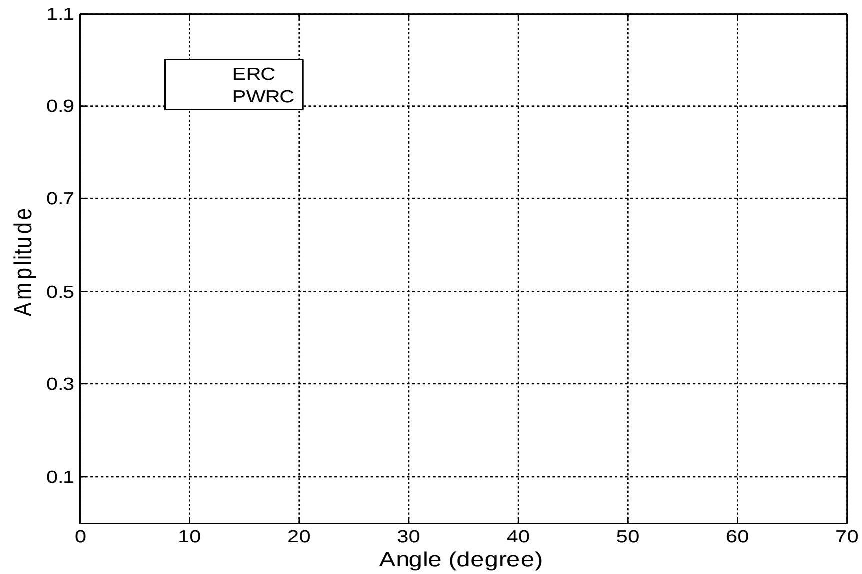
Multiplication with plane-wave reflection coefficient (PWRC)

↓

Summation

↓

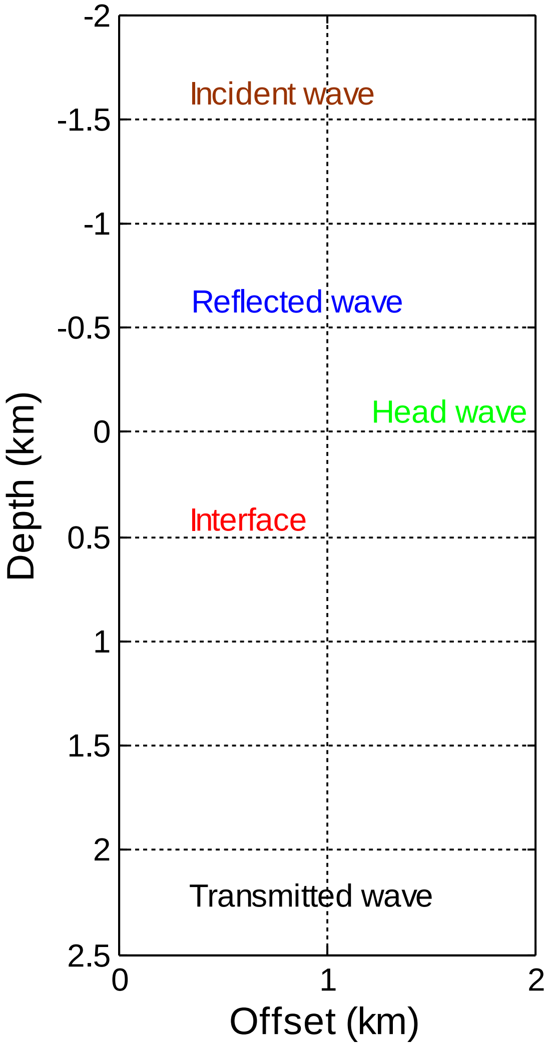
Division by incident wave



$$\chi(x) = \chi\left[\theta; \frac{\omega R^*}{V}\right]$$

θ	- incidence angle
$\omega = 2\pi f$	- frequency
R^*	- apparent wavefront radius
V	- velocity

R* for curved interface



Apparent wavefront radius at interface (Ayzenberg et al., 2007):

$$R^*(\mathrm{s}) = \frac{R_\mathrm{s}}{1 - \dfrac{2\cos\theta}{1+\cos^2\theta}\left[D_{11}+D_{22}\right]R_\mathrm{s}}$$

R_s	- source - reflection point distance
θ	- incidence angle
D_{11}, D_{22}	- main curvatures of interface

Apparent wavefront radius at receiver:

$$R^*(\mathrm{x}) = \frac{1+\cos^2\theta}{\cos^2\theta\left[K^*_{11}(\mathrm{x}) - \delta K_{11}(\mathrm{x})\right] + K^*_{22}(\mathrm{x})}$$

K^*_{11}, K^*_{22}	- apparent main curvatures of reflected wavefront
$\delta \mathrm{K}_{11}$	- head wavefront curvature

$$K^*_{11}, K^*_{22} = f\left(R_\mathrm{s}, R_{\mathrm{s|x}}, \theta, D_{11}, D_{22}\right)$$

$$\delta \mathrm{K}_{11} = f\left(R_{\mathrm{s|x}}, \theta, D_{11}\right)$$

Modelling

$$Z = 0.7 - 0.2\exp\left(-C\,x^2 - D\,y^2\right)$$

Concentric structure

$C = D = 1 \quad km^{-2}$

Linear structure

$C = 1; \quad D = 0 \quad km^{-2}$

Crossline

Inline

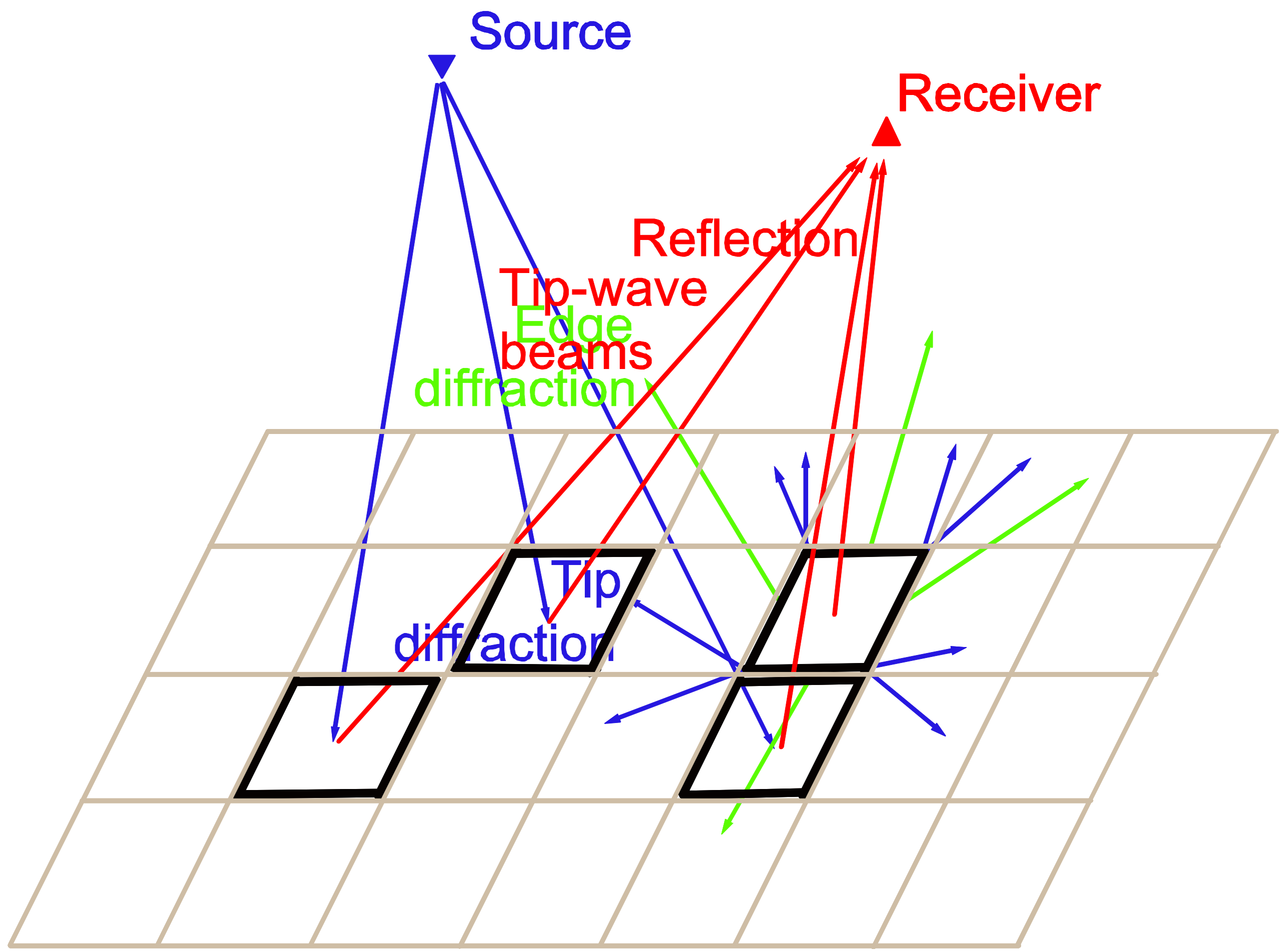
$$Vp_1 = 2 \quad km/s$$
$$Vs_1 = 1.1\ km/s$$
$$\rho_1 = 1.8\ kg/m^3$$

$$Vp_2 = 2.8\ km/s$$
$$Vs_2 = 1.6\ km/s$$
$$\rho_2 = 2.1\ kg/m^3$$

$D_{11} = D_{22} = 0.4\ km^{-1}$

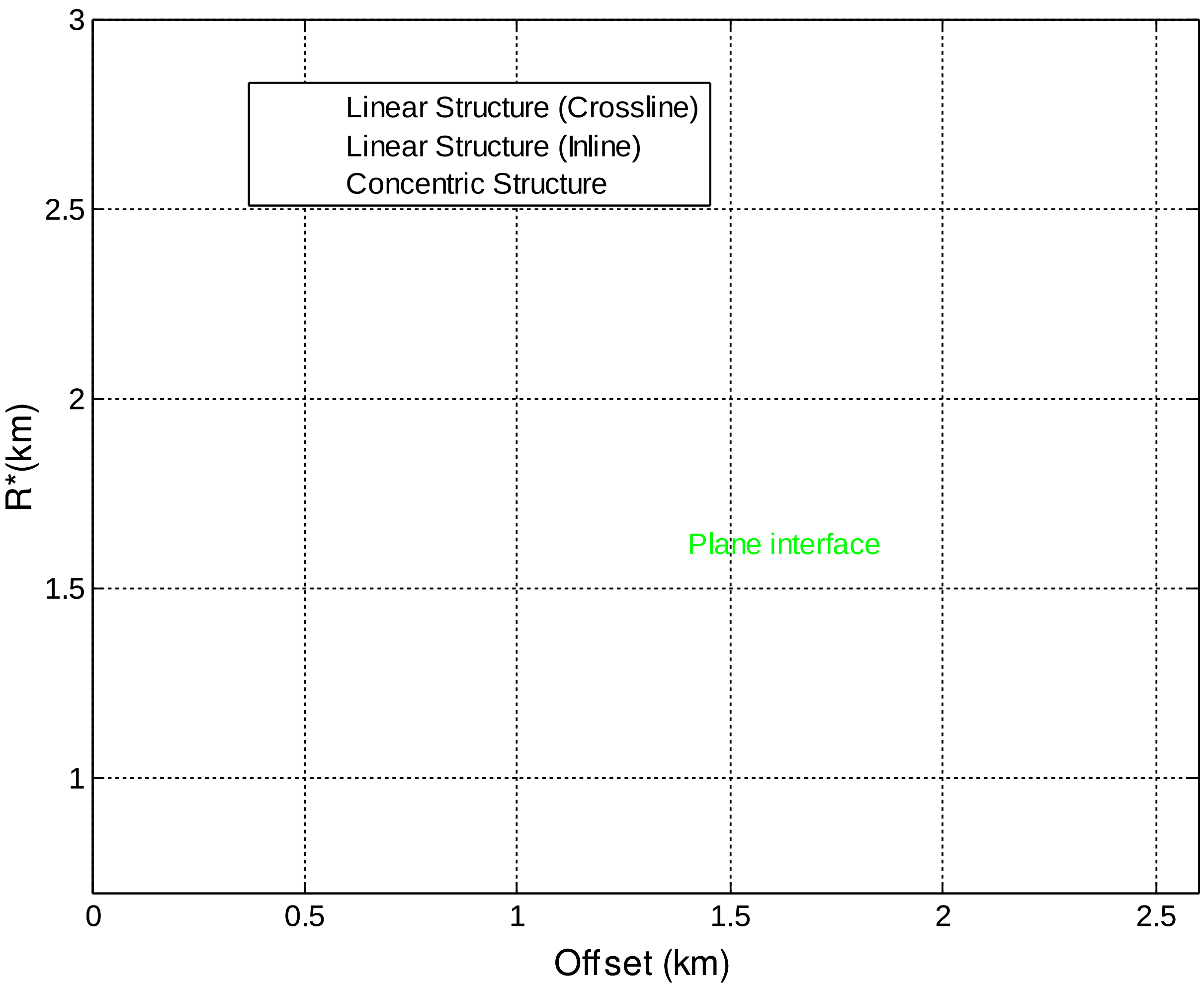
$D_{11} = 0.4; \quad D_{22} = 0 \quad km^{-1}$

Tip-wave superposition method (TWSM)



Valid for seismic frequencies

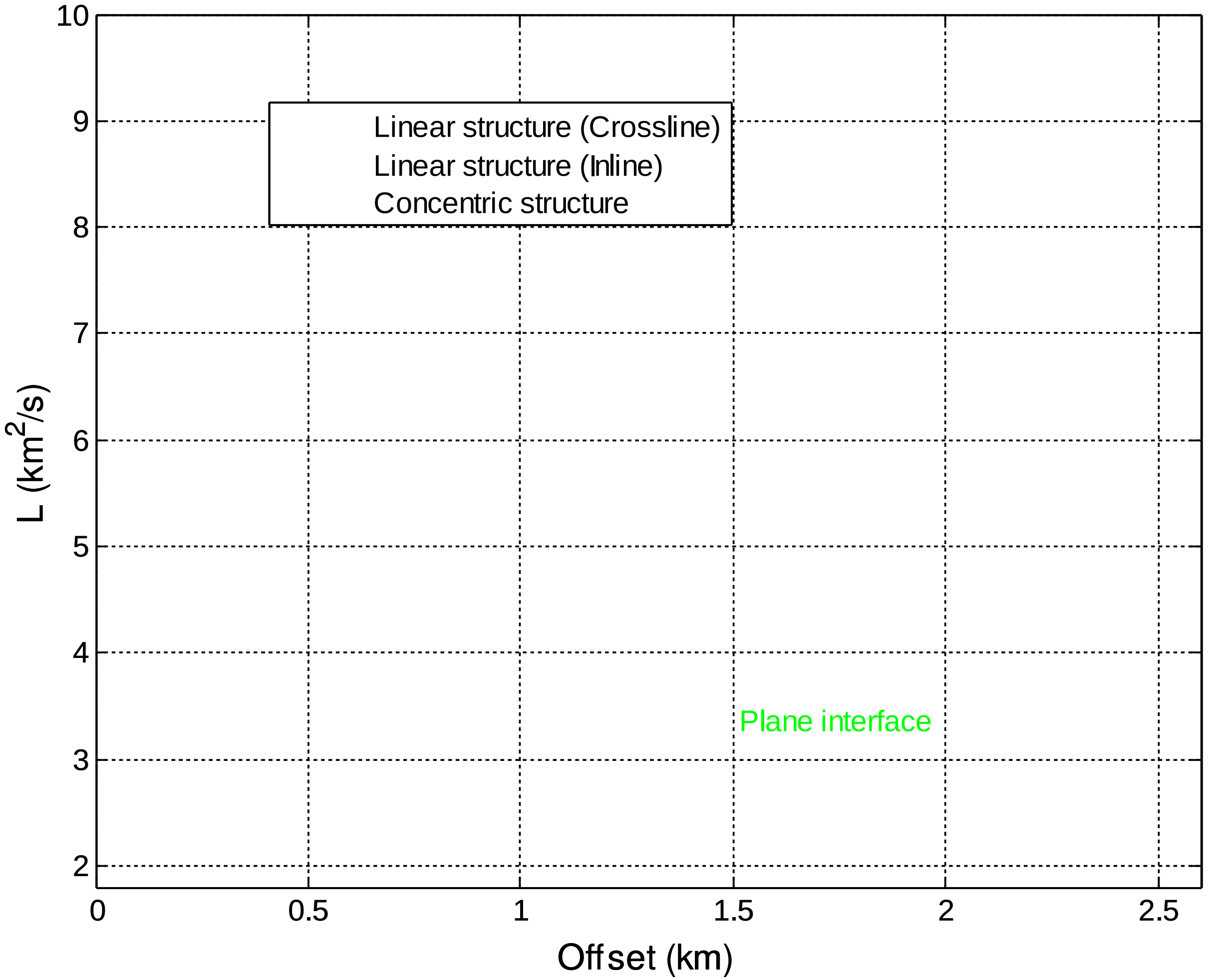
Apparent wavefront radii



Largest apparent radius is in Crossline direction

Smallest apparent radius is in Inline direction

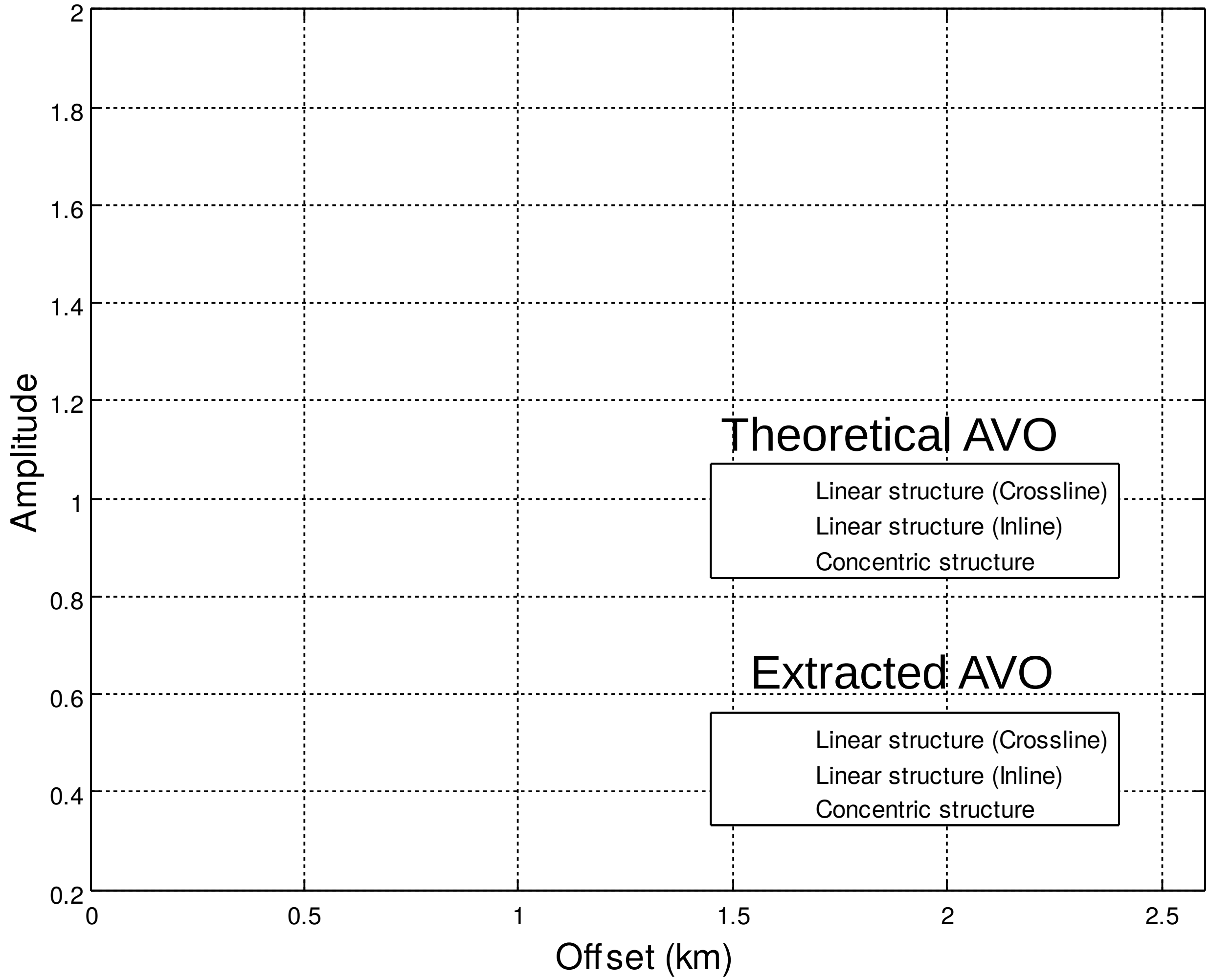
Geometrical spreading



Largest geometrical spreading is for Concentric Structure

Smalest geometrical spreading is in Inline direction

Extracted vs. theoretical AVO

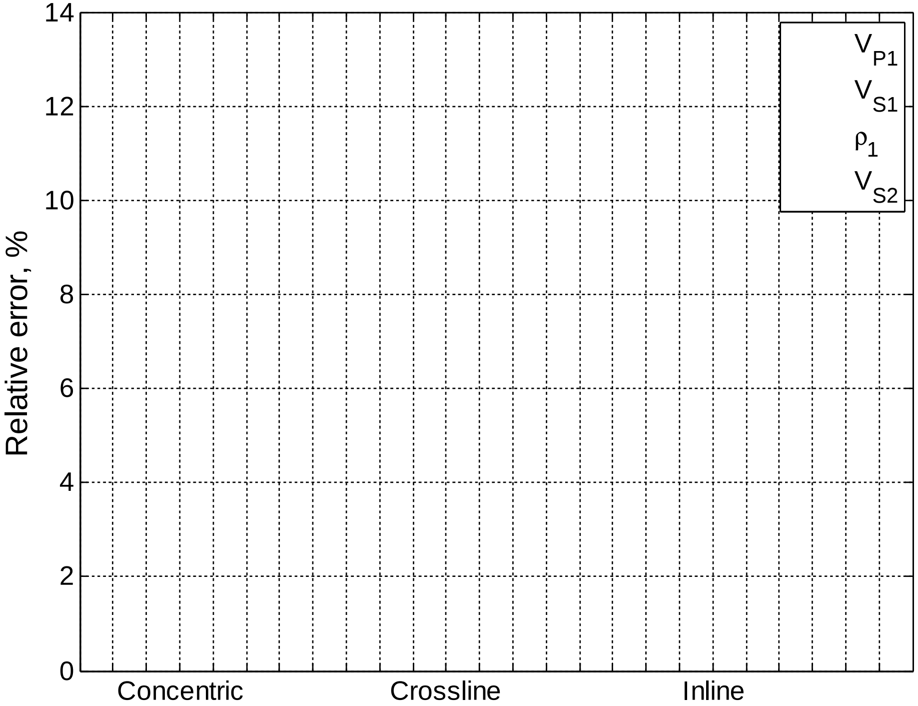


Captures main behavior of extracted AVO

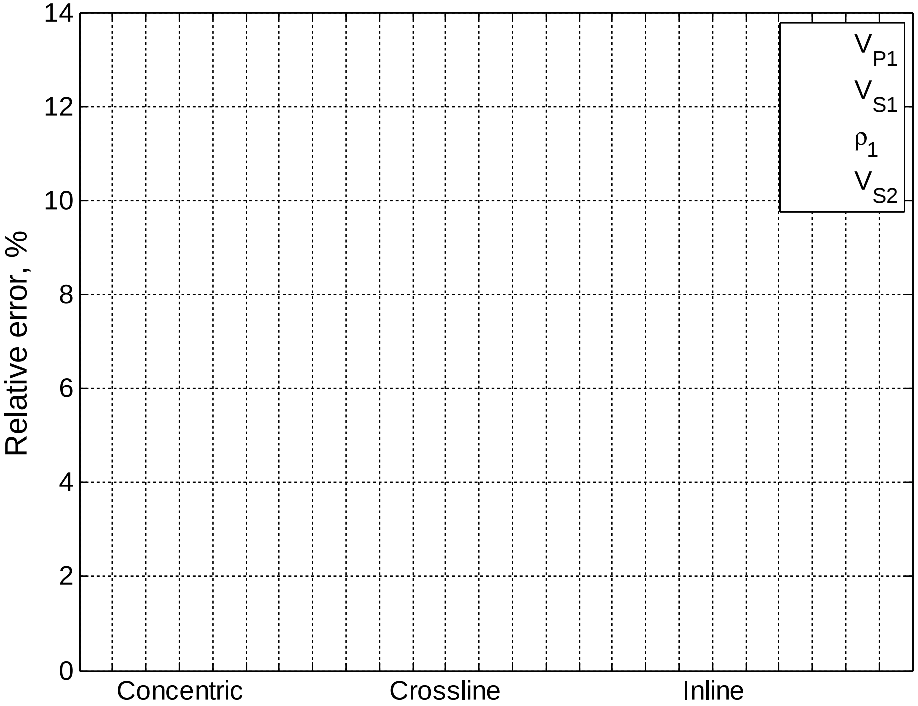
Does not include all effects we observe

Inversion results

Interface curvature neglected



Interface curvature included



Inversion is better when curvature is included

Conclusions

- Interface curvature strongly affects both the geometrical spreading and the reflection coefficient
- Theoretical AVO obtained with our method captures the main behaviour of the extracted AVO but are not that complete
- Inversion results are better when curvature is accounted for

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